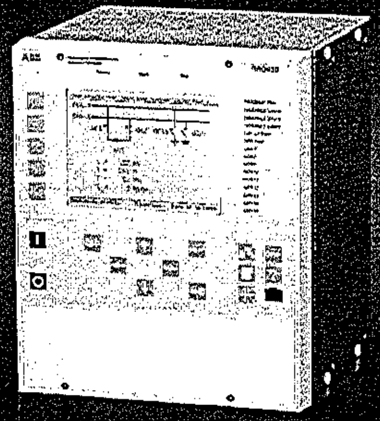

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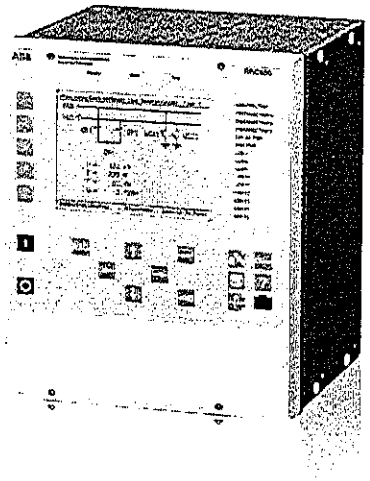

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Issued: February 2011
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Product version: 1.1

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Conformity

This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2004/108/EC) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2006/95/EC). This conformity is the result of tests conducted by ABB in accordance with the product standards EN 50263 and EN 60255-26 for the EMC directive, and with the product standards EN 60255-1 and EN 60255-27 for the low voltage directive. The IED is designed in accordance with the international standards of the IEC 60255 series.

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Section 1 Introduction

1.1 This manual

The application manual contains application descriptions and setting guidelines sorted per function. The manual can be used to find out when and for what purpose a typical protection function can be used. The manual can also be used when calculating settings.

1.2 Intended audience

This manual addresses the protection and control engineer responsible for planning, pre-engineering and engineering.

The protection and control engineer must be experienced in electrical power engineering and have knowledge of related technology, such as communication and protocols.

1.3 Product documentation

1.3.1 Product documentation set

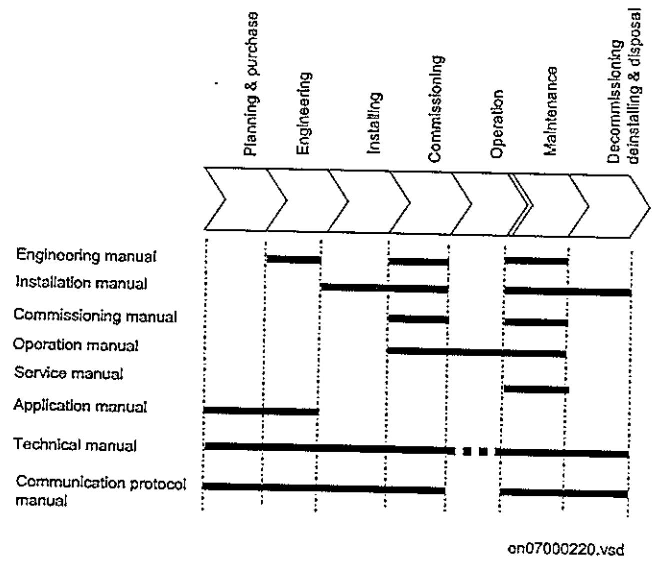

Figure 1: The intended use of manuals in different lifecycles

The engineering manual contains instructions on how to engineer the IEDs using the different tools in PCM600. The manual provides instructions on how to set up a PCM600 project and insert IEDs to the project structure. The manual also recommends a sequence for engineering of protection and control functions, LHMI functions as well as communication engineering for IEC 60870-5-103, IEC 61850 and DNP3.

The installation manual contains instructions on how to install the IED. The manual provides procedures for mechanical and electrical installation. The chapters are organized in chronological order in which the IED should be installed.

The commissioning manual contains instructions on how to commission the IED. The manual can also be used by system engineers and maintenance personnel for assistance during the testing phase. The manual provides procedures for checking of external circuitry and energizing the IED, parameter setting and configuration as well as verifying settings by secondary injection. The manual describes the process of testing an IED in a substation which is not in service. The chapters are organized in chronological order in which the IED should be commissioned.

The operation manual contains instructions on how to operate the IED once it has been commissioned. The manual provides instructions for monitoring, controlling and setting the IED. The manual also describes how to identify disturbances and how to view calculated and measured power grid data to determine the cause of a fault.

The service manual contains instructions on how to service and maintain the IED. The manual also provides procedures for de-energizing, de-commissioning and disposal of the IED.

The application manual contains application descriptions and setting guidelines sorted per function. The manual can be used to find out when and for what purpose a typical protection function can be used. The manual can also be used when calculating settings.

The technical manual contains application and functionality descriptions and lists function blocks, logic diagrams, input and output signals, setting parameters and technical data sorted per function. The manual can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service.

The communication protocol manual describes a communication protocol supported by the IED. The manual concentrates on vendor-specific implementations.

The point list manual describes the outlook and properties of the data points specific to the IED. The manual should be used in conjunction with the corresponding communication protocol manual.

The service manual is not available yet.

1.3.2 Document revision history

Document revision/date	Product series version	History
-/February 2011	1.1	First release

1.3.3 Related documents

Documents related to REC650	Identity number
Application manual	1MRK 511 246-UEN
Technical manual	1MRK 511 247-UEN
Commissioning manual	1MRK 511 248-UEN

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Documents related to REC650	Identity number
Product Guide	1MRK 511 249-BEN
Type test certificate	1MRK 511 249-TEN

650 series manuals	Identity number
Communication protocol manual, DNP3	1MRK 511 241-UEN
Communication protocol manual, IEC 61850	1MRK 511 242-UEN
Communication protocol manual, IEC 60870-5-103	1MRK 511 243-UEN
Point list manual, DNP3	1MRK 511 244-UEN
Engineering manual	1MRK 511 245-UEN
Operation manual	1MRK 500 093-UEN
Installation manual	1MRK 514 014-UEN

1.4 Symbols and conventions

1.4.1 Safety indication symbols

The electrical warning icon indicates the presence of a hazard which could result in electrical shock.

The warning icon indicates the presence of a hazard which could result in personal injury.

The caution icon indicates important information or warning related to the concept discussed in the text. It might indicate the presence of a hazard which could result in corruption of software or damage to equipment or property.

The information icon alerts the reader of important facts and conditions.

The tip icon indicates advice on, for example, how to design your project or how to use a certain function.

Although warning hazards are related to personal injury, it is necessary to understand that under certain operational conditions, operation of damaged

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equipment may result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2 Manual conventions

Conventions used in IED manuals. A particular convention may not be used in this manual.

- Abbreviations and acronyms in this manual are spelled out in the glossary. The glossary also contains definitions of important terms.
- Push button navigation in the LHMI menu structure is presented by using the push button icons, for example:
  To navigate between the options, use [icon] and [icon].
- HMI menu paths are presented in bold, for example:
  Select **Main menu/Settings**.
- LHMI messages are shown in Courier font, for example:
  To save the changes in non-volatile memory, select `Yes` and press [icon].
- Parameter names are shown in italics, for example:
  The function can be enabled and disabled with the *Operation* setting.
- The ^ character in front of an input or output signal name in the function block symbol given for a function, indicates that the user can set an own signal name in PCM600.
- The * character after an input or output signal name in the function block symbol given for a function, indicates that the signal must be connected to another function block in the application configuration to achieve a valid application configuration.

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Section 2 Application

2.1 REC650 application

REC650 is used for the control, protection and monitoring of different types of bays in power networks. The IED is especially suitable for applications in control systems with distributed control IEDs in all bays with high demands on reliability. It is intended mainly for sub-transmission stations. It is suitable for the control of all apparatuses in single busbar single CB, double busbar single CB switchgear arrangement.

The control is performed from remote (SCADA/Station) through the communication bus or from local HMI. Different control configurations can be used, and one control IED per bay is recommended. Interlocking modules are available for common types of switchgear arrangements. The control is based on the select before execute principle to give highest possible security. A synchronism control function is available to interlock breaker closing. Synchronizing function where breaker closes at the right instance in asynchronous networks is also provided.

A number of protection functions are available for flexibility in use for different station types and busbar arrangements. The auto-reclose includes priority circuits for single-breaker arrangements. It co-operates with the synchrocheck function with high-speed or delayed reclosing.

High set instantaneous phase and earth overcurrent, 4 step directional or non-directional delayed phase and earth overcurrent, thermal overload and two step under- and overvoltage functions are examples of the available functions allowing user to fulfill any application requirement.

Disturbance recording is available to allow independent post-fault analysis after primary disturbances.

Three packages have been defined for following applications:

- Single breaker for single busbar (A01)
- Single breaker for double busbar (A02)
- Bus coupler for double busbar (A07)

The packages are configured and ready for direct use. Analog and control circuits have been pre-defined. Other signals need to be applied as required for each application. The main differences between the packages above are the interlocking modules and the number of apparatuses to control.

The graphical configuration tool ensures simple and fast testing and commissioning.

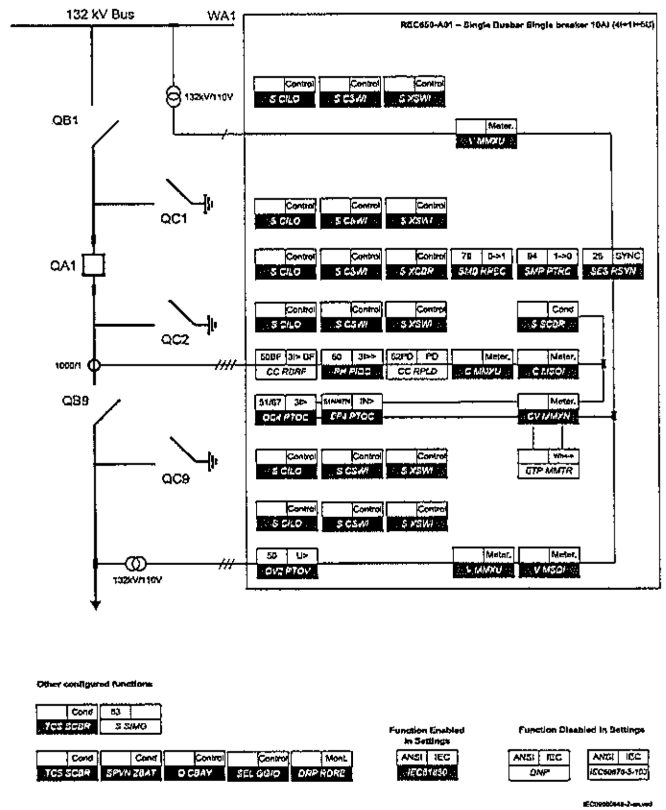

Figure 2: A typical protection and control application for a single busbar in single breaker arrangement

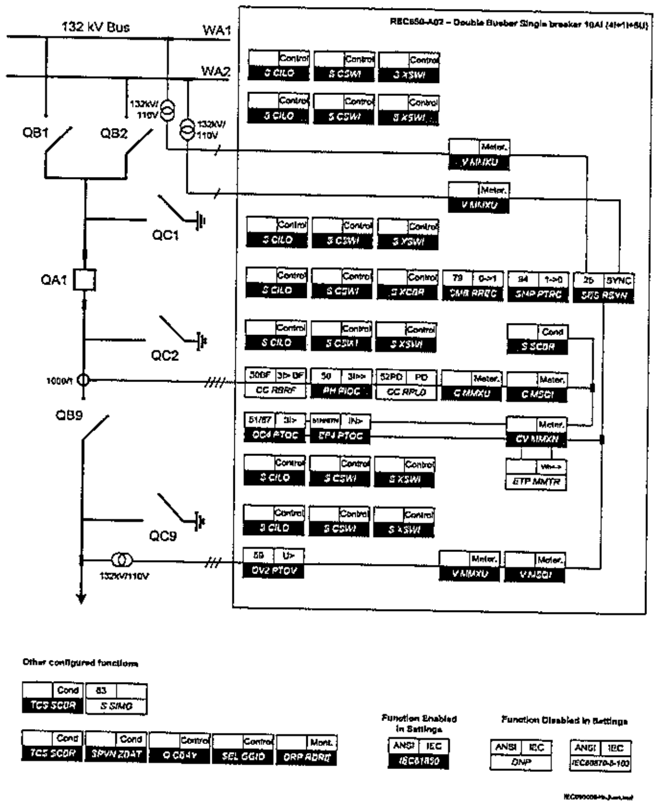

Figure 3: A typical protection and control application for a double busbar in single breaker arrangement

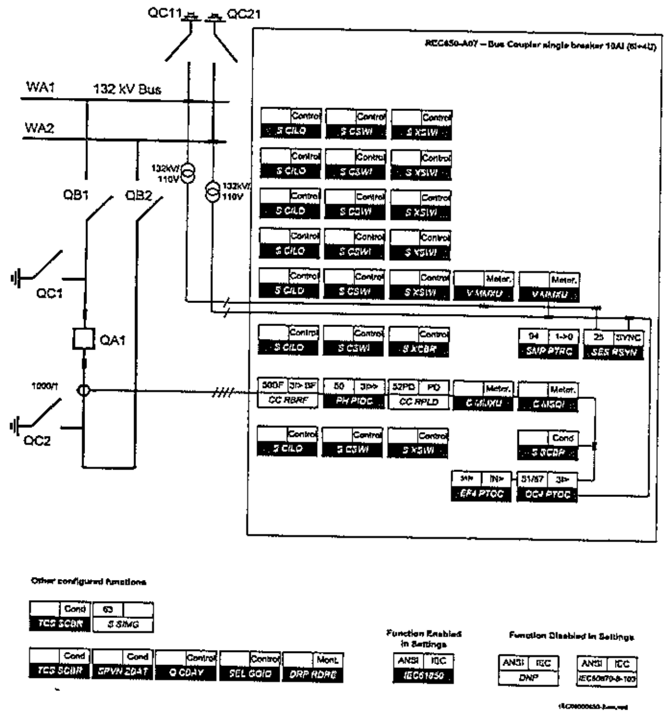

Figure 4: A typical protection and control application for a bus coupler in single breaker arrangement

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2.2 Available functions

2.2.1 Control and monitoring functions

IEC 61850/Function block name	ANSI	Function description	Bay REC650 (A01) 1CBA	Bay REC650 (A02) 1CBAB	Bay REC650 (A07) BCAB
Control					
SESRSYN	25	Synchrocheck, energizing check, and synchronizing	1	1	1
SMBRREC	79	Autorecloser	1	1	1
SCILO	3	Logical node for interlocking	8	8	8
BB_ES	3	Interlocking for busbar earthing switch	3	3	3
A1A2_BS	3	Interlocking for bus-section breaker	2	2	2
A1A2_DC	3	Interlocking for bus-section disconnector	3	3	3
ABC_BC	3	Interlocking for bus-coupler bay	1	1	1
BH_CONN	3	Interlocking for 1 1/2 breaker diameter	1	1	1
BH_LINE_A	3	Interlocking for 1 1/2 breaker diameter	1	1	1
BH_LINE_B	3	Interlocking for 1 1/2 breaker diameter	1	1	1
DB_BUS_A	3	Interlocking for double CB bay	1	1	1
DB_BUS_B	3	Interlocking for double CB bay	1	1	1
DB_LINE	3	Interlocking for double CB bay	1	1	1
ABC_LINE	3	Interlocking for line bay	1	1	1
AB_TRAFO	3	Interlocking for transformer bay	1	1	1
SCSWI		Switch controller	8	8	8
SXCBR		Circuit breaker	3	3	3
SXSWI		Circuit switch	7	7	7
POS_EVAL		Evaluation of position indication	8	8	8
SELGGIO		Select release	1	1	1
QCBAY		Bay control	1	1	1
LOCREM		Handling of LR-switch positions	1	1	1
LOCREMCTRL		LHMI control of Permitted Source To Operate (PSTO)	1	1	1
SLGGIO		Logic Rotating Switch for function selection and LHMI presentation	15	15	15
VSGGIO		Selector mini switch extension	20	20	20
DPGGIO		IEC 61850 generic communication I/O functions double point	16	16	16
SPC8GGIO		Single point generic control 8 signals	5	5	5
AUTOBITS		AutomationBits, command function for DNP3.0	3	3	3
I103CMD		Function commands for IEC60870-5-103	1	1	1

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IEC 61850/Function block name	ANSI	Function description	Bay REC650 (A01) 1CBA	Bay REC650 (A02) 1CBAB	Bay REC650 (A07) BCAB
I103IEDCMD		IED commands for IEC60870-5-103	1	1	1
I103USRCMD		Function commands user defined for IEC60870-5-103	4	4	4
I103GENCMD		Function commands generic for IEC60870-5-103	50	50	50
I103POSCMD		IED commands with position and select for IEC60870-5-103	50	50	50
Secondary system supervision					
CCSRDIF	87	Current circuit supervision	1	1	1
SDDRFUF		Fuse failure supervision	1	1	1
TCSSCBR		Breaker close/trip circuit monitoring	3	3	3
Logic					
SMPPTRC	94	Tripping logic	1	1	1
TMAGGIO		Trip matrix logic	12	12	12
OR		Configurable logic blocks, OR gate	283	283	283
INVERTER		Configurable logic blocks, Inverter gate	140	140	140
PULSETIMER		Configurable logic blocks, Pulse timer	40	40	40
GATE		Configurable logic blocks, Controllable gate	40	40	40
XOR		Configurable logic blocks, exclusive OR gate	40	40	40
LOOPDELAY		Configurable logic blocks, loop delay	40	40	40
TIMERSET		Configurable logic blocks, timer function block	40	40	40
AND		Configurable logic blocks, AND gate	280	280	280
SRMEMORY		Configurable logic blocks, set-reset memory flip-flop gate	40	40	40
RSMEMORY		Configurable logic blocks, reset-set memory flip-flop gate	40	40	40
ANDQT		Configurable logic Q/T, AND gate with quality and time	120	120	120
ORQT		Configurable logic Q/T, OR gate with quality and time	120	120	120
INVERTERQT		Configurable logic Q/T, inverter gate with quality and time	120	120	120
XORQT		Configurable logic Q/T, exclusive OR gate with quality and time	40	40	40
SRMEMORYQT		Configurable logic Q/T, set-reset with memory flip-flop gate with quality and time	40	40	40
RSMEMORYQT		Configurable logic Q/T, reset-set with memory flip-flop gate with quality and time	40	40	40
TIMERSETQT		Configurable logic Q/T, timer function block with quality and time	40	40	40
PULSETIMERQT		Configurable logic Q/T, pulse timer with quality and time	40	40	40
INVALIDQT		Configurable logic Q/T, used for invalidate data	12	12	12
INDCOMBSPQT		Configurable logic Q/T, single point indication logic signal combinator combining value with quality and time	20	20	20
INDEXTSPQT		Configurable logic Q/T, single point indication logic signal gate extracting value with quality and time	20	20	20

Table continues on next page

IEC 61850/Function block name	ANSI	Function description	Bay		
			REC650 (A01) 1CBA	REC650 (A02) 1CBAB	REC650 (A07) BCAB
FXDSIGN		Fixed signal function block	1	1	1
B16I		Boolean 16 to Integer conversion	16	16	16
B16IFCVI		Boolean 16 to Integer conversion with logic node representation	16	16	16
IB16A		Integer to Boolean 16 conversion	16	16	16
IB16FCVB		Integer to Boolean 16 conversion with logic node representation	16	16	16
Monitoring					
CVMMXN		Measurements	6	6	6
CMMXU		Phase current measurement	10	10	10
VMMXU		Phase-phase voltage measurement	6	6	6
CMSQI		Current sequence component measurement	6	6	6
VMSQI		Voltage sequence measurement	6	6	6
VNMMXU		Phase-neutral voltage measurement	6	6	6
CNTGGIO		Event counter	5	5	5
DRPRDRE		Disturbance report	1	1	1
AxRADR		Analog input signals	4	4	4
BxRBDR		Binary input signals	6	6	6
SPGGIO		IEC 61850 generic communication I/O functions	64	64	64
SP16GGIO		IEC 61850 generic communication I/O functions 16 inputs	16	16	16
MVGGIO		IEC 61850 generic communication I/O functions	16	16	16
MVEXP		Measured value expander block	66	66	66
SPVNZBAT		Station battery supervision	1	1	1
SSIMG	63	Insulation gas monitoring function	1	1	1
SSIML	71	Insulation liquid monitoring function	1	1	1
SSCBR		Circuit breaker condition monitoring	1	1	1
I103MEAS		Measurands for IEC60870-5-103	1	1	1
I103MEASUSR		Measurands user defined signals for IEC60870-5-103	3	3	3
I103AR		Function status auto-recloser for IEC60870-5-103	1	1	1
I103EF		Function status earth-fault for IEC60870-5-103	1	1	1
I103FLTPROT		Function status fault protection for IEC60870-5-103	1	1	1
I103IED		IED status for IEC60870-5-103	1	1	1
I103SUPERV		Supervison status for IEC60870-5-103	1	1	1
I103USRDEF		Status for user defined signals for IEC60870-5-103	20	20	20

Table continues on next page

IEC 61850/Function block name	ANSI	Function description	Bay		
			REC650 (A01) 1CBA	REC650 (A02) 1CBAB	REC650 (A07) BCAB
Metering					
PCGGIO		Pulse counter logic	16	16	16
ETPMMTR		Function for energy calculation and demand handling	3	3	3

2.2.2 Back-up protection functions

IEC 61850/ Function block name	ANSI	Function description	Bay		
			REC650 (A01) 1CBA	REC650 (A02) 1CBAB	REC650 (A07) BCAB
Current protection					
PHPIOC	50	Instantaneous phase overcurrent protection	1	1	1
OC4PTOC	51/67	Four step directional phase overcurrent protection	1	1	1
EFPIOC	50N	Instantaneous residual overcurrent protection	1	1	1
EF4PTOC	51N/67N	Four step directional residual overcurrent protection	1	1	
SDEPSDE	67N	Sensitive directional residual overcurrent and power protection	1	1	1
LPTTR	26	Thermal overload protection, one time constant	1	1	1
CCRBRF	50BF	Breaker failure protection	1	1	1
STBPTOC	50STB	Stub protection	1	1	1
CCRPLD	52PD	Pole discordance protection	1	1	1
BRCPTOC	46	Broken conductor check	1	1	1
GUPPDUP	37	Directional underpower protection	1	1	1
GOPPDOP	32	Directional overpower protection	1	1	1
DNSPTOC	46	Negative sequence based overcurrent function	1	1	1
Voltage protection					
UV2PTUV	27	Two step undervoltage protection	1	1	1
OV2PTOV	59	Two step overvoltage protection	1	1	1
ROV2PTOV	59N	Two step residual overvoltage protection	1	1	1
LOVPTUV	27	Loss of voltage check	1	1	1
Frequency protection					
SAPTUF	81	Underfrequency function	2	2	2
SAPTOF	81	Overfrequency function	2	2	2
SAPFRC	81	Rate-of-change frequency protection	2	2	2

2.2.3 Designed to communicate

IEC 61850/Function block name	ANSI	Function description	Bay		
			REC650 (A01) 1CBA	REC650 (A02) 1CBAB	REC650 (A07) BCAB
Station communication					
		IEC 61850 communication protocol, LAN1	1	1	1
		DNP3.0 for TCP/IP communication protocol, LAN1	1	1	1
IEC61870-5-103		IEC60870-5-103 serial communication via ST	1	1	1
GOOSEINTLKRCV		Horizontal communication via GOOSE for interlocking	59	59	59
GOOSEBINRCV		GOOSE binary receive	4	4	4
ETHFRNT ETHLAN1 GATEWAY		Ethernet configuration of front port, LAN1 port and gateway			
GOOSEDPRCV		GOOSE function block to receive a double point value	32	32	32
GOOSEINTRCV		GOOSE function block to receive an integer value	32	32	32
GOOSEMVRCV		GOOSE function block to receive a mesurand value	16	16	16
GOOSESPRCV		GOOSE function block to receive a single point value	64	64	64

2.2.4 Basic IED functions

IEC 61850/Function block name	Function description	
Basic functions included in all products		
INTERRSIG	Self supervision with internal event list	1
SELFSUPEVLST	Self supervision with internal event list	1
SNTP	Time synchronization	1
TIMESYNCHGEN	Time synchronization	1
DTSBEGIN, DTSEND, TIMEZONE	Time synchronization, daylight saving	1
IRIG-B	Time synchronization	1
SETGRPS	Setting group handling	1
ACTVGRP	Parameter setting groups	1
TESTMODE	Test mode functionality	1
CHNGLCK	Change lock function	1
TERMINALID	IED identifiers	1
PRODINF	Product information	1
PRIMVAL	Primary system values	1
SMAI_20_1-12	Signal matrix for analog inputs	2
3PHSUM	Summation block 3 phase	12

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IEC 61850/Function block name	Function description	
GBASVAL	Global base values for settings	6
ATHSTAT	Authority status	1
ATHCHCK	Authority check	1
FTPACCS	FTP access with password	1
DOSFRNT	Denial of service, frame rate control for front port	1
DOSLAN1	Denial of service, frame rate control for LAN1	1
DOSSCKT	Denial of service, socket flow control	1

2.3 REC650 application examples

2.3.1 Adaptation to different applications

The IED has pre-defined configurations mainly for sub-station control applications. There is however the possibility to integrate back-up protection functions in the IED. In sub-transmission systems it can be valuable to have another IED for line or transformer application, giving the main protection functionality and the bay control IED giving control functionality together with back-up protection.

The IED is available in three different versions:

- A01: for a single breaker bay connected to single busbar
- A02: for a single breaker bay connected to double busbar
- A07: for a bus coupler bay

A selection of common applications are described below.

- Application 1: Single breaker line bay, single or double busbar, in solidly earthed network
- Application 2: Single breaker line bay, single or double busbar, in high impedance earthed network
- Application 3: Bus coupler in solidly earthed network
- Application 4: Bus coupler in a high impedance earthed network

2.3.2 Single breaker line bay, single or double busbar, in solidly earthed network

Normally the following fault scenarios require back-up protection functions:

- Close in line short circuits: For close in faults the instantaneous phase overcurrent protection should be used. As the fault current is often high at this fault case fast tripping is essential. It is however important to base the setting on fault calculations considering different operational states.

- Short circuits on the whole line length. For these faults the four step phase overcurrent protection should be used. The four step phase overcurrent protection has the possibility of directional function as well as different time delay characteristics. It is important to base the setting on fault calculations considering different operational states as well as time delay co-ordination with other protections in the system.
- Close in line phase to earth faults: For close in faults the instantaneous residual overcurrent protection should be used. As the fault current is often high at this fault case fast tripping is essential. It is however important to base the setting on fault calculations considering different operational states.
- Phase to earth faults on the whole line length. For these faults the four step residual overcurrent protection should be used. The four step residual overcurrent protection has the possibility of directional function as well as different time delay characteristics. It is important to base the setting on fault calculations considering different operational states as well as time delay co-ordination with other protections in the system.
- Failure of the circuit beaker to interrupt fault current after protection trip. The breaker failure protection function is essential in a protection system using local redundancy.
- Autoreclosing is normally used on power lines as most faults are transient, that is, the arcing fault will extinguish after a short zero voltage interval.

2.3.3 Single breaker line bay, single or double busbar, in high impedance earthed network

Normally the following fault scenarios require back-up protection functions:

- Close in line short circuits: For close in faults the instantaneous phase overcurrent protection should be used. As the fault current is often high at this fault case fast tripping is essential. It is however important to base the setting on fault calculations considering different operational states
- Short circuits on the whole line length. For these faults the four step phase overcurrent protection should be used. The four step phase overcurrent protection has the possibility of directional function as well as different time delay characteristics. It is important to base the setting on fault calculations considering different operational states as well as time delay co-ordination with other protections in the system
- Phase-to-earth faults. In high impedance earthed networks the fault current at a single phase-to-earth fault is small. For these faults the sensitive residual overcurrent protection should be used. The sensitive residual overcurrent protection has the possibility of directional function. It is important to base the setting on fault calculations considering different operational states as well as

time delay co-ordination with other protections in the system. As a second protection a residual voltage protection is often used.

- Failure of the circuit beaker to interrupt fault current after protection trip. The breaker failure protection function is essential in a protection system using local redundancy.
- Autoreclosing is normally used on power lines as most faults are transient, that is the arcing fault will extinguish after a short zero voltage interval.

The recommendations in table 1 have the following meaning:

On: It is recommended to have the function activated in the application

Off: It is recommended to have the function deactivated in the application

Application dependent.: The decision to have the function activated or not is dependent on the specific conditions in each case

Application 1 and Application 2 in table 1 are according to application examples given in previous sections.

Table 1: Functionality table

Function	Application 1	Application 2
Instantaneous phase overcurrent protection PHPIOC	On	On
Four step phase overcurrent protection OC4PTOC	On	On
Instantaneous residual overcurrent protection EFPIOC	On	Off
Four step residual overcurrent protection EF4PTOC	On	Off
Sensitive directional residual overcurrent and power protection SDEPSDE	Off	On
Thermal overload protection LPTTR	Application dependent	Application dependent
Breaker failure protection CCRBRF	On	On
Pole discordance protection CCRPLD	Application dependent	Application dependent
Broken conductor check BRCPTOC	Application dependent	Application dependent
Directional under-power protection GUPPDUP	Application dependent	Application dependent
Directional over-power protection GOPPDOP	Application dependent	Application dependent
Negative sequence based overcurrent protection DNSPTOC	Application dependent	Application dependent
Two step undervoltage protection UV2PTUV	Application dependent	Application dependent
Two step overvoltage protection OV2PTOV	Application dependent	Application dependent
Two step residual overvoltage protection ROV2PTOV	Off	On

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Function	Application 1	Application 2
Under frequency protection SAPTUF (instance 1)	Application dependent	Application dependent
Under frequency protection SAPTUF (instance 2)	Application dependent	Application dependent
Over frequency protection SAPTOF (instance 1)	Application dependent	Application dependent
Over frequency protection SAPTOF (instance 2)	Application dependent	Application dependent
Rate-of-change of frequency protection SAPFRC (instance 1)	Application dependent	Application dependent
Rate-of-change of frequency protection SAPFRC (instance 2)	Application dependent	Application dependent
Current circuit supervision CCSRDIF	On	On
Fuse failure supervision SDDRFUF	On	On
Breaker close/trip circuit monitoring TCSSCBR	On	On
Synchrocheck, energizing check, and synchronizing SESRSYN	Application dependent	Application dependent
Autorecloser SMBRREC	On	On

2.3.4 Bus coupler in a solidly earthed network

Normally the following fault scenarios require back-up protection functions:

- Short circuits on one of the busbar sections and short circuits on outgoing lines. For these faults the four step phase overcurrent protection should be used. The four step phase overcurrent protection has the possibility of directional function as well as different time delay characteristics. It is important to base the setting on fault calculations considering different operational states as well as time delay coordination with other protections in the system.
- Phase-to-earth faults one of the busbar sections and phase-to-earth faults on outgoing lines. For these faults the four step residual overcurrent protection should be used. The four step residual overcurrent protection has the possibility of directional function as well as different time delay characteristics. It is important to base the setting on fault calculations considering different operational states as well as time delay coordination with other protections in the system.
- Failure of the circuit beaker to interrupt fault current after protection trip. The breaker failure protection function is essential in a protection system using local redundancy.

2.3.5 Bus coupler in a high impedance earthed' network

Normally the following fault scenarios require back-up protection functions:

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- Short circuits on one of the busbar sections and short circuits on outgoing lines. For these faults the four step phase overcurrent protection should be used. The four step phase overcurrent protection has the possibility of directional function as well as different time delay characteristics. It is important to base the setting on fault calculations considering different operational states as well as time delay co-ordination with other protections in the system.
- Phase-to-earth faults. In high impedance earthed networks the fault current at a single phase-to-earth fault is small. For these faults the sensitive residual overcurrent protection should be used. The sensitive residual overcurrent protection has the possibility of directional function. It is important to base the setting on fault calculations considering different operational states as well as time delay co-ordination with other protections in the system. As a second protection a residual voltage protection is often used.
- Failure of the circuit beaker to interrupt fault current after protection trip. The breaker failure protection function is essential in a protection system using local redundancy.

The recommendations in table 1 have the following meaning:

On: It is recommended to have the function activated in the application

Off: It is recommended to have the function deactivated in the application

Application dependent.: The decision to have the function activated or not is dependent on the specific conditions in each case

Application 3 and Application 4 in table 1 are according to application examples given in previous sections.

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Table 2: Functionality table

Function	Application 3	Application 4
Instantaneous phase overcurrent protection PHPIOC	Off	Off
Four step phase overcurrent protection OC4PTOC	Off	Off
Instantaneous residual overcurrent protection EFPIOC	On	On
Four step residual overcurrent protection EF4PTOC	On	Off
Sensitive directional residual overcurrent protection SDEPSDE	Off	On
Thermal overload protection LPTTR	Application dependent	Application dependent
Breaker failure protection CCRBRF	On	On
Pole discordance protection CCRPLD	Application dependent	Application dependent
Broken conductor check BRCPTOC	Application dependent	Application dependent

Table continues on next page

Function	Application 3	Application 4
Directional under-power protection GUPPDUP	Application dependent	Application dependent
Directional over-power protection GOPPDOP	Application dependent	Application dependent
Negative sequence overcurrent protection DNSPTOC	Application dependent	Application dependent
Two step Undervoltage Protection UV2PTUV	Application dependent	Application dependent
Two step Overvoltage Protection OV2PTOV	Application dependent	Application dependent
Two step Residual Overvoltage Protection ROV2PTOV	Off	On
Under frequency protection SAPTUF (instance 1)	Application dependent	Application dependent
Under frequency protection SAPTUF (instance 2)	Application dependent	Application dependent
Over frequency protection SAPTOF (instance 1)	Application dependent	Application dependent
Over frequency protection SAPTOF (instance 2)	Application dependent	Application dependent
Rate-of-change of frequency protection SAPFRC (instance 1)	Application dependent	Application dependent
Rate-of-change of frequency protection SAPFRC (instance 2)	Application dependent	Application dependent
Current circuit supervision CCSRDIF	On	On
Fuse failure supervision SDDRFUF	On	On
Breaker close/trip circuit monitoring TCSSCBR	On	On
Synchrocheck, energizing check, and synchronizing SESRSYN	Application dependent	Application dependent
Autorecloser SMBRREC	Off	Off

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Section 3 REC650 setting examples

3.1 Setting example when REC650 is used as back-up protection in a transformer protection application

The application example has a 145/22 kV transformer as shown in figure 5.

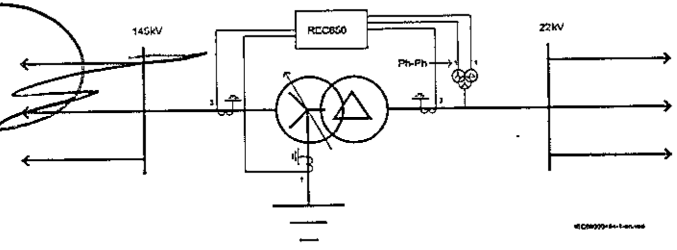

Figure 5: Two-winding HV/MV transformer, Y/Δ-transformer

Table 3: Typical data for the transformer application

The following data is assumed:

Item	Data
Transformer rated power SN	60 MVA
Transformer high voltage side rated voltage UN1	145 kV ±9 · 1.67 % (with on load tap changer)
Transformer low voltage side rated voltage UN2	22 kV
Transformer vector group	YNd11
Transformer short circuit voltage at tap changer mid point: ek	12 %
Maximum allowed continuous overload	1,30 · SN
Phase CT ratio at 145 kV level	300/1 A
CT at 145 kV earth point	300/1 A
Phase CT ratio at 22 kV level	2 000/1 A
22 kV VT ratio	$\frac{22}{\sqrt{3}} / \frac{0.11}{\sqrt{3}} / \frac{0.11}{3}$ kV
High positive sequence source impedance at the HV side	j10 Ω (about 2 100 MVA)
Low positive sequence source impedance at the HV side	j3.5 Ω (about 6 000 MVA)
Table continues on next page	

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Item	Data
High zero sequence source impedance at the HV side	j20 Ω
Low zero sequence source impedance at the HV side	j15 Ω
Positive sequence source impedance at the LV side	∞ (no generation in the 22 kV network)

Only settings that need adjustment due to the specific application are described in setting examples. It is recommended to keep the default values for all settings that are not described. Refer to Technical manual for setting tables for each protection and control function.

Refer to setting guideline section in Application manual for guidelines on how to set functions that are not presented in setting examples.

Use parameter setting tool in PCM600 to set the IED according to calculations for the particular application.

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3.1.1 Calculating general settings for analogue inputs 8I 2U

The analogue input has the capability of 8 current inputs (1 A) and 2 voltage inputs.

The 145 kV current CTs (three phase current transformer group) are connected to inputs 1 – 3 (L1, L2, L3).

The 22 kV current CTs (three phase current transformer group) are connected to inputs 4 – 6 (L1, L2, L3).

The 145 kV neutral point CT is connected to input 7 (IN).

The input 8 is not used. The input is used for connection of low voltage side CT (not in this application)

The 22 kV phase-to-phase (L1 – L2) VT is connected to input 9.

The 22 kV open delta connected VT (residual voltage) is connected to input 10.

1. Set the 145 kV current transformer input 1.
   1.1. Set *CTStarPoint1* to *ToObject*

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(The CT secondary is earthed towards the protected transformer)

1.2. Set *CTSec1* to *1 A*
   (The rated secondary current of the CT)
1.3. Set *CTPrim1* to *300 A*
   (The rated primary current of the CT)

2. Set current inputs 2 and 3 to the same values as for current input 1.
3. Set the 22 kV current transformer input 4.
   3.1. Set *CTStarPoint4* to *ToObject*
      (The CT secondary is earthed towards the protected transformer)
   3.2. Set *CTSec4* to *1 A*
      (The rated secondary current of the CT)
   3.3. Set *CTPrim4* to *2000 A*
      (The rated primary current of the CT)
4. Set current inputs 5 and 6 to the same values as for current input 4.
5. Set the 145 kV neutral point current transformer input 7.
   5.1. Set *CTStarPoint7* to *ToObject*
      (The CT secondary is earthed towards the protected line)
   5.2. Set *CTSec7* to *1 A*
      (The rated secondary current of the CT)
   5.3. Set *CTPrim7* to *300 A*
      (The rated primary current of the CT)

Current input 8 is intended for connection of low voltage side CT. In this application the input is not used.

6. Set the voltage transformer inputs 9 and 10.
   6.1. Set *VTSec9* to *110 V*
      (The rated secondary voltage of the VT, given as phase-phase voltage)
   6.2. Set *VTPrim9* to *22 kV*
      (The rated secondary voltage of the VT, given as phase-phase voltage)
   6.3. Set *VTSec10* to *110 V/√3*
      (The rated secondary voltage of the VT, given as phase-phase voltage)
   6.4. Set *VTPrim10* to *22 kV*
      (The rated secondary voltage of the VT, given as phase-phase voltage)

3.1.2 Calculating settings for global base values GBASVAL

Each function uses primary base values for reference of settings. The base values are defined in Global base values for setting GBASVAL function. It is possible to include up to six Global base values for settings functions. In this application GBASVAL instance 1 is used to define the base for 145 kV inputs and GBASVAL instance 2 for 22 kV inputs.

For transformer protection it is recommended to set the base parameters according to the power transformer primary rated values:

1. Set Global Base 1
   1.1. Set *IBase* to *239 A*
   1.2. Set *UBase* to *145 kV*
   1.3. Set *SBase* to *60 MVA* (*SBase=√3·UBase·IBase*)
2. Set Global Base 2
   2.1. Set *IBase* to *1575 A*
   2.2. Set *UBase* to *22 kV*
   2.3. Set *SBase* to *60 MVA* (*SBase=√3·UBase·IBase*)

The *GlobalBaseSel* setting in a protection and control function references a Global base values for setting function for reference of primary values.

3.1.3 Calculating settings for instantaneous phase overcurrent protection, HV-side, PHPIOC

1. Set *GlobalBaseSel* to *1*
   To relate the settings to the rated data of the transformer the (HV) winding data should be related to Global base 1.
2. Set *IP>>* to *1000 %* of *IBase*
   The instantaneous phase overcurrent protection on the high voltage side is used for fast trip of high current transformer internal faults. The protection shall be selective to the protections of the outgoing 22 kV feeders. Therefore the maximum 145 kV current at three-phase short circuit on the 22 kV side of the transformer is calculated:

$$I = \frac{145}{\sqrt{3}\cdot(Z_{net}+Z_T)} = \frac{145}{\sqrt{3}\cdot(3.5+\frac{145^2}{60}\cdot 0.12)} = 1.83\ kA$$

(Equation 1)

The dynamic overreach, due to fault current DC-component, shall be considered in the setting. This factor is less that 5 %. The setting is chosen with a safety margin of 1.2:

$I_{set} \geq 1.2 \cdot 1.05 \cdot 1\,830 = 2\,306$ A

Setting*IP>>* = *1000 %* of *IBase*

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3.1.4 Calculating settings for four step phase overcurrent protection, HV-side, OC4PTOC

The phase overcurrent protection is difficult to set as the short circuit current is highly dependent of the switching state in the power system as well as of the fault type. In order to achieve setting that assure selective fault clearance a large number of calculations have to be made with different fault locations, different switching states in the system and different fault types.

The 145 kV phase overcurrent protection have the following tasks:

- Backup protection for short circuits on the transformer
- Backup protection for short circuits on 22 kV busbar
- Backup protection for short circuits on outgoing 22 kV feeders (if possible)

The reach of phase overcurrent line protection depends on the operation state and the fault type. Therefore the setting must be based on fault calculations made for different faults, fault points and switching states in the network. Although it is possible to make hand calculations of the different faults it is recommended to use computer based fault calculations. Different time delay principles can be used. This is due to different praxis.

The following principle for the phase overcurrent protection is proposed:

- Only one step (step 1) is used. The time delay principle is chosen according to network praxis, in this case inverse time characteristics using IEC Normal inverse.

3.1.4.1 Calculating general settings

1. Set *GlobalBaseSel* to *1*
   The settings are made in primary values. These values are given in the base settings in Global base 1.
2. Set *DirMode1* to *Non-directional*
   The function shall be non-directional
3. Set *Characterist1* to *IEC Norm.inv.*
   For the choice of time delay characteristic IEC Normal inverse is used in this network.

3.1.4.2 Calculating settings for step 1

1. Set *I1>* to *140%* of *IBase* (334 A primary current)

The first requirement is that the phase overcurrent protection shall never trip for load current during the extreme high load situations. It is assumed that the transformer shall be able to be operated up to 130 % of the rated power during limited time. Further shall the protection resetting ratio be considered. The resetting ratio is 0.95. The minimum setting can be calculated as:

$$I_{pu} \geq 1.3 \cdot \frac{1}{0.95} \cdot \frac{60 \cdot 1000}{\sqrt{3} \cdot 145} = 327\ A$$

(Equation 2)

The next requirement is that the protection shall be able to detect all short circuits within the defined protected zone. In this case it is required, if possible, that the protection shall detect phase-to-phase short circuit at the most remote point of the outgoing feeders as shown in figure 6.

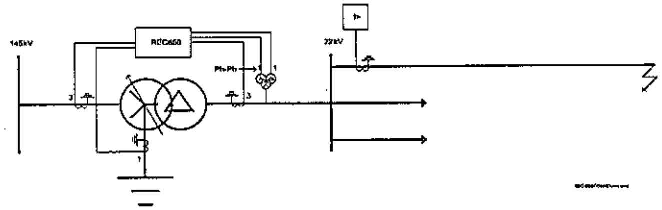

Figure 6: Fault calculation for phase overcurrent protection setting

The following fault is applied: phase-phase-earth short circuit. In this calculation should the short circuit power in the feeding substation be minimized (the source impedance maximized).
The longest 22 kV feeder has the impedance Z = 3 + j10 Ω. The external network has the maximum source impedance Z_{sc} = j10 Ω (145 kV level). This impedance is transformed to 22 kV level:

$$Z_{sc,22} = \left(\frac{22}{145}\right)^2 \cdot j10 = j0.23\ \Omega$$

(Equation 3)

The transformer impedance, referred to 22 kV level, is:

$$Z_{T,22} = j\frac{22^2}{60} \cdot 0.12 = j0.97\ \Omega$$

(Equation 4)

The fault current can be calculated:

$$I_{sc2ph} = \frac{\sqrt{3}}{2} \cdot \left| \frac{22000/\sqrt{3}}{j0.23 + j0.97 + 3 + j10} \right| = 948\ A$$

(Equation 5)

This fault current is recalculated to the 145 kV level:

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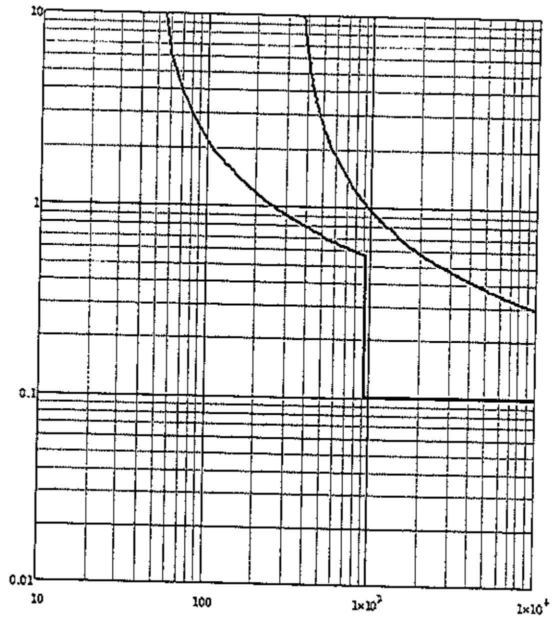
$$I_{sc2ph,145} = \frac{22}{145} \cdot 948 = 144\ A$$

(Equation 6)

This current is smaller than the required minimum setting to avoid unwanted trip at large load current. This means that the 145 kV phase overcurrent protection cannot serve as complete back-up protection for the 22 kV feeders out from the substation.

2. Set *k1* to *0.15*
The time setting must be coordinated with the feeder protections to assure selectivity. It can be stated that there is no need for selectivity between the high voltage side phase overcurrent protection and the low voltage side phase overcurrent protection.
The feeder short circuit protections have the following setting:
I>: 300 A which corresponds to 45 A on 145 kV level.
I>>: 6 000 A which corresponds to 910 A on 145 kV level.
Characteristic: IEC Normal Inverse with k-factor = 0.25
The setting of the k-factor for the 145 kV phase overcurrent protection is derived from graphical study of the inverse time curves. It is required that the smallest time difference between the inverse time curves shall be 0.4 s. With the setting *k1* = 0.15 the time margin between the characteristics is about 0.4 s as shown in figure 7.



IEC09000431-1-en.vsd

Figure 7: Inverse time operation characteristics for selectivity

3.1.5 Calculating settings for four step phase overcurrent protection, LV-side OC4PTOC

The 22 kV phase overcurrent protection has the following purpose:

- Main protection for short circuits on 22 kV busbar
- Backup protection for short circuits on outgoing 22 kV feeders (if possible)

The reach of phase overcurrent line protection is dependent of the operation state and the fault type. Therefore the setting must be based on fault calculations made for different faults, fault points and switching states in the network. Although it is possible to make manual calculations of the different faults it is recommended to use computer based fault calculations. Different time delay principles can be used. This is due to different praxis.

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The following principle for the phase overcurrent protection is proposed:

- Step 1 serves as main protection for the 22 kV busbar. This step has a short delay and also has blocking input from the phase overcurrent protections of the 22 kV feeders. This is a way to achieve fast trip of 22 kV busbar short circuits and the selectivity is realized by means of the blocking from the feeder protections.
- Step 4 is used as back-up short circuit protection for the 22 kV feeders as far as possible. The time delay principle is chosen according to network praxis, in this case inverse time characteristics using IEC Normal inverse. As the step shall have inverse time characteristic the step 4 function is used.

3.1.5.1 Calculating general settings

1. Set *GlobalBaseSel* to *2*
   The settings are made in primary values. These values are given in the base settings in Global base 2.
2. Set directional mode
   2.1. Set *DirMode1* to *Non-directional*
   2.2. Set *DirMode4* to *Non-directional*

   The function shall be non-directional. Step 4 is used to achieve inverse time characteristic which is not available for step 2 and 3.
3. Set *Characterist1* to *IEC Def.Time*
   Step 1 shall have definite time delay
4. Set *Characterist4* to *IEC Norm.inv*
   Step 4: For the choice of time delay characteristic IEC Normal inverse is used in this network.

3.1.5.2 Calculating settings for step 1

1. Set *I1>* to *500 %* of *IBase*
   The requirement is that step 1 shall detect all short circuits on the 22 kV busbar. The external network has the maximum source impedance $Z_{sc} = j10$ Ω (145 kV level). This impedance is transformed to 22 kV level:

$$Z_{sc,22} = \left(\frac{22}{145}\right)^2 \cdot j10 = j0.23\,\Omega$$

(Equation 7)

The transformer impedance, referred to 22 kV level, is:

$$Z_{T,22} = j\frac{22^2}{60} \cdot 0.12 = j0.97\,\Omega$$

(Equation 8)

Calculation of a phase-to-phase short circuit at this busbar:

$$I_{sc2,ph} = \frac{\sqrt{3}}{2} \cdot \left| \frac{22000/\sqrt{3}}{j0.23 + j0.97} \right| = 9167\,A$$

(Equation 9)

The setting is chosen to *5 IBase* with corresponds to 7 875 A primary current.

2. Set *t1* to *0.1 s*
   The time delay must be chosen so that the blocking signal shall be able to prevent unwanted operation at feeder short circuits. 0.1 s should be sufficient.

3.1.5.3 Calculating settings for step 2

The first requirement is that the phase overcurrent protection shall never trip for load current during the extreme high load situations. It is assumed that the transformer shall be able to be operated up to 130 % of the rated power during limited time. Further shall the protection resetting ratio be considered. The resetting ratio is 0.95. The minimum setting can be calculated as follows:

$$I_{pu} \geq 1.3 \cdot \frac{1}{0.95} \cdot \frac{60 \cdot 1000}{\sqrt{3} \cdot 22} = 2155\,A$$

(Equation 10)

The next requirement is that the protection shall be able to detect all short circuits within the defined protected zone. In this case it is required, if possible, that the protection shall detect phase-to-phase short circuit at the most remote point of the outgoing feeders as shown in figure 8.

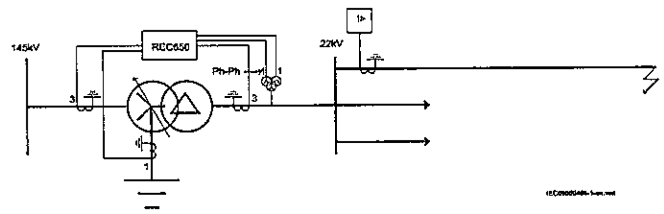

Figure 8: Fault calculation for phase overcurrent protection

The following fault is applied: phase-phase-earth short circuit. In this calculation should the short circuit power in the feeding substation be minimized (the source impedance maximized).

1. Set *I2>* to *140 %* of *IBase*
   2205 A primary current.

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The longest 22 kV feeder has the impedance Z = 3 + j10 Ω. The external network has the maximum source impedance Zsc = j10 Ω (145 kV level). This impedance is transformed to 22 kV level:

$$Z_{sc,22} = \left(\frac{22}{145}\right)^2 \cdot j10 = j0.23\,\Omega$$

(Equation 11)

The transformer impedance, referred to 22 kV level, is:
The phase-to-phase fault current can be calculated:

$$I_{sc2ph} = \frac{\sqrt{3}}{2} \cdot \left| \frac{22000/\sqrt{3}}{j0.23 + j0.97 + 3 + j10} \right| = 949\,A$$

(Equation 12)

This current is smaller than the required minimum setting to avoid unwanted trip at large load current. This means that the 22 kV phase overcurrent protection cannot serve as complete back-up protection for the 22 kV feeders out from the substation.

2. Set *k4* to *0.15*
The feeder short circuit protections have the following setting:
I>: 300 A.
I>>: 6 000 A.
Characteristic: IEC Normal Inverse with k-factor = 0.25
The setting of the k-factor for the 22 kV phase overcurrent protection is derived from graphical study of the inverse time curves. It is required that the smallest time difference between the inverse time curves is 0.4 s. With the setting *k4*= 0.15 the time margin between the characteristics is about 0.4 s as shown in figure 9.

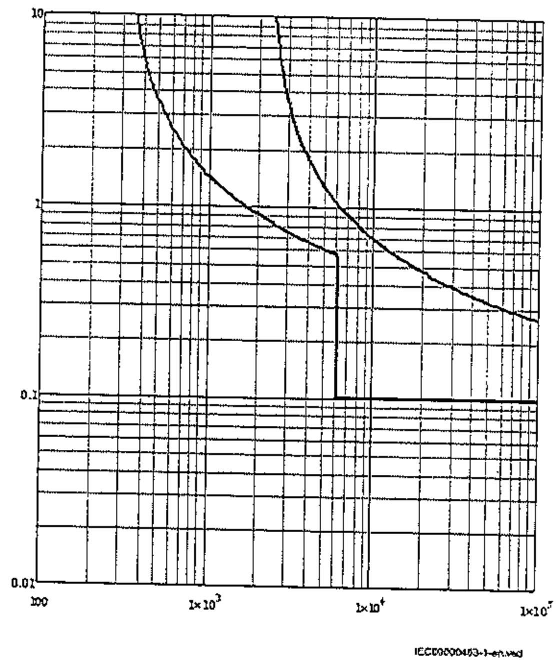

Figure 9: *Inverse time operation characteristics for selectivity*

3.1.6 Calculating settings for four step residual overcurrent protection HV-side EF4PTOC

The protection is fed from the 145 kV neutral point of the current transformer.

The residual overcurrent protection is more difficult to set as the earth-fault current is highly dependent of the switching state in the power system. In order to achieve setting that assure selective fault clearance a large number of calculations have to be made with different fault locations, different switching states in the system and different earth-fault types. Below one example of setting of residual overcurrent protection for a line in a meshed solidly earthed system is given.

If there is no generation at the low voltage side of the generator the transformer can only feed earth-fault currents as long as any of the non faulted lines are still in

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operation. If there is generation connected to the low voltage side of the transformer the transformer can feed 145 kV earth-faults alone.

The residual overcurrent protection has the following purpose:

- Fast and sensitive protection for earth-faults on the 145 kV busbar
- Backup protection for earth-faults in the 145 kV transformer winding
- Backup protection for earth-faults on the 145 kV lines out from the substation
- Sensitive detection of high resistive earth-faults and series faults in the 145 kV network

The reach of residual overcurrent line protection is dependent of the operation state and the fault type. Therefore the setting must be based on fault calculations made for different faults, fault points and switching states in the network. Although it is possible to make hand calculations of the different faults it is recommended to use computer based fault calculations. Different time delay principles can be used. This is due to different praxis.

The following principle for the residual overcurrent protection is proposed:

- Step 1 (*IN1>*) with high current setting and a short delay (about 0.4 s). Step 1 has non-directional function. This step gives fast trip for the busbar earth-faults and some earth-faults on the lines.
- Step 2 (*IN2>*) with a current setting, if possible, that enables detection of earth-faults on the 145 kV lines out from the substation. Step 2 has non-directional function. The function has a delay to enable selectivity to the line protections.
- Step 3 (*IN4>*) with a current setting that enables detection of high resistive earth-faults and series faults in the network. Step 3 has non-directional function. The function has a longer delay to enable selectivity.

3.1.6.1 Calculating general settings

The settings are made in primary values. These values are given in the base settings in Global base 1.

1. Set *GlobalBaseSel* to *1*
2. Set *DirMode1*, *DirMode2* and *DirMode4* to *Non-directional*
3. Set *DirMode3* to *Off*

3.1.6.2 Calculating settings for step 1

Set operating residual current level and time delay

1. Set *IN1>* to *650%* of *IBase*, corresponding to 1553 A
   Faults are applied at the 145 kV busbar as shown in figure 10.

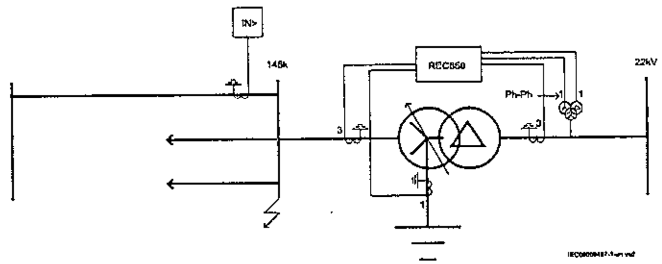

Figure 10: Fault calculation for 145 kV residual overcurrent protection setting

The following fault types are applied: phase-phase-earth short circuit and phase-earth-fault. The source impedance (both positive sequence and zero sequence) at the 145 kV level gives the following residual current from the transformer at phase-to-earth busbar fault (the current is hand-calculated but is normally calculated in a computer).
The zero sequence transformer impedance is assumed to be equal to the positive sequence short circuit impedance:

$$Z_{0T} = j\frac{U_N^2}{S_N}\cdot e_k = j\frac{145^2}{60}\cdot 0.12 = j42\,\Omega$$

(Equation 13)

The residual current from the transformer at single phase-earth-fault and maximum short circuit power is:

$$3I_{0T} = \frac{Z_{0,net}}{Z_{0,net}+Z_{0T}}\cdot\frac{\sqrt{3}\cdot U}{2\cdot Z_{1,net}+\frac{Z_{0,net}\cdot Z_{0T}}{Z_{0,net}+Z_{0T}}} = \frac{j15}{j15+j42}\cdot\frac{\sqrt{3}\cdot 145}{2\cdot j3.5+\frac{j15\cdot j42}{j15+j42}} = 3.7\,kA$$

(Equation 14)

The residual current from the transformer at single phase-earth-fault and minimum short circuit power is:

$$3I_{0T} = \frac{Z_{0,net}}{Z_{0,net}+Z_{0T}}\cdot\frac{\sqrt{3}\cdot U}{2\cdot Z_{1,net}+\frac{Z_{0,net}\cdot Z_{0T}}{Z_{0,net}+Z_{0T}}} = \frac{j20}{j20+j42}\cdot\frac{\sqrt{3}\cdot 145}{2\cdot j10+\frac{j20\cdot j42}{j20+j42}} = 2.4\,kA$$

(Equation 15)

The residual current from the transformer at phase-to-phase to earth-fault and maximum short circuit power is:

$$3I_{0T} = \frac{Z_{0,net}}{Z_{0,net}+Z_{0T}}\cdot\frac{\sqrt{3}\cdot U}{Z_{1,net}+2\cdot\frac{Z_{0,net}\cdot Z_{0T}}{Z_{0,net}+Z_{0T}}} = \frac{j15}{j15+j42}\cdot\frac{\sqrt{3}\cdot 145}{j3.5+2\cdot\frac{j15\cdot j42}{j15+j42}} = 2.6\,kA$$

(Equation 16)

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The residual current from the transformer at phase-to-phase to earth-fault and minimum short circuit power is:

$$3I_{0T} = \frac{Z_{0,net}}{Z_{0,net}+Z_{0T}} \cdot \frac{\sqrt{3}\cdot U}{Z_{1,net}+2\cdot\frac{Z_{0,net}\cdot Z_{0T}}{Z_{0,net}+Z_{0T}}} = \frac{j20}{j20+j42}\cdot\frac{\sqrt{3}\cdot 145}{j10+2\cdot\frac{j20\cdot j42}{j20+j42}} = 2.2\ kA$$

(Equation 17)

To assure that the protection detects all earth-faults on the 145 kV busbar the protection should be set:
Setting: $IN1> \leq 0.75 \cdot 2.2 = 1.65\ kA$

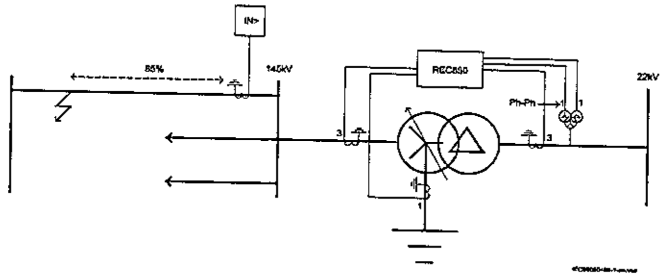

Figure 11: *Fault calculation for 145 kV residual overcurrent protection selectivity*

The calculations show the largest residual current from the transformer = 1.2 kA.
To assure selectivity the setting must fulfil:
$I_{high,set} \geq 1.2 \cdot k \cdot 3I_{0\,max}$
which gives about 1 500 A ,where k is the transient overreach (due to fault current DC-component) of the overcurrent function. For the four step phase overcurrent function; k = 1.05.

2. Set *t1* to *0.4 s*
   Characteristic1: ANSI Def.Time
   As the protection should be set for a time delay of 0.4 s the selectivity to the line protections should be assured. Therefore earth-faults should be calculated where the fault point on the lines is at zone 1 reach (about 85 % out on the line).

3.1.6.3 Calculating settings for step 2

1. Set *IN2>* to *400%* of *IBase*, corresponding to 956 A
   To assure that step 2 detects all earth-faults on the outgoing lines earth-faults calculations are made where single phase-faults and phase-to-phase-to earth-faults are applied to the adjacent busbars.

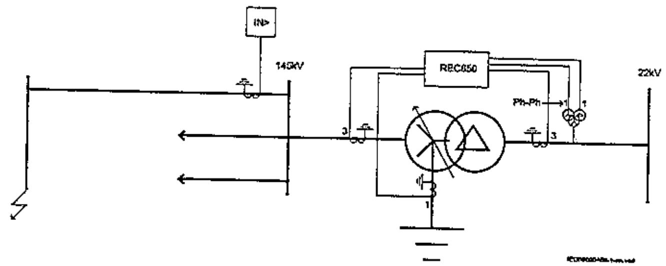

Figure 12: *Fault calculation for sufficient reach of the 145 kV residual overcurrent protection*

The minimum residual current to detect works out as $3I_{0AB,min}$ = 1.0 kA.

2. Set *t2* to *0.8 s*
   Characteristic2: ANSI Def.Time
   The delay of *IN2>* should be set longer than the distance protection zone 2 (normally 0.4 s). 0.8 s is proposed.

3.1.6.4 Calculating settings for step 4

1. Set *IN4>* to *42 %* of *IBase*, corresponding to 100 A
   The current setting of step 4 should be chosen according to standard procedure in the grid. From experience it can be concluded that the setting down to about 100 A can be used. This setting is however highly dependent on the line configuration, manly if the line is transposed or not.
   The delay of *IN4>* should be set larger than the delay of sensitive residual current protection of the lines.
2. Set *k4* to *0.3*
   Characteristic4: RD type
3. Set *t4Min* to *1.2 s*
4. Select *inverse time delay of type RD* to *logarithmic*
   If definite time delay is used there is some risk of unselective tip at high resistive earth-faults or series faults. If dependent time delay (inverse time) is used some degree of selectivity can be achieved.
   Here, inverse time delay of type RD is selected: logarithmic

3.1.7 Calculating settings for two step residual overvoltage protection LV-side, ROV2PTOV

The residual overvoltage protection is fed from the open delta connected voltage transformer at the 22 kV side of the transformer.

The residual overvoltage protection has the following purpose:

- Back-up protection for earth-faults on the 22 kV feeders out from the substation.
- Main protection for earth-faults on the 22 kV busbar
- Main protection for earth-faults on the 22 kV transformer winding

The residual voltage protection has two steps. In this application step 1 should trip the 22 kV circuit breaker and if the earth-fault is situated in the transformer 22 kV winding or between the transformer and the 22 kV breaker the 145 kV breaker is tripped from step 2.

The voltage setting of the protection is depending on the required sensitivity and the system earthing. The 22 kV system has earthing with a Petersen coil (connected to the system via a separate earthing transformer) and a parallel neutral point resistor. The Petersen coil is tuned to compensate for the capacitive earth-fault current in the 22 kV system. The neutral point resistor gives 10 A earth-fault current at zero resistance earth-fault. This means that the resistance is

$$R_N = \frac{22000/\sqrt{3}}{10} = 1270\ \Omega$$

(Equation 18)

The total zero sequence impedance of the 22 kV system is

$Z_0 = 3R_N // j3X_N // -jX_C\ \Omega / phase$

As the Petersen coil is tuned the zero sequence impedance is:

$Z_0 = 3R_N\ \Omega / phase$

The Residual voltage at resistive earth-fault in the 22 kV system is:

$$U_o = \frac{U_{Phase}}{1+\frac{3 \cdot R_f}{Z_0}} \text{ or } \frac{U_0}{U_{phase}} = \frac{1}{1+\frac{3 \cdot R_f}{Z_0}}$$

(Equation 19)

In our case the requirement is that earth-faults with resistance up to 5 000 Ω shall be detected. This gives:

$$\frac{U_0}{U_{phase}} = \frac{1}{1+\frac{3 \cdot 5000}{3 \cdot 1270}} = 0.20$$

(Equation 20)

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Step 1 and step 2 is given the same voltage setting but step 2 shall have longer time delay.

The residual earth-fault protection shall have definite time delay. The time setting is set longer than the time delay of the earth-fault protection of the outgoing feeders having maximum 2 s delay. Time delay for step 1 is set to 3 s and the time delay for step 2 is set to 4 s.

1. Set *GlobalBaseSel* to *2*
   The settings are made in primary values. These values are given in the base settings in Global base 2.
2. Set *Characteristic1* to *Definite time*
3. Set *U1>* to *20 %* of *UBase*
4. Set *t1* to *3.0 s*
5. Set *U2>* to *20 %* of *UBase*
6. Set *t2* to *4.0 s*

3.1.8 Calculating settings for breaker failure protection HV-side, CCRBRF

The breaker failure protection can use either contact function in the circuit breaker or current measurement to detect correct breaker function. For line protections it seems to be most suitable function is to use current measurement breaker check.

1. Set *GlobalBaseSel* to *1*
   The settings are made in primary values. These values are given in the base settings in Global base 1.
2. Set *FunctionMode* to *Current*
3. Set *BuTripMode* to *1 out of 4*
   In the current measurement the three-phase currents out on the line is used. It is also possible to measure the residual current (analogue input 4). The logics to detect failure of the circuit breaker can be chosen:
   - *1 out of 3*: at least one of the three-phase current shall be larger than the set level to detect failure to break
   - *1 out of 4*: at least one of the three-phase current and the residual current shall be larger than the set level to detect failure to break
   - *2 out of 4*: at least two of the three-phase current and the residual current shall be larger than the set level to detect failure to break As the residual current protection is one of the protection functions to initiate the breaker failure protection the setting *1 out of 4* is chosen.
4. Set *IP>* to *20 %* of *IBase*
   IP> should be set lower than the smallest current to be detected by the differential protection which is set 25 % of *IBase*.
5. Set *IN>* to *20 %* of *IBase*

IN> should be set lower than the smallest current to be detected by the most sensitive step of the residual ovecurrent protection which is 100 A.

6. Set the re-tip time delay *t1* to *0*
7. Set *t2* to *0.17 s*
   The delay time of the breaker failure protection (BuTrip) is chosen according to figure 13.
   The maximum opening time of the circuit breaker is considered to be 100 ms.
   The BFP reset time is maximum 15 ms.
   The margin should be chosen to about 2 cycles. This gives about 155 ms minimum setting of back-up trip delay *t2*.

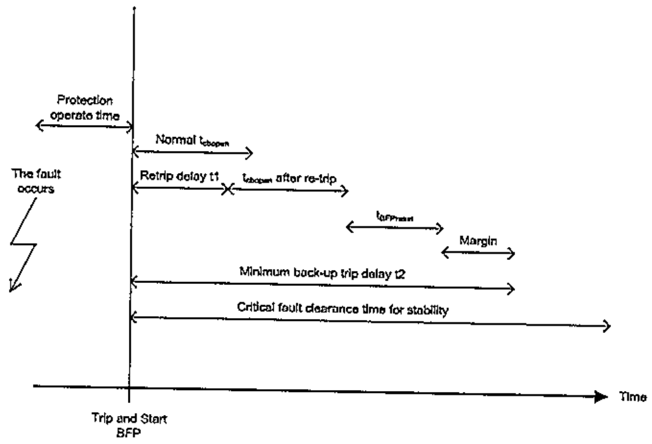

Figure 13: *Overexcitation protection characteristics*

Calculating settings for breaker failure protection LV-side CCRBRF

The breaker failure protection can use either contact function in the circuit breaker or current measurement to detect correct breaker function. For line protections it seems to be most suitable function is to use current measurement breaker check.

1. Set *GlobalBaseSel* to *2*

The settings are made in primary values. These values are given in the base settings in Global base 2.

2. Set *FunctionMode* to *Current*
3. Set *BuTripMode* to *1 out of 3*
   In the current measurement the three-phase currents out on the line is used. It is also possible to measure the residual current (analogue input 4). The logics to detect failure of the circuit breaker can be chosen:
   - *1 out of 3*: at least one of the three-phase current shall be larger than the set level to detect failure to break
   - *1 out of 4*: at least one of the three-phase current and the residual current shall be larger than the set level to detect failure to break
   - *2 out of 4*: at least two of the three-phase current and the residual current shall be larger than the set level to detect failure to break.

   There is no residual current measurement protection on the 22 kV side of the transformer. Therefore *1 out of 3* is chosen.
4. Set *IP>* to *20 % of IBase*
   IP> should be set lower than the smallest current to be detected by the differential protection which is set 25 % of *IBase*.
5. Set the re-tip time delay *t1* to *0 s*
6. Set *t2* to *0.17 s*
   The delay time of the breaker failure protection (BuTrip) is chosen according to figure 13.
   The maximum open time of the circuit breaker is considered to be 100 ms.
   The breaker failure protection reset time is maximum 15 ms.
   The margin should be chosen to about 2 cycles.
   This gives about 155 ms minimum setting of back-up trip delay t2.

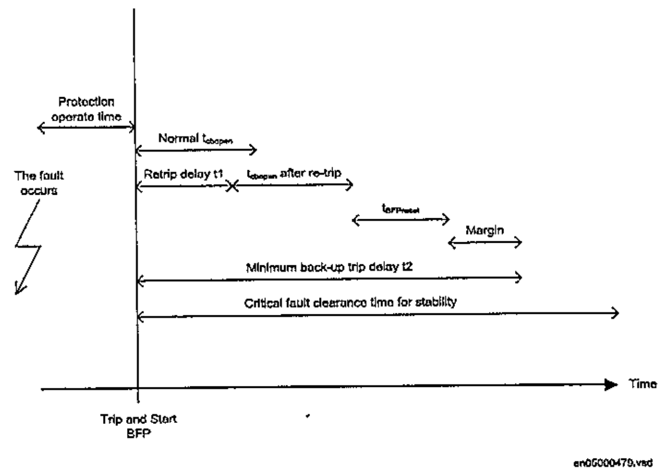

Figure 14: *Time sequences for breaker failure protection setting*

ВЯРНО С ОРИГИНАЛА

Section 4 Analog inputs

4.1 Introduction

Analog input channels are already configured inside the IED. However the IED has to be set properly to get correct measurement results and correct protection operations. For power measuring and all directional and differential functions the directions of the input currents must be defined properly. Measuring and protection algorithms in the IED use primary system quantities. Set values are done in primary quantities as well and it is important to set the data about the connected current and voltage transformers properly.

The availability of CT and VT inputs, as well as setting parameters depends on the ordered IED.

A reference *PhaseAngleRef*must be defined to facilitate service values reading. This analog channels phase angle will always be fixed to zero degree and all other angle information will be shown in relation to this analog input. During testing and commissioning of the IED the reference channel can be changed to facilitate testing and service values reading.

4.2 Setting guidelines

4.2.1 Setting of the phase reference channel

All phase angles are calculated in relation to a defined reference. An appropriate analog input channel is selected and used as phase reference. The parameter *PhaseAngleRef* defines the analog channel that is used as phase angle reference.

4.2.1.1 Example

The setting shall be used if a phase-to-earth voltage (usually the L1 phase-to-earth voltage connected to VT channel number of the analog card) is selected to be the phase reference.

4.2.1.2 Setting of current channels

The direction of a current to the IED is depending on the connection of the CT. Unless indicated otherwise, the main CTs are supposed to be star connected and can be connected with the earthing point to the object or from the object. This

information must be set to the IED. The convention of the directionality is defined as follows: A positive value of current, power, and so on means that the quantity has the direction into the object and a negative value means direction out from the object. For directional functions the direction into the object is defined as Forward and the direction out from the object is defined as Reverse. See figure 15

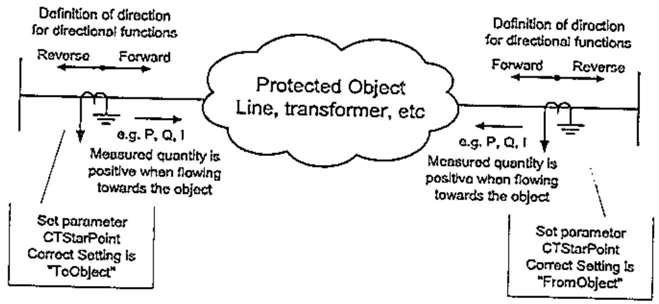

Figure 15: Internal convention of the directionality in the IED

With correct setting of the primary CT direction, *CTStarPoint* set to *FromObject* or *ToObject*, a positive quantities always flowing towards the object and a direction defined as Forward always is looking towards the object. The following examples show the principle.

4.2.1.3 Example 1

Two IEDs used for protection of two objects.

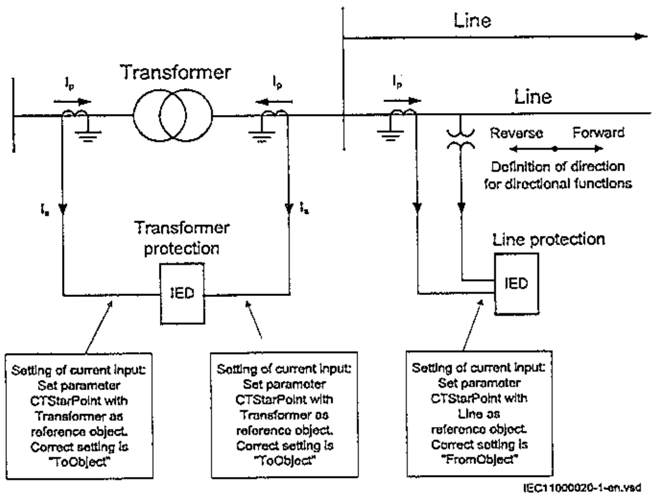

Figure 16: *Example how to set CTStarPoint parameters in the IED*

The figure 16 shows the most normal case where the objects have their own CTs. The settings for CT direction shall be done according to the figure. To protect the line the direction of the directional functions of the line protection shall be set to *Forward*. This means that the protection is looking towards the line.

4.2.1.4 Example 2

Two IEDs used for protection of two objects and sharing a CT.

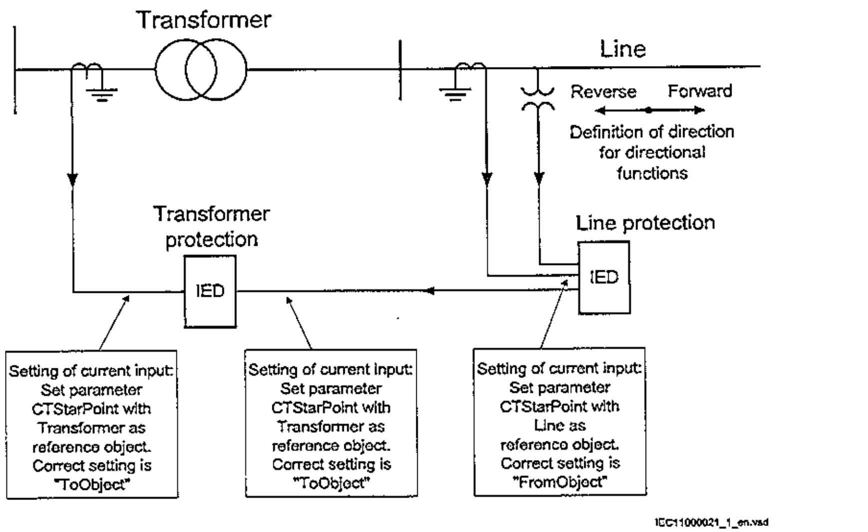

Figure 17: *Example how to set CTStarPoint parameters in the IED*

This example is similar to example 1 but the transformer is feeding just one line and the line protection uses the same CT as the transformer protection does. The CT direction is set with different reference objects for the two IEDs though it is the same current from the same CT that is feeding two IEDs. With these settings the directional functions of the line protection shall be set to *Forward* to look towards the line.

4.2.1.5 Examples how to connect, configure and set CT inputs for most commonly used CT connections

Figure 18 defines the marking of current transformers terminals commonly used around the world:

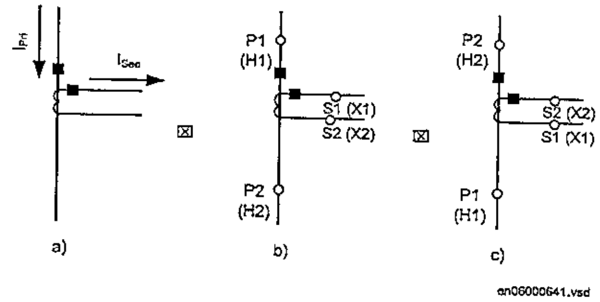

Figure 18: Commonly used markings of CT terminals

Where:

a) is symbol and terminal marking used in this document. Terminals marked with a dot indicates the primary and secondary winding terminals with the same (that is, positive) polarity

b) and c) are equivalent symbols and terminal marking used by IEC (ANSI) standard for CTs. Note that for this two cases the CT polarity marking is correct!

It shall be noted that depending on national standard and utility practices rated secondary current of a CT has typically one of the following values:

- 1A
- 5A

However in some cases the following rated secondary currents are as well used:

- 2A
- 10A

The IED fully supports all of these rated secondary values.

4.2.1.6 Example how to connect star connected three-phase CT set to the IED

Figure 19 gives an example how to connect the star connected three-phase CT set to the IED. It as well gives overview of required actions by the user in order to make this measurement available to the built-in protection and control functions within the IED.

For correct connections, see the connection diagrams valid for the delivered IED.

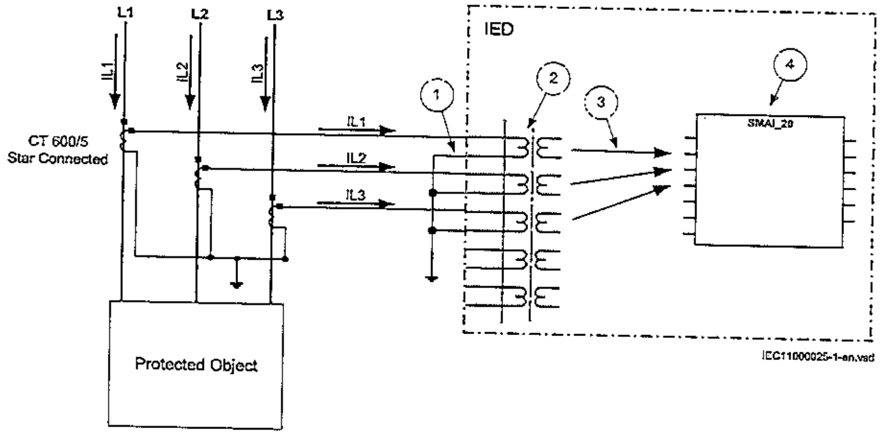

Figure 19: Star connected three-phase CT set with star point towards the protected object

Where:

1) shows how to connect three individual phase currents from star connected three-phase CT set to three CT inputs in the IED.

2) is TRM or AIM where these current inputs are located. It shall be noted that for all these current inputs the following setting values shall be entered.

- CTprim=600A
- CTsec=5A
- CTStarPoint=ToObject

Inside the IED only the ratio of the first two parameters is used. The third parameter as set in this example will have no influence on the measured currents (that is, currents are already measured towards the protected object).

3) are three connections, which connects these three current inputs to three input channels of the preprocessing function block 6). Depending on the type of functions, which need this current information, more than one preprocessing block might be connected in parallel to these three CT inputs.

4) Preprocessing block has a task to digitally filter the connected analog inputs and calculate:

- fundamental frequency phasors for all four input channels
- harmonic content for all four input channels
- positive, negative and zero sequence quantities by using the fundamental frequency phasors for the first three input channels (channel one taken as reference for sequence quantities)

These calculated values are then available for all built-in protection and control functions within the IED, which are connected to this preprocessing function block. For this application most of the preprocessing settings can be left to the default values.
If frequency tracking and compensation is required (this feature is typically required only for IEDs installed in the generating stations) then the setting parameters DFTReference shall be set accordingly.

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Another alternative is to have the star point of the three-phase CT set as shown in figure 20:

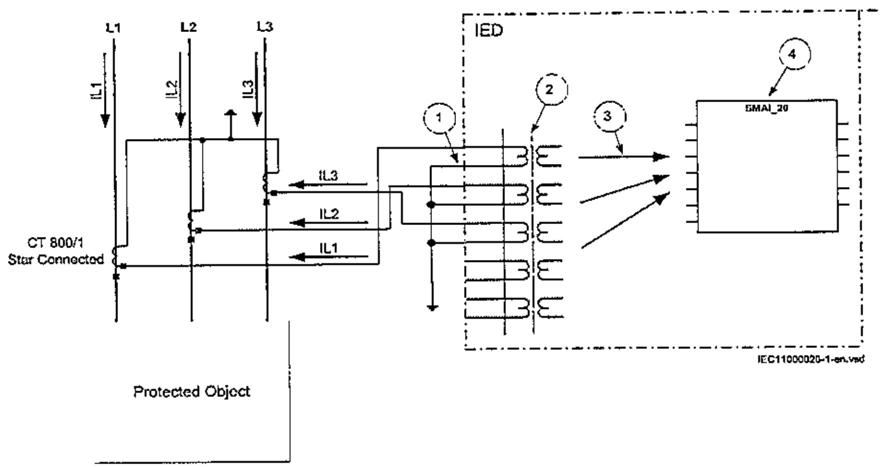

Figure 20: *Star connected three-phase CT set with star point from the protected object*

Please note that in this case everything is done in a similar way as in the above described example, except that for all used current inputs on the TRM the following setting parameters shall be entered:

- *CTprim*=800A
- *CTsec*=1A
- *CTStarPoint*=FromObject

Inside the IED only the ratio of the first two parameters is used. The third parameter as set in this example will reverse the measured currents (that is, turn the currents by 180°) in order to ensure that the currents within the IED are measured towards the protected object.

Setting of voltage channels

As the IED uses primary system quantities the main VT ratios must be known. This is done by setting the two parameters *VTsec* and *VTprim* for each voltage channel. The phase-to-phase value can be used even if each channel is connected to a phase-to-earth voltage from the VT.

Example

Consider a VT with the following data:

$$\frac{132kV}{\sqrt{3}} \Big/ \frac{110V}{\sqrt{3}}$$

(Equation 21)

The following setting should be used: *VTprim*=*132* (value in kV) *VTsec*=*110* (value in V)

4.2.1.9 Examples how to connect, configure and set VT inputs for most commonly used VT connections

Figure 21 defines the marking of voltage transformers terminals commonly used around the world.

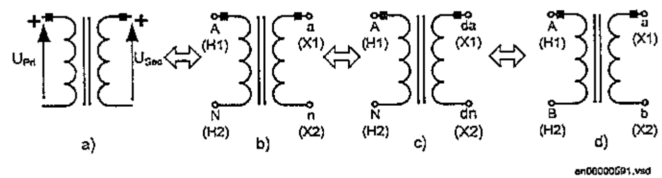

Figure 21: *Commonly used markings of VT terminals*

Where:

a) is symbol and terminal marking used in this document. Terminals marked with a dot indicates the primary and secondary winding terminals with the same (that is, positive) polarity

b) is equivalent symbol and terminal marking used by IEC (ANSI) standard for phase-to-earth connected VT

c) is equivalent symbol and terminal marking used by IEC (ANSI) standard for open delta connected VT

d) is equivalent symbol and terminal marking used by IEC (ANSI) standard for phase-to-phase connected VT

It shall be noted that depending on national standard and utility practices rated secondary voltage of a VT has typically one of the following values:

- 100 V
- 110 V
- 115 V
- 120 V

The IED fully supports all of these values and most of them will be shown in the following examples.

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4.2.1.10 Examples how to connect three phase-to-earth connected VTs to the IED

Figure 22 gives an example how to connect the three phase-to-earth connected VTs to the IED. It as well gives overview of required actions by the user in order to make this measurement available to the built-in protection and control functions within the IED.

For correct connections, see the connection diagrams valid for the delivered IED.

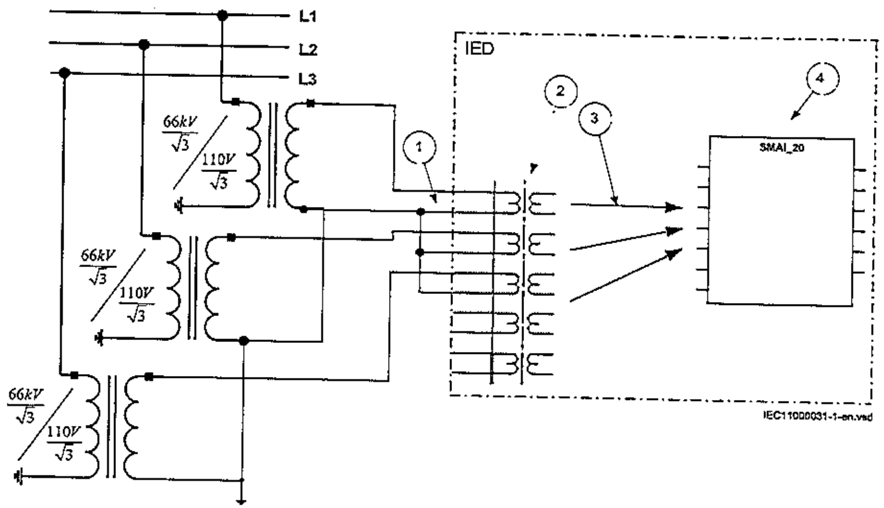

Figure 22: Three phase-to-earth connected VTs

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Where :

1) shows how to connect three secondary phase-to-earth voltages to three VT inputs in the IED

2) is TRM or AIM where these three voltage inputs are located. It shall be noted that for these three voltage inputs the following setting values shall be entered:
VTprim=66 kV
VTsec= 110 V
Inside the IED, only the ratio of these two parameters is used. It shall be noted that the ratio of the entered values exactly corresponds to ratio of one individual VT.

$$\frac{66}{110} = \frac{66/\sqrt{3}}{110/\sqrt{3}}$$

(Equation 22)

3) are three connections, which connect these three voltage inputs to three input channels of the preprocessing function block 5). Depending on type of functions which need this voltage information, more then one preprocessing block might be connected in parallel to these three VT inputs

4) Preprocessing block has a task to digitally filter the connected analog inputs and calculate:
- fundamental frequency phasors for all four input channels
- harmonic content for all four input channels
- positive, negative and zero sequence quantities by using the fundamental frequency phasors for the first three input channels (channel one taken as reference for sequence quantities)

These calculated values are then available for all built-in protection and control functions within the IED, which are connected to this preprocessing function block. For this application most of the preprocessing settings can be left to the default values. However the following settings shall be set as shown here:
UBase=66 kV (that is, rated Ph-Ph voltage)
If frequency tracking and compensation is required (this feature is typically required only for IEDs installed in the generating stations) then the setting parameters *DFTReference* shall be set accordingly.

4.2.1.11 Example how to connect two phase-to-phase connected VTs to the IED

Figure 23 gives an example how to connect the two phase-to-phase connected VTs to the IED. It as well gives overview of required actions by the user in order to make this measurement available to the built-in protection and control functions within the IED. It shall be noted that this VT connection is only used on lower voltage levels (that is, rated primary voltage below 40 kV).

For correct connections, see the connection diagrams valid for the delivered IED.

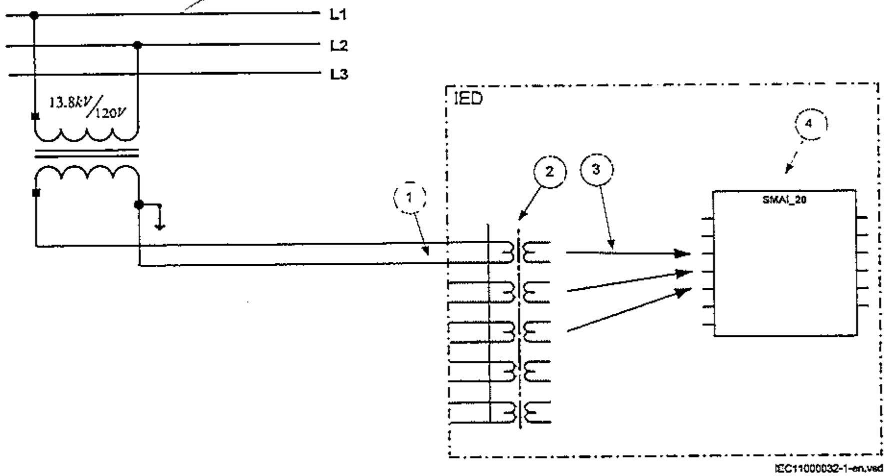

Figure 23: Phase-to-phase connected VTs

Where:

1) shows how to connect secondary side of two phase-to-phase VTs to three VT inputs in the IED

2) is the TRM or AIM where these three voltage inputs are located. It shall be noted that for these three voltage inputs the following setting values shall be entered:
VTprim=13.8 kV
VTsec=120 V
Please note that inside the IED only ratio of these two parameters is used.

3) are three connections, which connects these three voltage inputs to three input channels of the preprocessing function block 5). Depending on the type of functions, which need this voltage information, more than one preprocessing block might be connected in parallel to these three VT inputs

4) Preprocessing block has a task to digitally filter the connected analog inputs and calculate:

- fundamental frequency phasors for all four input channels
- harmonic content for all four input channels
- positive, negative and zero sequence quantities by using the fundamental frequency phasors for the first three input channels (channel one taken as reference for sequence quantities)

These calculated values are then available for all built-in protection and control functions within the IED, which are connected to this preprocessing function block. For this application most of the preprocessing settings can be left to the default values. However the following settings shall be set as shown here:
ConnectionType=*Ph-Ph*
UBase=13.8 kV
If frequency tracking and compensation is required (this feature is typically required only for IEDs installed in the generating stations) then the setting parameters *DFTReference* shall be set accordingly.

Section 5 Local human-machine interface

5.1 Local HMI

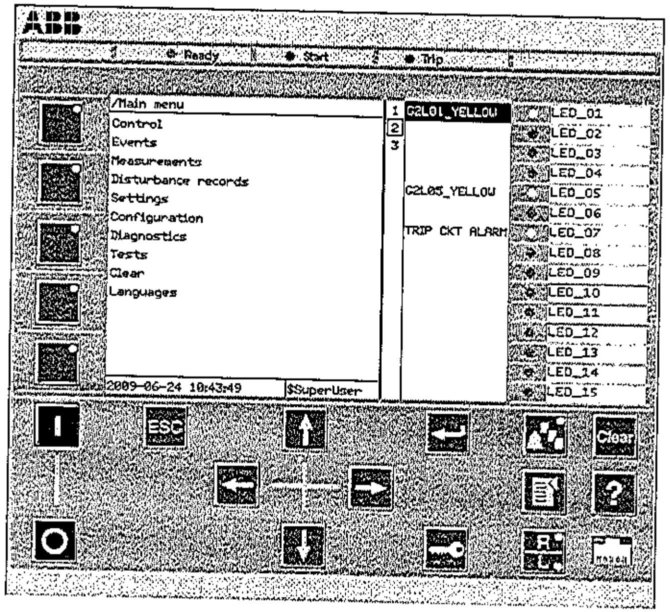

Figure 24: Local human-machine interface

The LHMI of the IED contains the following elements:

- Display (LCD)
- Buttons
- LED indicators
- Communication port

The LHMI is used for setting, monitoring and controlling .

5.1.1 Display

The LHMI includes a graphical monochrome display with a resolution of 320 x 240 pixels. The character size can vary. The amount of characters and rows fitting the view depends on the character size and the view that is shown.

The display view is divided into four basic areas.

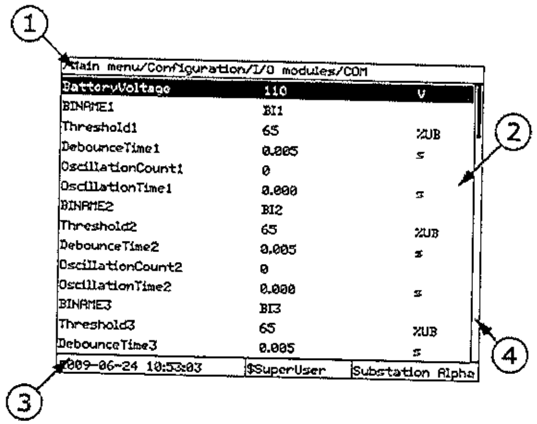

Figure 25: Display layout

1 Path
2 Content
3 Status
4 Scroll bar (appears when needed)

The function button panel shows on request what actions are possible with the function buttons. Each function button has a LED indication that can be used as a feedback signal for the function button control action. The LED is connected to the required signal with PCM600.

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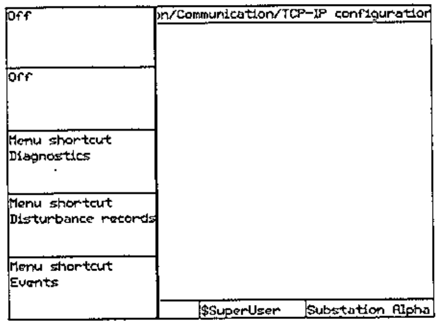

Figure 26: *Function button panel*

The alarm LED panel shows on request the alarm text labels for the alarm LEDs.

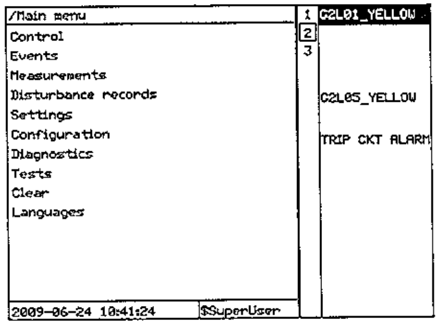

Figure 27: *Alarm LED panel*

The function button and alarm LED panels are not visible at the same time. Each panel is shown by pressing one of the function buttons or the Multipage button. Pressing the ESC button clears the panel from the display. Both the panels have dynamic width that depends on the label string length that the panel contains.

LEDs

The LHMI includes three protection indicators above the display: Ready, Start and Trip.

There are also 15 matrix programmable alarm LEDs on front of the LHMI. Each LED can indicate three states with the colors: green, yellow and red. The alarm texts related to each three-color LED are divided into three pages.The 15 physical

three-color LEDs in one LED group can indicate 45 different signals. Altogether, 135 signals can be indicated since there are three LED groups. The LEDs can be configured with PCM600 and the operation mode can be selected with the LHMI or PCM600.

5.1.3 Keypad

The LHMI keypad contains push-buttons which are used to navigate in different views or menus. With the push-buttons you can give open or close commands to one primary object, for example, a circuit breaker, disconnector or an earthing switch. The push-buttons are also used to acknowledge alarms, reset indications, provide help and switch between local and remote control mode.

The keypad also contains programmable push-buttons that can be configured either as menu shortcut or control buttons.

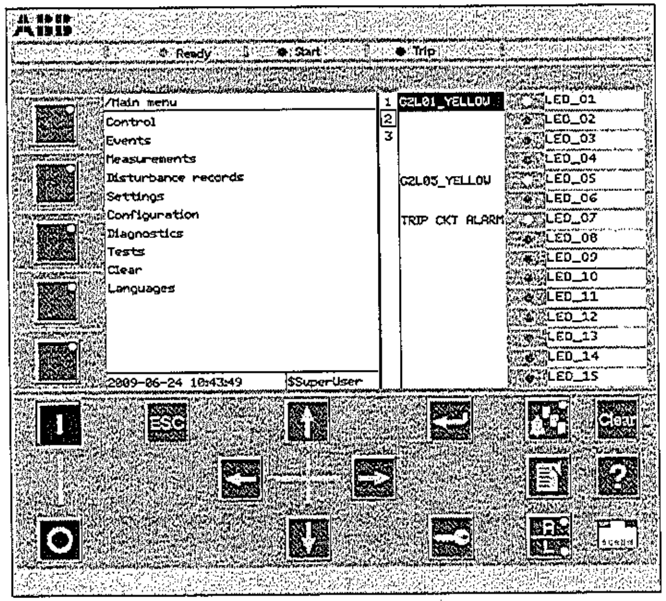

Figure 28: *LHMI keypad*

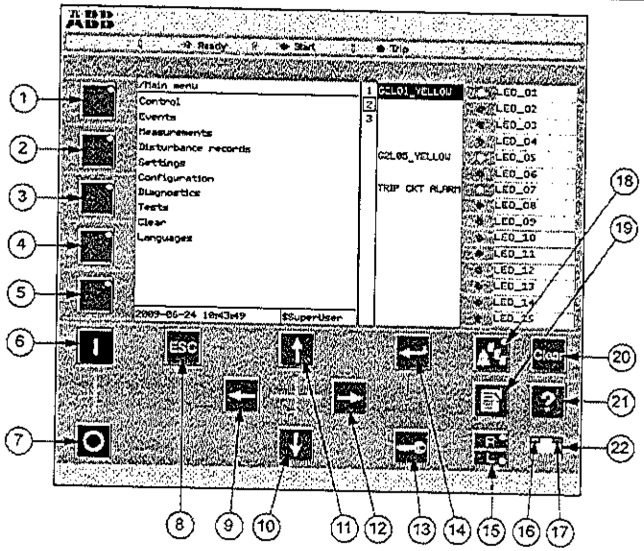

Figure 29: LHMI keypad with object control, navigation and command push-buttons and RJ-45 communication port

1...5 Function button
6 Close
7 Open
8 Escape
9 Left
10 Down
11 Up
12 Right
13 Key
14 Enter
15 Remote/Local
16 Uplink LED
17 Not in use
18 Multipage
19 Menu
20 Clear
21 Help

22 Communication port

5.1.4 Local HMI functionality

5.1.4.1 Protection and alarm indication

Protection indicators

The protection indicator LEDs are Ready, Start and Trip.

Configure the disturbance recorder to enable the start and trip LEDs.

Table 4: Ready LED (green)

LED state	Description
Off	Auxiliary supply voltage is disconnected.
On	Normal operation.
Flashing	Internal fault has occurred.

Table 5: Start LED (yellow)

LED state	Description
Off	Normal operation.
On	A protection function has started and an indication message is displayed. • The start indication is latching and must be reset via communication or by pressing [Clear].
Flashing	A flashing yellow LED has a higher priority than a steady yellow LED. The IED is in test mode and protection functions are blocked. • The indication disappears when the IED is no longer in test mode and blocking is removed.

Table 6: Trip LED (red)

LED state	Description
Off	Normal operation.
On	A protection function has tripped and an indication message is displayed. • The trip indication is latching and must be reset via communication or by pressing [Clear].

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Alarm indicators

The 15 programmable three-color LEDs are used for alarm indication. An individual alarm/status signal, connected to any of the LED function blocks, can be assigned to one of the three LED colors when configuring the IED.

Table 7: Alarm indications

LED state	Description
Off	Normal operation. All activation signals are off.
On	• Follow-S sequence: The activation signal is on. • LatchedColl-S sequence: The activation signal is on, or it is off but the indication has not been acknowledged. • LatchedAck-F-S sequence: The indication has been acknowledged, but the activation signal is still on. • LatchedAck-S-F sequence: The activation signal is on, or it is off but the indication has not been acknowledged. • LatchedReset-S sequence: The activation signal is on, or it is off but the indication has not been acknowledged.
Flashing	• Follow-F sequence: The activation signal is on. • LatchedAck-F-S sequence: The activation signal is on, or it is off but the indication has not been acknowledged. • LatchedAck-S-F sequence: The indication has been acknowledged, but the activation signal is still on.

Alarm indications for REC650

Table 8: Alarm group 1 indications in REC650 (A02) configuration

Alarm group 1 LEDs	LED color	Label
GRP1_LED1	Red LED	GENERAL TRIP
GRP1_LED2	Red LED	CB FAIL TRIP
GRP1_LED3	Red LED	50/51 OC TRIP
GRP1_LED4	Red LED	51N EF TRIP
GRP1_LED5	Red LED	59 OV TRIP
GRP1_LED6	Red LED	52 PD TRIP
GRP1_LED7	Red LED	EXTERNAL TRIP
GRP1_LED8	Red LED	LOCKOUT TRIP
GRP1_LED9	-	-
GRP1_LED10	-	-
GRP1_LED11	-	-
GRP1_LED12	-	-
GRP1_LED13	-	-
GRP1_LED14	-	-
GRP1_LED15	-	-

Table 9: Alarm group 2 indications in REC650 (A02) configuration

Alarm group 2 LEDs	LED color	Label
GRP2_LED1	Yellow LED	GENERAL START
GRP2_LED2	-	-
GRP2_LED3	Yellow LED	51 OC START
GRP2_LED4	Yellow LED	51N EF START
GRP2_LED5	Yellow LED	59 OV START
GRP2_LED6	Yellow LED	52 PD START
GRP2_LED7	-	-
GRP2_LED8	-	-
GRP2_LED9	-	-
GRP2_LED10	-	-
GRP2_LED11	-	-
GRP2_LED12	-	-
GRP2_LED13	-	-
GRP2_LED14	-	-
GRP2_LED15	-	-

Table 10: Alarm group 3 indications in REC650 (A02) configuration

Alarm group 3 LEDs	LED color	Label
GRP3_LED1 - GRP3_LED9	-	-
GRP3_LED10	Yellow LED	SELECT IN BAY
GRP3_LED11	Yellow LED	EXT RESERV
GRP3_LED12	Yellow LED	SYNCHRONIZING INPR
GRP3_LED13	Yellow LED	CB SUPV ALARM
GRP3_LED14	Yellow LED	TCS ALARM
GRP3_LED15	Red LED	BAT SUP ALARM
	Yellow LED	BAT SUP START

5.1.4.2 Parameter management

The LHMI is used to access the IED parameters. Three types of parameters can be read and written.

- Numerical values
- String values
- Enumerated values

Numerical values are presented either in integer or in decimal format with minimum and maximum values. Character strings can be edited character by character. Enumerated values have a predefined set of selectable values.

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5.1.4.3 Front communication

The RJ-45 port in the LHMI enables front communication.

- The green uplink LED on the left is lit when the cable is successfully connected to the port.

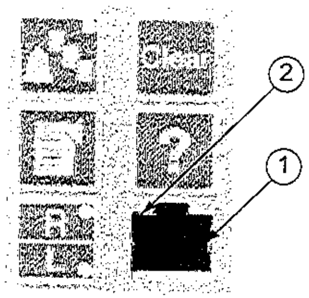

Figure 30: RJ-45 communication port and green indicator LED

1 RJ-45 connector
2 Green indicator LED

When a computer is connected to the IED front port with a crossed-over cable, the IED's DHCP server for the front interface assigns an IP address to the computer if *DHCPServer = On*. The default IP address for the front port is 10.1.150.3.

Do not connect the IED front port to LAN. Connect only a single local PC with PCM600 to front port.

5.1.4.4 Single-line diagram

Single-line diagram is used for bay monitoring and/or control. It shows a graphical presentation of the bay which is configured with PCM600.

Single-line diagram for REC650

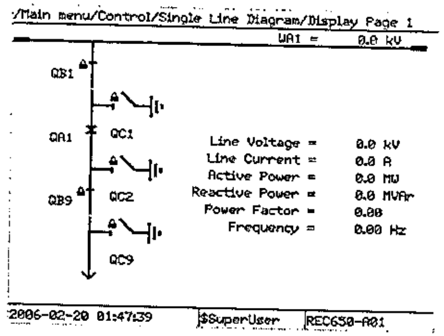

Figure 31: Single-line diagram for REC650 (A01)

Section 6 Current protection

6.1 Instantaneous phase overcurrent protection PHPIOC

6.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Instantaneous phase overcurrent protection	PHPIOC	3I>>	50

6.1.2 Application

Long transmission lines often transfer great quantities of electric power from production to consumption areas. The unbalance of the produced and consumed electric power at each end of the transmission line is very large. This means that a fault on the line can easily endanger the stability of a complete system.

The transient stability of a power system depends mostly on three parameters (at constant amount of transmitted electric power):

- The type of the fault. Three-phase faults are the most dangerous, because no power can be transmitted through the fault point during fault conditions.
- The magnitude of the fault current. A high fault current indicates that the decrease of transmitted power is high.
- The total fault clearing time. The phase angles between the EMFs of the generators on both sides of the transmission line increase over the permitted stability limits if the total fault clearing time, which consists of the protection operating time and the breaker opening time, is too long.

The fault current on long transmission lines depends mostly on the fault position and decreases with the distance from the generation point. For this reason the protection must operate very quickly for faults very close to the generation (and relay) point, for which very high fault currents are characteristic.

The instantaneous phase overcurrent protection PHPIOC can operate in 10 ms for faults characterized by very high currents.

6.1.3 Setting guidelines

The parameters for instantaneous phase overcurrent protection PHPIOC are set via the local HMI or PCM600.

This protection function must operate only in a selective way. So check all system and transient conditions that could cause its unwanted operation.

Only detailed network studies can determine the operating conditions under which the highest possible fault current is expected on the line. In most cases, this current appears during three-phase fault conditions. But also examine single-phase-to-earth and two-phase-to-earth conditions.

Also study transients that could cause a high increase of the line current for short times. A typical example is a transmission line with a power transformer at the remote end, which can cause high inrush current when connected to the network and can thus also cause the operation of the built-in, instantaneous, overcurrent protection.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

IP>>: Set operate current in % of *IBase*.

6.1.3.1 Meshed network without parallel line

The following fault calculations have to be done for three-phase, single-phase-to-earth and two-phase-to-earth faults. With reference to figure 32, apply a fault in B and then calculate the current through-fault phase current I_{fB}. The calculation should be done using the minimum source impedance values for Z_A and the maximum source impedance values for Z_B in order to get the maximum through fault current from A to B.

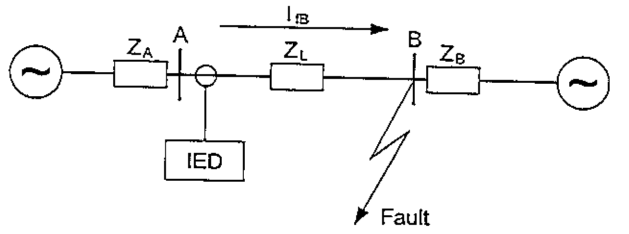

Figure 32: Through fault current from A to B: I_{fB}

Then a fault in A has to be applied and the through fault current I_{fA} has to be calculated, figure 33. In order to get the maximum through fault current, the minimum value for Z_B and the maximum value for Z_A have to be considered.

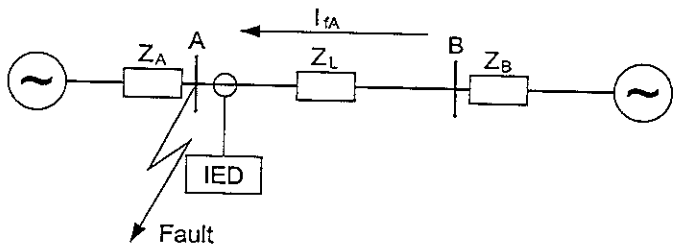

Figure 33: Through fault current from B to A: I_{fA}

The IED must not trip for any of the two through-fault currents. Hence the minimum theoretical current setting (Imin) will be:

$$Imin \geq MAX(I_{fA}, I_{fB})$$

(Equation 23)

A safety margin of 5% for the maximum protection static inaccuracy and a safety margin of 5% for the maximum possible transient overreach have to be introduced. An additional 20% is suggested due to the inaccuracy of the instrument transformers under transient conditions and inaccuracy in the system data.

The minimum primary setting (Is) for the instantaneous phase overcurrent protection is then:

$$Is \geq 1,3 \cdot Imin$$

(Equation 24)

The protection function can be used for the specific application only if this setting value is equal to or less than the maximum fault current that the IED has to clear, I_F in figure 34.

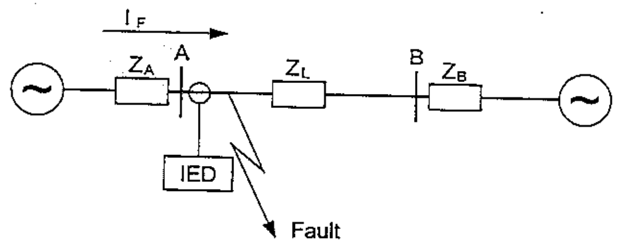

Figure 34: Fault current: I_F

$$IP >>= \frac{Is}{IBase} \cdot 100$$

(Equation 25)

6.1.3.2 Meshed network with parallel line

In case of parallel lines, the influence of the induced current from the parallel line to the protected line has to be considered. One example is given in figure 35 where the two lines are connected to the same busbars. In this case the influence of the induced fault current from the faulty line (line 1) to the healthy line (line 2) is considered together with the two through fault currents I_{fA} and I_{fB} mentioned previously. The maximal influence from the parallel line for the IED in figure 35 will be with a fault at the C point with the C breaker open.

A fault in C has to be applied, and then the maximum current seen from the IED (I_M) on the healthy line (this applies for single-phase-to-earth and two-phase-to-earth faults) is calculated.

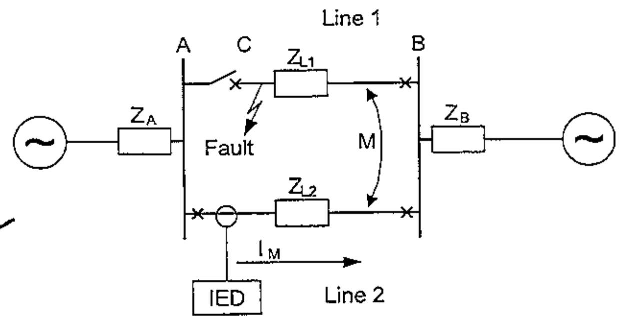

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Figure 35: Two parallel lines. Influence from parallel line to the through fault current: I_M

The minimum theoretical current setting for the overcurrent protection function (Imin) will be:

$$Imin \geq MAX(I_{fA}, I_{fB}, I_M)$$

(Equation 26)

Where I_{fA} and I_{fB} have been described in the previous paragraph. Considering the safety margins mentioned previously, the minimum setting (Is) for the instantaneous phase overcurrent protection is then:

$$Is \geq 1.3 \cdot Imin$$

(Equation 27)

The protection function can be used for the specific application only if this setting value is equal or less than the maximum phase fault current that the IED has to clear.

The IED setting value *IP>>* is given in percentage of the primary base current value, *IBase*. The value for *IP>>* is given from this formula:

$$IP>> = \frac{Is}{IBase} \cdot 100$$

(Equation 28)

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6.2 Four step phase overcurrent protection OC4PTOC

6.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Four step phase overcurrent protection	OC4PTOC	3I> 4 alt 4	51/67

6.2.2 Application

The Four step phase overcurrent protection OC4PTOC is used in several applications in the power system. Some applications are:

- Short circuit protection of feeders in distribution and subtransmission systems. Normally these feeders have radial structure.
- Back-up short circuit protection of transmission lines.
- Back-up short circuit protection of power transformers.
- Short circuit protection of different kinds of equipment connected to the power system such as; shunt capacitor banks, shunt reactors, motors and others.
- Back-up short circuit protection of power generators.

If VT inputs are not available or not connected, setting parameter *DirModex* (*x* = step 1, 2, 3 or 4) shall be left to default value *Non-directional*or set to *Off*.

In many applications several steps with different current pick up levels and time delays are needed. OC4PTOC can have up to four different, individual settable, steps. The flexibility of each step of OC4PTOC is great. The following options are possible:

Non-directional / Directional function: In most applications the non-directional functionality is used. This is mostly the case when no fault current can be fed from the protected object itself. In order to achieve both selectivity and fast fault clearance, the directional function can be necessary.

Choice of delay time characteristics: There are several types of delay time characteristics available such as definite time delay and different types of inverse time delay characteristics. The selectivity between different overcurrent protections is normally enabled by co-ordination between the function time delays of the different protections. To enable optimal co-ordination between all overcurrent protections, they should have the same time delay characteristic. Therefore a wide range of standardized inverse time characteristics are available: IEC and ANSI.

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The time characteristic for step 1 and 4 can be chosen as definite time delay or inverse time characteristic. Step 2 and 3 are always definite time delayed and are used in system where IDMT is not needed.

6.2.3 Setting guidelines

The parameters for Four step phase overcurrent protection OC4PTOC are set via the local HMI or PCM600.

The following settings can be done for OC4PTOC.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

MeasType: Selection of discrete Fourier filtered (DFT) or true RMS filtered (RMS) signals. RMS is used when the harmonic contents are to be considered, for example in applications with shunt capacitors.

Operation: The protection can be set to *Off* or *On*

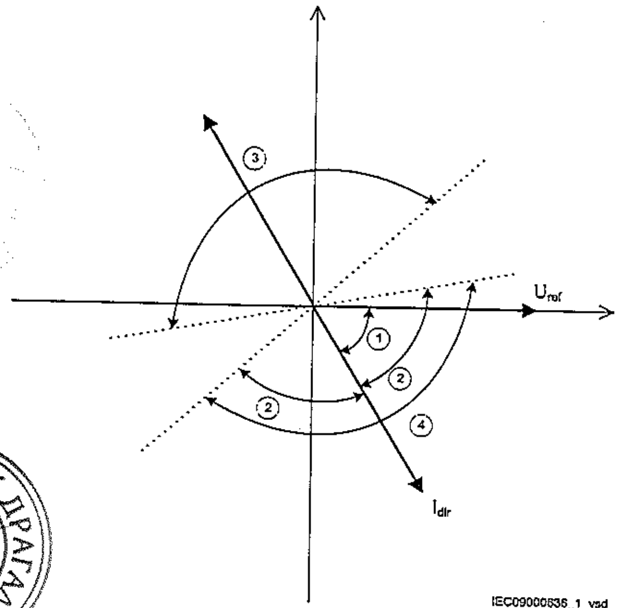

Figure 36: Directional function characteristic

1. RCA = Relay characteristic angle 55°
2. ROA = Relay operating angle 80°
3. Reverse
4. Forward

6.2.3.1 Settings for steps 1 to 4

n means step 1 and 4. *x* means step 1, 2, 3 and 4.

DirModex: The directional mode of step *x*. Possible settings are *Off/Non-directional/Forward/Reverse*.

Characteristn: Selection of time characteristic for step *n*. Definite time delay and different types of inverse time characteristics are available according to table 11. Step 2 and 3 are always definite time delayed.

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Table 11: *Inverse time characteristics*

Curve name
ANSI Extremely Inverse
ANSI Very Inverse
ANSI Normal Inverse
ANSI Moderately Inverse
ANSI/IEEE Definite time
ANSI Long Time Extremely Inverse
ANSI Long Time Very Inverse
ANSI Long Time Inverse
IEC Normal Inverse
IEC Very Inverse
IEC Inverse
IEC Extremely Inverse
IEC Short Time Inverse
IEC Long Time Inverse
IEC Definite Time
ASEA RI
RXIDG (logarithmic)

The different characteristics are described in Technical manual.

Ix>: Operation phase current level for step *x* given in % of *IBase*.

tx: Definite time delay for step *x*. Used if definite time characteristic is chosen.

kn: Time multiplier for inverse time delay for step *n*.

IMinn: Minimum operate current for step *n* in % of *IBase*. Set *IMinn* below *Ix>* for every step to achieve ANSI reset characteristic according to standard. If *IMinn* is set above *Ix>* for any step the ANSI reset works as if current is zero when current drops below *IMinn*.

tnMin: Minimum operation time for all inverse time characteristics. At high currents the inverse time characteristic might give a very short operation time. By setting this parameter the operation time of the step can never be shorter than the setting. Setting range: 0.000 - 60.000s in steps of 0.001s.

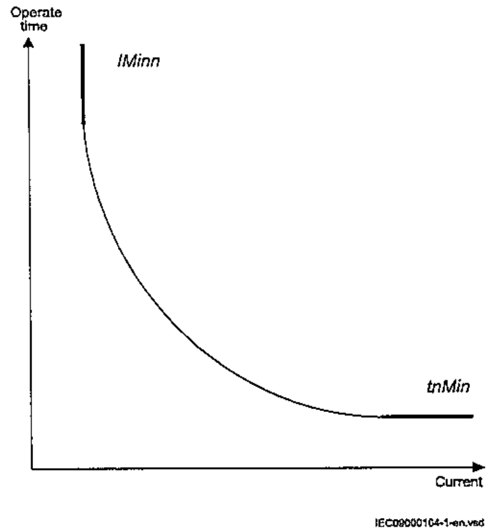

Figure 37: Minimum operate current and operation time for inverse time characteristics

In order to fully comply with curves definition setting parameter *tnMin* shall be set to the value, which is equal to the operating time of the selected inverse curve for measured current of twenty times the set current pickup value. Note that the operating time value is dependent on the selected setting value for time multiplier *kn*.

6.2.3.2 Current applications

The four step phase overcurrent protection can be used in different ways, depending on the application where the protection is used. A general description is given below.

The operating current setting inverse time protection or the lowest current step constant inverse time protection must be given a current setting so that the highest possible load current does not cause protection operation. Here consideration also has to be taken to the protection reset current, so that a short peak of overcurrent does not cause operation of the protection even when the overcurrent has ceased. This phenomenon is described in figure 38.

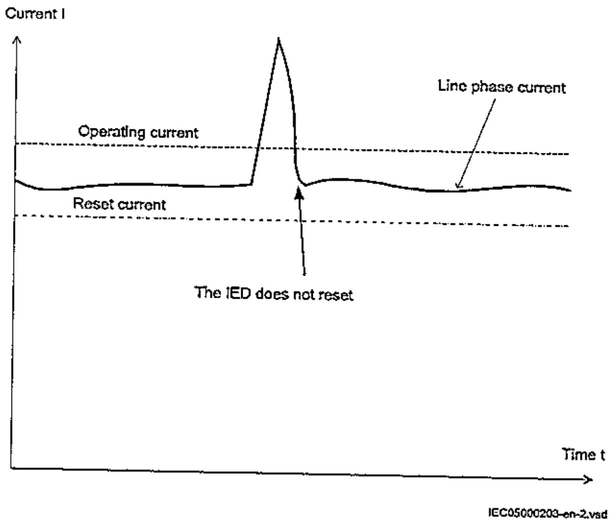

Figure 38: Operating and reset current for an overcurrent protection

The lowest setting value can be written according to equation 29.

$$Ipu \geq 1.2 \cdot \frac{Imax}{k}$$

(Equation 29)

where:

1.2 is a safety factor,

k is the resetting ratio of the protection, and

Imax is the maximum load current.

The maximum load current on the line has to be estimated. There is also a demand that all faults, within the zone that the protection shall cover, must be detected by the phase overcurrent protection. The minimum fault current Iscmin, to be detected by the protection, must be calculated. Taking this value as a base, the highest pick up current setting can be written according to equation 30.

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$$Ipu \leq 0.7 \cdot Isc\,min$$

(Equation 30)

where:

0.7 is a safety factor and

Iscmin is the smallest fault current to be detected by the overcurrent protection.

As a summary the operating current shall be chosen within the interval stated in equation 31.

$$1.2 \cdot \frac{Imax}{k} \leq Ipu \leq 0.7 \cdot Isc\,min$$

(Equation 31)

The high current function of the overcurrent protection, which only has a short delay of the operation, must be given a current setting so that the protection is selective to other protection in the power system. It is desirable to have a rapid tripping of faults within as large portion as possible of the part of the power system to be protected by the protection (primary protected zone). A fault current calculation gives the largest current of faults, Iscmax, at the most remote part of the primary protected zone. Considerations have to be made to the risk of transient overreach, due to a possible DC component of the short circuit current. The lowest current setting of the most rapid stage, of the phase overcurrent protection, can be written according to

$$I_{high} \geq 1.2 \cdot k_t \cdot I_{scmax}$$

(Equation 32)

where:

1.2 is a safety factor,

k_t is a factor that takes care of the transient overreach due to the DC component of the fault current and can be considered to be less than 1.1

Iscmax is the largest fault current at a fault at the most remote point of the primary protection zone.

The operate times of the phase overcurrent protection has to be chosen so that the fault time is so short that protected equipment will not be destroyed due to thermal overload, at the same time as selectivity is assured. For overcurrent protection, in a radial fed network, the time setting can be chosen in a graphical way. This is mostly used in the case of inverse time overcurrent protection. Figure 39 shows how the time-versus-current curves are plotted in a diagram. The time setting is chosen to get the shortest fault time with maintained selectivity. Selectivity is assured if the time difference between the curves is larger than a critical time difference.

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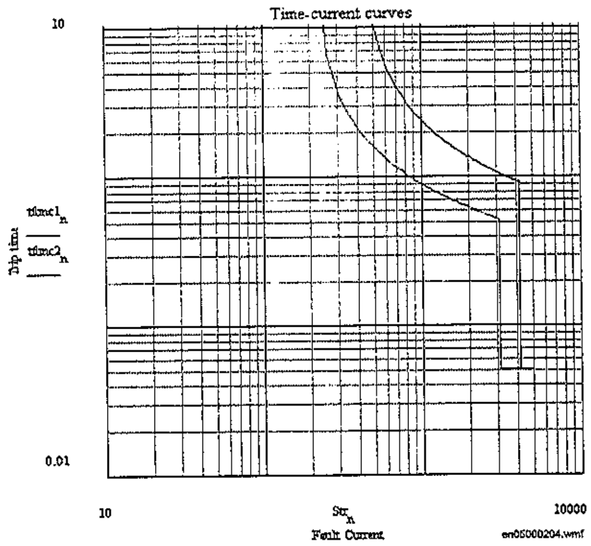

Figure 39: Fault time with maintained selectivity

To assure selectivity between different protections, in the radial network, there have to be a minimum time difference Δt between the time delays of two protections. The minimum time difference can be determined for different cases. To determine the shortest possible time difference, the operation time of protections, breaker opening time and protection resetting time must be known. These time delays can vary significantly between different protective equipment. The following time delays can be estimated:

Protection operation time:	15-60 ms
Protection resetting time:	15-60 ms
Breaker opening time:	20-120 ms

Example

Assume two substations A and B directly connected to each other via one line, as shown in the figure 40. Consider a fault located at another line from the station B. The fault current to the overcurrent protection of IED B1 has a magnitude so that the protection will have instantaneous function. The overcurrent protection of IED A1 must have a delayed function. The sequence of events during the fault can be described using a time axis, see figure 40.

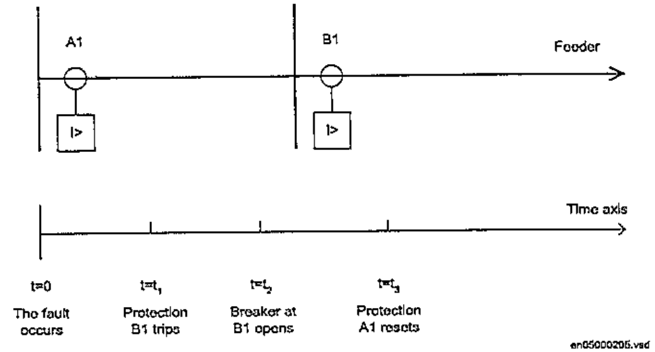

Figure 40: Sequence of events during fault

where:

t=0	is when the fault occurs,
$t=t_1$	is when the trip signal from the overcurrent protection at IED B1 is sent to the circuit breaker. The operation time of this protection is t_1,
$t=t_2$	is when the circuit breaker at IED B1 opens. The circuit breaker opening time is $t_2 - t_1$ and
$t=t_3$	is when the overcurrent protection at IED A1 resets. The protection resetting time is $t_3 - t_2$.

To ensure that the overcurrent protection at IED A1, is selective to the overcurrent protection at IED B1, the minimum time difference must be larger than the time t_3. There are uncertainties in the values of protection operation time, breaker opening time and protection resetting time. Therefore a safety margin has to be included. With normal values the needed time difference can be calculated according to equation 33.

$$\Delta t \geq 40\,ms + 100\,ms + 40\,ms + 40\,ms = 220\,ms \quad \text{(Equation 33)}$$

where it is considered that:

the operation time of overcurrent protection B1	is 40 ms
the breaker open time	is 100 ms
the resetting time of protection A1	is 40 ms and
the additional margin	is 40 ms

6.3 Instantaneous residual overcurrent protection EFPIOC

6.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Instantaneous residual overcurrent protection	EFPIOC	IN>>	50N

6.3.2 Application

In many applications, when fault current is limited to a defined value by the object impedance, an instantaneous earth-fault protection can provide fast and selective tripping.

The Instantaneous residual overcurrent EFPIOC, which can operate in 15 ms (50 Hz nominal system frequency) for faults characterized by very high currents, is included in the IED.

6.3.3 Setting guidelines

The parameters for the Instantaneous residual overcurrent protection EFPIOC are set via the local HMI or PCM600.

Some guidelines for the choice of setting parameter for EFPIOC is given.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

The setting of the function is limited to the operation residual current to the protection (*IN>>*).

The basic requirement is to assure selectivity, that is EFPIOC shall not be allowed to operate for faults at other objects than the protected object (line).

For a normal line in a meshed system single phase-to-earth faults and phase-to-phase-to-earth faults shall be calculated as shown in figure 41 and figure 42. The residual currents ($3I_0$) to the protection are calculated. For a fault at the remote line end this fault current is I_{fB}. In this calculation the operational state with high source impedance Z_A and low source impedance Z_B should be used. For the fault at the

home busbar this fault current is I_{fA}. In this calculation the operational state with low source impedance Z_A and high source impedance Z_B should be used.

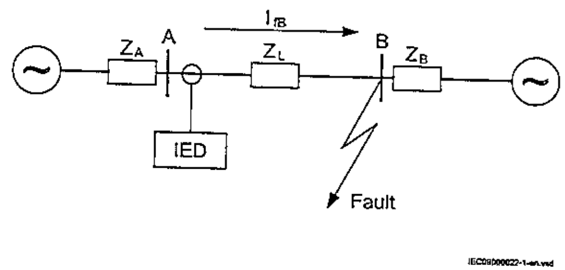

Figure 41: Through fault current from A to B: I_{fB}

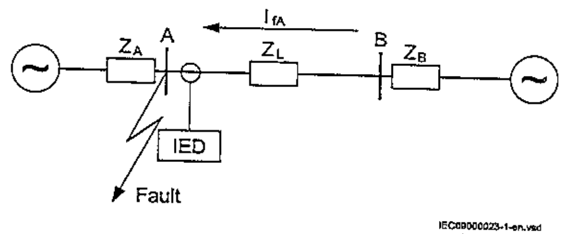

Figure 42: Through fault current from B to A: I_{fA}

The function shall not operate for any of the calculated currents to the protection. The minimum theoretical current setting (Imin) will be:

$$Imin \geq MAX(I_{fA}, I_{fA})$$ (Equation 34)

A safety margin of 5% for the maximum static inaccuracy and a safety margin of 5% for maximum possible transient overreach have to be introduced. An additional 20% is suggested due to inaccuracy of instrument transformers under transient conditions and inaccuracy in the system data.

The minimum primary current setting (Is) is:

$$Is \geq 1,3 \cdot Imin$$ (Equation 35)

In case of parallel lines with zero sequence mutual coupling a fault on the parallel line, as shown in figure 43, should be calculated.

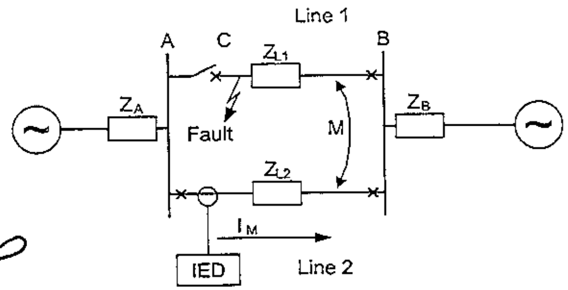

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Figure 43: Two parallel lines. Influence from parallel line to the through fault current: I_M

The minimum theoretical current setting (Imin) will in this case be:

$$I\min \geq MAX(I_{fA}, I_{fB}, I_M)$$ (Equation 36)

Where:

I_{fA} and I_{fB} have been described for the single line case.

Considering the safety margins mentioned previously, the minimum setting (Is) is:

$$Is \geq 1,3 \cdot I\min$$ (Equation 37)

Transformer inrush current shall be considered.

The setting of the protection is set as a percentage of the base current (*IBase*).

Operation: set the protection to *On* or *Off*.

IN>>: Set operate current in % of *IBase*. *IBase* is a global parameter valid for all functions in the IED.

6.4 Four step residual overcurrent protection EF4PTOC

6.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Four step residual overcurrent protection	EF4PTOC	IN 4 alt 4	51N/67N

6.4.2 Application

The four step residual overcurrent protection EF4PTOC is used in several applications in the power system. Some applications are:

- Earth-fault protection of feeders in effectively earthed distribution and subtransmission systems. Normally these feeders have radial structure.
- Back-up earth-fault protection of transmission lines.
- Sensitive earth-fault protection of transmission lines. EF4PTOC can have better sensitivity to detect resistive phase-to-earth-faults compared to distance protection.
- Back-up earth-fault protection of power transformers.
- Earth-fault protection of different kinds of equipment connected to the power system such as shunt capacitor banks, shunt reactors and others.

In many applications several steps with different current operating levels and time delays are needed. EF4PTOC can have up to four, individual settable steps. The flexibility of each step of EF4PTOC is great. The following options are possible:

Non-directional/Directional function: In some applications the non-directional functionality is used. This is mostly the case when no fault current can be fed from the protected object itself. In order to achieve both selectivity and fast fault clearance, the directional function can be necessary. This can be the case for earth-fault protection in meshed and effectively earthed transmission systems. The directional residual overcurrent protection is also well suited to operate in teleprotection communication schemes, which enables fast clearance of earth faults on transmission lines. The directional function uses the polarizing quantity as decided by setting. Voltage polarizing ($-3U_0$) is most commonly used but alternatively current polarizing where currents in transformer neutrals providing the neutral (zero sequence) source (ZN) is used to polarize ($IN \cdot ZN$) the function. Dual polarizing where the sum of both voltage and current components is allowed to polarize can also be selected.

Choice of time characteristics: There are several types of time characteristics available such as definite time delay and different types of inverse time

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characteristics. The selectivity between different overcurrent protections is normally enabled by co-ordination between the operating time of the different protections. To enable optimal co-ordination all overcurrent protections, to be co-ordinated against each other, should have the same time characteristic. Therefore a wide range of standardized inverse time characteristics are available: IEC and ANSI. The time characteristic for step 1 and 4 can be chosen as definite time delay or inverse time characteristic. Step 2 and 3 are always definite time delayed and are used in system where IDMT is not needed.

Table 12: Time characteristics

Curve name
ANSI Extremely Inverse
ANSI Very Inverse
ANSI Normal Inverse
ANSI Moderately Inverse
ANSI/IEEE Definite time
ANSI Long Time Extremely Inverse
ANSI Long Time Very Inverse
ANSI Long Time Inverse
IEC Normal Inverse
IEC Very Inverse
IEC Inverse
IEC Extremely Inverse
IEC Short Time Inverse
IEC Long Time Inverse
IEC Definite Time
ASEA RI
RXIDG (logarithmic)

Power transformers can have a large inrush current, when being energized. This inrush current can have residual current components. The phenomenon is due to saturation of the transformer magnetic core during parts of the cycle. There is a risk that inrush current will give a residual current that reaches level above the operating current of the residual overcurrent protection. The inrush current has a large second harmonic content. This can be used to avoid unwanted operation of the protection. Therefore, EF4PTOC has a possibility of second harmonic restrain *2ndHarmStab* if the level of this harmonic current reaches a value above a set percentage of the fundamental current.

6.4.3 Setting guidelines

The parameters for the four step residual overcurrent protection EF4PTOC are set via the local HMI or PCM600.

The following settings can be done for the four step residual overcurrent protection.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Operation: Sets the protection to *On* or *Off*.

6.4.3.1 Settings for steps 1 and 4

n means step 1 and 4.

DirModex: The directional mode of step *x*. Possible settings are *Off/Non-directional/Forward/Reverse*.

Characteristx: Selection of time characteristic for step *x*. Definite time delay and different types of inverse time characteristics are available.

Inverse time characteristic enables fast fault clearance of high current faults at the same time as selectivity to other inverse time phase overcurrent protections can be assured. This is mainly used in radial fed networks but can also be used in meshed networks. In meshed networks the settings must be based on network fault calculations.

To assure selectivity between different protections, in the radial network, there have to be a minimum time difference Δt between the time delays of two protections. The minimum time difference can be determined for different cases. To determine the shortest possible time difference, the operation time of protections, breaker opening time and protection resetting time must be known. These time delays can vary significantly between different protective equipment. The following time delays can be estimated:

Protection operation time:	15-60 ms
Protection resetting time:	15-60 ms
Breaker opening time:	20-120 ms

The different characteristics are described in the Technical Manual (TM).

INx>: Operation residual current level for step *x* given in % of *IBase*.

kx: Time multiplier for the dependent (inverse) characteristic for step *x*.

IMinn: Minimum operate current for step *n* in % of *IBase*. Set *IMinn* below *Ix>* for every step to achieve ANSI reset characteristic according to standard. If *IMinn* is set above *Ix>* for any step the ANSI reset works as if current is zero when current drops below *IMinn*.

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tnMin: Minimum operating time for inverse time characteristics. At high currents the inverse time characteristic might give a very short operation time. By setting this parameter the operation time of the step *n* can never be shorter than the setting.

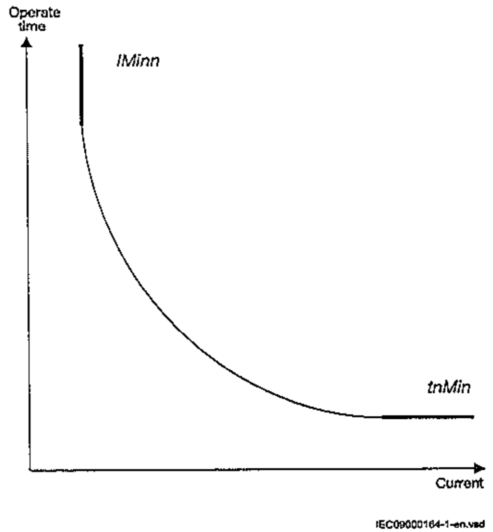

Figure 44: *Minimum operate current and operation time for inverse time characteristics*

In order to fully comply with curves definition the setting parameter *txMin* shall be set to the value which is equal to the operating time of the selected IEC inverse curve for measured current of twenty times the set current pickup value. Note that the operating time value is dependent on the selected setting value for time multiplier *kx*.

Common settings for all steps

tx: Definite time delay for step *x*. Used if definite time characteristic is chosen.

AngleRCA: Relay characteristic angle given in degree. This angle is defined as shown in figure 45. The angle is defined positive when the residual current lags the reference voltage (Upol = $-3U_0$)

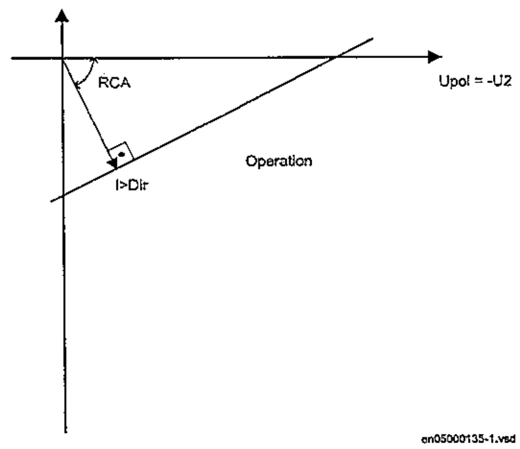

Figure 45: *Relay characteristic angle given in degree*

In a normal transmission network a normal value of RCA is about 65°. The setting range is -180° to +180°.

polMethod: Defines if the directional polarization is from

- voltage ($-3U_0$)
- current ($3I_0 \cdot$ ZNpol where ZNpol is RNpol + jXNpol), or
- both currents and voltage (dual polarizing, $-3U0 + 3I_0 \cdot$ ZNpol).

Normally voltage polarizing from the residual sum or an external open delta is used. Current polarizing is useful when the local source is strong and a high sensitivity is required. In such cases the polarizing voltage ($-3U_0$) can be below 1% and it is then necessary to use current polarizing or dual polarizing. Multiply the required set current (primary) with the minimum impedance (ZNpol) and check that the percentage of the phase-to-earth voltage is definitely higher than 1% (minimum $3U_0$>*UPolMin* setting) as a verification.

RNPol, XNPol: The zero-sequence source is set in primary ohms as base for the current polarizing. The polarizing voltage is then achieved as $3I_0 \cdot$ ZNpol. The ZNpol can be defined as $(ZS_1-ZS_0)/3$, that is the earth return impedance of the source behind the protection. The maximum earth-fault current at the local source can be used to calculate the value of ZN as $U/(\sqrt{3} \cdot 3I_0)$ Typically, the minimum ZNPol (3 · zero sequence source) is set. Setting is in primary ohms.

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When the dual polarizing method is used it is important that the setting *INx>* or the product $3I_0 \cdot$ ZNpol is not greater than $3U_0$. If so, there is a risk for incorrect operation for faults in the reverse direction.

IPolMin: is the minimum earth-fault current accepted for directional evaluation. For smaller currents than this value the operation will be blocked. Typical setting is 5-10% of *IBase*.

UPolMin: Minimum polarization (reference) residual voltage for the directional function, given in % of *UBase*/√3.

IN>Dir: Operating residual current release level in % of *IBase* for directional comparison scheme. The setting is given in % of *IBase*. The output signals, STFW and STRV can be used in a teleprotection scheme. The appropriate signal should be configured to the communication scheme block.

6.4.3.3 2nd harmonic restrain

If a power transformer is energized there is a risk that the current transformer core will saturate during part of the period, resulting in an inrush transformer current. This will give a declining residual current in the network, as the inrush current is deviating between the phases. There is a risk that the residual overcurrent function will give an unwanted trip. The inrush current has a relatively large ratio of 2nd harmonic component. This component can be used to create a restrain signal to prevent this unwanted function.

At current transformer saturation a false residual current can be measured by the protection. Also here the 2^{nd} harmonic restrain can prevent unwanted operation.

2ndHarmStab: The rate of 2nd harmonic current content for activation of the 2nd harmonic restrain signal. The setting is given in % of the fundamental frequency residual current.

HarmRestrainx: Enable block of step *x* from the harmonic restrain function.

6.4.3.4 Line application example

The Four step residual overcurrent protection EF4PTOC can be used in different ways. Below is described one application possibility to be used in meshed effectively earthed systems.

The protection measures the residual current out on the protected line. The protection function has a directional function where the residual voltage (zero-sequence voltage) is the polarizing quantity.

The residual voltage can be internally generated when a three-phase set of voltage transformers are used.

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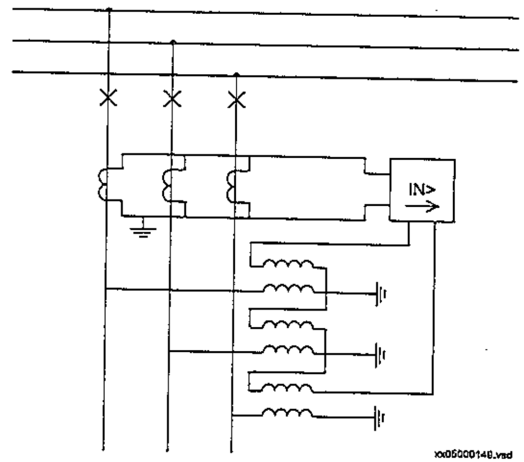

Figure 46: Connection of polarizing voltage from an open delta

The different steps can be described as follows.

Step 1

This step has directional instantaneous function. The requirement is that overreaching of the protected line is not allowed.

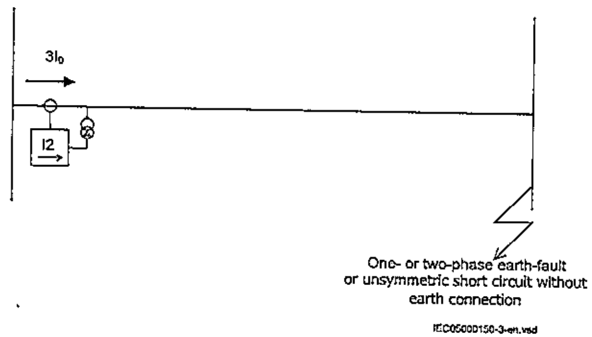

Figure 47: Step 1, first calculation

The residual current out on the line is calculated at a fault on the remote busbar (one- or two-phase-to-earth fault). To assure selectivity it is required that step 1 shall not give a trip at this fault. The requirement can be formulated according to equation 38.

$I_{set} \geq 1.2 \cdot 3I_0$ (remote busbar)

(Equation 38)

As a consequence of the distribution of zero sequence current in the power system, the current to the protection might be larger if one line out from the remote busbar is taken out of service, see figure 48.

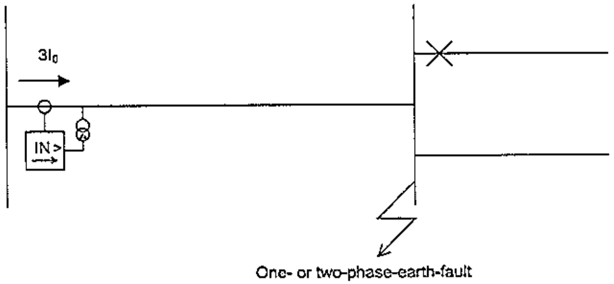

Figure 48: Step 1, second calculation. Remote busbar with, one line taken out of service

The requirement is now according to equation 39.

$I_{set} \geq 1.2 \cdot 3I_0$ (remote busbar with one line out)

(Equation 39)

A higher value of step 1 might occur if a big power transformer (Y0/D) at remote bus bar is disconnected.

A special case occurs at double circuit lines, with mutual zero-sequence impedance between the parallel lines, see figure 49.

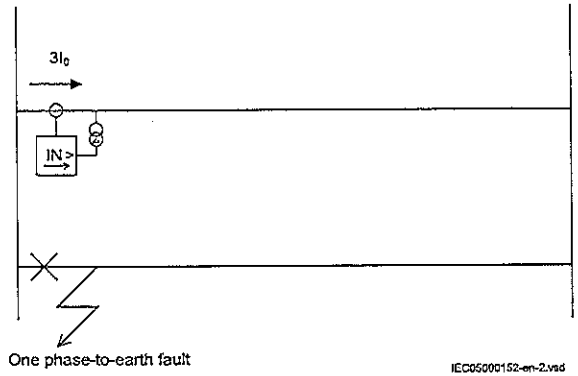

Figure 49: Step 1, third calculation

In this case the residual current out on the line can be larger than in the case of earth fault on the remote busbar.

$I_{set} \geq 1.2 \cdot 3I_0$

(Equation 40)

The current setting for step 1 is chosen as the largest of the above calculated residual currents, measured by the protection.

Step 2

This step has directional function and a short time delay, often about 0.4 s. Step 2 shall securely detect all earth faults on the line, not detected by step 1.

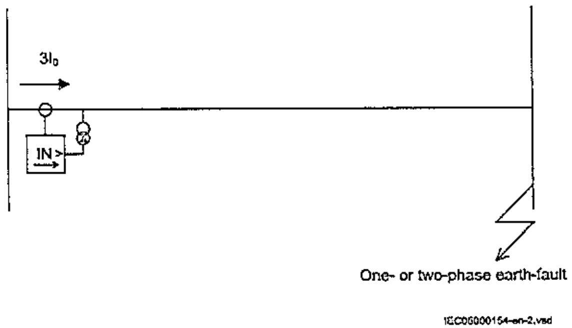

Figure 50: Step 2, check of reach calculation

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The residual current, out on the line, is calculated at an operational case with minimal earth-fault current. The requirement that the whole line shall be covered by step 2 can be formulated according to equation 41.

$$I_{step1} \geq 0.7 \cdot 3I_0 \text{ (at remote busbar)}$$

(Equation 41)

To assure selectivity the current setting must be chosen so that step 2 does not operate at step 2 for faults on the next line from the remote substation. Consider a fault as shown in figure 51.

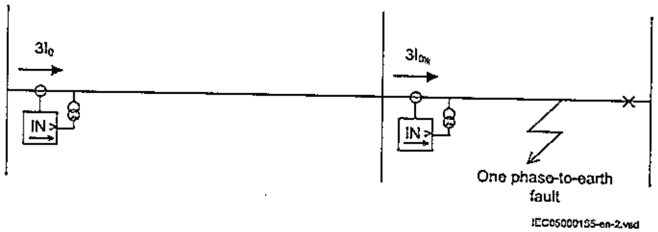

Figure 51: Step 2, selectivity calculation

A second criterion for step 2 is according to equation 42.

$$I_{step2} \geq 1.2 \cdot \frac{3I_0}{3I_{0x}} \cdot I_{step1x}$$

(Equation 42)

where:

Istep1x is the current setting for step 1 on the faulted line.

Step 3

This step has directional function and a time delay slightly larger than step 2, often 0.8 s. Step 3 shall enable selective trip of earth faults having some fault resistance to earth, so that step 2 is not activated. The requirement on step 3 is selectivity to other earth-fault protections in the network. One criterion for setting is shown in figure 52.

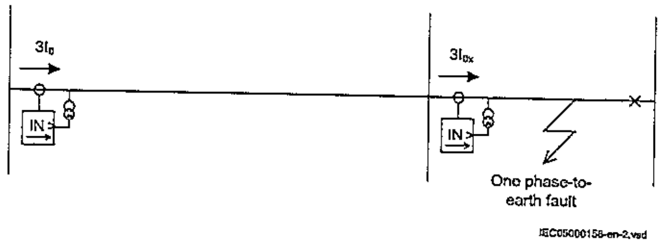

Figure 52: Step 3, Selectivity calculation

$$I_{step3} \geq 1.2 \cdot \frac{3I_0}{3I_{0x}} \cdot I_{step2x}$$

(Equation 43)

where:

Istep2x is the chosen current setting for step 2 on the faulted line.

Step 4

This step normally has non-directional function and a relatively long time delay. The task for step 4 is to detect and initiate trip for earth faults with large fault resistance, for example tree faults. Step 4 shall also detect series faults where one or two poles, of a breaker or other switching device, are open while the other poles are closed.

Both high resistance earth faults and series faults give zero-sequence current flow in the network. Such currents give disturbances on telecommunication systems and current to earth. It is important to clear such faults both concerning personal security as well as risk of fire.

The current setting for step 4 is often set down to about 100 A (primary $3I_0$). In many applications definite time delay in the range 1.2 - 2.0 s is used. In other applications a current dependent inverse time characteristic is used. This enables a higher degree of selectivity also for sensitive earth-fault current protection.

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6.5 Sensitive directional residual overcurrent and power protection SDEPSDE

6.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Sensitive directional residual over current and power protection	SDEPSDE	-	67N

6.5.2 Application

In networks with high impedance earthing, the phase-to-earth fault current is significantly smaller than the short circuit currents. Another difficulty for earth-fault protection is that the magnitude of the phase-to-earth fault current is almost independent of the fault location in the network.

Directional residual current can be used to detect and give selective trip of phase-to-earth faults in high impedance earthed networks. The protection uses the residual current component $3I_0 \cdot \cos \varphi$, where φ is the angle between the residual current and the residual voltage (-3U0), compensated with a characteristic angle. Alternatively, the function can be set to strict $3I_0$ level with an check of angle $3I_0$ and cos φ.

Directional residual power can also be used to detect and give selective trip of phase-to-earth faults in high impedance earthed networks. The protection uses the residual power component $3I_0 \cdot 3U_0 \cdot \cos \varphi$, where φ is the angle between the residual current and the reference residual voltage, compensated with a characteristic angle.

A normal non-directional residual current function can also be used with definite or inverse time delay.

A back-up neutral point voltage function is also available for non-directional sensitive back-up protection.

In an isolated network, that is, the network is only coupled to earth via the capacitances between the phase conductors and earth, the residual current always has -90° phase shift compared to the reference residual voltage. The characteristic angle is chosen to -90° in such a network.

In resistance earthed networks or in Petersen coil earthed, with a parallel resistor, the active residual current component (in phase with the residual voltage) should be used for the earth-fault detection. In such networks the characteristic angle is chosen to 0°.

As the amplitude of the residual current is independent of the fault location the selectivity of the earth-fault protection is achieved by time selectivity.

When should the sensitive directional residual overcurrent protection be used and when should the sensitive directional residual power protection be used? Consider the following facts:

- Sensitive directional residual overcurrent protection gives possibility for better sensitivity
- Sensitive directional residual power protection gives possibility to use inverse time characteristics. This is applicable in large high impedance earthed networks, with large capacitive earth-fault current
- In some power systems a medium size neutral point resistor is used, for example, in low impedance earthed system. Such a resistor will give a resistive earth-fault current component of about 200 - 400 A at a zero resistive phase-to-earth fault. In such a system the directional residual power protection gives better possibilities for selectivity enabled by inverse time power characteristics.

6.5.3 Setting guidelines

The sensitive earth-fault protection is intended to be used in high impedance earthed systems, or in systems with resistive earthing where the neutral point resistor gives an earth-fault current larger than what normal high impedance gives but smaller than the phase-to-phase short circuit current.

In a high impedance system the fault current is assumed to be limited by the system zero sequence shunt impedance to earth and the fault resistance only. All the series impedances in the system are assumed to be zero.

In the setting of earth-fault protection, in a high impedance earthed system, the neutral point voltage (zero sequence voltage) and the earth-fault current will be calculated at the desired sensitivity (fault resistance). The complex neutral point voltage (zero sequence) can be calculated as:

$$U_0 = \frac{U_{phase}}{1 + \frac{3 \cdot R_f}{Z_0}}$$

(Equation 44)

Where

U_{phase} is the phase voltage in the fault point before the fault,

R_f is the resistance to earth in the fault point and

Z_0 is the system zero sequence impedance to earth

The fault current, in the fault point, can be calculated as:

$$I_j = 3I_0 = \frac{3 \cdot U_{phase}}{Z_0 + 3 \cdot R_f}$$

(Equation 45)

The impedance Z_0 is dependent on the system earthing. In an isolated system (without neutral point apparatus) the impedance is equal to the capacitive coupling between the phase conductors and earth:

$$Z_0 = -jX_c = -j\frac{3 \cdot U_{phase}}{I_j}$$

(Equation 46)

Where

I_j is the capacitive earth-fault current at a non-resistive phase to earth-fault

X_c is the capacitive reactance to earth

In a system with a neutral point resistor (resistance earthed system) the impedance Z_0 can be calculated as:

$$Z_0 = \frac{-jX_c \cdot 3R_n}{-jX_c + 3R_n}$$

(Equation 47)

Where

R_n Is the resistance of the neutral point resistor

In many systems there is also a neutral point reactor (Petersen coil) connected to one or more transformer neutral points. In such a system the impedance Z_0 can be calculated as:

$$Z_0 = -jX_c // 3R_n // j3X_n = \frac{9R_n X_n X_c}{3X_n X_c + j3R_n \cdot (3X_n - X_c)}$$

(Equation 48)

Where

X_n Is the reactance of the Petersen coil. If the Petersen coil is well tuned we have $3X_n = X_c$ In this case the impedance Z_0 will be: $Z_0 = 3R_n$

Now consider a system with an earthing via a resistor giving higher earth-fault current than the high impedance earthing. The series impedances in the system can no longer be neglected. The system with a single phase to earth-fault can be described as in figure 53.

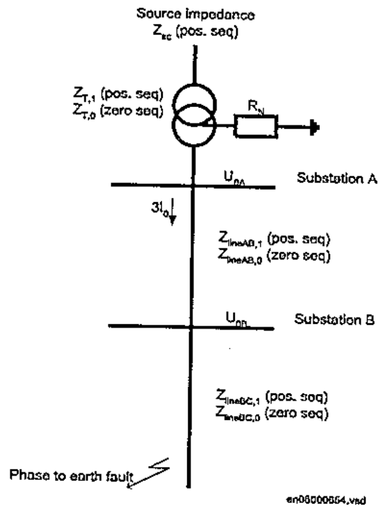

Figure 53: Equivalent of power system for calculation of setting

The residual fault current can be written:

$$3I_0 = \frac{3U_{phase}}{2 \cdot Z_1 + Z_0 + 3 \cdot R_f}$$

(Equation 49)

Where

U_{phase} is the phase voltage in the fault point before the fault

Z_1 Is the total positive sequence impedance to the fault point. $Z_1 = Z_{sc}+Z_{T,1}+Z_{lineAB,1}+Z_{lineBC,1}$

Z_0 is the total zero sequence impedance to the fault point. $Z_0 = Z_{T,0}+3R_N+Z_{lineAB,0}+Z_{lineBC,0}$

R_f Is the fault resistance.

The residual voltages in stations A and B can be written:

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$$U_{0A} = 3I_0 \cdot (Z_{T,0} + 3R_N)$$
(Equation 50)

$$U_{0B} = 3I_0 \cdot (Z_{T,0} + 3R_N + Z_{lineAB,0})$$
(Equation 51)

The residual power, measured by the sensitive earth-fault protections in A and B will be:

$$S_{0A} = 3U_{0A} \cdot 3I_0$$
(Equation 52)

$$S_{0B} = 3U_{0B} \cdot 3I_0$$
(Equation 53)

The residual power is a complex quantity. The protection will have a maximum sensitivity in the characteristic angle RCA. The apparent residual power component in the characteristic angle, measured by the protection, can be written:

$$S_{0A,prot} = 3U_{0A} \cdot 3I_0 \cdot \cos\varphi_A$$
(Equation 54)

$$S_{0B,prot} = 3U_{0B} \cdot 3I_0 \cdot \cos\varphi_B$$
(Equation 55)

The angles φ_A and φ_B are the phase angles between the residual current and the residual voltage in the station compensated with the characteristic angle RCA.

The protection will use the power components in the characteristic angle direction for measurement, and as base for the inverse time delay.

The inverse time delay is defined as:

$$t_{inv} = \frac{kSN \cdot (3I_0 \cdot 3U_0 \cdot \cos\varphi(reference))}{3I_0 \cdot 3U_0 \cdot \cos\varphi(measured)}$$
(Equation 56)

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

The function can be set *On/Off* with the setting of *Operation*.

With the setting *OpMode* the principle of directional function is chosen.

With *OpMode* set to *3I0cosfi* the current component in the direction equal to the characteristic angle*RCADir* is measured. The characteristic for *RCADir* is equal to 0° is shown in figure 54.

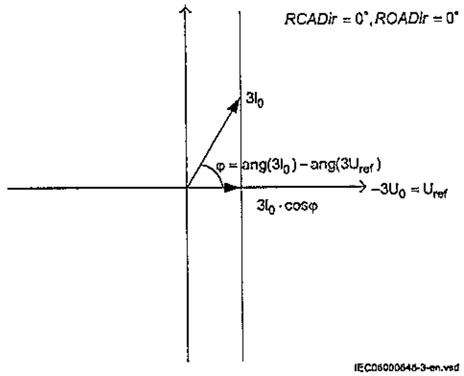

Figure 54: Characteristic for RCADir equal to 0°

The characteristic is for *RCADir* equal to -90° is shown in figure 55.

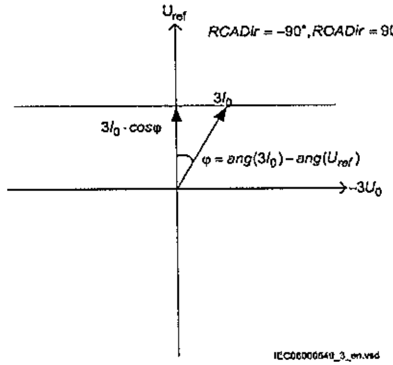

Figure 55: Characteristic for RCADir equal to -90°

When *OpMode* is set to *3U03I0cosfi* the apparent residual power component in the direction is measured.

When *OpMode* is set to *3I0 and fi* the function will operate if the residual current is larger than the setting *INDir>* and the residual current angle is within the sector *RCADir* ± *ROADir*.

The characteristic for *RCADir* = 0° and *ROADir* = 80° is shown in figure 56.

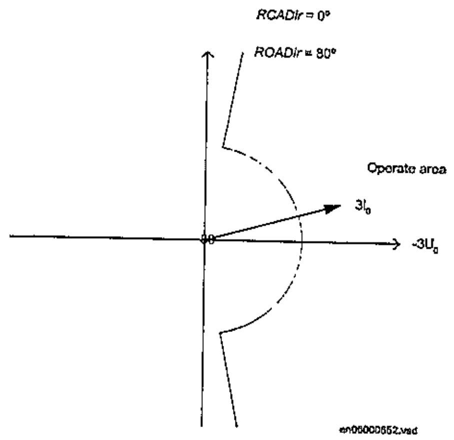

Figure 56: *Characteristic for RCADir = 0° and ROADir = 80°*

DirMode is set *Forward* or *Reverse* to set the direction of the trip function from the directional residual current function.

All the directional protection modes have a residual current release level setting *INRel>* which is set in % of *IBase*. This setting should be chosen smaller than or equal to the lowest fault current to be detected.

All the directional protection modes have a residual voltage release level setting *UNRel>* which is set in % of *UBase*. This setting should be chosen smaller than or equal to the lowest fault residual voltage to be detected.

tDef is the definite time delay, given in s, for the directional residual current protection if definite time delay is chosen.

The characteristic angle of the directional functions *RCADir* is set in degrees. *RCADir* is normally set equal to 0° in a high impedance earthed network with a neutral point resistor as the active current component is appearing out on the faulted feeder only. *RCADir* is set equal to -90° in an isolated network as all currents are mainly capacitive.

The relay open angle *ROADir* is set in degrees. For angles differing more than *ROADir* from*RCADir* the function from the protection is blocked. The setting can be used to prevent unwanted function for non-faulted feeders, with large capacitive earth-fault current contributions, due to CT phase angle error.

INCosPhi> is the operate current level for the directional function when *OpMode* is set *3I0Cosfi*. The setting is given in % of *IBase*. The setting should be based on

calculation of the active or capacitive earth-fault current at required sensitivity of the protection.

SN> is the operate power level for the directional function when *OpMode* is set *3I03U0Cosfi*. The setting is given in % of *IBase*. The setting should be based on calculation of the active or capacitive earth-fault residual power at required sensitivity of the protection.

The input transformer for the Sensitive directional residual over current and power protection function has the same short circuit capacity as the phase current transformers.

If the time delay for residual power is chosen the delay time is dependent on two setting parameters. *SRef* is the reference residual power, given in % of *SBase*. *kSN* is the time multiplier. The time delay will follow the following expression:

$$t_{inv} = \frac{kSN \cdot Sref}{3I_0 \cdot 3U_0 \cdot \cos\varphi(\text{measured})}$$

(Equation 57)

INDir> is the operate current level for the directional function when *OpMode* is set *3I0 and fi*. The setting is given in % of *IBase*. The setting should be based on calculation of the earth-fault current at required sensitivity of the protection.

OpINNonDir> is set *On* to activate the non-directional residual current protection.

INNonDir> is the operate current level for the non-directional function. The setting is given in % of *IBase*. This function can be used for detection and clearance of cross-country faults in a shorter time than for the directional function. The current setting should be larger than the maximum single-phase residual current out on the protected line.

TimeChar is the selection of time delay characteristic for the non-directional residual current protection. Definite time delay and different types of inverse time characteristics are available:

ANSI Extremely Inverse
ANSI Very Inverse
ANSI Normal Inverse
ANSI Moderately Inverse
ANSI/IEEE Definite time
ANSI Long Time Extremely Inverse
ANSI Long Time Very Inverse
ANSI Long Time Inverse
IEC Normal Inverse
IEC Very Inverse
IEC Inverse
Table continues on next page

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IEC Extremely Inverse
IEC Short Time Inverse
IEC Long Time Inverse
IEC Definite time
ASEA RI
RXIDG (logarithmic)

The different characteristics are described in Technical Manual.

tINNonDir is the definite time delay for the non directional earth-fault current protection, given in s.

OpUN> is set *On* to activate the trip function of the residual voltage protection.

tUN is the definite time delay for the trip function of the residual voltage protection, given in s.

6.6 Thermal overload protection, one time constant LPTTR

6.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Thermal overload protection, one time constant	LPTTR	⊓	26

6.6.2 Application

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Lines and cables in the power system are designed for a certain maximum load current level. If the current exceeds this level the losses will be higher than expected. As a consequence the temperature of the conductors will increase. If the temperature of the lines and cables reaches too high values the equipment might be damaged:

- The sag of overhead lines can reach unacceptable value.
- If the temperature of conductors, for example aluminium conductors, get too high the material will be destroyed.
- In cables the insulation can be damaged as a consequence of the overtemperature. As a consequence of this phase to phase or phase to earth faults can occur

In stressed situations in the power system it can be required to overload lines and cables for a limited time. This should be done without risks.

The thermal overload protection provides information that makes a temporary overloading of cables and lines possible. The thermal overload protection estimates the conductor temperature continuously. This estimation is made by using a thermal model of the line/cable based on the current measurement.

If the temperature of the protected object reaches a set warning level *AlarmTemp*, a signal ALARM can be given to the operator. This enables actions in the power system to be taken before dangerous temperatures are reached. If the temperature continues to increase to the trip value *TripTemp*, the protection initiates trip of the protected line.

6.6.3 Setting guidelines

The parameters for the Thermal overload protection LPTTR are set via the local HMI or PCM600.

The following settings can be done for the thermal overload protection.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Operation: *Off/On*

IRef: Reference, steady state current, given in % of *IBase* that will give a steady state (end) temperature *TRef*. It is suggested to set this current to the maximum steady state current allowed for the line/cable under emergency operation (a few hours per year).

TRef: Reference temperature (end temperature) corresponding to the steady state current *IRef*. From cable manuals current values with corresponding conductor temperature are often given. These values are given for conditions such as earth temperature, ambient air temperature, way of laying of cable and earth thermal resistivity. From manuals for overhead conductor temperatures and corresponding current is given.

Tau: The thermal time constant of the protected circuit given in minutes. Please refer to manufacturers manuals for details.

TripTemp: Temperature value for trip of the protected circuit. For cables a maximum allowed conductor temperature is often stated to be 90°C. For overhead lines the critical temperature for aluminium conductor is about 90 - 100°C. For a copper conductor a normal figure is 70°C.

AlarmTemp: Temperature level for alarm of the protected circuit. ALARM signal can be used as a warning before the circuit is tripped. Therefore the setting shall be lower than the trip level. It shall at the same time be higher than the maximum conductor temperature at normal operation. For cables this level is often given to 65°C. Similar values are stated for overhead lines. A suitable setting can be about 15°C below the trip value.

ReclTemp: Temperature where lockout signal LOCKOUT from the protection is released. When the thermal overload protection trips a lock-out signal is activated. This signal is intended to block switch in of the protected circuit as long as the conductor temperature is high. The signal is released when the estimated temperature is below the set value. This temperature value should be chosen below the alarm temperature.

6.7 Breaker failure protection CCRBRF

6.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Breaker failure protection	CCRBRF	3I>BF	50BF

6.7.2 Application

In the design of the fault clearance system the N-1 criterion is often used. This means that a fault needs to be cleared even if any component in the fault clearance system is faulty. One necessary component in the fault clearance system is the circuit breaker. It is from practical and economical reason not feasible to duplicate the circuit breaker for the protected component. Instead a breaker failure protection is used.

Breaker failure protection (CCRBRF) will issue a back-up trip command to adjacent circuit breakers in case of failure to trip of the "normal" circuit breaker for the protected component. The detection of failure to break the current through the breaker is made by means of current measurement or as detection of remaining trip signal (unconditional).

CCRBRF can also give a re-trip. This means that a second trip signal is sent to the protected circuit breaker. The re-trip function can be used to increase the probability of operation of the breaker, or it can be used to avoid back-up trip of many breakers in case of mistakes during relay maintenance and test.

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6.7.3 Setting guidelines

The parameters for Breaker failure protection CCRBRF are set via the local HMI or PCM600.

The following settings can be done for the breaker failure protection.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Operation: *Off*/*On*

FunctionMode This parameter can be set *Current* or *Contact*. This states the way the detection of failure of the breaker is performed. In the mode current the current measurement is used for the detection. In the mode *Contact* the long duration of breaker position signal is used as indicator of failure of the breaker. The mode *Current&Contact* means that both ways of detections are activated. *Contact* mode can be usable in applications where the fault current through the circuit breaker is small. This can be the case for some generator protection application (for example reverse power protection) or in case of line ends with weak end infeed.

RetripMode: This setting states how the re-trip function shall operate. *Retrip Off* means that the re-trip function is not activated. *CB Pos Check* (circuit breaker position check) and *Current* means that a phase current must be larger than the operate level to allow re-trip. *CB Pos Check* (circuit breaker position check) and *Contact* means re-trip is done when circuit breaker is closed (breaker position is used). *No CBPos Check* means re-trip is done without check of breaker position.

Table 13: Dependencies between parameters RetripMode and FunctionMode

RetripMode	FunctionMode	Description
Retrip Off	N/A	the re-trip function is not activated
CB Pos Check	Current	a phase current must be larger than the operate level to allow re-trip
	Contact	re-trip is done when breaker position indicates that breaker is still closed after re-trip time has elapsed
	Current&Contact	both methods are used
No CBPos Check	Current	re-trip is done without check of breaker position
	Contact	re-trip is done without check of breaker position
	Current&Contact	both methods are used

BuTripMode: Back-up trip mode is given to state sufficient current criteria to detect failure to break. For *Current* operation *2 out of 4* means that at least two currents, of the three-phase currents and the residual current, shall be high to indicate breaker failure. *1 out of 3* means that at least one current of the three-phase currents shall be high to indicate breaker failure. *1 out of 4* means that at least one current of the three-phase currents or the residual current shall be high to indicate breaker failure. In most applications *1 out of 3* is sufficient. For *Contact* operation means back-up trip is done when circuit breaker is closed (breaker position is used).

IP>: Current level for detection of breaker failure, set in % of *IBase*. This parameter should be set so that faults with small fault current can be detected. The setting can be chosen in accordance with the most sensitive protection function to start the breaker failure protection. Typical setting is 10% of *IBase*.

I>BlkCont: If any contact based detection of breaker failure is used this function can be blocked if any phase current is larger than this setting level. If the *FunctionMode* is set *Current&Contact* breaker failure for high current faults are safely detected by the current measurement function. To increase security the contact based function should be disabled for high currents. The setting can be given within the range 5 – 200% of *IBase*.

IN>: Residual current level for detection of breaker failure set in % of *IBase*. In high impedance earthed systems the residual current at phase- to-earth faults are normally much smaller than the short circuit currents. In order to detect breaker failure at single-phase-earth faults in these systems it is necessary to measure the residual current separately. Also in effectively earthed systems the setting of the earth-fault current protection can be chosen to relatively low current level. The *BuTripMode* is set *1 out of 4*. The current setting should be chosen in accordance to the setting of the sensitive earth-fault protection. The setting can be given within the range 2 – 200 % of *IBase*.

t1: Time delay of the re-trip. The setting can be given within the range 0 – 60s in steps of 0.001 s. Typical setting is 0 – 50ms.

t2: Time delay of the back-up trip. The choice of this setting is made as short as possible at the same time as unwanted operation must be avoided. Typical setting is 90 – 200ms (also dependent of re-trip timer).

The minimum time delay for the re-trip can be estimated as:

$$t2 \geq t1 + t_{cbopen} + t_{BFP\_reset} + t_{margin}$$ (Equation 58)

where:

t_{cbopen}	is the maximum opening time for the circuit breaker
t_{BFP_reset}	is the maximum time for breaker failure protection to detect correct breaker function (the current criteria reset)
t_{margin}	is a safety margin

It is often required that the total fault clearance time shall be less than a given critical time. This time is often dependent of the ability to maintain transient stability in case of a fault close to a power plant.

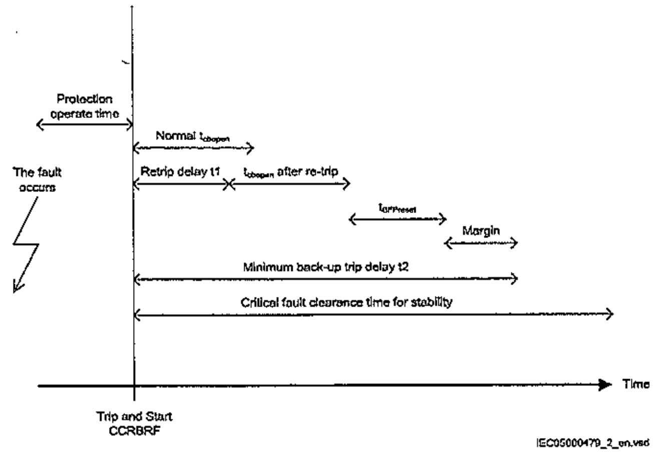

Figure 57: Time sequence

6.8 Stub protection STBPTOC

6.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Stub protection	STBPTOC	3I>STUB	50STB

6.8.2 Application

Stub protection STBPTOC is a simple phase overcurrent protection, fed from the two current transformer groups feeding the object taken out of service. The stub protection is only activated when the disconnector of the object is open. STBPTOCenables fast fault clearance of faults at the section between the CTs and the open disconnector.

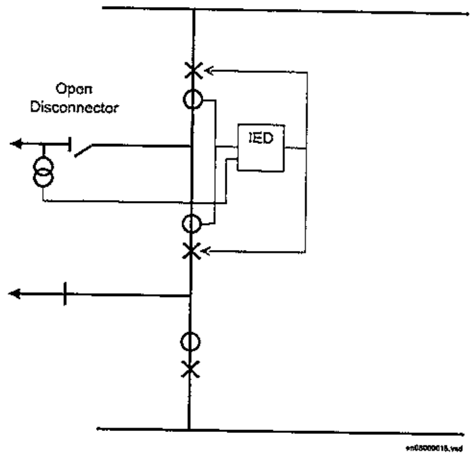

Figure 58: *Typical connection for stub protection in 1½-breaker arrangement.*

6.8.3 Setting guidelines

The parameters for Stub protection STBPTOC are set via the local HMI or PCM600.

The following settings can be done for the stub protection.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Operation: *Off/On*

I>: Current level for the Stub protection, set in % of *IBase*. This parameter should be set so that all faults on the stub can be detected. The setting should thus be based on fault calculations.

Pole discordance protection CCRPLD

6.9.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Pole discordance protection	CCRPLD	PD	52PD

6.9.2 Application

There is a risk that a circuit breaker will get discordance between the poles at circuit breaker operation: closing or opening. One pole can be open and the other two closed, or two poles can be open and one closed. Pole discordance of a circuit breaker will cause unsymmetrical currents in the power system. The consequence of this can be:

- Negative sequence currents that will give stress on rotating machines
- Zero sequence currents that might give unwanted operation of sensitive earth-fault protections in the power system.

It is therefore important to detect situations with pole discordance of circuit breakers. When this is detected the breaker should be tripped directly.

Pole discordance protection CCRPLD will detect situation with deviating positions of the poles of the protected circuit breaker. The protection has two different options to make this detection:

- By connecting the auxiliary contacts in the circuit breaker so that logic is created and a signal can be sent to the pole discordance protection, indicating pole discordance.
- Each phase current through the circuit breaker is measured. If the difference between the phase currents is larger than a *CurrUnsymLevel* this is an indication of pole discordance, and the protection will operate.

6.9.3 Setting guidelines

The parameters for the Pole discordance protection CCRPLD are set via the local HMI or PCM600.

The following settings can be done for the pole discordance protection.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

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Operation: *Off* or *On*

tTrip: Time delay of the operation.

ContSel: Operation of the contact based pole discordance protection. Can be set: *Off/PD signal from CB*. If *PD signal from CB* is chosen the logic to detect pole discordance is made in the vicinity to the breaker auxiliary contacts and only one signal is connected to the pole discordance function.

CurrSel: Operation of the current based pole discordance protection. Can be set: *Off/CB oper monitor/Continuous monitor*. In the alternative *CB oper monitor* the function is activated only directly in connection to breaker open or close command (during 200 ms). In the alternative *Continuous monitor* function is continuously activated.

CurrUnsymLevel: Unsymmetrical magnitude of lowest phase current compared to the highest, set in % of the highest phase current.

CurrRelLevel: Current magnitude for release of the function in % of *IBase*.

6.10 Broken conductor check BRCPTOC

6.10.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Broken conductor check	BRCPTOC	-	46

6.10.2 Application

Conventional protection functions can not detect the broken conductor condition. Broken conductor check (BRCPTOC) function, consisting of continuous current unsymmetrical check on the line where the IED connected will give alarm or trip at detecting broken conductors.

6.10.3 Setting guidelines

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Broken conductor check BRCPTOC must be set to detect open phase/s (series faults) with different loads on the line. BRCPTOC must at the same time be set to not operate for maximum asymmetry which can exist due to, for example, not transposed power lines.

All settings are in primary values or percentage.

Set minimum operating level per phase *IP>* to typically 10-20% of rated current.

Set the unsymmetrical current, which is relation between the difference of the minimum and maximum phase currents to the maximum phase current to typical *Iub>* = *50%*.

Note that it must be set to avoid problem with asymmetry under minimum operating conditions.

Set the time delay *tOper* = *5 - 60* seconds and reset time *tReset* = *0.010 - 60.000* seconds.

6.11 Directional over-/under-power protection GOPPDOP/GUPPDUP

6.11.1 Application

The task of a generator in a power plant is to convert mechanical energy available as a torque on a rotating shaft to electric energy.

Sometimes, the mechanical power from a prime mover may decrease so much that it does not cover bearing losses and ventilation losses. Then, the synchronous generator becomes a synchronous motor and starts to take electric power from the rest of the power system. This operating state, where individual synchronous machines operate as motors, implies no risk for the machine itself. If the generator under consideration is very large and if it consumes lots of electric power, it may be desirable to disconnect it to ease the task for the rest of the power system.

Often, the motoring condition may imply that the turbine is in a very dangerous state. The task of the reverse power protection is to protect the turbine and not to protect the generator itself.

Steam turbines easily become overheated if the steam flow becomes too low or if the steam ceases to flow through the turbine. Therefore, turbo-generators should have reverse power protection. There are several contingencies that may cause reverse power: break of a main steam pipe, damage to one or more blades in the steam turbine or inadvertent closing of the main stop valves. In the last case, it is highly desirable to have a reliable reverse power protection. It may prevent damage to an otherwise undamaged plant.

During the routine shutdown of many thermal power units, the reverse power protection gives the tripping impulse to the generator breaker (the unit breaker). By doing so, one prevents the disconnection of the unit before the mechanical power has become zero. Earlier disconnection would cause an acceleration of the turbine generator at all routine shutdowns. This should have caused overspeed and high centrifugal stresses.

When the steam ceases to flow through a turbine, the cooling of the turbine blades will disappear. Now, it is not possible to remove all heat generated by the windage losses. Instead, the heat will increase the temperature in the steam turbine and especially of the blades. When a steam turbine rotates without steam supply, the electric power consumption will be about 2% of rated power. Even if the turbine rotates in vacuum, it will soon become overheated and damaged. The turbine overheats within minutes if the turbine loses the vacuum.

The critical time to overheating of a steam turbine varies from about 0.5 to 30 minutes depending on the type of turbine. A high-pressure turbine with small and thin blades will become overheated more easily than a low-pressure turbine with long and heavy blades. The conditions vary from turbine to turbine and it is necessary to ask the turbine manufacturer in each case.

Power to the power plant auxiliaries may come from a station service transformer connected to the primary side of the step-up transformer. Power may also come from a start-up service transformer connected to the external network. One has to design the reverse power protection so that it can detect reverse power independent of the flow of power to the power plant auxiliaries.

Hydro turbines tolerate reverse power much better than steam turbines do. Only Kaplan turbine and bulb turbines may suffer from reverse power. There is a risk that the turbine runner moves axially and touches stationary parts. They are not always strong enough to withstand the associated stresses.

Ice and snow may block the intake when the outdoor temperature falls far below zero. Branches and leaves may also block the trash gates. A complete blockage of the intake may cause cavitations. The risk for damages to hydro turbines can justify reverse power protection in unattended plants.

A hydro turbine that rotates in water with closed wicket gates will draw electric power from the rest of the power system. This power will be about 10% of the rated power. If there is only air in the hydro turbine, the power demand will fall to about 3%.

Diesel engines should have reverse power protection. The generator will take about 15% of its rated power or more from the system. A stiff engine may require perhaps 25% of the rated power to motor it. An engine that is well run in might need no more than 5%. It is necessary to obtain information from the engine manufacturer and to measure the reverse power during commissioning.

Gas turbines usually do not require reverse power protection.

Figure 59 illustrates the reverse power protection with underpower protection and with overpower protection. The underpower protection gives a higher margin and should provide better dependability. On the other hand, the risk for unwanted operation immediately after synchronization may be higher. One should set the underpower protection to trip if the active power from the generator is less than

about 2%. One should set the overpower protection to trip if the power flow from the network to the generator is higher than 1%.

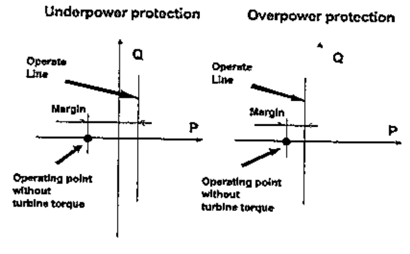

Figure 59: Reverse power protection with underpower or overpower protection

6.11.2 Directional over-power protection GOPPDOP

6.11.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Directional overpower protection	GOPPDOP	P > →	32

6.11.2.2 Setting guidelines

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Operation: With the parameter *Operation* the function can be set *On*/*Off*.

Mode: The voltage and current used for the power measurement. The setting possibilities are shown in table 14.

For reverse power applications *PosSeq* or *Arone* modes are strongly recommended.

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Table 14: *Complex power calculation*

Set value *Mode*	Formula used for complex power calculation
L1, L2, L3	$\bar{S} = \bar{U}_{L1} \cdot \bar{I}_{L1}^* + \bar{U}_{L2} \cdot \bar{I}_{L2}^* + \bar{U}_{L3} \cdot \bar{I}_{L3}^*$ (Equation 59)
Arone	$\bar{S} = \bar{U}_{L1L2} \cdot \bar{I}_{L1}^* - \bar{U}_{L2L3} \cdot \bar{I}_{L3}^*$ (Equation 60)
PosSeq	$\bar{S} = 3 \cdot \bar{U}_{PosSeq} \cdot \bar{I}_{PosSeq}^*$ (Equation 61)
L1L2	$\bar{S} = \bar{U}_{L1L2} \cdot (\bar{I}_{L1}^* - \bar{I}_{L2}^*)$ (Equation 62)
L2L3	$\bar{S} = \bar{U}_{L2L3} \cdot (\bar{I}_{L2}^* - \bar{I}_{L3}^*)$ (Equation 63)
L3L1	$\bar{S} = \bar{U}_{L3L1} \cdot (\bar{I}_{L3}^* - \bar{I}_{L1}^*)$ (Equation 64)
L1	$\bar{S} = 3 \cdot \bar{U}_{L1} \cdot \bar{I}_{L1}^*$ (Equation 65)
L2	$\bar{S} = 3 \cdot \bar{U}_{L2} \cdot \bar{I}_{L2}^*$ (Equation 66)
L3	$\bar{S} = 3 \cdot \bar{U}_{L3} \cdot \bar{I}_{L3}^*$ (Equation 57)

The function has two stages with the same setting parameters.

OpMode1(2) is set to define the function of the stage. Possible settings are:

On: the stage is activated *Off*: the stage is disabled

The function gives trip if the power component in the direction defined by the setting *Angle1(2)* is larger than the set pick up power value *Power1(2)*

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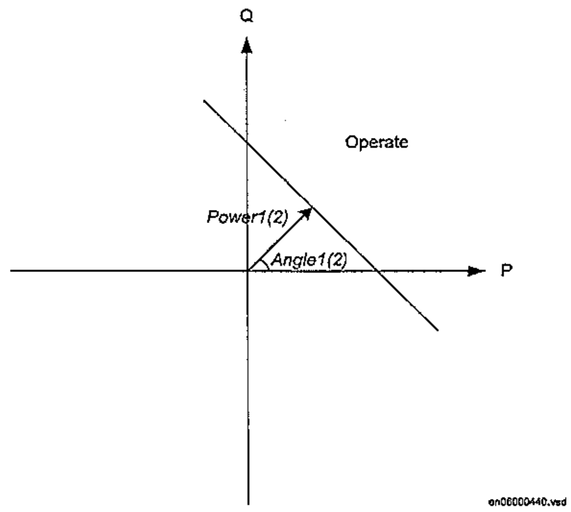

Figure 60: Overpower mode

The setting *Power1(2)* gives the power component pick up value in the *Angle1(2)* direction. The setting is given in p.u. of the generator rated power, see equation 68.

Minimum recommended setting is 1.0% of S_N. Note also that at the same time the minimum IED pickup current shall be bigger than 9mA secondary.

$$S_N = \sqrt{3} \cdot UBase \cdot IBase \quad \text{(Equation 68)}$$

The setting *Angle1(2)* gives the characteristic angle giving maximum sensitivity of the power protection function. The setting is given in degrees. For active power the set angle should be 0° or 180°. 180° should be used for generator reverse power protection in 50Hz network while -179.5° should be used for generator reverse power protection in 60Hz network. This angle adjustment in 60Hz networks will improve accuracy of the power function.

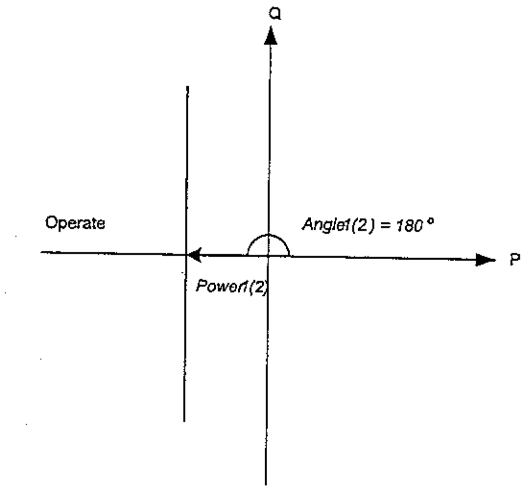

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Figure 61: *For reverse power the set angle should be 180° in the overpower function*

TripDelay1(2) is set in seconds to give the time delay for trip of the stage after pick up.

The possibility to have low pass filtering of the measured power can be made as shown in the formula:

$$S = k \cdot S_{Old} + (1 - k) \cdot S_{Calculated}$$ (Equation 69)

Where

S	is a new measured value to be used for the protection function
S_{old}	is the measured value given from the function in previous execution cycle
$S_{Calculated}$	is the new calculated value in the present execution cycle
k	is settable parameter

The value of *k=0.98* or even *k=0.99* is recommended in generator reverse power applications as the trip delay is normally quite long. This filtering will improve accuracy of the power function.

6.11.3 Directional under-power protection GUPPDUP

6.11.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Directional underpower protection	GUPPDUP	P < →	37

6.11.3.2 Setting guidelines

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Operation: With the parameter *Operation* the function can be set *On*/*Off*.

Mode: The voltage and current used for the power measurement. The setting possibilities are shown in table 15.

For reverse power applications *PosSeq* or *Arone* modes are strongly recommended.

Table 15: *Complex power calculation*

Set value *Mode*	Formula used for complex power calculation
L1, L2, L3	$\bar{S} = \bar{U}_{L1} \cdot \bar{I}_{L1}^* + \bar{U}_{L2} \cdot \bar{I}_{L2}^* + \bar{U}_{L3} \cdot \bar{I}_{L3}^*$ (Equation 70)
Arone	$\bar{S} = \bar{U}_{L1L2} \cdot \bar{I}_{L1}^* - \bar{U}_{L2L3} \cdot \bar{I}_{L3}^*$ (Equation 71)
PosSeq	$\bar{S} = 3 \cdot \bar{U}_{PosSeq} \cdot \bar{I}_{PosSeq}^*$ (Equation 72)
L1L2	$\bar{S} = \bar{U}_{L1L2} \cdot (\bar{I}_{L1}^* - \bar{I}_{L2}^*)$ (Equation 73)
L2L3	$\bar{S} = \bar{U}_{L2L3} \cdot (\bar{I}_{L2}^* - \bar{I}_{L3}^*)$ (Equation 74)
L3L1	$\bar{S} = \bar{U}_{L3L1} \cdot (\bar{I}_{L3}^* - \bar{I}_{L1}^*)$ (Equation 75)

Table continues on next page

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Set value *Mode*	Formula used for complex power calculation
L1	$\bar{S} = 3 \cdot \bar{U}_{L1} \cdot \bar{I}_{L1}^{*}$ (Equation 76)
L2	$\bar{S} = 3 \cdot \bar{U}_{L2} \cdot \bar{I}_{L2}^{*}$ (Equation 77)
L3	$\bar{S} = 3 \cdot \bar{U}_{L3} \cdot \bar{I}_{L3}^{*}$ (Equation 78)

The function has two stages with the same setting parameters.

OpMode1(2) is set to define the function of the stage. Possible settings are:

On: the stage is activated *Off*: the stage is disabled

The function gives trip if the power component in the direction defined by the setting *Angle1(2)* is smaller than the set pick up power value *Power1(2)*

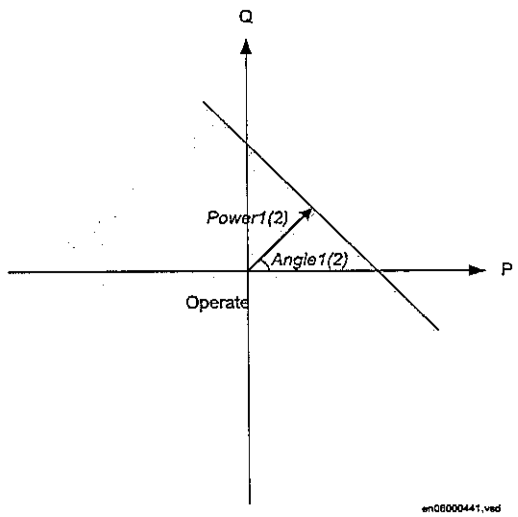

Figure 62: Underpower mode

The setting *Power1(2)* gives the power component pick up value in the *Angle1(2)* direction. The setting is given in p.u. of the generator rated power, see equation 79.

Minimum recommended setting is 1.0% of S_N. Note also that at the same time the minimum IED pickup current shall be bigger than 9mA secondary.

$$S_N = \sqrt{3} \cdot UBase \cdot IBase \quad \text{(Equation 79)}$$

The setting *Angle1(2)* gives the characteristic angle giving maximum sensitivity of the power protection function. The setting is given in degrees. For active power the set angle should be 0° or 180°. 0° should be used for generator low forward active power protection.

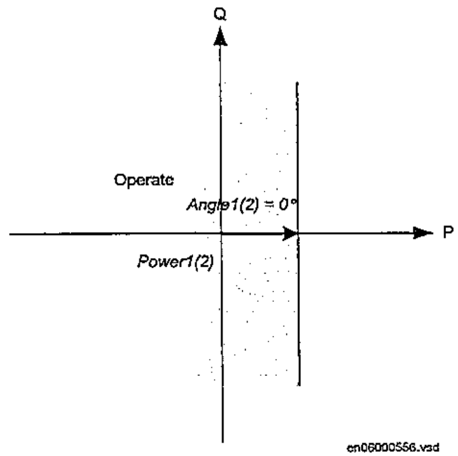

Figure 63: For low forward power the set angle should be 0° in the underpower function

TripDelay1(2) is set in seconds to give the time delay for trip of the stage after pick up.

The possibility to have low pass filtering of the measured power can be made as shown in the formula:

$$S = k \cdot S_{Old} + (1-k) \cdot S_{Calculated}$$

(Equation 80)

Where

S	is a new measured value to be used for the protection function
S_{old}	is the measured value given from the function in previous execution cycle
$S_{Calculated}$	is the new calculated value in the present execution cycle
k	is settable parameter

The value of *k=0.98* or even *k=0.99* is recommended in generator low forward power applications as the trip delay is normally quite long. This filtering will improve accuracy of the power function.

6.12 Negative sequence based overcurrent function DNSPTOC

6.12.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Negative sequence based overcurrent function	DNSPTOC	3I2>	46

6.12.2 Application

Negative sequence based overcurrent function (DNSPTOC) is typically used as sensitive earth-fault protection of power lines, where incorrect zero sequence polarization may result from mutual induction between two or more parallel lines.

Additionally, it is applied in applications on underground cables, where zero sequence impedance depends on the fault current return paths, but the cable negative sequence impedance is practically constant.

The directional function is current and voltage polarized. The function can be set to forward, reverse or non-directional independently for each step.

DNSPTOC protects against all unbalanced faults including phase-to-phase faults. The minimum start current of the function must be set to above the normal system unbalance level in order to avoid unintentional functioning.

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6.12.3 Setting guidelines

Below is an example of Negative sequence based overcurrent function (DNSPTOC) used as a sensitive earth-fault protection for power lines. The following settings must be done in order to ensure proper operation of the protection:

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

- setting *RCA_DIR* to value *+65 degrees*, that is, the negative sequence current typically lags the inverted negative sequence voltage for this angle during the fault
- setting *ROA_DIR* to value *90 degrees*
- setting *LowVolt_VM* to value *2%*, that is, the negative sequence voltage level above which the directional element will be enabled
- setting *Operation_OC1* to *On*
- setting *StartCurr_OC1* to value between *3-10%*, (typical values)
- setting *tDef_OC1* to insure proper time coordination with other earth-fault protections installed in the vicinity of this power line
- setting *DirMode_OC1* to *Forward*
- setting *DirPrinc_OC1* to *IcosPhi&U*
- setting *ActLowVolt1_VM* to *Block*

DNSPTOC is used in directional comparison protection scheme for the power line protection, when communication channels to the remote end of this power line are available. In that case, two negative sequence overcurrent steps are required - one in forward and another in reverse direction. The OC1 stage is used to detect faults in forward direction and the OC2 stage is used to detect faults in reverse direction.

However, the following must be noted for such application:

- setting *RCA_Dir* and *ROA_Dir* are applicable for both steps OC1 and OC2
- setting *DirMode_OC1* must be set to *Forward*
- setting *DirMode_OC2* must be set to *Reverse*
- setting *StartCurr_OC2* must be made more sensitive than *pickup* value of the forward OC1 element, that is, typically 60% of *StartCurr_OC1* set pickup level in order to insure proper operation of the directional comparison scheme during current reversal situations
- the start signals STOC1 and STOC2 from OC1 and OC2 elements is used to send forward and reverse signals to the remote end of the power line
- the available scheme communications function block within IED is used between the protection function and the teleprotection communication equipment, in order to insure proper conditioning of the above two start signals.

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Section 7 Voltage protection

7.1 Two step undervoltage protection UV2PTUV

7.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Two step undervoltage protection	UV2PTUV	2U<	27

7.1.2 Application

Two-step undervoltage protection function (UV2PTUV) is applicable in all situations, where reliable detection of low phase voltages is necessary. It is used also as a supervision and fault detection function for other protection functions, to increase the security of a complete protection system.

UV2PTUV is applied to power system elements, such as generators, transformers, motors and power lines in order to detect low voltage conditions. Low voltage conditions are caused by abnormal operation or fault in the power system. UV2PTUV is used in combination with overcurrent protections, either as restraint or in logic "and gates" of the trip signals issued by the two functions. Other applications are the detection of "no voltage" condition, for example, before the energization of a HV line or for automatic breaker trip in case of a blackout. UV2PTUV is also used to initiate voltage correction measures, like insertion of shunt capacitor banks to compensate for reactive load and thereby increasing the voltage. The function has a high measuring accuracy to allow applications to control reactive load.

UV2PTUV is used to disconnect from the network apparatuses, like electric motors, which will be damaged when subject to service under low voltage conditions. UV2PTUV deals with low voltage conditions at power system frequency, which can be caused by the following reasons:

1. Malfunctioning of a voltage regulator or wrong settings under manual control (symmetrical voltage decrease).
2. Overload (symmetrical voltage decrease).
3. Short circuits, often as phase-to-earth faults (unsymmetrical voltage decrease).

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UV2PTUV prevents sensitive equipment from running under conditions that could cause their overheating and thus shorten their life time expectancy. In many cases, it is a useful function in circuits for local or remote automation processes in the power system.

7.1.3 Setting guidelines

The parameters for Two step undervoltage protection UV2PTUV are set via the local HMI or PCM600.

All the voltage conditions in the system where UV2PTUV performs its functions should be considered. The same also applies to the associated equipment, its voltage and time characteristic.

There is a very wide application area where general undervoltage functions are used. All voltage related settings are made as a percentage of the global settings base voltage *UBase*, which normally is set to the primary nominal voltage level (phase-to-phase) of the power system or the high voltage equipment under consideration.

The setting for UV2PTUV is normally not critical, since there must be enough time available for the main protection to clear short circuits and earth faults.

Some applications and related setting guidelines for the voltage level are described in the following sections.

7.1.3.1 Equipment protection, such as for motors and generators

The setting must be below the lowest occurring "normal" voltage and above the lowest acceptable voltage for the equipment.

7.1.3.2 Disconnected equipment detection

The setting must be below the lowest occurring "normal" voltage and above the highest occurring voltage, caused by inductive or capacitive coupling, when the equipment is disconnected.

7.1.3.3 Power supply quality

The setting must be below the lowest occurring "normal" voltage and above the lowest acceptable voltage, due to regulation, good practice or other agreements.

7.1.3.4 Voltage instability mitigation

This setting is very much dependent on the power system characteristics, and thorough studies have to be made to find the suitable levels.

7.1.3.5 Backup protection for power system faults

The setting must be below the lowest occurring "normal" voltage and above the highest occurring voltage during the fault conditions under consideration.

7.1.3.6 Settings for Two step undervoltage protection

The following settings can be done for two step undervoltage protection (UV2PTUV).

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

ConnType: Sets whether the measurement shall be phase-to-earth fundamental value, phase-to-phase fundamental value, phase-to-earth RMS value or phase-to-phase RMS value.

Operation: Off/On.

UV2PTUV measures selectively phase-to-earth voltages, or phase-to-phase voltage chosen by the setting *ConnType*.

This means operation for phase-to-earth voltage if:

$$U < (\%) \cdot UBase(kV) / \sqrt{3}$$

(Equation 81)

and operation for phase-to-phase voltage if:

$$U < (\%) \cdot \mathrm{UBase(kV)}$$

(Equation 82)

Characteristic1: This parameter gives the type of time delay to be used for step 1. The setting can be. *Definite time/Inverse Curve A/Inverse Curve B*. The choice is highly dependent of the protection application.

OpModen: This parameter describes how many of the three measured voltages that should be below the set level to give operation for step *n* (*n*=step 1 and 2). The setting can be *1 out of 3*, *2 out of 3* or *3 out of 3*. In most applications it is sufficient that one phase voltage is low to give operation. If the function shall be insensitive for single phase-to-earth faults *2 out of 3* can be chosen.

Un<: Set operate undervoltage operation value for step *n* (*n*=step 1 and 2), given as % of the global parameter *UBase*. The setting is highly dependent of the protection application. Here it is essential to consider the minimum voltage at non-faulted situations. Normally this voltage is larger than 90% of nominal voltage.

tn: time delay for step *n* (*n*=step 1 and 2), given in s. The setting is highly dependent of the protection application. In many applications the protection function shall not directly trip in case of short circuits or earth faults in the system. The time delay must be coordinated to the short circuit protections.

t1Min: Minimum operation time for inverse time characteristic for step 1, given in s. For very low voltages the undervoltage function, using inverse time characteristic, can give very short operation time. This might lead to unselective trip. By setting *t1Min* longer than the operation time for other protections such unselective tripping can be avoided.

k1: Time multiplier for inverse time characteristic. This parameter is used for coordination between different inverse time delayed undervoltage protections.

The function must be externally blocked when the protected object is disconnected.

7.2 Two step overvoltage protection OV2PTOV

7.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Two step overvoltage protection	OV2PTOV	2U>	59

7.2.2 Application

Two step overvoltage protection OV2PTOV is applicable in all situations, where reliable detection of high voltage is necessary. OV2PTOV is used for supervision and detection of abnormal conditions, which, in combination with other protection functions, increase the security of a complete protection system.

High voltage conditions are caused by abnormal situations in the power system. OV2PTOV is applied to power system elements, such as generators, transformers, motors and power lines in order to detect high voltage conditions. OV2PTOV is used in combination with low current signals, to identify a transmission line, open in the remote end. In addition to that, OV2PTOV is also used to initiate voltage correction measures, like insertion of shunt reactors, to compensate for low load, and thereby decreasing the voltage. The function has a high measuring accuracy and setting hysteresis to allow applications to control reactive load.

OV2PTOV is used to disconnect, from the network, apparatuses, like electric motors, which will be damaged when subject to service under high voltage conditions. It deals with high voltage conditions at power system frequency, which can be caused by:

1. Different kinds of faults, where a too high voltage appears in a certain power system, like metallic connection to a higher voltage level (broken conductor falling down to a crossing overhead line, transformer flash over fault from the high voltage winding to the low voltage winding and so on).
2. Malfunctioning of a voltage regulator or wrong settings under manual control (symmetrical voltage decrease).
3. Low load compared to the reactive power generation (symmetrical voltage decrease).
4. Earth-faults in high impedance earthed systems causes, beside the high voltage in the neutral, high voltages in the two non-faulted phases, (unsymmetrical voltage increase).

OV2PTOV prevents sensitive equipment from running under conditions that could cause their overheating or stress of insulation material, and, thus, shorten their life time expectancy. In many cases, it is a useful function in circuits for local or remote automation processes in the power system.

7.2.3 Setting guidelines

The parameters for Two step overvoltage protection (OV2PTOV) are set via the local HMI or PCM600.

All the voltage conditions in the system where OV2PTOV performs its functions should be considered. The same also applies to the associated equipment, its voltage and time characteristic.

There is a very wide application area where general overvoltage functions are used. All voltage related settings are made as a percentage of a settable base primary voltage, which normally is set to the nominal voltage level (phase-to-phase) of the power system or the high voltage equipment under consideration.

The time delay for the OV2PTOV can sometimes be critical and related to the size of the overvoltage - a power system or a high voltage component can withstand smaller overvoltages for some time, but in case of large overvoltages the related equipment should be disconnected more rapidly.

Some applications and related setting guidelines for the voltage level are given below:

Equipment protection, such as for motors, generators, reactors and transformers

High voltage can cause overexcitation of the core and deteriorate the winding insulation. The setting must be above the highest occurring "normal" voltage and below the highest acceptable voltage for the equipment.

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Equipment protection, capacitors

High voltage can deteriorate the dielectricum and the insulation. The setting must be above the highest occurring "normal" voltage and below the highest acceptable voltage for the capacitor.

High impedance earthed systems

In high impedance earthed systems, earth-faults cause a voltage increase in the non-faulty phases. OV2PTOV can be used to detect such faults. The setting must be above the highest occurring "normal" voltage and below the lowest occurring voltage during faults. A metallic single-phase earth-fault causes the non-faulted phase voltages to increase a factor of $\sqrt{3}$.

The following settings can be done for Two step overvoltage protection

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

ConnType: Sets whether the measurement shall be phase-to-earth fundamental value, phase-to-phase fundamental value, phase-to-earth RMS value or phase-to-phase RMS value.

Operation: Off/On .

OV2PTOV measures the phase-to-earth voltages, or phase-to-phase voltages as selected. The function will operate if the voltage gets higher than the set percentage of the global set base voltage *UBase*. This means operation for phase-to-earth voltage over:

$$U > (\%) \cdot UBase(kV) / \sqrt{3}$$

(Equation 83)

and operation for phase-to-phase voltage over:

$$U > (\%) \cdot UBase(kV)$$

(Equation 84)

Characteristic1: This parameter gives the type of time delay to be used. The setting can be. *Definite time/Inverse Curve A/Inverse Curve B/Inverse Curve C*. The choice is highly dependent of the protection application.

OpModen: This parameter describes how many of the three measured voltages that should be above the set level to give operation for step n (n=step 1 and 2). The setting can be *1 out of 3, 2 out of 3 or 3 out of 3*. In most applications it is sufficient that one phase voltage is high to give operation. If the function shall be insensitive for single phase-to-earth faults *3 out of 3* can be chosen, because the voltage will normally rise in the non-faulted phases at single phase-to-earth faults.

Un>: Set operate overvoltage operation value for step n (n=step 1 and 2), given as % of the global parameter *UBase*. The setting is highly dependent of the protection application. Here it is essential to consider the Maximum voltage at non-faulted situations. Normally this voltage is less than 110% of nominal voltage.

tn: time delay for step n (n=step 1 and 2), given in s. The setting is highly dependent of the protection application. In many applications the protection function has the task to prevent damages to the protected object. The speed might be important for example in case of protection of transformer that might be overexcited. The time delay must be co-ordinated with other automated actions in the system.

t1Min: Minimum operation time for inverse time characteristic for step 1, given in s. For very high voltages the overvoltage function, using inverse time characteristic, can give very short operation time. This might lead to unselective trip. By setting *t1Min* longer than the operation time for other protections such unselective tripping can be avoided.

k1: Time multiplier for inverse time characteristic. This parameter is used for co-ordination between different inverse time delayed undervoltage protections.

7.3 Two step residual overvoltage protection ROV2PTOV

7.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Two step residual overvoltage protection	ROV2PTOV	3U0>	59N

7.3.2 Application

Two step residual overvoltage protection ROV2PTOV is primarily used in high impedance earthed distribution networks, mainly as a backup for the primary earth-fault protection of the feeders and the transformer. To increase the security for different earth-fault related functions, the residual overvoltage signal can be used as a release signal. The residual voltage can be measured either at the transformer neutral or from a voltage transformer open delta connection. The residual voltage can also be calculated internally, based on measurement of the three-phase voltages.

In high impedance earthed systems the system neutral voltage, that is, the residual voltage, will increase in case of any fault connected to earth. Depending on the type of fault and fault resistance the residual voltage will reach different values.

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The highest residual voltage, equal to three times the phase-to-earth voltage, is achieved for a single phase-to-earth fault. The residual voltage increases approximately the same amount in the whole system and does not provide any guidance in finding the faulted component. Therefore, ROV2PTOV is often used as a backup protection or as a release signal for the feeder earth-fault protection.

7.3.3 Setting guidelines

The parameters for Two step residual overvoltage protection ROV2PTOV are set via the local HMI or PCM600.

All the voltage conditions in the system where ROV2PTOV performs its functions should be considered. The same also applies to the associated equipment, its voltage and time characteristic.

There is a very wide application area where general single input or residual overvoltage functions are used. All voltage related settings are made as a percentage of a settable base voltage, which can be set to the primary nominal voltage (phase-phase) level of the power system or the high voltage equipment under consideration.

The time delay for ROV2PTOV are seldom critical, since residual voltage is related to earth-faults in a high impedance earthed system, and enough time must normally be given for the primary protection to clear the fault. In some more specific situations, where the single overvoltage protection is used to protect some specific equipment, the time delay is shorter.

Some applications and related setting guidelines for the residual voltage level are given below.

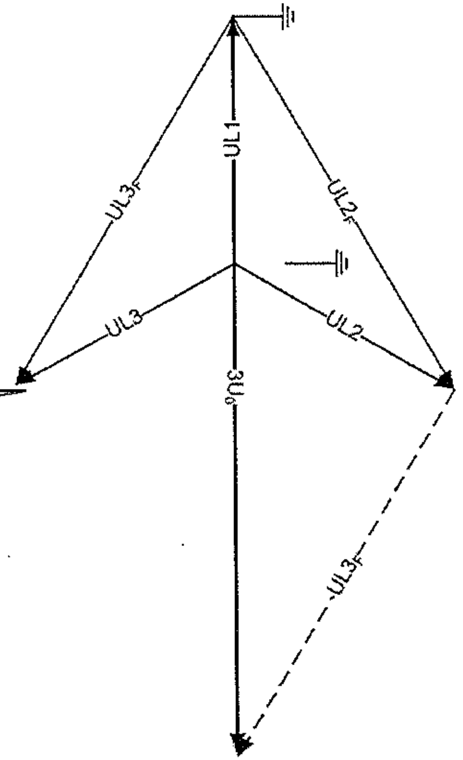
7.3.3.1 Power supply quality

The setting must be above the highest occurring "normal" residual voltage and below the highest acceptable residual voltage, due to regulation, good practice or other agreements.

7.3.3.2 High impedance earthed systems

In high impedance earthed systems, earth faults cause a neutral voltage in the feeding transformer neutral. Two step residual overvoltage protection ROV2PTOV is used to trip the transformer, as a backup protection for the feeder earth-fault protection, and as a backup for the transformer primary earth-fault protection. The setting must be above the highest occurring "normal" residual voltage, and below the lowest occurring residual voltage during the faults under consideration. A metallic single-phase earth fault causes a transformer neutral to reach a voltage equal to the normal phase-to-earth voltage.

The voltage transformers measuring the phase-to-earth voltages measure zero voltage in the faulty phase. The two healthy phases will measure full phase-to-phase voltage, as the earth is available on the faulty phase and the neutral has a full phase-to-earth voltage. The residual overvoltage will be three times the phase-to-earth voltage. See Figure 64.



en07000190.vsd

Figure 64: Non-effectivelyearthedsystems

Direct earthed system

In direct earthed systems, an earth-fault on one phase indicates a voltage collapse in that phase. The two healthy phases will have normal phase-to-earth voltages. The residual sum will have the same value as phase-to-earth voltage. See Figure 65.

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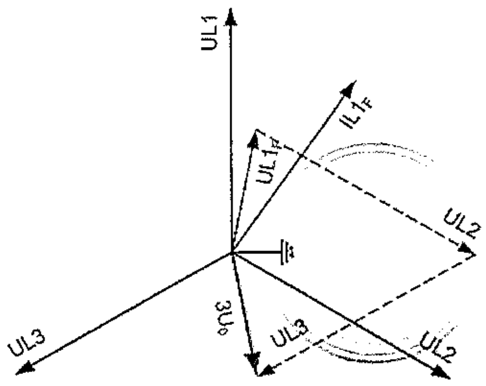

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Figure 65: Direct earthed system

7.3.3.4 Settings for Two step residual overvoltage protection

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Operation: *Off* or *On*

UBase is used as voltage reference for the voltage. The voltage can be fed to the IED in different ways:

1. The IED is fed from a normal voltage transformer group where the residual voltage is created from the phase-to-earth voltages within the protection software.
2. The IED is fed from a broken delta connection normal voltage transformer group. In a open delta connection the protection is fed by the voltage 3U0 (single input). The setting chapter in the application manual explains how the analog input needs to be set.
3. The IED is fed from a single voltage transformer connected to the neutral point of a power transformer in the power system. In this connection the protection is fed by the voltage UN=U0 (single input). The setting chapter in the application manual explains how the analog input needs to be set. ROV2PTOV will measure the residual voltage corresponding nominal phase-to-

earth voltage for high impedance earthed system. The measurement will be based on the neutral voltage displacement .

Characteristic1: This parameter gives the type of time delay to be used. The setting can be, *Definite time* or *Inverse curve A* or *Inverse curve B* or *Inverse curve C*. The choice is highly dependent of the protection application.

Un>: Set operate overvoltage operation value for step n (n=step 1 and 2), given as % of residual voltage corresponding to global set parameter *UBase*:

$$U > (\%) \cdot UBase(kV)/\sqrt{3}$$

The setting is dependent of the required sensitivity of the protection and the system earthing. In non-effectively earthed systems the residual voltage can be maximum the rated phase-to-earth voltage, which should correspond to 100%.

In effectively earthed systems this value is dependent of the ratio Z0/Z1. The required setting to detect high resistive earth-faults must be based on network calculations.

tn: time delay of step n (n=step 1 and 2), given in s. The setting is highly dependent of the protection application. In many applications, the protection function has the task to prevent damages to the protected object. The speed might be important for example in case of protection of transformer that might be overexcited. The time delay must be co-ordinated with other automated actions in the system.

t1Min: Minimum operation time for inverse time characteristic for step 1, given in s. For very high voltages the overvoltage function, using inverse time characteristic, can give very short operation time. This might lead to unselective trip. By setting *t1Min* longer than the operation time for other protections such unselective tripping can be avoided.

k1: Time multiplier for inverse time characteristic. This parameter is used for co-ordination between different inverse time delayed undervoltage protections.

7.4 Loss of voltage check LOVPTUV

7.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Loss of voltage check	LOVPTUV	-	27

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7.4.2 Application

The trip of the circuit breaker at a prolonged loss of voltage at all the three phases is normally used in automatic restoration systems to facilitate the system restoration after a major blackout. Loss of voltage check (LOVPTUV) generates a TRIP signal only if the voltage in all the three phases is low for more than the set time. If the trip to the circuit breaker is not required, LOVPTUV is used for signallization only through an output contact or through the event recording function.

7.4.3 Setting guidelines

Loss of voltage check (LOVPTUV) is in principle independent of the protection functions. It requires to be set to open the circuit breaker in order to allow a simple system restoration following a main voltage loss of a big part of the network and only when the voltage is lost with breakers still closed.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

All settings are in primary values or per unit. Set operating level per phase to typically 70% of the global parameter *UBase* level. Set the time delay *tTrip*=5-20 seconds.

7.4.4 Advanced users settings

For advanced users the following parameters need also to be set. Set the length of the trip pulse to typical *tPulse*=0.15 sec. The blocking time to block Loss of voltage check (LOVPTUV) if some but not all voltage are low *tBlock*=5.0 sec. set the time delay for enabling the function after restoration *tRestore* = 3 - 40 seconds.

Section 8 Frequency protection

8.1 Under frequency protection SAPTUF

8.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Underfrequency protection	SAPTUF	f<	81

8.1.2 Application

Underfrequency protection SAPTUF is applicable in all situations, where reliable detection of low fundamental power system voltage frequency is needed. The power system frequency, and rate of change of frequency, is a measure of the unbalance between the actual generation and the load demand. Low fundamental frequency in a power system indicates that the available generation is too low to fully supply the power demanded by the load connected to the power grid. SAPTUF detects such situations and provides an output signal, suitable for load shedding, generator boosting, HVDC-set-point change, gas turbine start up and so on. Sometimes shunt reactors are automatically switched in due to low frequency, in order to reduce the power system voltage and hence also reduce the voltage dependent part of the load. SAPTUF is very sensitive and accurate and is used to alert operators that frequency has slightly deviated from the set-point, and that manual actions might be enough. The underfrequency signal is also used for overexcitation detection. This is especially important for generator step-up transformers, which might be connected to the generator but disconnected from the grid, during a roll-out sequence. If the generator is still energized, the system will experience overexcitation, due to the low frequency.

8.1.3 Setting guidelines

The parameters for underfrequency protection SAPTUF are set via the local HMI or Protection and Control IED Manager (PCM600).

All the frequency and voltage magnitude conditions in the system where SAPTUF performs its functions should be considered. The same also applies to the associated equipment, its frequency and time characteristic.

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There are especially two application areas for SAPTUF:

1. to protect equipment against damage due to low frequency, such as generators, transformers, and motors. Overexcitation is also related to low frequency
2. to protect a power system, or a part of a power system, against breakdown, by shedding load, in generation deficit situations.

The under frequency START value is set in Hz. All voltage magnitude related settings are made as a percentage of a global base voltage parameter.

SAPTUF is not instantaneous, since the frequency is related to movements of the system inertia, but the time and frequency steps between different actions might be critical, and sometimes a rather short operation time is required, for example, down to 70 ms.

Some applications and related setting guidelines for the frequency level are given below:

Equipment protection, such as for motors and generators

The setting has to be well below the lowest occurring "normal" frequency and well above the lowest acceptable frequency for the equipment.

Power system protection, by load shedding

The setting has to be below the lowest occurring "normal" frequency and well above the lowest acceptable frequency for power stations, or sensitive loads. The setting level, the number of levels and the distance between two levels (in time and/or in frequency) depends very much on the characteristics of the power system under consideration. The size of the "largest loss of production" compared to "the size of the power system" is a critical parameter. In large systems, the load shedding can be set at a fairly high frequency level, and the time delay is normally not critical. In smaller systems the frequency START level has to be set at a lower value, and the time delay must be rather short.

8.2 Over frequency protection SAPTOF

8.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Overfrequency protection	SAPTOF	f>	81

8.2.2 Application

Overfrequency protection function SAPTOF is applicable in all situations, where reliable detection of high fundamental power system voltage frequency is needed. The power system frequency, and rate of change of frequency, is a measure of the unbalance between the actual generation and the load demand. High fundamental frequency in a power system indicates that the available generation is too large compared to the power demanded by the load connected to the power grid. SAPTOF detects such situations and provides an output signal, suitable for generator shedding, HVDC-set-point change and so on. SAPTOF is very sensitive and accurate and can also be used to alert operators that frequency has slightly deviated from the set-point, and that manual actions might be enough.

8.2.3 Setting guidelines

The parameters for Overfrequency protection (SAPTOF) are set via local HMI or PCM600.

All the frequency and voltage magnitude conditions in the system where SAPTOF performs its functions must be considered. The same also applies to the associated equipment, its frequency and time characteristic.

There are especially two application areas for SAPTOF:

1. to protect equipment against damage due to high frequency, such as generators, and motors
2. to protect a power system, or a part of a power system, against breakdown, by shedding generation, in generation surplus situations.

The overfrequency start value is set in Hz. All voltage magnitude related settings are made as a percentage of a settable global base voltage parameter *UBase*.

SAPTOF is not instantaneous, since the frequency is related to movements of the system inertia, but the time and frequency steps between different actions might be critical, and sometimes a rather short operation time is required, for example, down to 70 ms.

Some applications and related setting guidelines for the frequency level are given below:

Equipment protection, such as for motors and generators

The setting has to be well above the highest occurring "normal" frequency and well below the highest acceptable frequency for the equipment.

Power system protection, by generator shedding

The setting must be above the highest occurring "normal" frequency and below the highest acceptable frequency for power stations, or sensitive loads. The setting level, the number of levels and the distance between two levels (in time and/or in

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frequency) depend very much on the characteristics of the power system under consideration. The size of the "largest loss of load" compared to "the size of the power system" is a critical parameter. In large systems, the generator shedding can be set at a fairly low frequency level, and the time delay is normally not critical. In smaller systems the frequency START level has to be set at a higher value, and the time delay must be rather short.

8.3 Rate-of-change frequency protection SAPFRC

8.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Rate-of-change frequency protection	SAPFRC	df/dt ≷	81

8.3.2 Application

Rate-of-change frequency protection (SAPFRC), is applicable in all situations, where reliable detection of change of the fundamental power system voltage frequency is needed. SAPFRC can be used both for increasing frequency and for decreasing frequency. SAPFRC provides an output signal, suitable for load shedding or generator shedding, generator boosting, HVDC-set-point change, gas turbine start up. Very often SAPFRC is used in combination with a low frequency signal, especially in smaller power systems, where loss of a fairly large generator will require quick remedial actions to secure the power system integrity. In such situations load shedding actions are required at a rather high frequency level, but in combination with a large negative rate-of-change of frequency the underfrequency protection can be used at a rather high setting.

8.3.3 Setting guidelines

The parameters for Rate-of-change frequency protection SAPFRC are set via the local HMI or PCM600.

All the frequency and voltage magnitude conditions in the system where SAPFRC performs its functions should be considered. The same also applies to the associated equipment, its frequency and time characteristic.

There are especially two application areas for SAPFRC:

1. to protect equipment against damage due to high or to low frequency, such as generators, transformers, and motors
2. to protect a power system, or a part of a power system, against breakdown, by shedding load or generation, in situations where load and generation are not in balance.

SAPFRC is normally used together with an overfrequency or underfrequency function, in small power systems, where a single event can cause a large imbalance between load and generation. In such situations load or generation shedding has to take place very quickly, and there might not be enough time to wait until the frequency signal has reached an abnormal value. Actions are therefore taken at a frequency level closer to the primary nominal level, if the rate-of-change frequency is large (with respect to sign).

SAPFRCSTART value is set in Hz/s. All voltage magnitude related settings are made as a percentage of a settable base voltage, which normally is set to the primary nominal voltage level (phase-phase) of the power system or the high voltage equipment under consideration.

SAPFRC is not instantaneous, since the function needs some time to supply a stable value. It is recommended to have a time delay long enough to take care of signal noise. However, the time, rate-of-change frequency and frequency steps between different actions might be critical, and sometimes a rather short operation time is required, for example, down to 70 ms.

Smaller industrial systems might experience rate-of-change frequency as large as 5 Hz/s, due to a single event. Even large power systems may form small islands with a large imbalance between load and generation, when severe faults (or combinations of faults) are cleared - up to 3 Hz/s has been experienced when a small island was isolated from a large system. For more "normal" severe disturbances in large power systems, rate-of-change of frequency is much less, most often just a fraction of 1.0 Hz/s.

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Section 9 Secondary system supervision

9.1 Current circuit supervison CCSRDIF

9.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Current circuit supervision	CCSRDIF	-	87

9.1.2 Application

Open or short circuited current transformer cores can cause unwanted operation of many protection functions such as differential, earth-fault current and negative-sequence current functions. When currents from two independent three-phase sets of CTs, or CT cores, measuring the same primary currents are available, reliable current circuit supervision can be arranged by comparing the currents from the two sets. If an error in any CT circuit is detected, the protection functions concerned can be blocked and an alarm given.

In case of large currents, unequal transient saturation of CT cores with different remanence or different saturation factor may result in differences in the secondary currents from the two CT sets. Unwanted blocking of protection functions during the transient stage must then be avoided.

Current circuit supervision CCSRDIF must be sensitive and have short operate time in order to prevent unwanted tripping from fast-acting, sensitive numerical protections in case of faulty CT secondary circuits.

> Open CT circuits creates extremely high voltages in the circuits, which may damage the insulation and cause new problems.
> The application shall, thus, be done with this in consideration, especially if protection functions are blocked.

9.1.3 Setting guidelines

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

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Current circuit supervision CCSRDIF compares the residual current from a three-phase set of current transformer cores with the neutral point current on a separate input taken from another set of cores on the same current transformer.

The minimum operate current, *IMinOp*, must be set as a minimum to twice the residual current in the supervised CT circuits under normal service conditions and rated primary current.

The parameter *Ip>Block* is normally set at *150%* to block the function during transient conditions.

The FAIL output is connected in the PCM configuration to the blocking input of the protection function to be blocked at faulty CT secondary circuits.

9.2 Fuse failure supervision SDDRFUF

9.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Fuse failure supervision	SDDRFUF	-	-

9.2.2 Application

Different protection functions within the protection IED, operates on the basis of the measured voltage in the relay point. Examples are:

- distance protection function
- under/over-voltage function
- synchrocheck function and voltage check for the weak infeed logic.

These functions can operate unintensionally if a fault occurs in the secondary circuits between the voltage instrument transformers and the IED.

It is possible to use different measures to prevent such unwanted operations. Miniature circuit breakers in the voltage measuring circuits, located as close as possible to the voltage instrument transformers, are one of them. Separate fuse-failure monitoring IEDs or elements within the protection and monitoring devices are another possibilities. These solutions are combined to get the best possible effect in the fuse failure supervision function (SDDRFUF).

SDDRFUF function built into the IED products can operate on the basis of external binary signals from the miniature circuit breaker or from the line disconnector. The first case influences the operation of all voltage-dependent functions while the second one does not affect the impedance measuring functions.

The negative sequence detection algorithm, based on the negative-sequence measuring quantities, a high value of voltage $3U_2$ without the presence of the negative-sequence current $3I_2$, is recommended for use in isolated or high-impedance earthed networks.

The zero sequence detection algorithm, based on the zero sequence measuring quantities, a high value of voltage $3U_0$ without the presence of the residual current $3I_0$, is recommended for use in directly or low impedance earthed networks. In cases where the line can have a weak-infeed of zero sequence current this function shall be avoided.

A criterion based on delta current and delta voltage measurements can be added to the fuse failure supervision function in order to detect a three phase fuse failure, which in practice is more associated with voltage transformer switching during station operations.

9.2.3 Setting guidelines

9.2.3.1 General

The negative and zero sequence voltages and currents always exist due to different non-symmetries in the primary system and differences in the current and voltage instrument transformers. The minimum value for the operation of the current and voltage measuring elements must always be set with a safety margin of 10 to 20%, depending on the system operating conditions.

Pay special attention to the dissymmetry of the measuring quantities when the function is used on longer untransposed lines, on multicircuit lines and so on.

The settings of negative sequence, zero sequence and delta algorithm are in percent of the base voltage and base current for the function, *UBase* and *IBase* respectively. Set *UBase* to the primary rated phase-phase voltage of the potential voltage transformer and *IBase* to the primary rated current of the current transformer.

9.2.3.2 Setting of common parameters

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

The settings of negative sequence, zero sequence and delta algorithm are in percent of the global base voltage and global base current for the function, *UBase* and *IBase* respectively.

The voltage threshold *USealIn<* is used to identify low voltage condition in the system. Set *USealIn<* below the minimum operating voltage that might occur

during emergency conditions. We propose a setting of approximately 70% of the global parameter *UBase*.

The drop off time of 200 ms for dead phase detection makes it recommended to always set *SealIn* to *On* since this will secure a fuse failure indication at persistent fuse fail when closing the local breaker when the line is already energized from the other end. When the remote breaker closes the voltage will return except in the phase that has a persistent fuse fail. Since the local breaker is open there is no current and the dead phase indication will persist in the phase with the blown fuse. When the local breaker closes the current will start to flow and the function detects the fuse failure situation. But due to the 200 ms drop off timer the output BLKZ will not be activated until after 200 ms. This means that distance functions are not blocked and due to the "no voltage but current" situation might issue a trip.

The operation mode selector *OpMode* has been introduced for better adaptation to system requirements. The mode selector makes it possible to select interactions between the negative sequence and zero sequence algorithm. In normal applications the *OpMode* is set to either *UNsINs* for selecting negative sequence algorithm or *UZsIZs* for zero sequence based algorithm. If system studies or field experiences shows that there is a risk that the fuse failure function will not be activated due to the system conditions, the dependability of the fuse failure function can be increased if the *OpMode* is set to *UZsIZs OR UNsINs* or *OptimZsNs*. In mode *UZsIZs OR UNsINs* both the negative and zero sequence based algorithm is activated and working in an OR-condition. Also in mode *OptimZsNs* both the negative and zero sequence algorithm are activated and the one that has the highest magnitude of measured negative sequence current will operate. If there is a requirement to increase the security of the fuse failure function *OpMode* can be selected to *UZsIZs AND UNsINs* which gives that both negative and zero sequence algorithm is activated working in an AND-condition, that is, both algorithm must give condition for block in order to activate the output signals BLKU or BLKZ.

9.2.3.3 Negative sequence based

The relay setting value *3U2>* is given in percentage of the base voltage *UBase* and should not be set lower than according to equation 85.

$$3U2 >= \frac{3U2}{UBase} \cdot 100$$

(Equation 85)

where:

$3U2$	is maximal negative sequence voltage during normal operation condition
$UBase$	is setting of the global base voltage for all functions in the IED.

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The setting of the current limit *3I2<* is in percentage of global parameter *IBase*. The setting of *3I2<* must be higher than the normal unbalance current that might exist in the system and can be calculated according to equation 86.

$$3I2 <= \frac{3I2}{IBase} \cdot 100$$

(Equation 86)

where:

3I2 is maximal negative sequence current during normal operating condition

IBase is setting of base current for the function

9.2.3.4 Zero sequence based

The relay setting value *3U0>* is given in percentage of the global parameter *UBase*. The setting of *3U0>* should not be set lower than according to equation 87.

$$3U0 >= \frac{3U0}{UBase} \cdot 100$$

(Equation 87)

where:

3U0 Is maximal zero sequence voltage during normal operation condition

UBase is setting of global base voltage all functions in the IED.

The setting of the current limit *3I0<* is done in percentage of the global parameter *IBase*. The setting of *3I0<* must be higher than the normal unbalance current that might exist in the system. The setting can be calculated according to equation 88.

$$3I0 <= \frac{3I0}{IBase} \cdot 100$$

(Equation 88)

where:

3I0< is maximal zero sequence current during normal operating condition

IBase Is setting of global base current all functions in the IED.

9.2.3.5 Delta U and delta I

Set the operation mode selector *OpDUDI* to *On* if the delta function shall be in operation.

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The setting of *DU>* should be set high (approximately 60% of *UBase*) and the current threshold *DI<* low (approximately 10% of *IBase*) to avoid unwanted operation due to normal switching conditions in the network. The delta current and delta voltage function shall always be used together with either the negative or zero sequence algorithm. If *USetprim* is the primary voltage for operation of dU/dt and *ISetprim* the primary current for operation of dI/dt, the setting of *DU>* and *DI<* will be given according to equation 89and equation 90.

$$DU >= \frac{USet_{prim}}{UBase} \cdot 100$$

(Equation 89)

$$DI <= \frac{ISetprim}{IBase} \cdot 100$$

(Equation 90)

$$DIPU = \frac{ISetprim}{IBase} \cdot 100$$

(Equation 90)

The voltage thresholds *UPh>* is used to identify low voltage condition in the system. Set *UPh>* below the minimum operating voltage that might occur during emergency conditions. We propose a setting of approximately 70% of *UB*.

The current threshold *IPh>* shall be set lower than the *IMinOp* for the distance protection function. A 5-10% lower value is recommended.

9.2.3.6 Dead line detection

The condition for operation of the dead line detection is set by the parameters *IDLD<* for the current threshold and *UDLD<* for the voltage threshold.

Set the *IDLD<* with a sufficient margin below the minimum expected load current. A safety margin of at least 15-20% is recommended. The operate value must however exceed the maximum charging current of an overhead line, when only one phase is disconnected (mutual coupling to the other phases).

Set the *UDLD<* with a sufficient margin below the minimum expected operating voltage. A safety margin of at least 15% is recommended.

9.3 Breaker close/trip circuit monitoring TCSSCBR

9.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Breaker close/trip circuit monitoring	TCSSCBR	-	-

9.3.2 Application

TCSSCBR detects faults in the electrical control circuit of the circuit breaker. The function can supervise both open and closed coil circuits. This kind of supervision is necessary to find out the vitality of the control circuits continuously.

> Trip circuit supervision generates a current of approximately 1.0 mA through the supervised circuit. It must be ensured that this current will not cause a latch up of the controlled object.

> To protect the trip circuit supervision circuits in the IED, the output contacts are provided with parallel transient voltage suppressors. The breakdown voltage of these suppressors is 400 +/– 20 V DC.

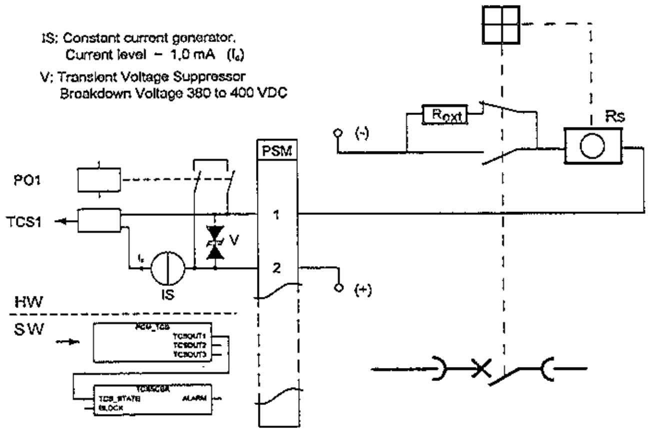

Figure 66: Operating principle of the trip-circuit supervision with an external resistor. The TCSSCBR blocking switch is not required since the external resistor is used.

If TCS is required only in a closed position, the external shunt resistance can be omitted. When the circuit breaker is in the open position, TCS sees the situation as a faulty circuit. One way to avoid TCS operation in this situation would be to block the supervision function whenever the circuit breaker is open.

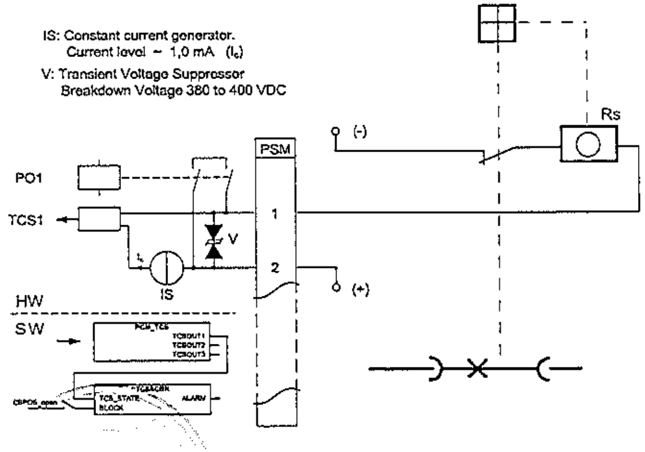

Figure 67: Operating principle of the trip-circuit supervision without an external resistor. The circuit breaker open indication is set to block TCSSCBR when the circuit breaker is open.

Trip-circuit supervision and other trip contacts

It is typical that the trip circuit contains more than one trip contact in parallel, for example in transformer feeders where the trip of a Buchholz relay is connected in parallel with the feeder terminal and other relays involved.

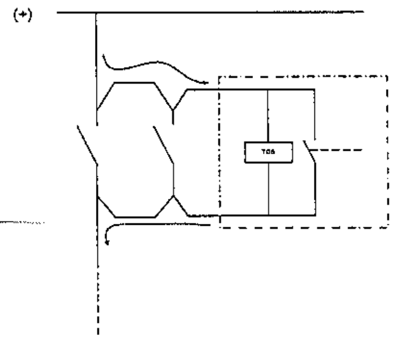

Figure 68: Constant test current flow in parallel trip contacts and trip-circuit supervision

Several trip-circuit supervision functions parallel in circuit

Not only the trip circuit often have parallel trip contacts, it is also possible that the circuit has multiple TCS circuits in parallel. Each TCS circuit causes its own supervising current to flow through the monitored coil and the actual coil current is a sum of all TCS currents. This must be taken into consideration when determining the resistance of R_{ext}.

Trip-circuit supervision with auxiliary relays

Many retrofit projects are carried out partially, that is, the old electromechanical relays are replaced with new ones but the circuit breaker is not replaced. This creates a problem that the coil current of an old type circuit breaker can be too high for the protection IED trip contact to break.

The circuit breaker coil current is normally cut by an internal contact of the circuit breaker. In case of a circuit breaker failure, there is a risk that the protection IED trip contact is destroyed since the contact is obliged to disconnect high level of electromagnetic energy accumulated in the trip coil.

An auxiliary relay can be used between the protection IED trip contact and the circuit breaker coil. This way the breaking capacity question is solved, but the TCS circuit in the protection IED monitors the healthy auxiliary relay coil, not the circuit breaker coil. The separate trip circuit supervision relay is applicable for this to supervise the trip coil of the circuit breaker.

Dimensioning of the external resistor

Mathematically, the operation condition can be expressed as:

If the external shunt resistance is used, it has to be calculated not to interfere with the functionality of the supervision or the trip coil. Too high a resistance causes too high a voltage drop, jeopardizing the requirement of at least 20 V over the internal circuit, while a resistance too low can enable false operations of the trip coil.

At lower (<48V DC) auxiliary circuit operating voltages, it is recommended to use the circuit breaker position to block unintentional operation of TCS. The use of the position indication is described earlier in this chapter.

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Section 10 Control

10.1 Synchrocheck, energizing check, and synchronizing SESRSYN

10.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Synchrocheck, energizing check, and synchronizing	SESRSYN	sc/vc	25

10.1.2 Application

10.1.2.1 Synchronizing

To allow closing of breakers between asynchronous networks a synchronizing function is provided. The breaker close command is issued at the optimum time when conditions across the breaker are satisfied in order to avoid stress on the network and its components.

The systems are defined to be asynchronous when the frequency difference between bus and line is larger than an adjustable parameter. If the frequency difference is less than this threshold value the system is defined to have a parallel circuit and the synchrocheck function is used.

The synchronizing function measures the difference between the U-line and the U-bus. It operates and enables a closing command to the circuit breaker when the calculated closing angle is equal to the measured phase angle and the following conditions are simultaneously fulfilled:

- The voltages U-line and U-bus are higher than the standard preset minimum values for line and bus voltage.
- The difference in the voltage is smaller than the functions standard value.
- The difference in frequency is less than the set value of *FreqDiffMax* and larger than the set value of *FreqDiffMin*. If the frequency is less than *FreqDiffMin* the synchrocheck is used and the value of *FreqDiffMin* must thus be identical to the value *FreqDiffM* resp *FreqDiffA* for synchrocheck function. The bus and line frequencies must also be within a range of +/- 5 Hz from the rated frequency. When the synchronizing option is included also for

autoreclose there is no reason to have different frequency setting for the manual and automatic reclosing and the frequency difference values for synchronism check should be kept low.
- The frequency rate of change is less than set value for both U-bus and U-line.
- The closing angle is decided by the calculation of slip frequency and required pre-closing time.

The synchronizing function compensates for measured slip frequency as well as the circuit breaker closing delay. The phase advance is calculated continuously. Closing angle is the change in angle during the set breaker closing operate time *tBreaker*.

The reference voltage can be phase-neutral L1, L2, L3 or phase-phase L1-L2, L2-L3, L3-L1 or positive sequence. The bus voltage must then be connected to the same phase or phases as are chosen for the line or a compensation angle set to compensate for the difference.

10.1.2.2 Synchrocheck

The main purpose of the synchrocheck function is to provide control over the closing of circuit breakers in power networks in order to prevent closing if conditions for synchronism are not detected. It is also used to prevent the re-connection of two systems, which are divided after islanding and after a three pole reclosing.

Single pole auto-reclosing does not require any synchrocheck since the system is tied together by two phases.

SESRSYN function block includes both the synchronism check function and the energizing function to allow closing when one side of the breaker is dead. SESRSYN function also includes a built in voltage selection scheme which allows simple application in busbar arrangements.

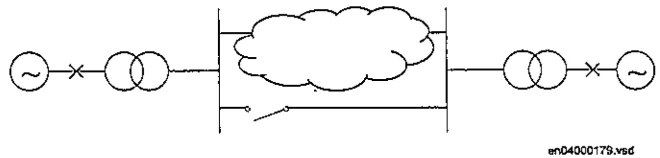

Figure 69: Two interconnected power systems

Figure 69 shows two interconnected power systems. The cloud means that the interconnection can be further away, that is, a weak connection through other stations. The need for a check of synchronization increases as the meshed system decreases since the risk of the two networks being out of synchronization at manual or automatic closing is greater.

The synchrocheck function measures the conditions across the circuit breaker and compares them to set limits. Output is generated only when all measured conditions are within their set limits simultaneously. The check consists of:

- Live line and live bus.
- Voltage level difference.
- Frequency difference (slip). The bus and line frequency must also be within a range of ±5 Hz from rated frequency.
- Phase angle difference.

A time delay is available to ensure that the conditions are fulfilled for a minimum period of time.

In very stable power systems the frequency difference is insignificant or zero for manually initiated closing or closing by automatic restoration. In steady conditions a bigger phase angle difference can be allowed as this is sometimes the case in a long and loaded parallel power line. For this application we accept a synchrocheck with a long operation time and high sensitivity regarding the frequency difference. The phase angle difference setting can be set for steady state conditions.

Another example, is when the operation of the power net is disturbed and high-speed auto-reclosing after fault clearance takes place. This can cause a power swing in the net and the phase angle difference may begin to oscillate. Generally, the frequency difference is the time derivative of the phase angle difference and will, typically oscillate between positive and negative values. When the circuit breaker needs to be closed by auto-reclosing after fault-clearance some frequency difference should be tolerated, to a greater extent than in the steady condition mentioned in the case above. But if a big phase angle difference is allowed at the same time, there is some risk that auto-reclosing will take place when the phase angle difference is big and increasing. In this case it should be safer to close when the phase angle difference is smaller.

To fulfill the above requirements the synchrocheck function is provided with duplicate settings, one for steady (Manual) conditions and one for operation under disturbed conditions (Auto).

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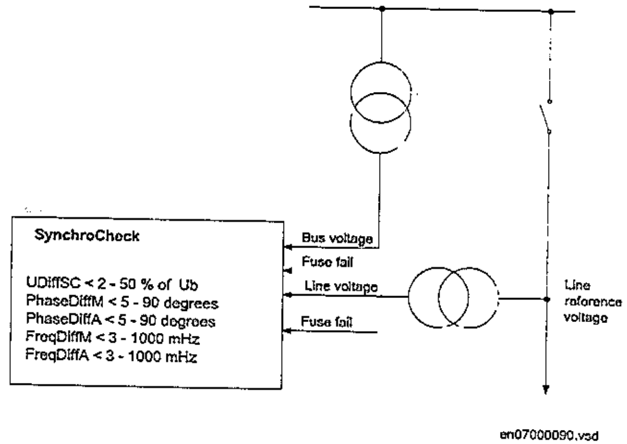

Figure 70: Principle for the synchrocheck function

10.1.2.3 Energizing check

The main purpose of the energizing check function is to facilitate the controlled re-connection of disconnected lines and buses to energized lines and buses.

The energizing check function measures the bus and line voltages and compares them to both high and low threshold values. The output is given only when the actual measured conditions match the set conditions. Figure 71 shows two power systems, where one (1) is energized and the other (2) is not energized. Power system 2 is energized (DLLB) from system 1 via the circuit breaker A.

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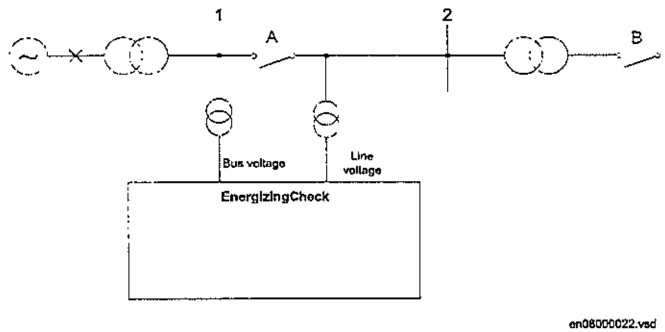

Figure 71: Principle for the energizing check function

The energizing operation can operate in the dead line live bus (DLLB) direction, dead bus live line (DBLL) direction, or in both directions over the circuit breaker. Energizing from different directions can be different for automatic reclosing and manual closing of the circuit breaker. For manual closing it is also possible to allow closing when both sides of the breaker are dead, Dead Bus Dead Line (DBDL).

The equipment is considered energized if the voltage is above a set value, for example, 80% of the base voltage, and non-energized if it is below a set value, for example, 30% of the base voltage. A disconnected line can have a considerable potential because of factors such as induction from a line running in parallel, or feeding via extinguishing capacitors in the circuit breakers. This voltage can be as high as 50% or more of the base voltage of the line. Normally, for breakers with single breaking elements (<330kV) the level is well below 30%.

When the energizing direction corresponds to the settings, the situation has to remain constant for a certain period of time before the close signal is permitted. The purpose of the delayed operate time is to ensure that the dead side remains de-energized and that the condition is not due to temporary interference.

10.1.2.4 Voltage selection

The voltage selection function is used for the connection of appropriate voltages to the synchrocheck and energizing check functions. For example, when the IED is used in a double bus arrangement, the voltage that should be selected depends on the status of the breakers and/or disconnectors. By checking the status of the disconnectors auxiliary contacts, the right voltages for the synchronizing, synchrocheck and energizing check functions can be selected.

The voltages from busbars and lines must be physically connected to the voltage inputs in the IED and connected, using the control software, to each of the maximum two SESRSYNfunctions available in the IED.

10.1.2.5 External fuse failure

External fuse-failure signals or signals from a tripped fuse switch/MCB are connected to binary inputs that are configured to inputs of SESRSYNfunction in the IED. The internal fuse failure supervision function can also be used, for at least the line voltage supply. The signal VTSU is then used and connected to the blocking input of the energizing check function block. In case of a fuse failure, SESRSYNand energizing check functions are blocked.

The UB1OK/UB2OK and UB1FF/UB2FF inputs are related to the busbar voltage and the ULNOK and ULNFF inputs are related to the line voltage.

External selection of energizing direction

The energizing can be selected by use of the available logic function blocks. Below is an example where the choice of mode is done from a symbol on the local HMI through selector switch function block, but alternatively there can for example, be a physical selector switch on the front of the panel which is connected to a binary to integer function block (B16I).

If the PSTO input is used, connected to the Local-Remote switch on the local HMI, the choice can also be from the station HMI system, typically ABB Microscada through IEC 61850 communication.

The connection example for selection of the manual energizing mode is shown in figure 72. Selected names are just examples but note that the symbol on the local HMI can only show three signs.

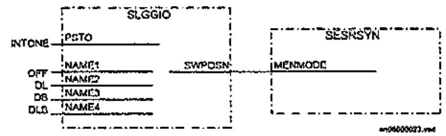

Figure 72: Selection of the energizing direction from a local HMI symbol through a selector switch function block.

10.1.3 Application examples

SESRSYN function block can also be used in some switchyard arrangements, but with different parameter settings. Below are some examples of how different arrangements are connected to the IED analogue inputs and to the function block SESRSYN. One function block is used per circuit breaker.

> The input used below in example are typical and can be changed by use of configuration and signal matrix tools.

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The SESRSYN and connected SMAI function block instances must have the same cycle time in the application configuration.

10.1.3.1 Single circuit breaker with single busbar

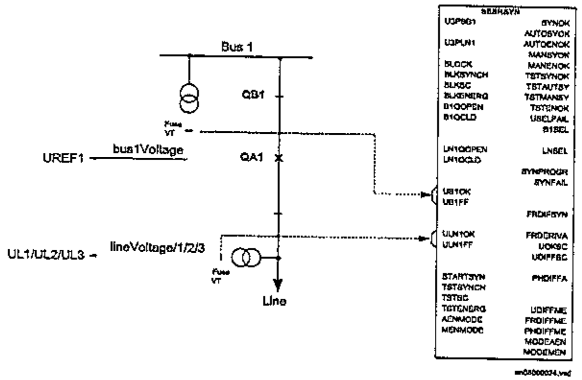

Figure 73: Connection of SESRSYN function block in a single busbar arrangement

Figure 73 illustrates connection principles. For the SESRSYN function there is one voltage transformer on each side of the circuit breaker. The voltage transformer circuit connections are straightforward; no special voltage selection is necessary. For SESRSYN , the voltage from the busbar VT is connected to analog input UREF1 on the analog input module. The line voltage is connected as a three-phase voltage to the analog inputs UL1, UL2 and UL3.

10.1.3.2 Single circuit breaker with double busbar, external voltage selection

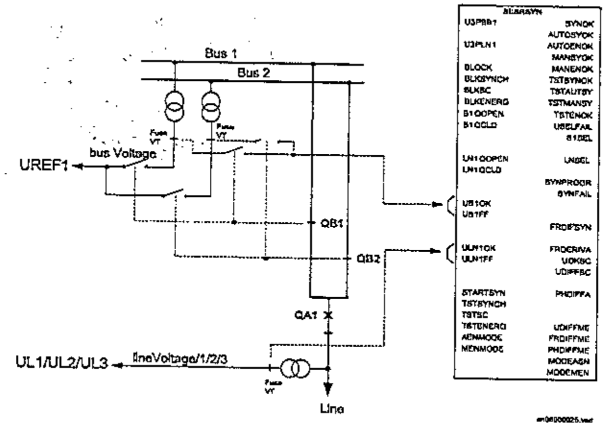

Figure 74: Connection of SESRSYN function block in a single breaker, double busbar arrangement with external voltage selection.

In this type of arrangement no internal voltage selection is required. The voltage selection is made by external relays typically connected according to figure 74. Suitable voltage and VT fuse failure supervision from the two busbars are selected based on the position of the busbar disconnectors. That means that the connections to the function block will be the same as for the single busbar arrangement.

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10.1.3.3 Single circuit breaker with double busbar, internal voltage selection

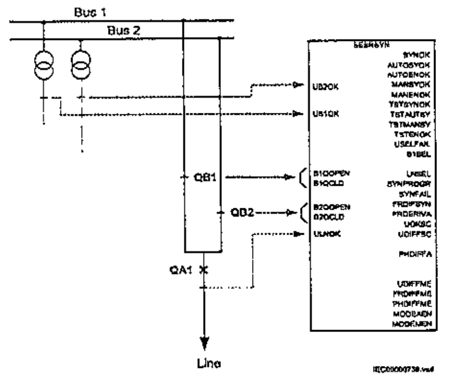

Figure 75: Connection of the Synchrocheck function block in a single breaker, double busbar arrangement with internal selection.

With the configuration according to figure 75, the voltage selection is made internally based on the signals from QB1 and QB2.

10.1.4 Setting guidelines

The setting parameters for the synchronizing, synchrocheck and energizing check function (SESRSYN) are set via the local HMI, or Protection and Control IED Manager (PCM600).

Common base IED value for primary voltage (*UBase*) is set in a Global base value function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Operation: The operation mode can be set *On* or *Off* from PST. The setting *Off* disables the whole function.

MeasVoltBus1 and *MeasVoltBus2*

Configuration parameters for selection of measuring phase of the voltage for the busbar 1 and 2 respectively, which can be single-phase (*UL1*), two-phase (*UL1L2*) or positive sequence voltage.

> *MeasVoltBus1* and *MeasVoltBus2* must always be set to measure the same type of voltage, either single-phase (*UL1*), two-phase (*UL1L2*) or positive sequence voltage.

MeasVoltLine1

Configuration parameters for selection of measuring phase of the voltage for the line, which can be a single-phase (*UL1*), two-phase (*UL1L2*) or positive sequence voltage.

> *MeasVoltLine1* must always be set to measure the same type of voltage as *MeasVoltBus1* and *MeasVoltBus2* , either single-phase (*UL1*), two-phase (*UL1L2*) or positive sequence voltage.

PhaseShift

This setting is used to compensate for a phase shift caused by a line transformer between the two measurement points for bus voltage and line voltage, or one voltage is measured phase-phase and the other phase-neutral. The set value is added to the measured line phase angle. The bus voltage is reference voltage.

URatio

The *URatio* is defined as *URatio=bus voltage/line voltage*. A typical use of the setting is to compensate for the voltage difference caused if one wishes to connect the bus voltage phase-phase and line voltage phase-neutral. The *MeasVoltBus1* setting should then be set to phase-phase and the *URatio* setting to $\sqrt{3}=1.73$. This setting scales up the line voltage to equal level with the bus voltage.

OperationSynch

The setting *Off* disables the Synchronizing function. With the setting *On*, the function is in service and the output signal depends on the input conditions.

FreqDiffMax

The setting *FreqDiffMax* is the maximum slip frequency at which synchronizing is accepted. 1/FreqDiffMax shows the time for the vector to move 360 degrees, one turn on the synchronoscope and is called the Beat time. A typical value for the *FreqDiffMax* is 200-250 mHz which gives beat times on 4-5 seconds. Higher values should be avoided as the two networks normally are regulated to nominal frequency independent of each other so the frequency difference shall be small.

FreqDiffMin

The setting *FreqDiffMin* is the minimum frequency difference where the system are defined to be asynchronous. For frequency difference lower than this value the systems are considered to be in parallel. A typical value for the *FreqDiffMin* is 10 mHz. Generally, the value should be low if both synchronizing and synchrocheck function is provided as it is better to let synchronizing function close as it will close at the exact right instance if the networks runs with a frequency difference. The synchrocheck function will at such a case close to the set phase angle difference value which can be 35 degrees from the correct angle.

The *FreqDiffMin* shall be set to the same value as *FreqDiffM* resp *FreqDiffA* for the Synchrocheck function dependent of whether the functions are used for manual operation, auto-reclosing or both.

FreqRateChange

The maximum allowed rate of change for the frequency.

tBreaker

The *tBreaker* shall be set to match the closing time for the circuit breaker and should also include the possible auxiliary relays in the closing circuit. It is important to check that no slow logic components are used in the configuration of the IED as there then can be big variations in closing time due to those components. Typical setting is 80-150 ms depending on the breaker closing time.

tClosePulse

Setting for the duration of the breaker close pulse.

tMinSynch

The *tMinSynch* is set to limit the minimum time at which synchronizing closing attempt is given. The setting will not give a closing should a condition fulfilled occur within this time from the synchronizing function is started. Typical setting is 200 ms.

tMaxSynch

The *tMaxSynch* is set to reset the operation of the synchronizing function if the operation does not take place within this time. The setting must allow for the setting of *FreqDiffMin* which will decide how long it will take maximum to reach phase equality. At a setting of 10ms the beat time is 100 seconds and the setting would thus need to be at least *tMinSynch* plus 100 seconds. If the network frequencies are expected to be outside the limits from start a margin needs to be added. Typical setting 300 seconds.

OperationSC

The *OperationSC* setting *Off* disables the synchrocheck function and sets the outputs AUTOSYOK, MANSYOK, TSTAUTSY and TSTMANSY to low.

With the setting *On*, the function is in service and the output signal depends on the input conditions.

UDiffSC

Setting for voltage difference between line and bus.

FreqDiffM and FreqDiffA

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The frequency difference level settings, *FreqDiffM* and *FreqDiffA*, shall be chosen depending on the condition in the network. At steady conditions a low frequency difference setting is needed, where the *FreqDiffM* setting is used. For auto-reclosing a bigger frequency difference setting is preferable, where the *FreqDiffA* setting is used. A typical value for the *FreqDiffM* can be 10 mHz and a typical value for the *FreqDiffA* can be 100-200 mHz.

PhaseDiffM and PhaseDiffA

The phase angle difference level settings, *PhaseDiffM* and *PhaseDiffA*, shall also be chosen depending on conditions in the network. The phase angle setting must be chosen to allow closing under maximum load condition. A typical maximum value in heavy loaded networks can be 45 degrees whereas in most networks the maximum occurring angle is below 25 degrees.

tSCM and tSCA

The purpose of the timer delay settings, *tSCM* and *tSCA*, is to ensure that the synchrocheck conditions remains constant and that the situation is not due to a temporary interference. Should the conditions not persist for the specified time, the delay timer is reset and the procedure is restarted when the conditions are fulfilled again. Circuit breaker closing is thus not permitted until the synchrocheck situation has remained constant throughout the set delay setting time. Under stable conditions a longer operation time delay setting is needed, where the *tSCM* setting is used. During auto-reclosing a shorter operation time delay setting is preferable, where the *tSCA* setting is used. A typical value for the *tSCM* may be 1 second and a typical value for the *tSCA* may be 0.1 second.

AutoEnerg and *ManEnerg*

Two different settings can be used for automatic and manual closing of the circuit breaker. The settings for each of them are:

- *Off*, the energizing function is disabled.
- *DLLB*, Dead Line Live Bus, the line voltage is below a standard value.
- *DBLL*, Dead Bus Live Line, the bus voltage is below a standard value.
- *Both*, energizing can be done in both directions, *DLLB* or *DBLL*.

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tAutoEnerg and *tManEnerg*

The purpose of the timer delay settings, *tAutoEnerg* and *tManEnerg*, is to ensure that the dead side remains de-energized and that the condition is not due to a temporary interference. Should the conditions not persist for the specified time, the delay timer is reset and the procedure is restarted when the conditions are fulfilled again. Circuit breaker closing is thus not permitted until the energizing condition has remained constant throughout the set delay setting time.

ManEnergDBDL

If the parameter is set to *On*, manual energizing is enabled.

10.2 Autorecloser SMBRREC

10.2.1 Identification

Function Description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Autorecloser	SMBRREC	O->I	79

10.2.2 Application

Automatic reclosing is a well-established method for the restoration of service in a power system after a transient line fault. The majority of line faults are flashover arcs, which are transient by nature. When the power line is switched off by the operation of line protection and line breakers, the arc de-ionizes and recovers its ability to withstand voltage at a somewhat variable rate. Thus, a certain dead time with a de-energized line is necessary. Line service can then be resumed by automatic reclosing of the line breakers. The dead time selected should be long enough to ensure a high probability of arc de-ionization and successful reclosing.

For individual line breakers, auto-reclosing equipment or functions, the auto-reclosing open time is used to determine line "dead time". When simultaneous tripping and reclosing at the two line ends occurs, auto-reclosing open time is approximately equal to the line "dead time". If the open time and dead time differ then, the line will be energized until the breakers at both ends have opened.

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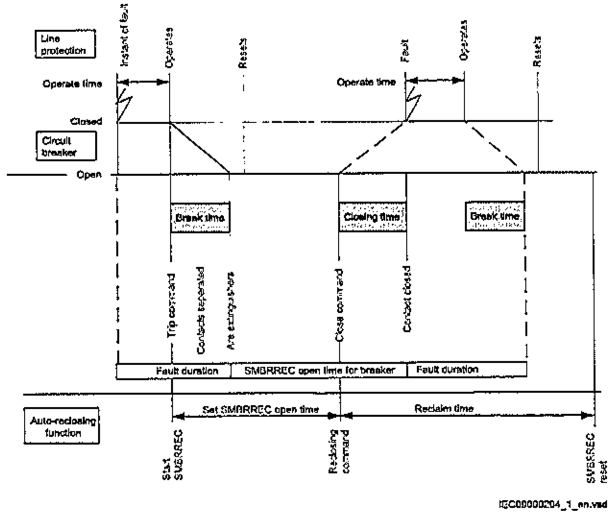

Figure 76: Single-shot automatic reclosing at a permanent fault

Three-phase automatic reclosing can be performed with or without the use of a synchrocheck, and an energizing check, such as dead line or dead busbar check.

For the individual line breakers and auto-reclosing equipment, the "auto-reclosing open time" expression is used. This is the dead time setting for the Auto-Recloser. During simultaneous tripping and reclosing at the two line ends, auto-reclosing open time is approximately equal to the line dead time. Otherwise these two times may differ as one line end might have a slower trip than the other end which means that the line will not be dead until both ends have opened.

If the fault is permanent, the line protection will trip again when reclosing is attempted in order to clear the fault.

It is common to use one automatic reclosing function per line circuit-breaker (CB). When one CB per line end is used, then there is one auto-reclosing function per line end. If auto-reclosing functions are included in duplicated line protection, which means two auto-reclosing functions per CB, one should take measures to avoid uncoordinated reclosing commands. In 1 1/2 breaker, double-breaker and ring bus arrangements, two CBs per line end are operated. One auto-reclosing function per CB is recommended. Arranged in such a way, sequential reclosing of the two CBs can be arranged with a priority circuit available in the auto-reclose function. In case of a permanent fault and unsuccessful reclosing of the first CB, reclosing of the second CB is cancelled and thus the stress on the power system is limited. Another advantage with the breaker connected auto-recloser is that

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checking that the breaker closed before the sequence, breaker prepared for an auto-reclose sequence and so on. is much simpler.

The auto-reclosing function performs three-phase automatic-reclosing with single-shot or multiple-shots.

In power transmission systems it is common practise to apply single and/or three phase, single-shot Auto-Reclosing. In Sub-transmission and Distribution systems tripping and auto-reclosing are usually three-phase. The mode of automatic-reclosing varies however. Single-shot and multi-shot are in use. The first shot can have a short delay, HSAR, or a longer delay, DAR. The second and following reclosing shots have a rather long delay. When multiple shots are used the dead time must harmonize with the breaker duty-cycle capacity.

Automatic-reclosing is usually started by the line protection and in particular by instantaneous tripping of such protection. The auto-reclosing function can be inhibited (blocked) when certain protection functions detecting permanent faults, such as shunt reactor, cable or busbar protection are in operation. Back-up protection zones indicating faults outside the own line are also connected to inhibit the Auto-Reclose.

Automatic-reclosing should not be attempted when closing a CB and energizing a line onto a fault (SOTF), except when multiple-shots are used where shots 2 etc. will be started at SOTF. Likewise a CB in a multi-breaker busbar arrangement which was not closed when a fault occurred should not be closed by operation of the Auto-Reclosing function. Auto-Reclosing is often combined with a release condition from synchrocheck and dead line or dead busbar check. In order to limit the stress on turbo-generator sets from Auto-Reclosing onto a permanent fault, one can arrange to combine Auto-Reclosing with a synchrocheck on line terminals close to such power stations and attempt energizing from the side furthest away from the power station and perform the synchrocheck at the local end if the energizing was successful.

Transmission protection systems are usually sub-divided and provided with two redundant protection IEDs. In such systems it is common to provide auto-reclosing in only one of the sub-systems as the requirement is for fault clearance and a failure to reclose because of the auto-recloser being out of service is not considered a major disturbance. If two auto-reclosers are provided on the same breaker, the application must be carefully checked and normally one must be the master and be connected to inhibit the other auto-recloser if it has started. This inhibit can for example be done from Autorecloser (SMBRREC ,79) In progress.

A permanent fault will cause the line protection to trip again when it recloses in an attempt to clear the fault.

The auto-reclosing function allows a number of parameters to be adjusted.

Examples:

- number of auto-reclosing shots
- auto-reclosing open times (dead time) for each shot

10.2.2.1 Auto-reclosing operation Off and On

Operation of the automatic reclosing can be set OFF and ON by a setting parameter and by external control. Parameter *Operation*= *Off*, or *On* sets the function OFF and ON. In setting *Operation*=*ExternalCtrl* OFF and ON control is made by input signal pulses, for example, from the control system or from the binary input (and other systems).

When the function is set ON and operative (other conditions such as CB closed and CB Ready are also fulfilled), the output SETON is activated (high). When the function is ready to accept a reclosing start.

10.2.2.2 Start auto-reclosing and conditions for start of a reclosing cycle

The usual way to start a reclosing cycle, or sequence, is to start it at tripping by line protection by applying a signal to the input START. Starting signals can be either, General Trip signals or, only the conditions for Differential, Distance protection Zone 1 and Distance protection Aided trip. In some cases also Directional Earth fault function Aided trip can be connected to start an Auto-Reclose attempt.

A number of conditions need to be fulfilled for the start to be accepted and a new auto-reclosing cycle to be started. They are linked to dedicated inputs. The inputs are:

- CBREADY, CB ready for a reclosing cycle, for example, charged operating gear.
- CBPOS to ensure that the CB was closed when the line fault occurred and start was applied.
- No signal at input INHIBIT that is, no blocking or inhibit signal present. After the start has been accepted, it is latched in and an internal signal "Started" is set. It can be interrupted by certain events, like an "Inhibit" signal.

10.2.2.3 Start auto-reclosing from CB open information

If a user wants to initiate auto-reclosing from the "CB open" position instead of from protection trip signals, the function offers such a possibility. This starting mode is selected with the setting parameter *StartByCBOpen*=*On*. It is then necessary to block reclosing for all manual trip operations. Typically *CBAuxContType*=*NormClosed* is also set and a CB auxiliary contact of type NC (normally closed) is connected to inputs CBPOS and START. When the signal changes from "CB closed" to "CB open" an auto-reclosing start pulse is generated and latched in the function, subject to the usual checks. Then the reclosing sequence continues as usual. One needs to connect signals from manual tripping and other functions, which shall prevent reclosing, to the input INHIBIT.

10.2.2.4 Blocking of the autorecloser

Auto-Reclose attempts are expected to take place only in the event of transient faults on the own line. The Auto-Recloser must be blocked for the following conditions:

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- Tripping from Delayed Distance protection zones
- Tripping from Back-up protection functions
- Tripping from Breaker failure function
- Intertrip received from remote end Breaker failure function
- Busbar protection tripping

Depending of the starting principle (General Trip or only Instantaneous trip) adopted above the delayed and back-up zones might not be required. Breaker failure local and remote must however always be connected.

10.2.2.5 Control of the auto-reclosing open time

There are settings for the three-phase auto-reclosing open time, *t1 3Ph to t5 3Ph.*

10.2.2.6 Long trip signal

In normal circumstances the trip command resets quickly because of fault clearance. The user can set a maximum trip pulse duration *tTrip*. A long trip signal interrupts the reclosing sequence in the same way as a signal to input INHIBIT.

10.2.2.7 Maximum number of reclosing shots

The maximum number of reclosing shots in an auto-reclosing cycle is selected by the setting parameter *NoOfShots*.

10.2.2.8 3-phase reclosing, one to five shots according to setting NoOfShots.

A trip operation is made as a three-phase trip at all types of fault. The reclosing is as a three-phase. Here, the auto-reclosing function is assumed to be "On" and "Ready". The breaker is closed and the operation gear ready (operating energy stored). Input START is received and sealed-in. The output READY is reset (set to false). Output ACTIVE is set. The timer for 3-phase auto-reclosing open time is started.

While any of the auto-reclosing open time timers are running, the output INPROGR is activated. When the "open time" timer runs out, the respective internal signal is transmitted to the output module for further checks and to issue a closing command to the circuit breaker.

When issuing a CB closing command a "reclaim" timer *tReclaim* is started. If no tripping takes place during that time the auto-reclosing function resets to the "Ready" state and the signal ACTIVE resets. If the first reclosing shot fails, 2nd to 5th reclosing shots will follow, if selected.

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10.2.2.9 Reclosing reclaim timer

The reclaim timer *tReclaim* defines the time it takes from issue of the reclosing command, until the reclosing function resets. Should a new trip occur during this time, it is treated as a continuation of the first fault. The reclaim timer is started when the CB closing command is given.

10.2.2.10 Transient fault

After the Reclosing command the reclaim timer keeps running for the set time. If no tripping occurs within this time, *tReclaim*, the Auto-Reclosing will reset. The CB remains closed and the operating gear recharges. The input signals CBPOS and CBREADY will be set

10.2.2.11 Permanent fault and reclosing unsuccessful signal

If a new trip occurs, and a new input signal START or TRSOTF appears, after the CB closing command, the output UNSUCCL (unsuccessful closing) is set high. The timer for the first shot can no longer be started. Depending on the set number of Reclosing shots further shots may be made or the Reclosing sequence is ended. After reclaim timer time-out the Auto-Reclosing function resets, but the CB remains open. The "CB closed" information through the input CBPOS is missing. Thus, the reclosing function is not ready for a new reclosing cycle.

Normally, the signal UNSUCCL appears when a new trip and start is received after the last reclosing shot has been made and the auto-reclosing function is blocked. The signal resets after reclaim time. The "unsuccessful" signal can also be made to depend on CB position input. The parameter *UnsucClByCBChk* should then be set to *CBCheck*, and a timer *tUnsucCl* should be set too. If the CB does not respond to the closing command and does not close, but remains open, the output UNSUCCL is set high after time *tUnsucCl*. The Unsuccessful output can for example, be used in Multi-Breaker arrangement to cancel the auto-reclosing function for the second breaker, if the first breaker closed onto a persistent fault. It can also be used to generate a Lock-out of manual closing until the operator has reset the Lock-out, see separate section.

10.2.2.12 Lock-out initiation

In many cases there is a requirement that a Lock-out is generated when the auto-reclosing attempt fails. This is done with logic connected to the in- and outputs of the Autoreclose function and connected to Binary IO as required. Many alternative ways of performing the logic exist depending on whether manual closing is interlocked in the IED, whether an external physical Lock-out relay exists and whether the reset is hardwired, or carried out by means of communication. There are also different alternatives regarding what shall generate Lock-out. Examples of questions are:

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- Shall back-up time delayed trip give Lock-out (normally yes)
- Shall Lock-out be generated when closing onto a fault (mostly)
- Shall Lock-out be generated when the Auto-Recloser was OFF at the fault
- Shall Lock-out be generated if the Breaker did not have sufficient operating power for an auto-reclosing sequence (normally not as no closing attempt has been given)

In figures 77 and 78 the logic shows how a closing Lock-out logic can be designed with the Lock-out relay as an external relay alternatively with the Lock-out created internally with the manual closing going through the Synchro-check function. An example of Lock-out logic.

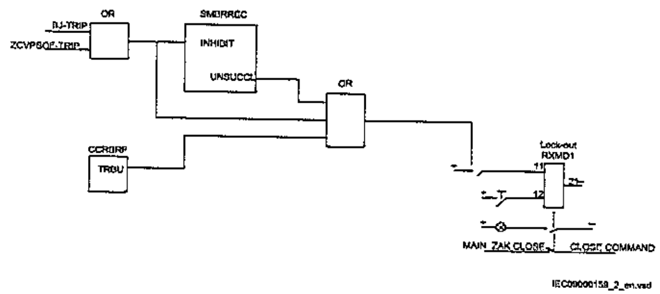

Figure 77: Lock-out arranged with an external Lock-out relay

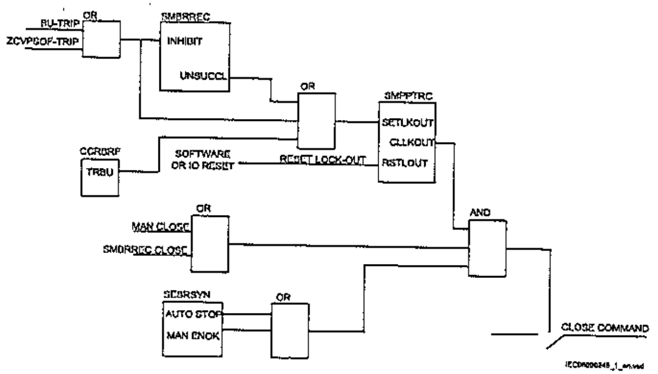

Figure 78: Lock-out arranged with internal logic with manual closing going through in IED

10.2.2.13 Automatic continuation of the reclosing sequence

The Autorecloser function can be programmed to proceed to the following reclosing shots (if multiple shots are selected) even if start signals are not received from the protection functions, but the breaker is still not closed. This is done by setting parameter *AutoCont* = *On* and *tAutoContWait* to the required delay for the function to proceed without a new start.

10.2.2.14 Thermal overload protection holding the auto-reclosing function back

If the input THOLHOLD (thermal overload protection holding reclosing back) is activated, it will keep the reclosing function on a hold until it is reset. There may thus be a considerable delay between start of Auto-Reclosing and reclosing command to the circuit-breaker. An external logic limiting the time and sending an inhibit to the INHIBIT input can be used. The input can also be used to set the Auto-Reclosing on hold for a longer or shorter period.

10.2.3 Setting guidelines

10.2.3.1 Configuration

Use the PCM600 configuration tool to configure signals.

Autorecloser function parameters are set via the local HMI or Parameter Setting Tool (PST). Parameter Setting Tool is a part of PCM600.

Recommendations for input signals

Please see examples in figure 79.

ON and OFF

These inputs can be connected to binary inputs or to a communication interface block for external control.

START

It should be connected to the trip output protection function, which starts the autorecloser (SMBRREC) function. It can also be connected to a binary input for start from an external contact. A logical OR-gate can be used to combine the number of start sources.

If *StartByCBOpen* is used, the CB Open condition shall also be connected to the input START.

INHIBIT

To this input shall be connected signals that interrupt a reclosing cycle or prevent a start from being accepted. Such signals can come from protection for a line connected shunt reactor, from transfer trip receive, from back-up protection functions, busbar protection trip or from breaker failure protection. When the CB open position is set to start SMBRREC, then manual opening must also be connected here. The inhibit is often a combination of signals from external IEDs via the IO and internal functions. An OR gate is then used for the combination.

CBPOS and CBREADY

These should be connected to binary inputs to pick-up information from the CB. The CBPOS input is interpreted as CB Closed, if parameter *CBAuxContType* is set *NormOpen*, which is the default setting. At three operating gears in the breaker (single pole operated breakers) the connection should be "All poles closed" (series connection of the NO contacts) or "At least one pole open" (parallel connection of NC contacts) if the *CBAuxContType* is set to *NormClosed*. The "CB Ready" is a signal meaning that the CB is ready for a reclosing operation, either Close-Open (CO), or Open-Close-Open (OCO). If the available signal is of type "CB not charged" or "not ready", an inverter can be inserted in front of the CBREADY input.

SYNC

This is connected to the internal synchrocheck function when required. It can also be connected to a binary input for synchronization from an external device. If neither internal nor external synchronism or energizing check is required, it can be connected to a permanently high source, TRUE. The signal is required for three phase shots 1-5 to proceed .

TRSOTF

This is the signal "Trip by Switch Onto Fault". It is usually connected to the "switch onto fault" output of line protection if multi-shot Auto-Reclose attempts are used. The input will start the shots 2-5. For single shot applications the input is set to FALSE.

THOLHOLD

Signal "Thermal overload protection holding back Auto-Reclosing". It is normally set to FALSE. It can be connected to a thermal overload protection trip signal which resets only when the thermal content has gone down to an acceptable level, for example, 70%. As long as the signal is high, indicating that the line is hot, the Auto-Reclosing is held back. When the signal resets, a reclosing cycle will continue. Please observe that this have a considerable delay. Input can also be used for other purposes if for some reason the Auto-Reclose shot is halted.

WAIT

Used to hold back reclosing of the "low priority unit" during sequential reclosing. See "Recommendation for multi-breaker arrangement" below. The signal is activated from output WFMASTER on the second breaker Auto-Recloser in multi-breaker arrangements.

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BLKON

Used to block the autorecloser (SMBRREC) function for example, when certain special service conditions arise. Input is normally set to FALSE. When used, blocking must be reset with BLOCKOFF.

BLOCKOFF

Used to Unblock SMBRREC function when it has gone to Block due to activating input BLKON or by an unsuccessful Auto-Reclose attempt if the setting *BlockUnsuc* is set to On. Input is normally set to FALSE.

RESET

Used to Reset SMBRREC to start condition. Possible Thermal overload Hold will be reset. Positions, setting On-Off. will be started and checked with set times. Input is normally set to FALSE.

Recommendations for output signals

Please see figure 79.

SETON

Indicates that Autorecloser (SMBRREC) function is switched *On* and operative.

BLOCKED

Indicates that SMRREC function is temporarily or permanently blocked.

ACTIVE

Indicates that SMBRREC is active, from start until end of Reclaim time.

INPROGR

Indicates that a sequence is in progress, from start until reclosing command.

UNSUCCL

Indicates unsuccessful reclosing.

CLOSECB

Connect to a binary output for circuit-breaker closing command.

READY

Indicates that SMBRREC function is ready for a new and complete reclosing sequence. It can be connected to the zone extension of a line protection should extended zone reach before automatic reclosing be necessary.

3PT1,-3PT2,-3PT3,-3PT4 and -3PT5

Indicates that three-phase automatic reclosing shots 1-5 are in progress. The signals can be used as an indication of progress or for own logic.

WFMASTER

Wait from master is used in high priority units to hold back reclosing of the low priority unit during sequential reclosing.

Other outputs

The other outputs can be connected for indication, disturbance recording, as required.

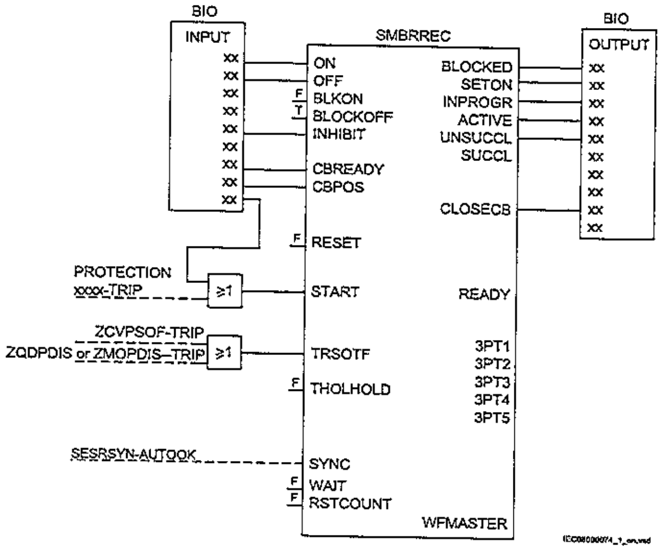

Figure 79: *Example of I/O-signal connections at a three-phase reclosing function*

Auto-recloser parameter settings

Operation

The operation of the Autorecloser (SMBRREC) function can be switched *On* and *Off*. The setting *External ctrl* makes it possible to switch it *On* or *Off* using an external switch via IO or communication ports.

NoOfShots, Number of reclosing shots

In sub-transmission 1 shot is mostly used. In most cases one reclosing shot is sufficient as the majority of arcing faults will cease after the first reclosing shot. In

power systems with many other types of faults caused by other phenomena, for example wind, a greater number of reclose attempts (shots) can be motivated.

Auto-reclosing open times, dead times

Three-phase shot 1 delay: For three-phase High-Speed Auto-Reclosing (HSAR) a typical open time is 400ms. Different local phenomena, such as moisture, salt, pollution etc. can influence the required dead time. Some users apply Delayed Auto-Reclosing (DAR) with delays of 10s or more. The delay of reclosing shot 2 and possible later shots are usually set at 30s or more. A check that the CB duty cycle can manage the selected setting must be done. The setting can in some cases be restricted by national regulations. For multiple shots the setting of shots 2-5 must be longer than the circuit breaker duty cycle time.

tSync, Maximum wait time for synchronizationcheck

The time window should be coordinated with the operate time and other settings of the synchronization check function. Attention should also be paid to the possibility of a power swing when reclosing after a line fault. Too short a time may prevent a potentially successful reclosing. A typical setting may be 2.0 s.

tTrip, Long trip pulse

Usually the trip command and start auto-reclosing signal reset quickly as the fault is cleared. A prolonged trip command may depend on a CB failing to clear the fault. A trip signal present when the CB is reclosed will result in a new trip. At a setting somewhat longer than the auto-reclosing open time, this facility will not influence the reclosing. A typical setting of *tTrip* could be close to the auto-reclosing open time.

tInhibit, Inhibit resetting delay

A typical setting is *tInhibit = 5.0 s* to ensure reliable interruption and temporary blocking of the function. Function will be blocked during this time after the *tinhibit* has been activated.

tReclaim, Reclaim time

The Reclaim time sets the time for resetting the function to its original state, after which a line fault and tripping will be treated as an independent new case with a new reclosing cycle. One may consider a nominal CB duty cycle of for instance, O-0.3sec CO- 3 min. – CO. However the 3 minute (180 s) recovery time is usually not critical as fault levels are mostly lower than rated value and the risk of a new fault within a short time is negligible. A typical time may be *tReclaim = 60 or 180 s* dependent of the fault level and breaker duty cycle.

StartByCBOpen

The normal setting is *Off*. It is used when the function is started by protection trip signals.

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FollowCB

The usual setting is *Follow CB = Off*. The setting *On* can be used for delayed reclosing with long delay, to cover the case when a CB is being manually closed during the "auto-reclosing open time" before the auto-reclosing function has issued its CB closing command.

tCBClosedMin

A typical setting is 5.0 s. If the CB has not been closed for at least this minimum time, a reclosing start will not be accepted.

CBAuxContType, CB auxiliary contact type

It shall be set to correspond to the CB auxiliary contact used. A *NormOpen* contact is recommended in order to generate a positive signal when the CB is in the closed position.

CBReadyType, Type of CB ready signal connected

The selection depends on the type of performance available from the CB operating gear. At setting *OCO* (CB ready for an Open – Close – Open cycle), the condition is checked only at the start of the reclosing cycle. The signal will disappear after tripping, but the CB will still be able to perform the C-O sequence. For the selection *CO* (CB ready for a Close – Open cycle) the condition is also checked after the set auto-reclosing dead time. This selection has a value first of all at multi-shot reclosing to ensure that the CB is ready for a C-O sequence at shot 2 and further shots. During single-shot reclosing, the *OCO* selection can be used. A breaker shall according to its duty cycle always have storing energy for a CO operation after the first trip. (IEC 56 duty cycle is O-0.3sec CO-3minCO).

tPulse, Breaker closing command pulse duration

The pulse should be long enough to ensure reliable operation of the CB. A typical setting may be *tPulse=200 ms*. A longer pulse setting may facilitate dynamic indication at testing, for example in "Debug" mode of PCM600 Application Configuration Tool (ACT) .

BlockByUnsucCl

Setting of whether an unsuccessful auto-reclose attempt shall set the Auto-Reclose in block. If used the inputs BLKOFF must be configured to unblock the function after an unsuccessful Reclosing attempt. Normal setting is *Off*.

UnsucClByCBCheck, Unsuccessful closing by CB check

The normal setting is *NoCBCheck*. The "auto-reclosing unsuccessful" event is then decided by a new trip within the reclaim time after the last reclosing shot. If one wants to get the UNSUCCL (Unsuccessful closing) signal in the case the CB does not respond to the closing command, CLOSECB, one can set *UnsucClByCBCheck= CB Check* and set *tUnsucCl* for instance to 1.0 s.

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Priority and time *tWaitForMaster*

In single CB applications, one sets *Priority = None*. At sequential reclosing the function of the first CB, e.g. near the busbar, is set *Priority = High* and for the second CB *Priority = Low*. The maximum waiting time, *tWaitForMaster* of the second CB is set longer than the "auto-reclosing open time" and a margin for synchrocheck at the first CB. Typical setting is *tWaitForMaster=2sec*.

AutoCont and *tAutoContWait*, Automatic continuation to the next shot if the CB is not closed within the set time

The normal setting is *AutoCont = Off*. The *tAutoContWait* is the length of time SMBRREC waits to see if the breaker is closed when *AutoCont* is set to *On*. Normally, the setting can be *tAutoContWait = 2 sec*.

10.3 Apparatus control

10.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Switch controller	SCSWI	-	-
Circuit breaker	SXCBR	-	-
Circuit switch	SXSWI	-	-
Position evaluation	POS_EVAL	-	-
Select release	SELGGIO	-	-
Bay control	QCBAY	-	-
Local remote	LOCREM	-	-
Local remote control	LOCREMCTRL	-	-

10.3.2 Application

The apparatus control is a function for control and supervising of circuit breakers, disconnectors, and earthing switches within a bay. Permission to operate is given after evaluation of conditions from other functions such as interlocking, synchrocheck, operator place selection and external or internal blockings.

Figure 80 gives an overview from what places the apparatus control function receive commands. Commands to an apparatus can be initiated from the Control Centre (CC), the station HMI or the local HMI on the IED front.

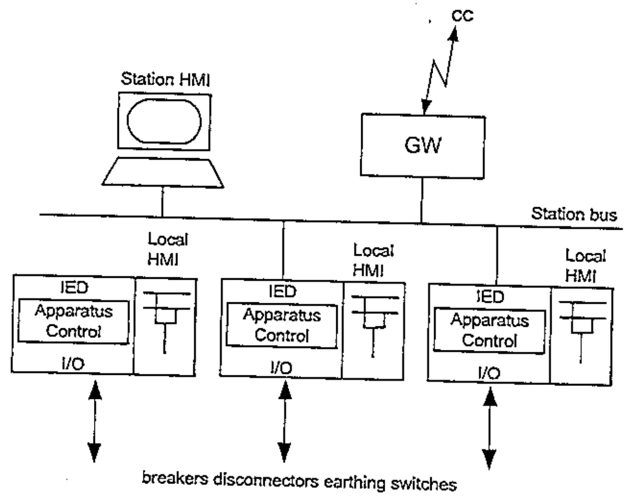

Figure 80: Overview of the apparatus control functions

Features in the apparatus control function:

- Operation of primary apparatuses
- Select-Execute principle to give high security
- Selection function to prevent simultaneous operation
- Selection and supervision of operator place
- Command supervision
- Block/deblock of operation
- Block/deblock of updating of position indications
- Substitution of position indications
- Overriding of interlocking functions
- Overriding of synchrocheck
- Operation counter
- Suppression of Mid position

The apparatus control function is realized by means of a number of function blocks designated:

- Switch controller SCSWI
- Circuit breaker SXCBR
- Circuit switch SXSWI
- Position evaluation POS_EVAL
- Select release SELGGIO

- Bay control QCBAY
- Local remote LOCREM
- Local remote control LOCREMCTRL

SCSWI, SXCBR, QCBAY, SXSWI and SELGGIO are logical nodes according to IEC 61850. The signal flow between these function blocks appears in figure 81. The function Logical node Interlocking (SCILO) in the figure 81 is the logical node for interlocking.

Control operation can be performed from the local HMI. If the administrator has defined users with the UM tool, then the local/remote switch is under authority control. If not, the default (factory) user is the SuperUser that can perform control operations from the local HMI without LogOn. The default position of the local/remote switch is on remote.

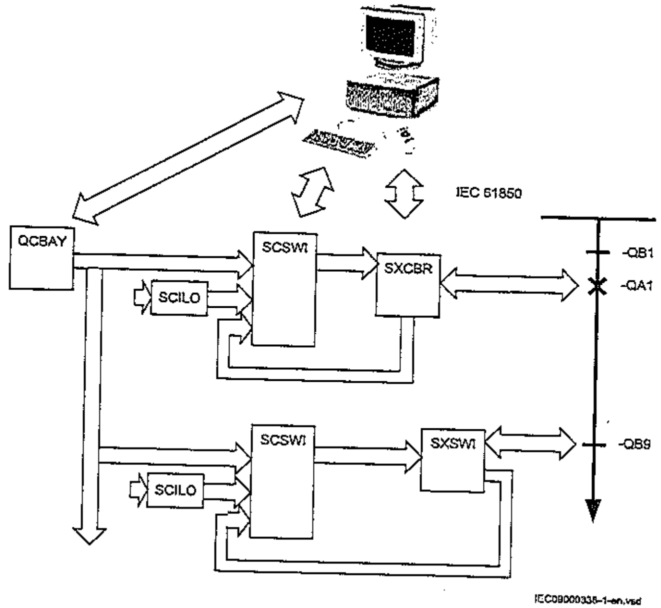

Figure 81: Signal flow between apparatus control function blocks

Switch controller (SCSWI)

The Switch controller (SCSWI) initializes and supervises all functions to properly select and operate switching primary apparatuses. The Switch controller may handle and operate on one three-phase device.

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After the selection of an apparatus and before the execution, the switch controller performs the following checks and actions:

- A request initiates to reserve other bays to prevent simultaneous operation.
- Actual position inputs for interlocking information are read and evaluated if the operation is permitted.
- The synchrocheck/synchronizing conditions are read and checked, and performs operation upon positive response.
- The blocking conditions are evaluated
- The position indications are evaluated according to given command and its requested direction (open or closed).

The command sequence is supervised regarding the time between:

- Select and execute.
- Select and until the reservation is granted.
- Execute and the final end position of the apparatus.
- Execute and valid close conditions from the synchrocheck.

At error the command sequence is cancelled.

The mid position of apparatuses can be suppressed at SCSWI by setting the *tIntermediate* at (SXCBR/SXSWI) to an appropriate value.

The switch controller is not dependent on the type of switching device SXCBR or SXSWI. The switch controller represents the content of the SCSWI logical node (according to IEC 61850) with mandatory functionality.

Switch (SXCBR/SXSWI)

The Switch is a function used to close and interrupt an ac power circuit under normal conditions, or to interrupt the circuit under fault, or emergency conditions. The intention with this function is to represent the lowest level of a power-switching device with or without short circuit breaking capability, for example, circuit breakers, disconnectors, earthing switches etc.

The purpose of this function is to provide the actual status of positions and to perform the control operations, that is, pass all the commands to the primary apparatus via output boards and to supervise the switching operation and position.

The Switch has this functionality:

- Local/Remote switch intended for the switchyard
- Block/deblock for open/close command respectively
- Update block/deblock of position indication
- Substitution of position indication
- Supervision timer that the primary device starts moving after a command
- Supervision of allowed time for intermediate position
- Definition of pulse duration for open/close command respectively

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The realization of this function is performed with SXCBR representing a circuit breaker and with SXSWI representing a circuit switch that is, a disconnector or an earthing switch.

The content of this function is represented by the IEC 61850 definitions for the logical nodes Circuit breaker (SXCBR) and Circuit switch (SXSWI) with mandatory functionality.

Reservation function (SELGGIO)

The purpose of the reservation function is to grant permission to operate only one device at a time in a group, like a bay or a station, thereby preventing double operation.

For interlocking evaluation in a substation, the position information from switching devices, such as circuit breakers, disconnectors and earthing switches can be required from the same bay or from several other bays. When information is needed from other bays, it is exchanged over the serial station bus between the distributed IEDs. The problem that arises, even at a high speed of communication, is a time interval during which the information about the position of the switching devices are uncertain. The interlocking function uses this information for evaluation, which means that also the interlocking conditions will be uncertain.

To ensure that the interlocking information is correct at the time of operation, a reservation method is available in the IEDs. With this reservation method the reserved signal can be used for evaluation of permission to select and operate the apparatus.

This functionality is realized over the station bus by means of the function block SELGGIO.

The SELECTED output signal from the respective SCSWI function block in the own bay is connected to the inputs of the SELGGIO function block. The output signal RESERVED from SELGGIO is connected to the input RES_EXT of the SCSWI function block. If the bay is not currently reserved, the SELGGIO output signal RESERVED is FALSE. Selection for operation on the SCSWI block is now possible. Once any SCSWI block is selected, and if its output SELECTED is connected to the SELGGIO block, then other SCSWI functions as configured are blocked for selection. The RESERVED signal from SELGGIO is also sent to other bay devices.

Due to the design of the plant, some apparatus might need reservation of the own bay as well as reservations from other bays. Received reservation from other bays are handled by a logical OR together with own bay reservation from the SELGGIO function block that checks whether the own bay is currently reserved.

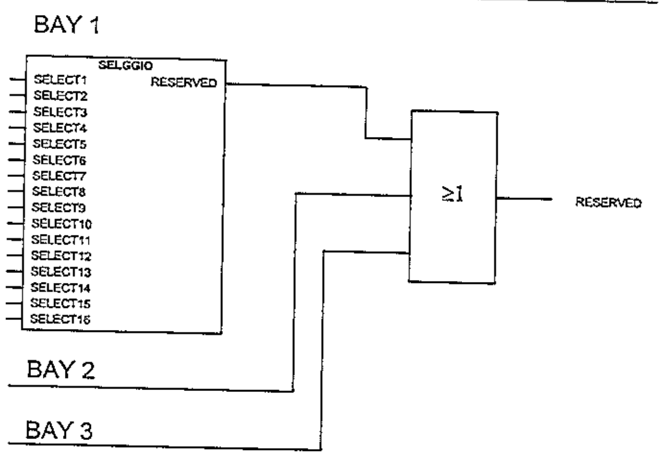

Figure 82: *Reservations from own and other bays*

The reservation can also be realized with external wiring according to the application example in figure 83. This solution is realized with external auxiliary relays and extra binary inputs and outputs in each IED.

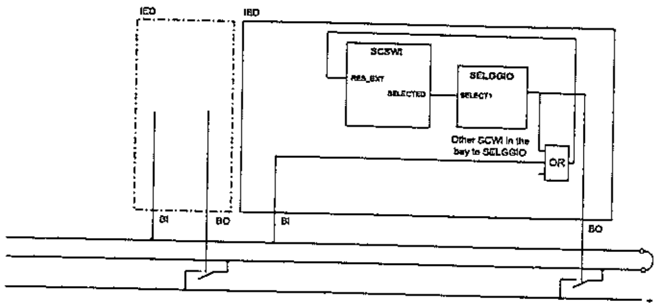

Figure 83: *Application principles for reservation with external wiring*

The solution in figure 83 can also be realized over the station bus according to the application example in figure 84.

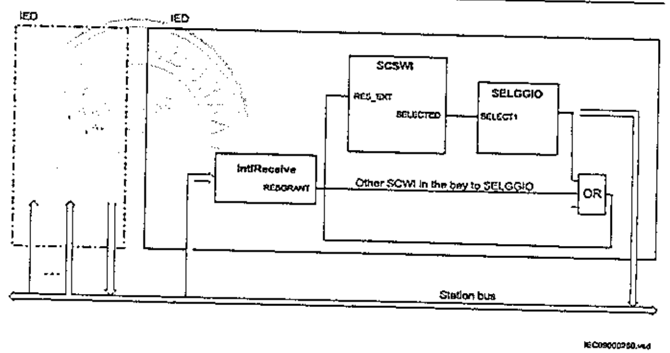

Figure 84: *Application principle for an alternative reservation solution*

Bay control (QCBAY)

The Bay control (QCBAY) is used to handle the selection of the operator place for the bay. The function gives permission to operate from two types of locations either from Remote (for example, control centre or station HMI) or from Local (local HMI on the IED) or from all (Local and Remote). The Local/Remote switch position can also be set to Off, which means no operator place selected that is, operation is not possible neither from local nor from remote.

QCBAY also provides blocking functions that can be distributed to different apparatuses within the bay. There are two different blocking alternatives:

- Blocking of update of positions
- Blocking of commands

The function does not have a corresponding functionality defined in the IEC 61850 standard, which means that this function is included as a vendor specific logical node.

10.3.3 Interaction between modules

A typical bay with apparatus control function consists of a combination of logical nodes or functions that are described here:

- The Switch controller (SCSWI) initializes all operations for one apparatus and performs the actual switching and is more or less the interface to the drive of one apparatus. It includes the position handling as well as the control of the position.
- The Circuit breaker (SXCBR) is the process interface to the circuit breaker for the apparatus control function.
- The Circuit switch (SXSWI) is the process interface to the disconnector or the earthing switch for the apparatus control function.

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- The Bay control (QCBAY) fulfils the bay-level functions for the apparatuses, such as operator place selection and blockings for the complete bay.
- The function (SELGGIO), deals with reservation of the bay.
- The Four step overcurrent protection (OC4PTOC) trips the breaker.
- The Protection trip logic (SMPPTRC) connects the "trip" outputs of one or more protection functions to a common "trip" to be transmitted to SXCBR.
- The Autorecloser (SMBRREC) consists of the facilities to automatically close a tripped breaker with respect to a number of configurable conditions.
- The logical node Interlocking (SCILO) provides the information to SCSWI whether it is permitted to operate due to the switchyard topology. The interlocking conditions are evaluated with separate logic and connected to SCILO.
- The Synchrocheck, energizing check, and synchronizing (SESRSYN) calculates and compares the voltage phasor difference from both sides of an open breaker with predefined switching conditions (synchrocheck). Also the case that one side is dead (energizing-check) is included.
- The logical node Generic Automatic Process Control, GAPC, is an automatic function that reduces the interaction between the operator and the system. With one command, the operator can start a sequence that will end with a connection of a process object (for example a line) to one of the possible busbars.

The overview of the interaction between these functions is shown in figure 85 below.

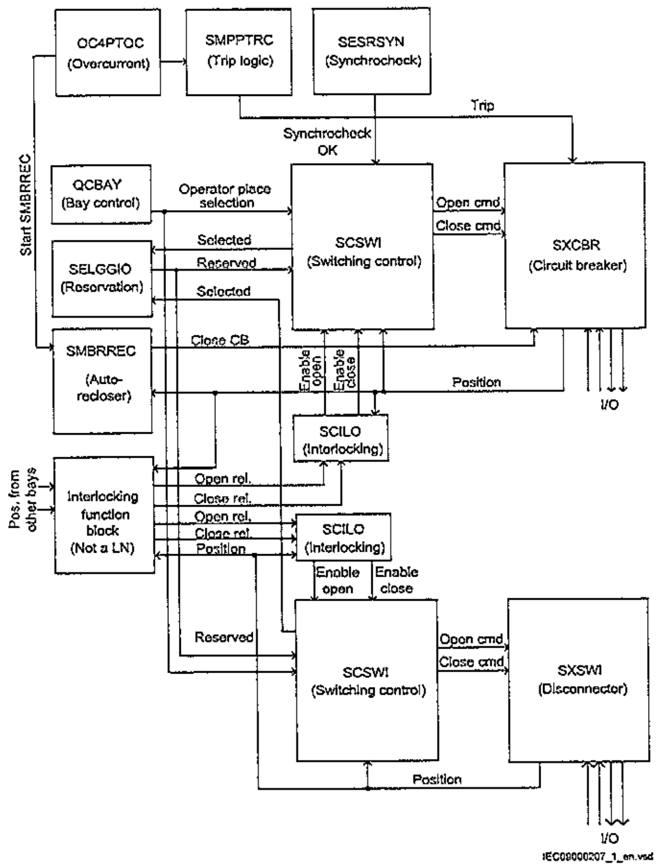

Figure 85: Example overview of the interactions between functions in a typical bay

10.3.4 Setting guidelines

The setting parameters for the apparatus control function are set via the local HMI or PCM600.

10.3.4.1 Switch controller (SCSWI)

The parameter *CtlModel* specifies the type of control model according to IEC 61850. For normal control of circuit breakers, disconnectors and earthing switches the control model is set to *SBO Enh* (Select-Before-Operate) with enhanced security.

When the operation shall be performed in one step, the model direct control with normal security is used.

At control with enhanced security there is an additional supervision of the status value by the control object, which means that each command sequence must be terminated by a termination command.

The parameter *PosDependent* gives permission to operate depending on the position indication, that is, at *Always permitted* it is always permitted to operate independent of the value of the position. At *Not perm at 00/11* it is not permitted to operate if the position is in bad or intermediate state.

tSelect is the maximum time between the select and the execute command signal, that is, the time the operator has to perform the command execution after the selection of the object to operate. When the time has expired, the selected output signal is set to false and a cause-code is given over IEC 61850.

tSynchrocheck is the allowed time for the synchrocheck function to fulfill the close conditions. When the time has expired, the control function is reset.

The timer *tSynchronizing* supervises that the signal synchronizing in progress is obtained in SCSWI after start of the synchronizing function. The start signal for the synchronizing is obtained if the synchrocheck conditions are not fulfilled. When the time has expired, the control function is reset. If no synchronizing function is included, the time is set to 0, which means no start of the synchronizing function.

tExecutionFB is the maximum time between the execute command signal and the command termination. When the time has expired, the control function is reset.

10.3.4.2 Switch (SXCBR/SXSWI)

tStartMove is the supervision time for the apparatus to start moving after a command execution. When the time has expired, the switch function is reset.

During the *tIntermediate* time the position indication is allowed to be in an intermediate (00) state. When the time has expired, the switch function is reset. The indication of the mid-position at SCSWI is suppressed during this time period when the position changes from open to close or vice-versa.

If the parameter *AdaptivePulse* is set to *Adaptive* the command output pulse resets when a new correct end position is reached. If the parameter is set to *Not adaptive* the command output pulse remains active until the timer *tOpenPulsetClosePulse* has elapsed.

tOpenPulse is the output pulse length for an open command. The default length is set to 200 ms for a circuit breaker (SXCBR) and 200 ms for a disconnector or earthing switch (SXSWI).

tClosePulse is the output pulse length for a close command. The default length is set to 200 ms for a circuit breaker (SXCBR) and 200 ms for a disconnector or earthing switch (SXSWI).

SuppressMidPos when *On* will suppress the mid-position during the time *tIntermediate.*

SwitchType is an enumeration according to IEC 61850-7-4 to indicate the switch type assigned to SXSWI

10.3.4.3 Bay control (QCBAY)

If the parameter *AllPSTOValid* is set to *No priority*, all originators from local and remote are accepted without any priority.

10.4 Interlocking

10.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Logical node for interlocking	SCILO	-	-
Interlocking for busbar earthing switch	BB_ES	-	-
Interlocking for bus-section breaker	A1A2_BS	-	-
Interlocking for bus-section disconnector	A1A2_DC	-	-
Interlocking for bus-coupler bay	ABC_BC	-	-
Interlocking for 1 1/2 breaker diameter	BH_CONN	-	-
Interlocking for 1 1/2 breaker diameter	BH_LINE_A	-	-
Interlocking for 1 1/2 breaker diameter	BH_LINE_B	-	-
Interlocking for double CB bay	DB_BUS_A	-	-
Interlocking for double CB bay	DB_BUS_B	-	-
Interlocking for double CB bay	DB_LINE	-	-
Interlocking for line bay	ABC_LINE	-	-
Interlocking for transformer bay	AB_TRAFO	-	-

10.4.2 Application

The main purpose of switchgear interlocking is:

- To avoid the dangerous or damaging operation of switchgear
- To enforce restrictions on the operation of the substation for other reasons for example, load configuration. Examples of the latter are to limit the number of parallel transformers to a maximum of two or to ensure that energizing is always from one side, for example, the high voltage side of a transformer.

This section only deals with the first point, and only with restrictions caused by switching devices other than the one to be controlled. This means that switch interlock, because of device alarms, is not included in this section.

Disconnectors and earthing switches have a limited switching capacity. Disconnectors may therefore only operate:

- With basically zero current. The circuit is open on one side and has a small extension. The capacitive current is small (for example, < 5A) and power transformers with inrush current are not allowed.
- To connect or disconnect a parallel circuit carrying load current. The switching voltage across the open contacts is thus virtually zero, thanks to the parallel circuit (for example, < 1% of rated voltage). Paralleling of power transformers is not allowed.

Earthing switches are allowed to connect and disconnect earthing of isolated points. Due to capacitive or inductive coupling there may be some voltage (for example < 40% of rated voltage) before earthing and some current (for example < 100A) after earthing of a line.

Circuit breakers are usually not interlocked. Closing is only interlocked against running disconnectors in the same bay, and the bus-coupler opening is interlocked during a busbar transfer.

The positions of all switching devices in a bay and from some other bays determine the conditions for operational interlocking. Conditions from other stations are usually not available. Therefore, a line earthing switch is usually not fully interlocked. The operator must be convinced that the line is not energized from the other side before closing the earthing switch. As an option, a voltage indication can be used for interlocking. Take care to avoid a dangerous *enable* condition at the loss of a VT secondary voltage, for example, because of a blown fuse.

The switch positions used by the operational interlocking logic are obtained from auxiliary contacts or position sensors. For each end position (open or closed) a true indication is needed - thus forming a double indication. The apparatus control function continuously checks its consistency. If neither condition is high (1 or TRUE), the switch may be in an intermediate position, for example, moving. This dynamic state may continue for some time, which in the case of disconnectors may be up to 10 seconds. Should both indications stay low for a longer period, the position indication will be interpreted as *unknown*. If both indications stay high, something is wrong, and the state is again treated as *unknown*.

In both cases an alarm is sent to the operator. Indications from position sensors shall be self-checked and system faults indicated by a fault signal. In the interlocking logic, the signals are used to avoid dangerous *enable* or *release* conditions. When the switching state of a switching device cannot be determined operation is not permitted.

10.4.3 Configuration guidelines

The following sections describe how the interlocking for a certain switchgear configuration can be realized in the IED by using standard interlocking modules and their interconnections. They also describe the configuration settings. The inputs for delivery specific conditions (Qx_EXy) are set to 1=TRUE if they are not used, except in the following cases:

- QB9_EX2 and QB9_EX4 in modules BH_LINE_A and BH_LINE_B
- QA1_EX3 in module AB_TRAFO

when they are set to 0=FALSE.

10.4.4 Interlocking for busbar earthing switch BB_ES

10.4.4.1 Application

The interlocking for busbar earthing switch (BB_ES) function is used for one busbar earthing switch on any busbar parts according to figure 86.

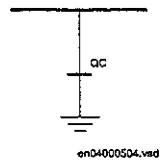

Figure 86: Switchyard layout BB_ES

The signals from other bays connected to the module BB_ES are described below.

10.4.4.2 Signals in single breaker arrangement

The busbar earthing switch is only allowed to operate if all disconnectors of the bus-section are open.

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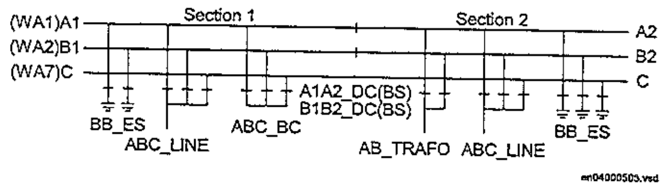

Figure 87: Busbars divided by bus-section disconnectors (circuit breakers)

The interlocking functionality in 650 series cannot handle the transfer bus (WA7)C.

To derive the signals:

Signal	
BB_DC_OP	All disconnectors on this part of the busbar are open.
VP_BB_DC	The switch status of all disconnector on this part of the busbar is valid.
EXDU_BB	No transmission error from any bay containing the above information.

These signals from each line bay (ABC_LINE), each transformer bay (AB_TRAFO), and each bus-coupler bay (ABC_BC) are needed:

Signal	
QB1OPTR	QB1 is open.
QB2OPTR	QB2 is open (AB_TRAFO, ABC_LINE)
QB220OTR	QB2 and QB20 are open (ABC_BC)
QB7OPTR	QB7 is open.
VPQB1TR	The switch status of QB1 is valid.
VPQB2TR	The switch status of QB2 is valid.
VQB220TR	The switch status of QB2and QB20 is valid.
VPQB7TR	The switch status of QB7 is valid.
EXDU_BB	No transmission error from the bay that contains the above information.

These signals from each bus-section disconnector bay (A1A2_DC) are also needed. For B1B2_DC, corresponding signals from busbar B are used. The same type of module (A1A2_DC) is used for different busbars, that is, for both bus-section disconnectors A1A2_DC and B1B2_DC.

Signal	
DCOPTR	The bus-section disconnector is open.
VPDCTR	The switch status of bus-section disconnector DC is valid.
EXDU_DC	No transmission error from the bay that contains the above information.

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If no bus-section disconnector exists, the signal DCOPTR, VPDCTR and EXDU_DC are set to 1 (TRUE).

If the busbar is divided by bus-section circuit breakers, the signals from the bus-section coupler bay (A1A2_BS) rather than the bus-section disconnector bay (A1A2_DC) must be used. For B1B2_BS, corresponding signals from busbar B are used. The same type of module (A1A2_BS) is used for different busbars, that is, for both bus-section circuit breakers A1A2_BS and B1B2_BS.

Signal	
QB1OPTR	QB1 is open.
QB2OPTR	QB2 is open.
VPQB1TR	The switch status of QB1 is valid.
VPQB2TR	The switch status of QB2 is valid.
EXDU_BS	No transmission error from the bay BS (bus-section coupler bay) that contains the above information.

For a busbar earthing switch, these conditions from the A1 busbar section are valid:

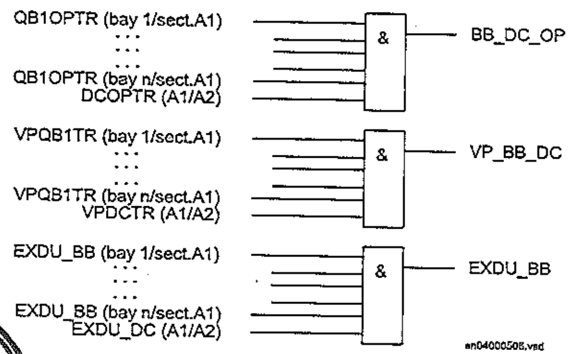

Figure 88: Signals from any bays in section A1 to a busbar earthing switch in the same section

For a busbar earthing switch, these conditions from the A2 busbar section are valid:

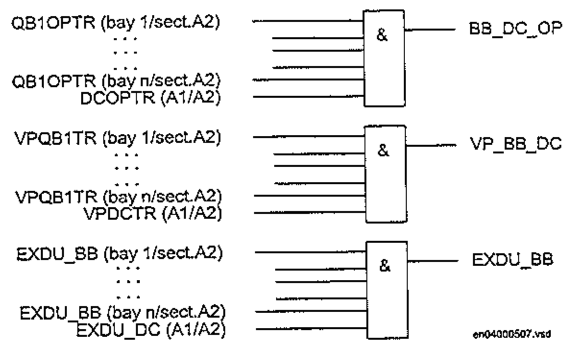

Figure 89: Signals from any bays in section A2 to a busbar earthing switch in the same section

For a busbar earthing switch, these conditions from the B1 busbar section are valid:

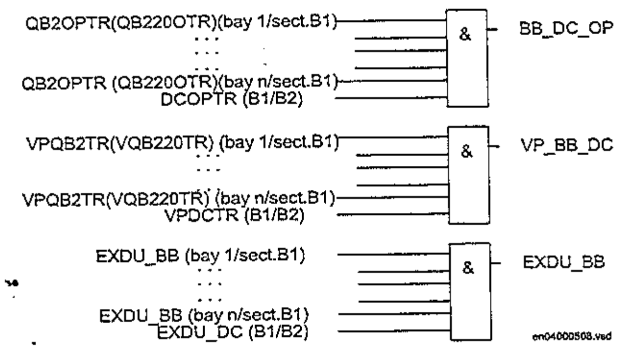

Figure 90: Signals from any bays in section B1 to a busbar earthing switch in the same section

For a busbar earthing switch, these conditions from the B2 busbar section are valid:

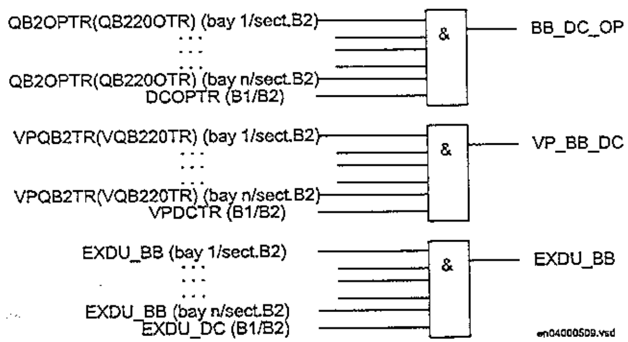

Figure 91: Signals from any bays in section B2 to a busbar earthing switch in the same section

For a busbar earthing switch on bypass busbar C, these conditions are valid:

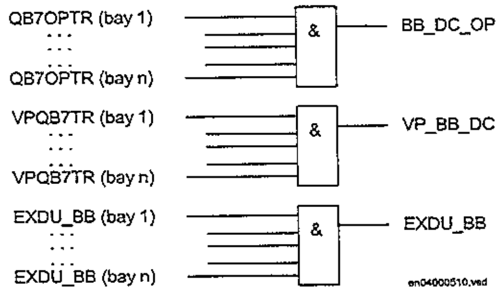

Figure 92: Signals from bypass busbar to busbar earthing switch

10.4.4.3 Signals in double-breaker arrangement

The busbar earthing switch is only allowed to operate if all disconnectors of the bus section are open.

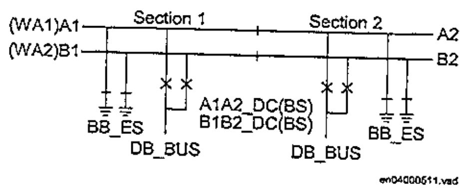

Figure 93: Busbars divided by bus-section disconnectors (circuit breakers)

To derive the signals:

Signal	
BB_DC_OP	All disconnectors of this part of the busbar are open.
VP_BB_DC	The switch status of all disconnectors on this part of the busbar are valid.
EXDU_BB	No transmission error from any bay that contains the above information.

These signals from each double-breaker bay (DB_BUS) are needed:

Signal	
QB1OPTR	QB1 is open.
QB2OPTR	QB2 is open.
VPQB1TR	The switch status of QB1 is valid.
VPQB2TR	The switch status of QB2 is valid.
EXDU_DB	No transmission error from the bay that contains the above information.

These signals from each bus-section disconnector bay (A1A2_DC) are also needed. For B1B2_DC, corresponding signals from busbar B are used. The same type of module (A1A2_DC) is used for different busbars, that is, for both bus-section disconnectors A1A2_DC and B1B2_DC.

Signal	
DCOPTR	The bus-section disconnector is open.
VPDCTR	The switch status of bus-section disconnector DC is valid.
EXDU_DC	No transmission error from the bay that contains the above information.

The logic is identical to the double busbar configuration described in section "Signals in single breaker arrangement".

10.4.4.4 Signals in 1 1/2 breaker arrangement

The busbar earthing switch is only allowed to operate if all disconnectors of the bus-section are open.

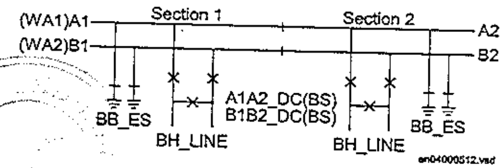

Figure 94: Busbars divided by bus-section disconnectors (circuit breakers)

The project-specific logic are the same as for the logic for the double busbar configuration described in section "Signals in single breaker arrangement".

Signal	
BB_DC_OP	All disconnectors on this part of the busbar are open.
VP_BB_DC	The switch status of all disconnectors on this part of the busbar is valid.
EXDU_BB	No transmission error from any bay that contains the above information.

10.4.5 Interlocking for bus-section disconnector A1A2_BS

10.4.5.1 Application

The interlocking for bus-section breaker (A1A2_BS) function is used for one bus-section circuit breaker between section 1 and 2 according to figure 95. The function can be used for different busbars, which includes a bus-section circuit breaker.

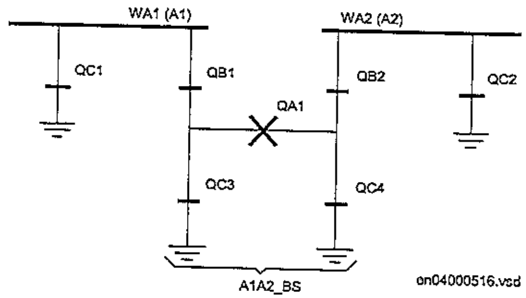

Figure 95: Switchyard layout A1A2_BS

The signals from other bays connected to the module A1A2_BS are described below.

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10.4.5.2 Signals from all feeders

If the busbar is divided by bus-section circuit breakers into bus-sections and both circuit breakers are closed, the opening of the circuit breaker must be blocked if a bus-coupler connection exists between busbars on one bus-section side and if on the other bus-section side a busbar transfer is in progress:

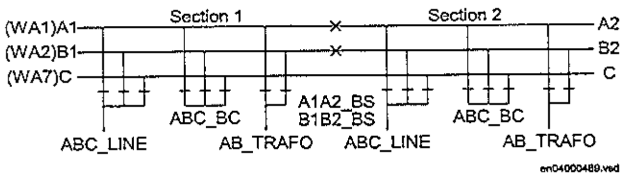

Figure 96: Busbars divided by bus-section circuit breakers

The interlocking functionality in 650 series can not handle the transfer bus (WA7)C.

To derive the signals:

Signal	
BBTR_OP	No busbar transfer is in progress concerning this bus-section.
VP_BBTR	The switch status of BBTR is valid.
EXDU_12	No transmission error from any bay connected to busbar 1(A) and 2(B).

These signals from each line bay (ABC_LINE), each transformer bay (AB_TRAFO), and bus-coupler bay (ABC_BC) are needed:

Signal	
QB12OPTR	QB1 or QB2 or both are open.
VPQB12TR	The switch status of QB1 and QB2 are valid.
EXDU_12	No transmission error from the bay that contains the above information.

These signals from each bus-coupler bay (ABC_BC) are needed:

Signal	
BC12OPTR	No bus-coupler connection through the own bus-coupler between busbar WA1 and WA2.
VPBC12TR	The switch status of BC_12 is valid.
EXDU_BC	No transmission error from the bay that contains the above information.

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These signals from the bus-section circuit breaker bay (A1A2_BS, B1B2_BS) are needed.

Signal	
S1S2OPTR	No bus-section coupler connection between bus-sections 1 and 2.
VPS1S2TR	The switch status of bus-section coupler BS is valid.
EXDU_BS	No transmission error from the bay that contains the above information.

For a bus-section circuit breaker between A1 and A2 section busbars, these conditions are valid:

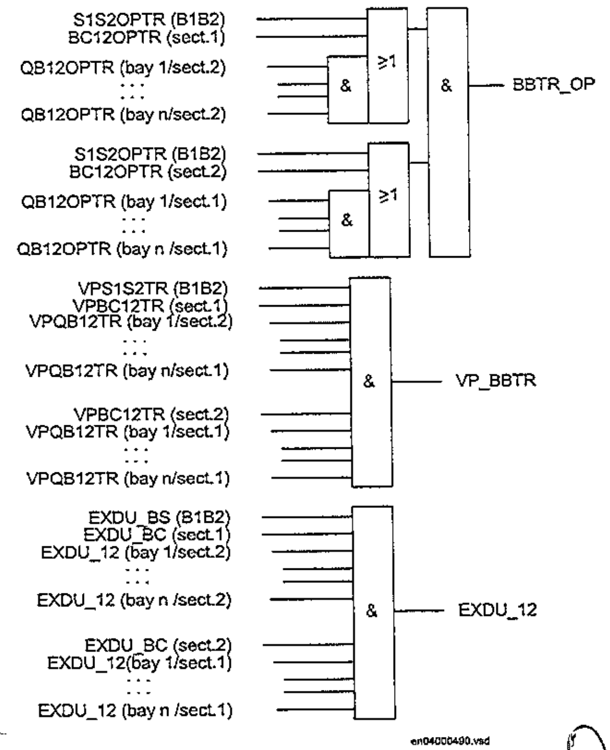

Figure 97: Signals from any bays for a bus-section circuit breaker between sections A1 and A2

For a bus-section circuit breaker between B1 and B2 section busbars, these conditions are valid:

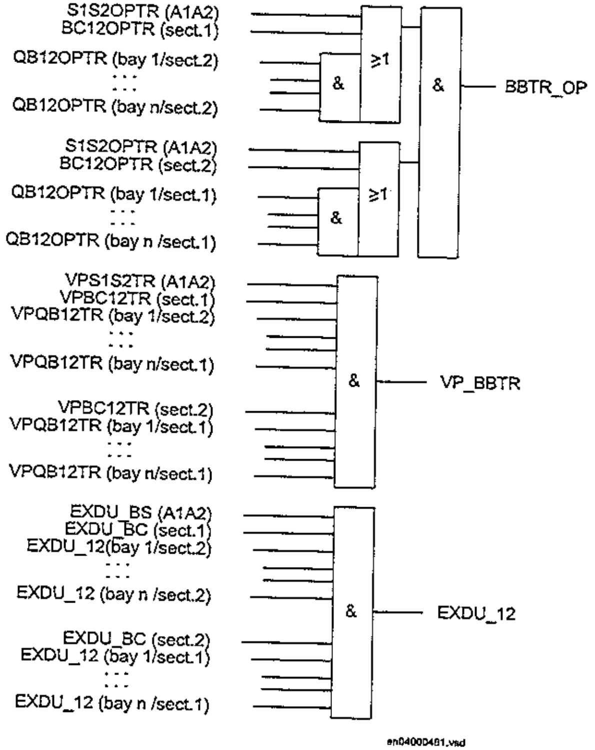

Figure 98: Signals from any bays for a bus-section circuit breaker between sections B1 and B2

10.4.5.3 Configuration setting

If there is no other busbar via the busbar loops that are possible, then either the interlocking for the QA1 open circuit breaker is not used or the state for BBTR is set to open. That is, no busbar transfer is in progress in this bus-section:

- BBTR_OP = 1
- VP_BBTR = 1

10.4.6 Interlocking for bus-section disconnector A1A2_DC

10.4.6.1 Application

The interlocking for bus-section disconnector (A1A2_DC) function is used for one bus-section disconnector between section 1 and 2 according to figure 99. A1A2_DC function can be used for different busbars, which includes a bus-section disconnector.

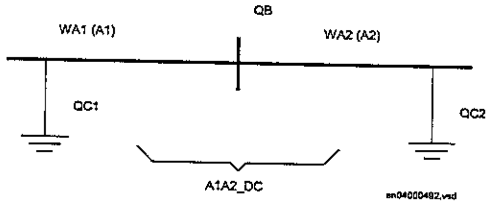

Figure 99: Switchyard layout A1A2_DC

The signals from other bays connected to the module A1A2_DC are described below.

10.4.6.2 Signals in single breaker arrangement

If the busbar is divided by bus-section disconnectors, the condition *no other disconnector connected to the bus-section* must be made by a project-specific logic.

The same type of module (A1A2_DC) is used for different busbars, that is, for both bus-section disconnector A1A2_DC and B1B2_DC. But for B1B2_DC, corresponding signals from busbar B are used.

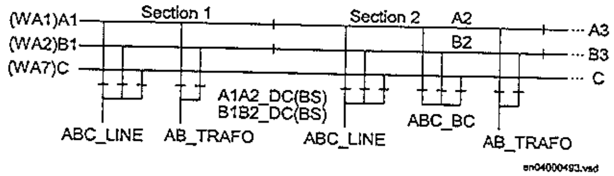

Figure 100: Busbars divided by bus-section disconnectors (circuit breakers)

The interlocking functionality in 650 series can not handle the transfer bus (WA7)C.

To derive the signals:

Signal	
S1DC_OP	All disconnectors on bus-section 1 are open.
S2DC_OP	All disconnectors on bus-section 2 are open.
VPS1_DC	The switch status of disconnectors on bus-section 1 is valid.
VPS2_DC	The switch status of disconnectors on bus-section 2 is valid.
EXDU_BB	No transmission error from any bay that contains the above information.

These signals from each line bay (ABC_LINE), each transformer bay (AB_TRAFO), and each bus-coupler bay (ABC_BC) are needed:

Signal	
QB1OPTR	QB1 is open.
QB2OPTR	QB2 is open (AB_TRAFO, ABC_LINE).
QB220OTR	QB2 and QB20 are open (ABC_BC).
VPQB1TR	The switch status of QB1 is valid.
VPQB2TR	The switch status of QB2 is valid.
VQB220TR	The switch status of QB2 and QB20 are valid.
EXDU_BB	No transmission error from the bay that contains the above information.

If there is an additional bus-section disconnector, the signal from the bus-section disconnector bay (A1A2_DC) must be used:

Signal	
DCOPTR	The bus-section disconnector is open.
VPDCTR	The switch status of bus-section disconnector DC is valid.
EXDU_DC	No transmission error from the bay that contains the above information.

If there is an additional bus-section circuit breaker rather than an additional bus-section disconnector the signals from the bus-section, circuit-breaker bay (A1A2_BS) rather than the bus-section disconnector bay (A1A2_DC) must be used:

Signal	
QB1OPTR	QB1 is open.
QB2OPTR	QB2 is open.
VPQB1TR	The switch status of QB1 is valid.
VPQB2TR	The switch status of QB2 is valid.
EXDU_BS	No transmission error from the bay BS (bus-section coupler bay) that contains the above information.

For a bus-section disconnector, these conditions from the A1 busbar section are valid:

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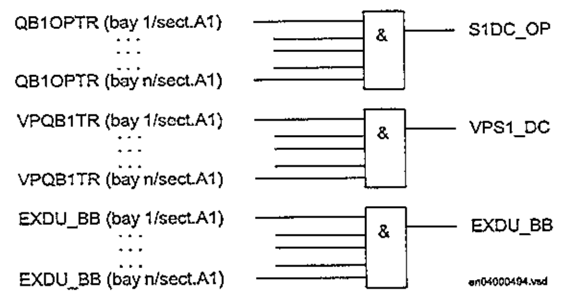

Figure 101: Signals from any bays in section A1 to a bus-section disconnector

For a bus-section disconnector, these conditions from the A2 busbar section are valid:

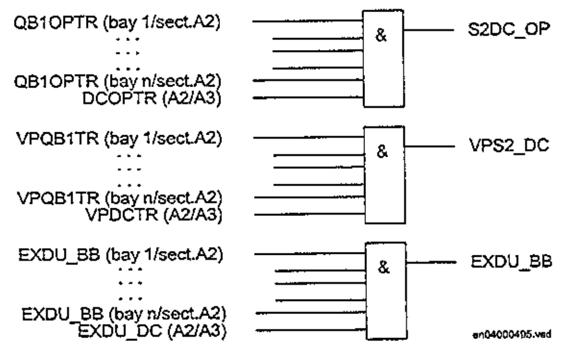

Figure 102: Signals from any bays in section A2 to a bus-section disconnector

For a bus-section disconnector, these conditions from the B1 busbar section are valid:

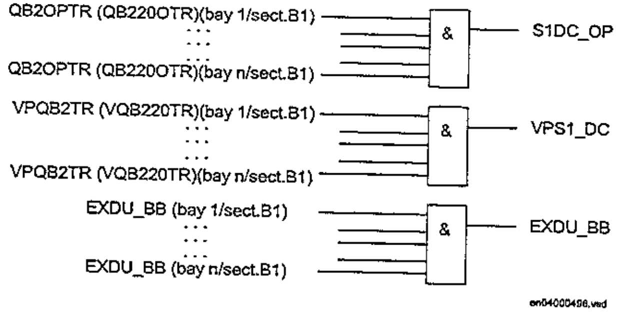

Figure 103: Signals from any bays in section B1 to a bus-section disconnector

For a bus-section disconnector, these conditions from the B2 busbar section are valid:

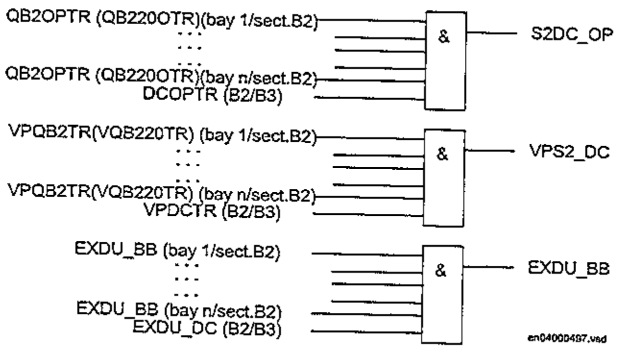

Figure 104: Signals from any bays in section B2 to a bus-section disconnector

Signals in double-breaker arrangement

If the busbar is divided by bus-section disconnectors, the condition for the busbar disconnector bay *no other disconnector connected to the bus-section* must be made by a project-specific logic.

The same type of module (A1A2_DC) is used for different busbars, that is, for both bus-section disconnector A1A2_DC and B1B2_DC. But for B1B2_DC, corresponding signals from busbar B are used.

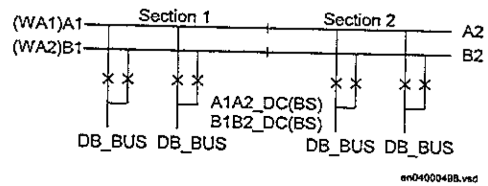

Figure 105: Busbars divided by bus-section disconnectors (circuit breakers)

To derive the signals:

Signal	
S1DC_OP	All disconnectors on bus-section 1 are open.
S2DC_OP	All disconnectors on bus-section 2 are open.
VPS1_DC	The switch status of all disconnectors on bus-section 1 is valid.
VPS2_DC	The switch status of all disconnectors on bus-section 2 is valid.
EXDU_BB	No transmission error from double-breaker bay (DB) that contains the above information.

These signals from each double-breaker bay (DB_BUS) are needed:

Signal	
QB1OPTR	QB1 is open.
QB2OPTR	QB2 is open.
VPQB1TR	The switch status of QB1 is valid.
VPQB2TR	The switch status of QB2 is valid.
EXDU_DB	No transmission error from the bay that contains the above information.

The logic is identical to the double busbar configuration "Signals in single breaker arrangement".

For a bus-section disconnector, these conditions from the A1 busbar section are valid:

840

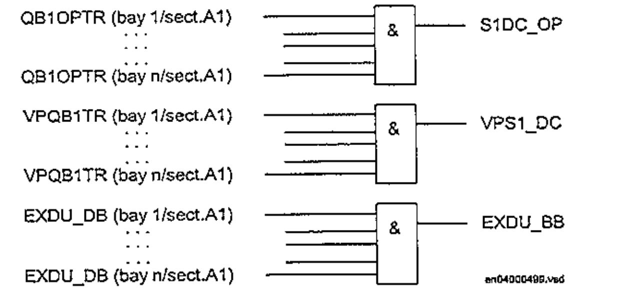

Figure 106: Signals from double-breaker bays in section A1 to a bus-section disconnector

For a bus-section disconnector, these conditions from the A2 busbar section are valid:

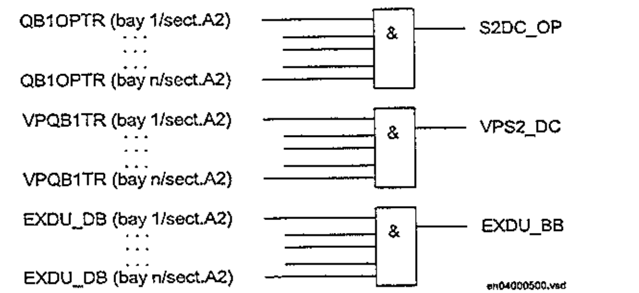

Figure 107: Signals from double-breaker bays in section A2 to a bus-section disconnector

For a bus-section disconnector, these conditions from the B1 busbar section are valid:

ВЯРНО С ОРИГИНАЛА

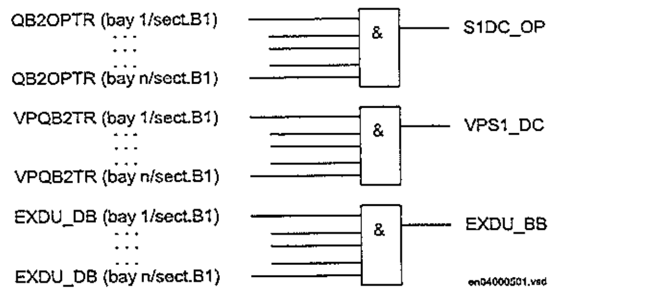

Figure 108: Signals from double-breaker bays in section B1 to a bus-section disconnector

For a bus-section disconnector, these conditions from the B2 busbar section are valid:

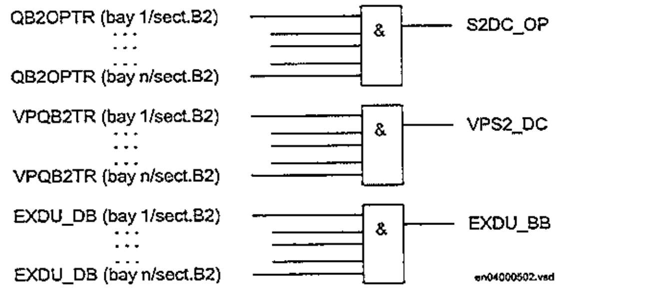

Figure 109: Signals from double-breaker bays in section B2 to a bus-section disconnector

10.4.6.4 Signals in 1 1/2 breaker arrangement

If the busbar is divided by bus-section disconnectors, the condition for the busbar disconnector bay *no other disconnector connected to the bus-section* must be made by a project-specific logic.

The same type of module (A1A2_DC) is used for different busbars, that is, for both bus-section disconnector A1A2_DC and B1B2_DC. But for B1B2_DC, corresponding signals from busbar B are used.

841

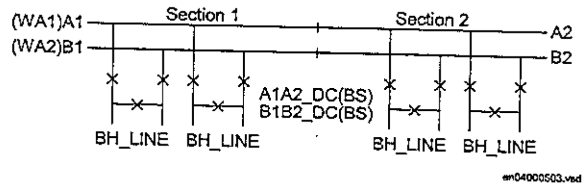

Figure 110: Busbars divided by bus-section disconnectors (circuit breakers)

The project-specific logic is the same as for the logic for the double-breaker configuration.

Signal	
S1DC_OP	All disconnectors on bus-section 1 are open.
S2DC_OP	All disconnectors on bus-section 2 are open.
VPS1_DC	The switch status of disconnectors on bus-section 1 is valid.
VPS2_DC	The switch status of disconnectors on bus-section 2 is valid.
EXDU_BB	No transmission error from breaker and a half (BH) that contains the above information.

10.4.7 Interlocking for bus-coupler bay ABC_BC

10.4.7.1 Application

The interlocking for bus-coupler bay (ABC_BC) function is used for a bus-coupler bay connected to a double busbar arrangement according to figure 111. The function can also be used for a single busbar arrangement with transfer busbar or double busbar arrangement without transfer busbar.

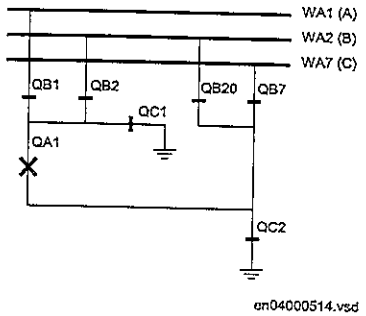

Figure 111: Switchyard layout ABC_BC

The interlocking functionality in 650 series can not handle the transfer bus (WA7)C.

10.4.7.2 Configuration

The signals from the other bays connected to the bus-coupler module ABC_BC are described below.

10.4.7.3 Signals from all feeders

To derive the signals:

Signal	
BBTR_OP	No busbar transfer is in progress concerning this bus-coupler.
VP_BBTR	The switch status is valid for all apparatuses involved in the busbar transfer.
EXDU_12	No transmission error from any bay connected to the WA1/WA2 busbars.

These signals from each line bay (ABC_LINE), each transformer bay (AB_TRAFO), and bus-coupler bay (ABC_BC), except the own bus-coupler bay are needed:

Signal	
QQB12OPTR	QB1 or QB2 or both are open.
VPQB12TR	The switch status of QB1 and QB2 are valid.
EXDU_12	No transmission error from the bay that contains the above information.

For bus-coupler bay n, these conditions are valid:

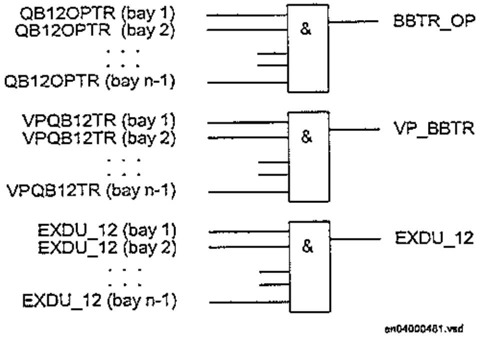

Figure 112: Signals from any bays in bus-coupler bay n

If the busbar is divided by bus-section disconnectors into bus-sections, the signals BBTR are connected in parallel - if both bus-section disconnectors are closed. So for the basic project-specific logic for BBTR above, add this logic:

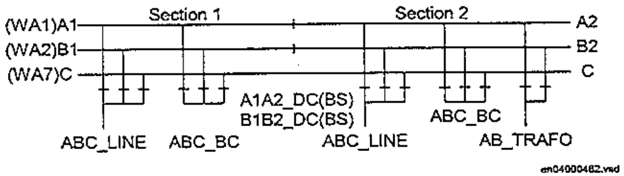

Figure 113: Busbars divided by bus-section disconnectors (circuit breakers)

The interlocking functionality in 650 series cannot handle the transfer bus (WA7)C.

The following signals from each bus-section disconnector bay (A1A2_DC) are needed. For B1B2_DC, corresponding signals from busbar B are used. The same type of module (A1A2_DC) is used for different busbars, that is, for both bus-section disconnector A1A2_DC and B1B2_DC.

Signal	
DCOPTR	The bus-section disconnector is open.
VPDCTR	The switch status of bus-section disconnector DC is valid.
EXDU_DC	No transmission error from the bay that contains the above information.

If the busbar is divided by bus-section circuit breakers, the signals from the bus-section coupler bay (A1A2_BS), rather than the bus-section disconnector bay (A1A2_DC), have to be used. For B1B2_BS, corresponding signals from busbar B are used. The same type of module (A1A2_BS) is used for different busbars, that is, for both bus-section circuit breakers A1A2_BS and B1B2_BS.

Signal	
S1S2OPTR	No bus-section coupler connection between bus-sections 1 and 2.
VPS1S2TR	The switch status of bus-section coupler BS is valid.
EXDU_BS	No transmission error from the bay that contains the above information.

For a bus-coupler bay in section 1, these conditions are valid:

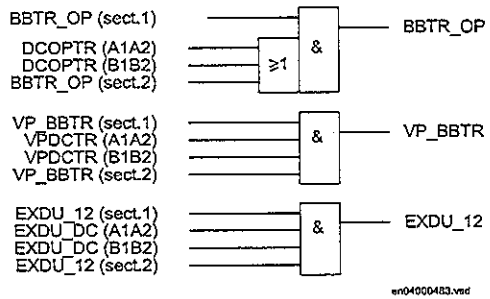

Figure 114: Signals to a bus-coupler bay in section 1 from any bays in each section

For a bus-coupler bay in section 2, the same conditions as above are valid by changing section 1 to section 2 and vice versa.

10.4.7.4 Signals from bus-coupler

If the busbar is divided by bus-section disconnectors into bus-sections, the signals BC_12 from the busbar coupler of the other busbar section must be transmitted to the own busbar coupler if both disconnectors are closed.

843

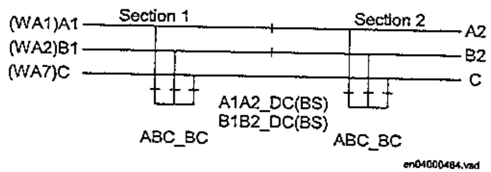

Figure 115: *Busbars divided by bus-section disconnectors (circuit breakers)*

The interlocking functionality in 650 series can not handle the transfer bus (WA7)C.

To derive the signals:

Signal	
BC_12_CL	Another bus-coupler connection exists between busbar WA1 and WA2.
VP_BC_12	The switch status of BC_12 is valid.
EXDU_BC	No transmission error from any bus-coupler bay (BC).

These signals from each bus-coupler bay (ABC_BC), except the own bay, are needed:

Signal	
BC12CLTR	A bus-coupler connection through the own bus-coupler exists between busbar WA1 and WA2.
VPBC12TR	The switch status of BC_12 is valid.
EXDU_BC	No transmission error from the bay that contains the above information.

These signals from each bus-section disconnector bay (A1A2_DC) are also needed. For B1B2_DC, corresponding signals from busbar B are used. The same type of module (A1A2_DC) is used for different busbars, that is, for both bus-section disconnector A1A2_DC and B1B2_DC.

Signal	
DCCLTR	The bus-section disconnector is closed.
VPDCTR	The switch status of bus-section disconnector DC is valid.
EXDU_DC	No transmission error from the bay that contains the above information.

If the busbar is divided by bus-section circuit breakers, the signals from the bus-section coupler bay (A1A2_BS), rather than the bus-section disconnector bay (A1A2_DC), must be used. For B1B2_BS, corresponding signals from busbar B are used. The same type of module (A1A2_BS) is used for different busbars, that is, for both bus-section circuit breakers A1A2_BS and B1B2_BS.

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Signal	
S1S2CLTR	A bus-section coupler connection exists between bus sections 1 and 2.
VPS1S2TR	The switch status of bus-section coupler BS is valid.
EXDU_BS	No transmission error from the bay containing the above information.

For a bus-coupler bay in section 1, these conditions are valid:

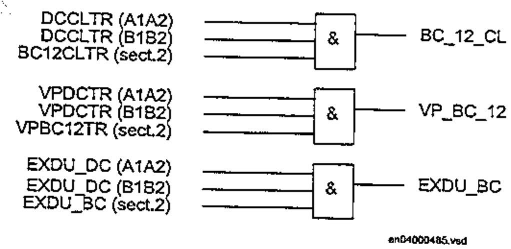

Figure 116: *Signals to a bus-coupler bay in section 1 from a bus-coupler bay in another section*

For a bus-coupler bay in section 2, the same conditions as above are valid by changing section 1 to section 2 and vice versa.

10.4.7.5 Configuration setting

If there is no bypass busbar and therefore no QB2 and QB7 disconnectors, then the interlocking for QB2 and QB7 is not used. The states for QB2, QB7, QC71 are set to open by setting the appropriate module inputs as follows. In the functional block diagram, 0 and 1 are designated 0=FALSE and 1=TRUE:

- QB2_OP = 1
- QB2_CL = 0

- QB7_OP = 1
- QB7_CL = 0

- QC71_OP = 1
- QC71_CL = 0

If there is no second busbar B and therefore no QB2 and QB20 disconnectors, then the interlocking for QB2 and QB20 are not used. The states for QB2, QB20, QC21, BC_12, BBTR are set to open by setting the appropriate module inputs as follows. In the functional block diagram, 0 and 1 are designated 0=FALSE and 1=TRUE:

- QB2_OP = 1
- QB2_CL = 0

- QB20_OP = 1
- QB20_CL = 0

- QC21_OP = 1
- QC21_CL = 0

- BC_12_CL = 0
- VP_BC_12 = 1

- BBTR_OP = 1
- VP_BBTR = 1

10.4.8 Interlocking for 1 1/2 breaker CB diameter

10.4.8.1 Application

The interlocking for 1 1/2 breaker diameter (BH_CONN, BH_LINE_A, BH_LINE_B) functions are used for lines connected to a 1 1/2 breaker diameter according to figure 117.

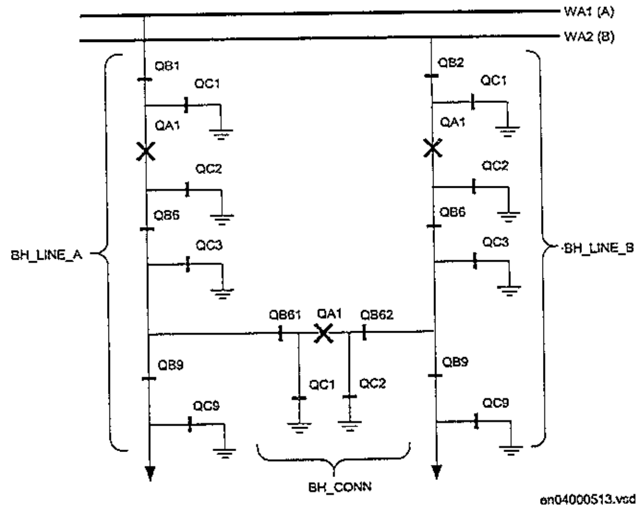

Figure 117: Switchyard layout 1 1/2 breaker

Three types of interlocking modules per diameter are defined. BH_LINE_A and BH_LINE_B are the connections from a line to a busbar. BH_CONN is the connection between the two lines of the diameter in the 1 1/2 breaker switchyard layout.

For a 1 1/2 breaker arrangement, the modules BH_LINE_A, BH_CONN and BH_LINE_B must be used.

10.4.8.2 Configuration setting

For application without QB9 and QC9, just set the appropriate inputs to open state and disregard the outputs. In the functional block diagram, 0 and 1 are designated 0=FALSE and 1=TRUE:

- QB9_OP = 1
- QB9_CL = 0

- QC9_OP = 1
- QC9_CL = 0

If, in this case, line voltage supervision is added, then rather than setting QB9 to open state, specify the state of the voltage supervision:

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- QB9_OP = VOLT_OFF
- QB9_CL = VOLT_ON

If there is no voltage supervision, then set the corresponding inputs as follows:

- VOLT_OFF = 1
- VOLT_ON = 0

10.4.9 Interlocking for double CB bay

10.4.9.1 Application

The interlocking for 1 1/2 breaker diameter including DB_BUS_A, DB_BUS_B, DB_LINEfunctions are used for a line connected to a double circuit breaker arrangement according to figure 118.

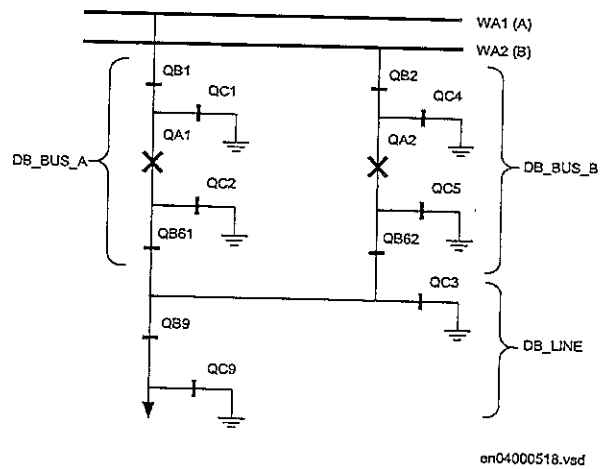

Figure 118: Switchyard layout double circuit breaker

Three types of interlocking modules per double circuit breaker bay are defined. DB_LINE is the connection from the line to the circuit breaker parts that are connected to the busbars. DB_BUS_A and DB_BUS_B are the connections from the line to the busbars.

For a double circuit-breaker bay, the modules DB_BUS_A, DB_LINE and DB_BUS_B must be used.

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10.4.9.2 Configuration setting

For application without QB9 and QC9, just set the appropriate inputs to open state and disregard the outputs. In the functional block diagram, 0 and 1 are designated 0=FALSE and 1=TRUE:

- QB9_OP = 1
- QB9_CL = 0

- QC9_OP = 1
- QC9_CL = 0

If, in this case, line voltage supervision is added, then rather than setting QB9 to open state, specify the state of the voltage supervision:

- QB9_OP = VOLT_OFF
- QB9_CL = VOLT_ON

If there is no voltage supervision, then set the corresponding inputs as follows:

- VOLT_OFF = 1
- VOLT_ON = 0

10.4.10 Interlocking for line bay ABC_LINE

10.4.10.1 Application

The interlocking for line bay (ABC_LINE) function is used for a line connected to a double busbar arrangement with a transfer busbar according to figure 119. The function can also be used for a double busbar arrangement without transfer busbar or a single busbar arrangement with/without transfer busbar.

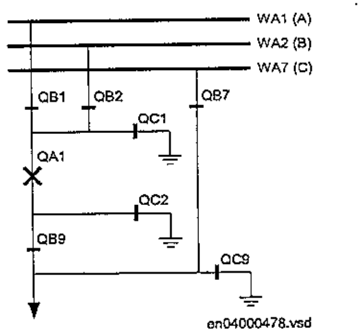

Figure 119: Switchyard layout ABC_LINE

The interlocking functionality in 650 series can not handle the transfer bus (WA7)C.

The signals from other bays connected to the module ABC_LINE are described below.

10.4.10.2 Signals from bypass busbar

To derive the signals:

Signal	
BB7_D_OP	All line disconnectors on bypass WA7 except in the own bay are open.
VP_BB7_D	The switch status of disconnectors on bypass busbar WA7 are valid.
EXDU_BPB	No transmission error from any bay containing disconnectors on bypass busbar WA7

These signals from each line bay (ABC_LINE) except that of the own bay are needed:

Signal	
QB7OPTR	Q7 is open
VPQB7TR	The switch status for QB7 is valid.
EXDU_BPB	No transmission error from the bay that contains the above information.

For bay n, these conditions are valid:

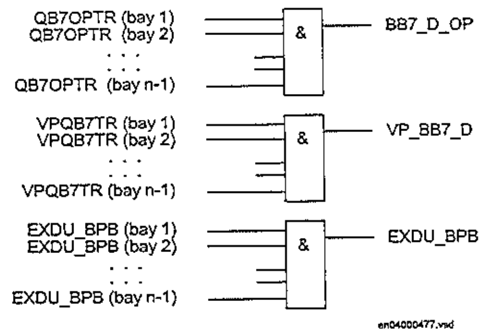

Figure 120: Signals from bypass busbar in line bay n

10.4.10.3 Signals from bus-coupler

If the busbar is divided by bus-section disconnectors into bus sections, the busbar-busbar connection could exist via the bus-section disconnector and bus-coupler within the other bus section.

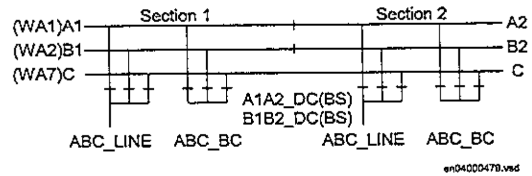

Figure 121: Busbars divided by bus-section disconnectors (circuit breakers)

The interlocking functionality in 650 series can not handle the transfer bus (WA7)C.

To derive the signals:

Signal	
BC_12_CL	A bus-coupler connection exists between busbar WA1 and WA2.
BC_17_OP	No bus-coupler connection between busbar WA1 and WA7.
BC_17_CL	A bus-coupler connection exists between busbar WA1and WA7.
BC_27_OP	No bus-coupler connection between busbar WA2 and WA7.

Table continues on next page

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Signal	
BC_27_CL	A bus-coupler connection exists between busbar WA2 and WA7.
VP_BC_12	The switch status of BC_12 is valid.
VP_BC_17	The switch status of BC_17 is valid.
VP_BC_27	The switch status of BC_27 is valid.
EXDU_BC	No transmission error from any bus-coupler bay (BC).

These signals from each bus-coupler bay (ABC_BC) are needed:

Signal	
BC12CLTR	A bus-coupler connection through the own bus-coupler exists between busbar WA1 and WA2.
BC17OPTR	No bus-coupler connection through the own bus-coupler between busbar WA1 and WA7.
BC17CLTR	A bus-coupler connection through the own bus-coupler exists between busbar WA1 and WA7.
BC27OPTR	No bus-coupler connection through the own bus-coupler between busbar WA2 and WA7.
BC27CLTR	A bus-coupler connection through the own bus-coupler exists between busbar WA2 and WA7.
VPBC12TR	The switch status of BC_12 is valid.
VPBC17TR	The switch status of BC_17 is valid.
VPBC27TR	The switch status of BC_27 is valid.
EXDU_BC	No transmission error from the bay that contains the above information.

These signals from each bus-section disconnector bay (A1A2_DC) are also needed. For B1B2_DC, corresponding signals from busbar B are used. The same type of module (A1A2_DC) is used for different busbars, that is, for both bus-section disconnector A1A2_DC and B1B2_DC.

Signal	
DCOPTR	The bus-section disconnector is open.
DCCLTR	The bus-section disconnector is closed.
VPDCTR	The switch status of bus-section disconnector DC is valid.
EXDU_DC	No transmission error from the bay that contains the above information.

If the busbar is divided by bus-section circuit breakers, the signals from the bus-section coupler bay (A1A2_BS), rather than the bus-section disconnector bay (A1A2_DC) must be used. For B1B2_BS, corresponding signals from busbar B are used. The same type of module (A1A2_BS) is used for different busbars, that is, for both bus-section circuit breakers A1A2_BS and B1B2_BS.

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Signal	
S1S2OPTR	No bus-section coupler connection between bus-sections 1 and 2.
S1S2CLTR	A bus-section coupler connection exists between bus-sections 1 and 2.
VPS1S2TR	The switch status of bus-section coupler BS is valid.
EXDU_BS	No transmission error from the bay that contains the above information.

For a line bay in section 1, these conditions are valid:

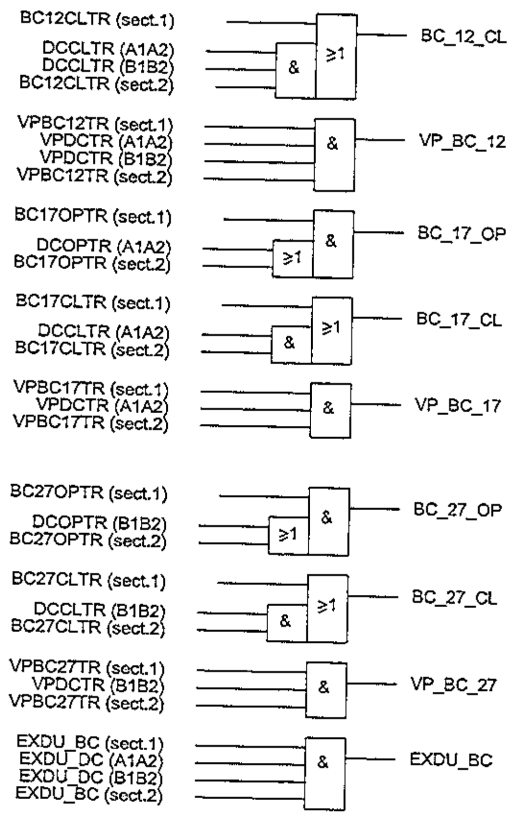

Figure 122: Signals to a line bay in section 1 from the bus-coupler bays in each section

For a line bay in section 2, the same conditions as above are valid by changing section 1 to section 2 and vice versa.

10.4.10.4 Configuration setting

If there is no bypass busbar and therefore no QB7 disconnector, then the interlocking for QB7 is not used. The states for QB7, QC71, BB7_D, BC_17, BC_27 are set to open by setting the appropriate module inputs as follows. In the functional block diagram, 0 and 1 are designated 0=FALSE and 1=TRUE:

- QB7_OP = 1
- QB7_CL = 0

- QC71_OP = 1
- QC71_CL = 0

- BB7_D_OP = 1

- BC_17_OP = 1
- BC_17_CL = 0
- BC_27_OP = 1
- BC_27_CL = 0

- EXDU_BPB = 1

- VP_BB7_D = 1
- VP_BC_17 = 1
- VP_BC_27 = 1

If there is no second busbar WA2 and therefore no QB2 disconnector, then the interlocking for QB2 is not used. The state for QB2, QC21, BC_12, BC_27 are set to open by setting the appropriate module inputs as follows. In the functional block diagram, 0 and 1 are designated 0=FALSE and 1=TRUE:

- QB2_OP = 1
- QB2_CL = 0

- QC21_OP = 1
- QC21_CL = 0

- BC_12_CL = 0
- BC_27_OP = 1
- BC_27_CL = 0

- VP_BC_12 = 1

10.4.11 Interlocking for transformer bay AB_TRAFO

10.4.11.1 Application

The interlocking for transformer bay (AB_TRAFO) function is used for a transformer bay connected to a double busbar arrangement according to figure 123. The function is used when there is no disconnector between circuit breaker and transformer. Otherwise, the interlocking for line bay (ABC_LINE) function can be used. This function can also be used in single busbar arrangements.

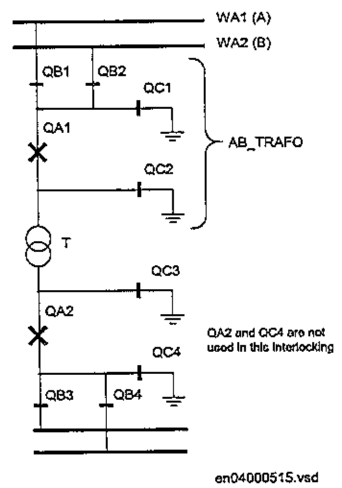

Figure 123: Switchyard layout AB_TRAFO

The signals from other bays connected to the module AB_TRAFO are described below.

10.4.11.2 Signals from bus-coupler

If the busbar is divided by bus-section disconnectors into bus-sections, the busbar-busbar connection could exist via the bus-section disconnector and bus-coupler within the other bus-section.

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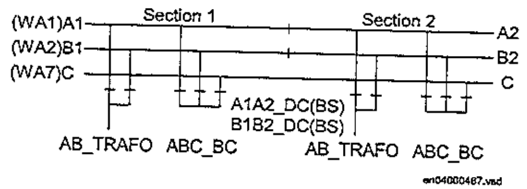

Figure 124: Busbars divided by bus-section disconnectors (circuit breakers)

The interlocking functionality in 650 series cannot handle the transfer bus (WA7)C.

The project-specific logic for input signals concerning bus-coupler are the same as the specific logic for the line bay (ABC_LINE):

Signal	
BC_12_CL	A bus-coupler connection exists between busbar WA1 and WA2.
VP_BC_12	The switch status of BC_12 is valid.
EXDU_BC	No transmission error from bus-coupler bay (BC).

The logic is identical to the double busbar configuration "Signals from bus-coupler".

10.4.11.3 Configuration setting

If there are no second busbar B and therefore no QB2 disconnector, then the interlocking for QB2 is not used. The state for QB2, QC21, BC_12 are set to open by setting the appropriate module inputs as follows. In the functional block diagram, 0 and 1 are designated 0=FALSE and 1=TRUE:

- QB2_OP = 1
- QB2QB2_CL = 0

- QC21_OP = 1
- QC21_CL = 0

- BC_12_CL = 0
- VP_BC_12 = 1

If there is no second busbar B at the other side of the transformer and therefore no QB4 disconnector, then the state for QB4 is set to open by setting the appropriate module inputs as follows:

- QB4_OP = 1
- QB4_CL = 0

10.5 Logic rotating switch for function selection and LHMI presentation SLGGIO

10.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Logic rotating switch for function selection and LHMI presentation	SLGGIO	-	-

10.5.2 Application

The logic rotating switch for function selection and LHMI presentation function (SLGGIO) (or the selector switch function block, as it is also known) is used to get a selector switch functionality similar with the one provided by a hardware selector switch. Hardware selector switches are used extensively by utilities, in order to have different functions operating on pre-set values. Hardware switches are however sources for maintenance issues, lower system reliability and extended purchase portfolio. The virtual selector switches eliminate all these problems.

SLGGIO function block has two operating inputs (UP and DOWN), one blocking input (BLOCK) and one operator position input (PSTO).

SLGGIO can be activated both from the local HMI and from external sources (switches), via the IED binary inputs. It also allows the operation from remote (like the station computer). SWPOSN is an integer value output, giving the actual output number. Since the number of positions of the switch can be established by settings (see below), one must be careful in coordinating the settings with the configuration (if one sets the number of positions to x in settings – for example, there will be only the first x outputs available from the block in the configuration). Also the frequency of the (UP or DOWN) pulses should be lower than the setting *tPulse*.

From the local HMI, there are two modes of operating the switch: from the menu and from the Single-line diagram (SLD).

10.5.3 Setting guidelines

The following settings are available for the Logic rotating switch for function selection and LHMI presentation (SLGGIO) function:

Operation: Sets the operation of the function *On* or *Off*.

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NrPos: Sets the number of positions in the switch (max. 32). This setting influence the behavior of the switch when changes from the last to the first position.

OutType: *Steady* or *Pulsed*.

tPulse: In case of a pulsed output, it gives the length of the pulse (in seconds).

tDelay: The delay between the UP or DOWN activation signal positive front and the output activation.

StopAtExtremes: Sets the behavior of the switch at the end positions – if set to *Disabled*, when pressing UP while on first position, the switch will jump to the last position; when pressing DOWN at the last position, the switch will jump to the first position; when set to *Enabled*, no jump will be allowed.

10.6 Selector mini switch VSGGIO

10.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Selector mini switch	VSGGIO	-	-

10.6.2 Application

Selector mini switch (VSGGIO) function is a multipurpose function used in the configuration tool in PCM600 for a variety of applications, as a general purpose switch. VSGGIO can be used for both acquiring an external switch position (through the IPOS1 and the IPOS2 inputs) and represent it through the single line diagram symbols (or use it in the configuration through the outputs POS1 and POS2) as well as, a command function (controlled by the PSTO input), giving switching commands through the CMDPOS12 and CMDPOS21 outputs.

The output POSITION is an integer output, showing the actual position as an integer number 0 – 3.

An example where VSGGIO is configured to switch Autorecloser on–off from a button symbol on the local HMI is shown in Figure 125. The I and O buttons on the local HMI are normally used for on–off operations of the circuit breaker.

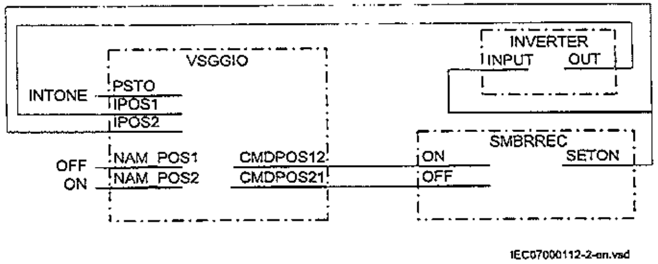

Figure 125: Control of Autorecloser from local HMI through Selector mini switch

10.6.3 Setting guidelines

Selector mini switch (VSGGIO) function can generate pulsed or steady commands (by setting the *Mode* parameter). When pulsed commands are generated, the length of the pulse can be set using the *tPulse* parameter. Also, being accessible on the single line diagram (SLD), this function block has two control modes (settable through *CtlModel*): *Dir Norm* and *SBO Enh*.

10.7 IEC61850 generic communication I/O functions DPGGIO

10.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IEC 61850 generic communication I/O functions	DPGGIO	-	-

10.7.2 Application

The IEC61850 generic communication I/O functions (DPGGIO) function block is used to send three logical outputs to other systems or equipment in the substation. The three inputs are named OPEN, CLOSE and VALID, since this function block is intended to be used as a position indicator block in interlocking and reservation station-wide logics.

10.7.3 Setting guidelines

The function does not have any parameters available in the local HMI or PCM600.

10.8 Single point generic control 8 signals SPC8GGIO

10.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Single point generic control 8 signals	SPC8GGIO	-	-

10.8.2 Application

The Single point generic control 8 signals (SPC8GGIO) function block is a collection of 8 single point commands, designed to bring in commands from REMOTE (SCADA) to those parts of the logic configuration that do not need complicated function blocks that have the capability to receive commands (for example SCSWI). In this way, simple commands can be sent directly to the IED outputs, without confirmation. Confirmation (status) of the result of the commands is supposed to be achieved by other means, such as binary inputs and SPGGIO function blocks.

PSTO is the universal operator place selector for all control functions. Even if PSTO can be configured to allow LOCAL or ALL operator positions, the only functional position usable with the SPC8GGIO function block is REMOTE.

10.8.3 Setting guidelines

The parameters for the single point generic control 8 signals (SPC8GGIO) function are set via the local HMI or PCM600.

Operation: turning the function operation *On*/*Off*.

There are two settings for every command output (totally 8):

Latchedx: decides if the command signal for output *x* is *Latched* (steady) or *Pulsed*.

tPulsex: if *Latchedx* is set to *Pulsed*, then *tPulsex* will set the length of the pulse (in seconds).

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10.9 Automation bits AUTOBITS

10.9.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
AutomationBits, command function for DNP3	AUTOBITS	-	-

10.9.2 Application

The AUTOBITS function block (or the automation bits function block) is used within PCM600 in order to get into the configuration the commands coming through the DNP3 protocol.AUTOBITS function block have 32 individual outputs which each can be mapped as a Binary Output point in DNP3. The output is operated by a "Object 12" in DNP3. This object contains parameters for control-code, count, on-time and off-time. To operate an AUTOBITS output point, send a control-code of latch-On, latch-Off, pulse-On, pulse-Off, Trip or Close. The remaining parameters are regarded as appropriate. For example, pulse-On, on-time=100, off-time=300, count=5 would give 5 positive 100 ms pulses, 300 ms apart.

See the communication protocol manual for a detailed description of the DNP3 protocol

10.9.3 Setting guidelines

AUTOBITS function block has one setting, (*Operation*: *On*/*Off*) enabling or disabling the function. These names will be seen in the DNP communication configuration tool in PCM600.

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Section 11 Logic

11.1 Tripping logic SMPPTRC

11.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Tripping logic	SMPPTRC	I->O	94

11.1.2 Application

All trip signals from the different protection functions shall be routed through the trip logic. In its simplest alternative the logic will only link the TRIP signal and make sure that it is long enough.

Tripping logic (SMPPTRC) in the IED for protection, control and monitoring offers three-phase tripping.

The three-phase trip for all faults offers a simple solution and is often sufficient in well meshed transmission systems and in High Voltage (HV) systems.

One SMPPTRC function block should be used for each breaker, if the line is connected to the substation via more than one breaker.

To prevent closing of a circuit breaker after a trip the function can block the closing.

11.1.2.1 Three-phase tripping

A simple application with three-phase tripping from the logic block utilizes a part of the function block. Connect the inputs from the protection function blocks to the input TRIN. If necessary (normally the case) use a logic OR block to combine the different function outputs to this input. Connect the output TRIP to the digital Output/s on the IO board.

For special applications such as Lock-out refer to the separate section below. The typical connection is shown below in figure 126. Signals that are not used are dimmed.

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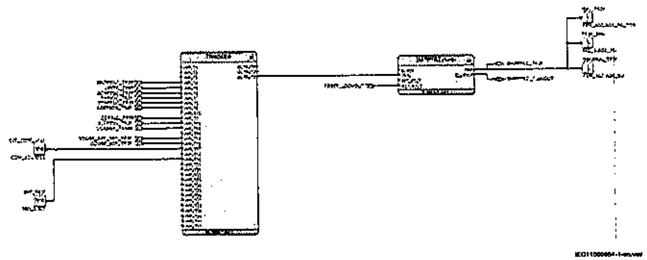

Figure 126: Tripping logic SMPPTRC is used for a simple three-phase tripping application

11.1.2.2 Lock-out

This function block is provided with possibilities to initiate lock-out. The lock-out can be set to only activate the block closing output CLLKOUT or initiate the block closing output and also maintain the trip signal (latched trip).

The lock-out can then be manually reset after checking the primary fault by activating the input reset Lock-Out RSTLKOUT.

If external conditions are required to initiate Lock-out but not initiate trip this can be achieved by activating input SETLKOUT. The setting *AutoLock* = *Off* means that the internal trip will not activate lock-out so only initiation of the input SETLKOUT will result in lock-out. This is normally the case for overhead line protection where most faults are transient. Unsuccessful autoreclose and back-up zone tripping can in such cases be connected to initiate Lock-out by activating the input SETLKOUT.

11.1.2.3 Blocking of the function block

Blocking can be initiated internally by logic, or by the operator using a communication channel. Total blockage of Tripping logic (SMPPTRC) function is done by activating the input BLOCK and can be used to block the output of SMPPTRC in the event of internal failures.

11.1.3 Setting guidelines

The parameters for Tripping logic SMPPTRC are set via the local HMI or PCM600.

The following trip parameters can be set to regulate tripping.

Operation: Sets the mode of operation. *Off* switches the tripping off. The normal selection is *On*.

TripLockout: Sets the scheme for lock-out. *Off* only activates lock-out output. *On* activates the lock-out output and latching output contacts. The normal selection is *Off*.

AutoLock: Sets the scheme for lock-out. *Off* only activates lock-out through the input SETLKOUT. *On* also allows activation from trip function itself and activates the lockout output. The normal selection is *Off*.

tTripMin: Sets the required minimum duration of the trip pulse. It should be set to ensure that the breaker is tripped and if a signal is used to start Breaker failure protection CCRBRF longer than the back-up trip timer in CCRBRF. Normal setting is *0.150s*.

11.2 Trip matrix logic TMAGGIO

11.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Trip matrix logic	TMAGGIO	-	-

11.2.2 Application

Trip matrix logic TMAGGIO function is used to route trip signals and other logical output signals to different output contacts on the IED.

TMAGGIO output signals and the physical outputs allows the user to adapt the signals to the physical tripping outputs according to the specific application needs.

11.2.3 Setting guidelines

Operation: Operation of function *On*/*Off*.

PulseTime: Defines the pulse time delay. When used for direct tripping of circuit breaker(s) the pulse time delay shall be set to approximately 0.150 seconds in order to obtain satisfactory minimum duration of the trip pulse to the circuit breaker trip coils.

OnDelay: Used to prevent output signals to be given for spurious inputs. Normally set to 0 or a low value.

OffDelay: Defines a minimum on time for the outputs. When used for direct tripping of circuit breaker(s) the off delay time shall be set to approximately 0.150 seconds in order to obtain satisfactory minimum duration of the trip pulse to the circuit breaker trip coils.

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ModeOutputx: Defines if output signal OUTPUTx (where x=1-3) is *Steady* or *Pulsed*.

11.3 Configurable logic blocks

11.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
OR Function block	OR	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Inverter function block	INVERTER	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
PULSETIMER function block	PULSETIMER	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Controllable gate function block	GATE	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Exclusive OR function block	XOR	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Logic loop delay function block	LOOPDELAY	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Timer function block	TIMERSET	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
AND function block	AND	-	-

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Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Set-reset memory function block	SRMEMORY	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Reset-set with memory function block	RSMEMORY	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
ORQT function block	ORQT	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
INVERTERQT function block	INVERTERQT	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Pulse timer function block	PULSTIMERQT	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
XORQT function block	XORQT	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Settable timer function block	TIMERSETQT	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
ANDQT function block	ANDQT	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Set/reset logic component	SRMEMORYQT	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Reset/set logic component	RSMEMORYQT	-	-

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Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
INVALIDQT function block	INVALIDQT	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Single indication signal combining function block	INDCOMBSPQT	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Single indication signal extractor function block	INDEXTSPQT	-	-

11.3.2 Application

A set of standard logic blocks, like AND, OR etc, and timers are available for adapting the IED configuration to the specific application needs. Additional logic blocks that, beside the normal logical function, have the capability to propagate timestamp and quality are also available. Those blocks have a designation including the letters QT, like ANDQT, ORQT etc.

There are no settings for AND gates, OR gates, inverters or XOR gates as well as, for ANDQT gates, ORQT gates or XORQT gates.

For normal On/Off delay and pulse timers the time delays and pulse lengths are set from the local HMI or via the PST tool.

Both timers in the same logic block (the one delayed on pick-up and the one delayed on drop-out) always have a common setting value.

For controllable gates, settable timers and SR flip-flops with memory, the setting parameters are accessible via the local HMI or via the PST tool.

11.3.3.1 Configuration

Logic is configured using the ACT configuration tool.

Execution of functions as defined by the configurable logic blocks runs according to a fixed sequence with different cycle times.

For each cycle time, the function block is given an serial execution number. This is shown when using the ACT configuration tool with the designation of the function block and the cycle time, see example below.

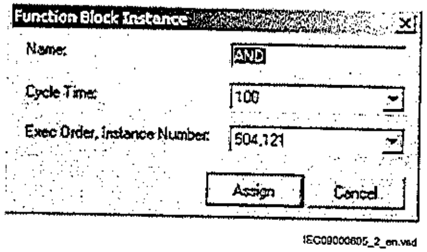

Figure 127: Example designation, serial execution number and cycle time for logic function

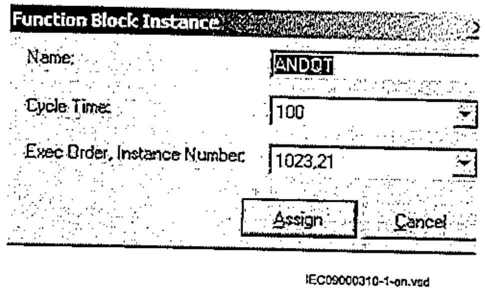

Figure 128: Example designation, serial execution number and cycle time for logic function that also propagates timestamp and quality of input signals

The execution of different function blocks within the same cycle is determined by the order of their serial execution numbers. Always remember this when connecting two or more logical function blocks in series.

Always be careful when connecting function blocks with a fast cycle time to function blocks with a slow cycle time.
Remember to design the logic circuits carefully and always check the execution sequence for different functions. In other cases, additional time delays must be introduced into the logic schemes to prevent errors, for example, race between functions.
Default value on all four inputs of the AND and ANDQT gate are logical 1 which makes it possible for the user to just use the required number of inputs and leave the rest un-connected. The output OUT has a default value 0 initially, which will suppress one cycle pulse if the function has been put in the wrong execution order.

11.4 Fixed signals FXDSIGN

11.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Fixed signals	FXDSIGN	-	-

11.4.2 Application

The Fixed signals function (FXDSIGN) generates a number of pre-set (fixed) signals that can be used in the configuration of an IED, either for forcing the unused inputs in other function blocks to a certain level/value, or for creating certain logic.

Example for use of GRP_OFF signal in FXDSIGN

The Restricted earth fault function REFPDIF can be used both for auto-transformers and normal transformers.

When used for auto-transformers, information from both windings parts, together with the neutral point current, needs to be available to the function. This means that three inputs are needed.

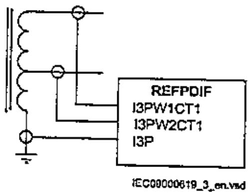

Figure 129: REFPDIF function inputs for autotransformer application

For normal transformers only one winding and the neutral point is available. This means that only two inputs are used. Since all group connections are mandatory to be connected, the third input needs to be connected to something, which is the GRP_OFF signal in FXDSIGN function block.

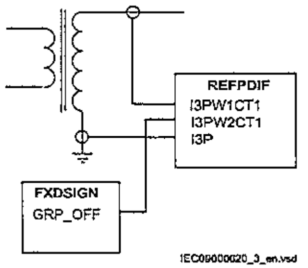

Figure 130: REFPDIF function inputs for normal transformer application

11.5 Boolean 16 to integer conversion B16I

11.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Boolean 16 to integer conversion	B16I	-	-

11.5.2 Application

Boolean 16 to integer conversion function B16I is used to transform a set of 16 binary (logical) signals into an integer. It can be used – for example, to connect logical output signals from a function (like distance protection) to integer inputs from another function (like line differential protection). B16I does not have a logical node mapping.

11.5.3 Setting guidelines

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

11.6 Boolean 16 to integer conversion with logic node representation B16IFCVI

11.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Boolean 16 to integer conversion with logic node representation	B16IFCVI	-	-

11.6.2 Application

Boolean 16 to integer conversion with logic node representation function B16IFCVI is used to transform a set of 16 binary (logical) signals into an integer. B16IFCVI can receive an integer from a station computer – for example, over IEC 61850. These functions are very useful when you want to generate logical commands (for selector switches or voltage controllers) by inputting an integer number. B16IFCVI has a logical node mapping in IEC 61850.

11.6.3 Setting guidelines

The function does not have any parameters available in the local HMI or Protection and Control IED Manager (PCM600).

11.7 Integer to boolean 16 conversion IB16A

11.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Integer to boolean 16 conversion	IB16A	-	-

11.7.2 Application

Integer to boolean 16 conversion function (IB16A) is used to transform an integer into a set of 16 binary (logical) signals. It can be used – for example, to connect integer output signals from a function (like distance protection) to binary (logical) inputs in another function (like line differential protection). IB16A function does not have a logical node mapping.

11.7.3 Setting guidelines

The function does not have any parameters available in the local HMI or Protection and Control IED Manager (PCM600).

11.8 Integer to boolean 16 conversion with logic node representation IB16FCVB

11.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Integer to boolean 16 conversion with logic node representation	IB16FCVB	-	-

11.8.2 Application

Integer to boolean 16 conversion with logic node representation function (IB16FCVB) is used to transform an integer into a set of 16 binary (logical) signals. IB16FCVB function can receive an integer from a station computer – for example, over IEC 61850. These functions are very useful when the user wants to generate logical commands (for selector switches or voltage controllers) by inputting an integer number. IB16FCVB function has a logical node mapping in IEC 61850.

11.8.3 Settings

The function does not have any parameters available in the local HMI or Protection and Control IED Manager (PCM600)

Section 12 Monitoring

12.1 IEC61850 generic communication I/O functions SPGGIO

12.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IEC 61850 generic communication I/O functions	SPGGIO	-	-

12.1.2 Application

IEC 61850 generic communication I/O functions (SPGGIO) function is used to send one single logical output to other systems or equipment in the substation. It has one visible input, that should be connected in ACT tool.

12.1.3 Setting guidelines

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

12.2 IEC61850 generic communication I/O functions 16 inputs SP16GGIO

12.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IEC 61850 generic communication I/O functions 16 inputs	SP16GGIO	-	-

12.2.2 Application

SP16GGIO function block is used to send up to 16 logical signals to other systems or equipment in the substation. Inputs should be connected in ACT tool.

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12.2.3 Setting guidelines

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

12.3 IEC61850 generic communication I/O functions MVGGIO

12.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IEC61850 generic communication I/O functions	MVGGIO	-	-

12.3.2 Application

IEC61850 generic communication I/O functions (MVGGIO) function is used to send the instantaneous value of an analog output to other systems or equipment in the substation. It can also be used inside the same IED, to attach a RANGE aspect to an analog value and to permit measurement supervision on that value.

12.3.3 Setting guidelines

The settings available for IEC61850 generic communication I/O functions (MVGGIO) function allows the user to choose a deadband and a zero deadband for the monitored signal. Values within the zero deadband are considered as zero.

The high and low limit settings provides limits for the high-high-, high, normal, low and low-low ranges of the measured value. The actual range of the measured value is shown on the range output of MVGGIO function block. When a Measured value expander block (MVEXP) is connected to the range output, the logical outputs of the MVEXP are changed accordingly.

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12.4 Measurements

12.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Measurements	CVMMXN	P, Q, S, I, U, f	-
Phase current measurement	CMMXU	I	-
Phase-phase voltage measurement	VMMXU	U	-
Current sequence component measurement	CMSQI	I1, I2, I0	-
Voltage sequence measurement	VMSQI	U1, U2, U0	-
Phase-neutral voltage measurement	VNMMXU	U	-

12.4.2 Application

Measurement functions is used for power system measurement, supervision and reporting to the local HMI, monitoring tool within PCM600 or to station level for example, via IEC 61850. The possibility to continuously monitor measured values of active power, reactive power, currents, voltages, frequency, power factor etc. is vital for efficient production, transmission and distribution of electrical energy. It provides to the system operator fast and easy overview of the present status of the power system. Additionally, it can be used during testing and commissioning of protection and control IEDs in order to verify proper operation and connection of instrument transformers (CTs and VTs). During normal service by periodic comparison of the measured value from the IED with other independent meters the proper operation of the IED analog measurement chain can be verified. Finally, it

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can be used to verify proper direction orientation for distance or directional overcurrent protection function.

> The available measured values of an IED are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

All measured values can be supervised with four settable limits that is, low-low limit, low limit, high limit and high-high limit. A zero clamping reduction is also supported, that is, the measured value below a settable limit is forced to zero which reduces the impact of noise in the inputs. There are no interconnections regarding any settings or parameters, neither between functions nor between signals within each function.

Zero clampings are handled by *ZeroDb* for each signal separately for each of the functions. For example, the zero clamping of U12 is handled by *ULZeroDb* in VMMXU, zero clamping of I1 is handled by *ILZeroDb* in CMMXU.

Dead-band supervision can be used to report measured signal value to station level when change in measured value is above set threshold limit or time integral of all changes since the last time value updating exceeds the threshold limit. Measure value can also be based on periodic reporting.

The measurement function, CVMMXN, provides the following power system quantities:

- P, Q and S: three phase active, reactive and apparent power
- PF: power factor
- U: phase-to-phase voltage amplitude
- I: phase current amplitude
- F: power system frequency

The output values are displayed in the local HMI under **Main menu/Tests/ Function status/Monitoring/CVMMXN/Outputs**

The measuring functions CMMXU, VNMMXU and VMMXU provide physical quantities:

- I: phase currents (amplitude and angle) (CMMXU)
- U: voltages (phase-to-earth and phase-to-phase voltage, amplitude and angle) (VMMXU, VNMMXU)

It is possible to calibrate the measuring function above to get better then class 0.5 presentation. This is accomplished by angle and amplitude compensation at 5, 30 and 100% of rated current and at 100% of rated voltage.

> The power system quantities provided, depends on the actual hardware, (TRM) and the logic configuration made in PCM600.

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The measuring functions CMSQI and VMSQI provide sequential quantities:

- I: sequence currents (positive, zero, negative sequence, amplitude and angle)
- U: sequence voltages (positive, zero and negative sequence, amplitude and angle).

The CVMMXN function calculates three-phase power quantities by using fundamental frequency phasors (DFT values) of the measured current respectively voltage signals. The measured power quantities are available either, as instantaneously calculated quantities or, averaged values over a period of time (low pass filtered) depending on the selected settings.

12.4.3 Setting guidelines

The available setting parameters of the measurement function CVMMXN, CMMXU, VMMXU, CMSQI, VMSQI, VNMMXU are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

The parameters for the Measurement functions CVMMXN, CMMXU, VMMXU, CMSQI, VMSQI, VNMMXU are set via the local HMI or PCM600.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Operation: *Off*/*On*. Every function instance (CVMMXN, CMMXU, VMMXU, CMSQI, VMSQI, VNMMXU) can be taken in operation (*On*) or out of operation (*Off*).

The following general settings can be set for the **Measurement function** (CVMMXN).

PowAmpFact: Amplitude factor to scale power calculations.

PowAngComp: Angle compensation for phase shift between measured I & U.

Mode: Selection of measured current and voltage. There are 9 different ways of calculating monitored three-phase values depending on the available VT inputs connected to the IED. See parameter group setting table.

k: Low pass filter coefficient for power measurement, U and I.

UAmpCompY: Amplitude compensation to calibrate voltage measurements at Y% of Ur, where Y is equal to 5, 30 or 100.

IAmpCompY: Amplitude compensation to calibrate current measurements at Y% of Ir, where Y is equal to 5, 30 or 100.

IAngCompY: Angle compensation to calibrate angle measurements at Y% of Ir, where Y is equal to 5, 30 or 100.

The following general settings can be set for the **Phase-phase current measurement** (CMMXU).

IAmpCompY: Amplitude compensation to calibrate current measurements at Y% of Ir, where Y is equal to 5, 30 or 100.

IAngCompY: Angle compensation to calibrate angle measurements at Y% of Ir, where Y is equal to 5, 30 or 100.

The following general settings can be set for the **Phase-phase voltage measurement** (VMMXU).

UAmpCompY: Amplitude compensation to calibrate voltage measurements at Y% of Ur, where Y is equal to 5, 30 or 100.

UAngCompY: Angle compensation to calibrate angle measurements at Y% of Ur, where Y is equal to 5, 30 or 100.

The following general settings can be set for **all monitored quantities** included in the functions (CVMMXN, CMMXU, VMMXU, CMSQI, VMSQI, VNMMXU) X in setting names below equals S, P, Q, PF, U, I, F, IL1-3, UL1-3UL12-31, I1, I2, 3I0, U1, U2 or 3U0.

Xmin: Minimum value for analog signal X.

Xmax: Maximum value for analog signal X.

> *Xmin* and *Xmax* values are directly set in applicable measuring unit, V, A, and so on, for all measurement functions, except CVMMXN where *Xmin* and *Xmax* values are set in % of *SBase*.

XZeroDb: Zero point clamping. A signal value less than *XZeroDb* is forced to zero.

XRepTyp: Reporting type. Cyclic (*Cyclic*), amplitude deadband (*Dead band*) or integral deadband (*Int deadband*). The reporting interval is controlled by the parameter *XDbRepInt*.

XDbRepInt: Reporting deadband setting. Cyclic reporting is the setting value and is reporting interval in seconds. Amplitude deadband is the setting value in % of measuring range. Integral deadband setting is the integral area, that is, measured value in % of measuring range multiplied by the time between two measured values.

> Limits are directly set in applicable measuring unit, V, A , and so on, for all measurement functions, except CVMMXN where limits are set in % of *SBase*.

XHiHiLim: High-high limit.

XHiLim: High limit.

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XLowLim: Low limit.

XLowLowLim: Low-low limit.

XLimHyst: Hysteresis value in % of range and is common for all limits.

All phase angles are presented in relation to defined reference channel. The parameter *PhaseAngleRef* defines the reference, see settings for analog input modules in PCM600.

Calibration curves

It is possible to calibrate the functions (CVMMXN, CMMXU, VNMMXU and VMMXU) to get class 0.5 presentations of currents, voltages and powers. This is accomplished by amplitude and angle compensation at 5, 30 and 100% of rated current and voltage. The compensation curve will have the characteristic for amplitude and angle compensation of currents as shown in figure 131 (example). The first phase will be used as reference channel and compared with the curve for calculation of factors. The factors will then be used for all related channels.

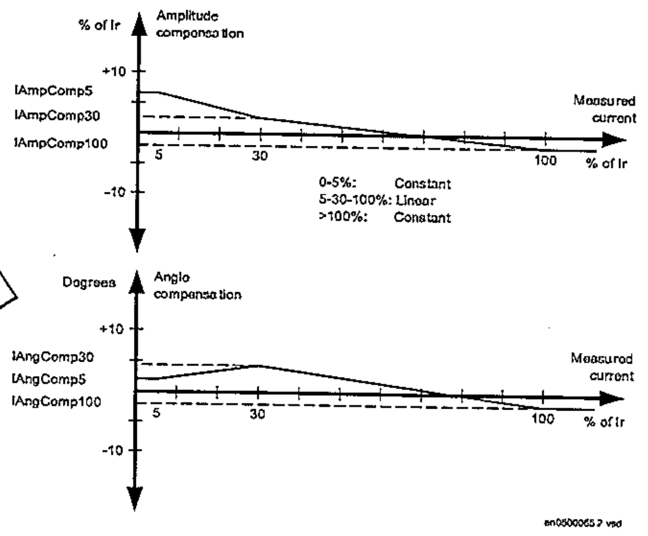

Figure 131: Calibration curves

12.4.4 Setting examples

Three setting examples, in connection to Measurement function (CVMMXN), are provided:

- Measurement function (CVMMXN) application for a 400 kV OHL
- Measurement function (CVMMXN) application on the secondary side of a transformer
- Measurement function (CVMMXN) application for a generator

For each of them detail explanation and final list of selected setting parameters values will be provided.

The available measured values of an IED are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

12.4.4.1 Measurement function application for a 400 kV OHL

Single line diagram for this application is given in figure 132:

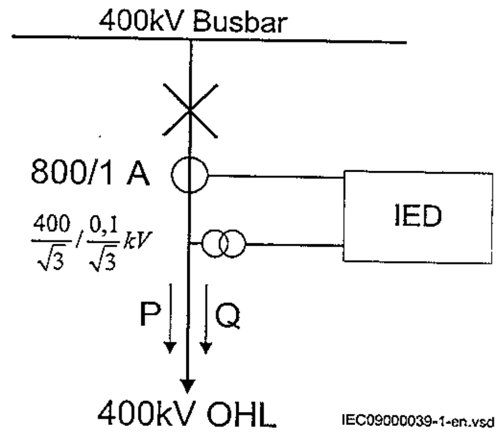

Figure 132: Single line diagram for 400 kV OHL application

In order to monitor, supervise and calibrate the active and reactive power as indicated in figure 132 it is necessary to do the following:

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1. Set correctly CT and VT data and phase angle reference channel *PhaseAngleRef* (see settings for analog input modules in PCM600) using PCM600 for analog input channels
2. Connect, in PCM600, measurement function to three-phase CT and VT inputs
3. Set under General settings parameters for the Measurement function:
   - general settings as shown in table 16.
   - level supervision of active power as shown in table 17.
   - calibration parameters as shown in table 18.

Table 16: *General settings parameters for the Measurement function*

Setting	Short Description	Selected value	Comments
Operation	Operation *Off/On*	*On*	Function must be *On*
PowAmpFact	Amplitude factor to scale power calculations	1.000	It can be used during commissioning to achieve higher measurement accuracy. Typically no scaling is required
PowAngComp	Angle compensation for phase shift between measured I & U	0.0	It can be used during commissioning to achieve higher measurement accuracy. Typically no angle compensation is required. As well here required direction of P & Q measurement is towards protected object (as per IED internal default direction)
Mode	Selection of measured current and voltage	*L1, L2, L3*	All three phase-to-earth VT inputs are available
k	Low pass filter coefficient for power measurement, U and I	0.00	Typically no additional filtering is required

Table 17: *Settings parameters for level supervision*

Setting	Short Description	Selected value	Comments
PMin	Minimum value	-750	Minimum expected load
PMax	Minimum value	750	Maximum expected load
PZeroDb	Zero point clamping in 0.001% of range	3000	Set zero point clamping to 45 MW that is, 3% of 1500 MW
PRepTyp	Reporting type	db	Select amplitude deadband supervision
PDbRepInt	Cycl: Report interval (s), Db: In % of range, Int Db: In %s	2	Set ±Δdb=30 MW that is, 2% (larger changes than 30 MW will be reported)
PHiHiLim	High High limit (physical value)	600	High alarm limit that is, extreme overload alarm
PHiLim	High limit (physical value)	500	High warning limit that is, overload warning
PLowLim	Low limit (physical value)	-800	Low warning limit. Not active
PLowLowLim	Low Low limit (physical value)	-800	Low alarm limit. Not active
PLimHyst	Hysteresis value in % of range (common for all limits)	2	Set ±Δ Hysteresis MW that is, 2%

Table continues on next page

Table 18: *Settings for calibration parameters*

Setting	Short Description	Selected value	Comments
IAmpComp5	Amplitude factor to calibrate current at 5% of Ir	0.00	
IAmpComp30	Amplitude factor to calibrate current at 30% of Ir	0.00	
IAmpComp100	Amplitude factor to calibrate current at 100% of Ir	0.00	
UAmpComp5	Amplitude factor to calibrate voltage at 5% of Ur	0.00	
UAmpComp30	Amplitude factor to calibrate voltage at 30% of Ur	0.00	
UAmpComp100	Amplitude factor to calibrate voltage at 100% of Ur	0.00	
IAngComp5	Angle calibration for current at 5% of Ir	0.00	
IAngComp30	Angle pre-calibration for current at 30% of Ir	0.00	
IAngComp100	Angle pre-calibration for current at 100% of Ir	0.00	

12.5 Event counter CNTGGIO

12.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Event counter	CNTGGIO	[o]— — —	-

12.5.2 Application

Event counter (CNTGGIO) has six counters which are used for storing the number of times each counter has been activated. CNTGGIO can be used to count how many times a specific function, for example the tripping logic, has issued a trip signal. All six counters have a common blocking and resetting feature.

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12.5.3 Setting guidelines

Operation: Sets the operation of Event counter (CNTGGIO) *On* or *Off*.

12.6 Disturbance report

12.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Disturbance report	DRPRDRE	-	-
Analog input signals	A1RADR	-	-
Analog input signals	A2RADR	-	-
Analog input signals	A3RADR	-	-
Analog input signals	A4RADR	-	-
Binary input signals	B1RBDR	-	-
Binary input signals	B2RBDR	-	-
Binary input signals	B3RBDR	-	-
Binary input signals	B4RBDR	-	-
Binary input signals	B5RBDR	-	-
Binary input signals	B6RBDR	-	-

12.6.2 Application

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To get fast, complete and reliable information about disturbances in the primary and/ or in the secondary system it is very important to gather information on fault currents, voltages and events. It is also important having a continuous event-logging to be able to monitor in an overview perspective. These tasks are accomplished by the disturbance report function DRPRDRE and facilitate a better understanding of the power system behavior and related primary and secondary equipment during and after a disturbance. An analysis of the recorded data provides valuable information that can be used to explain a disturbance, basis for change of IED setting plan, improve existing equipment, and so on. This information can also be used in a longer perspective when planning for and designing new installations, that is, a disturbance recording could be a part of Functional Analysis (FA).

Disturbance report DRPRDRE, always included in the IED, acquires sampled data of all selected analog and binary signals connected to the function blocks that is,

- maximum 30 external analog signals,
- 10 internal derived analog signals, and
- 96 binary signals.

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Disturbance report function is a common name for several functions that is, Indications, Event recorder, Event list, Trip value recorder, Disturbance recorder.

Disturbance report function is characterized by great flexibility as far as configuration, starting conditions, recording times, and large storage capacity are concerned. Thus, disturbance report is not dependent on the operation of protective functions, and it can record disturbances that were not discovered by protective functions for one reason or another. Disturbance report can be used as an advanced stand-alone disturbance recorder.

Every disturbance report recording is saved in the IED. The same applies to all events, which are continuously saved in a ring-buffer. Local HMI can be used to get information about the recordings, and the disturbance report files may be uploaded in the PCM600 using the Disturbance handling tool, for report reading or further analysis (using WaveWin, that can be found on the PCM600 installation CD). The user can also upload disturbance report files using FTP or MMS (over 61850) clients.

If the IED is connected to a station bus (IEC 61850-8-1), the disturbance recorder (record made and fault number) and the fault locator information are available as GOOSE or Report Control data.

12.6.3 Setting guidelines

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The setting parameters for the Disturbance report function DRPRDRE are set via the local HMI or PCM600.

It is possible to handle up to 40 analog and 96 binary signals, either internal signals or signals coming from external inputs. The binary signals are identical in all functions that is, Disturbance recorder, Event recorder, Indication, Trip value recorder and Event list function.

User-defined names of binary and analog input signals is set using PCM600. The analog and binary signals appear with their user-defined names. The name is used in all related functions (Disturbance recorder, Event recorder, Indication, Trip value recorder and Event list).

Figure 133 shows the relations between Disturbance report, included functions and function blocks. Event list, Event recorder and Indication uses information from the binary input function blocks (BxRBDR). Trip value recorder uses analog information from the analog input function blocks (AxRADR),. Disturbance report function acquires information from both AxRADR and BxRBDR.

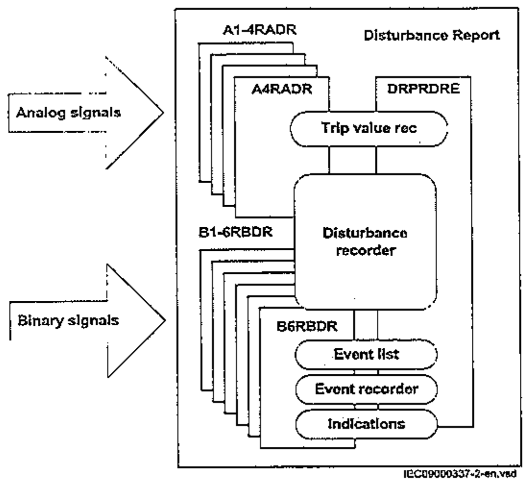

Figure 133: Disturbance report functions and related function blocks

For Disturbance report function there are a number of settings which also influences the sub-functions.

Three LED indications placed above the LCD screen makes it possible to get quick status information about the IED.

Green LED:	Steady light	In Service
	Flashing light	Internal failure
	Dark	No power supply
Yellow LED:	Function controlled by SetLEDn setting in Disturbance report function.	
Red LED:	Function controlled by SetLEDn setting in Disturbance report function.	

Operation
The operation of Disturbance report function DRPRDRE has to be set *On* or *Off*. If *Off* is selected, note that no disturbance report is registered, and none sub-function will operate (the only general parameter that influences Event list).

Operation = Off:

- Disturbance reports are not stored.
- LED information (yellow - start, red - trip) is not stored or changed.

Operation = On:

- Disturbance reports are stored, disturbance data can be read from the local HMI and from a PC using PCM600.
- LED information (yellow - start, red - trip) is stored.

Every recording will get a number (0 to 999) which is used as identifier (local HMI, disturbance handling tool and IEC 61850). An alternative recording identification is date, time and sequence number. The sequence number is automatically increased by one for each new recording and is reset to zero at midnight. The maximum number of recordings stored in the IED is 100. The oldest recording will be overwritten when a new recording arrives (FIFO).

> To be able to delete disturbance records, *Operation* parameter has to be *On*.

> The maximum number of recordings depend on each recordings total recording time. Long recording time will reduce the number of recordings to less than 100.

> The IED flash disk should NOT be used to store any user files. This might cause disturbance recordings to be deleted due to lack of disk space.

Recording times
The different recording times for Disturbance report are set (the pre-fault time, post-fault time, and limit time). These recording times affect all sub-functions more or less but not the Event list function.

Prefault recording time (*PreFaultRecT*) is the recording time before the starting point of the disturbance. The setting should be at least *0.1* s to ensure enough samples for the estimation of pre-fault values in the Trip value recorder function.

Postfault recording time (*PostFaultRecT*) is the maximum recording time after the disappearance of the trig-signal (does not influence the Trip value recorder function).

Recording time limit (*TimeLimit*) is the maximum recording time after trig. The parameter limits the recording time if some trigging condition (fault-time) is very long or permanently set (does not influence the Trip value recorder function).

Post retrigger (*PostRetrig*) can be set to *On* or *Off*. Makes it possible to choose performance of Disturbance report function if a new trig signal appears in the post-fault window.

PostRetrig = *Off*

The function is insensitive for new trig signals during post fault time.

PostRetrig = *On*

The function completes current report and starts a new complete report that is, the latter will include:

- new pre-fault- and fault-time (which will overlap previous report)
- events and indications might be saved in the previous report too, due to overlap
- new trip value calculations if installed, in operation and started

Operation in test mode

If the IED is in test mode and *OpModeTest* = *Off*. Disturbance report function does not save any recordings and no LED information is displayed.

If the IED is in test mode and *OpModeTest* = *On*. Disturbance report function works in normal mode and the status is indicated in the saved recording.

12.6.3.1 Binary input signals

Up to 96 binary signals can be selected among internal logical and binary input signals. The configuration tool is used to configure the signals.

For each of the 96 signals, it is also possible to select if the signal is to be used as a trigger for the start of Disturbance report and if the trigger should be activated on positive (1) or negative (0) slope.

OperationN: Disturbance report may trig for binary input N (*On*) or not (*Off*).

TrigLevelN: Trig on positive (*Trig on 1*) or negative (*Trig on 0*) slope for binary input N.

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12.6.3.2 Analog input signals

Up to 40 analog signals can be selected among internal analog and analog input signals. PCM600 is used to configure the signals.

The analog trigger of Disturbance report is not affected if analog input M is to be included in the disturbance recording or not (*OperationM* = *On*/*Off*).

If *OperationM* = *Off*, no waveform (samples) will be recorded and reported in graph. However, Trip value, pre-fault and fault value will be recorded and reported. The input channel can still be used to trig the disturbance recorder.

If *OperationM* = *On*, waveform (samples) will also be recorded and reported in graph.

NomValueM: Nominal value for input M.

OverTrigOpM, *UnderTrigOpM*: Over or Under trig operation, Disturbance report may trig for high/low level of analog input M (*On*) or not (*Off*).

OverTrigLeM, *UnderTrigLeM*: Over or under trig level, Trig high/low level relative nominal value for analog input M in percent of nominal value.

12.6.3.3 Sub-function parameters

All functions are in operation as long as Disturbance report is in operation.

Indications

IndicationMaN: Indication mask for binary input N. If set (*Show*), a status change of that particular input, will be fetched and shown in the disturbance summary on local HMI. If not set (*Hide*), status change will not be indicated.

SetLEDN: Set yellow *Start*and red *Trip* LED on local HMI in front of the IED if binary input N changes status.

Disturbance recorder

OperationM: Analog channel M is to be recorded by the disturbance recorder (*On*) or not (*Off*).

If *OperationM* = *Off*, no waveform (samples) will be recorded and reported in graph. However, Trip value, pre-fault and fault value will be recorded and reported. The input channel can still be used to trig the disturbance recorder.

If *OperationM* = *On*, waveform (samples) will also be recorded and reported in graph.

Event recorder

Event recorder function has no dedicated parameters.

Trip value recorder

ZeroAngleRef: The parameter defines which analog signal that will be used as phase angle reference for all other analog input signals. This signal will also be used for frequency measurement and the measured frequency is used when calculating trip values. It is suggested to point out a sampled voltage input signal, for example, a line or busbar phase voltage (channel 1-30).

Event list

Event list function has no dedicated parameters.

12.6.3.4 Consideration

The density of recording equipment in power systems is increasing, since the number of modern IEDs, where recorders are included, is increasing. This leads to a vast number of recordings at every single disturbance and a lot of information has

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to be handled if the recording functions do not have proper settings. The goal is to optimize the settings in each IED to be able to capture just valuable disturbances and to maximize the number that is possible to save in the IED.

The recording time should not be longer than necessary (*PostFaultrecT* and *TimeLimit*).

- Should the function record faults only for the protected object or cover more?
- How long is the longest expected fault clearing time?
- Is it necessary to include reclosure in the recording or should a persistent fault generate a second recording (*PostRetrig*)?

Minimize the number of recordings:

- Binary signals: Use only relevant signals to start the recording that is, protection trip, carrier receive and/or start signals.
- Analog signals: The level triggering should be used with great care, since unfortunate settings will cause enormously number of recordings. If nevertheless analog input triggering is used, chose settings by a sufficient margin from normal operation values. Phase voltages are not recommended for trigging.

Remember that values of parameters set elsewhere are linked to the information on a report. Such parameters are, for example, station and object identifiers, CT and VT ratios.

12.7 Measured value expander block MVEXP

12.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Measured value expander block	MVEXP	-	-

Application

The current and voltage measurements functions (CVMMXN, CMMXU, VMMXU and VNMMXU), current and voltage sequence measurement functions (CMSQI and VMSQI) and IEC 61850 generic communication I/O functions (MVGGIO) are provided with measurement supervision functionality. All measured values can be supervised with four settable limits, that is low-low limit, low limit, high limit and high-high limit. The measure value expander block (MVEXP) has been introduced to be able to translate the integer output signal from the measuring functions to 5 binary signals, that is below low-low limit, below low limit, normal, above high-high limit or above high limit. The output signals can be used as conditions in the configurable logic.

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12.7.3 Setting guidelines

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

12.8 Station battery supervision SPVNZBAT

12.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Station battery supervision function	SPVNZBAT	U<>	-

12.8.2 Application

Usually, the load on the DC system is a constant resistance load, for example, lamps, LEDs, electronic instruments and electromagnetic contactors in a steady state condition. A transient RL load exists when breakers are tripped or closed.

The battery voltage has to be continuously monitored as the batteries can withstand moderate overvoltage and undervoltage only for a short period of time.

- If the battery is subjected to a prolonged or frequent overvoltage, it leads to the ageing of the battery, which may lead to the earlier failure of the battery. The other occurrences may be the thermal runaway, generation of heat or increased amount of hydrogen gas and the depletion of fluid in case of valve regulated batteries.

- If the value of the charging voltage drops below the minimum recommended float voltage of the battery, the battery does not receive sufficient charging current to offset internal losses, resulting in a gradual loss of capacity.
    - If a lead acid battery is subjected to a continuous undervoltage, heavy sulfation occurs on the plates, which leads to the loss of the battery capacity.

12.9 Insulation gas monitoring function SSIMG

12.9.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Insulation gas monitoring function	SSIMG	-	63

12.9.2 Application

Insulation gas monitoring function (SSIMG) is used for monitoring the circuit breaker condition. Proper arc extinction by the compressed gas in the circuit breaker is very important. When the pressure becomes too low compared to the required value, the circuit breaker operation gets blocked to avoid disaster. Binary information based on the gas pressure in the circuit breaker is used as input signals to the function. In addition to that, the function generates alarms based on received information.

12.10 Insulation liquid monitoring function SSIML

12.10.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Insulation liquid monitoring function	SSIML	-	71

12.10.2 Application

Insulation liquid monitoring function (SSIML) is used for monitoring the circuit breaker condition. Proper arc extinction by the compressed oil in the circuit breaker is very important. When the level becomes too low, compared to the required value, the circuit breaker operation is blocked to avoid disaster. Binary information based on the oil level in the circuit breaker is used as input signals to the function. In addition to that, the function generates alarms based on received information.

12.11 Circuit breaker condition monitoring SSCBR

12.11.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker condition monitoring	SSCBR	-	-

12.11.2 Application

SSCBR includes different metering and monitoring subfunctions.

Circuit breaker status

Circuit breaker status monitors the position of the circuit breaker, that is, whether the breaker is in an open, closed or intermediate position.

Circuit breaker operation monitoring

The purpose of the circuit breaker operation monitoring is to indicate that the circuit breaker has not been operated for a long time. The function calculates the number of days the circuit breaker has remained inactive, that is, has stayed in the same open or closed state. There is also the possibility to set an initial inactive day.

Breaker contact travel time

High travelling times indicate the need for maintenance of the circuit breaker mechanism. Therefore, detecting excessive travelling time is needed. During the opening cycle operation, the main contact starts opening. The auxiliary contact A opens, the auxiliary contact B closes, and the main contact reaches its opening position. During the closing cycle, the first main contact starts closing. The auxiliary contact B opens, the auxiliary contact A closes, and the main contact reaches its close position. The travel times are calculated based on the state changes of the auxiliary contacts and the adding correction factor to consider the time difference of the main contact's and the auxiliary contact's position change.

Operation counter

Routine maintenance of the breaker, such as lubricating breaker mechanism, is generally based on a number of operations. A suitable threshold setting, to raise an alarm when the number of operation cycle exceeds the set limit, helps preventive maintenance. This can also be used to indicate the requirement for oil sampling for dielectric testing in case of an oil circuit breaker.

The change of state can be detected from the binary input of the auxiliary contact. There is a possibility to set an initial value for the counter which can be used to initialize this functionality after a period of operation or in case of refurbished primary equipment.

Accumulation of I^yt

Accumulation of I^yt calculates the accumulated energy ΣI^yt where the factor y is known as the current exponent. The factor y depends on the type of the circuit breaker. For oil circuit breakers the factor y is normally 2. In case of a high-voltage system, the factor y can be 1.4...1.5.

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Remaining life of the breaker

Every time the breaker operates, the life of the circuit breaker reduces due to wearing. The wearing in the breaker depends on the tripping current, and the remaining life of the breaker is estimated from the circuit breaker trip curve provided by the manufacturer.

Example for estimating the remaining life of a circuit breaker

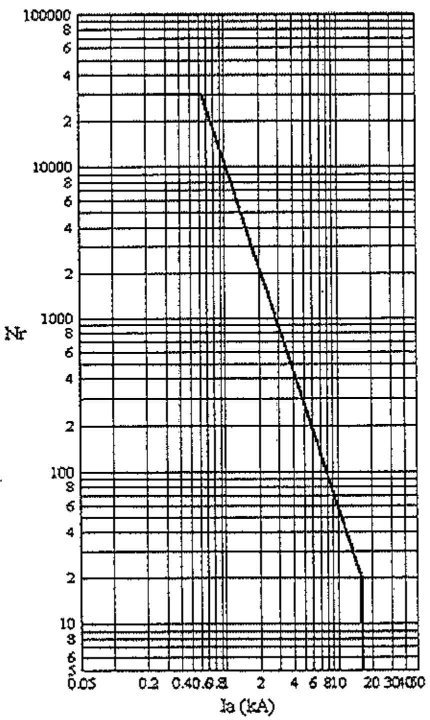

Figure 134: Trip Curves for a typical 12 kV, 630 A, 16 kA vacuum interrupter

Nr	the number of closing-opening operations allowed for the circuit breaker
Ia	the current at the time of tripping of the circuit breaker

Calculation of Directional Coef

The directional coefficient is calculated according to the formula:

$$Directional\ Coef = \frac{\log\left(\frac{B}{A}\right)}{\log\left(\frac{I_f}{I_r}\right)} = -2.2609$$

(Equation 91)

I_r	Rated operating current = 630 A
I_f	Rated fault current = 16 kA
A	Op number rated = 30000
B	Op number fault = 20

Calculation for estimating the remaining life

The equation shows that there are 30,000 possible operations at the rated operating current of 630 A and 20 operations at the rated fault current 16 kA. Therefore, if the tripping current is 10 kA, one operation at 10 kA is equivalent to 30,000/500=60 operations at the rated current. It is also assumed that prior to this tripping, the remaining life of the circuit breaker is 15,000 operations. Therefore, after one operation of 10 kA, the remaining life of the circuit breaker is 15,000-60=14,940 at the rated operating current.

Spring charged indication

For normal operation of the circuit breaker, the circuit breaker spring should be charged within a specified time. Therefore, detecting long spring charging time indicates that it is time for the circuit breaker maintenance. The last value of the spring charging time can be used as a service value.

Gas pressure supervision

The gas pressure supervision monitors the gas pressure inside the arc chamber. When the pressure becomes too low compared to the required value, the circuit breaker operations are locked. A binary input is available based on the pressure levels in the function, and alarms are generated based on these inputs.

Section 13 Metering

13.1 Pulse counter PCGGIO

13.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Pulse counter	PCGGIO		-

13.1.2 Application

Pulse counter (PCGGIO) function counts externally generated binary pulses, for instance pulses coming from an external energy meter, for calculation of energy consumption values. The pulses are captured by the binary input module (BIO), and read by the PCGGIO function. The number of pulses in the counter is then reported via the station bus to the substation automation system or read via the station monitoring system as a service value. When using IEC 61850, a scaled service value is available over the station bus.

The normal use for this function is the counting of energy pulses from external energy meters. An optional number of inputs from the binary input module in IED can be used for this purpose with a frequency of up to 10 Hz. PCGGIO can also be used as a general purpose counter.

13.1.3 Setting guidelines

From PCM600, these parameters can be set individually for each pulse counter:

- *Operation: Off/On*
- *tReporting: 0-3600s*
- *EventMask: NoEvents/ReportEvents*

The configuration of the inputs and outputs of PCGGIO function block is made with PCM600.

On the binary input output module (BIO), the debounce filter default time is set to 5 ms, that is, the counter suppresses pulses with a pulse length less than 5 ms. The

binary input channels on the binary input output module (BIO) have individual settings for debounce time, oscillation count and oscillation time. The values can be changed in the local HMI and PCM600 under **Main menu/Configuration/I/O modules**

The setting isindividual for all input channels on the binary input output module (BIO), that is, if changes of the limits are made for inputs not connected to the pulse counter, it will not influence the inputs used for pulse counting.

13.2 Energy calculation and demand handling EPTMMTR

13.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Energy calculation and demand handling	ETPMMTR	Wh↔	-

13.2.2 Application

Energy calculation and demand handling function ETPMMTR is intended for statistics of the forward and reverse active and reactive energy. It has a high accuracy basically given by the measurements function (CVMMXN). This function has a site calibration possibility to further increase the total accuracy.

The function is connected to the instantaneous outputs of (CVMMXN) as shown in figure 135.

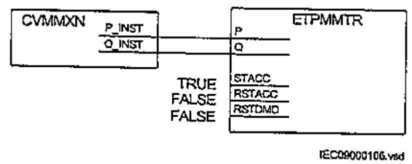

Figure 135: Connection of energy calculation and demand handling function ETPMMTR to the measurements function (CVMMXN)

The energy values can be read through communication in MWh and MVarh in monitoring tool of PCM600 and/or alternatively the values can be presented on the local HMI. The local HMI graphical display is configured with PCM600 Graphical display editor tool (GDE) with a measuring value which is selected to the active and reactive component as preferred. All four values can also be presented.

Maximum demand values are presented in MWh or MVarh in the same way.

Alternatively, the values can be presented with use of the pulse counters function (PCGGIO). The output values are scaled with the pulse output setting values *EAFAccPlsQty*, *EARAccPlsQty*, *ERFAccPlsQty* and *ERRAccPlsQty* of the energy metering function and then the pulse counter can be set-up to present the correct values by scaling in this function. Pulse counter values can then be presented on the local HMI in the same way and/or sent to the SA system through communication where the total energy then is calculated by summation of the energy pulses. This principle is good for very high values of energy as the saturation of numbers else will limit energy integration to about one year with 50 kV and 3000 A. After that the accumulation will start on zero again.

13.2.3 Setting guidelines

The parameters are set via the local HMI or PCM600.

The following settings can be done for the energy calculation and demand handling function ETPMMTR:

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Operation: *Off/On*

tEnergy: Time interval when energy is measured.

StartAcc: *Off/On* is used to switch the accumulation of energy on and off.

The input signal STACC is used to start accumulation. Input signal STACC cannot be used to halt accumulation. The energy content is reset every time STACC is activated. STACC can for example, be used when an external clock is used to switch two active energy measuring function blocks on and off to have indication of two tariffs.

tEnergyOnPls: gives the pulse length ON time of the pulse. It should be at least *100* ms when connected to the Pulse counter function block. Typical value can be *100* ms.

tEnergyOffPls: gives the OFF time between pulses. Typical value can be *100* ms.

EAFAccPlsQty and *EARAccPlsQty*: gives the MWh value in each pulse. It should be selected together with the setting of the Pulse counter (PCGGIO) settings to give the correct total pulse value.

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ERFAccPlsQty and *ERRAccPlsQty*: gives the MVarh value in each pulse. It should be selected together with the setting of the Pulse counter (PCGGIO) settings to give the correct total pulse value.

For the advanced user there are a number of settings for direction, zero clamping, max limit, and so on. Normally, the default values are suitable for these parameters.

Section 14 Station communication

14.1 IEC61850-8-1 communication protocol

14.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IEC 61850-8-1 communication protocol	IEC 61850-8-1	-	-

14.1.2 Application

IEC 61850-8-1 communication protocol allows vertical communication to HSI clients and allows horizontal communication between two or more intelligent electronic devices (IEDs) from one or several vendors to exchange information and to use it in the performance of their functions and for correct co-operation.

GOOSE (Generic Object Oriented Substation Event), which is a part of IEC 61850–8–1 standard, allows the IEDs to communicate state and control information amongst themselves, using a publish-subscribe mechanism. That is, upon detecting an event, the IED(s) use a multi-cast transmission to notify those devices that have registered to receive the data. An IED can, by publishing a GOOSE message, report its status. It can also request a control action to be directed at any device in the network.

Figure 136 shows the topology of an IEC 61850–8–1 configuration. IEC 61850–8–1 specifies only the interface to the substation LAN. The LAN itself is left to the system integrator.

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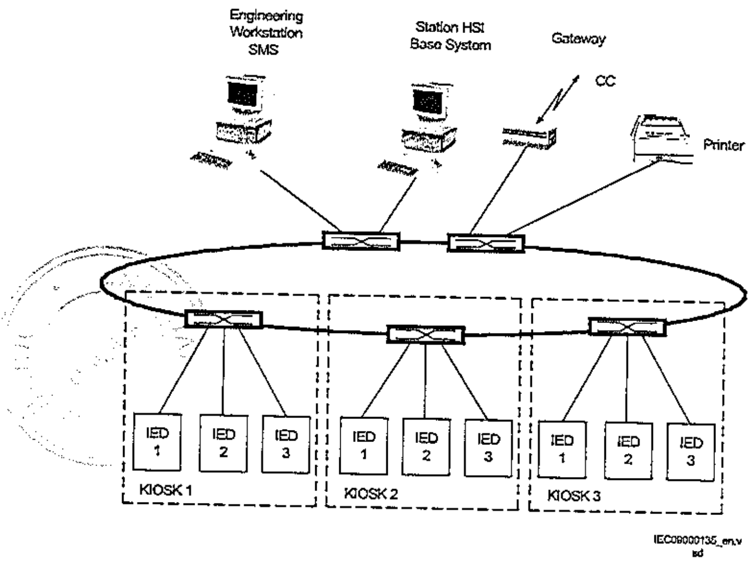

Figure 136: Example of a communication system with IEC 61850

Figure 137 shows the GOOSE peer-to-peer communication.

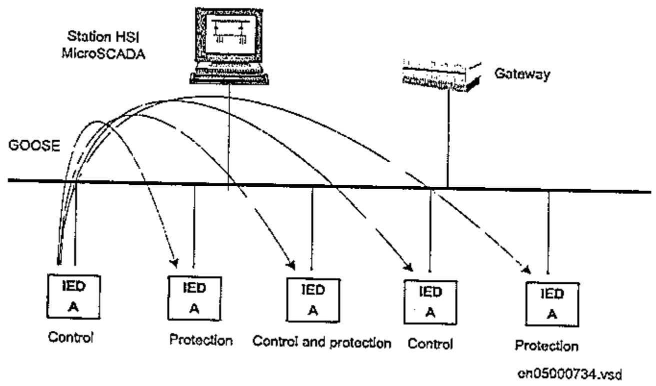

Figure 137: Example of a broadcasted GOOSE message

14.1.2.1 Horizontal communication via GOOSE

GOOSE messages are sent in horizontal communication between the IEDs. The information, which is exchanged, is used for station wide interlocking, breaker failure protection, busbar voltage selection and so on.

The simplified principle is shown in Figure 138 and can be described as follows. When IED1 has decided to transmit the data set it forces a transmission via the station bus. All other IEDs will receive the data set, but only those who have this data set in their address list will take it and keeps it in a input container. It is defined, that the receiving IED will take the content of the received data set and makes it available for the application configuration.

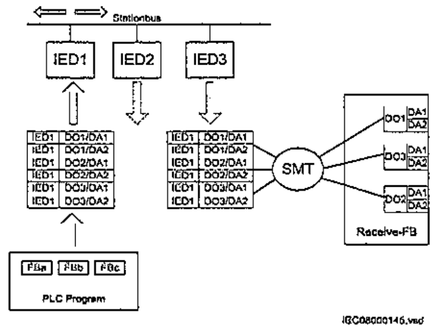

Figure 138: SMT: GOOSE principle and signal routing with SMT

Special function blocks take the data set and present it via the function block as output signals for application functions in the application configuration. Different GOOSE receive function blocks are available for the specific tasks.

SMT links the different data object attributes (for example stVal or magnitude) to the output signal to make it available for functions in the application configuration. When a matrix cell array is marked red the IEC 61850 data attribute type does not fit together, even if the GOOSE receive function block is the partner. SMT checks this on the content of the received data set. See Figure 139

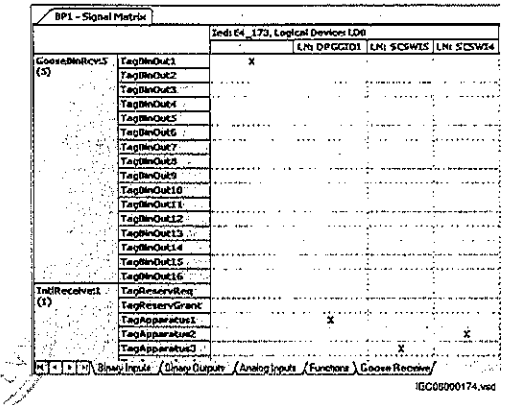

Figure 139: SMT: GOOSE marshalling with SMT

GOOSE receive function blocks extract process information, received by the data set, into single attribute information that can be used within the application configuration. Crosses in the SMT matrix connect received values to the respective function block signal in SMT, see Figure 140

The corresponding quality attribute is automatically connected by SMT. This quality attribute is available in ACT, through the outputs of the available GOOSE function blocks.

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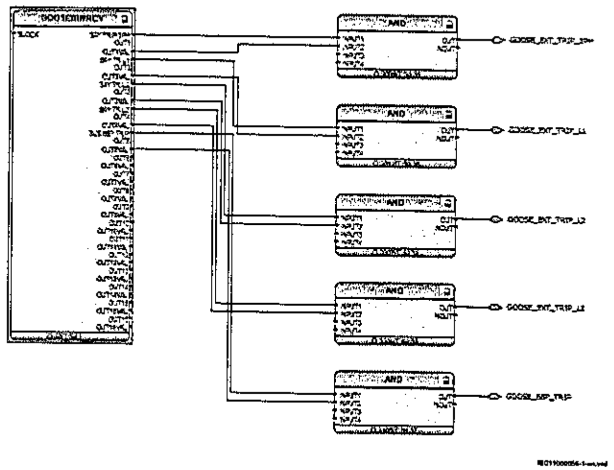

Figure 140: *SMT: GOOSE receive function block with converted signals*

14.1.3 Setting guidelines

There are two settings related to the IEC 61850–8–1 protocol:

Operation User can set IEC 61850 communication to *On* or *Off*.

GOOSE has to be set to the Ethernet link where GOOSE traffic shall be send and received.

IEC 61850–8–1 specific data (logical nodes etc.) per included function in an IED can be found in the communication protocol manual for IEC 61850.

DNP3 protocol

DNP3 (Distributed Network Protocol) is a set of communications protocols used to communicate data between components in process automation systems. For a detailed description of the DNP3 protocol, see the DNP3 Communication protocol manual.

14.3 IEC 60870-5-103 communication protocol

IEC 60870-5-103 is an unbalanced (master-slave) protocol for coded-bit serial communication exchanging information with a control system, and with a data transfer rate up to 38400 bit/s. In IEC terminology, a primary station is a master and a secondary station is a slave. The communication is based on a point-to-point principle. The master must have software that can interpret IEC 60870-5-103 communication messages.

The Communication protocol manual for IEC 60870-5-103 includes the 650 series vendor-specific IEC 60870-5-103 implementation.

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Section 15 Basic IED functions

15.1 Self supervision with internal event list

15.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Internal error signal	INTERRSIG	-	-
Internal event list	SELFSUPEVLST	-	-

15.1.2 Application

The protection and control IEDs have many included functions. Self supervision with internal event list (SELFSUPEVLST) and internal error signals (INTERRSIG) function provide supervision of the IED. The fault signals make it easier to analyze and locate a fault.

Both hardware and software supervision is included and it is also possible to indicate possible faults through a hardware contact on the power supply module and/or through the software communication.

Internal events are generated by the built-in supervisory functions. The supervisory functions supervise the status of the various modules in the IED and, in case of failure, a corresponding event is generated. Similarly, when the failure is corrected, a corresponding event is generated.

Apart from the built-in supervision of the various modules, events are also generated when the status changes for the:

- built-in real time clock (in operation/out of order).
- external time synchronization (in operation/out of order).
- Change lock (on/off)

Events are also generated:

- whenever any setting in the IED is changed.

The internal events are time tagged with a resolution of 1 ms and stored in a list. The list can store up to 40 events. The list is based on the FIFO principle, that is, when it is full, the oldest event is overwritten. The list can be cleared via the local HMI .

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The list of internal events provides valuable information, which can be used during commissioning and fault tracing.

The list of internal events can be found in the LHMI or viewed in PCM600 using the Event viewer tool.

15.2 Time synchronization

15.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time synchronization	TIMESYNCHGEN	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time system, summer time begins	DSTBEGIN	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time system, summer time ends	DSTEND	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time synchronization via IRIG-B	IRIG-B	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time synchronization via SNTP	SNTP	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time zone from UTC	TIMEZONE	-	-

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15.2.2 Application

Use time synchronization to achieve a common time base for the IEDs in a protection and control system. This makes comparison of events and disturbance data between all IEDs in the system possible.

Time-tagging of internal events and disturbances are an excellent help when evaluating faults. Without time synchronization, only the events within the IED can be compared to one another. With time synchronization, events and disturbances within the entire station, and even between line ends, can be compared at evaluation.

In the IED, the internal time can be synchronized from a number of sources:

- SNTP
- IRIG-B
- DNP
- IEC60870-5-103

Micro SCADA OPC server should not be used as a time synchronization source.

15.2.3 Setting guidelines

System time
The time is set with years, month, day, hour, minute and second.

Synchronization
The setting parameters for the real-time clock with external time synchronization (TIME) are set via local HMI or PCM600.

TimeSynch
When the source of the time synchronization is selected on the local HMI, the parameter is called *TimeSynch*. The time synchronization source can also be set from PCM600. The setting alternatives are:

FineSyncSource which can have the following values:

- *Off*
- *SNTP*
- *IRIG-B*

CoarseSyncSrc which can have the following values:

- *Off*
- *SNTP*
- *DNP*
- *IEC60870-5-103*

The system time can be set manually, either via the local HMI or via any of the communication ports. The time synchronization fine tunes the clock.

IEC 60870-5-103 time synchronization
An IED with IEC 60870-5-103 protocol can be used for time synchronization, but for accuracy reasons, it is not recommended. In some cases, however, this kind of synchronization is needed, for example, when no other synchronization is available.

First, set the IED to be synchronized via IEC 60870-5-103 either from **IED Configuration/Time/Synchronization/TIMESYNCHGEN:1** in PST or from the local HMI.

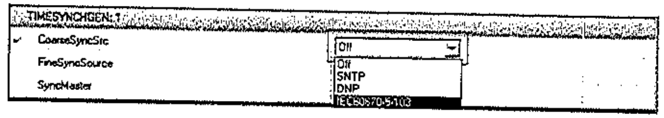

Figure 141: Settings under TIMESYNCHGEN:1 in PST

Only *CoarseSyncSrc* can be set to IEC 60870-5-103, not *FineSyncSource*.

After setting up the time synchronization source, the user must check and modify the IEC 60870-5-103 time synchronization specific settings, under: **IED Configuration/Communication/Station communication/IEC60870-5-103:1**.

- *MasterTimeDomain* specifies the format of the time sent by the master. Format can be:
  - Coordinated Universal Time (UTC)
  - Local time set in the master (Local)
  - Local time set in the master adjusted according to daylight saving time (Local with DST)
- *TimeSyncMode* specifies the time sent by the IED. The time synchronisation is done using the following ways:
  - *IEDTime*: The IED sends the messages with its own time.
  - *LinMasTime*: The IED measures the offset between its own time and the master time, and applies the same offset for the messages sent as in the *IEDTimeSkew*. But in *LinMasTime* it applies the time changes occurred between two synchronised messages.
  - *IEDTimeSkew*: The IED measures the offset in between its own time and the master time and applies the same offset for the messages sent.
- *EvalTimeAccuracy* evaluates time accuracy for invalid time. Specifies the accuracy of the synchronization (5, 10, 20 or 40 ms). If the accuracy is worse than the specified value, the "Bad Time" flag is raised. To accommodate those masters that are really bad in time sync, the *EvalTimeAccuracy* can be set to *Off*.

According to the standard, the "Bad Time" flag is reported when synchronization has been omitted in the protection for >23 h.

15.3 Parameter setting group handling

15.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Setting group handling	SETGRPS	-	-
Parameter setting groups	ACTVGRP	-	-

15.3.2 Application

Four sets of settings are available to optimize IED operation for different system conditions. By creating and switching between fine tuned setting sets, either from the local HMI or configurable binary inputs, results in a highly adaptable IED that can cope with a variety of system scenarios.

Different conditions in networks with different voltage levels require highly adaptable protection and control units to best provide for dependability, security and selectivity requirements. Protection units operate with a higher degree of availability, especially, if the setting values of their parameters are continuously optimized according to the conditions in the power system.

Operational departments can plan for different operating conditions in the primary equipment. The protection engineer can prepare the necessary optimized and pre-tested settings in advance for different protection functions. Four different groups of setting parameters are available in the IED. Any of them can be activated through the different programmable binary inputs by means of external or internal control signals.

15.3.3 Setting guidelines

The setting *ActiveSetGrp*, is used to select which parameter group to be active. The active group can also be selected with configured input to the function block ACTVGRP.

The parameter *MaxNoSetGrp* defines the maximum number of setting groups in use to switch between. Only the selected number of setting groups will be available in the Parameter Setting tool (PST) for activation with the ACTVGRP function block.

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15.4 Test mode functionality TESTMODE

15.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Test mode functionality	TESTMODE	-	-

15.4.2 Application

The protection and control IEDs have a complex configuration with many included functions. To make the testing procedure easier, the IEDs include the feature that allows individual blocking of a single-, several-, or all functions.

This means that it is possible to see when a function is activated or trips. It also enables the user to follow the operation of several related functions to check correct functionality and to check parts of the configuration, and so on.

15.4.3 Setting guidelines

Remember always that there are two possible ways to place the IED in the "Test mode: On" state. If, the IED is set to normal operation (*TestMode = Off*), but the functions are still shown being in the test mode, the input signal INPUT on the TESTMODE function block might be activated in the configuration.

Forcing of binary output signals is only possible when the IED is in test mode.

15.5 Change lock CHNGLCK

15.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Change lock function	CHNGLCK	-	-

15.5.2 Application

Change lock function CHNGLCK is used to block further changes to the IED configuration once the commissioning is complete. The purpose is to make it impossible to perform inadvertent IED configuration changes beyond a certain point in time.

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However, when activated, CHNGLCK will still allow the following changes of the IED state that does not involve reconfiguring of the IED:

- Monitoring
- Reading events
- Resetting events
- Reading disturbance data
- Clear disturbances
- Reset LEDs
- Reset counters and other runtime component states
- Control operations
- Set system time
- Enter and exit from test mode
- Change of active setting group

The binary input controlling the function is defined in ACT or SMT. The CHNGLCK function is configured using ACT.

LOCK	Binary input signal that will activate/deactivate the function, defined in ACT or SMT.
ACTIVE	Output status signal
OVERRIDE	Set if function is overridden

When CHNGLCK has a logical one on its input, then all attempts to modify the IED configuration will be denied and the message "Error: Changes blocked" will be displayed on the local HMI; in PCM600 the message will be "Operation denied by active ChangeLock". The CHNGLCK function should be configured so that it is controlled by a signal from a binary input card. This guarantees that by setting that signal to a logical zero, CHNGLCK is deactivated. If any logic is included in the signal path to the CHNGLCK input, that logic must be designed so that it cannot permanently issue a logical one on the CHNGLCK input. If such a situation would occur in spite of these precautions, then please contact the local ABB representative for remedial action.

15.5.3 Setting guidelines

The Change lock function CHNGLCK does not have any parameters available in the local HMI or PCM600.

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15.6 IED identifiers TERMINALID

15.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IED identifiers	TERMINALID	-	-

15.6.2 Application

15.6.2.1 Customer specific settings

The customer specific settings are used to give the IED a unique name and address. The settings are used by a central control system to communicate with the IED. The customer specific identifiers are found in the local HMI under **Configuration/ Power system/Identifiers/TERMINALID**

The settings can also be made from PCM600. For more information about the available identifiers, see the technical manual.

Use only characters A - Z, a - z and 0 - 9 in station, unit and object names.

15.7 Product information PRODINF

15.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Product information	PRODINF	-	-

15.7.2 Application

15.7.2.1 Factory defined settings

The factory defined settings are very useful for identifying a specific version and very helpful in the case of maintenance, repair, interchanging IEDs between different Substation Automation Systems and upgrading. The factory made settings can not be changed by the customer. They can only be viewed. The settings are found in the local HMI under **Main menu/Diagnostics/IED status/Product identifiers**

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The following identifiers are available:

- IEDProdType
  - Describes the type of the IED (like REL, REC or RET. Example: *REL650*
- ProductDef
  - Describes the release number, from the production. Example: *1.1.0.A1*
- ProductVer
  - Describes the product version. Example: *1.1.0*
- SerialNo
- OrderingNo
- ProductionDate

15.8 Primary system values PRIMVAL

15.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Primary system values	PRIMVAL	-	-

15.8.2 Application

The rated system frequency and phasor rotation are set under **Main menu/ Configuration/ Power system/ Primary values/PRIMVAL** in the local HMI and PCM600 parameter setting tree.

15.9 Signal matrix for analog inputs SMAI

15.9.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Signal matrix for analog inputs	SMAI_20_1	-	-

15.9.2 Application

Signal matrix for analog inputs function SMAI (or the pre-processing function) is used within PCM600 in direct relation with the Signal Matrix tool or the Application Configuration tool. Signal Matrix tool represents the way analog inputs are brought in for one IED configuration.

15.9.3 Setting guidelines

The parameters for the signal matrix for analog inputs (SMAI) functions are set via the local HMI, PCM600.

Every SMAI function block can receive four analog signals (three phases and one neutral value), either voltage or current. SMAI outputs give information about every aspect of the 3ph analog signals acquired (phase angle, RMS value, frequency and frequency derivates, and so on – 244 values in total). Besides the block "group name", the analog inputs type (voltage or current) and the analog input names that can be set directly in ACT.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

DFTRefExtOut: Parameter valid for function block SMAI_20_1:1, SMAI_20_1:2 and SMAI_80_1 only. Reference block for external output (SPFCOUT function output).

DFTReference: Reference DFT for the block.

These DFT reference block settings decide DFT reference for DFT calculations (*InternalDFTRef* will use fixed DFT reference based on set system frequency. *DFTRefGrpn* will use DFT reference from the selected group block, when own group selected adaptive DFT reference will be used based on calculated signal frequency from own group.*ExternalDFTRef* will use reference based on input DFTSPFC.

ConnectionType: Connection type for that specific instance (n) of the SMAI (if it is *Ph-N* or *Ph-Ph*). Depending on connection type setting the not connected *Ph-N* or *Ph-Ph* outputs will be calculated.

Negation: If the user wants to negate the 3ph signal, it is possible to choose to negate only the phase signals *Negate3Ph*, only the neutral signal *NegateN* or both *Negate3Ph+N*; negation means rotation with 180° of the vectors.

MinValFreqMeas: The minimum value of the voltage for which the frequency is calculated, expressed as percent of GlobeBasUaGrp(n) (for each instance n).

> Settings *DFTRefExtOut* and *DFTReference* shall be set to default value *InternalDFTRef* if no VT inputs are available.

Example of adaptive frequency tracking

Task time group 1	
SMAI instance	3 phase group
SMAI_20_1:1	1
SMAI_20_2:1	2
SMAI_20_3:1	3
SMAI_20_4:1	4
SMAI_20_5:1	5
SMAI_20_6:1	6
SMAI_20_7:1	7
SMAI_20_8:1	8
SMAI_20_9:1	9
SMAI_20_10:1	10
SMAI_20_11:1	11
SMAI_20_12:1	12

DFTRefGrp7

Task time group 2	
SMAI instance	3 phase group
SMAI_20_1:2	1
SMAI_20_2:2	2
SMAI_20_3:2	3
SMAI_20_4:2	4
SMAI_20_5:2	5
SMAI_20_6:2	6
SMAI_20_7:2	7
SMAI_20_8:2	8
SMAI_20_9:2	9
SMAI_20_10:2	10
SMAI_20_11:2	11
SMAI_20_12:2	12

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Figure 142: SMAI instances as organized in different task time groups and the corresponding parameter numbers

The example shows a situation with adaptive frequency tracking with one reference selected for all instances. In practice each instance can be adapted to the needs of the actual application.

Example 1

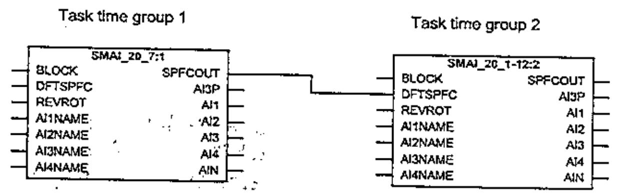

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Figure 143: Configuration for using an instance in task time group 1 as DFT reference

Assume instance SMAI_20_7:1 in task time group 1 has been selected in the configuration to control the frequency tracking (For the SMAI_20_x task time groups). Observe that the selected reference instance must be a voltage type.

For task time group 1 this gives the following settings (see Figure 142 for numbering):

SMAI_20_7:1: *DFTRefExtOut* = *DFTRefGrp7* to route SMAI_20_7:1 reference to the SPFCOUT output, *DFTReference* = *DFTRefGrp7* for SMAI_20_7:1 to use SMAI_20_7:1 as reference (see Figure 143). .

SMAI_20_2:1 - SMAI_20_12:1 *DFTReference* = *DFTRefGrp7* for SMAI_20_2:1 - SMAI_20_12:1 to use SMAI_20_7:1 as reference.

For task time group 2 this gives the following settings:

SMAI_20_1:2 - SMAI_20_12:2 *DFTReference* = *ExternalDFTRef* to use DFTSPFC input as reference (SMAI_20_7:1)

15.10 Summation block 3 phase 3PHSUM

15.10.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Summation block 3 phase	3PHSUM	-	-

15.10.2 Application

Summation block 3 phase function 3PHSUM is used to get the sum of two sets of three-phase analog signals (of the same type) for those IED functions that might need it.

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15.10.3 Setting guidelines

The summation block receives the three-phase signals from SMAI blocks. The summation block has several settings.

Common base IED values for primary current (*IBase*), primary voltage (*UBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

SummationType: Summation type (*Group 1 + Group 2*, *Group 1 - Group 2*, *Group 2 - Group 1* or *–(Group 1 + Group 2)*).

DFTReference: The reference DFT block (*InternalDFT Ref*,*DFTRefGrp1* or *External DFT ref*) .

FreqMeasMinVal: The minimum value of the voltage for which the frequency is calculated, expressed as percent of *UBase* (for each instance x).

15.11 Global base values GBASVAL

15.11.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Global base values	GBASVAL	-	-

15.11.2 Application

Global base values function (GBASVAL) is used to provide global values, common for all applicable functions within the IED. One set of global values consists of values for current, voltage and apparent power and it is possible to have six different sets.

This is an advantage since all applicable functions in the IED use a single source of base values. This facilitates consistency throughout the IED and also facilitates a single point for updating values when necessary.

Each applicable function in the IED has a parameter, *GlobalBaseSel*, defining one out of the six sets of GBASVAL functions.

15.11.3 Setting guidelines

UBase: Phase-to-phase voltage value to be used as a base value for applicable functions throughout the IED.

IBase: Phase current value to be used as a base value for applicable functions throughout the IED.

SBase: Standard apparent power value to be used as a base value for applicable functions throughout the IED, typically $SBase = \sqrt{3} \cdot UBase \cdot IBase$.

15.12 Authority check ATHCHCK

15.12.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Authority check	ATHCHCK	-	-

15.12.2 Application

To safeguard the interests of our customers, both the IED and the tools that are accessing the IED are protected, by means of authorization handling. The authorization handling of the IED and the PCM600 is implemented at both access points to the IED:

- local, through the local HMI
- remote, through the communication ports

15.12.2.1 Authorization handling in the IED

At delivery the default user is the SuperUser. No Log on is required to operate the IED until a user has been created with the User Management Tool.

Once a user is created and written to the IED, that user can perform a Log on, using the password assigned in the tool. Then the default user will be Guest.

If there is no user created, an attempt to log on will display a message box: "No user defined!"

If one user leaves the IED without logging off, then after the timeout (set in **Main menu/Configuration/HMI/Screen/1:SCREEN**) elapses, the IED returns to Guest state, when only reading is possible. By factory default, the display timeout is set to 60 minutes.

If one or more users are created with the User Management Tool and written to the IED, then, when a user attempts a Log on by pressing the key or when the user attempts to perform an operation that is password protected, the Log on window opens.

The cursor is focused on the User identity field, so upon pressing the key, one can change the user name, by browsing the list of users, with the "up" and "down" arrows. After choosing the right user name, the user must press the key again. When it comes to password, upon pressing the key, the following characters will show up: "********". The user must scroll for every letter in the password. After all the letters are introduced (passwords are case sensitive) choose OK and press the key again.

At successful Log on, the local HMI shows the new user name in the status bar at the bottom of the LCD. If the Log on is OK, when required to change for example a password protected setting, the local HMI returns to the actual setting folder. If the Log on has failed, an "Error Access Denied" message opens. If a user enters an incorrect password three times, that user will be blocked for ten minutes before a new attempt to log in can be performed. The user will be blocked from logging in, both from the local HMI and PCM600. However, other users are to log in during this period.

15.13 Authority status ATHSTAT

15.13.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Authority status	ATHSTAT	-	-

15.13.2 Application

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Authority status (ATHSTAT) function is an indication function block, which informs about two events related to the IED and the user authorization:

- the fact that at least one user has tried to log on wrongly into the IED and it was blocked (the output USRBLKED)
- the fact that at least one user is logged on (the output LOGGEDON)

The two outputs of ATHSTAT function can be used in the configuration for different indication and alarming reasons, or can be sent to the station control for the same purpose.

15.14 Denial of service

15.14.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Denial of service, frame rate control for front port	DOSFRNT	-	-

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Denial of service, frame rate control for LAN1 port	DOSLAN1	-	-

15.14.2 Application

The denial of service functions (DOSFRNT,DOSLAN1 and DOSSCKT) are designed to limit the CPU load that can be produced by Ethernet network traffic on the IED. The communication facilities must not be allowed to compromise the primary functionality of the device. All inbound network traffic will be quota controlled so that too heavy network loads can be controlled. Heavy network load might for instance be the result of malfunctioning equipment connected to the network.

DOSFRNT, DOSLAN1 and DOSSCKT measures the IED load from communication and, if necessary, limit it for not jeopardizing the IEDs control and protection functionality due to high CPU load. The function has the following outputs:

- LINKUP indicates the Ethernet link status
- WARNING indicates that communication (frame rate) is higher than normal
- ALARM indicates that the IED limits communication

15.14.3 Setting guidelines

The function does not have any parameters available in the local HMI or PCM600.

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Section 16 Requirements

16.1 Current transformer requirements

The performance of a protection function will depend on the quality of the measured current signal. Saturation of the current transformer (CT) will cause distortion of the current signal and can result in a failure to operate or cause unwanted operations of some functions. Consequently CT saturation can have an influence on both the dependability and the security of the protection. This protection IED has been designed to permit heavy CT saturation with maintained correct operation.

16.1.1 Current transformer classification

To guarantee correct operation, the current transformers (CTs) must be able to correctly reproduce the current for a minimum time before the CT will begin to saturate. To fulfill the requirement on a specified time to saturation the CTs must fulfill the requirements of a minimum secondary e.m.f. that is specified below.

There are several different ways to specify CTs. Conventional magnetic core CTs are usually specified and manufactured according to some international or national standards, which specify different protection classes as well. There are many different standards and a lot of classes but fundamentally there are three different types of CTs:

- High remanence type CT
- Low remanence type CT
- Non remanence type CT

The high remanence type has no limit for the remanent flux. This CT has a magnetic core without any airgap and a remanent flux might remain almost infinite time. In this type of transformers the remanence can be up to around 80% of the saturation flux. Typical examples of high remanence type CT are class P, PX, TPS, TPX according to IEC, class P, X according to BS (old British Standard) and non gapped class C, K according to ANSI/IEEE.

The low remanence type has a specified limit for the remanent flux. This CT is made with a small air gap to reduce the remanence to a level that does not exceed 10% of the saturation flux. The small air gap has only very limited influences on the other properties of the CT. Class PR, TPY according to IEC are low remanence type CTs.

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The non remanence type CT has practically negligible level of remanent flux. This type of CT has relatively big air gaps in order to reduce the remanence to practically zero level. In the same time, these air gaps reduce the influence of the DC-component from the primary fault current. The air gaps will also decrease the measuring accuracy in the non-saturated region of operation. Class TPZ according to IEC is a non remanence type CT.

Different standards and classes specify the saturation e.m.f. in different ways but it is possible to approximately compare values from different classes. The rated equivalent limiting secondary e.m.f. E_{al} according to the IEC 60044 – 6 standard is used to specify the CT requirements for the IED. The requirements are also specified according to other standards.

16.1.2 Conditions

The requirements are a result of investigations performed in our network simulator. The current transformer models are representative for current transformers of high remanence and low remanence type. The results may not always be valid for non remanence type CTs (TPZ).

The performances of the protection functions have been checked in the range from symmetrical to fully asymmetrical fault currents. Primary time constants of at least 120 ms have been considered at the tests. The current requirements below are thus applicable both for symmetrical and asymmetrical fault currents.

Depending on the protection function phase-to-earth, phase-to-phase and three-phase faults have been tested for different relevant fault positions for example, close in forward and reverse faults, zone 1 reach faults, internal and external faults. The dependability and security of the protection was verified by checking for example, time delays, unwanted operations, directionality, overreach and stability.

The remanence in the current transformer core can cause unwanted operations or minor additional time delays for some protection functions. As unwanted operations are not acceptable at all maximum remanence has been considered for fault cases critical for the security, for example, faults in reverse direction and external faults. Because of the almost negligible risk of additional time delays and the non-existent risk of failure to operate the remanence have not been considered for the dependability cases. The requirements below are therefore fully valid for all normal applications.

It is difficult to give general recommendations for additional margins for remanence to avoid the minor risk of an additional time delay. They depend on the performance and economy requirements. When current transformers of low remanence type (for example, TPY, PR) are used, normally no additional margin is needed. For current transformers of high remanence type (for example, P, PX, TPS, TPX) the small probability of fully asymmetrical faults, together with high remanence in the same direction as the flux generated by the fault, has to be kept in mind at the decision of an additional margin. Fully asymmetrical fault current will be achieved when the fault occurs at approximately zero voltage (0°).

Investigations have shown that 95% of the faults in the network will occur when the voltage is between 40° and 90°. In addition fully asymmetrical fault current will not exist in all phases at the same time.

16.1.3 Fault current

The current transformer requirements are based on the maximum fault current for faults in different positions. Maximum fault current will occur for three-phase faults or single phase-to-earth faults. The current for a single phase-to-earth fault will exceed the current for a three-phase fault when the zero sequence impedance in the total fault loop is less than the positive sequence impedance.

When calculating the current transformer requirements, maximum fault current for the relevant fault position should be used and therefore both fault types have to be considered.

16.1.4 Secondary wire resistance and additional load

The voltage at the current transformer secondary terminals directly affects the current transformer saturation. This voltage is developed in a loop containing the secondary wires and the burden of all relays in the circuit. For earth faults the loop includes the phase and neutral wire, normally twice the resistance of the single secondary wire. For three-phase faults the neutral current is zero and it is just necessary to consider the resistance up to the point where the phase wires are connected to the common neutral wire. The most common practice is to use four wires secondary cables so it normally is sufficient to consider just a single secondary wire for the three-phase case.

The conclusion is that the loop resistance, twice the resistance of the single secondary wire, must be used in the calculation for phase-to-earth faults and the phase resistance, the resistance of a single secondary wire, may normally be used in the calculation for three-phase faults.

As the burden can be considerable different for three-phase faults and phase-to-earth faults it is important to consider both cases. Even in a case where the phase-to-earth fault current is smaller than the three-phase fault current the phase-to-earth fault can be dimensioning for the CT depending on the higher burden.

In isolated or high impedance earthed systems the phase-to-earth fault is not the dimensioning case and therefore the resistance of the single secondary wire always can be used in the calculation, for this case.

16.1.5 General current transformer requirements

The current transformer ratio is mainly selected based on power system data for example, maximum load. However, it should be verified that the current to the protection is higher than the minimum operating value for all faults that are to be

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detected with the selected CT ratio. The minimum operating current is different for different functions and normally settable so each function should be checked.

The current error of the current transformer can limit the possibility to use a very sensitive setting of a sensitive residual overcurrent protection. If a very sensitive setting of this function will be used it is recommended that the current transformer should have an accuracy class which have an current error at rated primary current that is less than ±1% (for example, 5P). If current transformers with less accuracy are used it is advisable to check the actual unwanted residual current during the commissioning.

16.1.6 Rated equivalent secondary e.m.f. requirements

With regard to saturation of the current transformer all current transformers of high remanence and low remanence type that fulfill the requirements on the rated equivalent secondary e.m.f. E_{al} below can be used. The characteristic of the non remanence type CT (TPZ) is not well defined as far as the phase angle error is concerned. If no explicit recommendation is given for a specific function we therefore recommend contacting ABB to confirm that the non remanence type can be used.

The CT requirements for the different functions below are specified as a rated equivalent limiting secondary e.m.f. E_{al} according to the IEC 60044-6 standard. Requirements for CTs specified in different ways are given at the end of this section.

16.1.6.1 Breaker failure protection

The CTs must have a rated equivalent secondary e.m.f. E_{al} that is larger than or equal to the required secondary e.m.f. E_{alreq} below:

$$E_{al} \geq E_{alreq} = 5 \cdot I_{op} \cdot \frac{I_{sn}}{I_{pn}} \cdot \left(R_{CT} + R_L + \frac{S_R}{I_r^2} \right)$$

(Equation 92)

where:

I_{op}	The primary operate value (A)
I_{pn}	The rated primary CT current (A)
I_{sn}	The rated secondary CT current (A)
I_r	The rated current of the protection IED (A)
R_{CT}	The secondary resistance of the CT (Ω)
R_L	The resistance of the secondary cable and additional load (Ω). The loop resistance containing the phase and neutral wires, must be used for faults in solidly earthed systems. The resistance of a single secondary wire should be used for faults in high impedance earthed systems.
S_R	The burden of an IED current input channel (VA). S_R=0.010 VA/channel for I_r=1 A and S_R=0.250 VA/channel for I_r=5 A

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16.1.6.2 Non-directional instantaneous and definitive time, phase and residual overcurrent protection

The CTs must have a rated equivalent secondary e.m.f. E_{al} that is larger than or equal to the required secondary e.m.f. E_{alreq} below:

$$E_{al} \geq E_{alreq} = 1,5 \cdot I_{op} \cdot \frac{I_{sn}}{I_{pn}} \cdot \left(R_{CT} + R_L + \frac{S_R}{I_r^2} \right)$$

(Equation 93)

where:

I_{op}	The primary operate value (A)
I_{pn}	The rated primary CT current (A)
I_{sn}	The rated secondary CT current (A)
I_r	The rated current of the protection IED (A)
R_{CT}	The secondary resistance of the CT (Ω)
R_L	The resistance of the secondary cable and additional load (Ω). The loop resistance containing the phase and neutral wires, must be used for faults in solidly earthed systems. The resistance of a single secondary wire should be used for faults in high impedance earthed systems.
S_R	The burden of an IED current input channel (VA). S_R=0.010 VA/channel for I_r=1 A and S_R=0.250 VA/channel for I_r=5 A

16.1.6.3 Non-directional inverse time delayed phase and residual overcurrent protection

The requirement according to Equation 94 and Equation 95 does not need to be fulfilled if the high set instantaneous or definitive time stage is used. In this case Equation 93 is the only necessary requirement.

If the inverse time delayed function is the only used overcurrent protection function the CTs must have a rated equivalent secondary e.m.f. E_{al} that is larger than or equal to the required secondary e.m.f. E_{alreq} below:

$$E_{al} \geq E_{alreq} = 20 \cdot I_{op} \cdot \frac{I_{sn}}{I_{pn}} \cdot \left(R_{CT} + R_L + \frac{S_R}{I_r^2} \right)$$

(Equation 94)

where

I_{op}	The primary current set value of the inverse time function (A)
I_{pn}	The rated primary CT current (A)
I_{sn}	The rated secondary CT current (A)

Table continues on next page

I_r	The rated current of the protection IED (A)
R_{CT}	The secondary resistance of the CT (Ω)
R_L	The resistance of the secondary cable and additional load (Ω). The loop resistance containing the phase and neutral wires, must be used for faults in solidly earthed systems. The resistance of a single secondary wire should be used for faults in high impedance earthed systems.
S_R	The burden of an IED current input channel (VA). S_R=0.010 VA/channel for I_r=1 A and S_R=0.250 VA/channel for I_r=5 A

Independent of the value of I_{op} the maximum required E_{al} is specified according to the following:

$$E_{al} \geq E_{alreq\,max} = I_{k\,max} \cdot \frac{I_{sn}}{I_{pn}} \cdot \left(R_{CT} + R_L + \frac{S_R}{I_r^2} \right)$$

(Equation 95)

where

I_{kmax}	Maximum primary fundamental frequency current for close-in faults (A)

16.1.6.4 Directional phase and residual overcurrent protection

If the directional overcurrent function is used the CTs must have a rated equivalent secondary e.m.f. E_{al} that is larger than or equal to the required equivalent secondary e.m.f. E_{alreq} below:

$$E_{al} \geq E_{alreq} = I_{k\,max} \cdot \frac{I_{sn}}{I_{pn}} \cdot \left(R_{CT} + R_L + \frac{S_R}{I_r^2} \right)$$

(Equation 96)

where:

I_{kmax}	Maximum primary fundamental frequency current for close-in forward and reverse faults (A)
I_{pn}	The rated primary CT current (A)
I_{sn}	The rated secondary CT current (A)
I_r	The rated current of the protection IED (A)
R_{CT}	The secondary resistance of the CT (Ω)
R_L	The resistance of the secondary cable and additional load (Ω). The loop resistance containing the phase and neutral wires, must be used for faults in solidly earthed systems. The resistance of a single secondary wire should be used for faults in high impedance earthed systems.
S_R	The burden of an IED current input channel (VA). S_r=0.010 VA/channel for I_r=1 A and S_r=0.250 VA/channel for I_r=5 A

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16.1.7 Current transformer requirements for CTs according to other standards

All kinds of conventional magnetic core CTs are possible to use with the IEDs if they fulfill the requirements corresponding to the above specified expressed as the rated equivalent secondary e.m.f. E_{al} according to the IEC 60044-6 standard. From different standards and available data for relaying applications it is possible to approximately calculate a secondary e.m.f. of the CT comparable with E_{al}. By comparing this with the required secondary e.m.f. E_{alreq} it is possible to judge if the CT fulfills the requirements. The requirements according to some other standards are specified below.

16.1.7.1 Current transformers according to IEC 60044-1, class P, PR

A CT according to IEC 60044-1 is specified by the secondary limiting e.m.f. E_{2max}. The value of the E_{2max} is approximately equal to the corresponding E_{al} according to IEC 60044-6. Therefore, the CTs according to class P and PR must have a secondary limiting e.m.f. E_{2max} that fulfills the following:

$$E_{2max} > \max imum\ of\ E_{alreq}$$

(Equation 97)

16.1.7.2 Current transformers according to IEC 60044-1, class PX, IEC 60044-6, class TPS (and old British Standard, class X)

CTs according to these classes are specified approximately in the same way by a rated knee-point e.m.f. E_{knee} (E_k for class PX, E_{kneeBS} for class X and the limiting secondary voltage U_{al} for TPS). The value of the E_{knee} is lower than the corresponding E_{al} according to IEC 60044-6. It is not possible to give a general relation between the E_{knee} and the E_{al} but normally the E_{knee} is approximately 80 % of the E_{al}. Therefore, the CTs according to class PX, X and TPS must have a rated knee-point e.m.f. E_{knee} that fulfills the following:

$$E_{knee} \approx E_k \approx E_{kneeBS} \approx U_{al} > 0.8 \cdot (\text{maximum of } E_{alreq})$$

(Equation 98)

16.1.7.3 Current transformers according to ANSI/IEEE

Current transformers according to ANSI/IEEE are partly specified in different ways. A rated secondary terminal voltage U_{ANSI} is specified for a CT of class C. U_{ANSI} is the secondary terminal voltage the CT will deliver to a standard burden at 20 times rated secondary current without exceeding 10 % ratio correction. There are a number of standardized U_{ANSI} values for example, U_{ANSI} is 400 V for a C400

CT. A corresponding rated equivalent limiting secondary e.m.f. E_{alANSI} can be estimated as follows:

$$E_{alANSI} = |20 \cdot I_{sn} \cdot R_{CT} + U_{ANSI}| = |20 \cdot I_{sn} \cdot R_{CT} + 20 \cdot I_{sn} \cdot Z_{bANSI}|$$

(Equation 99)

where:

Z_{bANSI} The impedance (that is, complex quantity) of the standard ANSI burden for the specific C class (Ω)

U_{ANSI} The secondary terminal voltage for the specific C class (V)

The CTs according to class C must have a calculated rated equivalent limiting secondary e.m.f. E_{alANSI} that fulfills the following:

$$E_{alANSI} > \max imum\ of\ E_{alreq}$$

(Equation 100)

A CT according to ANSI/IEEE is also specified by the knee-point voltage $U_{kneeANSI}$ that is graphically defined from an excitation curve. The knee-point voltage $U_{kneeANSI}$ normally has a lower value than the knee-point e.m.f. according to IEC and BS. $U_{kneeANSI}$ can approximately be estimated to 75 % of the corresponding E_{al} according to IEC 60044 6. Therefore, the CTs according to ANSI/IEEE must have a knee-point voltage $U_{kneeANSI}$ that fulfills the following:

$$E_{kneeANSI} > 0.75 \cdot (\text{maximum of } E_{alreq})$$

(Equation 101)

16.2 Voltage transformer requirements

The performance of a protection function will depend on the quality of the measured input signal. Transients caused by capacitive voltage transformers (CVTs) can affect some protection functions.

Magnetic or capacitive voltage transformers can be used.

The capacitive voltage transformers (CVTs) should fulfill the requirements according to the IEC 60044–5 standard regarding ferro-resonance and transients. The ferro-resonance requirements of the CVTs are specified in chapter 7.4 of the standard.

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The transient responses for three different standard transient response classes, T1, T2 and T3 are specified in chapter 15.5 of the standard. CVTs according to all classes can be used.

The protection IED has effective filters for these transients, which gives secure and correct operation with CVTs.

16.3 SNTP server requirements

16.3.1 SNTP server requirements

The SNTP server to be used is connected to the local network, that is not more than 4-5 switches or routers away from the IED. The SNTP server is dedicated for its task, or at least equipped with a real-time operating system, that is not a PC with SNTP server software. The SNTP server should be stable, that is, either synchronized from a stable source like GPS, or local without synchronization. Using a local SNTP server without synchronization as primary or secondary server in a redundant configuration is not recommended.

Section 17 Glossary

AC	Alternating current
ACT	Application configuration tool within PCM600
A/D converter	Analog-to-digital converter
ADBS	Amplitude deadband supervision
AI	Analog input
ANSI	American National Standards Institute
AR	Autoreclosing
ASCT	Auxiliary summation current transformer
ASD	Adaptive signal detection
AWG	American Wire Gauge standard
BI	Binary input
BOS	Binary outputs status
BR	External bistable relay
BS	British Standards
CAN	Controller Area Network. ISO standard (ISO 11898) for serial communication
CB	Circuit breaker
CCITT	Consultative Committee for International Telegraph and Telephony. A United Nations-sponsored standards body within the International Telecommunications Union.
CCVT	Capacitive Coupled Voltage Transformer
Class C	Protection Current Transformer class as per IEEE/ ANSI
CMPPS	Combined megapulses per second
CMT	Communication Management tool in PCM600
CO cycle	Close-open cycle
Codirectional	Way of transmitting G.703 over a balanced line. Involves two twisted pairs making it possible to transmit information in both directions
COMTRADE	Standard format according to IEC 60255-24
Contra-directional	Way of transmitting G.703 over a balanced line. Involves four twisted pairs, two of which are used for transmitting data in both directions and two for transmitting clock signals

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CPU	Central processor unit
CR	Carrier receive
CRC	Cyclic redundancy check
CROB	Control relay output block
CS	Carrier send
CT	Current transformer
CVT	Capacitive voltage transformer
DAR	Delayed autoreclosing
DARPA	Defense Advanced Research Projects Agency (The US developer of the TCP/IP protocol etc.)
DBDL	Dead bus dead line
DBLL	Dead bus live line
DC	Direct current
DFC	Data flow control
DFT	Discrete Fourier transform
DHCP	Dynamic Host Configuration Protocol
DIP-switch	Small switch mounted on a printed circuit board
DI	Digital input
DLLB	Dead line live bus
DNP	Distributed Network Protocol as per IEEE/ANSI Std. 1379-2000
DR	Disturbance recorder
DRAM	Dynamic random access memory
DRH	Disturbance report handler
DSP	Digital signal processor
DTT	Direct transfer trip scheme
EHV network	Extra high voltage network
EIA	Electronic Industries Association
EMC	Electromagnetic compatibility
EMF	(Electric Motive Force)
EMI	Electromagnetic interference
EnFP	End fault protection
EPA	Enhanced performance architecture
ESD	Electrostatic discharge
FCB	Flow control bit; Frame count bit

FOX 20	Modular 20 channel telecommunication system for speech, data and protection signals
FOX 512/515	Access multiplexer
FOX 6Plus	Compact time-division multiplexer for the transmission of up to seven duplex channels of digital data over optical fibers
G.703	Electrical and functional description for digital lines used by local telephone companies. Can be transported over balanced and unbalanced lines
GCM	Communication interface module with carrier of GPS receiver module
GDE	Graphical display editor within PCM600
GI	General interrogation command
GIS	Gas-insulated switchgear
GOOSE	Generic object-oriented substation event
GPS	Global positioning system
HDLC protocol	High-level data link control, protocol based on the HDLC standard
HFBR connector type	Plastic fiber connector
HMI	Human-machine interface
HSAR	High speed autoreclosing
HV	High-voltage
HVDC	High-voltage direct current
IDBS	Integrating deadband supervision
IEC	International Electrical Committee
IEC 60044-6	IEC Standard, Instrument transformers – Part 6: Requirements for protective current transformers for transient performance
IEC 61850	Substation automation communication standard
IEEE	Institute of Electrical and Electronics Engineers
IEEE 802.12	A network technology standard that provides 100 Mbits/s on twisted-pair or optical fiber cable
IEEE P1386.1	PCI Mezzanine Card (PMC) standard for local bus modules. References the CMC (IEEE P1386, also known as Common Mezzanine Card) standard for the mechanics and the PCI specifications from the PCI SIG (Special Interest Group) for the electrical EMF (Electromotive force).
IED	Intelligent electronic device

I-GIS	Intelligent gas-insulated switchgear
Instance	When several occurrences of the same function are available in the IED, they are referred to as instances of that function. One instance of a function is identical to another of the same kind but has a different number in the IED user interfaces. The word "instance" is sometimes defined as an item of information that is representative of a type. In the same way an instance of a function in the IED is representative of a type of function.
IP	1. Internet protocol. The network layer for the TCP/IP protocol suite widely used on Ethernet networks. IP is a connectionless, best-effort packet-switching protocol. It provides packet routing, fragmentation and reassembly through the data link layer. 2. Ingression protection, according to IEC standard
IP 20	Ingression protection, according to IEC standard, level 20
IP 40	Ingression protection, according to IEC standard, level 40
IP 54	Ingression protection, according to IEC standard, level 54
IRF	Internal failure signal
IRIG-B:	InterRange Instrumentation Group Time code format B, standard 200
ITU	International Telecommunications Union
LAN	Local area network
LIB 520	High-voltage software module
LCD	Liquid crystal display
LDD	Local detection device
LED	Light-emitting diode
MCB	Miniature circuit breaker
MCM	Mezzanine carrier module
MVB	Multifunction vehicle bus. Standardized serial bus originally developed for use in trains.
NCC	National Control Centre
OCO cycle	Open-close-open cycle
OCP	Overcurrent protection
OLTC	On-load tap changer
OV	Over-voltage
Overreach	A term used to describe how the relay behaves during a fault condition. For example, a distance relay is overreaching when the impedance presented to it is smaller than the

	apparent impedance to the fault applied to the balance point, that is, the set reach. The relay "sees" the fault but perhaps it should not have seen it.
PCI	Peripheral component interconnect, a local data bus
PCM	Pulse code modulation
PCM600	Protection and control IED manager
PC-MIP	Mezzanine card standard
PISA	Process interface for sensors & actuators
PMC	PCI Mezzanine card
POR	Permissive overreach
POTT	Permissive overreach transfer trip
Process bus	Bus or LAN used at the process level, that is, in near proximity to the measured and/or controlled components
PSM	Power supply module
PST	Parameter setting tool within PCM600
PT ratio	Potential transformer or voltage transformer ratio
PUTT	Permissive underreach transfer trip
RASC	Synchrocheck relay, COMBIFLEX
RCA	Relay characteristic angle
RFPP	Resistance for phase-to-phase faults
RFPE	Resistance for phase-to-earth faults
RISC	Reduced instruction set computer
RMS value	Root mean square value
RS422	A balanced serial interface for the transmission of digital data in point-to-point connections
RS485	Serial link according to EIA standard RS485
RTC	Real-time clock
RTU	Remote terminal unit
SA	Substation Automation
SBO	Select-before-operate
SC	Switch or push button to close
SCS	Station control system
SCADA	Supervision, control and data acquisition
SCT	System configuration tool according to standard IEC 61850
SDU	Service data unit

SMA connector	Subminiature version A, A threaded connector with constant impedance.
SMT	Signal matrix tool within PCM600
SMS	Station monitoring system
SNTP	Simple network time protocol – is used to synchronize computer clocks on local area networks. This reduces the requirement to have accurate hardware clocks in every embedded system in a network. Each embedded node can instead synchronize with a remote clock, providing the required accuracy.
SRY	Switch for CB ready condition
ST	Switch or push button to trip
Starpoint	Neutral point of transformer or generator
SVC	Static VAr compensation
TC	Trip coil
TCS	Trip circuit supervision
TCP	Transmission control protocol. The most common transport layer protocol used on Ethernet and the Internet.
TCP/IP	Transmission control protocol over Internet Protocol. The de facto standard Ethernet protocols incorporated into 4.2BSD Unix. TCP/IP was developed by DARPA for Internet working and encompasses both network layer and transport layer protocols. While TCP and IP specify two protocols at specific protocol layers, TCP/IP is often used to refer to the entire US Department of Defense protocol suite based upon these, including Telnet, FTP, UDP and RDP.
TNC connector	Threaded Neill-Concelman, a threaded constant impedance version of a BNC connector
TPZ, TPY, TPX, TPS	Current transformer class according to IEC
UMT	User management tool
Underreach	A term used to describe how the relay behaves during a fault condition. For example, a distance relay is underreaching when the impedance presented to it is greater than the apparent impedance to the fault applied to the balance point, that is, the set reach. The relay does not "see" the fault but perhaps it should have seen it. See also Overreach.
U/I-PISA	Process interface components that deliver measured voltage and current values
UTC	Coordinated Universal Time. A coordinated time scale, maintained by the Bureau International des Poids et Mesures (BIPM), which forms the basis of a coordinated

	dissemination of standard frequencies and time signals. UTC is derived from International Atomic Time (TAI) by the addition of a whole number of "leap seconds" to synchronize it with Universal Time 1 (UT1), thus allowing for the eccentricity of the Earth's orbit, the rotational axis tilt (23.5 degrees), but still showing the Earth's irregular rotation, on which UT1 is based. The Coordinated Universal Time is expressed using a 24-hour clock, and uses the Gregorian calendar. It is used for aeroplane and ship navigation, where it is also sometimes known by the military name, "Zulu time." "Zulu" in the phonetic alphabet stands for "Z", which stands for longitude zero.
UV	Undervoltage
WEI	Weak end infeed logic
VT	Voltage transformer
X.21	A digital signalling interface primarily used for telecom equipment
$3I_O$	Three times zero-sequence current. Often referred to as the residual or the earth-fault current
$3U_O$	Three times the zero sequence voltage. Often referred to as the residual voltage or the neutral point voltage

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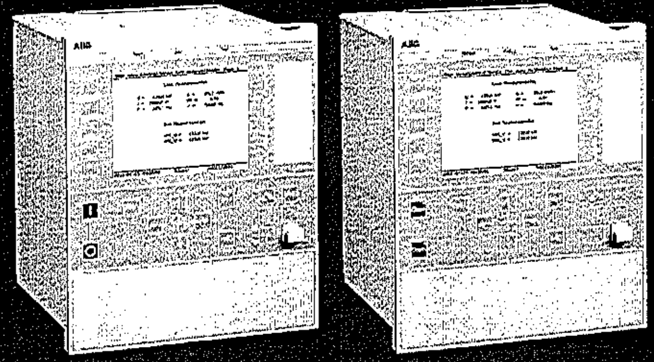

Relion® 650 series

Bay control REC650 2.1 IEC Product guide

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1. Application

REC650 is used for the control, protection and monitoring of different types of bays in power networks. The IED is especially suitable for applications in control systems with distributed control IEDs in all bays with high demands on reliability. It is suitable for the control of all apparatuses in the following switchgear arrangements:

- Single busbar, with a single circuit breaker
- Double busbar, with a single circuit breaker

The control is performed from remote (SCADA/Station) through various communication protocols or from the local HMI.

Different control configurations can be used, and one control IED per bay is recommended. Interlocking modules are available for common types of switchgear arrangements. The control is based on the select before execute principle to give highest possible security. A synchronism control function is available to interlock breaker closing. A synchronizing function where breaker closes at the right instance in asynchronous networks is also provided..

Disturbance recording is available to allow independent post-fault analysis after primary disturbances.

One pre-configured package has been defined for the following application:

- Single breaker for double busbar (A02)

The package is configured and ready for direct use. Analog and control circuits have been pre-defined and other signals need to be applied as required for each application. The pre-configured IED can be changed and adapted to suit specific applications with the graphical configuration tool.

Forcing of binary inputs and outputs is a convenient way to test wiring in substations as well as testing configuration logic in the IEDs. Basically it means that all binary inputs and outputs on the IED I/O modules (BOM, BIM and IOM) can be forced to arbitrary values.

Central Account Management is an authentication infrastructure that offers a secure solution for enforcing access control to IEDs and other systems within a substation. This incorporates management of user accounts, roles and certificates and the distribution of such, a procedure completely transparent to the user.

The Flexible Product Naming allows the customer to use an IED-vendor independent 61850 model of the IED. This customer model will be used as the IEC 61850 data model, but all other aspects of the IED will remain unchanged (e.g., names on the local HMI and names in the tools). This offers significant flexibility to adapt the IED to the customers system and standard solution

Description of A02
Single breaker for double busbar.

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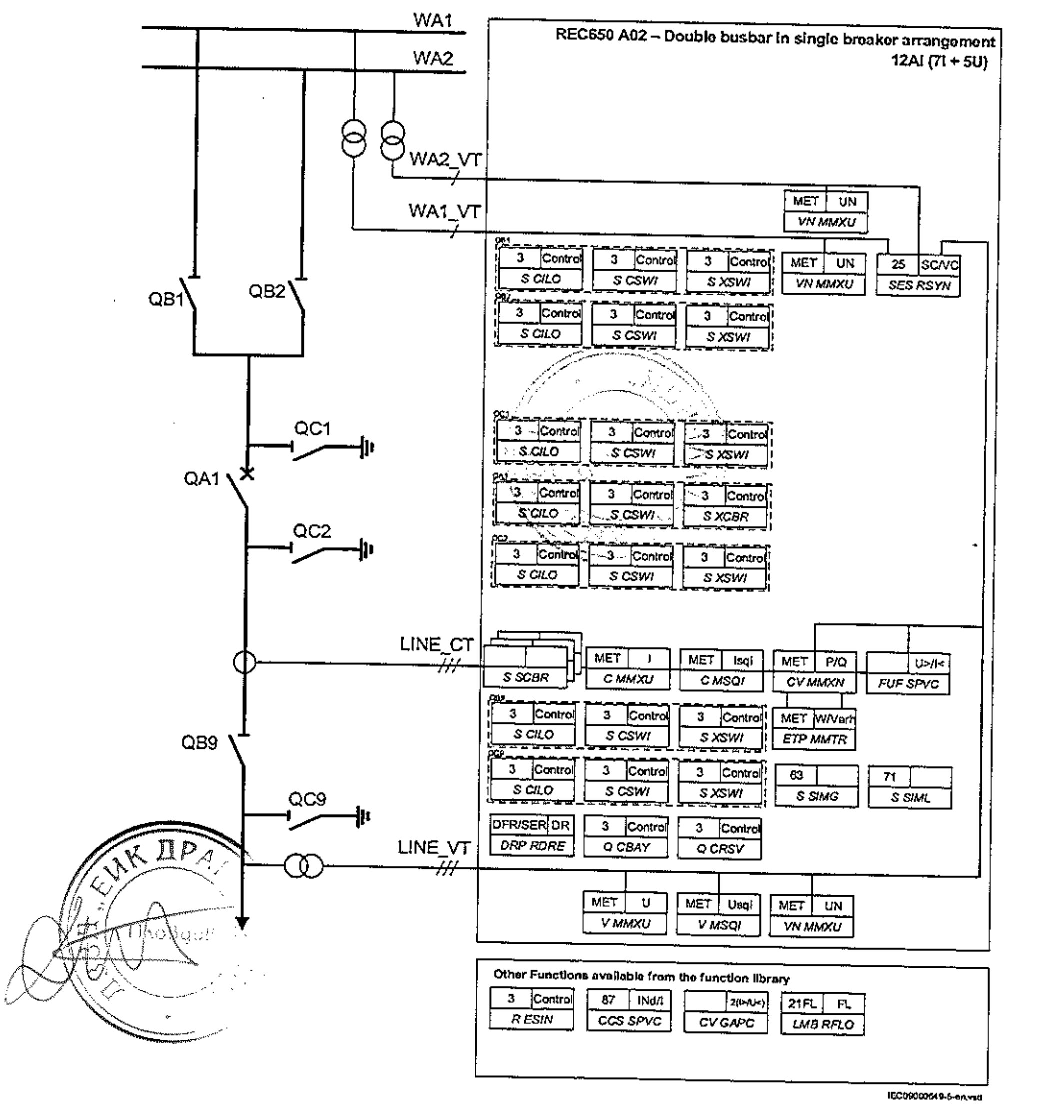

Figure 1. Configuration diagram for configuration A02

2. Available functions

Back-up protection functions

IEC 61850	ANSI	Function description	Bay Control
			REC650 (A02)
Multipurpose protection			
CVGAPC		General current and voltage protection	1

Control and monitoring functions

IEC 61850	ANSI	Function description	Bay control
			REC650 (A02)
Control			
SESRSYN		Synchrocheck, energizing check and synchronizing	1
APC10		Apparatus control for single bay, max 10 app. (1CB) incl. Interlocking	1
QCBAY		Apparatus control	1
LOCREM		Handling of LRswitch positions	1
LOCREMCTRL		LHMI control of PSTO	1
SLGAPC		Logic Rotating Switch for function selection and LHMI presentation	15
VSGAPC		Selector mini switch	20
DPGAPC		Generic communication function for Double Point Indication	16
SPC8GAPC		Single Point Generic Control 8 signals	5
AUTOBITS		AutomationBits, command function for DNP3.0	3
SINGLECMD		Single command, 16 signals	4
I103CMD		Function commands for IEC 60870-5-103	1
I103GENCMD		Function commands generic for IEC 60870-5-103	50
I103POSCMD		IED commands with position and select for IEC 60870-5-103	50
I103POSCMDV		IED direct commands with position for IEC 60870-5-503	50
I103IEDCMD		IED commands for IEC 60870-5-103	1
I103USRCMD		Function commands user defined for IEC 60870-5-103	4
Secondary system supervision			
CCSSPVC		Current circuit supervison	1
FUFSPVC		Fuse failure supervision	1
Logic			
TMAGAPC		Trip matrix logic	12
ALMCALH		Logic for group alarm	5
WRNCALH		Logic for group warning	5
INDCALH		Logic for group indication	5
AND, GATE, INV, LLD, OR, PULSETIMER, RSMEMORY, SRMEMORY, TIMERSET, XOR		Basic configurable logic blocks (see Table 1)	40–420

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IEC 61850	ANSI	Function description	Bay control REC650 (A02)
ANDQT, INDCOMBSPQT, INDEXTSPQT, INVALIDQT, INVERTERQT, ORQT, PULSETIMERQT, RSMEMORYQT, SRMEMORYQT, TIMERSETQT, XORQT		Configurable logic blocks Q/T (see Table 2)	1
FXDSIGN		Fixed signal function block	1
B16I		Boolean 16 to Integer conversion	18
BTIGAPC		Boolean 16 to Integer conversion with Logic Node representation	16
IB16		Integer to Boolean 16 conversion	18
ITBGAPC		Integer to Boolean 16 conversion with Logic Node representation	16
TEIGAPC		Elapsed time integrator with limit transgression and overflow supervision	12
INTCOMP		Comparator for integer inputs	12
REALCOMP		Comparator for real inputs	12
Monitoring			
CVMMXN, VMMXU, CMSQI, VMSQI, VNMMXU		Measurements	6
CMMXU		Measurements	10
AISVBAS		Function block for service value presentation of secondary analog inputs	1
SSIMG		Gas medium supervision	21
SSIML		Liquid medium supervision	3
SSCBR		Circuit breaker condition monitoring	3
EVENT		Event function	20
DRPRDRE, A1RADR-A4RADR, B1RBDR-B8RBDR		Disturbance report	1
B9RBDR-B22RBDR		Disturbance report	1
SPGAPC		Generic communication function for Single Point indication	64
SP16GAPC		Generic communication function for Single Point indication 16 inputs	24
MVGAPC		Generic communication function for Measured Value	24
BINSTATREP		Logical signal status report	3
RANGE_XP		Measured value expander block	66
LMBRFLO		Fault locator	1
I103MEAS		Measurands for IEC 60870-5-103	1
I103MEASUSR		Measurands user defined signals for IEC 60870-5-103	3

IEC 61850	ANSI	Function description	Bay control REC650 (A02)
I103AR		Function status auto-recloser for IEC 60870-5-103	1
I103EF		Function status earth-fault for IEC 60870-5-103	1
I103FLTPROT		Function status fault protection for IEC 60870-5-103	1
I103IED		IED status for IEC 60870-5-103	1
I103SUPERV		Supervison status for IEC 60870-5-103	1
I103USRDEF		Status for user defined signals for IEC 60870-5-103	20
L4UFCNT		Event counter with limit supervision	30
TEILGAPC		Running hour-meter	6
Metering			
PCFCNT		Pulse-counter logic	16
ETPMMTR		Function for energy calculation and demand handling	6

Table 1. Total number of instances for basic configurable logic blocks

Basic configurable logic block	Total number of instances
AND	280
GATE	40
INV	420
LLD	40
OR	280
PULSETIMER	40
RSMEMORY	40
SRMEMORY	40
TIMERSET	60
XOR	40

Table 2. Total number of instances for configurable logic blocks Q/T

Configurable logic blocks Q/T	Total number of instances
ANDQT	120
INDCOMBSPQT	20
INDEXTSPQT	20
INVALIDQT	22
INVERTERQT	120
ORQT	120
PULSETIMERQT	40
RSMEMORYQT	40
SRMEMORYQT	40
TIMERSETQT	40
XORQT	40

Communication

IEC 61850	ANSI	Function description	Bay control
			REC650 (A02)
Station communication			
LONSPA, SPA		SPA communication protocol	1
ADE		LON communciation protocol	1
HORZCOMM		Network variables via LON	1
PROTOCOL		Operation selection between SPA and IEC 60870-5-103 for SLM	1
RS485PROT		Operation selection for RS485	1
RS485GEN		RS485	1
DNPGEN		DNP3.0 communication general protocol	1
DNPGENTCP		DNP3.0 communication general TCP protocol	1
CHSERRS485		DNP3.0 for EIA-485 communication protocol	1
CH1TCP, CH2TCP, CH3TCP, CH4TCP		DNP3.0 for TCP/IP communication protocol	1
CHSEROPT		DNP3.0 for TCP/IP and EIA-485 communication protocol	1
MSTSER		DNP3.0 for serial communication protocol	1
MST1TCP, MST2TCP, MST3TCP, MST4TCP		DNP3.0 for TCP/IP communication protocol	1
DNPFREC		DNP3.0 fault records for TCP/IP and EIA-485 communication protocol	1
IEC 61850-8-1		Parameter setting function for IEC 61850	1
GOOSEINTLKRCV		Horizontal communication via GOOSE for interlocking	59
GOOSEBINRCV		GOOSE binary receive	16
GOOSEDPRCV		GOOSE function block to receive a double point value	64
GOOSEINTRCV		GOOSE function block to receive an integer value	32
GOOSEMVRCV		GOOSE function block to receive a measurand value	60
GOOSESPRCV		GOOSE function block to receive a single point value	64
MULTICMDRCV/ MULTICMDSND		Multiple command and transmit	60/10
FRONT, LANABI, LANAB, LANCDI, LANCD, GATEWAY		Ethernet configuration	1
OPTICAL103		IEC 60870-5-103 Optical serial communication	1
RS485103		IEC 60870-5-103 serial communication for RS485	1
AGSAL		Generic security application component	1
LD0LLN0		IEC 61850 LD0 LLN0	1
SYSLLN0		IEC 61850 SYS LLN0	1
LPHD		Physical device information	1
PCMACCS		IED configuration protocol	1
SECALARM		Component for mapping security events on protocols such as DNP3 and IEC103	1

IEC 61850	ANSI	Function description	Bay control
			REC650 (A02)
FSTACCS, FSTACCSNA		Field service tool access via SPA protocol over ethernet communication	1
ACTIVLOG		Activity logging parameters	1
ALTRK		Service Tracking	1
SINGLELCCH		Single ethernet port link status	1
PRPSTATUS		Dual ethernet port link status	1
PRP		IEC 62439-3 parallel redundancy protocol	1-P03

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Basic IED functions

Table 3. Basic IED functions

IEC 61850 or function name	Description
INTERRSIG	Self supervision with internal event list
SELFSUPEVLST	Self supervision with internal event list
TIMESYNCHGEN	Time synchronization module
BININPUT, SYNCHCAN, SYNCHGPS, SYNCHCMPPS, SYNCHLON, SYNCHPPH, SYNCHPPS, SNTP, SYNCHSPA, SYNCHCMPPS	Time synchronization
TIMEZONE	Time synchronization
DSTBEGIN, DSTENABLE, DSTEND	GPS time synchronization module
IRIG-B	Time synchronization
SETGRPS	Number of setting groups
ACTVGRP	Parameter setting groups
TESTMODE	Test mode functionality
CHNGLCK	Change lock function
SMBI	Signal matrix for binary inputs
SMBO	Signal matrix for binary outputs
SMAI1 - SMAI12	Signal matrix for analog inputs
3PHSUM	Summation block 3 phase
ATHSTAT	Authority status
ATHCHCK	Authority check
AUTHMAN	Authority management
FTPACCS	FTP access with password
SPACOMMMAP	SPA communication mapping
SPATD	Date and time via SPA protocol
DOSFRNT	Denial of service, frame rate control for front port
DOSLANAB	Denial of service, frame rate control for OEM port AB
DOSLANCD	Denial of service, frame rate control for OEM port CD
DOSSCKT	Denial of service, socket flow control
GBASVAL	Global base values for settings
PRIMVAL	Primary system values
ALTMS	Time master supervision
ALTIM	Time management
MSTSER	DNP3.0 for serial communication protocol

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Table 4. Local HMI functions

IEC 61850 or function name	ANSI	Description
LHMICTRL		Local HMI signals
LANGUAGE		Local human machine language
SCREEN		Local HMI Local human machine screen behavior
FNKEYTY1–FNKEYTY5 FNKEYMD1–FNKEYMD5		Parameter setting function for HMI in PCM600
LEDGEN		General LED indication part for LHMI
OPENCLOSE_LED		LHMI LEDs for open and close keys
GRP1_LED1–GRP1_LED15 GRP2_LED1–GRP2_LED15 GRP3_LED1–GRP3_LED15		Basic part for CP HW LED indication module

3. Control

Synchrocheck, energizing check, and synchronizing SESRSYN
The Synchronizing function allows closing of asynchronous networks at the correct moment including the breaker closing time, which improves the network stability.

Synchrocheck, energizing check, and synchronizing SESRSYN function checks that the voltages on both sides of the circuit breaker are in synchronism, or with at least one side dead to ensure that closing can be done safely.

SESRSYN function includes a built-in voltage selection scheme for double bus and 1½ breaker or ring busbar arrangements.

Manual closing as well as automatic reclosing can be checked by the function and can have different settings.

For systems, which are running asynchronous, a synchronizing function is provided. The main purpose of the synchronizing function is to provide controlled closing of circuit breakers when two asynchronous systems are going to be connected. The synchronizing function evaluates voltage difference, phase angle difference, slip frequency and frequency rate of change before issuing a controlled closing of the circuit breaker. Breaker closing time is a parameter setting.

Autorecloser SMBRREC
The autorecloser SMBRREC function provides high-speed and/or delayed auto-reclosing for single or multi-breaker applications.

Up to five three-phase reclosing attempts can be included by parameter setting. The first attempt can be single-, two and/or three phase for single phase or multi-phase faults respectively.

Multiple autoreclosing functions are provided for multi-breaker arrangements. A priority circuit allows one circuit breaker to close first and the second will only close if the fault proved to be transient.

Each autoreclosing function is configured to co-operate with the synchrocheck function.

The autoreclosing function provides high-speed and/or delayed three-pole autoreclosing.

Apparatus control APC
The apparatus control functions are used for control and supervision of circuit breakers, disconnectors and earthing switches within a bay. Permission to operate is given after evaluation of conditions from other functions such as interlocking, synchrocheck, operator place selection and external or internal blockings.

Apparatus control features:
- Select-Execute principle to give high reliability
- Selection function to prevent simultaneous operation
- Selection and supervision of operator place
- Command supervision
- Block/deblock of operation
- Block/deblock of updating of position indications
- Substitution of position and quality indications
- Overriding of interlocking functions

- Overriding of synchrocheck
- Operation counter
- Suppression of mid position

Two types of command models can be used:
- Direct with normal security
- SBO (Select-Before-Operate) with enhanced security

Normal security means that only the command is evaluated and the resulting position is not supervised. Enhanced security means that the command is evaluated with an additional supervision of the status value of the control object. The command sequence with enhanced security is always terminated by a CommandTermination service primitive and an AddCause telling if the command was successful or if something went wrong.

Control operation can be performed from the local HMI with authority control if so defined.

Features of the apparatus control function are:

- Operation of primary apparatuses
- Select-Execute principle to give high reliability
- Selection and reservation function to prevent simultaneous operation
- Selection and supervision of operator place
- Command supervision
- Block/deblock of operation
- Block/deblock of updating of position indications
- Substitution of position indications
- Overriding of interlocking functions
- Overriding of synchrocheck
- Pole discordance supervision
- Operation counter

The apparatus control function is realized by means of a number of function blocks designated:

- Bay control QCBAY
- Switch controller SCSWI
- Circuit breaker SXCBR
- Circuit switch SXSWI

The three latter functions are logical nodes according to IEC 61850-8-1. To realize the reservation function also the function blocks Reservation input (RESIN) and Bay reserve (QCRSV) are included in the apparatus control function.

Interlocking
The interlocking function blocks the possibility to operate primary switching devices, for instance when a disconnector is under load, in order to prevent material damage and/or accidental human injury.

Each apparatus control function has interlocking modules included for different switchyard arrangements, where each function handles interlocking of one bay. The interlocking function is distributed to each IED and is not dependent on any central function. For the station-wide interlocking, the IEDs communicate via the system-wide interbay bus (IEC 61850-8-1) or by using hard wired binary inputs/outputs. The interlocking conditions depend on the circuit configuration and apparatus position status at any given time.

For easy and safe implementation of the interlocking function, the IED is delivered with standardized and tested software interlocking modules containing logic for the interlocking conditions. The interlocking conditions can be altered, to meet the customer's specific requirements, by adding configurable logic by means of the graphical configuration tool.

The following interlocking modules are available:

- Line for double and transfer busbars, ABC_LINE
- Bus coupler for double and transfer busbars, ABC_BC
- Transformer bay for double busbars, AB_TRAFO
- Bus-section breaker for double busbars, A1A2_BS
- Bus-section disconnector for double busbars, A1A2_DC
- Busbar earthing switch, BB_ES
- Double CB Bay, DB_BUS_A, DB_LINE, DB_BUS_B
- 1 1/2-CB diameter, BH_LINE_A, BH_CONN, BH_LINE_B

Switch controller SCSWI
The Switch controller (SCSWI) initializes and supervises all functions to properly select and operate switching primary apparatuses. The Switch controller may handle and operate on one three-phase device or up to three one-phase devices.

Circuit breaker SXCBR
The purpose of Circuit breaker (SXCBR) is to provide the actual status of positions and to perform the control operations, that is, pass all the commands to primary apparatuses in the form of circuit breakers via binary output boards and to supervise the switching operation and position.

Circuit switch SXSWI
The purpose of Circuit switch (SXSWI) function is to provide the actual status of positions and to perform the control operations, that is, pass all the commands to primary apparatuses in the form of disconnectors or earthing switches via binary output boards and to supervise the switching operation and position.

Reservation function QCRSV
The purpose of the reservation function is primarily to transfer interlocking information between IEDs in a safe way and to prevent double operation in a bay, switchyard part, or complete substation.

Reservation input RESIN
The Reservation input (RESIN) function receives the reservation information from other bays. The number of instances is the same as the number of involved bays (up to 60 instances are available).

Bay control QCBAY
The Bay control QCBAY function is used together with Local remote and local remote control functions to handle the selection of the operator place per bay. QCBAY also provides blocking functions that can be distributed to different apparatuses within the bay.

Local remote LOCREM/Local remote control LOCREMCTRL
The signals from the local HMI or from an external local/remote switch are connected via the function blocks LOCREM and LOCREMCTRL to the Bay control QCBAY function block. The parameter *ControlMode* in function block LOCREM is set to choose if the switch signals are coming from the local HMI or from an external hardware switch connected via binary inputs.

Logic rotating switch for function selection and LHMI presentation SLGAPC
The logic rotating switch for function selection and LHMI presentation SLGAPC (or the selector switch function block) is used to get an enhanced selector switch functionality compared to the one provided by a hardware selector switch. Hardware selector switches are used extensively by utilities, in order to have different functions operating on pre-set values. Hardware switches are however sources for maintenance issues, lower system reliability and an extended purchase portfolio. The selector switch function eliminates all these problems.

Selector mini switch VSGAPC
The Selector mini switch VSGAPC function block is a multipurpose function used for a variety of applications, as a general purpose switch.

VSGAPC can be controlled from the menu, from a symbol on the single line diagram (SLD) on the local HMI or from Binary inputs

Generic communication function for Double Point indication DPGAPC
Generic communication function for Double Point indication DPGAPC function block is used to send double indications to other systems, equipment or functions in the substation through IEC 61850-8-1 or other communication protocols. It is especially used in the interlocking station-wide logics.

Single point generic control 8 signals SPC8GAPC
The Single point generic control 8 signals SPC8GAPC function block is a collection of 8 single point commands that can be used for direct commands for example reset of LED's or putting IED in "ChangeLock" state from remote. In this way, simple commands can be sent directly to the IED outputs, without confirmation. Confirmation (status) of the result of the commands is supposed to be achieved by other means, such as binary inputs and SPGAPC function blocks. The commands can be pulsed or steady with a settable pulse time.

AutomationBits, command function for DNP3.0 AUTOBITS
AutomationBits function for DNP3 (AUTOBITS) is used within PCM600 to get into the configuration of the commands coming through the DNP3 protocol. The AUTOBITS function plays the same role as functions GOOSEBINRCV (for IEC 61850) and MULTICMDRCV (for LON).

Single command, 16 signals
The IEDs can receive commands either from a substation automation system or from the local HMI. The command function block has outputs that can be used, for example, to control high voltage apparatuses or for other user defined functionality.

4. Multipurpose protection

General current and voltage protection CVGAPC
The General current and voltage protection (CVGAPC) can be utilized as a negative sequence current protection detecting unsymmetrical conditions such as open phase or unsymmetrical faults.

CVGAPC can also be used to improve phase selection for high resistive earth faults, outside the distance protection reach, for the transmission line. Three functions are used, which measures the neutral current and each of the three phase voltages. This will give an independence from load currents and this phase selection will be used in conjunction with the detection of the earth fault from the directional earth fault protection function.

5. Secondary system supervision

Current circuit supervision CCSSPVC
Open or short circuited current transformer cores can cause unwanted operation of many protection functions such as differential, earth-fault current and negative-sequence current functions.

Current circuit supervision (CCSSPVC) compares the residual current from a three phase set of current transformer cores with the neutral point current on a separate input taken from another set of cores on the current transformer.

A detection of a difference indicates a fault in the circuit and is used as alarm or to block protection functions expected to give inadvertent tripping.

Fuse failure supervision FUFSPVC
The aim of the fuse failure supervision function FUFSPVC is to block voltage measuring functions at failures in the secondary circuits between the voltage transformer and the IED in order to avoid inadvertent operations that otherwise might occur.

The fuse failure supervision function basically has three different detection methods, negative sequence and zero sequence based detection and an additional delta voltage and delta current detection.

The negative sequence detection algorithm is recommended for IEDs used in isolated or high-impedance earthed networks. It is based on the negative-sequence quantities.

The zero sequence detection is recommended for IEDs used in directly or low impedance earthed networks. It is based on the zero sequence measuring quantities.

The selection of different operation modes is possible by a setting parameter in order to take into account the particular earthing of the network.

A criterion based on delta current and delta voltage measurements can be added to the fuse failure supervision function in order to detect a three phase fuse failure, which in practice is more associated with voltage transformer switching during station operations.

6. Scheme communication

Scheme communication logic for distance or overcurrent protection ZCPSCH
To achieve instantaneous fault clearance for all line faults, scheme communication logic is provided. All types of communication schemes for permissive underreaching, permissive overreaching, blocking, delta based blocking, unblocking and intertrip are available.

The built-in communication module (LDCM) can be used for scheme communication signaling when included.

Current reversal and weak-end infeed logic for distance protection ZCRWPSCH
The ZCRWPSCH function provides the current reversal and weak-end infeed logic functions that supplement the standard scheme communication logic. It is not suitable for standalone use as it requires inputs from the distance protection functions and the scheme communications function included within the terminal.

On detection of a current reversal, the current reversal logic provides an output to block the sending of the teleprotection signal to the remote end, and to block the permissive tripping at the local end. This blocking condition is maintained long enough to ensure that no unwanted operation will occur as a result of the current reversal.

On verification of a weak end infeed condition, the weak end infeed logic provides an output for sending the received teleprotection signal back to the remote sending end and other output(s) for local tripping. For terminals equipped for single- and two-pole tripping, outputs for the faulted phase(s) are provided. Undervoltage detectors are used to detect the faulted phase(s).

Local acceleration logic ZCLCPSCH
To achieve fast clearing of faults on the whole line, when no communication channel is available, local acceleration logic ZCLCPSCH can be used. This logic enables fast fault clearing and re-closing during certain conditions, but naturally, it can not fully replace a communication channel.

The logic can be controlled either by the autorecloser (zone extension) or by the loss-of-load current (loss-of-load acceleration).

7. Logic

Tripping logic SMPPTRC
A function block for protection tripping is always provided as basic for each circuit breaker involved in the tripping of the fault. It provides a settable pulse prolongation to ensure a trip pulse of sufficient length, as well as all functionality necessary for correct co-operation with autoreclosing functions.

The trip function block also includes a settable latch functionality for evolving faults and breaker lock-out.

Trip matrix logic TMAGAPC
The trip matrix logic TMAGAPC function is used to route trip signals and other logical output signals to different output contacts on the IED.

The trip matrix logic function has 3 output signals and these outputs can be connected to physical tripping outputs according to the specific application needs for settable pulse or steady output.

Group alarm logic function ALMCALH
The group alarm logic function ALMCALH is used to route several alarm signals to a common indication, LED and/or contact, in the IED.

Group warning logic function WRNCALH
The group warning logic function WRNCALH is used to route several warning signals to a common indication, LED and/or contact, in the IED.

Group indication logic function INDCALH
The group indication logic function INDCALH is used to route several indication signals to a common indication, LED and/or contact, in the IED.

Basic configurable logic blocks
The basic configurable logic blocks do not propagate the time stamp and quality of signals (have no suffix QT at the end of their function name). A number of logic blocks and timers are always available as basic for the user to adapt the configuration to the specific application needs. The list below shows a summary of the function blocks and their features.

These logic blocks are also available as part of an extension logic package with the same number of instances.

- AND function block. Each block has four inputs and two outputs where one is inverted.
- GATE function block is used for whether or not a signal should be able to pass from the input to the output.
- INVERTER function block that inverts one input signal to the output.
- LLD function block. Loop delay used to delay the output signal one execution cycle.
- OR function block. Each block has up to six inputs and two outputs where one is inverted.
- PULSETIMER function block can be used, for example, for pulse extensions or limiting of operation of outputs, settable pulse time.
- RSMEMORY function block is a flip-flop that can reset or set an output from two inputs respectively. Each block has two outputs where one is inverted. The memory setting controls if, after a power interruption, the flip-flop resets or returns to the state it had before the power interruption. RESET input has priority.
- SRMEMORY function block is a flip-flop that can set or reset an output from two inputs respectively. Each block has two outputs where one is inverted. The memory setting controls if, after a power interruption, the flip-flop resets or returns to the state it had before the power interruption. The SET input has priority.
- TIMERSET function has pick-up and drop-out delayed outputs related to the input signal. The timer has a settable time delay.
- XOR function block. Each block has two outputs where one is inverted.

Extension logic package
The logic extension block package includes additional trip matrix logic and configurable logic blocks.

Logic rotating switch for function selection and LHMI presentation SLGAPC
The logic rotating switch for function selection and LHMI presentation SLGAPC (or the selector switch function block) is used to get an enhanced selector switch functionality compared to the one provided by a hardware selector switch. Hardware selector switches are used extensively by utilities, in order to have different functions operating on pre-set values. Hardware switches are however sources for maintenance issues, lower system reliability and an extended purchase portfolio. The selector switch function eliminates all these problems.

Fixed signal function block
The Fixed signals function FXDSIGN generates nine pre-set (fixed) signals that can be used in the configuration of an IED, either for forcing the unused inputs in other function blocks to a certain level/value, or for creating certain logic. Boolean, integer, floating point, string types of signals are available.

One FXDSIGN function block is included in all IEDs.

Elapsed time integrator with limit transgression and overflow supervision (TEIGAPC)
The Elapsed time integrator function TEIGAPC is a function that accumulates the elapsed time when a given binary signal has been high.

The main features of TEIGAPC

- Applicable to long time integration (≤999 999.9 seconds).
- Supervision of limit transgression conditions and overflow.
- Possibility to define a warning or alarm with the resolution of 10 milliseconds.
- Retaining of the integration value.
- Possibilities for blocking and reset.
- Reporting of the integrated time.

Boolean 16 to Integer conversion B16I
Boolean 16 to integer conversion function B16I is used to transform a set of 16 binary (logical) signals into an integer.

Boolean 16 to Integer conversion with logic node representation BTIGAPC
Boolean 16 to integer conversion with logic node representation function BTIGAPC is used to transform a set of 16 binary (logical) signals into an integer. The block input will freeze the output at the last value.

BTIGAPC can receive remote values via IEC 61850 depending on the operator position input (PSTO).

Integer to Boolean 16 conversion IB16
Integer to boolean 16 conversion function IB16 is used to transform an integer into a set of 16 binary (logical) signals.

Integer to Boolean 16 conversion with logic node representation ITBGAPC
Integer to boolean conversion with logic node representation function ITBGAPC is used to transform an integer which is transmitted over IEC 61850 and received by the function to 16 binary coded (logic) output signals.

ITBGAPC function can only receive remote values over IEC 61850 when the R/L (Remote/Local) push button on the front HMI, indicates that the control mode for the operator is in position R (Remote i.e. the LED adjacent to R is lit), and the corresponding signal is connected to the input PSTO ITBGAPC function block. The input BLOCK will freeze the output at the last received value and blocks new integer values to be received and converted to binary coded outputs.

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Comparator for integer inputs INTCOMP
The function gives the possibility to monitor the level of integer values in the system relative to each other or to a fixed value. It is a basic arithmetic function that can be used for monitoring, supervision, interlocking and other logics.

Comparator for real inputs REALCOMP
The function gives the possibility to monitor the level of real value signals in the system relative to each other or to a fixed value. It is a basic arithmetic function that can be used for monitoring, supervision, interlocking and other logics.

8. Monitoring

Measurements CVMMXN, CMMXU, VNMMXU, VMMXU, CMSQI, VMSQI
The measurement functions are used to get on-line information from the IED. These service values make it possible to display on-line information on the local HMI and on the Substation automation system about:

- measured voltages, currents, frequency, active, reactive and apparent power and power factor
- primary phasors
- positive, negative and zero sequence currents and voltages
- mA, input currents
- pulse counters

Supervision of mA input signals
The main purpose of the function is to measure and process signals from different measuring transducers. Many devices used in process control represent various parameters such as frequency, temperature and DC battery voltage as low current values, usually in the range 4-20 mA or 0-20 mA.

Alarm limits can be set and used as triggers, e.g. to generate trip or alarm signals.

The function requires that the IED is equipped with the mA input module.

Disturbance report DRPRDRE
Complete and reliable information about disturbances in the primary and/or in the secondary system together with continuous event-logging is accomplished by the disturbance report functionality.

Disturbance report DRPRDRE, always included in the IED, acquires sampled data of all selected analog input and binary signals connected to the function block with a, maximum of 40 analog and 352 binary signals.

The Disturbance report functionality is a common name for several functions:

- Event list
- Indications
- Event recorder
- Trip value recorder
- Disturbance recorder
- Fault locator

The Disturbance report function is characterized by great flexibility regarding configuration, starting conditions, recording times, and large storage capacity.

A disturbance is defined as an activation of an input to the AnRADR or BnRBDR function blocks, which are set to trigger the disturbance recorder. All connected signals from start of pre-fault time to the end of post-fault time will be included in the recording.

Every disturbance report recording is saved in the IED in the standard Comtrade format as a reader file HDR, a configuration file CFG, and a data file DAT. The same applies to all events, which are continuously saved in a ring-buffer. The local HMI is used to get information about the recordings. The disturbance report files may be uploaded to PCM600 for further analysis using the disturbance handling tool.

Event list DRPRDRE
Continuous event-logging is useful for monitoring the system from an overview perspective and is a complement to specific disturbance recorder functions.

The event list logs all binary input signals connected to the Disturbance recorder function. The list may contain up to 1000 time-tagged events stored in a ring-buffer.

Indications DRPRDRE
To get fast, condensed and reliable information about disturbances in the primary and/or in the secondary system it is important to know, for example binary signals that have changed status during a disturbance. This information is used in the short perspective to get information via the local HMI in a straightforward way.

There are three LEDs on the local HMI (green, yellow and red), which will display status information about the IED and the Disturbance recorder function (triggered).

The Indication list function shows all selected binary input signals connected to the Disturbance recorder function that have changed status during a disturbance.

Event recorder DRPRDRE
Quick, complete and reliable information about disturbances in the primary and/or in the secondary system is vital, for example, time-tagged events logged during disturbances. This information is used for different purposes in the short term (for example corrective actions) and in the long term (for example functional analysis).

The event recorder logs all selected binary input signals connected to the Disturbance recorder function. Each recording can contain up to 150 time-tagged events.

The event recorder information is available for the disturbances locally in the IED.

The event recording information is an integrated part of the disturbance record (Comtrade file).

Trip value recorder DRPRDRE
Information about the pre-fault and fault values for currents and voltages are vital for the disturbance evaluation.

The Trip value recorder calculates the values of all selected analog input signals connected to the Disturbance recorder function. The result is magnitude and phase angle before and during the fault for each analog input signal.

The trip value recorder information is available for the disturbances locally in the IED.

The trip value recorder information is an integrated part of the disturbance record (Comtrade file).

Disturbance recorder DRPRDRE
The Disturbance recorder function supplies fast, complete and reliable information about disturbances in the power system. It facilitates understanding system behavior and related primary and secondary equipment during and after a disturbance. Recorded information is used for different purposes in the short perspective (for example corrective actions) and long perspective (for example functional analysis).

The Disturbance recorder acquires sampled data from selected analog- and binary signals connected to the Disturbance recorder function (maximum 40 analog and binary signals). The binary signals available are the same as for the event recorder function.

The function is characterized by great flexibility and is not dependent on the operation of protection functions. It can record disturbances not detected by protection functions. Up to ten seconds of data before the trigger instant can be saved in the disturbance file.

The disturbance recorder information for up to 100 disturbances are saved in the IED and the local HMI is used to view the list of recordings.

Event function
When using a Substation Automation system with LON or SPA communication, time-tagged events can be sent at change or cyclically from the IED to the station level. These events are created from any available signal in the IED that is connected to the Event function (EVENT). The EVENT function block is used for LON and SPA communication.

Analog and double indication values are also transferred through the EVENT function.

Generic communication function for Single Point indication SPGAPC
Generic communication function for Single Point indication SPGAPC is used to send one single logical signal to other systems or equipment in the substation.

Generic communication function for Measured Value MVGAPC
Generic communication function for Measured Value MVGAPC function is used to send the instantaneous value of an analog signal to other systems or equipment in the substation. It can also be used inside the same IED, to attach a RANGE aspect to an analog value and to permit measurement supervision on that value.

Measured value expander block RANGE_XP
The current and voltage measurements functions (CVMMXN, CMMXU, VMMXU and VNMMXU), current and voltage sequence measurement functions (CMSQI and VMSQI) and IEC 61850 generic communication I/O functions (MVGAPC) are provided with measurement supervision functionality. All measured values can be supervised with four settable limits: low-low limit, low limit, high limit and high-high limit. The measure value expander block (RANGE_XP) has been introduced to enable translating the integer output signal from the measuring functions to 5 binary signals: below low-low limit, below low limit, normal, above high limit or above high-high limit. The output signals can be used as conditions in the configurable logic or for alarming purpose.

Gas medium supervision SSIMG
Gas medium supervision SSIMG is used for monitoring the circuit breaker condition. Binary information based on the gas pressure in the circuit breaker is used as input signals to the function. In addition, the function generates alarms based on received information.

Liquid medium supervision SSIML
Liquid medium supervision SSIML is used for monitoring the circuit breaker condition. Binary information based on the oil level in the circuit breaker is used as input signals to the function. In addition, the function generates alarms based on received information.

Breaker monitoring SSCBR
The breaker monitoring function SSCBR is used to monitor different parameters of the breaker condition. The breaker requires maintenance when the number of operations reaches a predefined value. For a proper functioning of the circuit breaker, it is essential to monitor the circuit breaker operation, spring charge indication or breaker wear, travel time, number of operation cycles and estimate the accumulated energy during arcing periods.

Fault locator LMBRFLO
The accurate fault locator is an essential component to minimize the outages after a persistent fault and/or to pin-point a weak spot on the line.

The fault locator is an impedance measuring function giving the distance to the fault in km, miles or % of line length. The main advantage is the high accuracy achieved by compensating for load current and for the mutual zero-sequence effect on double circuit lines.

The compensation includes setting of the remote and local sources and calculation of the distribution of fault currents from each side. This distribution of fault current, together with recorded load (pre-fault) currents, is used to exactly calculate the fault position. The fault can be recalculated with new source data at the actual fault to further increase the accuracy.

Especially on heavily loaded long lines, where the source voltage angles can be up to 35-40 degrees apart, the accuracy can be still maintained with the advanced compensation included in fault locator.

Event counter with limit supervison L4UFCNT
The 30 limit counter L4UFCNT provides a settable counter with four independent limits where the number of positive and/or negative flanks on the input signal are counted against the setting values for limits. The output for each limit is activated when the counted value reaches that limit.

Overflow indication is included for each up-counter.

Running hour-meter (TEILGAPC)
The Running hour-meter (TEILGAPC) function is a function that accumulates the elapsed time when a given binary signal has been high.

The main features of TEILGAPC are:

- Applicable to very long time accumulation (≤ 99999.9 hours)
- Supervision of limit transgression conditions and rollover/overflow
- Possibility to define a warning and alarm with the resolution of 0.1 hours
- Retain any saved accumulation value at a restart
- Possibilities for blocking and reset
- Possibility for manual addition of accumulated time
- Reporting of the accumulated time

9. Metering

Pulse-counter logic PCFCNT
Pulse-counter logic (PCFCNT) function counts externally generated binary pulses, for instance pulses coming from an external energy meter, for calculation of energy consumption values. The pulses are captured by the binary input module and then read by the PCFCNT function. A scaled service value is available over the station bus. The special Binary input module with enhanced pulse counting capabilities must be ordered to achieve this functionality.

Function for energy calculation and demand handling (ETPMMTR)
Measurements function block (CVMMXN) can be used to measure active as well as reactive power values. Function for energy calculation and demand handling (ETPMMTR) uses measured active and reactive power as input and calculates the accumulated active and reactive energy pulses, in forward and reverse direction. Energy values can be read or generated as pulses. Maximum demand power values are also calculated by the function. This function includes zero point clamping to remove noise from the input signal. As output of this function: periodic energy calculations, integration of energy values, calculation of energy pulses, alarm signals for limit violation of energy values and maximum power demand, can be found.

The values of active and reactive energies are calculated from the input power values by integrating them over a selected time *tEnergy*. The integration of active and reactive energy values will happen in both forward and reverse directions. These energy values are available as output signals and also as pulse outputs. Integration of energy values can be controlled by inputs (STARTACC and STOPACC) and *EnaAcc* setting and it can be reset to initial values with RSTACC input.

The maximum demand for active and reactive powers are calculated for the set time interval *tEnergy* and these values are updated every minute through output channels. The active and reactive maximum power demand values are calculated for both forward and reverse direction and these values can be reset with RSTDMD input.

10. Human machine interface

Local HMI

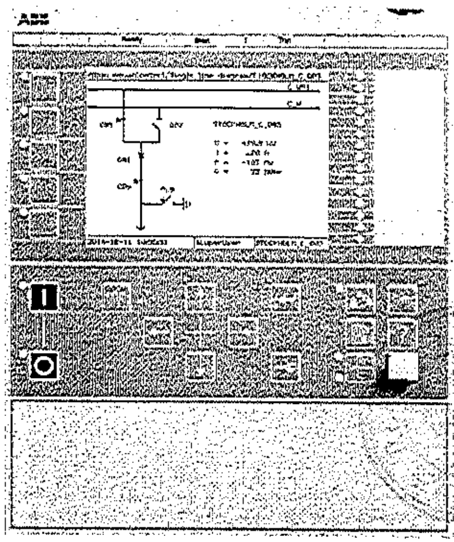

Figure 2. Local human-machine interface

The LHMI of the IED contains the following elements:
- Graphical display capable of showing a user defined single line diagram and provide an interface for controlling switchgear.
- Navigation buttons and five user defined command buttons to shortcuts in the HMI tree or simple commands.
- 15 user defined three-color LEDs.
- Communication port for PCM600.

The LHMI is used for setting, monitoring and controlling.

11. Basic IED functions

Time synchronization
The time synchronization function is used to select a common source of absolute time for the synchronization of the IED when it is a part of a control and a protection system. This makes it possible to compare events and disturbance data between all IEDs within a station automation system and in between sub-stations.

12. Station communication

Communication protocols
Each IED is provided with a communication interface, enabling it to connect to one or many substation level systems or equipment, either on the Substation Automation (SA) bus or Substation Monitoring (SM) bus.

Available communication protocols are:

- IEC 61850-8-1 communication protocol
- LON communication protocol
- SPA or IEC 60870-5-103 communication protocol
- DNP3.0 communication protocol

Several protocols can be combined in the same IED.

IEC 61850-8-1 communication protocol
IEC 61850 Ed.1 or Ed.2 can be chosen by a setting in PCM600. The IED is equipped with single or double optical Ethernet rear ports (order dependent) for IEC 61850-8-1 station bus communication. The IEC 61850-8-1 communication is also possible from the electrical Ethernet front port. IEC 61850-8-1 protocol allows intelligent electrical devices (IEDs) from different vendors to exchange information and simplifies system engineering. IED-to-IED communication using GOOSE and client-server communication over MMS are supported. Disturbance recording file (COMTRADE) uploading can be done over MMS or FTP.

The front port shall not be used due to interference.

LON communication protocol
Existing stations with ABB station bus LON can be extended with use of the optical LON interface. This allows full SA functionality including peer-to-peer messaging and cooperation between the IEDs.

SPA communication protocol
A single glass or plastic port is provided for the ABB SPA protocol. This allows extensions of simple substation automation systems but the main use is for Substation Monitoring Systems SMS.

IEC 60870-5-103 communication protocol
A single glass or plastic port is provided for the IEC 60870-5-103 standard. This allows design of simple substation automation systems including equipment from different vendors. Disturbance files uploading is provided.

DNP3.0 communication protocol
An electrical RS485 and an optical Ethernet port is available for the DNP3.0 communication. DNP3.0 Level 2 communication with unsolicited events, time synchronizing and disturbance reporting is provided for communication to RTUs, Gateways or HMI systems.

Multiple command and transmit
When IEDs are used in Substation Automation systems with LON, SPA or IEC 60870-5-103 communication protocols, the Event and Multiple Command function blocks are used as the communication interface for vertical communication to station HMI and gateway, and as interface for horizontal peer-to-peer communication (over LON only).

IEC 62439-3 Parallel Redundancy Protocol
Redundant station bus communication according to IEC 62439-3 Edition 1 and IEC 62439-3 Edition 2 parallel redundancy protocol (PRP) are available as options when ordering IEDs. Redundant station bus communication according to IEC 62439-3 uses both port AB and port CD on the OEM module.

13. Hardware description

Hardware modules
Power supply module PSM
The power supply module is used to provide the correct internal voltages and full isolation between the IED and the battery system. An internal fail alarm output is available.

Binary input module BIM
The binary input module has 16 optically isolated inputs and is available in two versions, one standard and one with enhanced pulse counting capabilities on the inputs to be used with the pulse counter function. The binary inputs are freely programmable and can be used for the input of logical signals to any of the functions. They can also be included in the disturbance recording and event-recording functions. This enables extensive monitoring and evaluation of operation of the IED and for all associated electrical circuits.

Binary output module BOM
The binary output module has 24 independent output relays and is used for trip output or any signaling purpose.

Binary input/output module IOM
The binary input/output module is used when only a few input and output channels are needed. The ten standard output channels are used for trip output or any signaling purpose. The two high speed signal output channels are used for applications where short operating time is essential. Eight optically isolated binary inputs cater for required binary input information.

Optical ethernet module OEM
The optical fast-ethernet module is used for fast and interference-free communication of synchrophasor data over IEEE C37.118 and/or IEEE 1344 protocols. It is also used to connect an IED to the communication buses (like the station bus) that use the IEC 61850-8-1 protocol (port A, B). The module has one or two optical ports with ST connectors.

Serial and LON communication module SLM, supports SPA/IEC 60870-5-103, LON and DNP 3.0
The serial and LON communication module (SLM) is used for SPA, IEC 60870-5-103, DNP3 and LON communication. The module has two optical communication ports for plastic/plastic, plastic/glass or glass/glass. One port is used for serial communication (SPA, IEC 60870-5-103 and DNP3 port) and one port is dedicated for LON communication.

Galvanic RS485 serial communication module
The Galvanic RS485 communication module (RS485) is used for DNP3.0 and IEC 60870-5-103 communication. The module has one RS485 communication port. The RS485 is a balanced serial communication that can be used either in 2-wire or 4-wire connections. A 2-wire connection uses the same signal for RX and TX and is a multidrop communication with no dedicated Master or slave. This variant requires however a control of the output. The 4-wire connection has separated signals for RX and TX multidrop communication with a dedicated Master and the rest are slaves. No special control signal is needed in this case.

IRIG-B Time synchronizing module
The IRIG-B time synchronizing module is used for accurate time synchronizing of the IED from a station clock.

Electrical (BNC) and optical connection (ST) for 0XX and 12X IRIG-B support.

Transformer input module TRM
The transformer input module is used to galvanically separate and adapt the secondary currents and voltages generated by the measuring transformers. The module has twelve inputs in different combinations of currents and voltage inputs.

Alternative connectors of Ring lug or Compression type can be ordered.

High impedance resistor unit
The high impedance resistor unit, with resistors for pick-up value setting and a voltage dependent resistor, is available in a single phase unit and a three phase unit. Both are mounted on a 1/1 19 inch apparatus plate with compression type terminals.

Layout and dimensions
Dimensions

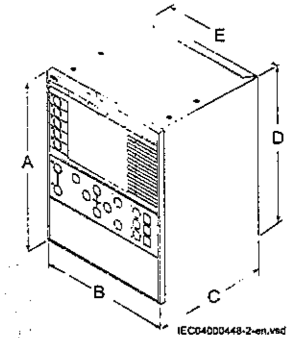

Figure 3. Case without rear cover

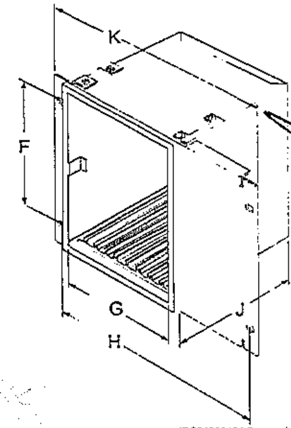

Figure 4. Case without rear cover with 19" rack mounting kit

Case size (mm)/(inches)	A	B	C	D	E	F	G	H	J	K
6U, 1/2 x 19"	265.9/ 10.47	223.7/ 8.81	242.1/ 9.53	255.8/ 10.07	205.7/ 8.10	190.5/ 7.50	203.7/ 8.02	-	228.6/ 9.00	-

The H and K dimensions are defined by the 19" rack mounting kit.

Mounting alternatives
- 19" rack mounting kit
- Flush mounting kit with cut-out dimensions (h) 259.3 mm/10.21"(w) 434.7 mm/17.11" for 1/1 case size
- Flush mounting kit with cut-out dimensions:
  - 1/2 case size (h) 254.3 mm/10.01" (w) 210.1 mm/8.27"
- Wall mounting kit

See ordering for details about available mounting alternatives.

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14. Connection diagrams

Connection diagrams
The connection diagrams are delivered on the IED Connectivity package DVD as part of the product delivery.

The latest versions of the connection diagrams can be downloaded from http://www.abb.com/substationautomation.

Connection diagrams for Configured products

650 series ver. 2.1, IEC symbols 1MRK006501-AF

650 series ver. 2.1, ANSI symbols 1MRK006502-AF

Connection diagram, REC650 2.1, A02 1MRK006505-CA

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15. Technical data

General

Definitions	
Reference value	The specified value of an influencing factor to which are referred the characteristics of the equipment
Nominal range	The range of values of an influencing quantity (factor) within which, under specified conditions, the equipment meets the specified requirements
Operative range	The range of values of a given energizing quantity for which the equipment, under specified conditions, is able to perform its intended functions according to the specified requirements

Energizing quantities, rated values and limits
Analog inputs

Table 5. TRM - Energizing quantities, rated values and limits for protection transformer modules

Quantity	Rated value	Nominal range
Current	I_r = 1 or 5 A	(0.2-40) × I_r
Operative range	(0-100) x I_r	
Permissive overload	4 × I_r cont. 100 × I_r for 1 s *)	
Burden	< 150 mVA at I_r = 5 A < 20 mVA at I_r = 1 A	
AC voltage	U_r = 110 V	0.5–288 V
Operative range	(0–340) V	
Permissive overload	420 V cont. 450 V 10 s	
Burden	< 20 mVA at 110 V	
Frequency	50/60 Hz	±5%

*) max. 350 A for 1 s when COMBITEST test switch is included.

Table 6. OEM - Optical ethernet module

Quantity	Rated value
Number of channels	1 or 2 (port A, B for IEC 61850-8-1 / IEEE C37.118)
Standard	IEEE 802.3u 100BASE-FX
Type of fiber	62.5/125 µm multimode fibre
Wave length	1300 nm
Optical connector	Type ST
Communication speed	Fast Ethernet 100 Mbit/s

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Auxiliary DC voltage

Table 7. PSM - Power supply module

Quantity	Rated value	Nominal range
Auxiliary DC voltage, EL (input)	EL = (24-60) V EL = (90-250) V	EL ±20% EL ±20%
Power consumption	32 W typically	-
Auxiliary DC power in-rush	< 10 A during 0.1 s	-

Binary inputs and outputs

Table 8. BIM - Binary input module

Quantity	Rated value	Nominal range
Binary inputs	16	-
DC voltage, RL	24/30 V 48/60 V 110/125 V 220/250 V	RL ±20% RL ±20% RL ±20% RL ±20%
Power consumption 24/30 V, 50 mA 48/60 V, 50 mA 110/125 V, 50 mA 220/250 V, 50 mA 220/250 V, 110 mA	max. 0.05 W/input max. 0.1 W/input max. 0.2 W/input max. 0.4 W/input max. 0.5 W/input	-
Counter input frequency	10 pulses/s max	-
Oscillating signal discriminator	Blocking settable 1–40 Hz Release settable 1–30 Hz	
Debounce filter	Settable 1–20 ms	

Maximum 176 binary input channels may be activated simultaneously with influencing factors within nominal range.

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Table 9. BIM - Binary input module with enhanced pulse counting capabilities

Quantity	Rated value	Nominal range
Binary inputs	16	-
DC voltage, RL	24/30 V 48/60 V 110/125 V 220/250 V	RL ±20% RL ±20% RL ±20% RL ±20%
Power consumption 24/30 V 48/60 V 110/125 V 220/250 V	max. 0.05 W/input max. 0.1 W/input max. 0.2 W/input max. 0.4 W/input	-
Counter input frequency	10 pulses/s max	-
Balanced counter input frequency	40 pulses/s max	-
Oscillating signal discriminator	Blocking settable 1–40 Hz Release settable 1–30 Hz	
Debounce filter	Settable 1-20 ms	

Maximum 176 binary input channels may be activated simultaneously with influencing factors within nominal range.

Table 10. IOM - Binary input/output module

Quantity	Rated value	Nominal range
Binary inputs	8	-
DC voltage, RL	24/30 V 48/60 V 110/125 V 220/250 V	RL ±20% RL ±20% RL ±20% RL ±20%
Power consumption 24/30 V, 50 mA 48/60 V, 50 mA 110/125 V, 50 mA 220/250 V, 50 mA 220/250 V, 110 mA	max. 0.05 W/input max. 0.1 W/input max. 0.2 W/input max. 0.4 W/input max. 0.5 W/input	-
Counter input frequency	10 pulses/s max	
Oscillating signal discriminator	Blocking settable 1-40 Hz Release settable 1-30 Hz	
Debounce filter	Settable 1-20 ms	

Maximum 176 binary input channels may be activated simultaneously with influencing factors within nominal range.

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Table 11. IOM - Binary input/output module contact data (reference standard: IEC 61810-2)

Function or quantity	Trip and signal relays	Fast signal relays (parallel reed relay)
Binary outputs	10	2
Max system voltage	250 V AC, DC	250 V DC
Test voltage across open contact, 1 min	1000 V rms	800 V DC
Current carrying capacity Per relay, continuous Per relay, 1 s Per process connector pin, continuous	 8 A 10 A 12 A	 8 A 10 A 12 A
Making capacity at inductive load with L/R > 10 ms 0.2 s 1.0 s	 30 A 10 A	 0.4 A 0.4 A
Making capacity at resistive load 0.2 s 1.0 s	 30 A 10 A	220–250 V/0.4 A 110–125 V/0.4 A 48–60 V/0.2 A 24–30 V/0.1 A
Breaking capacity for AC, cos φ > 0.4	250 V/8.0 A	250 V/8.0 A
Breaking capacity for DC with L/R < 40 ms	48 V/1 A 110 V/0.4 A 125 V/0.35 A 220 V/0.2 A 250 V/0.15 A	48 V/1 A 110 V/0.4 A 125 V/0.35 A 220 V/0.2 A 250 V/0.15 A
Maximum capacitive load	-	10 nF

Maximum 72 outputs may be activated simultaneously with influencing factors within nominal range. After 6 ms an additional 24 outputs may be activated. The activation time for the 96 outputs must not exceed 200 ms. 48 outputs can be activated during 1 s. Continued activation is possible with respect to current consumption but after 5 minutes the temperature rise will adversely affect the hardware life. Maximum two relays per BOM/IOM should be activated continuously due to power dissipation.

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Table 12. IOM with MOV and IOM 220/250 V, 110mA - contact data (reference standard: IEC 61810-2)

Function or quantity	Trip and Signal relays	Fast signal relays (parallel reed relay)
Binary outputs	IOM: 10	IOM: 2
Max system voltage	250 V AC, DC	250 V DC
Test voltage across open contact, 1 min	250 V rms	250 V rms
Current carrying capacity Per relay, continuous Per relay, 1 s Per process connector pin, continuous	 8 A 10 A 12 A	 8 A 10 A 12 A
Making capacity at inductive loadwith L/R > 10 ms 0.2 s 1.0 s	 30 A 10 A	 0.4 A 0.4 A
Making capacity at resistive load 0.2 s 1.0 s	 30 A 10 A	220–250 V/0.4 A 110–125 V/0.4 A 48–60 V/0.2 A 24–30 V/0.1 A
Breaking capacity for AC, cos φ > 0.4	250 V/8.0 A	250 V/8.0 A
Breaking capacity for DC with L/R < 40 ms	48 V/1 A 110 V/0.4 A 220 V/0.2 A 250 V/0.15 A	48 V/1 A 110 V/0.4 A 220 V/0.2 A 250 V/0.15 A
Maximum capacitive load	-	10 nF

Maximum 72 outputs may be activated simultaneously with influencing factors within nominal range. After 6 ms an additional 24 outputs may be activated. The activation time for the 96 outputs must not exceed 200 ms. 48 outputs can be activated during 1 s. Continued activation is possible with respect to current consumption but after 5 minutes the temperature rise will adversely affect the hardware life. Maximum two relays per BOM/IOM should be activated continuously due to power dissipation.

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Table 13. BOM - Binary output module contact data (reference standard: IEC 61810-2)

Function or quantity	Trip and Signal relays
Binary outputs	24
Max system voltage	250 V AC, DC
Test voltage across open contact, 1 min	1000 V rms
Current carrying capacity Per relay, continuous Per relay, 1 s Per process connector pin, continuous	 8 A 10 A 12 A
Making capacity at inductive load with L/R > 10 ms 0.2 s 1.0 s	 30 A 10 A
Breaking capacity for AC, cos φ > 0.4	250 V/8.0 A
Breaking capacity for DC with L/R < 40 ms	48 V/1 A 110 V/0.4 A 125 V/0.35 A 220 V/0.2 A 250 V/0.15 A

Influencing factors

Table 14. Temperature and humidity influence

Parameter	Reference value	Nominal range	Influence
Ambient temperature, operate value	+20°C	-20°C to +55°C	0.02%/°C
Relative humidity Operative range	10-90% 0-95%	10-90%	-
Storage temperature	-	-40°C to +70°C	-

Table 15. Auxiliary DC supply voltage influence on functionality during operation

Dependence on	Reference value	Within nominal range	Influence
Ripple, in DC auxiliary voltage Operative range	max. 2% Full wave rectified	15% of EL	0.01%/%
Auxiliary voltage dependence, operate value		±20% of EL	0.01%/%
Interrupted auxiliary DC voltage		24-60 V DC ± 20% 90-250 V DC ±20%	
Interruption interval 0–50 ms			No restart
0–∞ s			Correct behaviour at power down
Restart time			< 300 s

Table 16. Frequency influence (reference standard: IEC 60255–1)

Dependence on	Within nominal range	Influence
Frequency dependence, operate value	f_r ±2.5 Hz for 50 Hz f_r ±3.0 Hz for 60 Hz	±1.0%/Hz
Harmonic frequency dependence (20% content)	2nd, 3rd and 5th harmonic of f_r	±1.0%

Type tests according to standards

Table 17. Electromagnetic compatibility

Test	Type test values	Reference standards
1 MHz burst disturbance	2.5 kV	IEC 60255-26
100 kHz slow damped oscillatory wave immunity test	2.5 kV	IEC 61000-4-18, Class III
Ring wave immunity test, 100 kHz	2-4 kV	IEC 61000-4-12, Class IV
Surge withstand capability test	2.5 kV, oscillatory 4.0 kV, fast transient	IEEE/ANSI C37.90.1
Electrostatic discharge Direct application Indirect application	15 kV air discharge 8 kV contact discharge 8 kV contact discharge	IEC 60255-26 IEC 61000-4-2, Class IV
Electrostatic discharge Direct application Indirect application	15 kV air discharge 8 kV contact discharge 8 kV contact discharge	IEEE/ANSI C37.90.1
Fast transient disturbance	4 kV	IEC 60255-26, Zone A
Surge immunity test	2-4 kV, 1.2/50 μs high energy	IEC 60255-26, Zone A
Power frequency immunity test	150-300 V, 50 Hz	IEC 60255-26, Zone A
Conducted common mode immunity test	15 Hz-150 kHz	IEC 61000-4-16, Class IV
Power frequency magnetic field test	1000 A/m, 3 s 100 A/m, cont.	IEC 61000-4-8, Class V
Pulse magnetic field immunity test	1000 A/m	IEC 61000–4–9, Class V
Damped oscillatory magnetic field test	100 A/m	IEC 61000-4-10, Class V
Radiated electromagnetic field disturbance	20 V/m, 80-1000 MHz 1.4-2.7 GHz	IEC 60255-26
Radiated electromagnetic field disturbance	20 V/m 80-1000 MHz	IEEE/ANSI C37.90.2
Conducted electromagnetic field disturbance	10 V, 0.15-80 MHz	IEC 60255-26
Radiated emission	30-5000 MHz	IEC 60255-26
Radiated emission	30-5000 MHz	IEEE/ANSI C63.4, FCC
Conducted emission	0.15-30 MHz	IEC 60255-26

Table 18. Insulation

Test	Type test values	Reference standard
Dielectric test	2.0 kV AC, 1 min.	IEC 60255-27 ANSI C37.90
Impulse voltage test	5 kV, 1.2/50 μs, 0.5 J	
Insulation resistance	> 100 MΩ at 500 VDC	

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Table 19. Environmental tests

Test	Type test value	Reference standard
Cold operation test	Test Ad for 16 h at -25°C	IEC 60068-2-1
Cold storage test	Test Ab for 16 h at -40°C	IEC 60068-2-1
Dry heat operation test	Test Bd for 16 h at +70°C	IEC 60068-2-2
Dry heat storage test	Test Bb for 16 h at +85°C	IEC 60068-2-2
Change of temperature test	Test Nb for 5 cycles at -25°C to +70°C	IEC 60068-2-14
Damp heat test, steady state	Test Ca for 10 days at +40°C and humidity 93%	IEC 60068-2-78
Damp heat test, cyclic	Test Db for 6 cycles at +25 to +55°C and humidity 93 to 95% (1 cycle = 24 hours)	IEC 60068-2-30

Table 20. CE compliance

Test	According to
Immunity	EN 60255–26
Emissivity	EN 60255–26
Low voltage directive	EN 60255–27

Table 21. Mechanical tests

Test	Type test values	Reference standards
Vibration response test	Class II	IEC 60255-21-1
Vibration endurance test	Class I	IEC 60255-21-1
Shock response test	Class I	IEC 60255-21-2
Shock withstand test	Class I	IEC 60255-21-2
Bump test	Class I	IEC 60255-21-2
Seismic test	Class II	IEC 60255-21-3

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Voltage protection

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Multipurpose protection

Table 22. General current and voltage protection CVGAPC

Function	Range or value	Accuracy
Measuring current input	phase1, phase2, phase3, PosSeq, -NegSeq, -3*ZeroSeq, MaxPh, MinPh, UnbalancePh, phase1-phase2, phase2-phase3, phase3-phase1, MaxPh-Ph, MinPh-Ph, UnbalancePh-Ph	-
Measuring voltage input	phase1, phase2, phase3, PosSeq, -NegSeq, -3*ZeroSeq, MaxPh, MinPh, UnbalancePh, phase1-phase2, phase2-phase3, phase3-phase1, MaxPh-Ph, MinPh-Ph, UnbalancePh-Ph	-
Start overcurrent, step 1 - 2	(2 - 5000)% of IBase	±1.0% of I_r at $I \leq I_r$ ±1.0% of I at $I > I_r$
Start undercurrent, step 1 - 2	(2 - 150)% of IBase	±1.0% of I_r at $I \leq I_r$ ±1.0% of I at $I > I_r$
Independent time delay, overcurrent at 0 to 2 x I_{set}, step 1 - 2	(0.00 - 6000.00) s	±0.2% or ±35 ms whichever is greater
Independent time delay, undercurrent at 2 to 0 x I_{set}, step 1 - 2	(0.00 - 6000.00) s	±0.2% or ±35 ms whichever is greater
Overcurrent (non-directional):		
Start time at 0 to 2 x I_{set}	Min. = 15 ms Max. = 30 ms	-
Reset time at 2 to 0 x I_{set}	Min. = 15 ms Max. = 30 ms	-
Start time at 0 to 10 x I_{set}	Min. = 5 ms Max. = 20 ms	-
Reset time at 10 to 0 x I_{set}	Min. = 20 ms Max. = 35 ms	-
Undercurrent:		
Start time at 2 to 0 x I_{set}	Min. = 15 ms Max. = 30 ms	-
Reset time at 0 to 2 x I_{set}	Min. = 15 ms Max. = 30 ms	-
Overcurrent:		
Inverse time characteristics, see table 103, "" and table ""	16 curve types	See table 103, "" and table ""
Overcurrent:		
Minimum operate time for inverse curves, step 1 - 2	(0.00 - 6000.00) s	±0.2% or ±35 ms whichever is greater
Voltage level where voltage memory takes over	(0.0 - 5.0)% of UBase	±0.5% of U_r
Start overvoltage, step 1 - 2	(2.0 - 200.0)% of UBase	±0.5% of U_r at $U \leq U_r$ ±0.5% of U at $U > U_r$
Start undervoltage, step 1 - 2	(2.0 - 150.0)% of UBase	±0.5% of U_r at $U \leq U_r$ ±0.5% of U at $U > U_r$
Independent time delay, overvoltage at 0.8 to 1.2 x U_{set}, step 1 - 2	(0.00 - 6000.00) s	±0.2% or ±35 ms whichever is greater

Table 22. General current and voltage protection CVGAPC , continued

Function	Range or value	Accuracy
Independent time delay, undervoltage at 1.2 to 0.8 x U_{set}, step 1 - 2	(0.00 - 6000.00) s	±0.2% or ±35 ms whichever is greater
Overvoltage:		
Start time at 0.8 to 1.2 x U_{set}	Min. = 15 ms Max. = 30 ms	-
Reset time at 1.2 to 0.8 x U_{set}	Min. = 15 ms Max. = 30 ms	-
Undervoltage:		
Start time at 1.2 to 0.8 x U_{set}	Min. = 15 ms Max. = 30 ms	-
Reset time at 1.2 to 0.8 x U_{set}	Min. = 15 ms Max. = 30 ms	-
Overvoltage:		
Inverse time characteristics, see table 104	4 curve types	See table 104
Undervoltage:		
Inverse time characteristics, see table ""	3 curve types	See table ""
High and low voltage limit, voltage dependent operation, step 1 - 2	(1.0 - 200.0)% of UBase	±1.0% of U_r at $U \leq U_r$ ±1.0% of U at $U > U_r$
Directional function	Settable: NonDir, forward and reverse	-
Relay characteristic angle	(-180 to +180) degrees	±2.0 degrees
Relay operate angle	(1 to 90) degrees	±2.0 degrees
Reset ratio, overcurrent	> 95%	-
Reset ratio, undercurrent	< 105%	-
Reset ratio, overvoltage	> 95%	-
Reset ratio, undervoltage	< 105%	-
Overcurrent:		
Critical impulse time	10 ms typically at 0 to 2 x I_{set}	-
Impulse margin time	15 ms typically	-
Undercurrent:		
Critical impulse time	10 ms typically at 2 to 0 x I_{set}	-
Impulse margin time	15 ms typically	-
Overvoltage:		
Critical impulse time	10 ms typically at 0.8 to 1.2 x U_{set}	-
Impulse margin time	15 ms typically	-
Undervoltage:		
Critical impulse time	10 ms typically at 1.2 to 0.8 x U_{set}	-
Impulse margin time	15 ms typically	-

Table 23. Rotor earth fault protection based on General current and voltage protection (CVGAPC) and RXTTE4

Function	Range or value
For machines with:	
• rated field voltage up to	350 V DC
• static exciter with rated supply voltage up to	700 V 50/60 Hz
Supply voltage 120 or 230 V	50/60 Hz
Operate earth fault resistance value	Approx. 1–20 kΩ
Influence of harmonics in the DC field voltage	Negligible influence of 50 V, 150 Hz or 50 V, 300 Hz
Permitted leakage capacitance	(1–5) μF
Permitted shaft earthing resistance	Maximum 200 Ω
Protective resistor	220 Ω, 100 W, plate (the height is 160 mm (6,2 inches) and width 135 mm (5,31 inches))

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Secondary system supervision

Table 24. Current circuit supervision CCSSPVC

Function	Range or value	Accuracy
Operate current	(10-200)% of IBase	±10.0% of I_r at I ≤ I_r ±10.0% of I at I > I_r
Reset ratio, Operate current	>90%	
Block current	(20-500)% of IBase	±5.0% of I_r at I ≤ I_r ±5.0% of I at I > I_r
Reset ratio, Block current	>90% at (50-500)% of IBase	

Table 25. Fuse failure supervision FUFSPVC

Function	Range or value	Accuracy
Operate voltage, zero sequence	(1-100)% of UBase	±0.5% of U_r
Operate current, zero sequence	(1–100)% of IBase	±0.5% of I_r
Operate voltage, negative sequence	(1-100)% of UBase	±0.5% of U_r
Operate current, negative sequence	(1–100)% of IBase	±0.5% of I_r
Operate voltage change level	(1-100)% of UBase	±10.0% of U_r
Operate current change level	(1–100)% of IBase	±10.0% of I_r
Operate phase voltage	(1-100)% of UBase	±0.5% of U_r
Operate phase current	(1-100)% of IBase	±0.5% of I_r
Operate phase dead line voltage	(1-100)% of UBase	±0.5% of U_r
Operate phase dead line current	(1–100)% of IBase	±0.5% of I_r
Operate time, start, 1 ph, at 1 to 0 x U_r	Min. = 10 ms Max. = 25 ms	-
Reset time, start, 1 ph, at 0 to 1 x U_r	Min. = 15 ms Max. = [illegible] ms	-

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Control

Table 26. Synchronizing, synchrocheck and energizing check SESRSYN

Function	Range or value	Accuracy
Phase shift, $\varphi_{line} - \varphi_{bus}$	(-180 to 180) degrees	-
Voltage high limit for synchronizing and synchrocheck	(50.0-120.0)% of UBase	±0.5% of U_r at $U \leq U_r$ ±0.5% of U at $U > U_r$
Reset ratio, synchrocheck	> 95%	-
Frequency difference limit between bus and line for synchrocheck	(0.003-1.000) Hz	±2.5 mHz
Phase angle difference limit between bus and line for synchrocheck	(5.0-90.0) degrees	±2.0 degrees
Voltage difference limit between bus and line for synchronizing and synchrocheck	(0.02-0.5) p.u	±0.5% of U_r
Time delay output for synchrocheck when angle difference between bus and line jumps from "PhaseDiff" + 2 degrees to "PhaseDiff" - 2 degrees	(0.000-60.000) s	±0.2% or ±35 ms whichever is greater
Frequency difference minimum limit for synchronizing	(0.003-0.250) Hz	±2.5 mHz
Frequency difference maximum limit for synchronizing	(0.050-0.500) Hz	±2.5 mHz
Breaker closing pulse duration	(0.050-60.000) s	±0.2% or ±15 ms whichever is greater
tMaxSynch, which resets synchronizing function if no close has been made before set time	(0.000-6000.00) s	±0.2% or ±35 ms whichever is greater
Minimum time to accept synchronizing conditions	(0.000-60.000) s	±0.2% or ±35 ms whichever is greater
Voltage high limit for energizing check	(50.0-120.0)% of UBase	±0.5% of U_r at $U \leq U_r$ ±0.5% of U at $U > U_r$
Reset ratio, voltage high limit	> 95%	-
Voltage low limit for energizing check	(10.0-80.0)% of UBase	±0.5% of U_r
Reset ratio, voltage low limit	< 105%	-
Maximum voltage for energizing	(50.0-180.0)% of UBase	±0.5% of U_r at $U \leq U_r$ ±0.5% of U at $U > U_r$
Time delay for energizing check when voltage jumps from 0 to 90% of Urated	(0.000-60.000) s	±0.2% or ±100 ms whichever is greater
Operate time for synchrocheck function when angle difference between bus and line jumps from "PhaseDiff" + 2 degrees to "PhaseDiff" - 2 degrees	Min. = 15 ms Max. = 30 ms	–
Operate time for energizing function when voltage jumps from 0 to 90% of Urated	Min. = 70 ms Max. = 90 ms	–

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Table 27. Autorecloser SMBRREC

Function	Range or value	Accuracy
Number of autoreclosing shots	1-5	-
Autoreclosing open time: shot 1 - t1 1Ph shot 1 - t1 2Ph shot 1 - t1 3PhHS shot 1 - t1 3Ph	(0.000-120.000) s	±0.2% or ±35 ms whichever is greater
shot 2 - t2 3Ph shot 3 - t3 3Ph shot 4 - t4 3Ph shot 5 - t5 3Ph	(0.00-6000.00) s	±0.2% or ±35 ms whichever is greater
Extended autorecloser open time	(0.000-60.000) s	±0.2% or ±35 ms whichever is greater
Minimum time CB must be closed before AR becomes ready for autoreclosing cycle	(0.00-6000.00) s	±0.2% or ±35 ms whichever is greater
Maximum operate pulse duration	(0.000-60.000) s	±0.2% or ±15 ms whichever is greater
Reclaim time	(0.00-6000.00) s	±0.2% or ±15 ms whichever is greater
Circuit breaker closing pulse length	(0.000-60.000) s	±0.2% or ±15 ms whichever is greater
Wait for master release	(0.00-6000.00) s	±0.2% or ±15 ms whichever is greater
Inhibit reset time	(0.000-60.000) s	±0.2% or ±45 ms whichever is greater
Autorecloser maximum wait time for sync	(0.00-6000.00) s	±0.2% or ±45 ms whichever is greater
CB check time before unsuccessful	(0.00-6000.00) s	±0.2% or ±45 ms whichever is greater
Wait time after close command before proceeding to next shot	(0.000-60.000) s	±0.2% or ±45 ms whichever is greater

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Scheme communication

Table 28. Scheme communication logic for distance or overcurrent protection ZCPSCH

Function	Range or value	Accuracy
Scheme type	Off Intertrip Permissive UR Permissive OR Blocking DeltaBlocking	-
Operate voltage, Delta U	(0–100)% of UBase	±5.0% of ΔU
Operate current, Delta I	(0–200)% of IBase	±5.0% of ΔI
Operate zero sequence voltage, Delta 3U0	(0–100)% of UBase	±10.0% of Δ3U0
Operate zero sequence current, Delta 3I0	(0–200)% of IBase	±10.0% of Δ3I0
Co-ordination time for blocking communication scheme	(0.000-60.000) s	±0.2% or ±10 ms whichever is greater
Minimum duration of a carrier send signal	(0.000-60.000) s	±0.2% or ±10 ms whichever is greater
Security timer for loss of guard signal detection	(0.000-60.000) s	±0.2% or ±10 ms whichever is greater
Operation mode of unblocking logic	Off NoRestart Restart	-

Table 29. Current reversal and weak-end infeed logic for distance protection ZCRWPSCH

Function	Range or value	Accuracy
Detection level phase-to-neutral voltage	(10-90)% of UBase	±0.5% of U_r
Detection level phase-to-phase voltage	(10-90)% of UBase	±0.5% of U_r
Operate time for current reversal logic	(0.000-60.000) s	±0.2% or ±15 ms whichever is greater
Delay time for current reversal	(0.000-60.000) s	±0.2% or ±15 ms whichever is greater
Coordination time for weak-end infeed logic	(0.000-60.000) s	±0.2% or ±15 ms whichever is greater

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Logic

Table 30. Tripping logic common 3-phase output SMPPTRC

Function	Range or value	Accuracy
Trip action	3-ph, 1/3-ph, 1/2/3-ph	-
Minimum trip pulse length	(0.000-60.000) s	±0.2% or ±15 ms whichever is greater
3-pole trip delay	(0.020-0.500) s	±0.2% or ±15 ms whichever is greater
Evolving fault delay	(0.000-60.000) s	±0.2% or ±15 ms whichever is greater

Table 31. Number of SMPPTRC instances

Function	Quantity with cycle time
	3 ms
SMPPTRC	6

Table 32. Number of TMAGAPC instances

Function	Quantity with cycle time		
	3 ms	8 ms	100 ms
TMAGAPC	6	6	-

Table 33. Number of ALMCALH instances

Function	Quantity with cycle time		
	3 ms	8 ms	100 ms
ALMCALH	-	-	5

Table 34. Number of WRNCALH instances

Function	Quantity with cycle time		
	3 ms	8 ms	100 ms
WRNCALH	-	-	5

Table 35. Number of INDCALH instances

Function	Quantity with cycle time		
	3 ms	8 ms	100 ms
INDCALH	-	5	-

Table 36. Number of AND instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
AND	60	60	160

Table 37. Number of GATE instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
GATE	10	10	20

Table 38. Number of INV instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
INV	90	90	240

Table 39. Number of LLD instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
LLD	10	10	20

Table 40. Number of OR instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
OR	60	60	160

Table 41. Number of PULSETIMER instances

Logic block	Quantity with cycle time			Range or Value	Accuracy
	3 ms	8 ms	100 ms		
PULSETIMER	10	10	20	(0.000–90000.000) s	±0.5% ±10 ms

Table 42. Number of RSMEMORY instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
RSMEMORY	10	10	20

Table 43. Number of SRMEMORY instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
SRMEMORY	10	10	20

Table 44. Number of TIMERSET instances

Logic block	Quantity with cycle time			Range or Value	Accuracy
	3 ms	8 ms	100 ms		
TIMERSET	15	15	30	(0.000–90000.000) s	±0.5% ±10 ms

Table 45. Number of XOR instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
XOR	10	10	20

Table 46. Number of ANDQT instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
ANDQT	-	20	100

Table 47. Number of INDCOMBSPQT instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
INDCOMBSPQT	-	10	10

Table 48. Number of INDEXTSPQT instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
INDEXTSPQT	-	10	10

Table 49. Number of INVALIDQT instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
INVALIDQT	-	6	6

Table 50. Number of INVERTERQT instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
INVERTERQT	-	20	100

Table 51. Number of ORQT instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
ORQT	-	20	100

Table 52. Number of PULSETIMERQT instances

Logic block	Quantity with cycle time			Range or Value	Accuracy
	3 ms	8 ms	100 ms		
PULSETIMERQT	-	10	30	(0.000–90000.000) s	±0.5% ±10 ms

Table 53. Number of RSMEMORYQT instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
RSMEMORYQT	-	10	30

Table 54. Number of SRMEMORYQT instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
SRMEMORYQT	-	10	30

Table 55. Number of TIMERSETQT instances

Logic block	Quantity with cycle time			Range or Value	Accuracy
	3 ms	8 ms	100 ms		
TIMERSETQT	-	10	30	(0.000–90000.000) s	±0.5% ±10 ms

Table 56. Number of XORQT instances

Logic block	Quantity with cycle time		
	3 ms	8 ms	100 ms
XORQT	-	10	30

Table 57. Number of B16I instances

Function	Quantity with cycle time		
	3 ms	8 ms	100 ms
B16I	6	4	8

Table 58. Number of BTIGAPC instances

Function	Quantity with cycle time		
	3 ms	8 ms	100 ms
BTIGAPC	4	4	8

Table 59. Number of IB16 instances

Function	Quantity with cycle time		
	3 ms	8 ms	100 ms
IB16	6	4	8

Table 60. Number of ITBGAPC instances

Function	Quantity with cycle time		
	3 ms	8 ms	100 ms
ITBGAPC	4	4	8

Table 61. Elapsed time integrator with limit transgression and overflow supervision TEIGAPC

Function	Cycle time (ms)	Range or value	Accuracy
Elapsed time integration	3	0 ~ 999999.9 s	±0.2% or ±20 ms whichever is greater
	8	0 ~ 999999.9 s	±0.2% or ±100 ms whichever is greater
	100	0 ~ 999999.9 s	±0.2% or ±250 ms whichever is greater

Table 62. Number of TEIGAPC instances

Function	Quantity with cycle time		
	3 ms	8 ms	100 ms
TEIGAPC	4	4	4

Table 63. Running hour-meter TEILGAPC

Function	Range or value	Accuracy
Time limit for alarm supervision, tAlarm	(0 - 99999.9) hours	±0.1% of set value
Time limit for warning supervision, tWarning	(0 - 99999.9) hours	±0.1% of set value
Time limit for overflow supervision	Fixed to 99999.9 hours	±0.1%

Monitoring

Table 64. Measurements CVMMXN

Function	Range or value	Accuracy
Frequency	(0.95-1.05) x f_r	±2.0 mHz
Voltage	(10 to 300) V	±0.3% of U at U≤ 50 V ±0.2% of U at U> 50 V
Current	(0.1-4.0) x I_r	±0.8% of I at 0.1 x I_r< I < 0.2 x I_r ± 0.5% of I at 0.2 x I_r< I < 0.5 x I_r ±0.2% of I at 0.5 x I_r< I < 4.0 x I_r
Active power, P	(10 to 300) V (0.1-4.0) x I_r	±0.5% of S_r at S ≤0.5 x S_r ±0.5% of S at S > 0.5 x S_r
	(100 to 220) V (0.5-2.0) x I_r cos φ< 0.7	±0.2% of P
Reactive power, Q	(10 to 300) V (0.1-4.0) x I_r	±0.5% of S_r at S ≤0.5 x S_r ±0.5% of S at S > 0.5 x S_r
	(100 to 220) V (0.5-2.0) x I_r cos φ> 0.7	±0.2% of Q
Apparent power, S	(10 to 300) V (0.1-4.0) x I_r	±0.5% of S_r at S ≤0.5 x S_r ±0.5% of S at S >0.5 x S_r
	(100 to 220) V (0.5-2.0) x I_r	±0.2% of S
Power factor, cos (φ)	(10 to 300) V (0.1-4.0) x I_r	<0.02
	(100 to 220) V (0.5-2.0) x I_r	<0.01

Table 65. Phase current measurement CMMXU

Function	Range or value	Accuracy
Current at symmetrical load	(0.1-4.0) × I_r	±0.3% of I_r at I ≤ 0.5 × I_r ±0.3% of I at I > 0.5 × I_r
Phase angle at symmetrical load	(0.1-4.0) × I_r	±1.0 degrees at 0.1 × I_r < I ≤ 0.5 × I_r ±0.5 degrees at 0.5 × I_r < I ≤ 4.0 × I_r

Table 66. Phase-phase voltage measurement VMMXU

Function	Range or value	Accuracy
Voltage	(10 to 300) V	±0.5% of U at U ≤ 50 V ±0.2% of U at U > 50 V
Phase angle	(10 to 300) V	±0.5 degrees at U ≤ 50 V ±0.2 degrees at U > 50 V

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Table 67. Phase-neutral voltage measurement VNMMXU

Function	Range or value	Accuracy
Voltage	(5 to 175) V	±0.5% of U at U ≤ 50 V ±0.2% of U at U > 50 V
Phase angle	(5 to 175) V	±0.5 degrees at U ≤ 50 V ±0.2 degrees at U > 50 V

Table 68. Current sequence component measurement CMSQI

Function	Range or value	Accuracy
Current positive sequence, I1 Three phase settings	(0.1–4.0) × I_r	±0.3% of I_r at I ≤ 0.5 × I_r ±0.3% of I at I > 0.5 × I_r
Current zero sequence, 3I0 Three phase settings	(0.1–1.0) × I_r	±0.3% of I_r at I ≤ 0.5 × I_r ±0.3% of I at I > 0.5 × I_r
Current negative sequence, I2 Three phase settings	(0.1–1.0) × I_r	±0.3% of I_r at I ≤ 0.5 × I_r ±0.3% of I at I > 0.5 × I_r
Phase angle	(0.1–4.0) × I_r	±1.0 degrees at 0.1 × I_r < I ≤ 0.5 × I_r ±0.5 degrees at 0.5 × I_r < I ≤ 4.0 × I_r

Table 69. Voltage sequence measurement VMSQI

Function	Range or value	Accuracy
Voltage positive sequence, U1	(10 to 300) V	±0.5% of U at U ≤ 50 V ±0.2% of U at U > 50 V
Voltage zero sequence, 3U0	(10 to 300) V	±0.5% of U at U ≤ 50 V ±0.2% of U at U > 50 V
Voltage negative sequence, U2	(10 to 300) V	±0.5% of U at U ≤ 50 V ±0.2% of U at U > 50 V
Phase angle	(10 to 300) V	±0.5 degrees at U ≤ 50 V ±0.2 degrees at U > 50 V

Table 70. Supervision of mA input signals

Function	Range or value	Accuracy
mA measuring function	±5, ±10, ±20 mA 0-5, 0-10, 0-20, 4-20 mA	±0.1 % of set value ±0.005 mA
Max current of transducer to input	(-20.00 to +20.00) mA	
Min current of transducer to input	(-20.00 to +20.00) mA	
Alarm level for input	(-20.00 to +20.00) mA	
Warning level for input	(-20.00 to +20.00) mA	
Alarm hysteresis for input	(0.0-20.0) mA	

Table 71. Limit counter L4UFCNT

Function	Range or value	Accuracy
Counter value	0-65535	-
Max. count up speed	30 pulses/s (50% duty cycle)	-

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Table 72. Disturbance report DRPRDRE

Function	Range or value	Accuracy
Pre-fault time	(0.05–9.90) s	-
Post-fault time	(0.1–10.0) s	-
Limit time	(0.5–10.0) s	-
Maximum number of recordings	100, first in - first out	-
Time tagging resolution	1 ms	See table 101
Maximum number of analog inputs	30 + 10 (external + internally derived)	-
Maximum number of binary inputs	352	-
Maximum number of phasors in the Trip Value recorder per recording	30	-
Maximum number of indications in a disturbance report	96	-
Maximum number of events in the Event recording per recording	150	-
Maximum number of events in the Event list	1000, first in - first out	-
Maximum total recording time (3.4 s recording time and maximum number of channels, typical value)	340 seconds (100 recordings) at 50 Hz, 280 seconds (80 recordings) at 60 Hz	-
Sampling rate	1 kHz at 50 Hz 1.2 kHz at 60 Hz	-
Recording bandwidth	(5-300) Hz	-

Table 73. Insulation gas monitoring function SSIMG

Function	Range or value	Accuracy
Pressure alarm level	1.00-100.00	±10.0% of set value
Pressure lockout level	1.00-100.00	±10.0% of set value
Temperature alarm level	-40.00-200.00	±2.5% of set value
Temperature lockout level	-40.00-200.00	±2.5% of set value
Time delay for pressure alarm	(0.000-60.000) s	±0.2% or ±250ms whichever is greater
Reset time delay for pressure alarm	(0.000-60.000) s	±0.2% or ±250ms whichever is greater
Time delay for pressure lockout	(0.000-60.000) s	±0.2% or ±250ms whichever is greater
Time delay for temperature alarm	(0.000-60.000) s	±0.2% or ±250ms whichever is greater
Reset time delay for temperature alarm	(0.000-60.000) s	±0.2% or ±250ms whichever is greater
Time delay for temperature lockout	(0.000-60.000) s	±0.2% or ±250ms whichever is greater

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Table 74. Insulation liquid monitoring function SSIML

Function	Range or value	Accuracy
Oil alarm level	1.00-100.00	±10.0% of set value
Oil lockout level	1.00-100.00	±10.0% of set value
Temperature alarm level	-40.00-200.00	±2.5% of set value
Temperature lockout level	-40.00-200.00	±2.5% of set value
Time delay for oil alarm	(0.000-60.000) s	±0.2% or ±250ms whichever is greater
Reset time delay for oil alarm	(0.000-60.000) s	±0.2% or ±250ms whichever is greater
Time delay for oil lockout	(0.000-60.000) s	±0.2% or ±250ms whichever is greater
Time delay for temperature alarm	(0.000-60.000) s	±0.2% or ±250ms whichever is greater
Reset time delay for temperature alarm	(0.000-60.000) s	±0.2% or ±250ms whichever is greater
Time delay for temperature lockout	(0.000-60.000) s	±0.2% or ±250ms whichever is greater

Table 75. Breaker monitoring SSCBR

Function	Range or value	Accuracy
Alarm level for open and close travel time	(0 – 200) ms	±3 ms
Alarm level for number of operations	(0 – 9999)	-
Independent time delay for spring charging time alarm	(0.00 – 60.00) s	±0.2% or ±30 ms whichever is greater
Independent time delay for gas pressure alarm	(0.00 – 60.00) s	±0.2% or ±30 ms whichever is greater
Independent time delay for gas pressure lockout	(0.00 – 60.00) s	±0.2% or ±30 ms whichever is greater
CB Contact Travel Time, opening and closing		±3 ms
Remaining Life of CB		±2 operations
Accumulated Energy		±1.0% or ±0.5 whichever is greater

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Table 76. Fault locator LMBRFLO

Function	Value or range	Accuracy
Reactive and resistive reach	(0.001-1500.000) Ω/phase	±2.0% static accuracy Conditions: Voltage range: (0.1-1.1) x U_r Current range: (0.5-30) x I_r
Phase selection	According to input signals	-
Maximum number of fault locations	100	-

Table 77. Event list

Function		Value
Buffer capacity	Maximum number of events in the list	1000
Resolution		1 ms
Accuracy		Depending on time synchronizing

Table 78. Indications

Function		Value
Buffer capacity	Maximum number of indications presented for single disturbance	96
	Maximum number of recorded disturbances	100

Table 79. Event recorder

Function		Value
Buffer capacity	Maximum number of events in disturbance report	150
	Maximum number of disturbance reports	100
Resolution		1 ms
Accuracy		Depending on time synchronizing

Table 80. Trip value recorder

Function		Value
Buffer capacity	Maximum number of analog inputs	30
	Maximum number of disturbance reports	100

Table 81. Disturbance recorder

Function		Value
Buffer capacity	Maximum number of analog inputs	40
	Maximum number of binary inputs	96
	Maximum number of disturbance reports	100
Maximum total recording time (3.4 s recording time and maximum number of channels, typical value)		340 seconds (100 recordings) at 50 Hz 280 seconds (80 recordings) at 60 Hz

Table 82. Limit counter L4UFCNT

Function	Range or value	Accuracy
Counter value	0-65535	-
Max. count up speed	30 pulses/s (50% duty cycle)	-

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Metering

Table 83. Pulse-counter logic PCFCNT

Function	Setting range	Accuracy
Input frequency	See Binary Input Module (BIM)	-
Cycle time for report of counter value	(1–3600) s	-

Table 84. Energy metering ETPMMTR

Function	Range or value	Accuracy
Energy metering	kWh Export/Import, kvarh Export/Import	Input from MMXU. No extra error at steady load

Station communication

Table 85. Communication protocols

Function	Value
Protocol	IEC 61850-8-1
Communication speed for the IEDs	100BASE-FX
Protocol	IEC 60870–5–103
Communication speed for the IEDs	9600 or 19200 Bd
Protocol	DNP3.0
Communication speed for the IEDs	300–19200 Bd
Protocol	TCP/IP, Ethernet
Communication speed for the IEDs	100 Mbit/s

Table 86. LON communication protocol

Function	Value
Protocol	LON
Communication speed	1.25 Mbit/s

Table 87. SPA communication protocol

Function	Value
Protocol	SPA
Communication speed	300, 1200, 2400, 4800, 9600, 19200 or 38400 Bd
Slave number	1 to 899

Table 88. IEC 60870-5-103 communication protocol

Function	Value
Protocol	IEC 60870-5-103
Communication speed	9600, 19200 Bd

Table 89. SLM – LON port

Quantity	Range or value
Optical connector	Glass fiber: type ST Plastic fiber: type HFBR snap-in
Fiber, optical budget	Glass fiber: 11 dB (1000m/3000 ft typically *) Plastic fiber: 7 dB (10m/35ft typically *)
Fiber diameter	Glass fiber: 62.5/125 µm Plastic fiber: 1 mm

*) depending on optical budget calculation

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Table 90. SLM – SPA/IEC 60870-5-103/DNP3 port

Quantity	Range or value
Optical connector	Glass fiber: type ST Plastic fiber: type HFBR snap-in
Fiber, optical budget	Glass fiber: 11 dB (1000m/3000ft m typically *) Plastic fiber: 7 dB (25m/80ft m typically *)
Fiber diameter	Glass fiber: 62.5/125 µm Plastic fiber: 1 mm

*) depending on optical budget calculation

Table 91. Galvanic RS485 communication module

Quantity	Range or value
Communication speed	2400–19200 bauds
External connectors	RS-485 6-pole connector Soft ground 2-pole connector

Table 92. IEC 62439-3 Edition 1 and Edition 2 parallel redundancy protocol

Function	Value
Communication speed	100 Base-FX

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Hardware

IED

Table 93. Case

Material	Steel sheet
Front plate	Steel sheet profile with cut-out for HMI
Surface treatment	Aluzink preplated steel
Finish	Light grey (RAL 7035)

Table 94. Water and dust protection level according to IEC 60529

Front	IP40 (IP54 with sealing strip)
Sides, top and bottom	IP20
Rear side	IP20 with screw compression type IP10 with ring lug terminals

Table 95. Weight

Case size	Weight
6U, 1/2 x 19"	≤ 10 kg/22 lb

Electrical safety

Table 96. Electrical safety according to IEC 60255-27

Equipment class	I (protective earthed)
Overvoltage category	III
Pollution degree	2 (normally only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected)

Connection system

Table 97. CT and VT circuit connectors

Connector type	Rated voltage and current	Maximum conductor area
Screw compression type	250 V AC, 20 A	4 mm² (AWG12) 2 x 2.5 mm² (2 x AWG14)
Terminal blocks suitable for ring lug terminals	250 V AC, 20 A	4 mm² (AWG12)

Table 98. Auxiliary power supply connectors

Connector type	Rated voltage	Maximum conductor area
Screw compression type	250 V AC	2.5 mm² (AWG14) 2 × 1 mm² (2 x AWG18)
Terminal blocks suitable for ring lug terminals	300 V AC	3 mm² (AWG14)

Table 99. Binary I/O connectors

Connector type	Rated voltage	Maximum conductor area
Screw compression type	250 V AC	2.5 mm² (AWG14) 2 × 1 mm² (2 x AWG18)

Basic IED functions

Table 100. Self supervision with internal event list

Data	Value
Recording manner	Continuous, event controlled
List size	40 events, first in-first out

Table 101. Time synchronization, time tagging

Function	Value
Time tagging resolution, events and sampled measurement values	1 ms
Time tagging error with synchronization once/min (minute pulse synchronization), events and sampled measurement values	± 1.0 ms typically
Time tagging error with SNTP synchronization, sampled measurement values	± 1.0 ms typically

Table 102. IRIG-B

Quantity	Rated value
Number of channels IRIG-B	1
Number of optical channels	1
Electrical connector:	
Electrical connector IRIG-B	BNC
Pulse-width modulated	5 Vpp
Amplitude modulated – low level – high level	 1-3 Vpp 3 x low level, max 9 Vpp
Supported formats	IRIG-B 00x, IRIG-B 12x
Accuracy	+/-10μs for IRIG-B 00x and +/-100μs for IRIG-B 12x
Input impedance	100 k ohm
Optical connector:	
Optical connector IRIG-B	Type ST
Type of fibre	62.5/125 μm multimode fibre
Supported formats	IRIG-B 00x
Accuracy	+/- 1μs

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Inverse characteristic

Table 103. ANSI Inverse time characteristics

Function	Range or value	Accuracy
Operating characteristic: $t = \left(\frac{A}{(I^P - 1)} + B \right) \cdot k + tDef$ Reset characteristic: $t = \frac{t_r}{(I^2 - 1)} \cdot k$ $I = I_{measured}/I_{set}$	$0.10 \leq k \leq 3.00$ $1.5 \times I_{set} \leq I \leq 20 \times I_{set}$	ANSI/IEEE C37.112 , ±2.0% or ±40 ms whichever is greater
ANSI Extremely Inverse	A=28.2, B=0.1217, P=2.0 , tr=29.1	
ANSI Very Inverse	A=19.61, B=0.491, P=2.0 , tr=21.6	
ANSI Normal Inverse	A=0.0086, B=0.0185, P=0.02, tr=0.46	
ANSI Moderately Inverse	A=0.0515, B=0.1140, P=0.02, tr=4.85	
ANSI Long Time Extremely Inverse	A=64.07, B=0.250, P=2.0, tr=30	
ANSI Long Time Very Inverse	A=28.55, B=0.712, P=2.0, tr=13.46	
ANSI Long Time Inverse	A=0.086, B=0.185, P=0.02, tr=4.6	

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ИНТЕРКОМПЛЕКС ПЛОВДИВ ООД

Table 104. Inverse time characteristics for overvoltage protection

Function	Range or value	Accuracy
Type A curve: $t = \frac{k}{\left(\frac{U - U>}{U>} \right)}$ $U> = U_{set}$ $U = U_{measured}$	k = (0.05-1.10) in steps of 0.01	±5.0% or ±45 ms whichever is greater
Type B curve: $t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5 \right)^{2.0}} + 0.035$	k = (0.05-1.10) in steps of 0.01	
Type C curve: $t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5 \right)^{3.0}} + 0.035$	k = (0.05-1.10) in steps of 0.01	
Programmable curve: $t = \frac{k \cdot A}{\left(B \cdot \frac{U - U>}{U>} - C \right)^{P}} + D$	k = (0.05-1.10) in steps of 0.01 A = (0.005-200.000) in steps of 0.001 B = (0.50-100.00) in steps of 0.01 C = (0.0-1.0) in steps of 0.1 D = (0.000-60.000) in steps of 0.001 P = (0.000-3.000) in steps of 0.001	

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Table 105. Inverse time characteristics for residual overvoltage protection

Function	Range or value	Accuracy
Type A curve: $t = \frac{k}{\left(\frac{U - U>}{U>}\right)}$ $U> = U_{set}$ $U = U_{measured}$	k = (0.05-1.10) in steps of 0.01	±5.0% or ±45 ms whichever is greater
Type B curve: $t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{2.0}} + 0.035$	k = (0.05-1.10) in steps of 0.01	
Type C curve: $t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{3.0}} + 0.035$	k = (0.05-1.10) in steps of 0.01	
Programmable curve: $t = \frac{k \cdot A}{\left(B \cdot \frac{U - U>}{U>} - C\right)^{P}} + D$	k = (0.05-1.10) in steps of 0.01 A = (0.005-200.000) in steps of 0.001 B = (0.50-100.00) in steps of 0.01 C = (0.0-1.0) in steps of 0.1 D = (0.000-60.000) in steps of 0.001 P = (0.000-3.000) in steps of 0.001	

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16. Ordering for pre-configured IED

Guidelines
Carefully read and follow the set of rules to ensure problem-free order management.
Please refer to the available functions table for included application functions.
PCM600 can be used to make changes and/or additions to the delivered factory configuration of the pre-configured.

To obtain the complete ordering code, please combine code from the tables, as given in the example below.
Example code: REC650*2.1-A02X00- P03-B1A12-AC-MP-B-A3X0-D1AB1N1-GXFX-AX. Using the code of each position #1-13 specified as REC650*1-2 2-3-4 4-5-6-7 7-8-9-10 10 10 10-11 11 11-12 12 12 12-13 13

#	1	-	2	-	3	-	4	-	5	6	-	7	-	8	-	9	-
REC650*		-		-		-		-			-		-		-		-

10				-	11			-	12			-	13	
				-				-				-		

SOFTWARE	Position #1	Notes and Rules
Version number		
Version no	2.1	
Selection for position #1.		

Configuration alternatives	#2		Notes and Rules
Single breaker, double busbar	A02		
ACT configuration			
ABB Standard configuration		X00	
Selection for position #2.			

Software options	#3		Notes and Rules
No option	X00		All fields in the ordering form do not need to be filled in
IEC 62439-3 parallel redundancy protocol		P03	Note! Requires 2-channel OEM
Selection for position #3			

First local HMI user dialogue language	#4		Notes and Rules
HMI language, English IEC	B1		
Additional local HMI user dialogue language			
No additional HMI language		X0	
HMI language, English US		A12	
Selection for position #4.			

Casing	#5	Notes and Rules
1/2 x 19" case	A	
Selection for position #5.	A	

Mounting details with IP40 of protection from the front	#6	Notes and Rules
No mounting kit included	X	
19" rack mounting kit for 1/2 x 19" case of 2xRHGS6 or RHGS12	A	
Wall mounting kit	D	Note: Wall mounting not recommended with communication modules with fibre connection (SLM, OEM, LDCM)
Flush mounting kit	E	
Flush mounting kit + IP54 mounting seal	F	
Selection for position #6.		

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Connection type for Power supply modules	#7		Notes and Rules
Compression terminals	M		
Ringlug terminals	N		
Auxiliary power supply			
24-60 VDC		A	
90-250 VDC		B	
Selection for position #7.			

Connection type for Input/output modules	#8	Notes and Rules
Compression terminals	P	
Selection for position #8.	P	

Human machine hardware interface	#9	Notes and Rules
Medium size - graphic display, IEC keypad symbols	B	
Medium size - graphic display, ANSI keypad symbols	C	
Selection for position #9.		

Connection type for Analog modules	#10		Notes and Rules
Compression terminals	A		
Ringlug terminals	B		
Analog system			
TRM, 7I+5U 1A		A12	
TRM, 7I+5U 5A		A13	
TRM, 6I, 5A + 1I, 1A + 5U		A14	
TRM, 3I, 5A + 4I, 1A + 5U		A15	
Selection for position #10.			

Binary input/output module, mA and time synchronization boards.	#11			Notes and Rules
For pulse counting, for example kWh metering, the BIM with enhanced pulse counting capabilities must be used. Note: 1 BIM and 1 BOM always included.				
Slot position (rear view)	X31	X41	X51	Note: Max 3 positions in 1/2 rack.
1/2 Case with 1 TRM	■	■	■	
No board in slot			X	
Binary output module 24 output relays (BOM)		A	A	
BIM 16 inputs, 24-30 VDC, 50mA	B1		B1	
BIM 16 inputs, 48-60 VDC, 50mA	C1		C1	
BIM 16 inputs, 110-125 VDC, 50mA	D1		D1	
BIM 16 inputs, 220-250 VDC, 50mA	E1		E1	
BIM 16 inputs, 220-250 VDC, 120mA	E2		E2	
BIMp 16 inputs, 24-30 VDC, 30mA, for pulse counting			F	
BIMp 16 inputs, 48-60 VDC, 30mA, for pulse counting			G	
BIMp 16 inputs, 110-125 VDC, 30mA, for pulse counting			H	
BIMp 16 inputs, 220-250 VDC, 30mA, for pulse counting			K	
IOM 8 inputs 10+2 output relays, 24-30 VDC, 50mA			L1	
IOM 8 inputs 10+2 output relays, 48-60 VDC, 50mA			M1	
IOM 8 inputs 10+2 output relays, 110-125 VDC, 50mA			N1	
IOM 8 inputs 10+2 output relays, 220-250 VDC, 50mA			P1	
IOM 8 inputs 10+2 output relays, 220-250 VDC, 110mA			P2	
IOM with MOV 8 inputs ,10 out, 2 high-speed, 24-30 VDC, 30mA			U	
IOM with MOV 8 inputs 10 out, 2 high-speed, 48-60 VDC, 30mA			V	
IOM with MOV 8 inputs 10 out, 2 high-speed, 110-125 VDC, 30mA			W	
IOM with MOV 8 inputs 10 out, 2 high-speed, 220-250 VDC, 30mA			Y	
Selection for position #11.				

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Remote and communication, DNP serial comm. and time synchronization modules	#12				Notes and Rules
Slot position (rear view)	X312	X313	X302	X303	
Available slots	■	■	■	■	
No remote communication board included	X	X	X	X	
IRIG-B Time synchronization module	F	F	F	F	
Galvanic RS485 communication module	G	G	G	G	
Selection for position #12.					

Serial communication unit for station communication	#13		Notes and Rules
Slot position (rear view)	X301	X311	
No communication board included	X	X	
Serial SPA/LON/DNP/IEC 60870-5-103 plastic interface	A		
Serial SPA/LON/DNP/IEC 60870-5-103 plastic/glass interface	B		
Serial SPA/LON/DNP/IEC 60870-5-103 glass interface	C		
Optical ethernet module, 1 channel glass		D	
Optical ethernet module, 2 channel glass		E	
Selection for position #13.			

17. Ordering for Accessories

Accessories

Test switch

The test system COMBITEST intended for use with the IEDs is described in 1MRK 512 001-BEN and 1MRK 001024-CA. Please refer to the website: www.abb.com/substationautomation for detailed information.

Test switches type RTXP 24 is ordered separately. Please refer to Section Related documents for references to corresponding documents.

RHGS 6 Case or RHGS 12 Case with mounted RTXP 24 and the on/off switch for dc-supply are ordered separately. Please refer to Section Related documents for references to corresponding documents.

Protection cover

Protective cover for rear side of RHGS6, 6U, 1/4 x 19"	Quantity:	☐	1MRK 002 420-AE
Protective cover for rear side of terminal, 6U, 1/2 x 19"	Quantity:	☐	1MRK 002 420-AC

External resistor unit

High impedance resistor unit 1-ph with resistor and voltage dependent resistor for 20-100V operating voltage	Quantity:	1 ☐ 2 ☐ 3 ☐	RK 795 101-MA
High impedance resistor unit 3-ph with resistor and voltage dependent resistor for 20-100V operating voltage	Quantity:	☐	RK 795 101-MB
High impedance resistor unit 1-ph with resistor and voltage dependent resistor for 100-400V operating voltage	Quantity:	1 ☐ 2 ☐ 3 ☐	RK 795 101-CB
High impedance resistor unit 3-ph with resistor and voltage dependent resistor for 100-400V operating voltage	Quantity:	☐	RK 795 101-DC

Combiflex

Key switch for settings

Key switch for lock-out of settings via LCD-HMI	Quantity:	☐	1MRK 000 611-A

Note: To connect the key switch, leads with 10 A Combiflex socket on one end must be used.

Mounting kit

			Ordering number
Side-by-side mounting kit	Quantity:	☐	1MRK 002 420-Z

Configuration and monitoring tools

Front connection cable between LCD-HMI and PC	Quantity:	☐	1MRK 001 665-CA
LED Label special paper A4, 1 pc	Quantity:	☐	1MRK 002 038-CA
LED Label special paper Letter, 1 pc	Quantity:	☐	1MRK 002 038-DA

Manuals

Note: One (1) IED Connect CD containing user documentation (Operation manual, Technical manual, Installation manual, Commissioning manual, Application manual and Getting started guide), Connectivity packages and LED label template is always included for each IED.

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Rule: Specify additional quantity of IED Connect CD requested.	Quantity:	☐	1MRK 002 290-AD

User documentation

Rule: Specify the number of printed manuals requested

Application manual	IEC	Quantity:	☐	1MRK 511 384-UEN
Technical manual	IEC	Quantity:	☐	1MRK 511 385-UEN
Commissioning manual	IEC	Quantity:	☐	1MRK 511 386-UEN
Communication protocol manual, IEC 61850 Edition 1	IEC	Quantity:	☐	1MRK 511 375-UEN
Communication protocol manual, IEC 61850 Edition 2	IEC	Quantity:	☐	1MRK 511 376-UEN
Communication protocol manual, IEC 60870-5-103	IEC	Quantity:	☐	1MRK 511 377-UEN
Communication protocol manual, LON	IEC	Quantity:	☐	1MRK 511 378-UEN
Communication protocol manual, SPA	IEC	Quantity:	☐	1MRK 511 379-UEN
Communication protocol manual, DNP	ANSI	Quantity:	☐	1MRK 511 374-UUS
Point list manual, DNP	ANSI	Quantity	☐	1MRK 511 380-UUS
Operation manual	IEC	Quantity:	☐	1MRK 500 125-UEN
Installation manual	IEC	Quantity:	☐	1MRK 514 025-UEN
Engineering manual	IEC	Quantity:	☐	1MRK 511 381-UEN
Cyber security guideline	IEC	Quantity:	☐	1MRK 511 382-UEN

Reference information

For our reference and statistics we would be pleased to be provided with the following application data:

Country:

End user:

Station name:

Voltage level: kV

Related documents

Documents related to REC650	Document numbers
Application manual	1MRK 511 384-UEN
Commissioning manual	1MRK 511 386-UEN
Product guide	1MRK 511 387-BEN
Technical manual	1MRK 511 385-UEN
Type test certificate	1MRK 511 387-TEN

650 series manuals	Document numbers
Operation manual	1MRK 500 125-UEN
Engineering manual	1MRK 511 381-UEN
Installation manual	1MRK 514 025-UEN
Communication protocol manual, DNP3	1MRK 511 374-UUS
Communication protocol manual, IEC 60870-5-103	1MRK 511 377-UEN
Communication protocol manual, IEC 61850 Edition 1	1MRK 511 375-UEN
Communication protocol manual, IEC 61850 Edition 2	1MRK 511 376-UEN
Communication protocol manual, LON	1MRK 511 378-UEN
Communication protocol manual, SPA	1MRK 511 379-UEN
Point list manual, DNP3	1MRK 511 380-UUS
Accessories guide	IEC: 1MRK 514 012-UEN ANSI: 1MRK 514 012-UUS
Cyber security deployment guideline	1MRK 511 382-UEN
Connection and Installation components	1MRK 513 003-BEN
Test system, COMBITEST	1MRK 512 001-BEN

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Power and productivity
for a better world™

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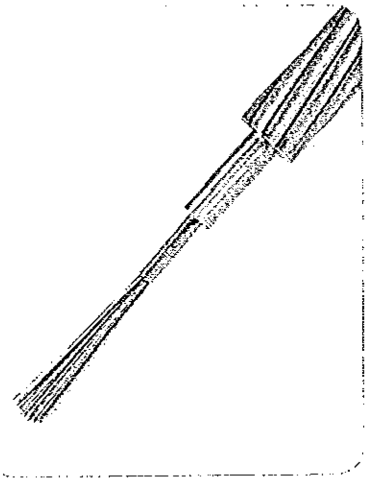
Приложение № 1.5 Заверено копие на каталог на Мълниезащитно гръм въже с вграден оптичен кабел (OPGW)

AFL



CentraCore OPGW

CentraCore Optical Ground Wire is available in fiber counts up to 96, and due to its small size, offers a unique solution to the diameter and weight concerns on many of today's overloaded towers. A central stainless steel tube houses the optical fibers. The stainless steel tube is then inserted into an aluminum pipe which provides added crush protection while increasing the conductivity. The fibers are protected from environmental conditions (lightning, short circuit, loading) to ensure reliability and longevity.

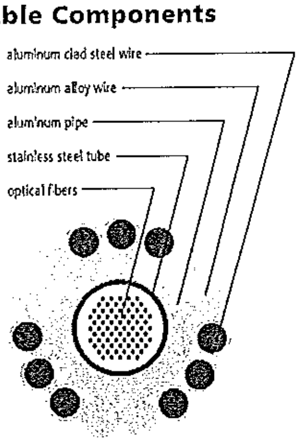
Temperature Range

Operating - 40°C to + 85°C
Storage - 50°C to + 85°C
Installation - 30°C to + 85°C

Features

- Fiber counts up to 96
- Very small diameter, low weight
- Laser-welded, hermetically sealed stainless steel tubes provide mechanical and thermal protection for optical fibers
- Central tube provides mechanical and thermal protection for optical fibers
- Excellent crush resistance and high fault current rating capability
- Unique designs have maximum allowable tension to control fiber strain
- Stranded wires selected to optimize mechanical and electrical properties of cable

Cable Components



Typical Designs

FIBERS (max)	OPGW SIZE	FAULT CURRENT	TOTAL CONDUCTOR AREA		OVERALL DIAMETER		WEIGHT		RBS		SAG10 CHART #	MAX SHIP LENGTH (per reel type)	
		(kA)²sec	in²	mm²	in	mm	lbs/ft	kg/m	lbs	kgf		Wood (m)	Steel (m)
48	CC-57/465	43	0.1248	80.52	0.465	11.80	0.314	0.467	16,626	7,541	1-1421	7000	7000
48	CC-29/29/465	54	0.1248	80.52	0.465	11.80	0.238	0.354	10,755	4,878	1-1455	7000	7000
48	CC-54/472	53	0.1334	86.09	0.472	12.00	0.316	0.470	16,080	7,294	1-1450	7000	7000
48	CC-27/27/472	63	0.1334	86.09	0.472	12.00	0.244	0.362	10,514	4,769	1-1438	7000	7000
48	CC-72/504	58	0.1482	95.64	0.504	12.80	0.382	0.568	20,740	9,408	1-1442	6350	7000
48	CC-32/40/504	73	0.1482	95.64	0.504	12.80	0.296	0.441	14,144	6,416	1-1440	7000	7000
48	CC-75/528	77	0.1663	107.28	0.528	13.40	0.411	0.612	21,845	9,909	1-1453	5950	7000
48	CC-38/38/528	96	0.1663	107.28	0.528	13.40	0.310	0.462	14,106	6,398	1-1439	7000	7000
72	CC-54/472	51	0.1318	85.01	0.472	12.00	0.316	0.470	16,067	7,288	1-1457	7000	7000
72	CC-27/27/472	61	0.1318	85.01	0.472	12.00	0.243	0.362	10,501	4,763	1-1438	7000	7000
72	CC-63/507	71	0.1547	99.80	0.507	12.90	0.367	0.546	18,677	8,472	1-1450	6650	7000
72	CC-32/32/507	85	0.1547	99.80	0.507	12.90	0.282	0.420	12,195	5,532	1-1438	7000	7000
72	CC-75/528	75	0.1646	106.20	0.528	13.40	0.410	0.611	21,831	9,903	1-1421	5950	7000
72	CC-38/38/528	94	0.1646	106.20	0.528	13.40	0.310	0.461	14,092	6,392	1-1455	7000	7000
96	CC-65/500	51	0.1393	89.86	0.500	12.70	0.385	0.573	19,194	8,706	1-1442	4800	4800
96	CC-30/36/500	64	0.1393	89.86	0.500	12.70	0.306	0.456	13,104	5,944	1-1440	4800	4800
96	CC-75/528	62	0.1550	100.00	0.528	13.40	0.431	0.641	21,953	9,958	1-1442	4800	4800
96	CC-38/38/528	81	0.1550	100.00	0.528	13.40	0.331	0.492	14,214	6,448	1-917	4800	4800
96	CC-86/563	86	0.1803	116.31	0.563	14.30	0.488	0.726	24,879	11,285	1-1425	4800	4800
96	CC-34/51/563	106	0.1803	116.31	0.563	14.30	0.340	0.591	17,768	8,060	1-1460	4800	4800

This information denotes the input data needed for Sag10™ (sag and tension calculation) software. WIR files of all these catalog designs can be found on PLS-CADD web page.
NOTE: The designs above are only a sampling of the options available from AFL. Contact customer service for a cable designed to your exact specifications.

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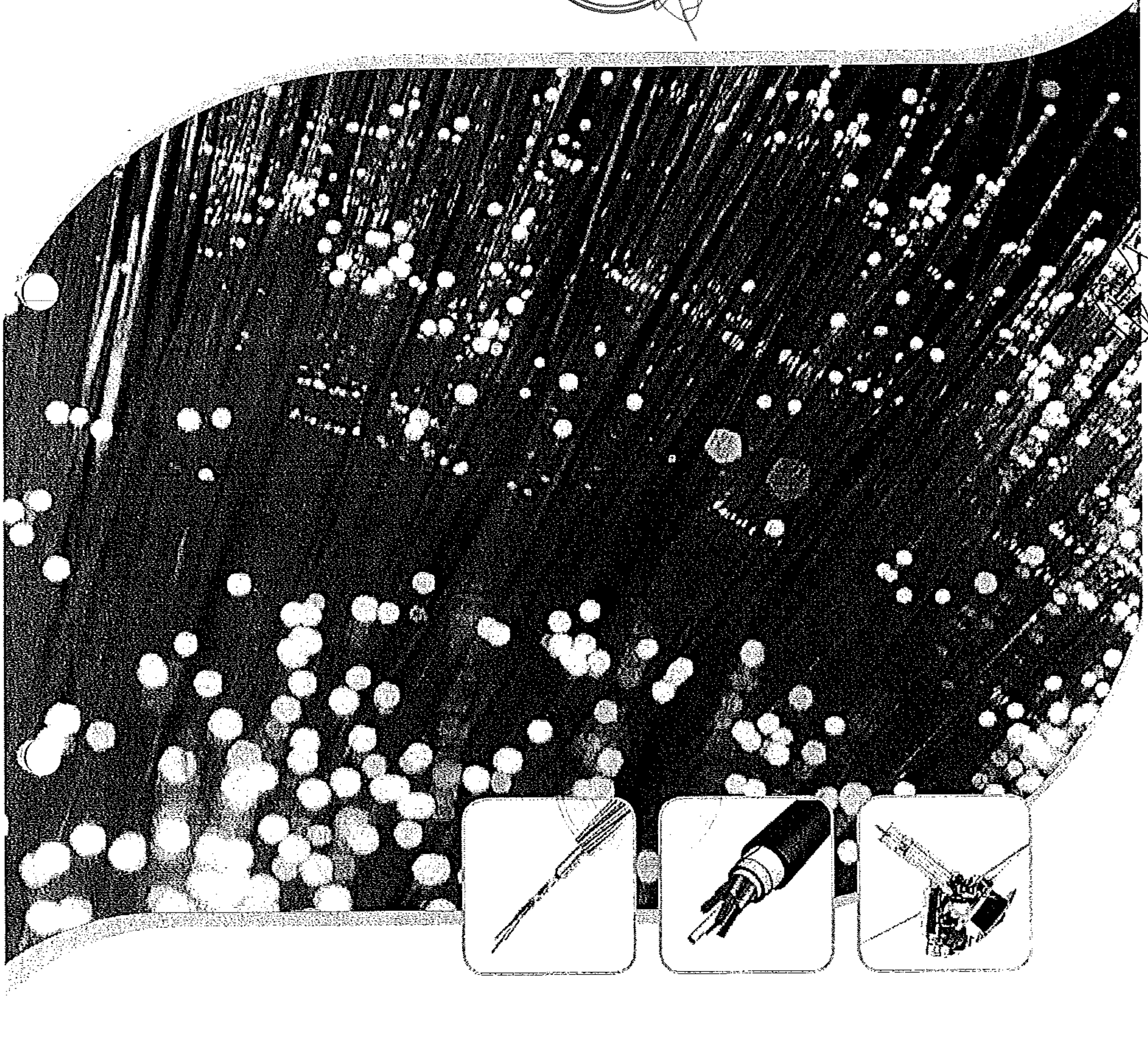
AFL



AERIAL FIBER OPTIC CABLE

Optical Ground Wire | AFL-ADSS® | Loose Tube | SkyWrap®

Founded in 1984, AFL is an international manufacturer
providing end-to-end solutions to the energy, service provider,
enterprise and industrial markets as well as several emerging markets.

AFL's products are in use in over 130 countries
and include fiber optic cable and hardware, transmission and
substation accessories, outside plant equipment, connectivity,
test and inspection equipment, fusion splicers and training.

AFL also offers a wide variety of services supporting
data center, enterprise, wireless and outside plant applications.

AFL is dedicated to bringing our customers
a quality product as well as delivering superior value.

AFL

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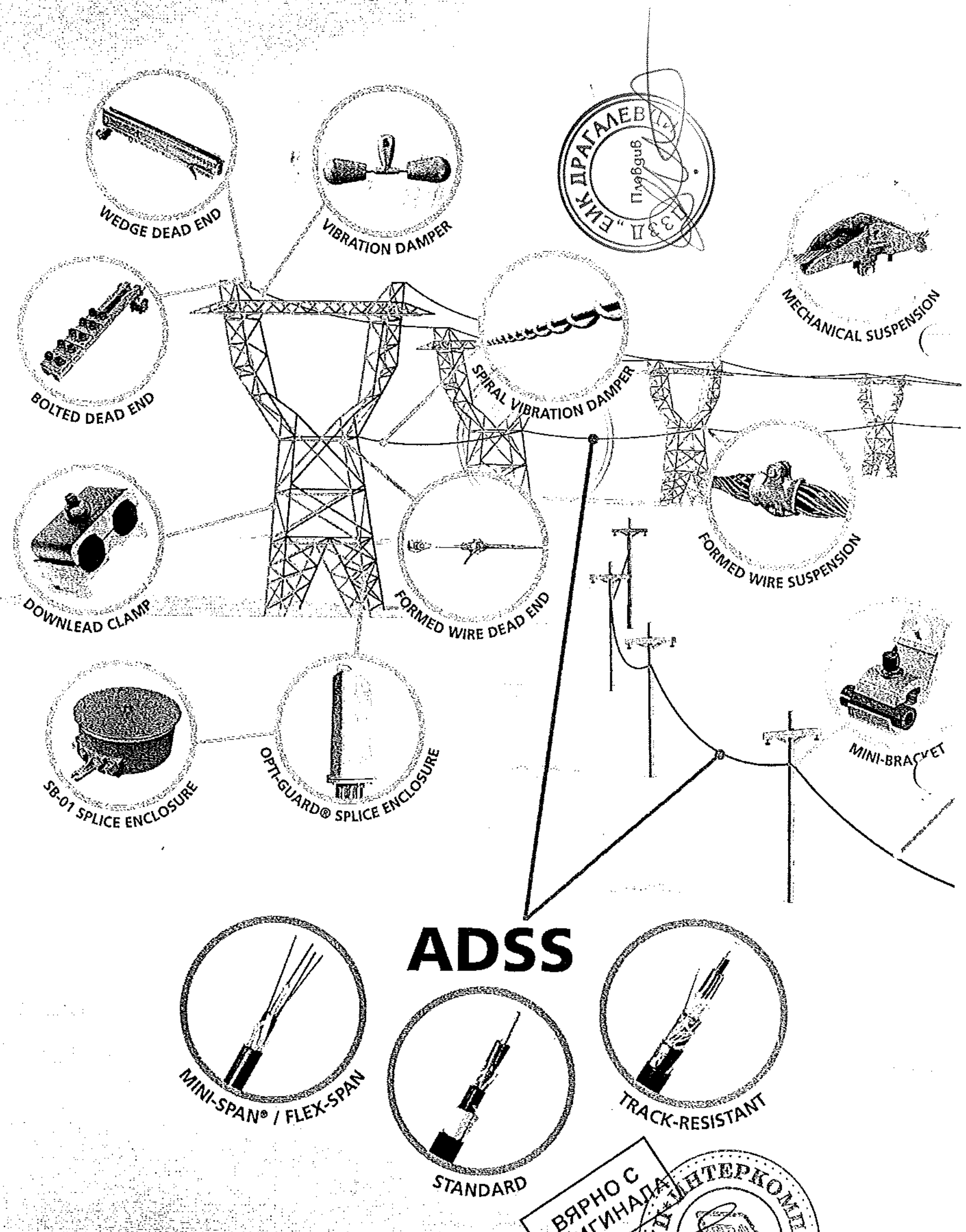
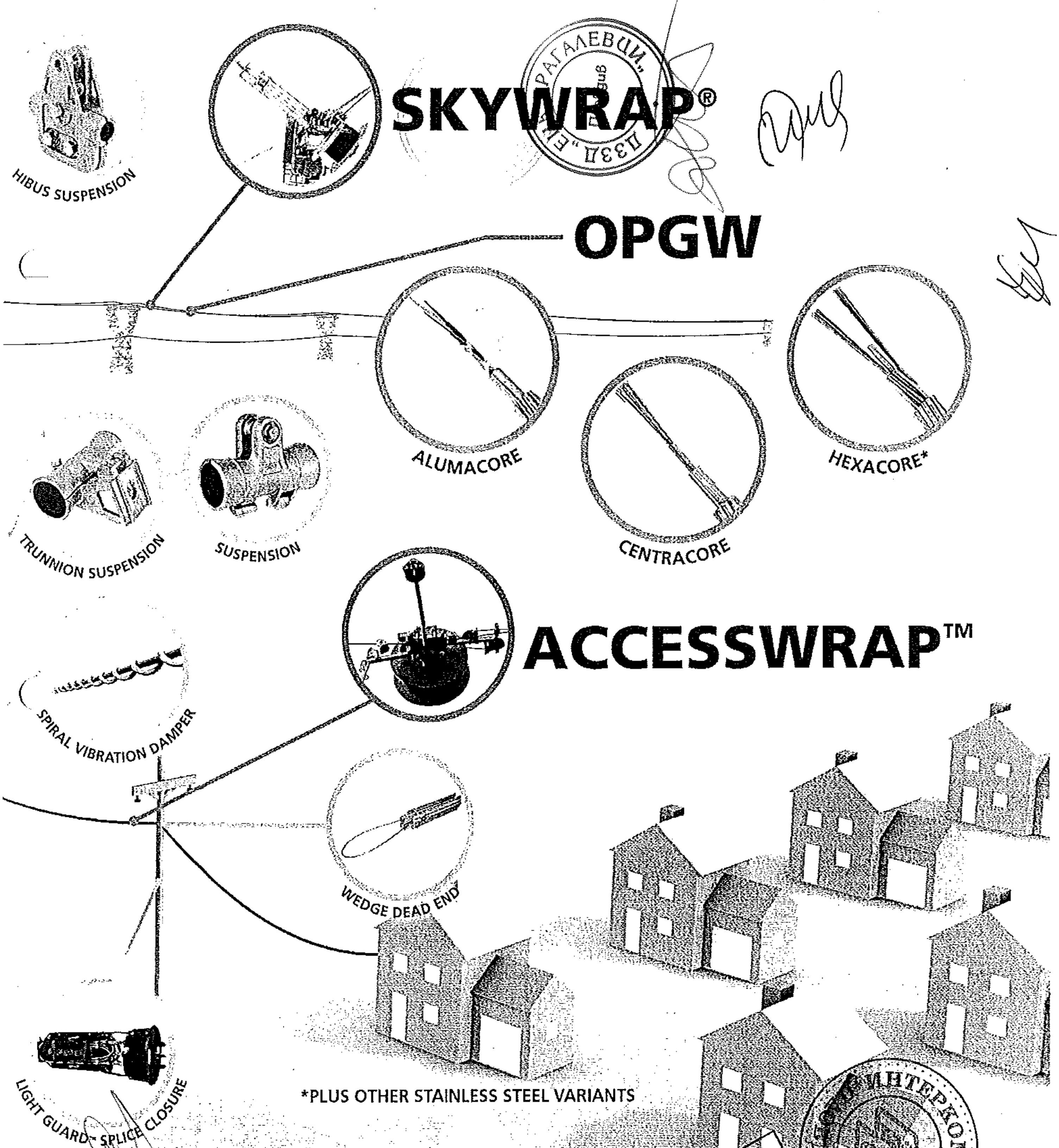
AFL Aerial Cable Solutions



AFL offers a systems solution for your demanding aerial applications. From a variety of cable design options to the accessories required for the cable, AFL offers the industry's widest array of solutions.



*PLUS OTHER STAINLESS STEEL VARIANTS

ВЯРНО С ОРИГИНАЛА

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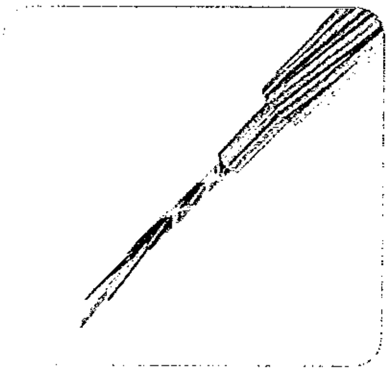
AFL



AlumaCore OPGW

AlumaCore Optical Ground Wire is preferred for its performance under the most rugged conditions. Its central aluminum pipe provides superb fiber protection making it ideal for everything from basic installations to these applications requiring high tensions or for extremely long spans.

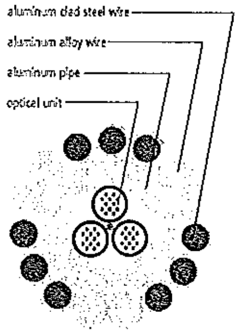
Temperature Range

Operating -40°C to +85°C
Storage -50°C to +85°C
Installation -30°C to +85°C

Features

- Fiber counts up to 144
- Optical unit provides exceptional mechanical and thermal protection for fibers
- Thick-walled aluminum pipe provides hermetic seal for optical units, excellent crush resistance and low resistivity
- Stranded wires selected to optimize mechanical and electrical properties
- Dielectric optical units are available with 6, 8, 12, 18 and 24 fibers
- Supplied with up to 6 optical units, depending on fiber count

Cable Components



Typical Designs

FIBERS (max)	OPGW SIZE	FAULT CURRENT	TOTAL CONDUCTOR AREA		OVERALL DIAMETER		WEIGHT		RBS		SAG10 CHART #	MAX SHIP LENGTH (per reel type)	
		(kA)²sec	in²	mm²	in	mm	lbs/ft	kg/m	lbs	kgf		Wood (m)	Steel (m)
24	AC-64/528	68	0.1510	97.43	0.528	13.4	0.359	0.535	18,391	8,342	1-1450	6,700	7,000
24	AC-29/34/528	81	0.1510	97.43	0.528	13.4	0.281	0.418	12,351	5,602	1-1439	7,000	7,000
24	AC-74/552	81	0.1666	107.51	0.552	14.0	0.405	0.602	21,132	9,585	1-1453	6,000	7,000
24	AC-37/37/552	98	0.1666	107.51	0.552	14.0	0.306	0.455	13,556	6,149	1-1438	7,000	7,000
36	AC-71/571	95	0.1758	113.39	0.571	14.5	0.411	0.611	20,546	9,320	1-1461	5,900	7,000
36	AC-33/38/571	110	0.1758	113.39	0.571	14.5	0.323	0.478	13,779	6,250	1-1438	7,000	7,000
36	AC-86/607	118	0.2002	129.14	0.607	15.4	0.481	0.713	24,829	11,263	1-1457	5,000	6,900
36	AC-40/47/607	141	0.2002	129.14	0.607	15.4	0.375	0.558	16,646	7,551	1-1439	6,500	7,000
48	AC-86/646	151	0.2208	142.43	0.646	16.4	0.509	0.757	25,098	11,384	1-1461	4,700	6,600
48	AC-34/52/646	172	0.2208	142.43	0.646	16.4	0.417	0.621	18,053	8,189	1-1439	5,800	7,000
48	AC-129/724	239	0.2876	185.57	0.724	18.4	0.703	1.046	35,034	15,891	1-1453	3,400	4,700
48	AC-65/65/724	292	0.2876	185.57	0.724	18.4	0.530	0.789	22,524	10,217	1-1438	4,500	5,500
72	AC-88/659	154	0.2232	143.98	0.659	16.7	0.516	0.768	25,556	11,592	1-1461	4,700	6,500
72	AC-38/49/659	177	0.2232	143.98	0.659	16.7	0.414	0.615	17,698	8,028	1-1438	5,800	6,800
72	AC-102/691	182	0.2460	158.96	0.691	17.5	0.582	0.866	29,555	13,406	1-1450	4,100	5,700
72	AC-44/58/691	212	0.2460	158.96	0.691	17.5	0.465	0.692	20,566	9,329	1-1439	5,200	6,800
144	AC-82/646	144	0.2147	138.52	0.646	16.4	0.498	0.741	24,069	10,918	1-1461	4,800	6,500
144	AC-39/43/646	166	0.2147	138.52	0.646	16.4	0.395	0.588	16,145	7,323	1-355	6,100	6,500
144	AC-125/726	230	0.2813	181.48	0.726	18.4	0.6919	1.030	34,882	15,823	1-1453	3,500	4,800
144	AC-58/67/726	277	0.2813	181.48	0.726	18.4	0.5378	0.800	23,286	10,562	1-1439	4,500	6,100

This information denotes the input data needed for Sag10™ (sag and tension calculation) software. WIR files of all these catalog designs can be found on PLS-CADD web page.

NOTE: The designs above are only a sampling of the options available from AFL. Contact customer service for a cable designed to your exact specifications.

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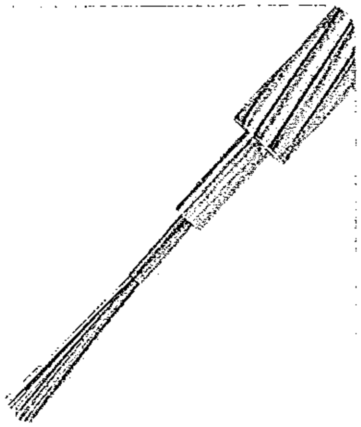


CentraCore OPGW

CentraCore Optical Ground Wire is available in fiber counts up to 96, and due to its small size, offers a unique solution to the diameter and weight concerns on many of today's overloaded towers. A central stainless steel tube houses the optical fibers. The stainless steel tube is then inserted into an aluminum pipe which provides added crush protection while increasing the conductivity. The fibers are protected from environmental conditions (lightning, short circuit, loading) to ensure reliability and longevity.

Temperature Range

Operating - 40°C to + 85°C

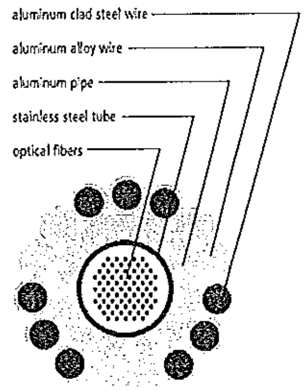
Storage - 50°C to + 85°C

Installation - 30°C to + 85°C

Features

- Fiber counts up to 96
- Very small diameter, low weight
- Laser-welded, hermetically sealed stainless steel tubes provide mechanical and thermal protection for optical fibers
- Central tube provides mechanical and thermal protection for optical fibers
- Excellent crush resistance and high fault current rating capability
- Unique designs have maximum allowable tension to control fiber strain
- Stranded wires selected to optimize mechanical and electrical properties of cable

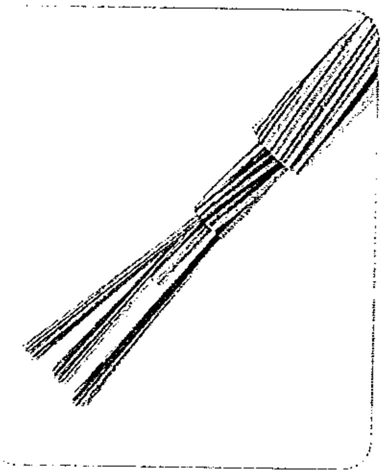
Cable Components



Typical Designs

FIBERS (max)	OPGW SIZE	FAULT CURRENT	TOTAL CONDUCTOR AREA		OVERALL DIAMETER		WEIGHT		RBS		SAG10 CHART #	MAX SHIP LENGTH (per reel type)	
		(kA)²sec	in²	mm²	in	mm	lbs/ft	kg/m	lbs	kgf		Wood (m)	Steel (m)
48	CC-57/465	43	0.1248	80.52	0.465	11.80	0.314	0.467	16,626	7,541	1-1421	7000	7000
48	CC-29/29/465	54	0.1248	80.52	0.465	11.80	0.238	0.354	10,755	4,878	1-1455	7000	7000
48	CC-54/472	53	0.1334	86.09	0.472	12.00	0.316	0.470	16,080	7,294	1-1450	7000	7000
48	CC-27/27/472	63	0.1334	86.09	0.472	12.00	0.244	0.362	10,514	4,769	1-1438	7000	7000
48	CC-72/504	58	0.1482	95.64	0.504	12.80	0.382	0.568	20,740	9,408	1-1442	6350	7000
48	CC-32/40/504	73	0.1482	95.64	0.504	12.80	0.296	0.441	14,144	6,416	1-1440	7000	7000
48	CC-75/528	77	0.1663	107.28	0.528	13.40	0.411	0.612	21,845	9,909	1-1453	5950	7000
48	CC-38/38/528	96	0.1663	107.28	0.528	13.40	0.310	0.462	14,106	6,398	1-1439	7000	7000
72	CC-54/472	51	0.1318	85.01	0.472	12.00	0.316	0.470	16,067	7,288	1-1457	7000	7000
72	CC-27/27/472	61	0.1318	85.01	0.472	12.00	0.243	0.362	10,501	4,763	1-1438	7000	7000
72	CC-63/507	71	0.1547	99.80	0.507	12.90	0.367	0.546	18,677	8,472	1-1450	6650	7000
72	CC-32/32/507	85	0.1547	99.80	0.507	12.90	0.282	0.420	12,195	5,532	1-1438	7000	7000
72	CC-75/528	75	0.1646	106.20	0.528	13.40	0.410	0.611	21,831	9,903	1-1421	5950	7000
72	CC-38/38/528	94	0.1646	106.20	0.528	13.40	0.310	0.461	14,092	6,392	1-1455	7000	7000
96	CC-65/500	51	0.1393	89.86	0.500	12.70	0.385	0.573	19,194	8,706	1-1442	4800	4800
96	CC-30/36/500	64	0.1393	89.86	0.500	12.70	0.306	0.456	13,104	5,944	1-1440	4800	4800
96	CC-75/528	62	0.1550	100.00	0.528	13.40	0.431	0.641	21,953	9,958	1-1442	4800	4800
96	CC-38/38/528	81	0.1550	100.00	0.528	13.40	0.331	0.492	14,214	6,448	1-917	4800	4800
96	CC-86/563	86	0.1803	116.31	0.563	14.30	0.488	0.726	24,879	11,285	1-1425	4800	4800
96	CC-34/51/563	106	0.1803	116.31	0.563	14.30	0.340	0.591	17,768	8,060	1-1460	4800	4800

This information denotes the input data needed for Sag10™ (sag and tension calculation) software. WIR files of all these catalog designs can be found on PLS-CADD web page.
NOTE: The designs above are only a sampling of the options available from AFL. Contact customer service for a cable designed to your exact specifications.



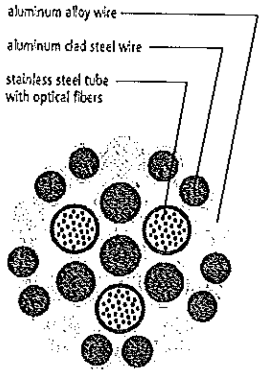
HexaCore OPGW

HexaCore Optical Ground Wire cable houses and protects the optical fibers within gel-filled stainless steel tubes. Aluminum clad steel and aluminum alloy wires are stranded with the tubes to create a dual-layer design suitable for a variety of applications.

Features

- Fiber counts up to 432 or higher for custom designs
- Laser-welded, hermetically sealed stainless steel tubes provide mechanical and thermal protection for optical fibers
- High load, long span capability
- Anti-rotational devices usually not required for installation
- Each stainless steel tube is uniquely identified for organization at splice locations
- Stranded wires selected to optimize mechanical and electrical properties of cable

Cable Components



Temperature Range

Operating - 40°C to + 85°C
Storage - 50°C to + 85°C
Installation - 30°C to + 85°C

Typical Designs

FIBERS (max)	OPGW SIZE	FAULT CURRENT (kA)²sec	TOTAL CONDUCTOR AREA in²	TOTAL CONDUCTOR AREA mm²	OVERALL DIAMETER in	OVERALL DIAMETER mm	WEIGHT lbs/ft	WEIGHT kg/m	RBS lbs	RBS kgf	SAG10 CHART #	MAX SHIP LENGTH (per reel type) Wood (m)	MAX SHIP LENGTH (per reel type) Steel (m)
24	SX-32/45/472	41	0.1235	79.67	0.472	12.0	0.281	0.418	14947	6780	1-1461	7000	7000
36	SX-41/32/472	41	0.1186	76.53	0.472	12.0	0.247	0.368	12122	5498	1-350	7000	7000
24	SX-75/37/555	96	0.1757	113.37	0.555	14.1	0.317	0.471	15392	6982	1-1438	7000	7000
24	SX-90/30/575	116	0.1889	121.86	0.575	14.6	0.313	0.466	14464	6561	1-430	7000	7000
96	S1-82/52/630	137	0.2131	137.45	0.630	16.0	0.417	0.621	20,042	9,091	1-1170	5800	7000
96	S1-83/59/647	152	0.2265	146.13	0.647	16.4	0.453	0.674	22,131	10,039	1-917	5300	7000
96	S1-91/61/668	177	0.2429	156.69	0.668	17.0	0.479	0.712	23,302	10,570	1-917	5100	6450
144	S1-71/52/630	118	0.2006	129.41	0.630	16.0	0.416	0.619	19,791	8,977	1-1440	5950	7000
144	S1-73/59/647	132	0.2140	138.09	0.647	16.4	0.452	0.673	21,880	9,925	1-350	5400	6850
144	S1-81/61/668	155	0.2304	148.65	0.668	17.0	0.472	0.702	23,051	10,456	1-1440	5150	6450
288	S1-41/52/630	68	0.1632	105.28	0.630	16.0	0.414	0.616	19,038	8,636	1-1461	5890	7000
288	S1-42/59/647	79	0.1766	113.96	0.647	16.4	0.450	0.670	21,128	9,584	1-1461	5400	6850
288	S1-50/61/668	97	0.1930	124.52	0.668	17.0	0.476	0.708	22,299	10,115	1-1461	5125	6450

This information denotes the input data needed for Sag10™ (sag and tension calculation) software. WIR files of all these catalog designs can be found on PLS-CADD web page.
NOTE: The designs above are only a sampling of the options available from AFL. Contact customer service for a cable designed to your exact specifications.

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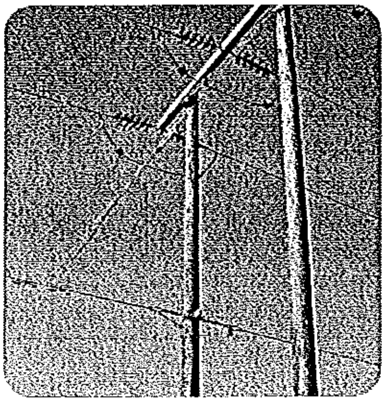
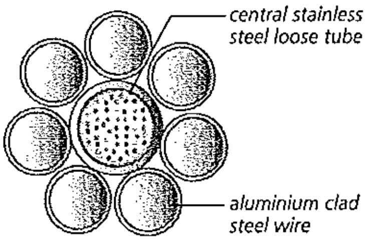
AFL

Fiber Optic Cable



Metallic Aerial Self-Supporting Cable (MASS)

Metallic Aerial Self-Supporting (MASS) Cable is an alternative solution used for installing optical cable on medium and high voltage power lines. It is typically used when existing phase or ground wire replacement is not possible or economical. MASS cable is a compact, light-weight solution with no electrical function, designed to provide a telecommunications path without interfering with the existing power lines or infrastructure. Its small size helps minimize loading on towers and poles, yet it is completely self-supporting to meet sag and tension requirements. It is typically installed in "under build" applications beneath the live phases.



Features:

- Central Stainless Steel loose tube design
- Typical diameter between 9 – 12 mm (0.35" – 0.47")
- Fiber counts up to 72
- No voltage limit – suitable for medium & high voltage lines
- Suitable for use on lines without a ground wire
- Convenient means to add fiber where OPGW is already installed
- Deployed in regions with high lightning activity
- Can be installed without an outage
- Small cable size limits additional structural loading
- Wind loading properties similar to standard conductors
- Suitable for wooden poles with universal attachment
- Aluminum Clad, Aluminum Alloy or Galvanized Steel wire options available depending on mechanical properties required

Specifications:

FIBERS	TYPICAL SIZE	OVERALL DIAMETER		WEIGHT		RBS		STAINLESS STEEL TUBE ID / OD		WIRE DIAMETER	
(max)		in	mm	lbs/ft	kg/m	lbs	Kg	in	mm	in	mm
24	ACS 28	0.30	7.5	1.50	0.207	7,958	3,610	0.10 / 0.11	2.6 / 3.0	0.09	2.25
24	ACS 42	0.35	9.0	2.19	0.303	12,140	5,506	0.10 / 0.11	2.6 / 3.0	0.11	3.0
30	ACS 34	0.33	8.3	1.83	0.253	9,824	4,456	0.11 / 0.13	2.9 / 3.3	0.09	2.5
30	ACS 50	0.39	9.8	2.57	0.355	14,253	6,465	0.11 / 0.13	2.85 / 3.25	0.13	3.25
36	ACS 37	0.34	8.6	1.99	0.275	10,633	4,823	0.11 / 0.13	2.9 / 3.4	0.10	2.6
36	ACS 58	0.41	10.5	2.99	0.414	15,647	7,097	0.11 / 0.14	3.0 / 3.5	0.14	3.5
48	ACS 40	0.35	9.0	2.15	0.298	11,465	5,201	0.12 / 0.14	3.1 / 3.6	0.10	2.7
48	ACS 61	0.43	10.8	3.17	0.438	16,568	7,515	0.12 / 0.14	3.1 / 3.6	0.14	3.6
60	ACS 45	0.37	9.5	2.39	0.331	12,769	5,792	0.13 / 0.15	3.3 / 3.8	0.11	2.85
60	ACS 66	0.44	11.3	3.43	0.475	17,692	8,025	0.13 / 0.15	3.3 / 3.8	0.14	3.75
72	ACS 49	0.39	10.0	2.67	0.369	14,163	6,424	0.13 / 0.15	3.4 / 4.0	0.11	3.0
72	ACS 75	0.47	12.0	3.92	0.542	19,491	8,841	0.13 / 0.15	3.4 / 4.0	0.16	4.0

ACS - Aluminum Clad Steel wire.
Wire is available in ACS and Aluminum Alloy. Both are available in a variety of grades, please ask for details.
MASS cables are designed to customer specification.
NOTE: The designs above are only a sampling of the options available from AFL. Contact customer service for a cable designed to your exact specifications.

ВЯРНО С ОРИГИНАЛА

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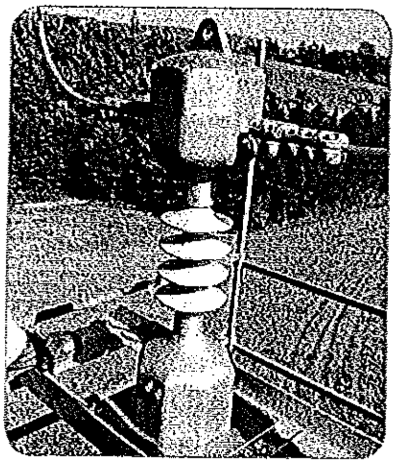


Optical Phase Conductor

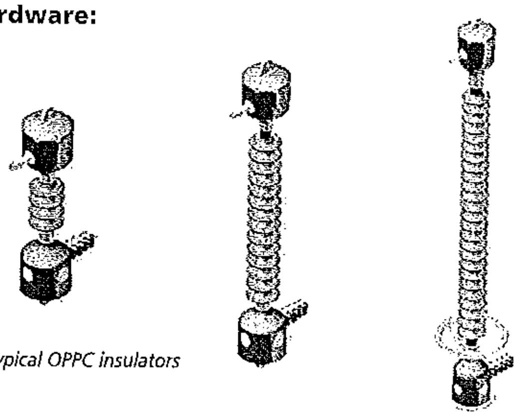
Optical Phase Conductor (OPPC) is used as an alternative telecommunications solution when there is no existing ground wire, meaning Optical Ground Wire (OPGW) is not a viable option. The basic construction is similar to conventional OPGW, only it is designed to simulate the mechanical and electrical characteristics of the phase wire it replaces. Unlike OPGW, where the cable is not carrying continuous current, OPPC is energized along high voltage power lines. Therefore it requires specially adapted splice boxes and insulators to accommodate the live line conditions.

AFL can design a cable to accommodate your precise application. To do so, we need the properties of the phase conductor you are seeking to replace. With that, we can do the rest.

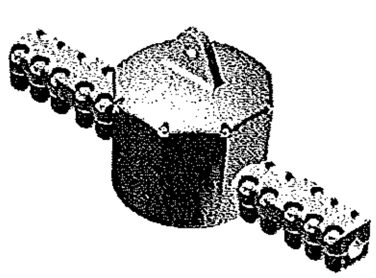
Features:

- Engineered to match existing conductors
- Available in fiber counts up to 144
- Distribution or Transmission -- from 36 to 245 kV
- Suitable for any type of optical fiber, single-mode or multimode
- Designed to match electrical properties of conductor it replaces
- Uses standard fiber optic deadends and suspension grips
- Full range of hardware options available

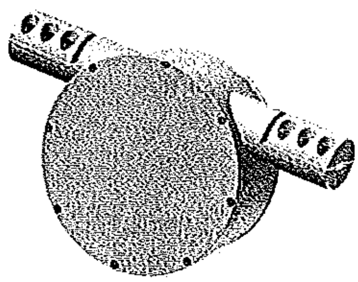
OPPC Hardware:



Typical OPPC insulators



OPPC joint box - Cast Aluminium



OPPC joint box - Self Supporting

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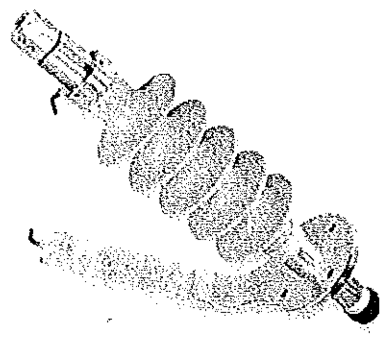


26 kV Isolator Kit for OPGW

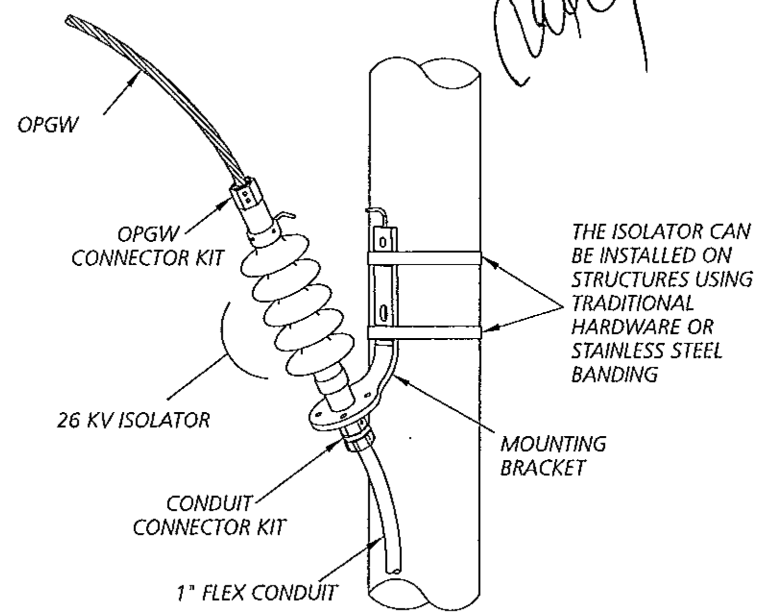
The 26 kV Isolator Kit is designed for aerial optical cable system applications in which complete electrical discontinuity is required. The isolator kit provides reliable interruption of electrical current, at voltages up to 26 kV and is a critical component of optical conductor and neutral systems, as well as optical ground-wire systems in which sectionalization of transient currents is required. The isolator can be installed on structures using traditional hardware or stainless steel banding.

Kit Includes

- OPGW Connector Kit
- 26 kV Isolator
- Conduit Connector Kit
- Mounting Bracket
- For use on AFL AlumaCore cables only

Specifications

PARAMETER	VALUE
Max. Voltage	26 kV
Weight	5 lbs. (approx.)



Ordering Information

ISOL	P	XX/YY	ZZZ
Isolator	Blank = Standard Bracket (as shown) P = 90° Bracket for Routing Cable Parallel to Pole	Cross Sectional Area Aluminum Strands / AW Strands (mm²)	Cable OD (Decimal Inches)

Ordering Example: *ISOL47/53/680*

AFL

Fiber Optic Cable

NEW

Renewables Optimized OPGW

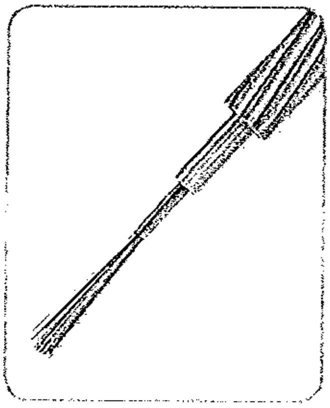
Renewable energy initiatives such as wind and solar farms have become a routine part of the new global energy business. Like most traditional transmission line projects, Optical Ground Wire is a key component in the planned power grid. Typical renewable applications require smaller, lighter-weight cables that can be delivered with minimal delay. In response to the needs of this market, AFL has optimized a select group of its Optical Ground Wire family specifically for these renewable applications. These designs take advantage of CentraCore's compact and robust design features—48 single-mode fibers are protected by a gel-filled, laser-welded stainless steel tube, central Aluminum pipe and stranded outer wires. Refer to all of the features of CentraCore OPGW cable.

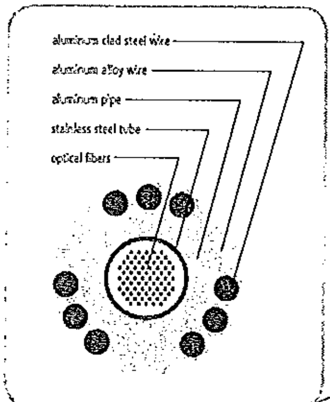
Ordering Information

Below is only a partial list of designs. Any of AFL's catalog or custom OPGW designs are available for renewable applications.

DESIGN NUMBER	FIBERS	OPGW SIZE	FAULT CURRENT	TOTAL CONDUCTOR AREA		OVERALL DIAMETER		WEIGHT		RBS		SAG10 CHART NO.	MAX SHIP LENGTH (PER REEL TYPE)	
			(KA)² SEC	IN²	MM²	IN	MM	LBS/FT	KG/M	LBS	KGF		WOOD (M)	STEEL (M)
DNO-10126	48	CC-52/461	47	0.1265	81.62	0.461	11.70	0.302	0.450	15,403	6,987	1-1457	6,400	6,400
DNO-10155	48	CC-26/26/461	56	0.1265	81.62	0.461	11.70	0.233	0.346	10,066	4,566	1-1438	6,400	6,400
DNO-10156	48	CC-54/465	49	0.1300	83.86	0.465	11.80	0.312	0.464	16,012	7,263	1-1457	6,400	6,400
DNO-10157	48	CC-27/27/465	59	0.1300	83.86	0.465	11.80	0.240	0.357	10,446	4,738	1-1438	6,400	6,400
DNO-10167	48	CC-61/484	56	0.1399	90.25	0.484	12.30	0.341	0.508	17,748	8,051	1-1453	6,400	6,400
DNO-10168	48	CC-28/33/484	67	0.1399	90.25	0.484	12.30	0.268	0.398	12,093	5,485	1-1455	6,400	6,400
DNO-10159	48	CC-70/512	67	0.1554	100.26	0.512	13.00	0.385	0.573	20,473	9,286	1-1421	6,400	6,400
DNO-10160	48	CC-35/35/512	84	0.1554	100.26	0.512	13.00	0.291	0.433	13,225	5,999	1-1455	6,400	6,400
DNO-10161	48	CC-87/551	88	0.1801	116.17	0.551	14.00	0.457	0.680	24,195	10,975	1-1425	5,300	6,400
DNO-10162	48	CC-38/48/551	109	0.1801	116.17	0.551	14.00	0.355	0.528	16,464	7,468	1-917	5,300	6,400
DNO-10163	48	CC-89/555	91	0.1839	118.66	0.555	14.10	0.468	0.696	24,856	11,275	1-1425	5,200	6,400
DNO-10164	48	CC-40/49/555	114	0.1839	118.66	0.555	14.10	0.363	0.539	16,902	7,667	1-917	5,200	6,400

This information denotes the input data needed for Sag10™ (sag and tension calculation) software. WIR files of all these are available through your AFL representative.





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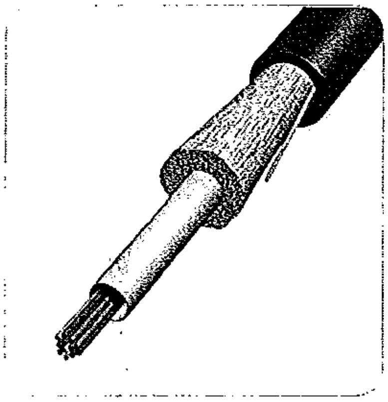
ДЗЗП "ЕИК ДРАГАЛЕВЦИ" Пловдив

AFL

Fiber Optic Cable



Aerial Drop Cable

Aerial Drop Cable is specifically designed for Fiber-to-the-Subscriber applications. It is a round, all dielectric cable ideally suited for self-supporting drop-type installations as well as in lashed or conduit builds.

6-Fiber Design

Typical Spans with 2.0% Installation Sag:

- NESC Heavy 100 ft (30 meters)
- NESC Medium 185 ft (56 meters)
- NESC Light 370 ft (113 meters)

12-Fiber Design

Typical Spans with 2.0% Installation Sag:

- NESC Heavy 75 ft (23 meters)
- NESC Medium 140 ft (43 meters)
- NESC Light 260 ft (75 meters)

Note: Typical installations should not be more than 4-6 spans. Point-to-point distance should not exceed 400 ft.

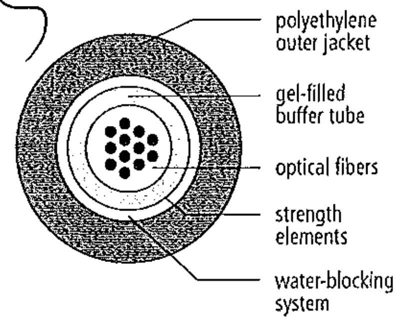
Temperature Range

Operating: -40°C to + 70°C

Storage: -50°C to + 70°C

Installation: -30°C to + 70°C

Cable Components



Features

- Designed for use with inexpensive attachment hardware
- Compatible with standard splice closures
- Self-supporting - no messenger needed
- Small cross section for maximum density in closures and conduit

Mechanical Data

FIBER COUNT	NOMINAL DIAMETER		NOMINAL WEIGHT		MAXIMUM LENGTHS*			
					SINGLE-MODE		MULTIMODE	
	INCHES	MM	LBS/1000 FT	KG/KM	FEET	METERS	FEET	METERS
1 - 6	.256	6.5	23	34	32,800	10,000	26,250	8,000
7 - 12	.307	7.8	34	50	27,500	8,400	26,250	8,000

* Longer lengths may be available upon request.

Installation Information

FIBER COUNT	MAXIMUM LOADING OPERATING TENSION		MINIMUM BENDING RADIUS (DYNAMIC)		MINIMUM BENDING RADIUS (STATIC)	
	LBS	N	INCHES	CM	INCHES	CM
1 - 6	270	1113	5	13	2.5	6.5
7 - 12	270	1113	6	16	3	8

NOTE: AFL recommends coiling a minimum of 12 feet (3.6 meters) into 6 inch (0.15 meters) loops at the entrance to all splice closures.

Ordering Information

FIBER COUNT	FIBER TYPE	AFL NO.	MAXIMUM ATTENUATION (DB/KM)			BANDWIDTH (MHZ•KM)	
			850 NM	1300 NM	1550 NM	850 NM	1300 NM
1 - 6	62.5/125 Giga-Link™ 300	AE00666110AA9	3.5	1.2	N/A	200	600
7 - 12		AE0126C110AC1					
1 - 6	50/125 Giga-Link™ 600	AE00656110AA9	2.9	0.9	N/A	500	500
7 - 12		AE0125C110AC1					
1 - 6	Single-mode	AE00696110AA9	N/A	0.35	0.25	N/A	N/A
7 - 12		AE0129C110AC1					

ВЯРНО С ОРИГИНАЛА

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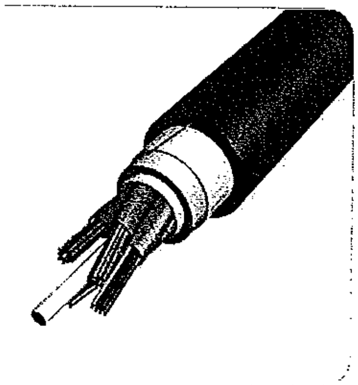


Mini-Span® ADSS Cable

AFL Mini-Span All-Dielectric Self-Supporting (ADSS) cable is designed for outside plant aerial and duct applications in local and campus network loop architectures. From pole-to-build to town-town installations, the Mini-Span cabling system, which includes cables, suspension, dead end and termination enclosures, offers a comprehensive transmission circuit infrastructure with proven, high-reliability performance. See AFL's Fiber Optic Cable Hardware catalog for more information. As the ADSS cabling concept implies, a separate messenger support wire hanging system is not required, greatly reducing installation time and improving upfront and maintenance labor costs.

Mini-Span includes fiber counts up to 96 optical fibers and any type or combination of single-mode and laser-optimized multimode fibers with the cable. Pole-to-Pole span lengths range from 50 feet to over 1000 feet.

Temperature Range

Operating: -40°C to +70°C

Storage: -50°C to +70°C

Installation: -30°C to +70°C

Installation Information

CABLE	NESC SPANS (@ 1.5% INITIAL SAG) FEET (METERS)			MAX. SAGGING TENSION		MAX. LOADING OPERATING TENSION		MIN. BENDING RADIUS (DYNAMIC)		MIN. BENDING RADIUS (STATIC)	
	LIGHT	MEDIUM	HEAVY	LBS	N	LBS	N	INCHES	CM	INCHES	CM
Mini-Span 323	500 (152)	300 (91)	175 (53)	147	654	374	1668	7	17	3.5	8.5
Mini-Span 383	450 (137)	300 (91)	180 (55)	183	814	402	1,785	8	20	4	10

CABLE	NESC SPANS (@ 1% INITIAL SAG) FEET (METERS)			MAX. SAGGING TENSION		MAX. LOADING OPERATING TENSION		MIN. BENDING RADIUS (DYNAMIC)		MIN. BENDING RADIUS (STATIC)	
	LIGHT	MEDIUM	HEAVY	LBS	N	LBS	N	INCHES	CM	INCHES	CM
Mini-Span 424	600 (183)	440 (134)	275 (84)	424	1886	707	3145	9	22	4	11
Mini-Span 535	1050 (320)	850 (259)	575 (175)	1,306	5,809	1,783	7,936	13	27	5	14

Optical Information

CABLE	MAXIMUM ATTENUATION (db/km)			BANDWIDTH (MHz•km)		
	SINGLE-MODE (1310 nm/1550 nm)	MULTIMODE *62.5/125 µm (850 nm/1300 nm)	MULTIMODE 50/125 µm (850 nm/1300 nm)	SINGLE-MODE (1310 nm/1550 nm)	MULTIMODE *62.5/125 µm (850 nm/1300 nm)	MULTIMODE 50/125 µm (850 nm/1300 nm)
Mini-Span 323	0.40/0.30	3.5/1.2	3.5/1.2	n/a	200/600	500/500
Mini-Span 383	0.35/0.25	3.5/1.2	2.9/0.9			
Mini-Span 424						
Mini-Span 535						

* All 62.5/125 µm multimode ADSS cable transmission performances meet or exceed FDDI requirements.
Premium transmission performance fibers available on request.

Mini-Span® ADSS Cable

Mechanical Data

CABLE	FIBER COUNT	NOMINAL DIAMETER		NOMINAL WEIGHT		MAXIMUM LENGTHS*			
						SINGLE-MODE		MULTIMODE	
		INCHES	MM	LBS/1000'	KG/KM	FEET	METERS	FEET	METERS
Mini-Span 323	2-24	0.323	8.2	35	53	32,800	10,000	26,250	8,000
Mini-Span 383	2-48	0.383	9.7	49	72	32,800	10,000	26,250	8,000
Mini-Span 424	2-60	0.424	10.8	57	84	32,800	10,000	26,250	8,000
Mini-Span 535	2-96	0.535	13.6	100	148	32,800	10,000	26,250	8,000

* Longer lengths may be available upon request.

Ordering Information

CABLE	FIBER COUNT	FIBERS PER TUBE	NUMBER OF TUBES / FIBERS	AFL NO.		
				SINGLE-MODE	MULTIMODE 62.5/125	MULTIMODE 50/125
Mini-Span 323	6	6	1 w/6	AE00696420AA1	AE00666420AA1	AE00656420AA1
	12	6	2 w/6	AE01296420AA1	AE01266420AA1	AE01256420AA1
	18	6	3 w/6	AE01896420AA1	AE01866420AA1	AE01856420AA1
	24	6	4 w/6	AE02496420AA1	AE02466420AA1	AE02456420AA1
Mini-Span 383	6	6	1 w/6 (3 fillers)	AE0069C420AA0	AE0066C420AA0	AE0065C420AA0
	12	12	1 w/12 (3 fillers)	AE0129C420AA0	AE0126C420AA0	AE0125C420AA0
	18	12	1 w/12, 1 w/6 (2 fillers)	AE0189C420AA0	AE0186C420AA0	AE0185C420AA0
	24	12	2 w/12 (2 fillers)	AE0249C420AA0	AE0246C420AA0	AE0245C420AA0
	30	12	2 w/12, 1 w/6 (1 filler)	AE0309C420AA0	AE0306C420AA0	AE0305C420AA0
	36	12	3 w/12 (1 filler)	AE0369C420AA0	AE0366C420AA0	AE0365C420AA0
	48	12	4 w/12	AE0489C420AA0	AE0486C420AA0	AE0485C420AA0
Mini-Span 424	6	6	1 w/6 (4 fillers)	AE0069C520AA4	AE0066C520AA4	AE0065C520AA4
	12	12	1 w/12 (4 fillers)	AE0129C520AA4	AE0126C520AA4	AE0125C520AA4
	18	12	1 w/12, 1 w/6 (3 fillers)	AE0189C520AA4	AE0186C520AA4	AE0185C520AA4
	24	12	2 w/12 (3 fillers)	AE0249C520AA4	AE0246C520AA4	AE0245C520AA4
	30	12	2 w/12, 1 w/6 (2 fillers)	AE0309C520AA4	AE0306C520AA4	AE0305C520AA4
	36	12	3 w/12 (2 fillers)	AE0369C520AA4	AE0366C520AA4	AE0365C520AA4
	48	12	4 w/12 (1 filler)	AE0489C520AA4	AE0486C520AA4	AE0485C520AA4
	60	12	5 w/12 (no fillers)	AE0609C520AA4	AE0606C520AA4	AE0605C520AA4
Mini-Span 535	6	6	1 w/6 (7 fillers)	AE0069C820EA7	AE0066C820EA7	AE0065C820EA7
	12	12	1 w/12 (7 fillers)	AE0129C820EA7	AE0126C820EA7	AE0125C820EA7
	18	12	1 w/12, 1 w/6 (6 fillers)	AE0189C820EA7	AE0186C820EA7	AE0185C820EA7
	24	12	2 w/12 (6 fillers)	AE0249C820EA7	AE0246C820EA7	AE0245C820EA7
	30	12	2 w/12, 1 w/6 (5 fillers)	AE0309C820EA7	AE0306C820EA7	AE0305C820EA7
	36	12	3 w/12 (5 fillers)	AE0369C820EA7	AE0366C820EA7	AE0365C820EA7
	48	12	4 w/12 (4 fillers)	AE0489C820EA7	AE0486C820EA7	AE0485C820EA7
	60	12	5 w/12 (3 fillers)	AE0609C820EA7	AE0606C820EA7	AE0605C820EA7
	72	12	6 w/12 (2 fillers)	AE0729C820EA7	AE0726C820EA7	AE0725C820EA7
	84	12	7 w/12 (1 filler)	AE0849C820EA7	AE0846C820EA7	AE0845C820EA7
	96	12	8 w/12 (no fillers)	AE0969C820EA7	AE0966C820EA7	AE0965C820EA7

Contact customer service for price and availability. Non-zero dispersion-shifted fibers are also available.

AFL

Fiber Optic Cable

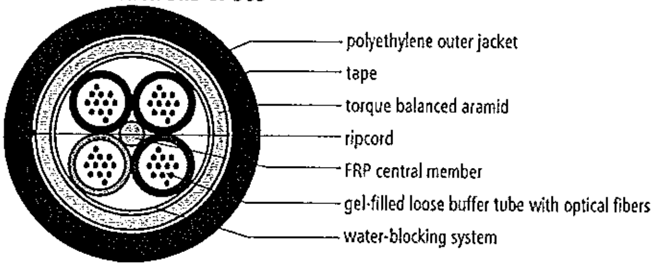
Mini-Span® ADSS Cable

Sag and Tension Information

CABLE	SPAN FEET	SPAN METERS	INITIAL SAG %	INITIAL TENSION LBS	INITIAL TENSION N	NESC LIGHT LOADING SAG %	NESC LIGHT LOADING TENSION LBS	NESC LIGHT LOADING TENSION N	NESC MEDIUM LOADING SAG %	NESC MEDIUM LOADING TENSION LBS	NESC MEDIUM LOADING TENSION N	NESC HEAVY LOADING SAG %	NESC HEAVY LOADING TENSION LBS	NESC HEAVY LOADING TENSION N
MINI-SPAN 323	50	15	1.5	15	67	0.4	66	294	2.1	101	449	3.2	152	677
	75	23	1.5	22	98	0.5	90	339	2.3	135	602	3.6	202	901
	100	30	1.5	30	133	0.5	111	494	2.5	166	741	3.9	248	1,102
	125	38	1.5	37	165	0.5	131	583	2.7	195	867	4.2	289	1,288
	150	46	1.5	44	196	0.5	150	667	2.8	222	989	4.5	329	1,463
	175	53	1.5	52	232	0.6	168	748	3.0	248	1,104	4.7	366	1,629
	200	61	1.5	59	262	0.6	185	825	3.1	273	1,214	—	—	—
	225	69	1.5	66	294	0.6	202	900	3.2	297	1,321	—	—	—
	250	76	1.5	74	329	0.6	219	973	3.3	320	1,424	—	—	—
	275	84	1.5	81	360	0.6	235	1,044	3.4	342	1,524	—	—	—
	300	91	1.5	88	392	0.6	250	1,113	3.5	364	1,621	—	—	—
	325	99	1.5	96	427	0.7	265	1,181	—	—	—	—	—	—
	350	107	1.5	103	458	0.7	280	1,247	—	—	—	—	—	—
	375	114	1.5	111	494	0.7	295	1,312	—	—	—	—	—	—
	400	122	1.5	118	525	0.7	309	1,376	—	—	—	—	—	—
	425	130	1.5	125	556	0.7	324	1,440	—	—	—	—	—	—
	450	137	1.5	133	592	0.7	338	1,502	—	—	—	—	—	—
	475	145	1.5	140	623	0.7	351	1,563	—	—	—	—	—	—
	500	152	1.5	147	654	0.7	365	1,624	—	—	—	—	—	—
MINI-SPAN 383	50	15	1.5	20	89	0.5	76	337	2.2	108	482	3.2	161	717
	75	23	1.5	30	133	0.5	103	457	2.4	146	648	3.6	215	956
	100	30	1.5	41	182	0.6	128	568	2.6	179	798	4.0	263	1,171
	125	38	1.5	51	227	0.6	151	671	2.8	211	938	4.2	308	1,370
	150	46	1.5	61	271	0.6	173	768	2.9	240	1,070	4.5	350	1,558
	175	53	1.5	71	316	0.6	194	862	3.0	269	1,196	4.7	390	1,736
	200	61	1.5	81	360	0.7	214	952	3.2	296	1,317	—	—	—
	225	69	1.5	91	405	0.7	234	1,040	3.3	322	1,434	—	—	—
	250	76	1.5	101	449	0.7	253	1,125	3.4	348	1,547	—	—	—
	275	84	1.5	112	498	0.7	272	1,209	3.5	372	1,657	—	—	—
	300	91	1.5	122	543	0.7	290	1,290	3.5	397	1,765	—	—	—
	325	99	1.5	132	587	0.8	308	1,370	—	—	—	—	—	—
	350	107	1.5	142	632	0.8	325	1,448	—	—	—	—	—	—
	375	114	1.5	152	676	0.8	343	1,525	—	—	—	—	—	—
	400	122	1.5	162	721	0.8	360	1,601	—	—	—	—	—	—
	425	130	1.5	172	765	0.8	377	1,676	—	—	—	—	—	—
	450	137	1.5	183	814	0.8	393	1,750	—	—	—	—	—	—

Typical Cable Components

4 Position 323 or 383



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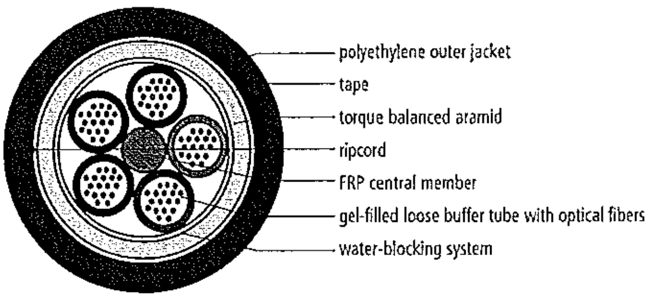
Mini-Span® ADSS Cable

Sag and Tension Information

CABLE	SPAN		INITIAL SAG	INITIAL TENSION		NESC LIGHT LOADING			NESC MEDIUM LOADING			NESC HEAVY LOADING		
						SAG	TENSION		SAG	TENSION		SAG	TENSION	
	FEET	METERS	%	LBS	N	%	LBS	N	%	LBS	N	%	LBS	N
MINI-SPAN 424	50	15	1.0	35	156	0.4	104	463	1.7	142	632	2.6	207	921
	75	23	1.0	53	236	0.4	142	632	1.9	191	850	3.0	275	1,223
	100	30	1.0	71	316	0.5	176	783	2.1	235	1,095	3.2	337	1,499
	125	38	1.0	88	391	0.5	208	925	2.2	276	1,228	3.4	395	1,757
	150	46	1.0	106	472	0.5	238	1,059	2.4	315	1,401	3.6	449	1,997
	175	53	1.0	124	552	0.5	268	1,192	2.5	353	1,570	3.8	501	2,229
	200	61	1.0	141	627	0.6	296	1,317	2.6	389	1,730	4.0	50	2,447
	225	69	1.0	159	707	0.6	324	1,441	2.7	424	1,886	4.1	598	2,660
	250	76	1.0	177	787	0.6	351	1,561	2.7	458	2,037	4.2	645	2,869
	275	84	1.0	194	863	0.6	378	1,681	2.8	491	2,184	4.3	690	3,069
	300	91	1.0	212	943	0.6	404	1,737	2.8	524	2,331	—	—	—
	325	99	1.0	230	1,023	0.6	429	1,908	2.9	556	2,473	—	—	—
	350	107	1.0	247	1,099	0.6	455	2,024	3.0	587	2,611	—	—	—
	375	114	1.0	265	1,179	0.6	479	2,131	3.0	618	2,749	—	—	—
	400	122	1.0	283	1,259	0.6	504	2,242	3.1	648	2,882	—	—	—
	425	130	1.0	300	1,334	0.7	528	2,349	3.1	678	3,016	—	—	—
	450	137	1.0	318	1,415	0.7	552	2,455	3.2	703	3,145	—	—	—
	475	145	1.0	336	1,495	0.7	576	2,562	—	—	—	—	—	—
	500	152	1.0	353	1,570	0.7	600	2,669	—	—	—	—	—	—
	525	160	1.0	371	1,650	0.7	623	2,771	—	—	—	—	—	—
	550	168	1.0	389	1,730	0.7	646	2,874	—	—	—	—	—	—
	575	175	1.0	406	1,806	0.7	669	2,976	—	—	—	—	—	—
	600	183	1.0	424	1,886	0.7	692	3,078	—	—	—	—	—	—

Typical Cable Components

5 Position 424



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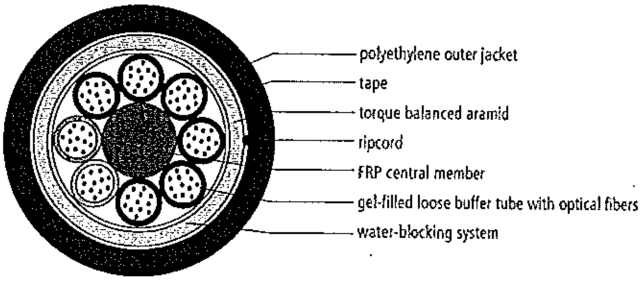
Mini-Span® ADSS Cable

Sag and Tension Information

CABLE	SPAN FEET	SPAN METERS	INITIAL SAG %	INITIAL TENSION LBS	INITIAL TENSION N	NESC LIGHT LOADING SAG %	NESC LIGHT LOADING TENSION LBS	NESC LIGHT LOADING TENSION N	NESC MEDIUM LOADING SAG %	NESC MEDIUM LOADING TENSION LBS	NESC MEDIUM LOADING TENSION N	NESC HEAVY LOADING SAG %	NESC HEAVY LOADING TENSION LBS	NESC HEAVY LOADING TENSION N
MINI-SPAN 535	50	15	1	62	276	0.4	160	713	1.5	206	918	2.1	297	1,319
	100	30	1	124	552	0.5	274	1,220	1.7	347	1,542	2.5	489	2,176
	150	46	1	187	832	0.6	375	1,670	1.9	469	2,087	2.8	655	2,915
	200	61	1	249	1,108	0.6	469	2,088	2.1	582	2,590	3.1	807	3,588
	250	76	1	311	1,383	0.6	559	2,486	2.2	689	3,063	3.3	948	4,217
	300	91	1	373	1,659	0.6	645	2,868	2.3	790	3,515	3.4	1,082	4,813
	350	107	1	435	1,935	0.7	728	3,239	2.4	888	3,951	3.6	1,210	5,384
	400	122	1	497	2,211	0.7	810	3,601	2.5	983	4,374	3.7	1,334	5,935
	450	137	1	560	2,491	0.7	889	3,956	2.5	1,076	4,785	3.8	1,454	6,469
	500	152	1	622	2,767	0.7	968	4,304	2.6	1,166	5,188	3.9	1,571	6,988
	550	168	1	684	3,043	0.7	1,045	4,647	2.7	1,255	5,583	4.0	1,685	7,495
	575	175	1	715	3,180	0.7	1,083	4,817	2.7	1,299	5,778	4.1	1,741	7,745
	600	183	1	746	3,318	0.7	1,121	4,985	2.7	1,342	5,971	—	—	—
	650	198	1	808	3,594	0.8	1,196	5,320	2.8	1,428	6,353	—	—	—
	700	213	1	870	3,870	0.8	1,270	5,650	2.8	1,513	6,730	—	—	—
	750	229	1	933	4,150	0.8	1,344	5,978	2.8	1,597	7,102	—	—	—
	800	244	1	995	4,426	0.8	1,417	6,303	2.9	1,679	7,469	—	—	—
	850	259	1	1,057	4,702	0.8	1,489	6,625	2.9	1,761	7,833	—	—	—
	900	274	1	1,119	4,978	0.8	1,561	6,945	—	—	—	—	—	—
	950	290	1	1,181	5,253	0.8	1,633	7,263	—	—	—	—	—	—
	1,000	305	1	1,243	5,529	0.8	1,704	7,579	—	—	—	—	—	—
	1,050	320	1	1,306	5,809	0.8	1,775	7,894	—	—	—	—	—	—

Typical Cable Components

8 Position 535



945

Mini-Span® ADSS Cable

Reel Information

REEL SPECS	REEL A		REEL B		REEL C		REEL D		REEL E	
ITEM	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM
Reel Height	42	106.7	58	147.3	66	167.6	72	182.8	84	213.4
Reel Width Outside	36	91.4	38	96.5	42	106.7	42	106.7	40	101.6
Reel Width Inside	32	81.6	32	81.3	36	91.4	36	91.4	34	86.4
Drum Diameter	23	58.7	28	71.1	36	91.4	36	91.4	35	88.9
Arbor Hole Diameter	3	7.9	3	7.9	3	7.9	3	7.9	3	7.9
Reel Weight with Lagging	180 lbs	82 kg	420 lbs	191 kg	685 lbs	311 kg	710 lbs	320 kg	950 lbs	431 kg
MAXIMUM CABLE LENGTH (feet/meters)										
Mini-Span 323	15,256 ft	4,650 m	32,800 ft	10,000 m	—	—	—	—	—	—
Mini-Span 383	10,827 ft	3,300 m	25,202 ft	7,700 m	32,800 ft	10,000 m	—	—	—	—
Mini-Span 424	8,850 ft	2,700 m	20,250 ft	6,200 m	26,250 ft	8,000 m	32,800 ft	10,000 m	—	—
Mini-Span 484	6,500 ft	2,000 m	15,750 ft	4,800 m	21,000 ft	6,450 m	32,800 ft	10,000 m	—	—
Mini-Span 535	5,500 ft	1,675 m	12,800 ft	3,900 m	17,225 ft	5,250 m	26,000 ft	6,920 m	32,800 ft	10,000 m

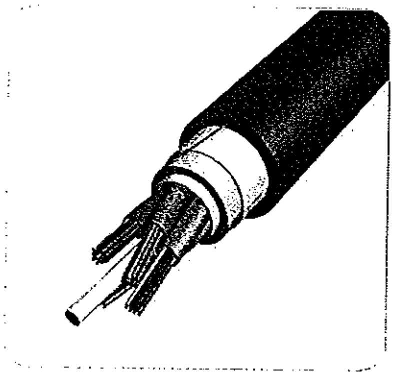
AFL provides ADSS cable on several standard sizes of non-returnable wooden reels. Non-standard reel sizes are available on request.

ВЯРНО С ОРИГИНАЛА

946

AFL

Fiber Optic Cable



Flex-Span® ADSS Fiber Optic Cable

Flex-Span ADSS expands on AFL's single jacket ADSS portfolio. Flex-Span designs are optimized for a broader combination of fiber counts and span lengths, providing ADSS system designers more flexibility in their product selection. As its name indicates, there is no support or messenger wire required, so installation is achieved in a single pass.

Flex-Span ADSS includes fiber counts up to 144 optical fibers and any type or combination of single-mode or multimode fibers within the cable. Pole-to-pole span lengths range from 50 ft. to over 1,000 ft.

Features

- Suitable for use on distribution lines
- Gel-filled buffer tubes are S-Z stranded for easy mid-span access
- Cable is water-blocked using dry core technology, therefore no messy flooding compounds
- Design details listed below for span lengths up to 1100 ft (457 m) and fiber counts up to 144
- Requires the use of formed wire dead ends

Temperature Range

Operating: -40°C to +70°C

Storage: -50°C to +70°C

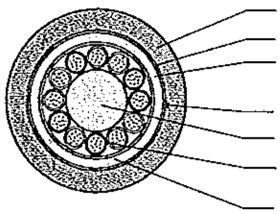
Installation: -30°C to +70°C

Typical Maximum Lengths

CABLE DIAMETER	REEL CAPACITY	
	FEET	METERS
≤ 0.85" (21.6 mm)	23,000	7,000

NOTE: Longer lengths may be available upon request.

Cable Components (Representative)



Optical Information

FIBER TYPE	MAXIMUM ATTENUATION (dB/km)				OVERFILL LAUNCH MIN. BANDWIDTH (MHz•km)		GIGABIT ETHERNET MINIMUM LINK DISTANCE (meters)	
	850 nm	1300 nm	1310 nm	1550 nm	850 nm	1300 nm	850 nm	1300 nm
(6) 62.5/125 GIGA-Link™ 300	3.5	1.2	N/A	N/A	200	600	300	550
(8) 62.5/125 GIGA-Link™ 1000	3.5	1.2	N/A	N/A	350	600	500	1000
(5) 50/125 GIGA-Link™ 600	2.9	0.9	N/A	N/A	500	500	600	600
(7) 50/125 GIGA-Link™ 2000	2.9	0.9	N/A	N/A	500	800	750	2000
(L) 50 Laser-Link™ 300	2.9	0.9	N/A	N/A	1500	500	900	550
(9) Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000
(Q) Non-zero Dispersion-shifted Single-mode	N/A	N/A	N/A	0.25	N/A	N/A	N/A	N/A
(K) SM Futureguide SR-15e Bend Insensitive	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000

Gigabit Ethernet Minimum Link Distances are based on "bandwidth"/modal dispersion constraints.
Actual link distances may be constrained by attenuation, depending on specific loss budget.

Reel Information

ITEM	REEL A		REEL B		REEL C		REEL D		REEL E	
	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM
Reel Height	42	106.7	58	147.3	66	167.6	72	167.6	84	213.4
Reel Width Outside	36	91.4	38	96.5	42	106.7	42	106.7	40	101.6
Reel Width Inside	32	81.6	32	81.3	36	91.4	36	91.4	34	86.4
Drum Diameter	23	58.7	28	71.1	36	91.4	36	91.4	35	88.9
Arbor Hole Diameter	3	7.9	3	7.9	3	7.9	3	7.9	3	7.9
Reel Weight with Lagging	180 lbs	82 kg	420 lbs	191 kg	685 lbs	311 kg	710 lbs	311 kg	950 lbs	431 kg

AFL provides ADSS cable on several standard sizes of non-returnable wooden reels. Non-standard reel sizes are available upon request.

947

Flex-Span® ADSS Fiber Optic Cable

LIGHT

NESC LIGHT @ 1.5% INSTALLATION SAG

SPAN		AFL NO.	WEIGHT		DIAMETER		MRCL		INITIAL TENSION[1]				
									UNLOADED		LOADED		
FEET	METERS		LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
12 FIBERS													
525	160	AE012∗C520A08	0.057	84	0.425	10.8	539	2398	248	1104	0.8	521	2318
600	183	AE012∗C520AA0	0.057	84	0.425	10.8	598	2661	284	1264	0.8	592	2634
700	213	AE012∗C520AA5	0.057	84	0.425	10.8	746	3320	333	1482	0.8	702	3124
800	244	AE012∗C520E08	0.059	88	0.433	11	809	3600	395	1758	0.8	807	3591
925	282	AE012∗C520EA1	0.059	88	0.433	11	999	4445	457	2034	0.8	947	4214
1050	320	AE012∗C520EA2	0.059	88	0.433	11	1062	4726	519	2309	0.8	1059	4712
1100	335	AE012∗C520EA4	0.059	88	0.433	11	1189	5291	544	2421	0.8	1127	5015
24 FIBERS													
525	160	AE024∗C520A08	0.058	86	0.425	10.8	539	2398	252	1121	0.8	523	2327
600	183	AE024∗C520AA0	0.058	86	0.425	10.8	598	2661	289	1286	0.8	594	2643
700	213	AE024∗C520AA5	0.058	86	0.425	10.8	746	3320	338	1504	0.8	705	3137
800	244	AE024∗C520EA0	0.06	90	0.433	11	936	4165	402	1789	0.8	838	3729
925	282	AE024∗C520EA1	0.06	90	0.433	11	999	4445	464	2065	0.8	951	4232
1010	308	AE024∗C520EA2	0.06	90	0.433	11	1062	4726	507	2256	0.8	1032	4592
1100	335	AE024∗C520EA4	0.06	90	0.433	11	1189	5291	553	2461	0.8	1131	5033
48 FIBERS													
525	160	AE048∗C520A08	0.06	89	0.425	10.8	539	2398	261	1161	0.9	528	2350
600	183	AE048∗C520AA1	0.06	89	0.425	10.8	628	2794	298	1326	0.9	606	2697
700	213	AE048∗C520AA5	0.06	89	0.425	10.8	746	3320	349	1553	0.8	711	3164
800	244	AE048∗C520EA0	0.062	93	0.433	11	936	4165	414	1842	0.8	845	3760
925	282	AE048∗C520EA1	0.062	93	0.433	11	999	4445	479	2131	0.9	958	4263
1030	314	AE048∗C520EA2	0.062	93	0.433	11	1062	4726	534	2376	0.9	1056	4699
1100	335	AE048∗C520EA4	0.062	93	0.433	11	1189	5291	570	2536	0.9	1140	5073
72 FIBERS													
725	221	AE072∗C620A08	0.075	112	0.465	11.8	854	3800	454	2020	0.9	832	3702
800	244	AE072∗C620AA0	0.075	112	0.465	11.8	913	4063	501	2229	0.9	911	4054
875	267	AE072∗C620AA3	0.075	112	0.465	11.8	1002	4459	548	2438	0.9	998	4441
975	297	AE072∗C620AA7	0.075	112	0.465	11.8	1120	4984	611	2719	0.9	1113	4953
1075	328	AE072∗C620EA0	0.075	112	0.465	11.8	1250	5562	674	2999	0.9	1230	5473
96 FIBERS													
925	282	AE096∗C820A08	0.1	148	0.528	13.4	1296	5767	769	3422	1	1270	5651
1000	305	AE096∗C820AA1	0.1	149	0.528	13.4	1384	6159	832	3702	1	1370	6096
144 FIBERS													
1050	320	AE144∗CC20A08	0.164	244	0.673	17.10	2070	9211	1433	6377	1.1	2048	9113

[1] Initial tension indicates tension before 10 year creep.

Note: Diameter and weight subject to change without notice

∗ Fiber Types – Replace asterisk (∗) in AFL number with number corresponding to desired fiber type below.

5 = 50/125 µm multimode GIGA-Link™ 600
7 = 50/125 µm multimode GIGA-Link™ 2000
6 = 62.5/125 µm multimode GIGA-Link™ 300
8 = 62.5/125 µm multimode GIGA-Link™ 1000
L = 50/125 µm multimode Laser-Link™ 300
9 = Single-mode
K = SM Futureguide SR-15e Bend Insensitive
Q = Non-zero dispersion-shifted single-mode

ВЯРНО С ОРИГИНАЛА

948

AFL

Fiber Optic Cable

Flex-Span® ADSS Fiber Optic Cable

NESC MEDIUM @ 1.5% INSTALLATION SAG

SPAN		AFL NO.	WEIGHT		DIAMETER		MRCL		INITIAL TENSION[1]				
									UNLOADED		LOADED		
FEET	METERS		LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
12 FIBERS													
375	114	AE012✱C520A08	0.057	84	0.425	10.8	539	2398	178	792	3.5	532	2367
400	122	AE012✱C520AA0	0.057	84	0.425	10.8	598	2661	189	841	3.5	573	2550
500	152	AE012✱C520AA5	0.057	84	0.425	10.8	746	3320	238	1059	3.5	717	3191
550	168	AE012✱C520E08	0.059	88	0.433	11	809	3600	272	1210	3.5	793	3529
650	198	AE012✱C520EA1	0.059	88	0.433	11	999	4445	321	1428	3.4	949	4223
700	213	AE012✱C520EA2	0.059	88	0.433	11	1062	4726	346	1540	3.5	1018	4530
800	244	AE012✱C520EA4	0.059	88	0.433	11	1189	5291	396	1762	3.5	1157	5148
24 FIBERS													
375	114	AE024✱C520A08	0.058	86	0.425	10.8	539	2398	181	805	3.5	533	2372
400	122	AE024✱C520AA0	0.058	86	0.425	10.8	598	2661	192	854	3.5	575	2559
500	152	AE024✱C520AA5	0.058	86	0.425	10.8	746	3320	242	1077	3.5	719	3199
625	190	AE024✱C520EA0	0.06	90	0.433	11	936	4165	314	1397	3.5	908	4040
650	198	AE024✱C520EA1	0.06	90	0.433	11	999	4445	326	1451	3.4	951	4232
700	213	AE024✱C520EA2	0.06	90	0.433	11	1062	4726	352	1566	3.5	1021	4543
800	244	AE024✱C520EA4	0.06	90	0.433	11	1189	5291	402	1789	3.5	1160	5162
48 FIBERS													
375	114	AE048✱C520A08	0.06	89	0.425	10.8	539	2398	187	832	3.5	536	2385
425	130	AE048✱C520AA1	0.06	89	0.425	10.8	628	2794	211	939	3.5	612	2723
500	152	AE048✱C520AA5	0.06	89	0.425	10.8	746	3320	250	1112	3.5	723	3217
625	190	AE048✱C520EA0	0.062	93	0.433	11	936	4165	324	1442	3.5	913	4063
650	198	AE048✱C520EA1	0.062	93	0.433	11	999	4445	337	1500	3.4	957	4258
700	213	AE048✱C520EA2	0.062	93	0.433	11	1062	4726	363	1615	3.5	1027	4570
800	244	AE048✱C520EA4	0.062	93	0.433	11	1189	5291	415	1847	3.5	1167	5193
72 FIBERS													
525	160	AE072✱C620A08	0.075	112	0.465	11.8	854	3800	328	1460	3.4	825	3671
575	175	AE072✱C620AA0	0.075	112	0.465	11.8	913	4063	360	1602	3.4	899	4000
625	190	AE072✱C620AA3	0.075	112	0.465	11.8	1002	4459	391	1740	3.4	979	4356
710	216	AE072✱C620AA7	0.075	112	0.465	11.8	1120	4984	445	1980	3.5	1108	4930
800	244	AE072✱C620EA0	0.075	112	0.465	11.8	1250	5562	501	2229	3.5	1245	5540
96 FIBERS													
725	221	AE096✱C820A08	0.1	148	0.528	13.4	1296	5767	603	2683	3.4	1282	5705
775	236	AE096✱C820AA1	0.1	149	0.528	13.4	1384	6159	645	2870	3.4	1370	6096
144 FIBERS													
875	267	AE144✱CC20A08	0.164	244	0.673	17.10	2070	9211	1195	5318	3.2	2028	9024

[1] Initial tension indicates tension before 10 year creep.

Note: Diameter and weight subject to change without notice

✱ Fiber Types – Replace asterisk (✱) in AFL number with number corresponding to desired fiber type below.

5 = 50/125 µm multimode GIGA-Link™ 600
7 = 50/125 µm multimode GIGA-Link™ 2000
6 = 62.5/125 µm multimode GIGA-Link™ 300
8 = 62.5/125 µm multimode GIGA-Link™ 1000
L = 50/125 µm multimode Laser-Link™ 300
9 = Single-mode
K = SM Futureguide SR-15e Bend Insensitive
Q = Non-zero dispersion-shifted single-mode

Flex-Span® ADSS Fiber Optic Cable

NESC HEAVY @ 1.5% INSTALLATION SAG

HEAVY

SPAN		AFL NO.	WEIGHT		DIAMETER		MRCL		INITIAL TENSION[1]				
									UNLOADED		LOADED		
FEET	METERS		LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
12 FIBERS													
200	61	AE012✱C520A08	0.057	84	0.425	10.8	539	2398	95	423	4.5	485	2158
250	76	AE012✱C520AA0	0.057	84	0.425	10.8	598	2661	118	525	4.6	585	2603
300	91	AE012✱C520AA5	0.057	84	0.425	10.8	746	3320	143	636	4.6	710	3159
325	99	AE012✱C520E08	0.059	88	0.433	11	809	3600	160	712	4.6	775	3449
400	122	AE012✱C520EA1	0.059	88	0.433	11	999	4445	198	881	4.6	955	4250
450	137	AE012✱C520EA2	0.059	88	0.433	11	1062	4726	222	988	4.7	1057	4703
500	152	AE012✱C520EA4	0.059	88	0.433	11	1189	5291	247	1099	4.7	1177	5237
24 FIBERS													
200	61	AE024✱C520A08	0.058	86	0.425	10.8	539	2398	96	427	4.5	485	2158
250	76	AE024✱C520AA0	0.058	86	0.425	10.8	598	2661	120	534	4.6	586	2608
300	91	AE024✱C520AA5	0.058	86	0.425	10.8	746	3320	145	645	4.6	712	3168
375	114	AE024✱C520EA0	0.06	90	0.433	11	936	4165	188	837	4.6	897	3991
400	122	AE024✱C520EA1	0.06	90	0.433	11	999	4445	201	894	4.6	957	4258
450	137	AE024✱C520EA2	0.06	90	0.433	11	1062	4726	219	975	4.7	1054	4690
500	152	AE024✱C520EA4	0.06	90	0.433	11	1189	5291	251	1117	4.7	1179	5246
48 FIBERS													
200	61	AE048✱C520A08	0.06	89	0.425	10.8	539	2398	99	441	4.5	487	2167
250	76	AE048✱C520AA1	0.06	89	0.425	10.8	628	2794	124	552	4.6	596	2652
300	91	AE048✱C520AA5	0.06	89	0.425	10.8	746	3320	150	667	4.6	714	3177
375	114	AE048✱C520EA0	0.062	93	0.433	11	936	4165	194	863	4.6	900	4005
400	122	AE048✱C520EA1	0.062	93	0.433	11	999	4445	207	921	4.6	960	4272
450	137	AE048✱C520EA2	0.062	93	0.433	11	1062	4726	233	1037	4.7	1062	4726
500	152	AE048✱C520EA4	0.062	93	0.433	11	1189	5291	259	1153	4.7	1183	5264
72 FIBERS													
300	91	AE072✱C620A08	0.075	112	0.465	11.8	854	3800	188	837	4.4	774	3444
350	107	AE072✱C620AA0	0.075	112	0.465	11.8	913	4063	219	975	4.6	880	3916
400	122	AE072✱C620AA3	0.075	112	0.465	11.8	1002	4459	250	1112	4.6	995	4428
450	137	AE072✱C620AA7	0.075	112	0.465	11.8	1120	4984	282	1255	4.6	1117	4970
500	152	AE072✱C620EA0	0.075	112	0.465	11.8	1250	5562	313	1393	4.6	1243	5531
96 FIBERS													
400	122	AE096✱C820A08	0.1	148	0.528	13.4	1296	5767	333	1482	4.3	1140	5073
500	152	AE096✱C820AA1	0.1	149	0.528	13.4	1384	6159	416	1851	4.5	1364	6070
144 FIBERS													
600	183	AE144✱CC20A08	0.164	244	0.673	17.10	2070	9211	819	3644	4.3	2007	8931

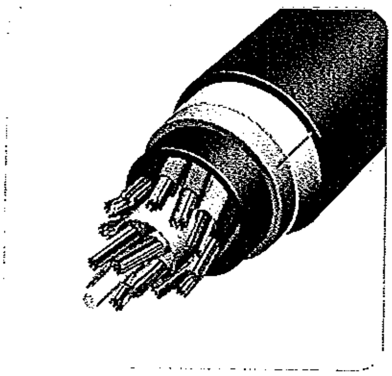
[1] Initial tension indicates tension before 10 year creep.

Note: Diameter and weight subject to change without notice

✱ Fiber Types – Replace asterisk (✱) in AFL number with number corresponding to desired fiber type below.

5 = 50/125 µm multimode GIGA-Link™ 600
7 = 50/125 µm multimode GIGA-Link™ 2000
6 = 62.5/125 µm multimode GIGA-Link™ 300
8 = 62.5/125 µm multimode GIGA-Link™ 1000
L = 50/125 µm multimode Laser-Link™ 300
9 = Single-mode
K = SM Futureguide SR-15e Bend Insensitive
Q = Non-zero dispersion-shifted single-mode

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable



AFL-ADSS® (All-Dielectric Self-Supporting) cable is ideal for installation in distribution as well as transmission environments, even when live-line installations are required. As its name indicates, there is no support or messenger wire required, so installation is achieved in a single pass, making ADSS an economical and simple means of achieving a fiber optic network. AFL manufactures its own line of attachment hardware as well as supplies formed wire fittings when preferred.

Features

- Suitable for use on distribution and high voltage transmission lines
- Track-resistant outer jacket available for installations on high voltage lines where space potentials reach up to 25 kV
- Gel-filled buffer tubes are S-Z stranded for easy mid-span access
- Cable is water-blocked using dry core technology, therefore no messy flooding compounds
- Design details listed below for span lengths up to 1500 ft (457 m) and fiber counts up to 432
- Custom designs available for larger span lengths or other fiber counts

Temperature Range

Operating: -40°C to +70°C

Storage: -50°C to +70°C

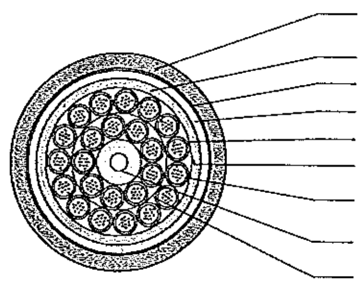
Installation: -30°C to +70°C

Typical Maximum Lengths

	REEL CAPACITY	
CABLE DIAMETER	FEET	METERS
≤ 0.85" (21.6 mm)	23,000	7,000
> 0.85" (21.6 mm)	10,000	3,000

NOTE: Longer lengths may be available upon request. Lengths shown may require non-standard reel sizes/types.

Cable Components



Quote Request Information

A - XXX - XXXX - X - X - X - X

Fiber Count
002 = 2 fibers
432 = 432 fibers

Span Length
0100=100
1500=1500

Unit of Measure
F=Feet
M=Meters

NESC Loading Condition
L=Light
M=Medium
H=Heavy

Fiber Code
6=62.5/125 GIGA-Link™ 300
8=62.5/125 GIGA-Link™ 1000
5=50/125 GIGA-Link™ 600
7=50/125 GIGA-Link™ 2000
L=50 Laser-Link™ 300
9=Single-mode
Q=Non-zero Dispersion-shifted Single-mode
K=SM Futureguide SR-15e Bend Insensitive

Line Voltage
A= Less than 115 kV
B= ≥115 kV

NOTE: The designs listed are only a sampling of the options available from AFL. Contact customer service for a cable designed to your exact specifications.

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All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

Optical Information

FIBER TYPE	MAXIMUM ATTENUATION (dB/km)				OVERFILL LAUNCH MIN. BANDWIDTH (MHz•km)		GIGABIT ETHERNET MINIMUM LINK DISTANCE (meters)	
	850 nm	1300 nm	1310 nm	1550 nm	850 nm	1300 nm	850 nm	1300 nm
(6) 62.5/125 GIGA-Link™ 300	3.5	1.2	N/A	N/A	200	600	300	550
(8) 62.5/125 GIGA-Link™ 1000	3.5	1.2	N/A	N/A	350	600	500	1000
(5) 50/125 GIGA-Link™ 600	2.9	0.9	N/A	N/A	500	500	600	600
(7) 50/125 GIGA-Link™ 2000	2.9	0.9	N/A	N/A	500	800	750	2000
(L) 50 Laser-Link™ 300	3.5	1.2	N/A	N/A	1500	500	900	550
(9) Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000
(Q) Non-zero Dispersion-shifted Single-mode	N/A	N/A	N/A	0.25	N/A	N/A	N/A	N/A
(K) SM Futureguide SR-15e Bend Insensitive	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000

Gigabit Ethernet Minimum Link Distances are based on "bandwidth"/modal dispersion constraints.
Actual link distances may be constrained by attenuation, depending on specific loss budget.

Reel Information

ITEM	REEL A		REEL B		REEL C		REEL D		REEL E	
	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM
Reel Height	42	106.7	58	147.3	66	167.6	72	167.6	84	213.4
Reel Width Outside	36	91.4	38	96.5	42	106.7	42	106.7	40	101.6
Reel Width Inside	32	81.6	32	81.3	36	91.4	36	91.4	34	86.4
Drum Diameter	23	58.7	28	71.1	36	91.4	36	91.4	35	88.9
Arbor Hole Diameter	3	7.9	3	7.9	3	7.9	3	7.9	3	7.9
Reel Weight with Lagging	180 lbs	82 kg	420 lbs	191 kg	685 lbs	311 kg	710 lbs	311 kg	950 lbs	431 kg

AFL provides ADSS cable on several standard sizes of non-returnable wooden reels. Non-standard reel sizes are available upon request.

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC LIGHT LOADING @ 1% INSTALLATION SAG

LIGHT

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
12 FIBERS												
100	30	0.080	119	0.500	12.7	539	2398	100	446	0.6	194	862
200	61	0.080	119	0.500	12.7	539	2398	201	892	0.7	333	1479
300	91	0.080	119	0.500	12.7	539	2398	301	1338	0.7	459	2043
400	122	0.080	119	0.500	12.7	628	2793	401	1785	0.8	597	2654
500	152	0.080	119	0.500	12.7	746	3320	502	2232	0.8	739	3286
600	183	0.080	119	0.500	12.7	936	4162	602	2679	0.8	894	3976
700	213	0.084	125	0.512	13.0	1126	5008	737	3280	0.8	1079	4800
800	244	0.084	125	0.512	13.0	1253	5572	843	3750	0.8	1227	5459
900	274	0.084	126	0.512	13.0	1569	6981	949	4221	0.8	1409	6269
1000	305	0.084	126	0.512	13.0	1569	6981	1054	4690	0.8	1535	6829
1100	335	0.085	126	0.512	13.0	1823	8108	1162	5171	0.8	1708	7595
1200	366	0.090	134	0.528	13.4	1950	8672	1350	6005	0.8	1926	8569
1300	396	0.090	134	0.528	13.4	2203	9799	1463	6508	0.8	2103	9356
1400	427	0.090	134	0.528	13.4	2330	10363	1576	7010	0.8	2258	10044
1500	457	0.090	134	0.528	13.4	2456	10927	1689	7512	0.8	2412	10731
24 FIBERS												
100	30	0.081	121	0.500	12.7	539	2398	102	452	0.6	194	865
200	61	0.081	121	0.500	12.7	539	2398	203	904	0.7	334	1486
300	91	0.081	121	0.500	12.7	539	2398	305	1356	0.7	462	2053
400	122	0.081	121	0.500	12.7	628	2793	407	1808	0.8	600	2668
500	152	0.081	121	0.500	12.7	746	3320	508	2261	0.8	743	3304
600	183	0.081	121	0.500	12.7	936	4162	610	2714	0.8	899	3998
700	213	0.085	127	0.512	13.0	1126	5008	747	3322	0.8	1085	4826
800	244	0.085	127	0.512	13.0	1253	5572	854	3797	0.8	1234	5489
900	274	0.085	127	0.512	13.0	1569	6981	961	4274	0.8	1416	6301
1000	305	0.085	127	0.512	13.0	1696	7545	1068	4750	0.8	1566	6965
1100	335	0.086	127	0.512	13.0	1823	8108	1177	5236	0.8	1717	7635
1200	366	0.091	135	0.528	13.4	1950	8672	1366	6075	0.8	1937	8614
1300	396	0.091	136	0.528	13.4	2203	9799	1480	6584	0.8	2114	9405
1400	427	0.091	136	0.528	13.4	2456	10927	1595	7094	0.8	2292	10194
1500	457	0.091	136	0.528	13.4	2583	11490	1709	7602	0.8	2447	10886
36 FIBERS												
100	30	0.082	123	0.500	12.7	539	2398	103	458	0.6	195	867
200	61	0.082	123	0.500	12.7	598	2661	206	916	0.7	343	1526
300	91	0.082	123	0.500	12.7	598	2661	309	1375	0.8	464	2064
400	122	0.082	123	0.500	12.7	598	2661	412	1833	0.8	598	2660
500	152	0.082	123	0.500	12.7	776	3452	515	2291	0.8	752	3345
600	183	0.082	123	0.500	12.7	999	4444	618	2749	0.8	915	4070
700	213	0.086	129	0.512	13.0	1189	5290	756	3363	0.8	1102	4902
800	244	0.086	129	0.512	13.0	1253	5572	864	3843	0.8	1241	5520
900	274	0.086	129	0.512	13.0	1569	6981	973	4328	0.8	1424	6334
1000	305	0.086	129	0.512	13.0	1569	6981	1081	4809	0.8	1552	6904
1100	335	0.087	129	0.512	13.0	1823	8108	1192	5302	0.8	1726	7678
1200	366	0.092	137	0.528	13.4	2076	9236	1382	6147	0.8	1969	8759
1300	396	0.092	137	0.528	13.4	2203	9799	1497	6659	0.8	2125	9452
1400	427	0.092	137	0.528	13.4	2330	10363	1613	7175	0.8	2281	10146
1500	457	0.092	137	0.528	13.4	2456	10927	1728	7687	0.8	2438	10845

* Initial tension indicates tension before 10 year creep.

AFL

Fiber Optic Cable

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC LIGHT LOADING @ 1% INSTALLATION SAG

LIGHT

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
48 FIBERS												
100	30	0.083	124	0.500	12.7	539	2398	104	463	0.6	196	872
200	61	0.083	124	0.500	12.7	598	2661	209	930	0.7	344	1530
300	91	0.083	124	0.500	12.7	598	2661	313	1392	0.7	476	2117
400	122	0.083	124	0.500	12.7	628	2793	417	1855	0.8	606	2696
500	152	0.083	124	0.500	12.7	776	3452	522	2322	0.8	756	3363
600	183	0.083	124	0.500	12.7	999	4444	626	2785	0.8	920	4092
700	213	0.087	130	0.512	13.0	1189	5290	765	3403	0.8	1108	4929
800	244	0.087	130	0.512	13.0	1253	5572	875	3892	0.8	1247	5547
900	274	0.088	130	0.512	13.0	1569	6981	985	4381	0.8	1431	6365
1000	305	0.088	130	0.512	13.0	1569	6981	1094	4866	0.8	1560	6939
1100	335	0.088	131	0.512	13.0	1823	8108	1206	5365	0.8	1735	7718
1200	366	0.093	139	0.528	13.4	2076	9236	1398	6219	0.8	1979	8803
1300	396	0.093	139	0.528	13.4	2330	10363	1515	6739	0.8	2158	9599
1400	427	0.093	139	0.528	13.4	2456	10927	1632	7259	0.8	2315	10298
1500	457	0.093	139	0.528	13.4	2456	10927	1748	7775	0.8	2450	10898
60 FIBERS												
100	30	0.084	126	0.500	12.7	539	2398	106	472	0.6	197	876
200	61	0.084	126	0.500	12.7	539	2398	211	939	0.7	339	1508
300	91	0.084	126	0.500	12.7	539	2398	317	1410	0.8	469	2086
400	122	0.084	126	0.500	12.7	628	2793	422	1877	0.8	610	2713
500	152	0.085	126	0.500	12.7	809	3599	528	2349	0.8	766	3407
600	183	0.085	126	0.500	12.7	936	4162	634	2820	0.8	914	4066
700	213	0.089	132	0.512	13.0	1126	5008	775	3447	0.8	1102	4902
800	244	0.089	132	0.512	13.0	1316	5854	885	3937	0.8	1265	5627
900	274	0.089	132	0.512	13.0	1569	6981	997	4435	0.8	1439	6401
1000	305	0.089	132	0.512	13.0	1569	6981	1107	4924	0.8	1568	6975
1100	335	0.089	132	0.512	13.0	1823	8108	1221	5431	0.8	1744	7758
1200	366	0.094	140	0.528	13.4	2076	9236	1414	6290	0.8	1989	8848
1300	396	0.094	140	0.528	13.4	2330	10363	1532	6815	0.8	2169	9648
1400	427	0.094	140	0.528	13.4	2330	10363	1650	7340	0.8	2305	10253
1500	457	0.094	140	0.528	13.4	2710	12054	1769	7869	0.8	2507	11152
72 FIBERS												
100	30	0.100	148	0.535	13.6	854	3797	125	556	0.6	235	1045
200	61	0.100	148	0.535	13.6	854	3797	249	1108	0.7	405	1802
300	91	0.100	148	0.535	13.6	854	3797	374	1664	0.7	561	2495
400	122	0.100	148	0.535	13.6	854	3797	499	2220	0.8	709	3154
500	152	0.100	148	0.535	13.6	854	3797	623	2771	0.8	853	3794
600	183	0.100	149	0.535	13.6	1031	4587	748	3327	0.8	1025	4559
700	213	0.108	161	0.559	14.2	1314	5843	949	4221	0.8	1280	5694
800	244	0.108	161	0.559	14.2	1504	6689	1084	4822	0.8	1464	6512
900	274	0.108	161	0.559	14.2	1884	8380	1221	5431	0.8	1677	7460
1000	305	0.108	161	0.559	14.2	1884	8380	1356	6032	0.8	1831	8145
1100	335	0.109	161	0.559	14.2	2011	8943	1492	6637	0.8	2004	8914
1200	366	0.109	162	0.559	14.2	2264	10071	1628	7242	0.8	2198	9777
1300	396	0.109	162	0.559	14.2	2391	10634	1767	7860	0.8	2374	10560
1400	427	0.109	162	0.559	14.2	2644	11762	1903	8465	0.8	2568	11423
1500	457	0.109	162	0.559	14.2	2771	12326	2040	9074	0.8	2741	12193

* Initial tension indicates tension before 10 year creep.

AFL

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC LIGHT LOADING @ 1% INSTALLATION SAG (LIGHT)

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
84 FIBERS												
100	30	0.131	195	0.610	15.5	1296	5763	164	730	0.6	295	1312
200	61	0.131	195	0.610	15.5	1296	5763	328	1459	0.7	512	2277
300	91	0.131	195	0.610	15.5	1296	5763	492	2189	0.8	712	3167
400	122	0.131	195	0.610	15.5	1296	5763	656	2918	0.8	903	4017
500	152	0.131	195	0.610	15.5	1296	5763	820	3648	0.8	1089	4844
600	183	0.131	195	0.610	15.5	1296	5763	984	4377	0.9	1270	5649
700	213	0.131	195	0.610	15.5	1503	6685	1148	5107	0.9	1481	6588
800	244	0.131	195	0.610	15.5	1692	7528	1313	5841	0.9	1689	7513
900	274	0.131	195	0.610	15.5	1946	8655	1477	6570	0.9	1907	8483
1000	305	0.138	205	0.626	15.9	2326	10346	1725	7673	0.9	2216	9857
1100	335	0.138	205	0.626	15.9	2453	10910	1898	8443	0.9	2422	10774
1200	366	0.138	205	0.626	15.9	2706	12037	2071	9212	0.9	2647	11774
1300	396	0.138	206	0.626	15.9	2960	13165	2244	9982	0.9	2872	12775
1400	427	0.138	206	0.626	15.9	3086	13728	2417	10751	0.9	3079	13696
1500	457	0.138	206	0.626	15.9	3340	14856	2590	11521	0.9	3304	14697
96 FIBERS												
100	30	0.132	197	0.610	15.5	1296	5763	165	734	0.6	296	1317
200	61	0.132	197	0.610	15.5	1296	5763	331	1472	0.7	514	2286
300	91	0.132	197	0.610	15.5	1296	5763	496	2206	0.8	715	3180
400	122	0.132	197	0.610	15.5	1296	5763	661	2940	0.8	907	4035
500	152	0.132	197	0.610	15.5	1296	5763	827	3679	0.8	1093	4862
600	183	0.132	197	0.610	15.5	1296	5763	992	4413	0.9	1276	5676
700	213	0.132	197	0.610	15.5	1503	6685	1158	5151	0.9	1488	6619
800	244	0.132	197	0.610	15.5	1756	7810	1324	5889	0.9	1706	7589
900	274	0.132	197	0.610	15.5	1946	8655	1489	6623	0.9	1915	8518
1000	305	0.139	207	0.626	15.9	2326	10346	1738	7731	0.9	2225	9897
1100	335	0.139	207	0.626	15.9	2453	10910	1912	8505	0.9	2433	10823
1200	366	0.139	207	0.626	15.9	2706	12037	2087	9283	0.9	2659	11828
1300	396	0.139	207	0.626	15.9	2960	13165	2261	10057	0.9	2885	12833
1400	427	0.139	207	0.626	15.9	3213	14292	2436	10836	0.9	3111	13838
1500	457	0.139	207	0.626	15.9	3340	14856	2610	11610	0.9	3319	14764
108 FIBERS												
100	30	0.170	254	0.685	17.4	2070	9207	213	947	0.6	371	1650
200	61	0.170	254	0.685	17.4	2070	9207	426	1895	0.7	648	2882
300	91	0.170	254	0.685	17.4	2070	9207	639	2842	0.8	904	4021
400	122	0.170	254	0.685	17.4	2070	9207	852	3790	0.8	1149	5111
500	152	0.170	254	0.685	17.4	2070	9207	1065	4737	0.8	1387	6170
600	183	0.170	254	0.685	17.4	2070	9207	1278	5685	0.9	1621	7211
700	213	0.170	254	0.685	17.4	2070	9207	1491	6632	0.9	1851	8234
800	244	0.170	254	0.685	17.4	2129	9470	1704	7580	0.9	2087	9283
900	274	0.178	264	0.701	17.8	2467	10972	1999	8892	0.9	2430	10809
1000	305	0.178	265	0.701	17.8	2720	12099	2222	9884	0.9	2698	12001
1100	335	0.178	265	0.701	17.8	3100	13790	2447	10885	0.9	2984	13273
1200	366	0.178	265	0.701	17.8	3354	14918	2670	11877	0.9	3252	14466
1300	396	0.178	265	0.701	17.8	3607	16045	2893	12869	0.9	3520	15658
1400	427	0.178	265	0.701	17.8	3860	17172	3117	13865	0.9	3789	16854
1500	457	0.178	265	0.701	17.8	4114	18300	3340	14857	0.9	4057	18046

* Initial tension indicates tension before 10 year creep.

AFL

Fiber Optic Cable

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC LIGHT LOADING @ 1% INSTALLATION SAG

LIGHT

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
120 FIBERS												
100	30	0.171	255	0.685	17.4	2070	9207	214	952	0.6	371	1650
200	61	0.171	255	0.685	17.4	2070	9207	429	1908	0.7	650	2891
300	91	0.171	255	0.685	17.4	2070	9207	643	2860	0.8	906	4030
400	122	0.171	255	0.685	17.4	2070	9207	857	3812	0.8	1152	5124
500	152	0.171	255	0.685	17.4	2070	9207	1072	4768	0.8	1392	6192
600	183	0.171	255	0.685	17.4	2070	9207	1286	5720	0.9	1627	7237
700	213	0.171	255	0.685	17.4	2070	9207	1501	6677	0.9	1858	8265
800	244	0.172	255	0.685	17.4	2129	9470	1715	7629	0.9	2095	9319
900	274	0.179	266	0.701	17.8	2467	10972	2011	8945	0.9	2440	10854
1000	305	0.179	266	0.701	17.8	2720	12099	2235	9942	0.9	2709	12050
1100	335	0.179	266	0.701	17.8	3100	13790	2462	10952	0.9	2995	13322
1200	366	0.179	267	0.701	17.8	3354	14918	2686	11948	0.9	3264	14519
1300	396	0.179	267	0.701	17.8	3607	16045	2911	12949	0.9	3533	15716
1400	427	0.179	267	0.701	17.8	3860	17172	3136	13950	0.9	3803	16917
1500	457	0.179	267	0.701	17.8	4114	18300	3360	14946	0.9	4072	18113
132 FIBERS												
100	30	0.208	310	0.764	19.4	2070	9207	260	1157	0.7	415	1846
200	61	0.208	310	0.764	19.4	2070	9207	520	2313	0.8	734	3265
300	91	0.208	310	0.764	19.4	2070	9207	780	3470	0.8	1031	4586
400	122	0.208	310	0.764	19.4	2070	9207	1040	4626	0.9	1318	5863
500	152	0.208	310	0.764	19.4	2070	9207	1300	5783	0.9	1599	7113
600	183	0.208	310	0.764	19.4	2070	9207	1560	6939	0.9	1875	8340
700	213	0.208	310	0.764	19.4	2188	9734	1821	8100	0.9	2163	9622
800	244	0.208	310	0.764	19.4	2530	11253	2081	9257	0.9	2476	11014
900	274	0.208	310	0.764	19.4	2783	12381	2342	10418	0.9	2778	12357
1000	305	0.216	322	0.780	19.8	3227	14354	2704	12028	0.9	3194	14208
1100	335	0.216	322	0.780	19.8	3607	16045	2975	13233	0.9	3521	15662
1200	366	0.217	322	0.780	19.8	3860	17172	3248	14448	0.9	3835	17059
1300	396	0.217	322	0.780	19.8	4241	18863	3520	15658	0.9	4162	18513
1400	427	0.217	322	0.780	19.8	4494	19991	3792	16868	0.9	4475	19906
1500	457	0.217	323	0.780	19.8	4874	21682	4064	18078	0.9	4802	21360
144 FIBERS												
100	30	0.209	311	0.764	19.4	2070	9207	261	1161	0.7	416	1850
200	61	0.209	311	0.764	19.4	2070	9207	523	2326	0.8	736	3274
300	91	0.209	311	0.764	19.4	2070	9207	784	3487	0.8	1034	4599
400	122	0.209	311	0.764	19.4	2070	9207	1046	4653	0.9	1322	5881
500	152	0.209	311	0.764	19.4	2070	9207	1307	5814	0.9	1604	7135
600	183	0.209	311	0.764	19.4	2070	9207	1568	6975	0.9	1882	8372
700	213	0.209	311	0.764	19.4	2188	9734	1830	8140	0.9	2170	9653
800	244	0.209	311	0.764	19.4	2530	11253	2092	9306	0.9	2484	11049
900	274	0.209	311	0.764	19.4	2847	12663	2354	10471	0.9	2795	12433
1000	305	0.217	324	0.780	19.8	3227	14354	2717	12086	0.9	3205	14257
1100	335	0.217	324	0.780	19.8	3607	16045	2990	13300	0.9	3533	15716
1200	366	0.218	324	0.780	19.8	3860	17172	3265	14523	0.9	3848	17117
1300	396	0.218	324	0.780	19.8	4241	18863	3538	15738	0.9	4176	18576
1400	427	0.218	324	0.780	19.8	4494	19991	3811	16952	0.9	4489	19968
1500	457	0.218	324	0.780	19.8	4874	21682	4084	18167	0.9	4818	21432

* Initial tension indicates tension before 10 year creep.

ВЯРНО С ОРИГИНАЛА

956

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC LIGHT LOADING @ 1% INSTALLATION SAG

LIGHT

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
216 FIBERS												
100	30	0.202	301	0.780	19.8	854	3797	253	1125	0.8	353	1570
200	61	0.202	301	0.780	19.8	854	3797	505	2246	0.9	635	2825
300	91	0.202	301	0.780	19.8	913	4060	758	3372	0.9	911	4052
400	122	0.202	301	0.780	19.8	1250	5561	1011	4497	0.9	1219	5422
500	152	0.202	301	0.780	19.8	1630	7252	1264	5623	0.9	1533	6819
600	183	0.202	301	0.780	19.8	1884	8380	1517	6748	0.9	1831	8145
700	213	0.211	313	0.795	20.2	2264	10071	1843	8198	0.9	2208	9822
800	244	0.211	313	0.795	20.2	2517	11198	2106	9368	0.9	2516	11192
900	274	0.211	314	0.795	20.2	2898	12889	2371	10547	0.9	2839	12629
1000	305	0.211	314	0.795	20.2	3151	14017	2634	11717	0.9	3147	13999
1100	335	0.211	314	0.795	20.2	3531	15708	2899	12895	0.9	3470	15435
1200	366	0.211	314	0.795	20.2	3785	16835	3163	14070	0.9	3778	16805
1300	396	0.219	326	0.811	20.6	4292	19090	3564	15853	0.9	4238	18852
1400	427	0.220	327	0.811	20.6	4689	20857	3845	17103	0.9	4577	20360
1500	457	0.220	327	0.811	20.6	5069	22548	4121	18331	0.9	4909	21836
288 FIBERS												
100	30	0.259	385	0.890	22.6	1296	5763	323	1439	0.8	444	1975
200	61	0.259	385	0.890	22.6	1296	5763	647	2878	0.9	802	3569
300	91	0.259	385	0.890	22.6	1296	5763	970	4317	0.9	1146	5096
400	122	0.259	385	0.890	22.6	1566	6964	1294	5757	0.9	1511	6723
500	152	0.259	385	0.890	22.6	2072	9219	1618	7198	0.9	1901	8457
600	183	0.259	385	0.890	22.6	2326	10346	1942	8639	0.9	2265	10077
700	213	0.259	385	0.890	22.6	2706	12037	2267	10082	0.9	2643	11755
800	244	0.259	386	0.890	22.6	3086	13728	2591	11525	0.9	3020	13434
900	274	0.269	400	0.906	23.0	3593	15983	3023	13447	0.9	3507	15602
1000	305	0.269	400	0.906	23.0	3973	17674	3360	14945	0.9	3896	17330
1100	335	0.269	400	0.906	23.0	4354	19365	3697	16444	0.9	4284	19058
1200	366	0.269	400	0.906	23.0	4734	21056	4034	17943	0.9	4673	20787
1300	396	0.268	399	0.921	23.4	5069	22548	4354	19368	0.9	5062	22516
1400	427	0.268	399	0.921	23.4	5576	24803	4691	20865	0.9	5464	24307
1500	457	0.268	399	0.921	23.4	5956	26494	5027	22361	0.9	5854	26039
432 FIBERS												
100	30	0.298	444	0.953	24.2	1296	5763	373	1658	0.8	487	2168
200	61	0.298	444	0.953	24.2	1296	5763	745	3316	0.9	890	3959
300	91	0.298	444	0.953	24.2	1296	5763	1118	4974	0.9	1279	5689
400	122	0.298	444	0.953	24.2	1756	7810	1491	6634	0.9	1708	7598
500	152	0.298	444	0.953	24.2	2326	10346	1865	8295	0.9	2148	9554
600	183	0.298	444	0.953	24.2	2579	11474	2238	9956	0.9	2558	11379
700	213	0.299	444	0.953	24.2	3086	13728	2612	11619	0.9	2992	13310
800	244	0.299	444	0.953	24.2	3466	15419	2986	13281	0.9	3415	15189
900	274	0.309	459	0.969	24.6	3973	17674	3473	15448	0.9	3952	17580
1000	305	0.309	460	0.969	24.6	4480	19929	3860	17170	0.9	4398	19564
1100	335	0.309	460	0.969	24.6	4860	21620	4247	18891	0.9	4832	21496
1200	366	0.320	476	0.984	25.0	5449	24239	4796	21333	0.9	5433	24168
1300	396	0.320	476	0.984	25.0	5956	26494	5197	23118	0.9	5892	26208
1400	427	0.319	474	0.984	25.0	6336	28185	5576	24804	0.9	6321	28118
1500	457	0.319	474	0.984	25.0	6970	31003	5977	26585	0.9	6791	30207

* Initial tension indicates tension before 10 year creep.

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AFL

Fiber Optic Cable

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC MEDIUM LOADING @ 1% INSTALLATION SAG

MEDIUM

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
12 FIBERS												
100	30	0.080	119	0.500	12.7	539	2398	100	446	2.3	242	1074
200	61	0.080	119	0.500	12.7	539	2398	201	892	2.8	406	1807
300	91	0.080	119	0.500	12.7	598	2661	301	1339	0.9	518	2304
400	122	0.080	119	0.500	12.7	746	3320	401	1785	3.0	744	3311
500	152	0.080	120	0.500	12.7	999	4444	502	2232	3.0	946	4206
600	183	0.084	125	0.512	13.0	1189	5290	632	2812	0.9	1055	4694
700	213	0.084	126	0.512	13.0	1569	6981	738	3283	2.9	1387	6168
800	244	0.084	126	0.512	13.0	1569	6981	844	3752	3.0	1536	6834
900	274	0.085	126	0.512	13.0	1823	8108	951	4231	3.0	1742	7751
1000	305	0.090	134	0.528	13.4	2076	9236	1125	5005	1.0	1825	8118
1100	335	0.090	134	0.528	13.4	2203	9799	1238	5506	3.0	2180	9698
1200	366	0.090	134	0.528	13.4	2456	10927	1351	6010	2.9	2391	10634
1300	396	0.090	134	0.528	13.4	2583	11490	1464	6512	3.0	2573	11444
1400	427	0.090	134	0.528	13.4	2837	12618	1577	7016	3.0	2783	12380
1500	457	0.090	134	0.528	13.4	3090	13745	1691	7520	2.9	2994	13316
24 FIBERS												
100	30	0.081	121	0.500	12.7	539	2398	102	452	2.3	242	1078
200	61	0.081	121	0.500	12.7	539	2398	203	904	2.8	408	1813
300	91	0.081	121	0.500	12.7	598	2661	305	1356	0.9	520	2314
400	122	0.081	121	0.500	12.7	776	3452	407	1809	3.0	754	3355
500	152	0.081	121	0.500	12.7	999	4444	508	2262	3.0	950	4224
600	183	0.085	127	0.512	13.0	1189	5290	640	2847	0.9	1060	4714
700	213	0.085	127	0.512	13.0	1569	6981	747	3324	2.9	1392	6192
800	244	0.085	127	0.512	13.0	1696	7545	854	3800	2.9	1571	6986
900	274	0.086	127	0.512	13.0	1823	8108	963	4284	3.0	1750	7782
1000	305	0.091	136	0.528	13.4	2076	9236	1138	5064	1.0	1833	8152
1100	335	0.091	136	0.528	13.4	2203	9799	1252	5571	3.0	2189	9737
1200	366	0.091	136	0.528	13.4	2456	10927	1367	6080	2.9	2400	10676
1300	396	0.091	136	0.528	13.4	2583	11490	1481	6588	3.0	2583	11490
1400	427	0.091	136	0.528	13.4	2837	12618	1596	7098	2.9	2794	12430
1500	457	0.091	136	0.528	13.4	3090	13745	1710	7608	2.9	3006	13369
36 FIBERS												
100	30	0.082	123	0.500	12.7	539	2398	103	458	2.3	243	1081
200	61	0.082	123	0.500	12.7	598	2661	206	916	2.7	420	1868
300	91	0.082	123	0.500	12.7	598	2661	309	1375	3.0	572	2544
400	122	0.082	123	0.500	12.7	776	3452	412	1833	3.0	757	3367
500	152	0.082	123	0.500	12.7	999	4444	515	2291	3.0	953	4239
600	183	0.086	129	0.512	13.0	1189	5290	648	2882	3.0	1164	5178
700	213	0.086	129	0.512	13.0	1506	6699	756	3363	2.9	1384	6156
800	244	0.087	129	0.512	13.0	1823	8108	867	3857	2.9	1604	7135
900	274	0.087	129	0.512	13.0	1823	8108	975	4337	2.9	1757	7816
1000	305	0.092	137	0.528	13.4	2076	9236	1152	5124	2.9	2014	8959
1100	335	0.092	137	0.528	13.4	2456	10927	1268	5640	2.9	2252	10017
1200	366	0.092	137	0.528	13.4	2456	10927	1383	6152	2.9	2410	10720
1300	396	0.092	137	0.528	13.4	2710	12054	1499	6668	2.9	2621	11659
1400	427	0.092	137	0.528	13.4	2837	12618	1614	7179	2.9	2806	12482
1500	457	0.092	137	0.528	13.4	3090	13745	1730	7695	2.9	3017	13420

* Initial tension indicates tension before 10 year creep.

ВЯРНО С ОРИГИНАЛА

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AFL

Fiber Optic Cable

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC MEDIUM LOADING @ 1% INSTALLATION SAG

MEDIUM

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
48 FIBERS												
100	30	0.083	124	0.500	12.7	539	2398	104	463	2.3	244	1085
200	61	0.083	124	0.500	12.7	598	2661	209	930	2.7	421	1873
300	91	0.083	124	0.500	12.7	598	2661	313	1392	3.0	574	2553
400	122	0.083	124	0.500	12.7	776	3452	417	1855	3.0	761	3385
500	152	0.083	124	0.500	12.7	999	4444	522	2322	3.0	957	4257
600	183	0.087	130	0.512	13.0	1189	5290	656	2918	3.0	1169	5200
700	213	0.088	130	0.512	13.0	1506	6699	766	3407	2.9	1390	6183
800	244	0.088	131	0.512	13.0	1823	8108	877	3901	2.9	1610	7162
900	274	0.088	131	0.512	13.0	1823	8108	987	4390	2.9	1764	7847
1000	305	0.093	139	0.528	13.4	2076	9236	1165	5182	1.0	1848	8220
1100	335	0.093	139	0.528	13.4	2456	10927	1282	5703	2.9	2261	10057
1200	366	0.093	139	0.528	13.4	2456	10927	1399	6223	2.9	2419	10760
1300	396	0.093	139	0.528	13.4	2710	12054	1516	6744	2.9	2632	11708
1400	427	0.093	139	0.528	13.4	2963	13182	1633	7264	2.9	2844	12651
1500	457	0.093	139	0.528	13.4	3090	13745	1750	7784	2.9	3029	13474
60 FIBERS												
100	30	0.084	126	0.500	12.7	539	2398	106	472	2.3	244	1085
200	61	0.084	126	0.500	12.7	539	2398	211	939	2.8	412	1833
300	91	0.084	126	0.500	12.7	598	2661	317	1410	3.0	576	2562
400	122	0.085	126	0.500	12.7	776	3452	423	1882	3.0	764	3398
500	152	0.085	126	0.500	12.7	999	4444	528	2349	3.0	961	4275
600	183	0.089	132	0.512	13.0	1189	5290	664	2954	3.0	1174	5222
700	213	0.089	132	0.512	13.0	1379	6135	775	3447	3.0	1368	6085
800	244	0.089	132	0.512	13.0	1569	6981	886	3941	3.0	1562	6948
900	274	0.089	132	0.512	13.0	1823	8108	999	4444	2.9	1771	7878
1000	305	0.094	140	0.528	13.4	2076	9236	1178	5240	2.9	2030	9030
1100	335	0.094	140	0.528	13.4	2330	10363	1296	5765	2.9	2243	9977
1200	366	0.094	140	0.528	13.4	2456	10927	1414	6290	2.9	2429	10805
1300	396	0.094	140	0.528	13.4	2710	12054	1533	6819	2.9	2642	11752
1400	427	0.094	140	0.528	13.4	2963	13182	1652	7348	2.9	2856	12704
1500	457	0.094	140	0.528	13.4	3090	13745	1770	7873	2.9	3042	13531
72 FIBERS												
100	30	0.100	148	0.535	13.6	854	3797	125	556	2.1	290	1290
200	61	0.100	148	0.535	13.6	854	3797	249	1108	2.5	489	2175
300	91	0.100	148	0.535	13.6	854	3797	374	1664	2.7	668	2971
400	122	0.100	148	0.535	13.6	854	3797	499	2220	2.9	836	3719
500	152	0.100	149	0.535	13.6	1061	4719	624	2776	2.9	1044	4644
600	183	0.108	161	0.559	14.2	1314	5843	813	3616	2.9	1310	5827
700	213	0.108	161	0.559	14.2	1567	6970	949	4221	2.9	1536	6832
800	244	0.108	161	0.559	14.2	1884	8380	1085	4826	2.8	1775	7896
900	274	0.109	161	0.559	14.2	2011	8943	1221	5431	2.9	1975	8785
1000	305	0.109	162	0.559	14.2	2264	10071	1357	6036	2.8	2201	9791
1100	335	0.109	162	0.559	14.2	2517	11198	1495	6650	2.8	2428	10800
1200	366	0.109	162	0.559	14.2	2644	11762	1631	7255	2.9	2628	11690
1300	396	0.109	162	0.559	14.2	2898	12889	1768	7864	2.9	2854	12695
1400	427	0.109	162	0.559	14.2	3151	14017	1905	8474	2.8	3080	13701
1500	457	0.115	171	0.575	14.6	3405	15144	2153	9577	2.8	3392	15088

* Initial tension indicates tension before 10 year creep.

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AFL

Fiber Optic Cable

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC MEDIUM LOADING @ 1% INSTALLATION SAG

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
84 FIBERS												
100	30	0.131	195	0.610	15.5	1296	5763	164	730	1.9	354	1575
200	61	0.131	195	0.610	15.5	1296	5763	328	1459	2.3	602	2678
300	91	0.131	195	0.610	15.5	1296	5763	492	2189	2.5	826	3674
400	122	0.131	195	0.610	15.5	1296	5763	656	2918	2.6	1037	4613
500	152	0.131	195	0.610	15.5	1296	5763	820	3648	2.7	1240	5516
600	183	0.131	195	0.610	15.5	1473	6554	984	4377	2.8	1473	6552
700	213	0.131	195	0.610	15.5	1756	7810	1149	5111	2.8	1726	7678
800	244	0.131	195	0.610	15.5	2009	8937	1313	5841	2.8	1973	8776
900	274	0.138	205	0.626	15.9	2326	10346	1552	6904	2.7	2291	10191
1000	305	0.138	205	0.626	15.9	2579	11474	1725	7673	2.7	2545	11321
1100	335	0.138	205	0.626	15.9	2833	12601	1898	8443	2.7	2799	12451
1200	366	0.138	206	0.626	15.9	3086	13728	2072	9217	2.7	3053	13580
1300	396	0.138	206	0.626	15.9	3340	14856	2245	9986	2.7	3307	14710
1400	427	0.138	206	0.626	15.9	3593	15983	2418	10756	2.7	3562	15845
1500	457	0.145	216	0.642	16.3	3973	17674	2716	12081	2.7	3938	17517
96 FIBERS												
100	30	0.132	197	0.610	15.5	1296	5763	165	734	1.9	354	1575
200	61	0.132	197	0.610	15.5	1296	5763	331	1472	2.3	604	2687
300	91	0.132	197	0.610	15.5	1296	5763	496	2206	2.5	829	3688
400	122	0.132	197	0.610	15.5	1296	5763	661	2940	2.6	1041	4631
500	152	0.132	197	0.610	15.5	1296	5763	827	3679	2.7	1245	5538
600	183	0.132	197	0.610	15.5	1503	6685	992	4413	2.8	1484	6601
700	213	0.132	197	0.610	15.5	1756	7810	1158	5151	2.8	1732	7704
800	244	0.132	197	0.610	15.5	2009	8937	1324	5889	2.8	1980	8807
900	274	0.139	207	0.626	15.9	2326	10346	1564	6957	2.7	2299	10226
1000	305	0.139	207	0.626	15.9	2706	12037	1739	7735	2.7	2577	11463
1100	335	0.139	207	0.626	15.9	2833	12601	1913	8509	2.7	2809	12495
1200	366	0.139	207	0.626	15.9	3086	13728	2088	9288	2.7	3064	13629
1300	396	0.139	207	0.626	15.9	3340	14856	2262	10062	2.7	3319	14764
1400	427	0.139	207	0.626	15.9	3593	15983	2437	10840	2.7	3574	15898
1500	457	0.146	217	0.642	16.3	3973	17674	2737	12175	2.7	3952	17579
108 FIBERS												
100	30	0.170	254	0.685	17.4	2070	9207	213	947	1.8	436	1939
200	61	0.170	254	0.685	17.4	2070	9207	426	1895	2.0	748	3327
300	91	0.170	254	0.685	17.4	2070	9207	639	2842	2.2	1030	4582
400	122	0.170	254	0.685	17.4	2070	9207	852	3790	2.4	1297	5769
500	152	0.170	254	0.685	17.4	2070	9207	1065	4737	2.5	1554	6913
600	183	0.170	254	0.685	17.4	2070	9207	1278	5685	2.5	1805	8029
700	213	0.170	254	0.685	17.4	2070	9207	1491	6632	2.6	2050	9119
800	244	0.170	254	0.685	17.4	2340	10408	1704	7580	2.6	2339	10404
900	274	0.178	265	0.701	17.8	2720	12099	2000	8896	2.6	2713	12068
1000	305	0.178	265	0.701	17.8	3100	13790	2225	9897	2.6	3029	13474
1100	335	0.178	265	0.701	17.8	3354	14918	2448	10889	2.6	3323	14781
1200	366	0.178	265	0.701	17.8	3734	16609	2671	11881	2.6	3638	16183
1300	396	0.178	265	0.701	17.8	3987	17736	2894	12873	2.6	3933	17495
1400	427	0.186	276	0.717	18.2	4367	19427	3248	14448	2.6	4355	19372
1500	457	0.186	276	0.717	18.2	4748	21118	3481	15484	2.6	4678	20809

* Initial tension indicates tension before 10 year creep.

AFL

Fiber Optic Cable

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC MEDIUM LOADING @ 1% INSTALLATION SAG

MEDIUM

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
120 FIBERS												
100	30	0.171	255	0.685	17.4	2070	9207	214	952	1.8	437	1944
200	61	0.171	255	0.685	17.4	2070	9207	429	1908	2.0	749	3332
300	91	0.171	255	0.685	17.4	2070	9207	643	2860	2.2	1033	4595
400	122	0.171	255	0.685	17.4	2070	9207	857	3812	2.4	1301	5787
500	152	0.171	255	0.685	17.4	2070	9207	1072	4768	2.5	1559	6935
600	183	0.171	255	0.685	17.4	2070	9207	1286	5720	2.5	1810	8051
700	213	0.171	255	0.685	17.4	2070	9207	1501	6677	2.6	2057	9150
800	244	0.179	266	0.701	17.8	2467	10972	1788	7953	2.6	2427	10796
900	274	0.179	266	0.701	17.8	2783	12381	2012	8950	2.6	2732	12153
1000	305	0.179	266	0.701	17.8	3100	13790	2238	9955	2.6	3039	13518
1100	335	0.179	267	0.701	17.8	3354	14918	2463	10956	2.6	3334	14830
1200	366	0.179	267	0.701	17.8	3734	16609	2687	11952	2.6	3650	16236
1300	396	0.179	267	0.701	17.8	4114	18300	2912	12953	2.6	3966	17642
1400	427	0.187	278	0.717	18.2	4621	20554	3267	14532	2.5	4409	19612
1500	457	0.187	278	0.717	18.2	4748	21118	3501	15573	2.6	4693	20876
132 FIBERS												
100	30	0.208	310	0.764	19.4	2070	9207	260	1157	1.8	476	2117
200	61	0.208	310	0.764	19.4	2070	9207	520	2313	2.1	826	3674
300	91	0.208	310	0.764	19.4	2070	9207	780	3470	2.2	1146	5098
400	122	0.208	310	0.764	19.4	2070	9207	1040	4626	2.3	1451	6454
500	152	0.208	310	0.764	19.4	2070	9207	1300	5783	2.4	1748	7775
600	183	0.208	310	0.764	19.4	2070	9207	1560	6939	2.5	2038	9065
700	213	0.208	310	0.764	19.4	2467	10972	1821	8100	2.5	2386	10613
800	244	0.208	310	0.764	19.4	2720	12099	2081	9257	2.5	2712	12064
900	274	0.216	322	0.780	19.8	3227	14354	2433	10823	2.5	3153	14025
1000	305	0.216	322	0.780	19.8	3607	16045	2704	12028	2.5	3507	15600
1100	335	0.217	322	0.780	19.8	3860	17172	2978	13247	2.5	3844	17099
1200	366	0.217	322	0.780	19.8	4241	18863	3249	14452	2.5	4198	18674
1300	396	0.217	322	0.780	19.8	4621	20554	3521	15662	2.5	4553	20253
1400	427	0.217	323	0.780	19.8	5001	22246	3793	16872	2.5	4908	21832
1500	457	0.225	335	0.795	20.2	5508	24500	4220	18771	2.4	5411	24069
144 FIBERS												
100	30	0.209	311	0.764	19.4	2070	9207	261	1161	1.8	477	2122
200	61	0.209	311	0.764	19.4	2070	9207	523	2326	2.1	827	3679
300	91	0.209	311	0.764	19.4	2070	9207	784	3487	2.2	1149	5111
400	122	0.209	311	0.764	19.4	2070	9207	1046	4653	2.3	1455	6472
500	152	0.209	311	0.764	19.4	2070	9207	1307	5814	2.4	1753	7798
600	183	0.209	311	0.764	19.4	2070	9207	1568	6975	2.5	2044	9092
700	213	0.209	311	0.764	19.4	2467	10972	1830	8140	2.5	2393	10645
800	244	0.209	311	0.764	19.4	2783	12381	2093	9310	2.5	2730	12144
900	274	0.217	324	0.780	19.8	3227	14354	2446	10880	2.5	3162	14065
1000	305	0.217	324	0.780	19.8	3607	16045	2718	12090	2.5	3517	15644
1100	335	0.218	324	0.780	19.8	3860	17172	2993	13314	2.5	3855	17148
1200	366	0.218	324	0.780	19.8	4241	18863	3266	14528	2.5	4211	18731
1300	396	0.218	324	0.780	19.8	4621	20554	3539	15742	2.5	4566	20311
1400	427	0.218	324	0.780	19.8	5001	22246	3812	16957	2.5	4922	21894
1500	457	0.226	337	0.795	20.2	5508	24500	4241	18865	2.4	5427	24140

* Initial tension indicates tension before 10 year creep.

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AFL

Fiber Optic Cable

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC MEDIUM LOADING @ 1% INSTALLATION SAG

MEDIUM

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
216 FIBERS												
100	30	0.202	301	0.780	19.8	854	3797	253	1125	2.1	394	1753
200	61	0.202	301	0.780	19.8	854	3797	505	2246	2.4	694	3087
300	91	0.202	301	0.780	19.8	1002	4455	758	3372	2.5	1000	4448
400	122	0.202	301	0.780	19.8	1377	6125	1011	4497	2.5	1341	5965
500	152	0.202	301	0.780	19.8	1884	8380	1264	5623	2.5	1701	7566
600	183	0.202	301	0.780	19.8	2011	8943	1518	6752	2.5	2003	8910
700	213	0.211	313	0.795	20.2	2517	11198	1843	8198	2.5	2423	10778
800	244	0.211	314	0.795	20.2	2771	12326	2107	9372	2.5	2754	12250
900	274	0.211	314	0.795	20.2	3151	14017	2371	10547	2.5	3104	13807
1000	305	0.211	314	0.795	20.2	3658	16271	2636	11726	2.5	3473	15449
1100	335	0.211	314	0.795	20.2	3785	16835	2899	12895	2.5	3784	16832
1200	366	0.219	326	0.811	20.6	4292	19090	3290	14635	2.5	4259	18945
1300	396	0.220	327	0.811	20.6	4689	20857	3570	15880	2.5	4624	20569
1400	427	0.220	327	0.811	20.6	5069	22548	3846	17108	2.5	4984	22170
1500	457	0.220	327	0.811	20.6	5576	24803	4125	18349	2.5	5364	23860
288 FIBERS												
100	30	0.259	385	0.890	22.6	1296	5763	323	1439	2.0	488	2172
200	61	0.259	385	0.890	22.6	1296	5763	647	2878	2.2	866	3851
300	91	0.259	385	0.890	22.6	1296	5763	970	4317	2.4	1222	5437
400	122	0.259	385	0.890	22.6	1692	7528	1294	5757	2.4	1625	7229
500	152	0.259	385	0.890	22.6	2072	9219	1618	7198	2.4	2026	9013
600	183	0.259	385	0.890	22.6	2579	11474	1943	8641	2.4	2444	10872
700	213	0.259	386	0.890	22.6	2833	12601	2267	10083	2.4	2828	12580
800	244	0.259	386	0.890	22.6	3340	14856	2593	11534	2.4	3248	14447
900	274	0.269	400	0.906	23.0	3847	17111	3024	13450	2.4	3757	16710
1000	305	0.269	400	0.906	23.0	4227	18802	3360	14948	2.4	4168	18542
1100	335	0.269	400	0.906	23.0	4734	21056	3698	16448	2.4	4597	20450
1200	366	0.268	399	0.921	23.4	5069	22548	4019	17879	2.4	5002	22252
1300	396	0.268	399	0.921	23.4	5449	24239	4355	19373	2.4	5415	24085
1400	427	0.268	399	0.921	23.4	5829	25930	4692	20869	2.4	5827	25918
1500	457	0.267	397	0.921	23.4	6336	28185	5005	22265	2.4	6239	27750
432 FIBERS												
100	30	0.298	444	0.953	24.2	1296	5763	373	1658	2.0	529	2355
200	61	0.298	444	0.953	24.2	1296	5763	745	3316	2.2	949	4221
300	91	0.298	444	0.953	24.2	1384	6158	1118	4974	2.3	1360	6050
400	122	0.298	444	0.953	24.2	1819	8091	1491	6634	2.3	1811	8054
500	152	0.298	444	0.953	24.2	2326	10346	1865	8295	2.3	2270	10098
600	183	0.298	444	0.953	24.2	2833	12601	2238	9957	2.3	2730	12143
700	213	0.299	444	0.953	24.2	3340	14856	2612	11620	2.3	3190	14188
800	244	0.309	459	0.969	24.6	3973	17674	3087	13732	2.3	3752	16689
900	274	0.309	459	0.969	24.6	4227	18802	3473	15451	2.3	4192	18648
1000	305	0.309	460	0.969	24.6	4734	21056	3861	17172	2.3	4663	20744
1100	335	0.320	476	0.984	25.0	5322	23675	4396	19554	2.3	5273	23456
1200	366	0.320	476	0.984	25.0	5829	25930	4797	21338	2.3	5756	25605
1300	396	0.319	474	0.984	25.0	6336	28185	5178	23032	2.3	6223	27683
1400	427	0.319	474	0.984	25.0	6716	29876	5577	24809	2.3	6690	29760
1500	457	0.319	474	0.984	25.0	7223	32131	5977	26589	2.3	7173	31906

* Initial tension indicates tension before 10 year creep.

ВЯРНО С ОРИГИНАЛА

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC HEAVY LOADING @ 1% INSTALLATION SAG

HEAVY

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
12 FIBERS												
100	30	0.080	119	0.500	12.7	539	2398	100	446	3.5	335	1492
200	61	0.080	119	0.500	12.7	598	2661	201	892	4.1	569	2533
300	91	0.080	119	0.500	12.7	936	4162	301	1339	4.1	864	3844
400	122	0.084	125	0.512	13.0	1189	5290	421	1875	4.2	1152	5125
500	152	0.084	126	0.512	13.0	1506	6699	527	2345	4.1	1445	6429
600	183	0.085	126	0.512	13.0	1823	8108	634	2821	4.1	1739	7737
700	213	0.090	134	0.528	13.4	2076	9236	788	3503	4.1	2052	9127
800	244	0.090	134	0.528	13.4	2456	10927	901	4006	4.1	2367	10530
900	274	0.090	134	0.528	13.4	2710	12054	1014	4509	4.1	2649	11785
1000	305	0.090	134	0.528	13.4	2963	13182	1127	5012	4.1	2931	13040
1100	335	0.093	138	0.535	13.6	3344	14873	1278	5687	4.1	3276	14572
1200	366	0.093	138	0.535	13.6	3597	16000	1395	6207	4.1	3561	15839
1300	396	0.102	151	0.559	14.2	4104	18255	1652	7349	4.1	4017	17869
1400	427	0.102	152	0.559	14.2	4309	19166	1783	7933	4.1	4300	19125
1500	457	0.102	152	0.559	14.2	4689	20857	1915	8517	4.1	4628	20585
24 FIBERS												
100	30	0.081	121	0.500	12.7	539	2398	102	452	3.5	336	1495
200	61	0.081	121	0.500	12.7	598	2661	203	904	4.1	571	2539
300	91	0.081	121	0.500	12.7	936	4162	305	1357	4.1	866	3853
400	122	0.085	127	0.512	13.0	1189	5290	427	1898	4.1	1155	5137
500	152	0.085	127	0.512	13.0	1506	6699	534	2374	4.1	1449	6445
600	183	0.086	127	0.512	13.0	1823	8108	642	2856	4.1	1743	7755
700	213	0.091	136	0.528	13.4	2076	9236	797	3545	4.1	2057	9149
800	244	0.091	136	0.528	13.4	2456	10927	911	4054	4.1	2373	10555
900	274	0.091	136	0.528	13.4	2837	12618	1026	4563	4.1	2689	11960
1000	305	0.091	136	0.528	13.4	2963	13182	1140	5071	4.1	2938	13071
1100	335	0.094	140	0.535	13.6	3344	14873	1293	5752	4.1	3284	14606
1200	366	0.094	140	0.535	13.6	3724	16564	1411	6278	4.1	3602	16025
1300	396	0.103	153	0.559	14.2	4231	18819	1670	7427	4.0	4059	18055
1400	427	0.103	153	0.559	14.2	4435	19729	1802	8017	4.1	4343	19317
1500	457	0.103	154	0.559	14.2	4689	20857	1935	8605	4.1	4638	20633
36 FIBERS												
100	30	0.082	123	0.500	12.7	539	2398	103	458	3.5	337	1499
200	61	0.082	123	0.500	12.7	598	2661	206	916	4.1	572	2544
300	91	0.082	123	0.500	12.7	936	4162	309	1375	4.1	868	3861
400	122	0.086	129	0.512	13.0	1189	5290	432	1922	4.1	1158	5151
500	152	0.086	129	0.512	13.0	1506	6699	540	2402	4.1	1452	6459
600	183	0.087	129	0.512	13.0	1823	8108	650	2891	4.1	1748	7775
700	213	0.092	137	0.528	13.4	2076	9236	806	3585	4.1	2062	9172
800	244	0.092	137	0.528	13.4	2456	10927	922	4101	4.1	2379	10582
900	274	0.092	137	0.528	13.4	2710	12054	1038	4617	4.1	2662	11841
1000	305	0.092	137	0.528	13.4	3090	13745	1154	5133	4.1	2979	13251
1100	335	0.095	142	0.535	13.6	3470	15436	1308	5818	4.1	3324	14786
1200	366	0.095	142	0.535	13.6	3597	16000	1427	6348	4.1	3578	15916
1300	396	0.104	154	0.559	14.2	4104	18255	1687	7504	4.1	4036	17953
1400	427	0.104	155	0.559	14.2	4435	19729	1821	8100	4.1	4353	19363
1500	457	0.104	155	0.559	14.2	4689	20857	1954	8692	4.1	4649	20680

* Initial tension indicates tension before 10 year creep.

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All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC HEAVY LOADING @ 1% INSTALLATION SAG

HEAVY

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
48 FIBERS												
100	30	0.083	124	0.500	12.7	539	2398	104	463	3.5	338	1503
200	61	0.083	124	0.500	12.7	598	2661	209	930	4.1	574	2553
300	91	0.083	124	0.500	12.7	936	4162	313	1392	4.1	870	3870
400	122	0.087	130	0.512	13.0	1189	5290	437	1944	4.1	1160	5160
500	152	0.088	130	0.512	13.0	1506	6699	547	2433	4.1	1456	6477
600	183	0.088	131	0.512	13.0	1823	8108	658	2927	4.1	1752	7793
700	213	0.093	139	0.528	13.4	2076	9236	815	3625	4.1	2067	9194
800	244	0.093	139	0.528	13.4	2456	10927	932	4146	4.1	2384	10605
900	274	0.093	139	0.528	13.4	2710	12054	1049	4666	4.1	2668	11868
1000	305	0.093	139	0.528	13.4	3090	13745	1167	5191	4.1	2986	13282
1100	335	0.096	143	0.535	13.6	3470	15436	1322	5881	4.1	3332	14821
1200	366	0.096	143	0.535	13.6	3724	16564	1443	6419	4.1	3620	16103
1300	396	0.105	156	0.559	14.2	4104	18255	1704	7580	4.1	4045	17993
1400	427	0.105	156	0.559	14.2	4435	19729	1839	8180	4.1	4363	19408
1500	457	0.105	157	0.559	14.2	4689	20857	1974	8781	4.1	4660	20729
60 FIBERS												
100	30	0.084	126	0.500	12.7	539	2398	106	472	3.5	338	1503
200	61	0.084	126	0.500	12.7	598	2661	211	939	4.1	575	2558
300	91	0.085	126	0.500	12.7	936	4162	317	1410	4.1	872	3879
400	122	0.089	132	0.512	13.0	1189	5290	443	1971	4.1	1163	5173
500	152	0.089	132	0.512	13.0	1569	6981	554	2464	4.1	1476	6566
600	183	0.089	132	0.512	13.0	1823	8108	666	2963	4.1	1756	7811
700	213	0.094	140	0.528	13.4	2076	9236	825	3670	4.1	2072	9217
800	244	0.094	140	0.528	13.4	2456	10927	943	4195	4.1	2390	10631
900	274	0.094	140	0.528	13.4	2710	12054	1061	4720	4.1	2675	11899
1000	305	0.094	140	0.528	13.4	2963	13182	1180	5249	4.1	2960	13167
1100	335	0.097	145	0.535	13.6	3344	14873	1337	5947	4.1	3307	14710
1200	366	0.097	145	0.535	13.6	3597	16000	1459	6490	4.1	3595	15991
1300	396	0.106	158	0.559	14.2	4104	18255	1721	7655	4.1	4055	18038
1400	427	0.106	158	0.559	14.2	4435	19729	1858	8265	4.0	4373	19452
1500	457	0.106	158	0.559	14.2	4689	20857	1994	8870	4.1	4671	20778
72 FIBERS												
100	30	0.100	148	0.535	13.6	854	3797	125	556	3.1	400	1779
200	61	0.100	148	0.535	13.6	854	3797	249	1108	3.7	662	2945
300	91	0.100	148	0.535	13.6	913	4060	374	1664	4.1	907	4035
400	122	0.108	161	0.559	14.2	1314	5843	542	2411	4.0	1267	5636
500	152	0.108	161	0.559	14.2	1567	6970	678	3016	4.0	1565	6961
600	183	0.108	161	0.559	14.2	1884	8380	814	3621	4.0	1879	8358
700	213	0.109	162	0.559	14.2	2264	10071	950	4226	4.0	2210	9831
800	244	0.109	162	0.559	14.2	2644	11762	1088	4840	4.0	2541	11303
900	274	0.109	162	0.559	14.2	2898	12889	1224	5445	4.0	2839	12629
1000	305	0.109	162	0.559	14.2	3151	14017	1361	6054	4.0	3138	13959
1100	335	0.115	171	0.575	14.6	3531	15708	1579	7024	4.0	3531	15707
1200	366	0.115	171	0.575	14.6	3911	17399	1723	7664	4.0	3867	17201
1300	396	0.115	171	0.575	14.6	4292	19090	1870	8318	4.0	4205	18705
1400	427	0.115	171	0.575	14.6	4545	20217	2015	8963	4.0	4509	20057
1500	457	0.123	183	0.594	15.1	5069	22548	2308	10266	3.9	4994	22214

* Initial tension indicates tension before 10 year creep.

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AFL

Fiber Optic Cable

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

HEAVY

NESC HEAVY LOADING @ 1% INSTALLATION SAG

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
84 FIBERS												
100	30	0.131	195	0.610	15.5	1296	5763	164	730	2.8	483	2148
200	61	0.131	195	0.610	15.5	1296	5763	328	1459	3.3	803	3572
300	91	0.131	195	0.610	15.5	1296	5763	492	2189	3.7	1085	4826
400	122	0.131	195	0.610	15.5	1384	6158	656	2918	3.9	1369	6090
500	152	0.131	195	0.610	15.5	1756	7810	821	3652	3.9	1718	7642
600	183	0.131	195	0.610	15.5	2072	9219	985	4381	3.9	2053	9132
700	213	0.138	205	0.626	15.9	2453	10910	1208	5373	3.9	2448	10889
800	244	0.138	205	0.626	15.9	2833	12601	1381	6143	3.9	2806	12482
900	274	0.138	206	0.626	15.9	3213	14292	1554	6913	3.9	3163	14070
1000	305	0.138	206	0.626	15.9	3593	15983	1727	7682	3.9	3521	15662
1100	335	0.145	216	0.642	16.3	3973	17674	1992	8861	3.9	3948	17562
1200	366	0.145	216	0.642	16.3	4354	19365	2174	9670	3.8	4312	19181
1300	396	0.145	216	0.642	16.3	4734	21056	2356	10480	3.8	4676	20800
1400	427	0.148	220	0.661	16.8	5196	23112	2587	11508	3.8	5115	22753
1500	457	0.148	220	0.661	16.8	5576	24803	2773	12335	3.8	5483	24390
96 FIBERS												
100	30	0.132	197	0.610	15.5	1296	5763	165	734	2.8	483	2148
200	61	0.132	197	0.610	15.5	1296	5763	331	1472	3.3	805	3581
300	91	0.132	197	0.610	15.5	1296	5763	496	2206	3.7	1088	4840
400	122	0.132	197	0.610	15.5	1384	6158	662	2945	3.9	1372	6103
500	152	0.132	197	0.610	15.5	1756	7810	827	3679	3.9	1722	7660
600	183	0.132	197	0.610	15.5	2072	9219	993	4417	3.9	2058	9154
700	213	0.139	207	0.626	15.9	2579	11474	1217	5413	3.8	2484	11049
800	244	0.139	207	0.626	15.9	2833	12601	1391	6187	3.9	2812	12508
900	274	0.139	207	0.626	15.9	3213	14292	1566	6966	3.9	3170	14101
1000	305	0.139	207	0.626	15.9	3593	15983	1741	7744	3.9	3528	15693
1100	335	0.146	217	0.642	16.3	3973	17674	2007	8928	3.8	3957	17602
1200	366	0.146	217	0.642	16.3	4480	19929	2191	9746	3.8	4352	19359
1300	396	0.146	217	0.642	16.3	4734	21056	2374	10560	3.8	4686	20844
1400	427	0.149	222	0.661	16.8	5196	23112	2606	11592	3.8	5126	22802
1500	457	0.149	222	0.661	16.8	5576	24803	2793	12424	3.8	5495	24443
108 FIBERS												
100	30	0.170	254	0.685	17.4	2070	9207	213	947	2.5	589	2620
200	61	0.170	254	0.685	17.4	2070	9207	426	1895	2.9	986	4386
300	91	0.170	254	0.685	17.4	2070	9207	639	2842	3.3	1337	5947
400	122	0.170	254	0.685	17.4	2070	9207	852	3790	3.5	1662	7393
500	152	0.170	254	0.685	17.4	2070	9207	1065	4737	3.7	1972	8772
600	183	0.170	254	0.685	17.4	2340	10408	1278	5685	3.7	2334	10382
700	213	0.178	265	0.701	17.8	2847	12663	1556	6921	3.7	2799	12451
800	244	0.178	265	0.701	17.8	3227	14354	1780	7918	3.7	3195	14212
900	274	0.178	265	0.701	17.8	3607	16045	2003	8910	3.7	3589	15965
1000	305	0.178	265	0.701	17.8	3987	17736	2226	9902	3.7	3984	17722
1100	335	0.186	276	0.717	18.2	4494	19991	2552	11352	3.7	4487	19959
1200	366	0.186	276	0.717	18.2	5001	22246	2785	12388	3.7	4917	21872
1300	396	0.186	276	0.717	18.2	5381	23937	3019	13429	3.7	5320	23665
1400	427	0.186	277	0.717	18.2	5761	25628	3252	14466	3.7	5722	25453
1500	457	0.188	279	0.748	19.0	6336	28185	3518	15649	3.7	6235	27735

* Initial tension indicates tension before 10 year creep.

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AFL **Fiber Optic Cable**

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

HEAVY

NESC HEAVY LOADING @ 1% INSTALLATION SAG

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
120 FIBERS												
100	30	0.171	255	0.685	17.4	2070	9207	214	952	2.5	590	2624
200	61	0.171	255	0.685	17.4	2070	9207	429	1908	2.9	988	4395
300	91	0.171	255	0.685	17.4	2070	9207	643	2860	3.3	1339	5956
400	122	0.171	255	0.685	17.4	2070	9207	857	3812	3.5	1666	7411
500	152	0.171	255	0.685	17.4	2070	9207	1072	4768	3.7	1976	8790
600	183	0.172	255	0.685	17.4	2340	10408	1287	5725	3.7	2339	10404
700	213	0.179	266	0.701	17.8	2847	12663	1565	6961	3.7	2805	12477
800	244	0.179	266	0.701	17.8	3227	14354	1791	7967	3.7	3201	14239
900	274	0.179	267	0.701	17.8	3607	16045	2015	8963	3.7	3597	16000
1000	305	0.179	267	0.701	17.8	4114	18300	2240	9964	3.7	4021	17886
1100	335	0.187	278	0.717	18.2	4621	20554	2567	11419	3.6	4524	20124
1200	366	0.187	278	0.717	18.2	5001	22246	2802	12464	3.6	4928	21921
1300	396	0.187	278	0.717	18.2	5381	23937	3036	13505	3.7	5331	23713
1400	427	0.187	278	0.717	18.2	5761	25628	3271	14550	3.7	5734	25506
1500	457	0.189	281	0.748	19.0	6336	28185	3539	15742	3.7	6247	27788
132 FIBERS												
100	30	0.208	310	0.764	19.4	2070	9207	260	1157	2.5	631	2807
200	61	0.208	310	0.764	19.4	2070	9207	520	2313	2.9	1064	4733
300	91	0.208	310	0.764	19.4	2070	9207	780	3470	3.2	1450	6450
400	122	0.208	310	0.764	19.4	2070	9207	1040	4626	3.5	1811	8056
500	152	0.208	310	0.764	19.4	2188	9734	1300	5783	3.6	2183	9710
600	183	0.208	310	0.764	19.4	2657	11817	1561	6944	3.6	2626	11681
700	213	0.216	322	0.780	19.8	3227	14354	1893	8420	3.5	3147	13999
800	244	0.216	322	0.780	19.8	3607	16045	2164	9626	3.5	3580	15925
900	274	0.217	322	0.780	19.8	4114	18300	2437	10840	3.5	4041	17975
1000	305	0.217	322	0.780	19.8	4494	19991	2708	12046	3.5	4474	19901
1100	335	0.217	323	0.780	19.8	5001	22246	2980	13256	3.5	4935	21952
1200	366	0.225	335	0.795	20.2	5508	24500	3376	15017	3.5	5493	24434
1300	396	0.221	328	0.811	20.6	5956	26494	3584	15942	3.5	5921	26338
1400	427	0.220	327	0.811	20.6	6463	28749	3844	17099	3.5	6377	28366
1500	457	0.220	327	0.811	20.6	6843	30440	4120	18327	3.6	6816	30319
144 FIBERS												
100	30	0.209	311	0.764	19.4	2070	9207	261	1161	2.5	632	2811
200	61	0.209	311	0.764	19.4	2070	9207	523	2326	2.9	1065	4737
300	91	0.209	311	0.764	19.4	2070	9207	784	3487	3.2	1452	6459
400	122	0.209	311	0.764	19.4	2070	9207	1046	4653	3.4	1815	8074
500	152	0.209	311	0.764	19.4	2188	9734	1307	5814	3.6	2187	9728
600	183	0.209	311	0.764	19.4	2657	11817	1569	6979	3.6	2631	11703
700	213	0.217	324	0.780	19.8	3227	14354	1902	8461	3.5	3153	14025
800	244	0.217	324	0.780	19.8	3607	16045	2175	9675	3.5	3587	15956
900	274	0.218	324	0.780	19.8	4114	18300	2449	10894	3.5	4049	18011
1000	305	0.218	324	0.780	19.8	4494	19991	2722	12108	3.5	4483	19941
1100	335	0.218	324	0.780	19.8	5001	22246	2995	13322	3.5	4944	21992
1200	366	0.226	337	0.795	20.2	5508	24500	3392	15088	3.5	5504	24483
1300	396	0.222	330	0.811	20.6	6083	27057	3602	16022	3.5	5960	26511
1400	427	0.221	329	0.811	20.6	6463	28749	3863	17183	3.5	6389	28420
1500	457	0.221	329	0.811	20.6	6843	30440	4141	18420	3.6	6829	30377

* Initial tension indicates tension before 10 year creep.

ВЯРНО С ОРИГИНАЛА

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AFL

Fiber Optic Cable

All-Dielectric Self-Supporting (AFL-ADSS®) Fiber Optic Cable

NESC HEAVY LOADING @ 1% INSTALLATION SAG

HEAVY

SPAN		WEIGHT		DIAMETER		MRCL		INITIAL TENSION				
								UNLOADED		LOADED		
FEET	METERS	LBS/FT	KG/KM	INCHES	MM	LBS	N	LBS	N	SAG %	LBS	N
216 FIBERS												
100	30	0.202	301	0.780	19.8	854	3797	253	1125	3.1	505	2246
200	61	0.202	301	0.780	19.8	913	4060	505	2246	3.6	875	3892
300	91	0.202	301	0.780	19.8	1314	5843	758	3372	3.6	1300	5783
400	122	0.202	301	0.780	19.8	1884	8380	1012	4502	3.6	1762	7838
500	152	0.211	313	0.795	20.2	2264	10071	1316	5854	3.6	2224	9893
600	183	0.211	314	0.795	20.2	2771	12326	1580	7028	3.6	2681	11926
700	213	0.211	314	0.795	20.2	3151	14017	1844	8203	3.6	3111	13838
800	244	0.211	314	0.795	20.2	3658	16271	2108	9377	3.6	3568	15871
900	274	0.211	314	0.795	20.2	4038	17963	2373	10556	3.6	3998	17784
1000	305	0.219	326	0.811	20.6	4545	20217	2742	12197	3.6	4538	20186
1100	335	0.220	327	0.811	20.6	5069	22548	3022	13443	3.5	5010	22286
1200	366	0.220	327	0.811	20.6	5576	24803	3300	14679	3.5	5477	24363
1300	396	0.229	340	0.827	21.0	6083	27057	3716	16530	3.5	6053	26925
1400	427	0.228	339	0.827	21.0	6590	29312	3983	17717	3.5	6515	28980
1500	457	0.228	339	0.827	21.0	6970	31003	4269	18989	3.5	6962	30969
288 FIBERS												
100	30	0.259	385	0.890	22.6	1296	5763	323	1439	2.8	619	2753
200	61	0.259	385	0.890	22.6	1296	5763	647	2878	3.3	1061	4720
300	91	0.259	385	0.890	22.6	1566	6964	971	4317	3.4	1522	6771
400	122	0.259	385	0.890	22.6	2072	9219	1295	5759	3.4	2027	9016
500	152	0.259	385	0.890	22.6	2579	11474	1619	7201	3.4	2532	11262
600	183	0.259	386	0.890	22.6	3086	13728	1943	8644	3.4	3037	13509
700	213	0.269	400	0.906	23.0	3720	16547	2351	10460	3.4	3633	16163
800	244	0.269	400	0.906	23.0	4227	18802	2688	11958	3.4	4148	18453
900	274	0.269	400	0.906	23.0	4734	21056	3025	13457	3.4	4663	20744
1000	305	0.268	399	0.921	23.4	5196	23112	3350	14900	3.4	5176	23026
1100	335	0.268	399	0.921	23.4	5703	25366	3686	16396	3.4	5692	25321
1200	366	0.268	399	0.921	23.4	6209	27621	4022	17892	3.4	6208	27616
1300	396	0.267	397	0.921	23.4	6716	29876	4339	19301	3.4	6711	29854
1400	427	0.277	412	0.937	23.8	7477	33258	4845	21552	3.4	7412	32972
1500	457	0.277	412	0.937	23.8	7984	35513	5193	23098	3.4	7938	35308
432 FIBERS												
100	30	0.298	444	0.953	24.2	1296	5763	373	1658	2.8	659	2931
200	61	0.298	444	0.953	24.2	1296	5763	745	3316	3.2	1140	5070
300	91	0.298	444	0.953	24.2	1692	7528	1118	4975	3.3	1665	7405
400	122	0.298	444	0.953	24.2	2326	10346	1492	6636	3.3	2233	9932
500	152	0.298	444	0.953	24.2	2833	12601	1865	8298	3.3	2778	12356
600	183	0.299	444	0.953	24.2	3340	14856	2239	9960	3.3	3322	14779
700	213	0.309	459	0.969	24.6	3973	17674	2701	12015	3.3	3962	17625
800	244	0.309	460	0.969	24.6	4607	20493	3088	13737	3.3	4541	20202
900	274	0.320	476	0.984	25.0	5322	23675	3597	15999	3.2	5233	23279
1000	305	0.320	476	0.984	25.0	5829	25930	3997	17781	3.2	5800	25800
1100	335	0.319	474	0.984	25.0	6463	28749	4382	19490	3.2	6379	28374
1200	366	0.319	474	0.984	25.0	6970	31003	4781	21268	3.3	6945	30891
1300	396	0.329	490	1.000	25.4	7730	34385	5350	23799	3.2	7695	34229
1400	427	0.329	490	1.000	25.4	8364	37204	5764	25639	3.2	8295	36899
1500	457	0.329	490	1.000	25.4	8997	40022	6178	27479	3.2	8896	39570

* Initial tension indicates tension before 10 year creep.

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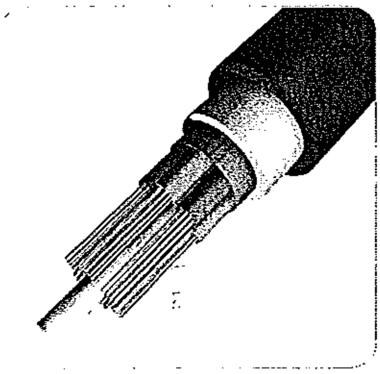
AFL

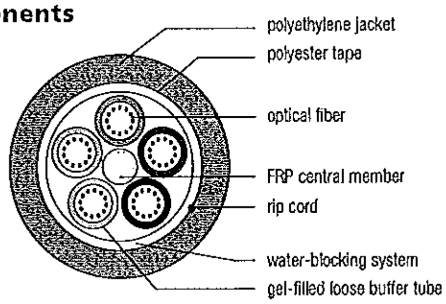
Fiber Optic Cable



Non-Armored OSP Loose Tube (LE Series SJ)

Acting as the backbone for most of today's fiber based systems, stranded fiber optic cables play a critical role in the high speed network. AFL's Non-Armored Loose Tube fiber optic cables are designed to provide high fiber counts with the flexibility and versatility required for today's most demanding installations. With fiber counts up to 576 and S-Z strand designs for easy mid-span access, AFL's cables comply with EIA/TIA, REA/RUS PE-90 and GR-20. Industry standard designs combined with innovative technologies, such as a dry core product, yield a world class cable that will support today's and tomorrow's technological needs.

Cable Components



Product Applications

- Long Haul Networking
- Building Interconnections (Campus LAN)
- Trunking Lines Direct to Telecommunications Closet
- Local Loop
- Distance Learning
- Distribution
- Intrabuilding Backbones

Temperature Specifications

TEMPERATURE RANGE	
INSTALLATION	-30°C to +70°C
OPERATING	-40°C to +70°C
STORAGE	-40°C to +75°C

Typical Lengths

MAXIMUM LENGTHS*				
FIBER COUNT	SINGLE-MODE		MULTIMODE	
	FEET	METERS	FEET	METERS
6 - 60	22,900	7,000	22,900	7,000
72 - 96	22,900	7,000	22,900	7,000
108 - 120	22,900	7,000	22,900	7,000
132 - 144	22,900	7,000	22,900	7,000
146 - 216	22,900	7,000	22,900	7,000
218 - 288	16,400	5,000	16,400	5,000
290 - 432	14,100	4,300	14,000	4,300
434 - 576	10,800	3,300	11,000	3,300

* Longer lengths may be available upon request.

Fiber Specifications

	MAXIMUM ATTENUATION (DB/KM)				OVERFILL LAUNCH MIN. BANDWIDTH (MHZ•KM)		GIGABIT ETHERNET MIN. LINK DISTANCE (METERS)	
FIBER TYPE	850 NM	1300 NM	1310 NM	1550 NM	850 NM	1300 NM	850 NM	1300 NM
(6) 62.5/125 GIGA-Link™ 300	3.5	1.2	N/A	N/A	200	600	300	550
(5) 50/125 GIGA-Link™ 600	2.9	0.9	N/A	N/A	500	500	600	600
(L) 50/125 Laser-Link™ 300	2.9	0.9	N/A	N/A	1500	500	900	550
(9) Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000
(Q) Non-zero Dispersion-shifted Single-mode	N/A	N/A	N/A	0.25	N/A	N/A	N/A	N/A
(K) AFL G.657.A1 Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000

Gigabit Ethernet Minimum Link Distances are based on "bandwidth"/modal dispersion constraints.
Actual link distances may be constrained by attenuation, depending on specific loss budget.

Non-Armored OSP Loose Tube (LE Series SJ)

Ordering Information

AFL NO.	FIBER COUNT	NUMBER OF TUBES/FIBERS	NOMINAL DIAMETER		NOMINAL WEIGHT		MAXIMUM TENSILE LOAD LBS (N)		MINIMUM BEND RADIUS INCHES (CM)	
			INCHES	MM	LBS/1,000FT	KG/KM	SHORT TERM	LONG TERM	SHORT TERM	LONG TERM
LE006*C5101N1	6	1w/6 (4 fillers)	0.41	10.5	56	83	600 (2670)	200 (890)	8.2 (21)	4.1 (11)
LE012*C5101N1	12	1w/12 (4 fillers)	0.41	10.5	56	84	600 (2670)	200 (890)	8.2 (21)	4.1 (11)
LE018*C5101N1	18	1w/12,1w/6 (3 fillers)	0.41	10.5	57	85	600 (2670)	200 (890)	8.2 (21)	4.1 (11)
LE024*C5101N1	24	2w/12 (3 fillers)	0.41	10.5	57	85	600 (2670)	200 (890)	8.2 (21)	4.1 (11)
LE030*C5101N1	30	2w/12,1w/6 (2 fillers)	0.41	10.5	58	86	600 (2670)	200 (890)	8.2 (21)	4.1 (11)
LE036*C5101N1	36	3w/12 (2 fillers)	0.41	10.5	58	86	600 (2670)	200 (890)	8.2 (21)	4.1 (11)
LE048*C5101N1	48	4w/12 (1 filler)	0.41	10.5	59	87	600 (2670)	200 (890)	8.2 (21)	4.1 (11)
LE060*C5101N1	60	5w/12 (no fillers)	0.41	10.5	60	89	600 (2670)	200 (890)	8.2 (21)	4.1 (11)
LE072*C6101N1	72	6w/12 (no fillers)	0.45	11.5	71	106	600 (2670)	200 (890)	9.0 (22)	4.5 (11.5)
LE084*C8101N1	84	7w/12 (1 filler)	0.52	13.3	90	135	600 (2670)	200 (890)	10.4 (27)	5.2 (14)
LE096*C8101N1	96	8w/12 (no fillers)	0.52	13.3	91	136	600 (2670)	200 (890)	10.4 (27)	5.2 (14)
LE108*CA101N1	108	9w/12 (1 filler)	0.59	15.1	117	174	600 (2670)	200 (890)	11.8 (31)	5.9 (16)
LE120*CA101N1	120	10w/12 (no fillers)	0.59	15.1	118	175	600 (2670)	200 (890)	11.8 (31)	5.9 (16)
LE132*CC101N1	132	11w/12 (1 filler)	0.67	17.0	147	219	600 (2670)	200 (890)	13.4 (34)	6.7 (17)
LE144*CC101N1	144	12w/12 (no fillers)	0.67	17.0	148	220	600 (2670)	200 (890)	13.4 (34)	6.7 (17)
LE216*CI301N1	216	18w/12 (no fillers)	0.69	17.4	150	224	600 (2670)	200 (890)	14.0 (35)	6.9 (18)
LE288*CO301N1	288	24w/12 (no fillers)	0.79	20.1	202	301	600 (2670)	200 (890)	17.3 (41)	7.9 (21)
LE432*IO301N1	432	24w/18 (no fillers)	0.87	22.0	242	360	600 (2670)	200 (890)	17.4 (44)	8.7 (22)
LE576*OO301N1	576	24w/24 (no fillers)	1.00	25.3	319	475	600 (2670)	200 (890)	20.1 (51)	10.2 (26)

Note: Diameter and weight subject to change without notice

* Fiber Types – Replace asterisk (*) in AFL number with number in the Fiber Specifications table on previous page.

Reel Information

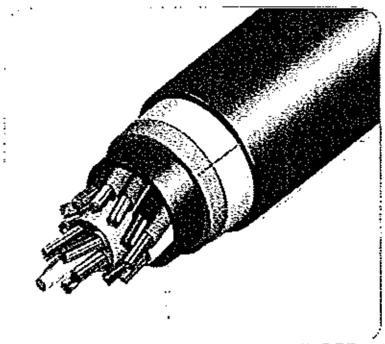
ITEM	REEL A		REEL B		REEL C		REEL D		REEL E	
	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM
Reel Height	42	106.7	58	147.3	66	167.6	72	182.8	84	213.4
Reel Width Outside	36	91.4	38	96.5	42	106.7	42	106.7	40	101.6
Reel Width Inside	32	81.6	32	81.3	36	91.4	36	91.4	34	86.4
Drum Diameter	23	58.7	28	71.1	36	91.4	36	91.4	35	88.9
Arbor Hole Diameter	3	7.9	3	7.9	3	7.9	3	7.9	3	7.9
Reel Weight With Lagging	180 lbs	82 kg	420 lbs	191 kg	685 lbs	311 kg	710 lbs	320 kg	950 lbs	431 kg

AFL typically provides Loose Tube cable on several standard sizes of non-returnable wooden reels. Non-standard reel sizes are available upon request.
Larger reel sizes may be required to accomodate long cable lengths.

ВЯРНО С ОРИГИНАЛА

AFL

Fiber Optic Cable



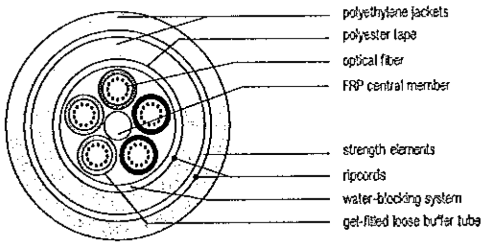
Non-Armored Loose Tube Cable—Double Jacket (LE Series DJ)

Acting as the backbone for most of today's fiber based systems, stranded fiber optic cables play a critical role in the high speed network. AFL's Non-Armored Double Jacket Loose Tube fiber optic cables are designed to provide high fiber counts with the flexibility and versatility required for today's most demanding installations while incorporating a second jacket when extra mechanical protection is desired. With fiber counts up to 576 and S-Z strand designs for easy mid-span access, AFL's cables comply with EIA/TIA, REA/RUS PE-90 and GR-20. Industry standard designs combined with innovative technologies, such as a dry core product, yield a world class cable that will support today's and tomorrow's technological needs.

Product Applications

- Long Haul Networking
- Building Interconnections (Campus LAN)
- Trunking Lines Direct to Telecommunications Closet
- Local Loop
- Distance Learning
- Distribution
- Intrabuilding Backbones

Cable Components



Temperature Specifications

TEMPERATURE RANGE	
INSTALLATION	-30°C to +70°C
OPERATING	-40°C to +70°C
STORAGE	-40°C to +75°C

Typical Lengths

MAXIMUM LENGTHS*				
FIBER COUNT	SINGLE-MODE		MULTIMODE	
	FEET	METERS	FEET	METERS
6 - 60	22,900	7,000	22,900	7,000
72 - 96	22,900	7,000	22,900	7,000
108 - 120	22,900	7,000	22,900	7,000
132 - 144	22,900	7,000	22,900	7,000
146 - 216	17,000	5,200	17,000	5,200
218 - 288	15,000	4,600	15,000	4,600
290 - 432	10,800	3,300	10,800	3,300
434 - 576	6,500	2,000	6,500	2,000

* Longer lengths may be available upon request.

Fiber Specifications

FIBER TYPE	MAXIMUM ATTENUATION (DB/KM)				OVERFILL LAUNCH MIN. BANDWIDTH (MHZ•KM)		GIGABIT ETHERNET MIN. LINK DISTANCE (METERS)	
	850 NM	1300 NM	1310 NM	1550 NM	850 NM	1300 NM	850 NM	1300 NM
(6) 62.5/125 GIGA-Link™ 300	3.5	1.2	N/A	N/A	200	600	300	550
(5) 50/125 GIGA-Link™ 600	2.9	0.9	N/A	N/A	500	500	600	600
(L) 50/125 Laser-Link™ 300	2.9	0.9	N/A	N/A	1500	500	900	550
(9) Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000
(Q) Non-zero Dispersion-shifted Single-mode	N/A	N/A	N/A	0.25	N/A	N/A	N/A	N/A
(K) AFL G.657.A1 Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000

Gigabit Ethernet Minimum Link Distances are based on "bandwidth"/modal dispersion constraints.
Actual link distances may be constrained by attenuation, depending on specific loss budget.

ВЯРНО С ОРИГИНАЛА

970

Non-Armored Loose Tube Cable—Double Jacket (LE Series DJ)

Ordering Information

AFL NO.	FIBER COUNT	NUMBER OF TUBES/FIBERS	NOMINAL DIAMETER		NOMINAL WEIGHT		MAXIMUM TENSILE LOAD LBS (N)		MINIMUM BEND RADIUS INCHES (CM)	
			INCHES	MM	LBS/1,000FT	KG/KM	SHORT TERM	LONG TERM	SHORT TERM	LONG TERM
LE006∗C5111N1	6	1w/6 (4 fillers)	0.49	12.5	79	118	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LE012∗C5111N1	12	1w/12 (4 fillers)	0.49	12.5	80	119	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LE018∗C5111N1	18	1w/12,1w/6 (3 fillers)	0.49	12.5	81	120	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LE024∗C5111N1	24	2w/12 (3 fillers)	0.49	12.5	81	120	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LE030∗C5111N1	30	2w/12,1w/6 (2 fillers)	0.49	12.5	82	121	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LE036∗C5111N1	36	3w/12 (2 fillers)	0.49	12.5	82	121	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LE048∗C5111N1	48	4w/12 (1 filler)	0.49	12.5	83	123	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LE060∗C5111N1	60	5w/12 (no fillers)	0.49	12.5	84	125	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LE072∗C6111N1	72	6w/12 (no fillers)	0.53	13.4	97	144	600 (2670)	200 (890)	10.6 (27)	5.3 (14)
LE084∗C8111N1	84	7w/12 (1 filler)	0.60	15.2	120	178	600 (2670)	200 (890)	12.0 (31)	6.0 (16)
LE096∗C8111N1	96	8w/12 (no fillers)	0.60	15.2	121	180	600 (2670)	200 (890)	12.0 (31)	6.0 (16)
LE108∗CA111N1	108	9w/12 (1 filler)	0.67	17.1	150	222	600 (2670)	200 (890)	13.4 (34)	6.7 (17)
LE120∗CA111N1	120	10w/12 (no fillers)	0.67	17.1	151	224	600 (2670)	200 (890)	13.4 (34)	6.7 (17)
LE132∗CC111N1	132	11w/12 (1 filler)	0.75	19.0	184	273	600 (2670)	200 (890)	15.0 (38)	7.5 (19)
LE144∗CC111N1	144	12w/12 (no fillers)	0.75	19.0	185	275	600 (2670)	200 (890)	15.0 (38)	7.5 (19)
LE216∗CI311N1	216	18w/12 (no fillers)	0.76	19.3	188	280	600 (2670)	200 (890)	15.2 (39)	7.6 (20)
LE288∗CO311N1	288	24w/12 (no fillers)	0.87	22.0	245	365	600 (2670)	200 (890)	17.4 (44)	8.7 (22)
LE432∗IO311N1	432	24w/18 (no fillers)	0.94	23.9	289	430	600 (2670)	200 (890)	18.8 (48)	9.4 (24)
LE576∗OO311N1	576	24w/24 (no fillers)	1.08	27.3	372	554	600 (2670)	200 (890)	21.4 (55)	10.7 (28)

Note: Diameter and weight subject to change without notice

∗ Fiber Types – Replace asterisk (∗) in AFL number with number in the Fiber Specifications table on previous page.

Reel Information

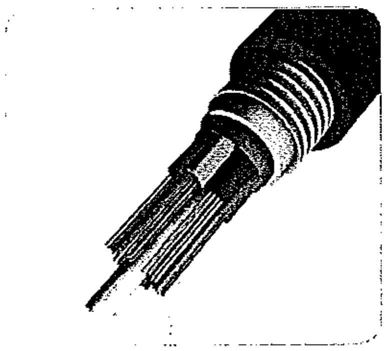
ITEM	REEL A		REEL B		REEL C		REEL D		REEL E	
	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM
Reel Height	42	106.7	58	147.3	66	167.6	72	182.8	84	213.4
Reel Width Outside	36	91.4	38	96.5	42	106.7	42	106.7	40	101.6
Reel Width Inside	32	81.6	32	81.3	36	91.4	36	91.4	34	86.4
Drum Diameter	23	58.7	28	71.1	36	91.4	36	91.4	35	88.9
Arbor Hole Diameter	3	7.9	3	7.9	3	7.9	3	7.9	3	7.9
Reel Weight With Lagging	180 lbs	82 kg	420 lbs	191 kg	685 lbs	311 kg	710 lbs	320 kg	950 lbs	431 kg

AFL typically provides Loose Tube cable on several standard sizes of non-returnable wooden reels. Non-standard reel sizes are available upon request. Larger reel sizes may be required to accomodate long cable lengths.

AFL

Fiber Optic Cable

ЕИК ДРАГАЛЕВСКИ, Пловдив



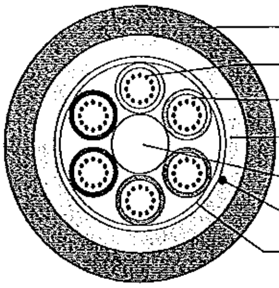
Single-Jacket Single-Armor OSP Loose Tube (LE Series SASJ)

Acting as the backbone for most of today's fiber based systems, stranded fiber optic cables play a critical role in the high speed network. AFL's Armored Loose Tube Single Jacket/Single Armor fiber optic cables are designed to provide high fiber counts with the flexibility and versatility required for today's most demanding installations, including direct buried. With fiber counts up to 288 and S-Z strand designs for easy mid-span access, AFL's cables comply with EIA/TIA, REA/RUS PE-90 and GR-20. Industry standard designs combined with innovative technologies, such as a dry core product, yield a world class cable that will support today's and tomorrow's technological needs.

Product Applications

- Long Haul Networking
- Building Interconnections (Campus LAN)
- Trunking Lines Direct to Telecommunications Closet
- Local Loop
- Distance Learning
- Distribution
- Intrabuilding Backbones

Cable Components



Temperature Specifications

TEMPERATURE RANGE	
INSTALLATION	-30°C to +70°C
OPERATING	-40°C to +70°C
STORAGE	-40°C to +75°C

Typical Lengths

MAXIMUM LENGTHS*				
	SINGLE-MODE		MULTIMODE	
FIBER COUNT	FEET	METERS	FEET	METERS
6 - 288	19,686	6,000	19,686	6,000

* Longer lengths may be available upon request.

Fiber Specifications

	MAXIMUM ATTENUATION (DB/KM)				OVERFILL LAUNCH MIN. BANDWIDTH (MHZ•KM)		GIGABIT ETHERNET MIN. LINK DISTANCE (METERS)	
FIBER TYPE	850 NM	1300 NM	1310 NM	1550 NM	850 NM	1300 NM	850 NM	1300 NM
(6) 62.5/125 GIGA-Link™ 300	3.5	1.2	N/A	N/A	200	600	300	550
(5) 50/125 GIGA-Link™ 600	2.9	0.9	N/A	N/A	500	500	600	600
(L) 50/125 Laser-Link™ 300	2.9	0.9	N/A	N/A	1500	500	900	550
(9) Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000
(Q) Non-zero Dispersion-shifted Single-mode	N/A	N/A	N/A	0.25	N/A	N/A	N/A	N/A
(K) AFL G.657.A1 Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000

Gigabit Ethernet Minimum Link Distances are based on "bandwidth"/modal dispersion constraints.
Actual link distances may be constrained by attenuation, depending on specific loss budget.

ВЯРНО С ОРИГИНАЛА

AFL **Fiber Optic Cable**

Пловдив

Single-Jacket Single-Armor OSP Loose Tube (LE Series SASJ)

Ordering Information

AFL NO.	FIBER COUNT	NUMBER OF TUBES/FIBERS	NOMINAL DIAMETER INCHES	NOMINAL DIAMETER MM	NOMINAL WEIGHT LBS/1,000FT	NOMINAL WEIGHT KG/KM	MAXIMUM TENSILE LOAD LBS (N) SHORT TERM	MAXIMUM TENSILE LOAD LBS (N) LONG TERM	MINIMUM BEND RADIUS INCHES (CM) SHORT TERM	MINIMUM BEND RADIUS INCHES (CM) LONG TERM
LE006∗C5201S1	6	1w/6 (4 fillers)	0.52	13.3	102	152	600 (2670)	200 (890)	10.7 (28)	5.4 (14)
LE012∗C5201S1	12	1w/12 (4 fillers)	0.52	13.3	102	152	600 (2670)	200 (890)	10.7 (28)	5.4 (14)
LE018∗C5201S1	18	1w/12,1w/6 (3 fillers)	0.52	13.3	103	153	600 (2670)	200 (890)	10.7 (28)	5.4 (14)
LE024∗C5201S1	24	2w/12 (3 fillers)	0.52	13.3	103	154	600 (2670)	200 (890)	10.7 (28)	5.4 (14)
LE030∗C5201S1	30	2w/12,1w/6 (2 fillers)	0.52	13.3	104	155	600 (2670)	200 (890)	10.7 (28)	5.4 (14)
LE036∗C5201S1	36	3w/12 (2 fillers)	0.52	13.3	104	155	600 (2670)	200 (890)	10.7 (28)	5.4 (14)
LE048∗C5201S1	48	4w/12 (1 filler)	0.52	13.3	105	157	600 (2670)	200 (890)	10.7 (28)	5.4 (14)
LE060∗C5201S1	60	5w/12 (no fillers)	0.52	13.3	106	158	600 (2670)	200 (890)	10.7 (28)	5.4 (14)
LE072∗C6201S1	72	6w/12 (no fillers)	0.56	14.2	120	179	600 (2670)	200 (890)	11.4 (29)	5.7 (15)
LE084∗C8201S1	84	7w/12 (1 filler)	0.63	16.0	146	218	600 (2670)	200 (890)	12.8 (33)	6.4 (16.3)
LE096∗C8201S1	96	8w/12 (no fillers)	0.63	16.0	147	219	600 (2670)	200 (890)	12.8 (33)	6.4 (16.3)
LE108∗CA201S1	108	9w/12 (1 filler)	0. 70	17.8	176	262	600 (2670)	200 (890)	14.2 (37)	7.1 (18)
LE120∗CA201S1	120	10w/12 (no fillers)	0. 70	17.8	177	264	600 (2670)	200 (890)	14.2 (37)	7.1 (18)
LE132∗CC201S1	132	11w/12 (1 filler)	0. 78	19.7	213	317	600 (2670)	200 (890)	15.7 (40)	7.9 (20)
LE144∗CC201S1	144	12w/12 (no fillers)	0. 78	19.7	214	319	600 (2670)	200 (890)	15.7 (40)	7.9 (20)
LE192∗08201S1	192	8 w/24 (no fillers)	0.63	16.0	152	226	600 (2670)	200 (890)	12.8 (33)	6.4 (163)
LE288∗0C201S1	288	12 w/24 (no fillers)	0.78	19.7	219	326	600 (2670)	200 (890)	15.7 (40)	7.9 (20)

Note: Diameter and weight subject to change without notice

∗ Fiber Types – Replace asterisk (∗) in AFL number with number in the Fiber Specifications table on previous page.

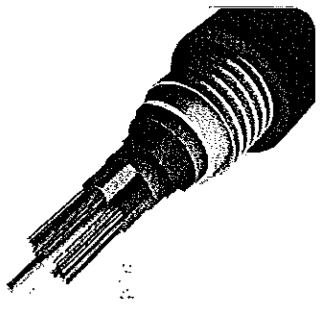
Reel Information

ITEM	REEL A INCHES	REEL A CM	REEL B INCHES	REEL B CM	REEL C INCHES	REEL C CM	REEL D INCHES	REEL D CM	REEL E INCHES	REEL E CM
Reel Height	42	106.7	58	147.3	66	167.6	72	182.8	84	213.4
Reel Width Outside	36	91.4	38	96.5	42	106.7	42	106.7	40	101.6
Reel Width Inside	32	81.6	32	81.3	36	91.4	36	91.4	34	86.4
Drum Diameter	23	58.7	28	71.1	36	91.4	36	91.4	35	88.9
Arbor Hole Diameter	3	7.9	3	7.9	3	7.9	3	7.9	3	7.9
Reel Weight With Lagging	180 lbs	82 kg	420 lbs	191 kg	685 lbs	311 kg	710 lbs	320 kg	950 lbs	431 kg

AFL typically provides Loose Tube cable on several standard sizes of non-returnable wooden reels. Non-standard reel sizes are available upon request.
Larger reel sizes may be required to accomodate long cable lengths.

ВЯРНО С ОРИГИНАЛА

973



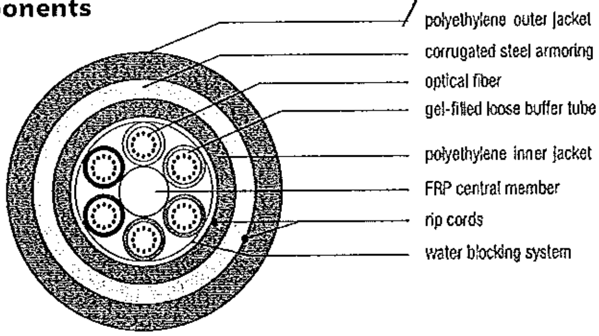
Double-Jacket Single-Armor OSP Loose Tube (LE Series SADJ)

Acting as the backbone for most of today's fiber based systems, stranded fiber optic cables play a critical role in the high speed network. AFL's Armored Loose Tube Double Jacket/Single Armor fiber optic cables are designed to provide high fiber counts with the flexibility and versatility required for today's most demanding installations, including direct buried. With fiber counts up to 312 and S-Z strand designs for easy mid-span access, AFL's cables comply with EIA/TIA, REA/RUS PE-90 and GR-20. Industry standard designs combined with innovative technologies, such as a dry core product, yield a world class cable that will support today's and tomorrow's technological needs.

Product Applications

- Long Haul Networking
- Building Interconnections (Campus LAN)
- Trunking Lines Direct to Telecommunications Closet
- Local Loop
- Distance Learning
- Distribution
- Intrabuilding Backbones

Cable Components



Temperature Specifications

TEMPERATURE RANGE	
INSTALLATION	-30°C to +70°C
OPERATING	-40°C to +70°C
STORAGE	-40°C to +75°C

Typical Lengths

MAXIMUM LENGTHS*				
	SINGLE-MODE		MULTIMODE	
FIBER COUNT	FEET	METERS	FEET	METERS
6 - 72	20,000	6,000	20,000	6,000
84 - 96	14,700	4,500	14,700	4,500
108 -120	13,000	4,000	13,000	4,000
132 - 144	11,100	3,400	11,100	3,400
146 - 312	10,000	3,000	10,000	3,000

* Longer lengths may be available upon request.

Fiber Specifications

	MAXIMUM ATTENUATION (DB/KM)				OVERFILL LAUNCH MIN. BANDWIDTH (MHZ•KM)		GIGABIT ETHERNET MIN. LINK DISTANCE (METERS)	
FIBER TYPE	850 NM	1300 NM	1310 NM	1550 NM	850 NM	1300 NM	850 NM	1300 NM
(6) 62.5/125 GIGA-Link™ 300	3.5	1.2	N/A	N/A	200	600	300	550
(S) 50/125 GIGA-Link™ 600	2.9	0.9	N/A	N/A	500	500	600	600
(L) 50/125 Laser-Link™ 300	2.9	0.9	N/A	N/A	1500	500	900	550
(9) Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000
(Q) Non-zero Dispersion-shifted Single-mode	N/A	N/A	N/A	0.25	N/A	N/A	N/A	N/A
(K) AFL G.657.A1 Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000

Gigabit Ethernet Minimum Link Distances are based on "bandwidth"/modal dispersion constraints.
Actual link distances may be constrained by attenuation, depending on specific loss budget.

Double-Jacket Single-Armor OSP Loose Tube (LE Series SADJ)

Ordering Information

AFL NO.	FIBER COUNT	NUMBER OF TUBES/FIBERS	NOMINAL DIAMETER		NOMINAL WEIGHT		MAXIMUM TENSILE LOAD LBS (N)		MINIMUM BEND RADIUS INCHES (CM)	
			INCHES	MM	LBS/1,000FT	KG/KM	SHORT TERM	LONG TERM	SHORT TERM	LONG TERM
LE006∗C5111S1	6	1w/6 (4 fillers)	0.59	15.0	128	190	600 (2670)	180 (800)	12.4 (32.0)	5.9 (15.0)
LE012∗C5111S1	12	1w/12 (4 fillers)	0.59	15.0	128	190	600 (2670)	180 (800)	12.4 (32.0)	5.9 (15.0)
LE018∗C5111S1	18	1w/12,1w/6 (3 fillers)	0.59	15.0	128	190	600 (2670)	180 (800)	12.4 (32.0)	5.9 (15.0)
LE024∗C5111S1	24	2w/12 (3 fillers)	0.59	15.0	128	190	600 (2670)	180 (800)	12.4 (32.0)	5.9 (15.0)
LE030∗C5111S1	30	2w/12,1w/6 (2 fillers)	0.59	15.0	128	190	600 (2670)	180 (800)	12.4 (32.0)	5.9 (15.0)
LE036∗C5111S1	36	3w/12 (2 fillers)	0.59	15.0	128	190	600 (2670)	180 (800)	12.4 (32.0)	5.9 (15.0)
LE048∗C5111S1	48	4w/12 (1 filler)	0.59	15.0	128	190	600 (2670)	180 (800)	12.4 (32.0)	5.9 (15.0)
LE060∗C5111S1	60	5w/12 (no fillers)	0.59	15.0	128	190	600 (2670)	180 (800)	12.4 (32.0)	5.9 (15.0)
LE072∗C6111S1	72	6w/12 (no fillers)	0.62	15.9	143	212	600 (2670)	180 (800)	13.0 (33.0)	6.5 (16.4)
LE084∗C8111S1	84	7w/12 (1 filler)	0.69	17.6	169	252	600 (2670)	180 (800)	14.4 (36.4)	7.2 (18.2)
LE096∗C8111S1	96	8w/12 (no fillers)	0.69	17.6	169	252	600 (2670)	180 (800)	14.4 (36.4)	7.2 (18.2)
LE108∗CA111S1	108	9w/12 (1 filler)	0.76	19.3	201	299	600 (2670)	180 (800)	15.8 (40.2)	7.9 (20.1)
LE120∗CA111S1	120	10w/12 (no fillers)	0.76	19.3	201	299	600 (2670)	180 (800)	15.8 (40.2)	7.9 (20.1)
LE132∗CC111S1	132	11w/12 (1 filler)	0.83	21.2	234	348	600 (2670)	180 (800)	18.0 (46.0)	9.0 (22.9)
LE144∗CC111S1	144	12w/12 (no fillers)	0.83	21.2	234	348	600 (2670)	180 (800)	18.0 (46.0)	9.0 (22.9)

Note: Diameter and weight subject to change without notice

∗ Fiber Types – Replace asterisk (∗) in AFL number with number in the Fiber Specifications table on previous page.

ВЯРНО С ОРИГИНАЛА

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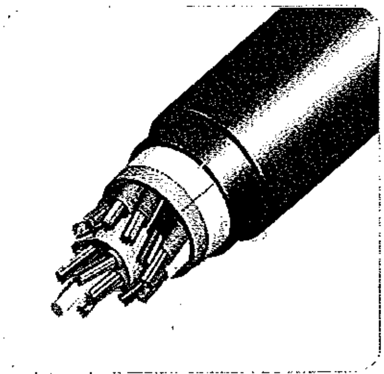
AFL

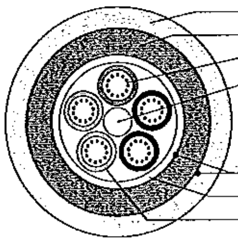
Fiber Optic Cable



All-Dielectric Armored Rodent-Resistant OSP Loose Tube (LN Series)

AFL's All-dielectric Rodent-Resistant cable is designed specifically for environments that have an increased risk of rodent infestation and disturbance. The LN-series product line covers the range of fiber-counts of up to 576 fibers. The ultra-hard, non-metallic outer polymer shell reduces risk of transmission interruptions in vital OSP network interconnections. In addition, the cable line meets all applicable RUS, GR-20 and IEC and TIA related design and performance guidelines.

Cable Components



Applications

- Long Haul Networking
- Building Interconnections (Campus LAN)
- Steam-tunnel Substreet Drainage Networks
- Local Loop
- Airport (FAA-E-2761c, Type B)

Temperature Specifications

TEMPERATURE RANGE	
INSTALLATION	-30°C to +70°C
OPERATING	-40°C to +70°C
STORAGE	-40°C to +75°C

Typical Lengths

	MAXIMUM LENGTHS*			
	SINGLE-MODE		MULTIMODE	
FIBER COUNT	FEET	METERS	FEET	METERS
6 - 60	22,900	7,000	22,900	8,000
72 - 96	22,900	7,000	22,900	7,000
108 -120	22,900	7,000	22,900	7,000
132 - 144	22,600	6,900	22,600	6,900
146 - 216	17,000	5,200	17,000	5,200
218 - 288	15,000	4,600	15,000	4,600
290 - 432	10,800	3,300	10,800	3,300
434 - 576	6,500	2,000	6,500	2,000

* Longer lengths may be available upon request.

Fiber Specifications

	MAXIMUM ATTENUATION (DB/KM)				OVERFILL LAUNCH MIN. BANDWIDTH (MHZ•KM)		GIGABIT ETHERNET MIN. LINK DISTANCE (METERS)	
FIBER TYPE	850 NM	1300 NM	1310 NM	1550 NM	850 NM	1300 NM	850 NM	1300 NM
(6) 62.5/125 GIGA-Link™ 300	3.5	1.2	N/A	N/A	200	600	300	550
(5) 50/125 GIGA-Link™ 600	2.9	0.9	N/A	N/A	500	500	600	600
(L) 50/125 Laser-Link™ 300	2.9	0.9	N/A	N/A	1500	500	900	550
(9) Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000
(Q) Non-zero Dispersion-shifted Single-mode	N/A	N/A	N/A	0.25	N/A	N/A	N/A	N/A
(K) AFL G.657.A1 Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000

Gigabit Ethernet Minimum Link Distances are based on "bandwidth"/modal dispersion constraints.
Actual link distances may be constrained by attenuation, depending on specific loss budget.

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AFL

Fiber Optic Cable

All-Dielectric Armored Rodent-Resistant OSP Loose Tube (LN Series)

Ordering Information

AFL NO.	FIBER COUNT	NUMBER OF TUBES/FIBERS	NOMINAL DIAMETER INCHES	NOMINAL DIAMETER MM	NOMINAL WEIGHT LBS/1,000FT	NOMINAL WEIGHT KG/KM	MAXIMUM TENSILN LOAD LBS (N) SHORT TERM	MAXIMUM TENSILN LOAD LBS (N) LONG TERM	MINIMUM BEND RADIUS INCHES (CM) SHORT TERM	MINIMUM BEND RADIUS INCHES (CM) LONG TERM
LN006*C5101N1	6	1w/6 (4 fillers)	0.49	12.5	56	84	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LN012*C5101N1	12	1w/12 (4 fillers)	0.49	12.5	56	84	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LN018*C5101N1	18	1w/12, 1w/6 (3 fillers)	0.49	12.5	56	84	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LN024*C5101N1	24	2w/12 (3 fillers)	0.49	12.5	56	84	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LN030*C5101N1	30	2w/12, 1w/6 (2 fillers)	0.49	12.5	56	84	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LN036*C5101N1	36	3w/12 (2 fillers)	0.49	12.5	56	84	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LN048*C5101N1	48	4w/12 (1 filler)	0.49	12.5	56	84	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LN060*C5101N1	60	5w/12 (no fillers)	0.49	12.5	56	84	600 (2670)	200 (890)	9.8 (25)	4.9 (13)
LN072*C6101N1	72	6w/12 (no fillers)	0.53	13.4	65	97	600 (2670)	200 (890)	10.6 (27)	5.3 (14)
LN084*C8101N1	84	7w/12 (1 filler)	0.60	15.2	81	121	600 (2670)	200 (890)	12.0 (31)	6.0 (16)
LN096*C8101N1	96	8w/12 (no fillers)	0.60	15.2	81	121	600 (2670)	200 (890)	12.0 (31)	6.0 (16)
LN108*CA101N1	108	9w/12 (1 filler)	0.67	17.1	101	151	600 (2670)	200 (890)	13.4 (34)	6.7 (17)
LN120*CA101N1	120	10w/12 (no fillers)	0.67	17.1	101	151	600 (2670)	200 (890)	13.4 (34)	6.7 (17)
LN132*CC101N1	132	11w/12 (1 filler)	0.75	19.0	123	184	600 (2670)	200 (890)	15.0 (38)	7.5 (19)
LN144*CC101N1	144	12w/12 (no fillers)	0.75	19.0	123	184	600 (2670)	200 (890)	15.0 (38)	7.5 (19)
LN216*CI301N1	216	18w/12 (no fillers)	0.76	19.3	125	187	600 (2670)	200 (890)	15.2 (39)	7.6 (20)
LN288*CO301N1	288	24w/12 (no fillers)	0.87	22.0	156	234	600 (2670)	200 (890)	17.4 (44)	8.7 (22)
LN432*IO301N1	432	24w/18 (no fillers)	0.94	23.9	183	273	600 (2670)	200 (890)	18.8 (48)	9.4 (24)
LN576*OO301N1	576	24w/24 (no fillers)	1.07	27.3	243	303	600 (2670)	200 (890)	21.4 (55)	10.7 (28)

Note: Diameter and weight subject to change without notice

* Fiber Types – Replace asterisk (*) in AFL number with number in the Fiber Specifications table on previous page.

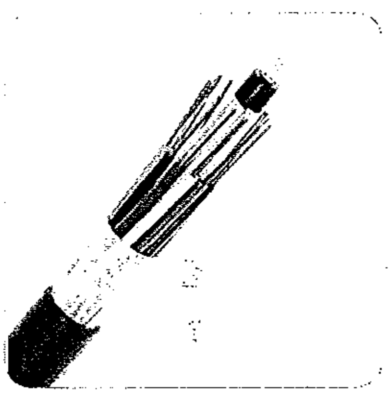
Reel Information

ITEM	REEL A INCHES	REEL A CM	REEL B INCHES	REEL B CM	REEL C INCHES	REEL C CM	REEL D INCHES	REEL D CM	REEL E INCHES	REEL E CM
Reel Height	42	106.7	58	147.3	66	167.6	72	182.8	84	213.4
Reel Width Outside	36	91.4	38	96.5	42	106.7	42	106.7	40	101.6
Reel Width Inside	32	81.6	32	81.3	36	91.4	36	91.4	34	86.4
Drum Diameter	23	58.7	28	71.1	36	91.4	36	91.4	35	88.9
Arbor Hole Diameter	3	7.9	3	7.9	3	7.9	3	7.9	3	7.9
Reel Weight With Lagging	180 lbs	82 kg	420 lbs	191 kg	685 lbs	311 kg	710 lbs	320 kg	950 lbs	431 kg

AFL typically provides Loose Tube cable on several standard sizes of non-returnable wooden reels. Non-standard reel sizes are available upon request.
Larger reel sizes may be required to accomodate long cable lengths.

AFL

Fiber Optic Cable



Non-Armored Single Jacket Dry Loose Tube Cable

Acting as the backbone for most of today's fiber based systems, stranded fiber optic cables play a critical role in the high speed network. AFL's Non-Armored Dry Loose Tube fiber optic cables are designed to provide high fiber counts with the flexibility and versatility required for today's most demanding installations. Our dry buffer tube cables feature fiber counts up to 288, compliance with EIA/TIA and REA/RUS PE-90, and are S-Z stranded for easy mid-span access. The dry buffer tube and core permit rapid cable preparation and termination. Water blocking materials are easily removed. Industry standard designs combined with innovative technologies, such as a dry core and dry tube product, yield a world class cable that will support today's and tomorrow's technological needs.

Applications

- Building Interconnections (Campus LAN)
- Trunking Lines Direct to Telecommunications Closet
- Local Loop
- Distance Learning
- Distribution
- Intrabuilding Backbones

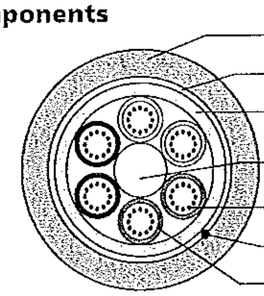
Temperature Range

Operating: -40°C to + 70°C

Storage: -40°C to + 75°C

Installation: -30°C to + 60°C

Cable Components



Typical Lengths

MAXIMUM LENGTHS*				
FIBER COUNT	SINGLE-MODE		MULTIMODE	
	FEET	METERS	FEET	METERS
6 - 60	39,370	12,000	26,200	8,000
72 - 96	32,800	10,000	26,200	8,000
108 -120	31,100	9,500	26,200	8,000
132 - 144	22,900	7,000	22,900	7,000
146 - 288	22,900	7,000	—	—

* Longer lengths may be available upon request.

Optical Information

FIBER TYPE	MAXIMUM ATTENUATION (dB/km)				OVERFILL LAUNCH MIN. BANDWIDTH (MHz•km)		GIGABIT ETHERNET MIN. LINK DISTANCE (METERS)	
	850nm	1300nm	1310nm	1550nm	850nm	1300nm	850nm	1300nm
(6) 62.5/125 GIGA-Link™ 300	3.5	1.2	N/A	N/A	200	600	300	550
(8) 62.5/125 GIGA-Link™ 1000	3.5	1.2	N/A	N/A	350	600	500	1000
(5) 50/125 GIGA-Link™ 600	2.9	0.9	N/A	N/A	500	500	600	600
(7) 50/125 GIGA-Link™ 2000	2.9	0.9	N/A	N/A	500	800	750	2000
(L) 50/125 Laser-Link™ 300	2.9	0.9	N/A	N/A	1500	500	900	550
(9) Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000
(Q) Non-zero Dispersion-shifted Single-mode	N/A	N/A	N/A	0.25	N/A	N/A	N/A	N/A
(K) SM Futureguide SR-15e Bend Insensitive	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000

Gigabit Ethernet Minimum Link Distances are based on "bandwidth"/modal dispersion constraints.
Actual link distances may be constrained by attenuation, depending on specific loss budget.

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AFL

Fiber Optic Cable

Non-Armored Single Jacket Dry Loose Tube Cable

Ordering Information

AFL NO.	FIBER COUNT	NUMBER OF TUBES/FIBERS	NOMINAL DIAMETER INCHES (MM)	NOMINAL WEIGHT LBS/1,000FT (KG/KM)	MAXIMUM TENSILE LOAD LBS. (N) SHORT TERM	LONG TERM	MINIMUM BEND RADIUS INCHES (CM) SHORT TERM	LONG TERM
LE006*C5101N1D	6	1w/6 (4 fillers)	0.45 (11.4)	53.8 (80.2)	600 (2700)	200 (890)	9.0 (22.8)	4.5 (11.4)
LE012*C5101N1D	12	1w/12 (4 fillers)	0.45 (11.4)	53.8 (80.2)	600 (2700)	200 (890)	9.0 (22.8)	4.5 (11.4)
LE018*C5101N1D	18	1w/12, 1w/6 (3 fillers)	0.45 (11.4)	53.8 (80.2)	600 (2700)	200 (890)	9.0 (22.8)	4.5 (11.4)
LE024*C5101N1D	24	2w/12 (3 fillers)	0.45 (11.4)	53.8 (80.2)	600 (2700)	200 (890)	9.0 (22.8)	4.5 (11.4)
LE030*C5101N1D	30	2w/12, 1w/6 (2 fillers)	0.45 (11.4)	53.8 (80.2)	600 (2700)	200 (890)	9.0 (22.8)	4.5 (11.4)
LE036*C5101N1D	36	3w/12 (2 fillers)	0.45 (11.4)	53.8 (80.2)	600 (2700)	200 (890)	9.0 (22.8)	4.5 (11.4)
LE048*C5101N1D	48	4w/12 (1 filler)	0.45 (11.4)	53.8 (80.2)	600 (2700)	200 (890)	9.0 (22.8)	4.5 (11.4)
LE060*C5101N1D	60	5w/12 (No fillers)	0.45 (11.4)	53.8 (80.2)	600 (2700)	200 (890)	9.0 (22.8)	4.5 (11.4)
LE072*C6101N1D	72	6w/12 (No fillers)	0.49 (12.4)	62.6 (93.4)	600 (2700)	200 (890)	9.8 (24.8)	4.9 (12.4)
LE084*C8101N1D	84	7w/12 (1 filler)	0.56 (14.2)	80.9 (120.7)	600 (2700)	200 (890)	11.2 (28.4)	5.6 (14.2)
LE096*C8101N1D	96	8w/12 (No fillers)	0.56 (14.2)	80.9 (120.7)	600 (2700)	200 (890)	11.2 (28.4)	5.6 (14.2)
LE108*CA101N1D	108	9w/12 (1 filler)	0.63 (15.9)	101.5 (151.4)	600 (2700)	200 (890)	12.6 (31.8)	6.3 (15.9)
LE120*CA101N1D	120	10w/12 (No fillers)	0.63 (15.9)	101.5 (151.4)	600 (2700)	200 (890)	12.6 (31.8)	6.3 (15.9)
LE132*CC101N1D	132	11w/12 (1 filler)	0.70 (17.8)	127.5 (190.1)	600 (2700)	200 (890)	14.0 (35.6)	7.0 (17.8)
LE144*CC101N1D	144	12w/12 (No fillers)	0.70 (17.8)	127.5 (190.1)	600 (2700)	200 (890)	14.0 (35.6)	7.0 (17.8)
LE216*C1301N1D	216	18w/12 (No fillers)	0.71 (18.0)	116.1 (173.1)	600 (2700)	200 (890)	14.2 (36.0)	7.1 (18.0)

Note: Diameter and weight subject to change without notice

* Fiber Types – Replace asterisk (*) in part number with number corresponding to desired fiber type below.

5 = 50/125µm multimode GIGA-Link™ 600
7 = 50/125µm multimode GIGA-Link™ 2000
6 = 62.5/125µm multimode GIGA-Link™ 300
8 = 62.5/125µm multimode GIGA-Link™ 1000
9 = Single-mode
L = 50/125µm multimode Laser-Link™ 300
K = SM Futureguide SR-15e Bend Insensitive
Q = Non-zero dispersion-shifted single-mode

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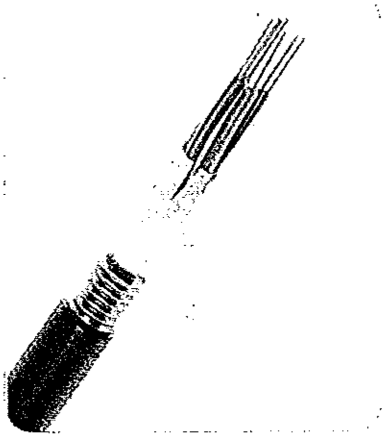
Armored Single Jacket/Single Armor Dry Loose Tube Cable



Acting as the backbone for most of today's fiber based systems, stranded fiber optic cables play a critical role in the high speed network. AFL's Armored Dry Loose Tube Single Jacket/Single Armor fiber optic cables are designed to provide high fiber counts with the flexibility and versatility required for today's most demanding installations, including direct buried. Our dry buffer tube cables feature fiber counts up to 144, compliance with EIA/TIA and REA/RUS PE-90, and are S-Z stranded for easy mid-span access. The dry buffer tube and core permit rapid cable preparation and termination. Water blocking materials are easily removed. Industry standard designs combined with innovative technologies, such as a dry core and dry tube product, yield a world class cable that will support today's and tomorrow's technological needs.

Applications

- Building Interconnections (Campus LAN)
- Trunking Lines Direct to Telecommunications Closet
- Local Loop
- Distance Learning
- Distribution
- Intrabuilding Backbones

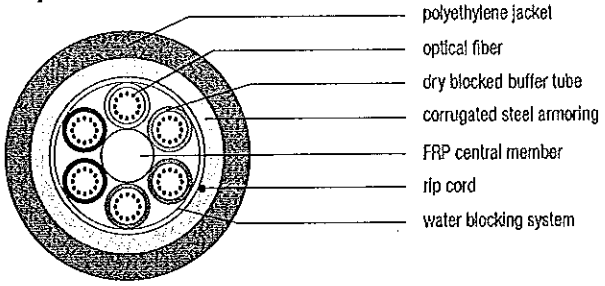
Temperature Range

Operating: -40°C to + 70°C

Storage : -40°C to + 75°C

Installation: -30°C to + 60°C

Cable Components



Typical Lengths

MAXIMUM LENGTHS*				
FIBER COUNT	SINGLE-MODE		MULTIMODE	
	FEET	METERS	FEET	METERS
6 - 60	39,370	12,000	26,200	8,000
72 - 96	32,800	10,000	26,200	8,000
108 -120	31,100	9,500	26,200	8,000
132 - 144	22,900	7,000	22,900	7,000

* Longer lengths may be available upon request.

Optical Information

FIBER TYPE	MAXIMUM ATTENUATION (dB/km)				OVERFILL LAUNCH MIN. BANDWIDTH (MHz•km)		GIGABIT ETHERNET MIN. LINK DISTANCE (METERS)	
	850nm	1300nm	1310nm	1550nm	850nm	1300nm	850nm	1300nm
(6) 62.5/125 GIGA-Link™ 300	3.5	1.2	N/A	N/A	200	600	300	550
(8) 62.5/125 GIGA-Link™ 1000	3.5	1.2	N/A	N/A	350	600	500	1000
(5) 50/125 GIGA-Link™ 600	2.9	0.9	N/A	N/A	500	500	600	600
(7) 50/125 GIGA-Link™ 2000	2.9	0.9	N/A	N/A	500	800	750	2000
(L) 50/125 Laser-Link™ 300	2.9	0.9	N/A	N/A	1500	500	900	550
(9) Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000
(Q) Non-zero Dispersion-shifted Single-mode	N/A	N/A	N/A	0.25	N/A	N/A	N/A	N/A
(K) SM Futureguide SR-15e Bend Insensitive	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000

Gigabit Ethernet Minimum Link Distances are based on "bandwidth"/modal dispersion constraints.
Actual link distances may be constrained by attenuation, depending on specific loss budget.

ВЯРНО С ОРИГИНАЛА

AFL

Fiber Optic Cable

Armored Single Jacket/Single Armor Dry Loose Tube Cable

Ordering Information

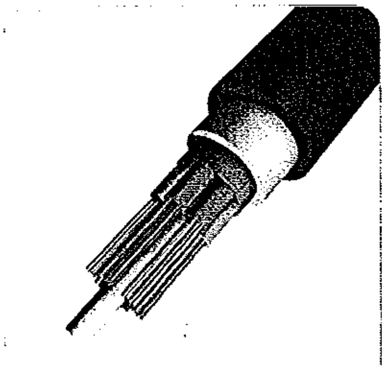
AFL NO.	FIBER COUNT	NUMBER OF TUBES/FIBERS	NOMINAL DIAMETER	NOMINAL WEIGHT	MAXIMUM TENSILE LOAD LBS. (N)		MINIMUM BEND RADIUS INCHES (CM)	
			INCHES (MM)	LBS/1,000FT (KG/KM)	SHORT TERM	LONG TERM	SHORT TERM	LONG TERM
LE006*C5201S1D	6	1w/6 (4 fillers)	0.52 (13.2)	94 (140)	600 (2700)	180 (800)	10.4 (26.4)	5.2 (13.2)
LE012*C5201S1D	12	1w/12 (4 fillers)	0.52 (13.2)	94 (140)	600 (2700)	180 (800)	10.4 (26.4)	5.2 (13.2)
LE018*C5201S1D	18	1w/12, 1w/6 (3 fillers)	0.52 (13.2)	94 (140)	600 (2700)	180 (800)	10.4 (26.4)	5.2 (13.2)
LE024*C5201S1D	24	2w/12 (3 fillers)	0.52 (13.2)	94 (140)	600 (2700)	180 (800)	10.4 (26.4)	5.2 (13.2)
LE030*C5201S1D	30	2w/12, 1w/6 (2 fillers)	0.52 (13.2)	94 (140)	600 (2700)	180 (800)	10.4 (26.4)	5.2 (13.2)
LE036*C5201S1D	36	3w/12 (2 fillers)	0.52 (13.2)	94 (140)	600 (2700)	180 (800)	10.4 (26.4)	5.2 (13.2)
LE048*C5201S1D	48	4w/12 (1 filler)	0.52 (13.2)	94 (140))	600 (2700)	180 (800)	10.4 (26.4)	5.2 (13.2)
LE060*C5201S1D	60	5w/12 (No fillers)	0.52 (13.2)	94 (140)	600 (2700)	180 (800)	10.4 (26.4)	5.2 (13.2)
LE072*C6201S1D	72	6w/12 (No fillers)	0.55 (14.0)	108 (161)	600 (2700)	180 (800)	11.0 (28.0)	5.5 (14.0)
LE084*C8201S1D	84	7w/12 (1 filler)	0.62 (15.8)	130 (193)	600 (2700)	180 (800)	12.4 (31.6)	6.2 (15.8)
LE096*C8201S1D	96	8w/12 (No fillers)	0.62 (15.8)	130 (193)	600 (2700)	180 (800)	12.4 (31.6)	6.2 (15.8)
LE108*CA201S1D	108	9w/12 (1 filler)	0.70 (17.7)	159 (237)	600 (2700)	180 (800)	14.0 (35.4)	7.0 (17.7)
LE120*CA201S1D	120	10w/12 (No fillers)	0.70 (17.7)	159 (237)	600 (2700)	180 (800)	14.0 (35.4)	7.0 (17.7)
LE132*CC201S1D	132	11w/12 (1 filler)	0.77 (19.6)	192 (285)	600 (2700)	180 (800)	15.4 (39.2)	7.7 (19.6)
LE144*CC201S1D	144	12w/12 (No fillers)	0.77 (19.6)	192 (285)	600 (2700)	180 (800)	15.4 (39.2)	7.7 (19.6)

Note: Diameter and weight subject to change without notice

* Fiber Types – Replace asterisk (*) in part number with number corresponding to desired fiber type below.

5 = 50/125µm multimode GIGA-Link™ 600
7 = 50/125µm multimode GIGA-Link™ 2000
6 = 62.5/125µm multimode GIGA-Link™ 300
8 = 62.5/125µm multimode GIGA-Link™ 1000
9 = Single-mode
L = 50/125µm multimode Laser-Link™ 300
K = SM Futureguide SR-15e Bend Insensitive
Q = Non-zero dispersion-shifted single-mode

ВЯРНО С ОРИГИНАЛА



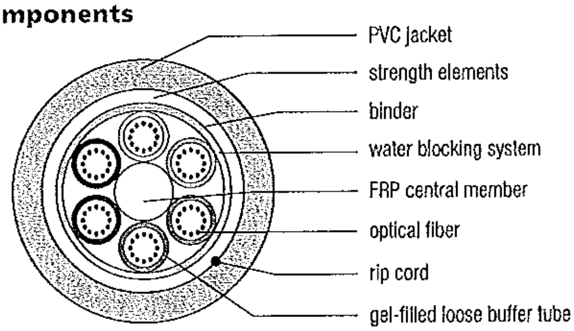
Riser Single-Jacket I/O Loose Tube (LV Series SJ)

Indoor/outdoor stranded loose tube combines the robust mechanical and environmental characteristics of an outside plant cable with the flexibility of an inside plant riser cable. By installing indoor/outdoor stranded loose tube, costly splice locations entering into a building are avoided, being routed directly from the outside plant to telecommunications closets, or main distribution frames (MDF) through the riser of a building and eliminating the "50-foot rule." Indoor/Outdoor Stranded Design loose tube cable is moisture and U.V. resistant, S-Z stranded for easy mid-span access, listed for OFNR use per UL standards, and can be used in both duct and lashed applications.

Applications

- Building Interconnections (Campus LAN)
- Trunking Lines Direct to Telecommunications Closet
- Local Loop
- Distance Learning
- Distribution
- Intrabuilding Backbones
- MSHA Approved for Mining Applications

Cable Components



Temperature Specifications

TEMPERATURE RANGE	
INSTALLATION	-30°C to +70°C
OPERATING	-40°C to +70°C
STORAGE	-40°C to +75°C

Typical Lengths

MAXIMUM LENGTHS*	SINGLE-MODE		MULTIMODE	
FIBER COUNT	FEET	METERS	FEET	METERS
6 - 144	22,900	7,000	22,900	7,000

* Longer lengths may be available.

Fiber Specifications

FIBER TYPE	MAXIMUM ATTENUATION (DB/KM)				OVERFILL LAUNCH MIN. BANDWIDTH (MHZ•KM)		GIGABIT ETHERNET MIN. LINK DISTANCE (METERS)	
	850 NM	1300 NM	1310 NM	1550 NM	850 NM	1300 NM	850 NM	1300 NM
(6) 62.5/125 GIGA-Link™ 300	3.5	1.2	N/A	N/A	200	600	300	550
(5) 50/125 GIGA-Link™ 600	2.9	0.9	N/A	N/A	500	500	600	600
(L) 50/125 Laser-Link™ 300	2.9	0.9	N/A	N/A	1500	500	900	550
(9) Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000
(Q) Non-zero Dispersion-shifted Single-mode	N/A	N/A	N/A	0.25	N/A	N/A	N/A	N/A
(K) AFL G.657.A1 Single-mode	N/A	N/A	0.35	0.25	N/A	N/A	N/A	5000

Gigabit Ethernet Minimum Link Distances are based on "bandwidth"/modal dispersion constraints.
Actual link distances may be constrained by attenuation, depending on specific loss budget.

MSHA

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AFL

Fiber Optic Cable

Riser Single-Jacket I/O Loose Tube (LV Series SJ)

Ordering Information

AFL NO.	FIBER COUNT	NUMBER OF TUBES/FIBERS	NOMINAL DIAMETER INCHES (MM)	NOMINAL WEIGHT LBS/1,000 FT (KG/KM)	MAXIMUM TENSILE LOAD LBS. (N) SHORT TERM	LONG TERM	MINIMUM BEND RADIUS INCHES (CM) SHORT TERM	LONG TERM
LV006∗C5101N1	6	1w/6 (4 fillers)	0.51 (12.9)	107 (159)	600 (2700)	200 (890)	10.2 (26)	5.1 (13)
LV012∗C5101N1	12	1w/12 (4 fillers)	0.51 (12.9)	108 (160)	600 (2700)	200 (890)	10.2 (26)	5.1 (13)
LV018∗C5101N1	18	1w/12, 1w/6 (3 fillers)	0.51 (12.9)	108 (161)	600 (2700)	200 (890)	10.2 (26)	5.1 (13)
LV024∗C5101N1	24	2w/12 (3 fillers)	0.51 (12.9)	108 (161)	600 (2700)	200 (890)	10.2 (26)	5.1 (13)
LV030∗C5101N1	30	2w/12, 1w/6 (2 fillers)	0.51 (12.9)	109 (162)	600 (2700)	200 (890)	10.2 (26)	5.1 (13)
LV036∗C5101N1	36	3w/12 (2 fillers)	0.51 (12.9)	109 (162)	600 (2700)	200 (890)	10.2 (26)	5.1 (13)
LV048∗C5101N1	48	4w/12 (1 filler)	0.51 (12.9)	110 (164)	600 (2700)	200 (890)	10.2 (26)	5.1 (13)
LV060∗C5101N1	60	5w/12 (No fillers)	0.51 (12.9)	111 (165)	600 (2700)	200 (890)	10.2 (26)	5.1 (13)
LV072∗C6101N1	72	6w/12 (No fillers)	0.54 (13.7)	128 (190)	600 (2700)	200 (890)	10.8 (28)	5.4 (14)
LV084∗C8101N1	84	7w/12 (1 filler)	0.61 (15.5)	158 (236)	600 (2700)	200 (890)	12.2 (31)	6.1 (16)
LV096∗C8101N1	96	8w/12 (No fillers)	0.61 (15.5)	159 (237)	600 (2700)	200 (890)	12.2 (31)	6.1 (16)
LV108∗CA101N1	108	9w/12 (1 filler)	0.69 (17.4)	197 (294)	600 (2700)	200 (890)	14.0 (35)	7.0 (18)
LV120∗CA101N1	120	10w/12 (No fillers)	0.69 (17.4)	198 (295)	600 (2700)	200 (890)	14.0 (35)	7.0 (18)
LV132∗CC101N1	132	11w/12 (1 filler)	0.76 (19.3)	242 (360)	600 (2700)	200 (890)	15.2 (39)	7.6 (20)
LV144∗CC101N1	144	12w/12 (No fillers)	0.76 (19.3)	243 (361)	600 (2700)	200 (890)	15.2 (39)	7.6 (20)

Note: Diameter and weight subject to change without notice

∗ Fiber Types – Replace asterisk (∗) in AFL number with number in the Fiber Specifications table on previous page.

Reel Information

ITEM	REEL A INCHES	CM	REEL B INCHES	CM	REEL C INCHES	CM	REEL D INCHES	CM	REEL E INCHES	CM
Reel Height	42	106.7	58	147.3	66	167.6	72	182.8	84	213.4
Reel Width Outside	36	91.4	38	96.5	42	106.7	42	106.7	40	101.6
Reel Width Inside	32	81.6	32	81.3	36	91.4	36	91.4	34	86.4
Drum Diameter	23	58.7	28	71.1	36	91.4	36	91.4	35	88.9
Arbor Hole Diameter	3	7.9	3	7.9	3	7.9	3	7.9	3	7.9
Reel Weight With Lagging	180 lbs	82 kg	420 lbs	191 kg	685 lbs	311 kg	710 lbs	320 kg	950 lbs	431 kg

AFL typically provides Loose Tube cable on several standard sizes of non-returnable wooden reels. Non-standard reel sizes are available upon request.
Larger reel sizes may be required to accomodate long cable lengths.

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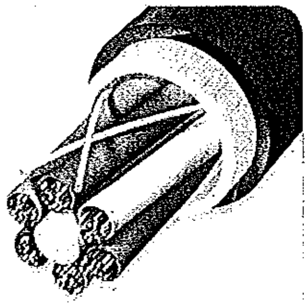
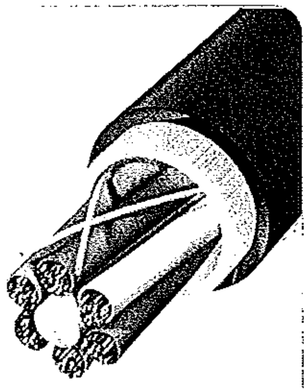
Specialized Loose Tube Cables



Low Smoke Zero Halogen Loose Tube Cable with Thermoset Jacket

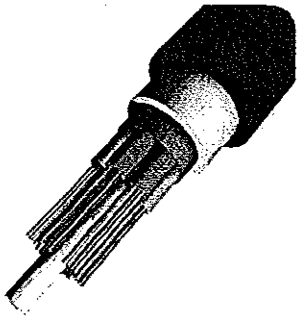
Consisting of thermoset (XLPO) jacket, AFL's LX-series of low-smoke zero-halogen (LSZH) loose tube cables are specifically designed for harsh environments. Ideal for indoor and outdoor industrial applications, the cable design includes dry-core water blocking system, SZ-stranded core for easy mid-span access to fibers, and a highly chemical resistant, cross-linked UV-resistant outer jacket. For even greater mechanical robustness, a corrugated steel armor version is available. Applications include mining, industrial, railways, subways, and much more.



Low Smoke Zero Halogen OFN-LS Listed Loose Tube Cable

AFL's Low Smoke Zero Halogen (LSZH) Loose Tube cable is designed for use in outdoor aerial and indoor duct appplications including subways and tunnels with requirements for limited smoke and zero halogen. Optical fibers are located within S-Z strandard buffer tubes, providing stable and reliable long-term performance. The cable is dry-blocked (no messy gel flooding the core) to prevent axial flow of moisture and utilizes a flame-retardant, non-halogenated UV-resistant outer jacket.

AFL's Low Smoke Zero Halogen (LSZH) loose tube cable group includes OFN-LS Listed as well as non-listed designs. The OFN-LS listed loose tube cable line (LL-Series) is specially engineered for applications that require UL/NEC compliant cables intended for inside-building applications and must meet minimum flame and smoke generation guideline.The Non-Listed cables are also constructed with LSZH materials and are intended for OSP installations where NFPA/NEC listing is not required.

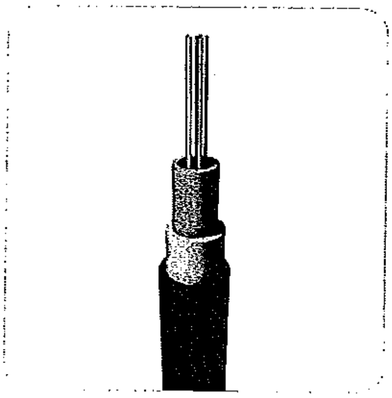


LA-Series Low Temp Harsh Environment LSZH Loose Tube Fiber Optic Cable

The LA-Series is specially designed for applications that demand reliable performance in harsh environment installations. The cable construction incorporates a variety of packaging technologies that allow the product to operate in extremely low temperatures, mechanically abusive installations and highly caustic and acidic environments. The key to the reliable, ultra-high performance is the specially designed cable core and the dual layer jacketing system.

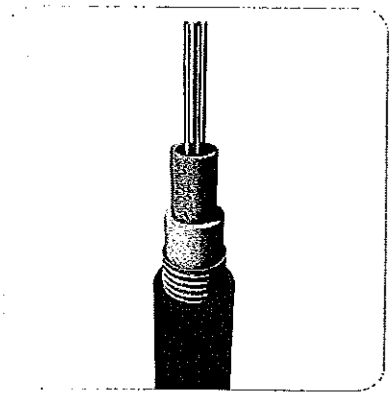
The cable core is constructed using materials and engineered geometry that optimizes the isolation of the optical fibers from the stresses and strains imparted on the cable and commonly realized in extreme environments. The outer jacketing is designed to further protect the ruggedized core assembly with a myltiplying system made up of a double-ply, low smoke zero halogen (LSZH) flame resistant jacketing system that integrates a strong layer of aramid yarn between the inner and outer sheaths.

Specialized Loose Tube Cables (cont.)



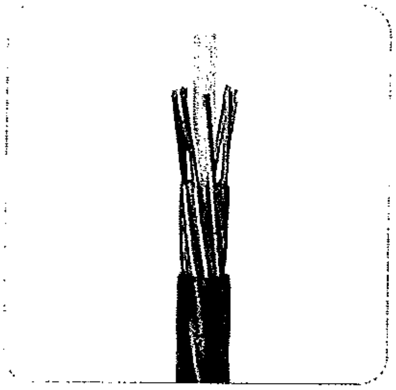
Uniflex® Non-Armored Loose Tube Cable

AFL's non-armored Uniflex® is a central loose tube cable used for duct and low fiber drop applications.



Uniflex® Armored Loose Tube Cable

AFL's Armored Uniflex cable is a central loose tube product used in various outside plant applications. Its compact design holds up to 12 fibers. The corrugated steel armor provides additional mechanical protection and also serves as toneable element within the cable.



Outside Plant (OSP) MicroCore® Blown Fiber Optic Cable

AFL OSP MicroCore cable series is designed for outside plant installation in microduct conduit systems. The unique, high-fiber density geometry yields a cable construction that can safely accommodate up to 144-fiber within cable package that can be air-blown into a microduct with an inside diameter as small as 10 mm or (0.394"). This cable solution offers the system designer the flexibility to install from 12- to 144-fibers within each 10 mm ID microduct within the multi-duct system.

For example, with a 7-way 12.7 mm x 10 mm (conduit with seven microducts) in place, the system designer has the flexibility to install from 12 to 144 fibers per microduct. With this approach, only the number of fibers required for initial networking requirements need to be installed. Then as future network upgrades and expansions are required, the spare microducts can be jetted with addition OSP MicroCore cables without having to add additional pathway space.

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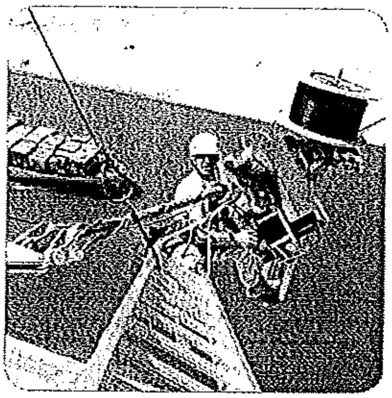
Reel and Packaging Information

REEL TYPE	FL	TR	DR	OW	TARE	FL	TR	DR	OW	TARE
	(CM)				(KGS)	(IN)				(LBS)
Wood	147	81	71	97	196	58	32	28	38	434
Wood	168	91	91	107	260	66	36	36	42	574
Wood	183	91	91	107	300	72	36	36	42	661
Wood	213	86	89	104	384	84	34	35	41	847
Steel	152	81	81	97	156	60	32	32	38	345
Steel	183	91	102	107	245	72	36	40	42	540
Steel	213	114	107	130	350	84	45	42	51	773

- **FL** - Flange Diameter; **TR** - Inside Traverse Width; **DR** - Drum Diameter; **OW** - Outside Overall Width
- Arbor Hole Diameter: Wood: 3-1/8 in (7.9 cm)
  Steel: 3 in (7.6 cm)
- Ordered lengths should include a distribution of lengths, i.e., all reels cannot be ordered at the maximum.
  A typical reel length distribution is as follows:
  6000 m – 7000 m ~ 15% of reels
  4500 m – 6000 m ~ 55% of reels
  2500 m – 4500 m ~ 25% of reels
  < 2500 m ~ 5% of reels
- Wood reels with flex-wrap covering are standard. Non-returnable steel reels and/or wood lagging are available upon request. Additional reel sizes may be available upon request.
- Steel reels are recommended for long term storage (>4 months). Reference AFL's "Fiber Optic Cable Receiving, Handling and Storage" document for additional information.



SkyWrap®

Successfully installed worldwide since 1982, SkyWrap is a fiber optic cable helically applied on ground wires or phase conductors. A specially designed spinning machine is used to wrap the cable under controlled conditions. This system offers a complete communication link designed and engineered for high-voltage environments at low cost.

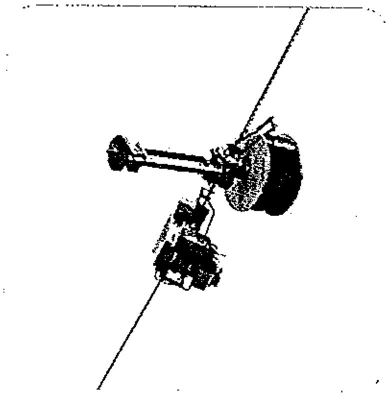
SkyWrap is the ideal solution when access to the overhead line is problematic due to environment or terrain. The installation equipment is lightweight, easy to handle and quick to install. When power outages are hard to coordinate SkyWrap can be installed on ground wire while the phase conductors remain live, or on phase conductors with single circuit outage.

Temperature Range

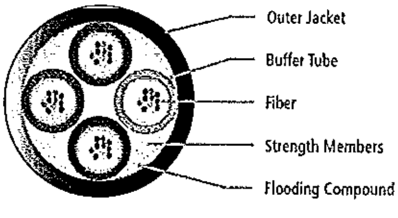
Operating:	-40°C to +85°C
Store:	-40°C to +50°C
Installation:	-20°C to +50°C

Benefits

- Quick, cost effective installation
- Utilize existing power line infrastructure
- Use where access is limited (e.g. mountains and river crossings)
- Use for both ground wires and phase conductors
- Live line installations on ground wire or single circuit outage on phase
- Complete lifetime turn-key solutions
- Over 30 years installation experience



Cable Components



Cable Features

- Designed for ground wires or phase conductors
- Zero fiber strain under all service conditions
- Up to 96 fibers per cable with 4 gel-filled tubes
- Double SkyWrap installations provides 192 fiber capacity
- SkyWrap can be installed on OPGW to increase existing fiber count
- Shotgun (birdshot) resistant jacket designs for tougher environments
- Small size and low weight ensures minimum loads on overhead lines
- All-dielectric construction provides immunity from electromagnetic interference
- Complies with IEEE 1594-2008 specification

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AFL

Fiber Optic Cable

SkyWrap®

Part Number

	Fiber Count	Cable Type	# Tubes		Fiber type
SW —	n	CA	4	—	*
	up to 96	CA = Standard Ground HA = Standard Phase JM = Birdshot Ground HM = Birdshot Phase	Only 4 buffer tube designs are available at this time		5 = 50/125µm multimode GIGA-Link™ 600 7 = 50/125µm multimode GIGA-Link™ 2000 6 = 62.5/125µm multimode GIGA-Link™ 300 8 = 62.5/125µm multimode GIGA-Link™ 1000 L = 50/125µm multimode Laser-Link™ 300 9 = Single-mode

SkyWrap Ordering Information - Technical Figures as of 11 June 2014

ITEM NUMBER	FIBER COUNT	CABLE O.D. INCHES (mm)	WEIGHT LBS/MILE (kg/km)	LENGTH PER REEL FEET (m)	CASSETTE LENGTH FEET (m)
STANDARD GROUND WIRE					
SW-nCA4-*	04 - 24	0.252 (6.4)	128 (36)	8,005 (2,440)	16,010 (4,880)
SW-nCA4-*	26 - 48	0.260 (6.6)	138 (39)	7,530 (2,295)	15,059 (4,590)
SW-nCA4-*	50 - 96	0.315 (8.0)	209 (59)	5,125 (1,562)	10,249 (3,124)
BIRDSHOT RESISTANT GROUND WIRE					
SW-nJM4-*	04 - 24	0.287 (7.3)	163 (46)	5,991 (1,826)	11,982 (3,652)
SW-nJM4-*	26 - 48	0.295 (7.5)	177 (50)	5,676 (1,730)	11,352 (3,460)
SW-nJM4-*	50 - 96	0.350 (8.9)	252 (71)	4,029 (1,228)	8,058 (2,456)
STANDARD PHASE CONDUCTOR					
SW-nHA4-*	04 - 24	0.287 (7.3)	195 (55)	6,280 (1,914)	12,559 (3,828)
SW-nHA4-*	26 - 48	0.295 (7.5)	209 (59)	5,948 (1,813)	11,896 (3,626)
SW-nHA4-*	50 - 96	0.350 (8.9)	291 (82)	4,226 (1,288)	8,451 (2,576)
BIRDSHOT RESISTANT PHASE CONDUCTOR					
SW-nHM4-*	04 - 24	0.315 (8.0)	216 (61)	5,230 (1,594)	10,459 (3,188)
SW-nHM4-*	26 - 48	0.323 (8.2)	231 (65)	4,977 (1,517)	9,954 (3,034)
SW-nHM4-*	50 - 96	0.378 (9.6)	316 (89)	3,632 (1,107)	7,264 (2,214)

Note: Diameter and weight subject to change without notice

Installation equipment information

PARAMETER	VALUE	
Typical Weight (includes cable and balance weight)	550 lbs	(250kg)
Min-Max Radius of rotation	2.85-4.76 ft	(0.87-1.45m)
Wrapping Speed	3 miles per hour	(5km per hour)

Installation Hardware

A full range of hardware and accessories are available as part of the SkyWrap solution. Many different options are available to suit individual structure types and environmental conditions. Please contact AFL for more information.

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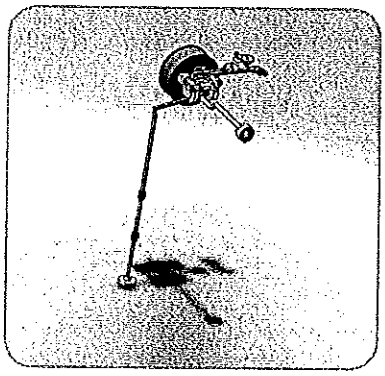
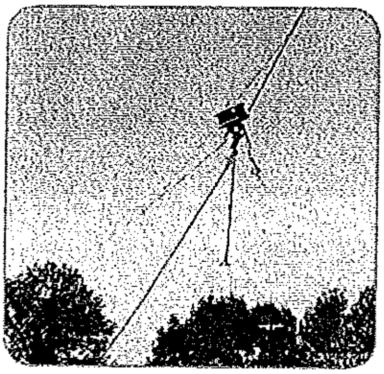
AFL

Fiber Optic Cable





AccessWrap™

AccessWrap provides a quick, cost effective and sustainable solution to taking fibre optic connections the 'last mile' on distribution power lines.

Based on proven SkyWrap® technology, cable is wrapped around the existing overhead powerline infrastructure with minimal disruption to service and no modification requirements to structures. The cable can be wrapped on phase conductors of 6 kV to 50 kV and is designed to withstand the aggressive environments of aerial applications in any climate.

AFL provides a complete solution from line surveys, installation planning to supply of cable, installation equipment and project management. AFL can also offer after sales service support packages to suit specific requirements.

Benefits:

- Utilise existing power line infrastructure to minimise capital investment
- Alleviate problems of land access and areas of difficult terrain
- Significantly reduce cost of excavation and trenching
- Extend fibre networks to remote LTE equipment in the roll out of mobile 4G
- Connectivity where terrain and line of sight issues make wireless less reliable
- Extend customer reach for FTTx applications particularly in rural and remote areas
- Integration as part of Smart Metering technology
- Reduce capital costs for subscriber based fibre networks

Features:

- Proven technology, SkyWrap installations has been in service for over 25 years
- Quick, cost effective installation
- Use where access is limited (e.g. easements and rights of way)
- Minimal environmental impact
- Installation equipment weight and size is specially designed for installation on overhead lines in the 6 kV to 50 kV range
- Fibre counts up to 24, any type of single mode or multimode fibre
- The AccessWrap System includes fibre optic cable, hardware and installation equipment

Ordering Information:

Please contact your local AFL Representative or sales@AFL-europe.com to discuss your requirement for AccessWrap

ВЯРНО С ОРИГИНАЛА

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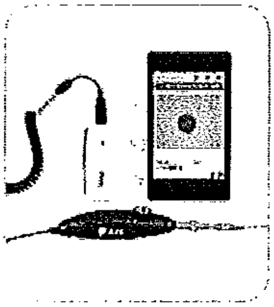
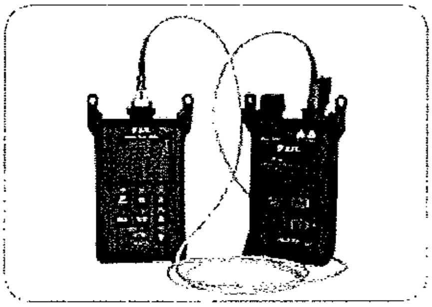
Please Contact your AFL Sales Rep for information about any of our other products or services.

TEST AND INSPECTION

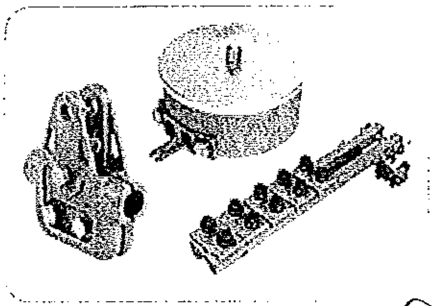


FOCIS WiFi



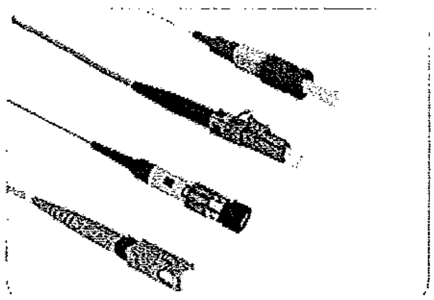
SMLP5-5 Optical Loss Test Kit

FIBER OPTIC CABLE ACCESSORIES

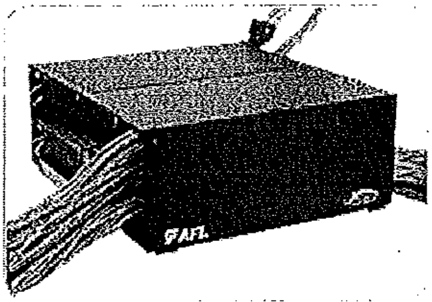


OPGW Suspension, SB01 Splice Enclosure, Bolted Dead End

FIBER INSIDE PLANT



FUSEConnect® Connectors



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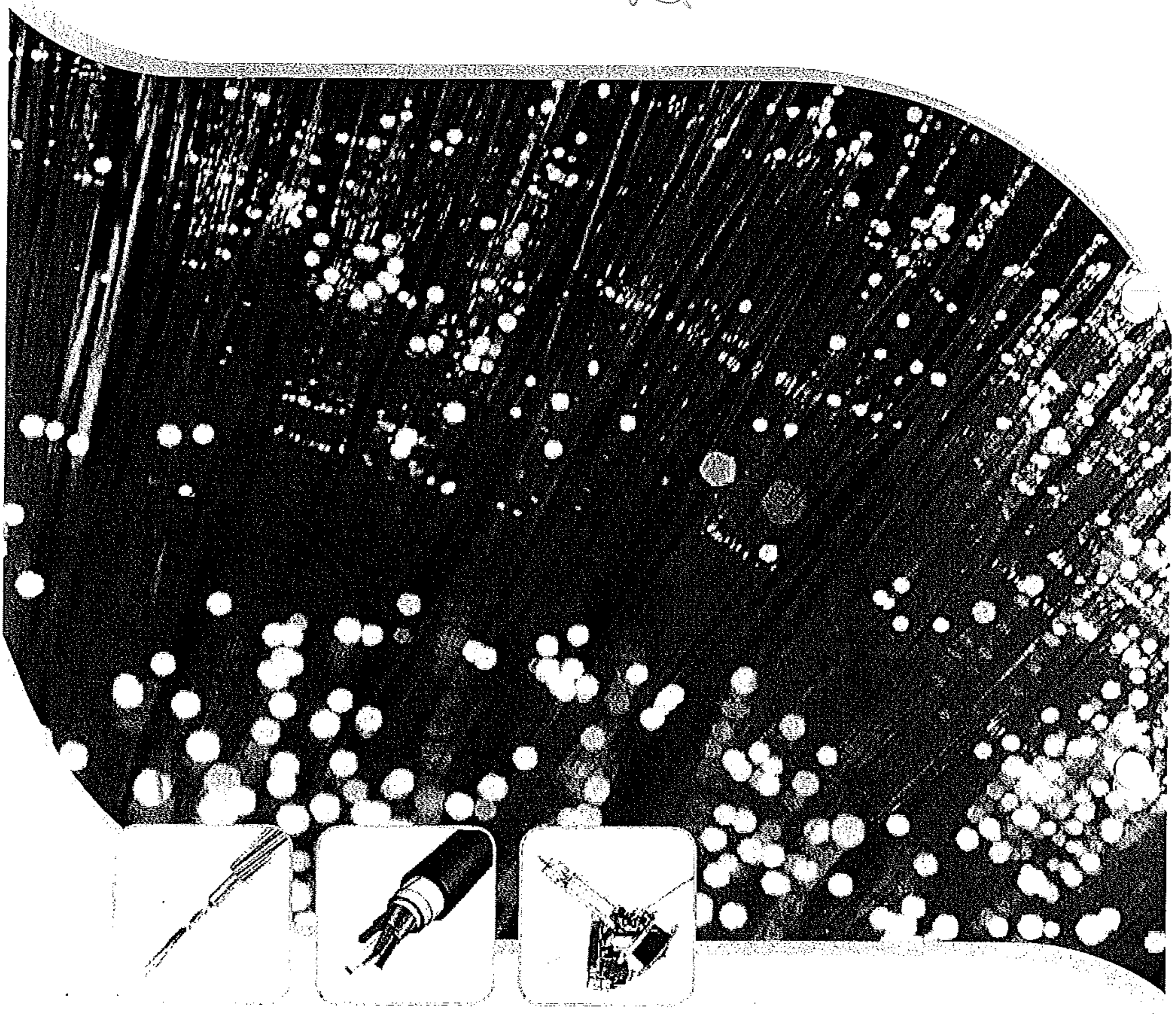

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CAT-01009 6.5.2017

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Приложение № 2 към Предложение за изпълнение на поръчката – декларации за съответствие, включително и на предлаганото изпълнение с изискванията на параграф „Съответствие на предлаганото изделие със стандартизационните документи”

ДЗЗД „ЕИК ДРАГАЛЕВЦИ"
Пловдив

ДЕКЛАРАЦИЯ

За съответствие на предлаганите материали, апаратура, оборудване, съоръжения и резервни части

Долуподписаният, Ехиязар Гарабед Узунян, Представляващ обединение - ДЗЗД „ЕИК ДРАГАЛЕВЦИ", участник в открита процедура, обявена от "ЧЕЗ Разпределение България" АД, с предмет: „Подмяна на маслонапълнена кабелна електропроводна линия 110 kV „Драгалевци" - елемент от критичната инфраструктура на разпределителната мрежа 110 kV на град София", реф. № PPC 17-041, с настоящото

ДЕКЛАРИРАМ, ЧЕ:

Доставяните от нас материали, апаратура, оборудване, съоръжения и резервни части са в съответствие с изискванията и стандартите, посочени от възложителя в раздел II. Технически спецификации.

В допълнение, съгласно изискването на т. 3 от таблица 10.4.1 от Предложение за изпълнение на поръчката, предлаганото изпълнение на Основна цифрова надлъжна диференциална защита (комплект от две релета), Съкратено наименование на материала: ЦЗ ВКЕЛ 110 kV, съответства със стандартизационните документи:

- БДС EN 60255-22-1:2008 Измервателни релета и защитни съоръжения Част 22-1: Изпитване на смущаващи въздействия. Изпитване на пакети импулси с честота 1 MHz (IEC 60255-22-1:2007) или еквивалентно/и;
- БДС EN 60255-22-2:2008 Измервателни релета и защитни съоръжения. Част 22-2: Изпитвания на електрически смущаващи въздействия - Изпитване на устойчивост на електростатични разряди (IEC 60255-22-2:2008) или еквивалентно/и;
- БДС EN 60255-22-3:2008 Измервателни релета и защитни съоръжения. Част 22-3: Изпитвания на електрически смущаващи въздействия. Изпитване на устойчивост на излъчено електромагнитно поле (IEC 60255-22-3:2007) или еквивалентно/и;
- БДС EN 60255-22-4:2008 Измервателни релета и защитни съоръжения. Част 22-4: Изпитвания на електрически смущаващи въздействия. Изпитване на устойчивост на електрически бърз преходен процес/пакет импулси (IEC 60255-22-4:2008) или еквивалентно/и;
- БДС EN 60255-22-5:2011 Измервателни релета и защитни съоръжения. Част 22-5: Изпитвания на електрически смущаващи въздействия. Изпитване на устойчивост на импулс (IEC 60255-22-5:2008) или еквивалентно/и;
- БДС EN 60255-22-6:2003 Електрически релета. Част 22-6: Изпитвания за електрически смущаващи въздействия на измервателни релета и защитни съоръжения. Устойчивост на кондуктивни смущаващи въздействия, индуктирани от радиочестотни полета (IEC 60255-22-6:2001) или еквивалентно/и;
- БДС EN 60255-27:2014 Измервателни релета и защитни съоръжения. Част 27: Изисквания за безопасност на продукта (IEC 60255-27:2013) или еквивалентно/и;
- БДС EN 60255-1:2010 Измервателни релета и защитни съоръжения. Част 1: Общи изисквания (IEC 60255-1:2009) или еквивалентно/и;
- БДС EN 60255-5:2002 Електрически релета. Част 5: Координация на изолацията за измервателни релета и защитни съоръжения. Изисквания и изпитвания (IEC 60255-5:2000) или еквивалентно/и;
- БДС EN 60255-6:2003 Електрически релета. Част 6: Измервателни релета и защитни съоръжения (IEC 60255-6:1988, с промени) или еквивалентно/и;
- БДС EN 60255-11:2010 Измервателни релета и защитни съоръжения. Част 11: Спадания, кратковременни прекъсвания, промени и пулсации на напрежението върху помощни захранващи изводи (IEC 60255-11:2008) или еквивалентно/и;
- БДС EN 60255-21-1:2003 Електрически релета. Част 21: Изпитвания на вибрации, удари, тръскане и сеизмични изпитвания на измервателни релета и защитни съоръжения. Раздел 1: Изпитвания на вибрации (синусоидални) (IEC 60255-21-1:1988) или еквивалентно/и;
- БДС EN 60255-21-2:2003 Електрически релета. Част 21: Изпитвания на вибрации, удари, тръскане и сеизмични изпитвания на измервателни релета и защитни съоръжения. Раздел 2: Изпитвания на удари и тръскане (IEC 60255-21-2:1988) или еквивалентно/и;

- БДС EN 60255-21-3:2003 Електрически релета. Част 21: Изпитвания на вибрации, удари, тръскане и сеизмични изпитвания на измервателни релета и защитни съоръжения. Раздел 3: Сеизмични изпитвания (IEC 60255-21-3:1993) или еквивалентно/и;
- БДС EN 60068-2-1:2007 Изпитване на въздействия на околната среда. Част 2-1: Изпитвания. Изпитване А: Студ (IEC 60068-2-1:2007) или еквивалентно/и;
- БДС EN 60068-2-2:2008 Изпитване на въздействия на околната среда. Част 2-2: Изпитвания. Изпитване В: Суха топлина (IEC 60068-2-2:2007) или еквивалентно/и;
- БДС EN 61000-4-3:2006 Електромагнитна съвместимост (ЕМС). Част 4-3: Методи за изпитване и измерване. Изпитване за устойчивост на излъчено радиочестотно електромагнитно поле (IEC 61000-4-3:2006) или еквивалентно/и;
- БДС EN 61000-4-4:2006 Електромагнитна съвместимост (ЕМС). Част 4-4: Методи за изпитване и измерване. Изпитване на устойчивост на електрически бърз преходен процес/пакет импулси (IEC 61000-4-4:2004) или еквивалентно/и;
- БДС EN 61000-4-5:2014 Електромагнитна съвместимост (ЕМС). Част 4-5: Методи за изпитване и измерване. Изпитване на устойчивост на отскок (IEC 61000-4-5:2014) или еквивалентно/и;
- БДС EN 61000-4-6:2014 Електромагнитна съвместимост (ЕМС). Част 4-6: Методи за изпитване и измерване. Устойчивост на кондуктивни смущаващи въздействия, индуктирани от радиочестотни полета (IEC 61000-4-6:2013) или еквивалентно/и;
- БДС EN 61000-4-8:2010 Електромагнитна съвместимост (ЕМС). Част 4-8: Методи за изпитване и измерване. Изпитване на устойчивост на магнитно поле, причинено от честоти на захранващите напрежения (IEC 61000-4-8:2009) или еквивалентно/и;
- БДС EN 61850-5:2013 Съобщителни мрежи и системи за автоматизация на преноса и разпределението на енергия. Част 5: Изисквания за връзки за функции и модели на устройства (IEC 61850-5:2013) или еквивалентно/и;
- БДС EN 60870-5-103:2003 Устройства и системи за дистанционно управление. Част 5-103: Протоколи за предаване. Съпътстващ стандарт за информационния интерфейс на защитни устройства (IEC 60870-5-103:1997) или еквивалентно/и.

Дата 19.06.2017 г.

Декларатор: ____________

Ехиязар Узунян

Представляващ Обединение – ДЗЗД "ЕИК ДРАГАЛЕВЦИ"

ДЗЗД „ЕИК ДРАГАЛЕВЦИ" Пловдив

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Превод от английски език, извършен от Даниела Кирилова Тодорова:

[Лого – не се чете]

Дата
2017 – Юни -14
Съгласувано от, телефон
АндерсАхлщтрьом, +46 240 7834 56
И-мейл
anders.ahlstrom@se.abb.com
Факс:
+ 46 240 78 38 91
Наш реф.:
17BG365611
Проект:
ЧЕЗ Разпределение България АД поръчка за подмяна и модернизация на кабелна линия 110 kV „Драгалевци" в София

ДЕКЛАРАЦИЯ ЗА СЪОТВЕТСТВИЕ СЪС СТАНДАРТИ И ПРОИЗХОД

На вниманието на всички заинтересовани,

Ние, АББ АЛ, Лудвика, Швеция, с настоящото декларираме, че всички наши вентилни отводи тип PEXLIM PO96-XV123 са проектирани, произведени и тествани, съгласно и в съответствие със следните стандарти, директиви и други нормативни документи:

Директива: ЕМС директива 2004/108/ЕС
Приложим ЕС IEC 60099-4, Вентилни отводи – Част 4 – Металоокисни хармонизирани вентилни отводи без отвори за а.с. системи.

ANSI/IEEE C62.11 и изискванията посочени по-долу в нашето предложение за горепосочения проект.
Оборудването се произвежда в нашата фабрика АББ в Лудвика, Швеция.
Процесът по Инженеринг, Производство и Тестване на посочените стоки ще бъде извършен съгласно нашите Системи за качество и управление, съгласно сертификацията по ISO 9001/ISO 14001.
Настоящото се издава да послужи, където е необходимо.

Искрено Ваш,

[подпис-не се чете]

АндерсАхлщрьом
Локален Маркет Мениджър
АББ АБ
Високоволтови Продукти

ДЗЗД „ЕИК ДРАГАЛЕВЦИ" Пловдив

ИНТЕРКОМПЛЕКС ООД ПЛОВДИВ