REF 541, REF 543 and REF 545 Feeder terminals

Buyer’s guide

(Blanck page)

REF 541, REF 543 and REF 545
Feeder terminals

1MRS 750443-MBG

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Features

- Feeder terminal for protection, control, measurement and supervision of medium voltage networks
- New application areas for power quality measurement, protection, capacitor bank protection and control and motor protection
- Voltage and current measurement via conventional measuring transformers or current and voltage sensors
- Fixed man-machine interface including a large graphic display, or an external display module for flexible switchgear installation
- Extended functionality including protection, control, measurement, communication, power quality and condition monitoring
- Protection functions including e.g. non-directional and directional overcurrent and earth-fault protection, residual voltage, overvoltage and undervoltage protection, thermal overload protection, CBFP and auto-reclosing
- Control functions including local and remote control of switching objects, status indication of the switching objects and interlockings on bay and station level
- Measurement of phase currents, phase-to-phase and phase-to-neutral voltages, residual current and voltage, frequency, power factor, active and reactive power and energy, etc.
- Condition monitoring including circuit-breaker condition monitoring, trip circuit supervision and internal self-supervision of the feeder terminal
- Additional functions including synchro-check, frequency protection, capacitor bank protection and control, measurement of current and voltage harmonics
- RTD/analogue module for temperature measurement, current/voltage measurement and mA-outputs
- Communication over two communication interfaces: one for local communication with a PC and the other for remote communication via a substation communication system
- Part of the ABB Substation Automation system

Application

The REF 541, REF 543 and REF 545 feeder terminals are designed to be used for protection, control, measurement and supervision of medium voltage networks. They can be used with different kinds of switchgear including single busbar, double busbar and duplex systems. The protection functions also support different types of networks such as isolated neutral networks, resonant-earthed networks and partially earthed networks. Application area also covers medium-sized three phase asynchronous motors as well as protection and control of shunt capacitor banks used for reactive power compensation. In addition to protection, measurement, control and condition monitoring functions, the feeder terminals are provided with a large amount of PLC functions allowing several automation and sequence logic functions needed for substation automation to be integrated into one unit.

The data communication properties include SPA bus communication or LON bus communication with higher-level equipment. Further, the LON communication together with the PLC functions minimizes the need for hardwiring between the feeder terminals.

Design

The feeder terminals REF 541, REF 543 and REF 545 differ from each other regarding the number of digital inputs and outputs available. Please, refer to section “Ordering” for more details. These feeder terminals incorporate a wide range of feeder terminal functions:

- Protection functions
- Measurement functions
- Power quality functions
- Control functions
- Condition monitoring functions
- General functions
- Communication functions
- Standard functions

The function blocks are documented on the CD-ROM “Technical Descriptions of Functions” (1MRS 750889-MCD).

Protection functions

Protection is one of the most important functions of the REF 54_ feeder terminal. The protection function blocks are independent of each other and have their own setting groups, data recording, etc.

Either Rogowski coils or conventional current transformers can be used for protection functions based on current measurement. Correspondingly, voltage dividers or voltage transformers are used for protection functions based on voltage measurement.

For further information about functionality levels and the protection functions included in them, refer to the table “Functionality levels, protection functions” in section “Ordering”.

Measurement functions

The measurement functions include three-phase currents, neutral current, three-phase voltages, residual voltage, frequency, active and reactive power and power factor. In addition, other measurement functions are available.

As a standard feature the REF 54_ terminal includes pulse counter inputs. The number of pulse inputs varies from 7 (REF 541) to 10 (REF 545) according to the REF variant.

Disturbance recorder

The transient disturbance recorder is able to record 16 current or voltage waveforms and 16 logic digital signals. The sampling frequency of the analogue inputs is 2 kHz at the rated frequency of 50 Hz and 2.4 kHz at the rated frequency of 60 Hz.

The user can set the length of a recording within a range determined by the number of analogue inputs used. The number of recordings depends on the sampling frequency, length of recordings and number of analogue inputs.

The recordings can be uploaded with a DR-Collector Tool which converts the data to a COMTRADE format. The DR-Collector Tool is supported in CAP501 and CAP505 relay tools.

Power quality functions

Power quality functions enable measurement of total harmonic distortion (THD) of voltage and current, and total demand distortion (TDD) of current. Individual harmonics are measured up to 13th.

The power quality functions produce statistical data about harmonic distortion for long term evaluation. Short time average and maximum values for THD and individual harmonics are also supported.

LIB 510 supports graphical presentation of harmonics in the PQ Monitoring Tool.

Control functions

The control functions are used to indicate the status of switching devices, i.e. circuit breakers and disconnectors, and to execute open and close commands for controllable switching devices of the switchgear. Furthermore, control functions provide on/off switching objects for control logic purposes and miscellaneous objects for data monitoring, etc.

The control functions configured with the CAP 505 Relay Product Engineering Tools are linked to object status indicators included in the MIMIC configuration picture displayed on the MMI. The object status indicators are used to indicate the status of switching devices via the MIMIC picture and to control them locally. The status of different objects, e.g. open/close/undefined, displayed in the MIMIC view can be freely designed.

Condition monitoring functions

Condition monitoring function blocks such as supervision of the energizing current and voltage input circuit, operation time counter, circuit breaker electric wear, scheduled maintenance, trip circuit supervision and breaker travel time are available for the REF 54_ feeder terminals.

General functions

Additional functions are available for different general purposes to be used in logics such as activation of MMI backlight, switchgroups, and resetting of operation indications, latched output signals, registers and disturbance recorder.

Communication functions

The feeder terminal REF 54_ provides two serial communication protocols: SPA and LON.

Standard functions

Standard functions are used for logics such as interlocking, alarming and control sequencing. The use of logic functions is not limited and the functions can be interconnected with each other as well as with protection, measurement, power quality, control, condition monitoring and general functions. In addition, the digital inputs and outputs and LON inputs and outputs can be connected to standard functions by using the Relay Configuration Tool.

Other functions

Low auxiliary voltage indication

The REF 54_ feeder terminal is provided with a low auxiliary voltage indication feature. The power supply module issues an internal alarm signal when a drop in the power supply voltage is detected (ACFail, active low). The alarm signal is activated if the power supply voltage falls about 10% below the lowest rated DC input voltage of the power supply module.

The indication of a low auxiliary voltage is available in the feeder terminal configuration environment and can be configured to activate an alarm.

Overtemperature indication

The REF 54_ feeder terminal includes an internal temperature supervision function. The power supply module issues an internal alarm signal when overtemperature has been detected inside the terminal enclosure. The alarm signal will be activated once the temperature inside the terminal enclosure increases to +78°C (+75°...+83°C). Overtemperature indication is available in the feeder terminal configuration and can be configured to activate an alarm.

Analogue channels

The feeder terminal measures the analogue signals needed for protection, measuring, etc. via sensors or galvanically separated matching transformers.

Depending on whether sensors are included or not, REF 54_ feeder terminals have 9 (without sensors) or 10 (with sensors) analogue channels. The number of channels used depends on the feeder terminal configuration and the kind of matching transformers or sensor inputs used.

In addition to 9 conventional matching transformers, sensors developed by ABB can be used parallel in REF 54_ feeder terminals. The feeder terminal has 9 sensor inputs. A current sensor (Rogowski coil) or a voltage divider can be connected to each sensor input. Please, see the connection diagram below for details. When ordering, please note the type of analogue inputs.

Analogue channels of the feeder terminal are configured with the CAP 505 Relay Product Engineering Tools.

A separate scaling factor can be set for each analogue channel. The factors enable differences between the ratings of the protected unit and those of the measuring device (CTs, VTs etc.). The setting value 1.00 means that the rated value of the protected unit is exactly the same as that of the measuring device.

Calculated analogue channels

The REF 54_ feeder terminal includes virtual channels to obtain neutral current and residual voltage when sensors are used. Sensors are connected to the feeder terminal via coaxial cables and therefore a residual connection of phase currents or an open-delta connection of phase voltages cannot be made. Both the amplitude and the phase angle are calculated for the virtual channels.

Though primarily meant to be used with sensors, the calculated analogue channels can also be used with conventional current and voltage transformers.

Note! When sensitive earth-fault protection is needed, core balance transformers are not recommended to be replaced with the numerically derived sum of phase currents. Normally, an earth-fault setting below 10% of the rated value requires the use of a core balance transformer.

Digital inputs

The digital inputs of the feeder terminals are voltage-controlled and optically isolated. The function of a digital input can be inverted. The programmable filter time removes debounces and short disturbances on a digital input. The filter time can be set for each digital input separately.

Some specific digital inputs can be programmed to operate as pulse counters. When a digital input is programmed to operate as a pulse counter, pulse counting frequency can be up to100 Hz.

Oscillation suppression

The feeder terminals have two global parameters for the suppression of digital input oscillation. The settings of these parameters determine the oscillation level and hysteresis for all digital inputs. Event is generated in case oscillation is detected.

Attributes of a digital input for feeder terminal configuration

For each digital input, the status of the input (value), the time tag for the status change (time) and the validity of the digital input (invalidity) can be issued by the attributes. These attributes are available in the feeder terminal configuration and can be used for various purposes.

RTD/analogue inputs

The REF 541 and REF 543 feeder terminals equipped with an RTD/analogue module (RTD1) have eight general purpose analogue inputs for DC measurement. The RTD/analogue inputs are galvanically isolated from the feeder terminal power supply and enclosure. The general purpose RTD/analogue inputs accept voltage-, current- or resistance-type signals. For each signal type, a number of measurement ranges is availaible. RTD/analogue inputs can be applied for e.g. temperature measurement.

Digital outputs

The outputs of the feeder terminal are categorized as follows:

- HSPO: High-speed power output, double-pole contact, preferred for tripping purposes and for circuit breaker and disconnector control
- PO: Power output, either single-pole or double-pole contact, preferred for circuit breaker and disconnector control
- SO: Signal output, either NO (Normally Open) or NO/NC (Normally Open/Normally Closed) contact. The output contact is a normal-duty contact and cannot be used for controlling a heavy load such as a circuit breaker.

Analogue outputs

The REF 541 and REF 543 feeder terminals equipped with an RTD/analogue module have four general purpose 0...20 mA analogue current outputs. All outputs are galvanically isolated from the supply and enclosure of the feeder terminal and from each other. Analogue outputs can be applied when interfacing with panels meters, existing station equipment, etc.

Alarm LED indicators

The feeder terminal offers eight alarm LED indicators to be configured with the CAP 505 Relay Product Engineering Tools. The LED colours (green, yellow, red), their use, and the ON and OFF state texts can be freely defined. Three basic operation modes are supported: non-latched, latched-steady and latched blinking. Alarms can be acknowledged remotely, locally or by using logic of the feeder terminal.

The alarm channels include time tagging for detected alarms. The time tagging principle used depends on the operation mode.

Interlocking LED indicator

The interlocking LED indicates that control operation has been interlocked or that the interlocking is in bybass mode, e.g. when control is possible despite of interlocking.

Trip Circuit Supervision

The purpose of this function is to supervise the tripping circuitry of the circuit breaker. An alarm will be generated in case a faulty tripping circuit, e.g. a circuit is not able to perform a trip, is detected.

The supervision is based on the constant-current injection through the tripping circuitry.

Display panel

The feeder terminal is provided with either a fixed display or an external display module. The external display module requires a separate voltage supply from a common source with the main unit. The display consists of 19 rows divided into two windows: a main window (17 rows) and an assisting window (2 rows).

The graphic display presents detailed information on MIMIC, objects, events, measurements, control alarms, and parameters. The assisting window is used for terminal-dependent indications/alarms and help messages.

Additionally, the panel includes the following MMI items:

- three push-buttons for object control (I, O, object selection)
- eight freely programmable alarm LEDs
- LED indicator for control interlocking
- three protection LED indicators
- MMI push-button section with four arrow buttons and buttons for clear and enter
- optically isolated serial communication port
- backlight and contrast control
- freely programmable button (F) which can be used in the configuration of the feeder terminal
- a button for remote/local control

The MMI has two main levels, the user level and the technical level. The user level is for “everyday” measurements and monitoring whereas the technical level is intended for advanced feeder terminal programming.

Serial communication

The feeder terminal has two serial communication ports, one on the front panel and the other on the rear panel.

The standard optical ABB connector (RS-232 connection) on the front panel is intended for the connection of a PC for configuring the feeder terminal with the CAP 50_ tools. The front interface uses the SPA bus protocol.

The 9-pin RS-485 connection on the rear panel connects the feeder terminal to the substation automation system via the SPA bus or the LON bus. The fibre-optic interface module type RER 103 is used to connect the feeder terminal to the fibre-optic communication bus. The RER 103 module supports both SPA bus and LON bus communication.

Self-supervision

The feeder terminal REF 54_ is provided with an extensive self-supervision system. The self-supervision system handles run-time fault situations and informs the user of faults via the MMI and LON/SPA communication.

When a fault has been detected, the green Ready indicator starts blinking and a fault indication text appears on the MMI. At the same time, the feeder terminal delivers a fault signal to the self-supervision output relay and blocks the protection trip outputs.

The fault code is stored in the memory and can be read from the feeder terminal main menu.

Feeder terminal configuration

The Relay Configuration Tool, which is included in the CAP 505 Relay Product Engineering Tools, is used for configuring the basic terminal, protection and logic function blocks, control and measurement functions, timers and other functional elements included in the logic functions category.

The Relay Configuration Tool is based on the IEC 61131-3 standard. The programmable system of REF 54_ feeder terminals allows the output contacts to be operated in accordance with the state of the logic inputs and the outputs of the protection, control, measurement and condition monitoring functions. The PLC functions (e.g. interlocking and alarm logic) are programmed with Boolean functions, timers, counters, comparators and flip-flops. The program is written in a function block diagram language by using the configuration software.

Mimic configuration with Relay Mimic Editor

The Relay Mimic Editor, which is included in the CAP 505 Relay Product Engineering Tools, is used for designing the MIMIC configuration picture displayed on the graphic LCD and the alarm channels of the feeder terminal. The mimic configuration picture may include circuit breakers, disconnectors, indicators, measurement data objects and user-defined texts and explanations. Any configuration can be saved for later use.

All of the eight alarm function blocks can be configured in the same alarm view of the mimic editor. ON and OFF state texts (only one language version at a time can be supported for the alarm) and LED colours can be defined. Three different colours can be used to define the ON and OFF state. Three basic modes are available:

- non-latched
- latched-steady
- latched blinking

Interlocking LED texts can also be defined in the same alarm view but the colour of the interlocking LED cannot be changed.

Lon network configuration

The LON Network Tool is used for binding network variables between the feeder terminal units. Typically, LON is used for transferring object status data (open, close, undefined) between units for interlocking sequences running in each feeder terminal.

Feeder terminal parameterization

The parameters of the feeder terminal units can be set either locally over the MMI or externally via the serial communication using the CAP 505 Relay Product Engineering Tools.

Local parameterization

When the parameters are set locally, the setting parameters can be chosen from the hierarchical menu structure. The desired language for parameter description can be selected.

External parameterization

CAP 505 Relay Product Engineering Tools are used for parameterizing and setting the feeder terminals externally. The parameters can be set off-line on a PC and downloaded to the feeder terminal over a communication port. The menu structure of the setting tool, including views for parameterization and settings, is the same as the menu structure of the feeder terminal.

Terminal connections

All external circuits are connected to the terminal blocks on the rear panel. The terminal block for the measuring transformers consists of fixed screw terminals.

ABB sensors (Rogowski coil or voltage divider) are connected to the feeder terminal with special type of shielded twin BNC connectors. This type of connectors are used to improve reliability and protection against disturbances. Unused sensor inputs must be short-circuited with special connectors, type 1MRS 120515.

The serial interface RS-485 on the rear panel is used for connecting the feeder terminal to the SPA bus or the LON bus. The SPA/LON bus is connected via a connection module type RER 103 fitted to the 9-pin D-type subminiature connector and screwed to the rear panel.

The digital input and output contacts of the feeder terminal are connected to the multipole connectors.

Protective earth is connected to the screw marked with the earth symbol.

Connector description

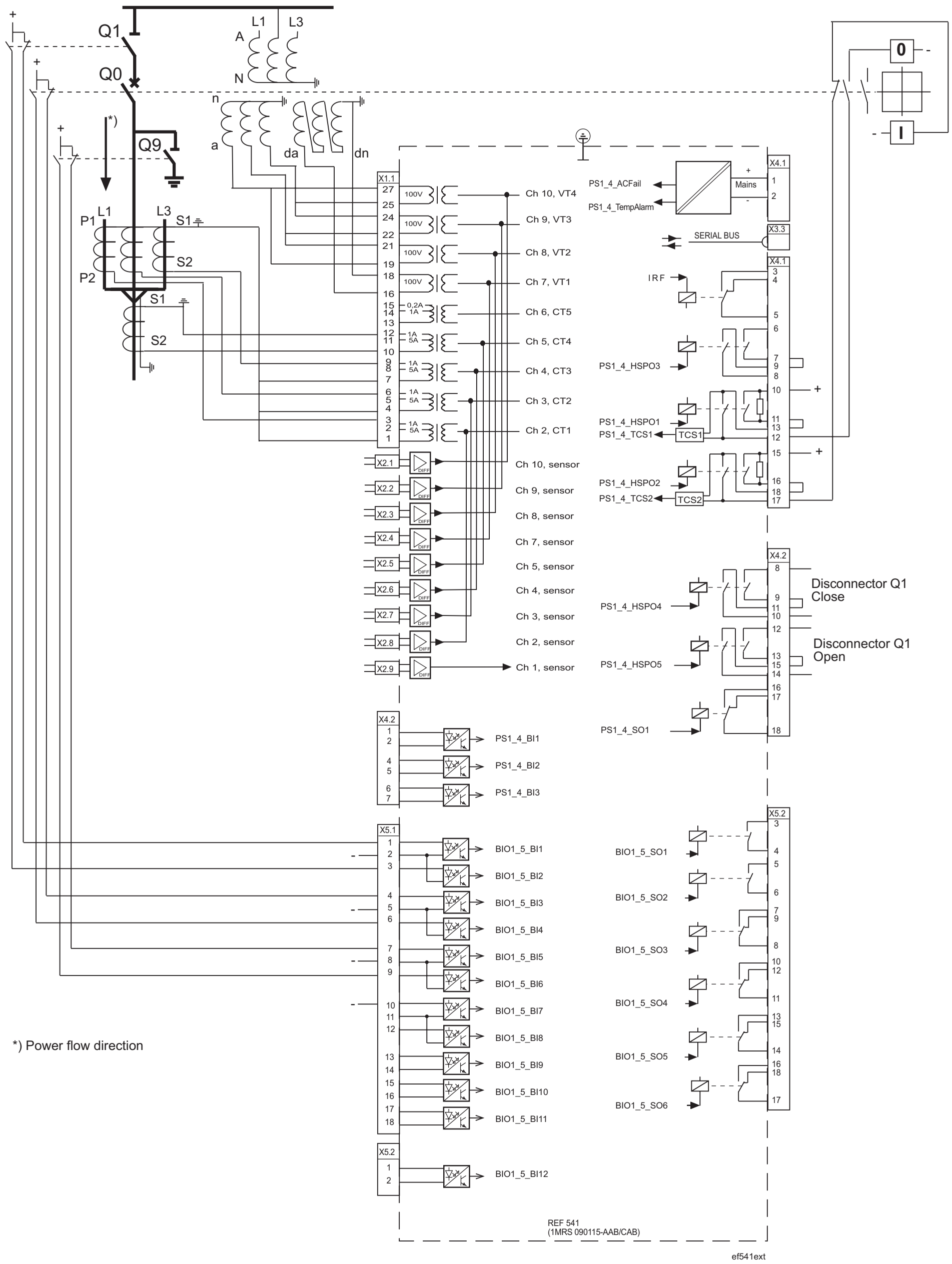


Fig. 1 Sample connection diagram of REF 541

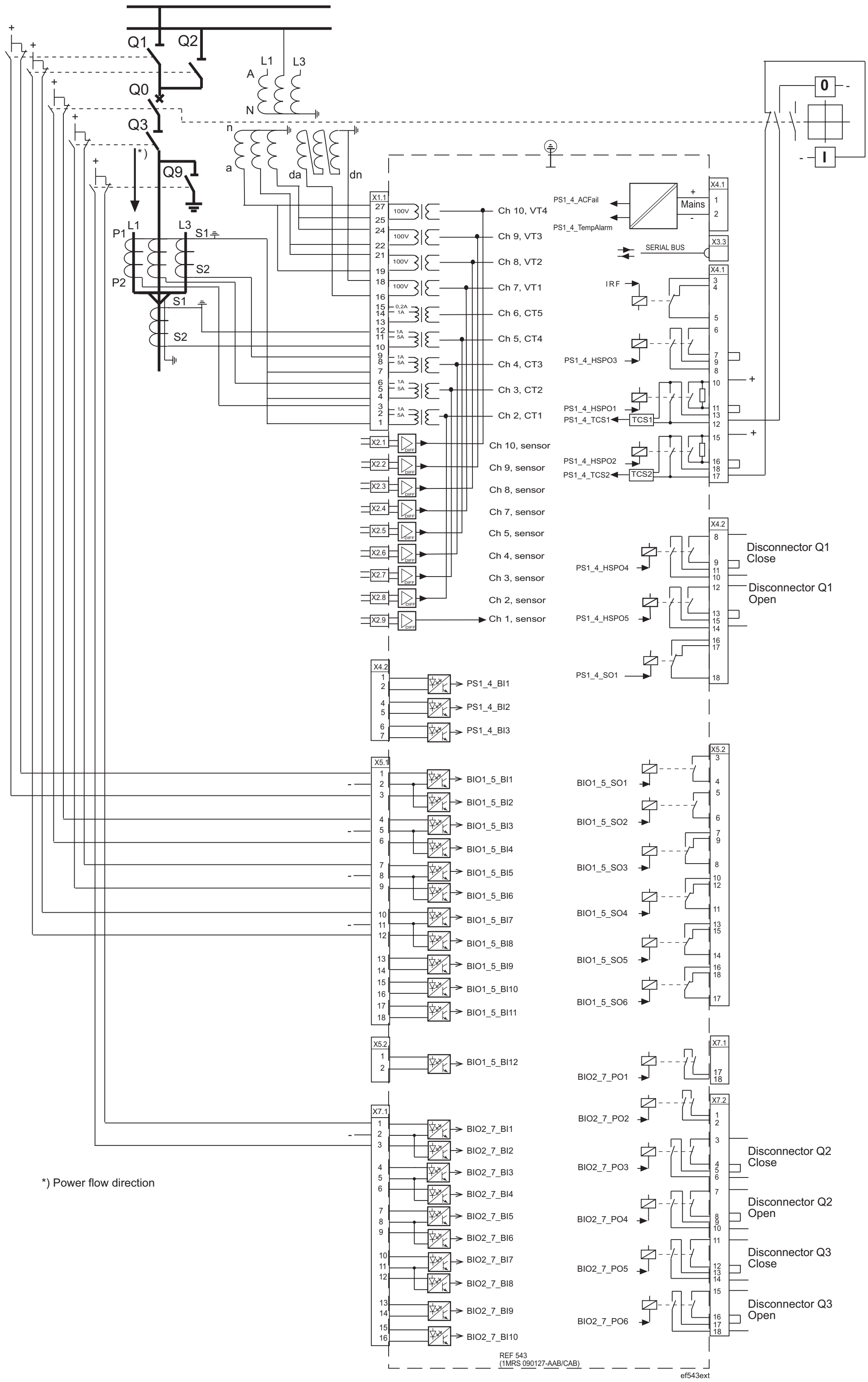


Fig. 2 Sample connection diagram of REF 543

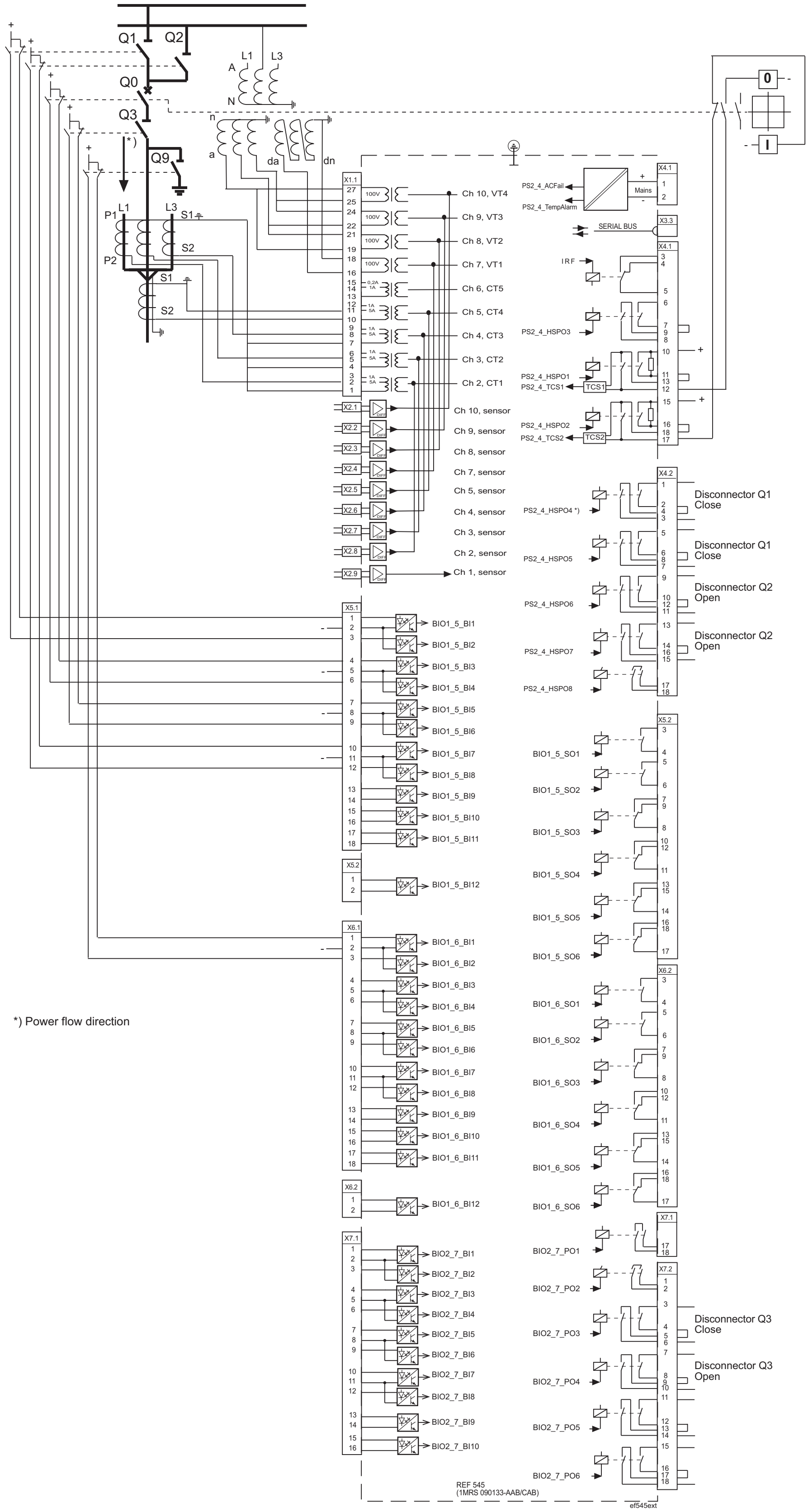


Fig. 3 Sample connection diagram of REF 545

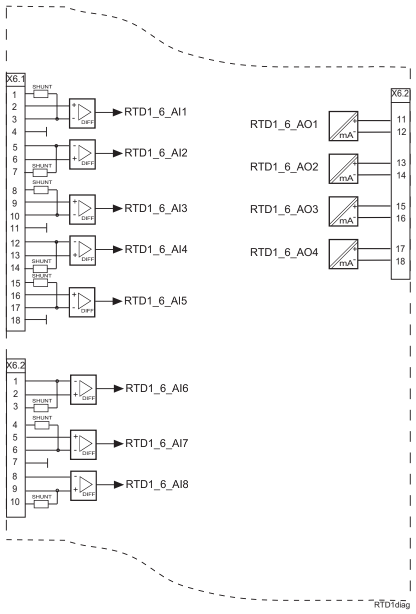


Fig. 4 Terminal diagram of the RTD/analogue module

Auxiliary voltage

For its operation, the REF 54_ terminal, including the external display module, requires a secured auxiliary voltage supply. The feeder terminal's internal power supply module forms the voltages required by the feeder terminal electronics. The power supply module is a galvanically isolated (fly-back type) dc/dc converter. A green LED indicator on the front panel is lit when the power supply module is in operation.

Power supply

There are two basic versions of power supply modules available for the REF 54_: type PS1/_ and type PS2/_, see Table 9.
The sensitivity of digital inputs depends on the type of the power supply module.

Technical data

Table 1: General function blocks

Functions	Description
INDRESET	Resetting of operation indicators, latched output signals, registers and waveforms of i.e. in the disturbance recorder
MMIWAKE	Activation of MMI backlight
SWGRP1…SWGRP20	Switchgroup SWGRP1…SWGRP20

Table 2: Standard function blocks

Functions	Description
ABS	Absolute value
ACOS	Principal arc cosine
ADD	Extensible adder
AND	Extensible AND connection
ASIN	Arc sine
ATAN	Arc tangent
BITGET	Get one bit
BITSET	Set one bit
BOOL_TO_*	Type conversion from BOOL to WORD/ USINT/ UINT/ UDINT/ SINT/ REAL/ DWORD/ DINT/ BYTE
BOOL2INT	Type conversion from BOOL inputs to INT output
BYTE_TO_*	Type conversion from BYTE to WORD/ DWORD
COMH	Hysteresis comparator
COS	Cosine in radians
CTD	Down-counter
CTU	Up-counter
CTUD	Up-down counter
DATE_TO_UDINT	Type conversion from DATE to UDINT
DINT_TO_*	Type conversion from DINT to SINT/ REAL/ INT
DIV	Divider
DWORD_TO_*	Type conversion from DWORD to WORD/ BYTE
EQ	Extensible comparison to equal
EXP	Natural exponential
EXPT	Exponentiation
F_TRIG	Falling edge detector
GE	Extensible comparison to greater or equal
GT	Extensible comparison to greater
INT_TO_*	Type conversion from INT to REAL/ DINT
INT2BOOL	Type conversion from INT input to BOOL outputs
LE	Extensible comparison to less or equal
LIMIT	Limitation
LN	Natural logarithm
LOG	Logarithm base 10
LT	Extensible comparison to less
MAX	Extensible maximum
MIN	Extensible minimum
MOD	Modulo
MOVE	Move
MUL	Extensible multiplier
MUX	Extensible multiplexer
NE	Comparison to greater or less
NOT	Complement
OR	Extensible OR connection
R_TRIG	Rising edge detector
REAL_TO_*	Type conversion from REAL to USINT/ UINT/ UDINT/ SINT/ INT/ DINT
ROL	Rotate to left
ROR	Rotate to right
RS	Reset dominant bistable function block
RS_D	Reset dominant bistable function block with data input
SEL	Binary selection
SHL	Bit-shift to left
SHR	Bit-shift to right
SIN	Sine in radians
SINT_TO_*	Type conversion from SINT to REAL/ INT/ DINT
SUB	Subtractor
SQRT	Square root
SR	Set dominant bistable function block
XOR	Extensible exclusive OR connection
TAN	Tangent in radians
TIME_TO_*	Type conversion from TIME to UDINT/ TOD/ REAL
TOD_TO_*	Type conversion from TOD to UDINT/ TIME/ REAL

Table 2: Standard function blocks

Functions	Description
TOF	Off-delay timer
TON	On-delay timer
TP	Pulse
TRUNC_*	Truncation toward zero
UDINT_TO_*	Type conversion from UDINT to USINT/ UINT/ REAL
UINT_TO_*	Type conversion from UINT to USINT/ UDINT/ REAL/ BOOL
USINT_TO_*	Type conversion from USINT to UINT/ UDINT/ REAL
WORD_TO_*	Type conversion from WORD to DWORD/ BYTE

Table 3: Condition monitoring function blocks

Functions	Description
CMBWEAR1	Circuit-breaker electric wear 1
CMBWEAR2	Circuit-breaker electric wear 2
CMCU3	Supervision function of the energizing current input circuit
CMGAS1	Gas pressure monitoring
CMGAS3	Three-pole gas pressure monitoring
CMSCHED	Scheduled maintenance
CMSPRC1	Spring charging control 1
CMTCS1	Trip circuit supervision 1
CMTCS2	Trip circuit supervision 2
CMTIME1	Operate time counter 1 for the operate time used (motors)
CMTIME2	Operate time counter 2 for the operate time used (motors)
CMTRAV1	Breaker travel time 1
CMVO3	Supervision function of the energizing voltage input circuit

Table 4: Control function blocks

Functions	Description
COCB1	Circuit breaker 1 control with indication
COCB2	Circuit breaker 2 control with indication
COCBDIR	Direct open for CBs via MMI
CO3DC1	Three-state disconnector 1 with indication
CO3DC2	Three-state disconnector 2 with indication
CODC1…COCD5	Disconnector 1…5 control with indication
COIND1…COIND8	Switching device 1…8 indication
COLOCAT	Logic-controlled control position selector
COSW1…COSW4	On/off switch 1…4
MMIALAR1…MMIALAR8	Alarm channel 1…8, LED indicator
MMIDATA1…MMIDATA5	MIMIC data monitoring point 1...5

Power factor controller, COPFC	
The number of capacitor banks to be controlled	1...4
The relational step sizes and the type of the switching sequence	1:1:1:1 linear; 1:1:1:1 circul.; 1:1:2:2 circul.; 1:2:2:2 linear; 1:2:2:2 circul.; 1:2:4:4 linear; 1:2:4:4 circul.; 1:2:4:8
Size of the first capacitor bank (should be the smallest)	10.0...50000.0 kvar
Target value for daytime cos φ	0.70...1.00
Day unit	Inductive; Capacitive
Target value for night-time cos φ	0.70...1.00
Night unit	Inductive; Capacitive
Setting the reconnection inhibit time (discharge time)	0.5...6000.0 s
Sensitivity in the inductive side	60.0...200.0%
Sensitivity in the capacitive side	0.0...100.0%
Alarm limit for the maximum reactive power	0.1...100.0 Mvar
Alarm limit for the minimum reactive power	-100.0...0.0 Mvar
Overvoltage limit when the switching in is inhibited	0.80...1.60 x Un
Operation mode	Not in use; Automatic mode; Manual mode; Testing mode
Starting the automatic testing sequence	Not activated; Start
Calculation method	Normal; Integral
Control principle	Progressive; Direct
Duration demand	0.5...6000.0 s
Day&night switch	Not in use; Digital input; Internal clock; By setting
Manual command	Not activated; Remove one step; Add one step: Disconnect all
Recorded data	
Number of switching operations per day	0...65535
Number of switching operations per week	0...65535
Operation accuracies	±2.0% of set value or ±0.02 x rated value
Accuracy class of operation	2.0

Table 5: Measurement function blocks

General measurement/ analogue input on RTD/analogue module, MEAI1...8	
The general measurement function blocks can be used to measure general purpose dc or ac voltage signals with a sensor input. They also include a REAL type input which can be used to monitor any internal REAL type IEC 61131-3 based signal, e.g. input data from the RTD/analogue module.	
GE1…3 (V dc/ac)	-10000.00000...10000.00000
General REAL type input	-10000.00000...10000.00000

Analogue output on RTD/analogue module, MEAO1...4	
The analogue output function blocks handle the scaling of any internal REAL type IEC 61131-3 based signal to fit a selectable 0…20 mA or 4…20 mA range for use with the outputs on the RTD/analogue module.	
General REAL type input	-10000.00000...10000.00000

Neutral current measurement, MECU1A and MECU1B	
Io (A)	0.0…20000.0 A
Io (%)	0.0…80.0% In

Three-phase current measurement, MECU3A and MECU3B	
IL1	0.0…20000.0 A
IL2	0.0…20000.0 A
IL3	0.0…20000.0 A
IL1	0.0…1000.0% In
IL2	0.0…1000.0% In
IL3	0.0…1000.0% In
IL1 demand	0.0…20000.0 A
IL2 demand	0.0…20000.0 A
IL3 demand	0.0…20000.0 A
IL1 demand	0.0…1000.0% In
IL2 demand	0.0…1000.0% In
IL3 demand	0.0…1000.0% In

Transient disturbance recorder for 16 analogue channels, MEDREC16	
The transient disturbance recorder MEDREC16 is used for recording the current and voltage waveforms, as well as the status data of internal IEC 61131-3 based logic signals and digital inputs connected to the feeder terminals. The maximum number of analogue inputs and logic signals is 16. One fundamental cycle contains 40 samples.	
Operation mode	Saturation Overwrite Extension
Pre-trg time	0…100%
Over limit ILx	0.00…40.00 x In
Over limit Io	0.00…40.00 x In
Over limit Iob	0.00…40.00 x In
Over limit Uo	0.00…2.00 x Un
Over limit Ux	0.00…2.00 x Un
Over limit Uxy	0.00…2.00 x Un
Over limit U12b	0.00…2.00 x Un
Over limit ILxb	0.00…40.00 x In
Under limit Ux	0.00…2.00 x Un
Under limit Uxy	0.00…2.00 x Un
AI filter time	0.000…60.000 s

The recording can be triggered by any (or several) of the alternatives listed below:

- triggering on the rising or falling edge of any (or several) of the digital inputs
- triggering on overcurrent, overvoltage or undervoltage
- manual triggering via the menu or with the push-button F on the front panel (if configured)
- triggering via serial communication
- periodic triggering

The recording length depends on the number of recordings and inputs used. For example, the following combination of recording length, number of recordings and number of inputs is available at 50 Hz:

# recordings \ # inputs	1	3	10
1	1066 cyc. 21.3 s	399 cyc. 7.9 s	125 cyc. 2.5 s
5	212 cyc. 4.2 s	79 cyc. 1.5 s	25 cyc. 0.5 s
10	106 cyc. 2.1 s	39 cyc. 0.7 s	12 cyc. 0.24 s

System frequency measurement, MEFR1	
Frequency	10.00…75.00 Hz
Average Freq.	10.00…75.00 Hz
Voltage U	0.0…2.0 x Un

Three-phase power and energy measurement, MEPE7	
P3 (kW)	-999999…999999 kW
Q3 (kvar)	-999999…999999 kvar
Power factor DPF	-1.00…1.00
Power factor PF	-1.00…1.00
P3 demand (kW)	-999999…999999 kW
Q3 demand (kvar)	-999999…999999 kvar
Energy kWh	0…999999999 kWh
Reverse kWh	0…999999999 kWh
Energy kvarh	0…999999999 kvarh
Reverse kvarh	0…999999999 kvarh

Residual voltage measurement, MEVO1A and MEVO1B	
Uo	0…150000 V
Uo	0.0…120.0% Un

Three-phase voltage measurement, MEVO3A and MEVO3B	
UL1_U12	0.00…999.99 kV
UL2_U23	0.00…999.99 kV
UL3_U31	0.00…999.99 kV
UL1_U12	0.00…2.00 x Un
UL2_U23	0.00…2.00 x Un
UL3_U31	0.00…2.00 x Un
UL1_U12 average	0.00…999.99 kV
UL2_U23 average	0.00…999.99 kV
UL3_U31 average	0.00…999.99 kV
UL1_U12 average	0.00…2.00 x Un
UL2_U23 average	0.00…2.00 x Un
UL3_U31 average	0.00…2.00 x Un

Table 6: Protection function blocks

Three-phase non-directional overcurrent protection, low-set stage, NOC3Low, 3I>	
Start current	0.10…5.00 x In
Operate time at DT mode	0.05…300.00 s
Time multiplier at IDMT mode	0.05…1.00
Operation mode	Not in use Definite time Extremely inverse Very inverse Normal inverse Long time inverse RI-type inverse RD-type inverse
Measuring mode	Peak-to-peak Fundamental frequency
Drop-off time of the operate time counter	0...1000 ms
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	±2.5% of set value or ±0.01 x In
Start time	Injected currents > 2.0 x start current: internal time < 32 ms total time < 40 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the trip output)
Reset ratio, typically	0.95
Retardation time	< 45 ms
Operate time accuracy at DT mode	±2% of set value or ±20 ms
Accuracy class index E at IDMT mode	Class index E = 5.0 or ±20 ms

Three-phase non-directional overcurrent protection, high-set stage, NOC3High, 3I>> and instantaneous stage, NOC3Inst, 3I>>>	
Start current	0.10…40.00 x In
Operate time	0.05…300.00 s
Operation mode	Not in use Definite time Instantaneous
Measuring mode	Peak-to-peak Fundamental frequency
Drop-off time of the operate time counter	0...1000 ms
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	0.1...10 x In: ±2.5% of set value or ±0.01 x In 10...40 x In: ±5.0% of set value
Start time	Injected currents > 2.0 x start current: internal time < 32 ms total time < 40 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the trip output)
Reset ratio, typically	0.95
Retardation time	< 45 ms
Operate time accuracy at DT mode	±2% of set value or ±20 ms

Three-phase directional O/C function, low-set stage, DOC6Low, I>→	
Operation mode	Not in use; Definite time Extremely inv.; Very inverse Normal inverse Long-time inv.; RI-type inverse RD-type inverse
Start current	0.05…40.00 x In
Operate time	0.05…300.00 s
Time multiplier	0.05…1.00
Basic angle φ_b	0…90°
Operation direction	Forward Reverse
Earth-fault protection	Disabled Enabled
Measuring mode	Phase-to-phase voltages, peak-to-peak measurement Phase-to-phase voltages, fundamental freq. measurement Phase-to-earth voltages, peak-to-peak measurement Phase-to-earth voltages, fundamental freq. measurement
Drop-off time of the operate time counter	0...1000 ms
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	0.1...10 x In: ±2.5% of set value or ±0.01 x In 10...40 x In: ±5.0% of set value ±2.5% of measured voltage or ±0.01 x Un ±2°
Start time	Injected currents > 2.0 x start current: internal time < 42 ms total time < 50 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the trip output)
Reset ratio, typically	0.95
Retardation time	< 45 ms
Operate time accuracy at DT mode	±2% of set value or ±20 ms
Accuracy class index E at IDMT mode	Class index E = 5.0 or ±20 ms

Three-phase directional O/C function, high-set stage, DOC6High, I>>→, and instantaneous stage, DOC6Inst, I>>>→	
Operation mode	Not in use Definite time Instantaneous
Start current	0.05…40.00 x In
Operate time	0.05…300.00 s
Basic angle φ_b	0…90°
Operation direction	Forward Reverse
Earth-fault protection	Disabled Enabled
Non-directional operation (when the direction cannot be determined)	Disabled Enabled
Measuring mode	Phase-to-phase voltages, peak-to-peak measurement Phase-to-phase voltages, fundamental freq. measurement Phase-to-earth voltages, peak-to-peak measurement Phase-to-earth voltages, fundamental freq. measurement
Drop-off time of the operate time counter	0...1000 ms
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	0.1...10 x In: ±2.5% of set value or ±0.01 x In 10...40 x In: ±5.0% of set value ±2.5% of measured voltage or ±0.01 x Un ±2°
Start time	Injected currents > 2.0 x start current: internal time < 42 ms total time < 50 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the trip output)
Reset ratio, typically	0.95
Retardation time	< 45 ms
Operate time accuracy at DT mode	±2% of set value or ±20 ms

Non-directional earth-fault protection, low-set stage, NEF1Low, Io>	
Start current	1.0…100.0% of In
Operate time at DT mode	0.05…300.00 s
Time multiplier at IDMT mode	0.05…1.00
Operation mode	Not in use Definite time Extremely inverse Very inverse Normal inverse Long time inverse RI-type inverse RD-type inverse
Measuring mode	Peak-to-peak Fundamental frequency
Drop-off time of the operate time counter	0...1000 ms
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	±2.5% of set value + 0.0005 x In
Start time	Injected currents > 2.0 x start current: internal time < 32 ms total time < 40 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the trip output)
Reset ratio, typically	0.95
Retardation time	< 45 ms
Operate time accuracy at DT mode	±2% of set value or ±20 ms
Accuracy class index E at IDMT mode	Class index E = 5.0 or ±20 ms

Non-directional earth-fault protection, high-set stage, NEF1High, Io>>, and instantaneous stage, NEF1Inst, Io>>>	
Start current	0.10…12.00 x In
Operate time	0.05…300.00 s
Operation mode	Not in use Definite time Instantaneous
Measuring mode	Peak-to-peak Fundamental frequency
Drop-off time of the operate time counter	0...1000 ms
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	±2.5% of set value or + 0.01 x In
Start time	Injected currents > 2.0 x start current: internal time < 32 ms total time < 40 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the trip output)
Reset ratio, typically	0.95
Retardation time	< 45 ms
Operate time accuracy at DT mode	±2% of set value or ±20 ms

Directional earth-fault protection, low-set stage, DEF2Low, Io>→	
Start current Start voltage Operate time at DT mode Time multiplier at IDMT mode Operation mode Operation criteria Operation direction Basic angle φ_b Operation characteristic Intermittent E/F Measuring mode Drop-off time of the operate time counter	1.0…25.0% of In 2.0…100.0% of Un 0.1…300.0 s 0.05…1.00 Not in use Definite time Extremely inverse Very inverse Normal inverse Long time inverse Basic angle & Uo Basic angle IoSin/Cos & Uo IoSin/Cos Non-directional Io Non-directional Uo Forward Reverse -90° -60° -30° 0° IoSin(φ) IoCos(φ) Not active Active Peak-to-peak Fundamental frequency 0...1000 ms
 Operation accuracy Start time Reset time Reset ratio, typically Retardation time Operate time accuracy at DT mode Accuracy class index E at IDMT mode	Note! The values below apply when f/fn = 0.95...1.05 ±2.5% of set value + 0.0005 x In ±2.5% of set value or + 0.01 x Un Phase angle ±2° Injected neutral current > 2.0 x start current and residual voltage > 2.0 x start voltage: internal time < 72 ms total time < 80 ms 40...1000 ms (depends on the minimum pulse width set for the trip output) 0.95 < 50 ms ±2% of set value or ±20 ms Class index E = 5.0 or ±20 ms

Directional earth-fault protection, high-set stage, DEF2High, Io>>→, and instantaneous stage, DEF2Inst, Io>>>→	
Start current	1.0…200.0% of In
Start voltage	2.0…100.0% of Un
Operate time	0.1…300.0 s
Operation mode	Not in use Definite time Instantaneous
Operation criteria	Basic angle & Uo Basic angle IoSin/Cos & Uo IoSin/Cos Non-directional Io Non-directional Uo
Operation direction	Forward Reverse
Basic angle φ_b	-90° -60° -30° 0°
Operation characteristic	IoSin(φ) IoCos(φ)
Intermittent E/F	Not active Active
Measuring mode	Peak-to-peak Fundamental frequency
Drop-off time of the operate time counter	0...1000 ms
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	±2.5% of set value + 0.0005 x In ±2.5% of set value or + 0.01 x Un Phase angle ±2°
Start time	Injected neutral current > 2.0 x start current and residual voltage > 2.0 x start voltage: internal time < 72 ms total time < 80 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the trip output)
Reset ratio, typically	0.95
Retardation time	< 50 ms
Operate time accuracy at DT mode	±2% of set value or ±20 ms

Residual overvoltage protection, low-set stage, ROV1Low, Uo>	
Start voltage Operate time Operation mode Measuring mode	2.0…20.0% of Un 0.05…300.00 s Not in use Definite time Peak-to-peak Fundamental frequency
 Operation accuracy Start time Reset time Reset ratio, typically Retardation time Operate time accuracy at DT mode	Note! The values below apply when f/fn = 0.95...1.05 ±2.5% of set value or ±0.01 x Un Injected voltages >2 x start voltage: internal time < 32 ms total time < 40 ms 40...1000 ms (depends on the minimum pulse width set for the trip output) 0.95 Total time for blocking: < 25 ms Total time when voltage drops below start value: < 50 ms ±2% of set value or ±20 ms

Residual overvoltage protection, high-set stage, ROV1High, Uo>>, and instantaneous stage, ROV1Inst, Uo>>>	
Start voltage Operate time Operation mode Measuring mode	2.0…80.0% of Un 0.05…300.00 s Not in use Definite time Peak-to-peak Fundamental frequency
 Operation accuracy Start time Reset time Reset ratio, typically Retardation time Operate time accuracy at DT mode	Note! The values below apply when f/fn = 0.95...1.05 ±2.5% of set value or ±0.01 x Un Injected voltages >2 x start voltage: internal time < 32 ms total time < 40 ms 40...1000 ms (depends on the minimum pulse width set for the trip output) 0.95 Total time for blocking: < 25 ms Total time when voltage drops below start value: < 50 ms ±2% of set value or ±20 ms

Three-phase thermal overload protection for cables, TOL3Cab, 3	
Time constant for the cable Maximum load current for the cable Maximum temperature of conductor Reference temperature Trip temperature Prior alarm temperature Reclosure temperature Ambient temperature Operation mode (principle of ambient temperature compensation)	1…999 min 1.0…5000.0 A 40.0…150.0°C -50.0…100.0°C 80.0…120.0% 40.0…100.0% 40.0…100.0% -50.0…100.0°C Not in use No sensors; the set ambient temperature 1 sensor used 2 sensors used
 Operation accuracy Reset ratio	Note! The values below apply when f/fn = 0.95...1.05 ±1.0%, I = 0.1...10.0 x In Trip: (Calculated temp. rise - 0.1) / Trip temperature Start: (Calculated temp. rise - 0.1) / Prior alarm temperature

Three-phase thermal overload protection for motors, generators and transformers, TOL3Dev, 3	
BASIC SETTINGS	
Starting current of the motor	0.10...10.00 x In
Max. starting time permitted for the motor	0.1...120.0 s
Number of starts allowed from cold state	1...3
Type of device to be protected	Motor; through-ventilated, rated power < 1500 kW
	Motor; through-ventilated, rated power > 1500 kW
	Motor; surface cooling, rated power < 500 kW
	Motor; surface cooling, rated power > 500 kW
	Generator; hydro or small air-cooled turbine generators
	Generator; large turbine generators
	Transformer
Trip temperature	80.0…120.0%
Prior alarm temperature	40.0…100.0%
Restart inhibit (temperature limit for	
successful restarting)	40.0…100.0%
Ambient temperature	-50.0…100.0°C
Cooling time-constant	1.0...10.0 x time constant
Heating time-constant for generator or	
transformer	1...999 min
ADVANCED SETTINGS	
Short time-constant for stator	0.0...999.0 min
Long time-constant for stator	0.0...999.0 min
Weighting factor of the short time-constant for	
stator	0.00...1.00
Temperature rise of stator at rated current	
Maximum temperature of stator	0.0...350.0 °C
Short time-constant for rotor	0.0...350.0 °C
Long time-constant for rotor	0.0...999.0 min
Weighting factor of the short time-constant for	0.0...999.0 min
rotor	
Temperature rise of rotor at rated current	0.00...1.00
Maximum temperature of rotor	
	0.0...350.0 °C
	0.0...350.0 °C
Operation mode (principle of ambient	Not in use
temperature compensation)	No sensors; the set ambient temperature
	1 sensor used
	2 sensors used
Waiting time for a successful restart (Read-	
only parameter)	0...86400 s
Predicted time to the trip (Read-only	
parameter)	0...86400 s
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	±1.0%, I = 0.1...10.0 x In
Reset ratio	Trip: (Calculated temp. rise - 0.1) / Trip temperature
	Start: (Calculated temp. rise - 0.1) / Prior alarm temperature
	Restart: (Calculated temp. rise - 0.1) / Restart inhibit temperature limit

Three-phase overvoltage protection, low-set stage, OV3Low, 3U>	
Start voltage	0.10…1.60 x Un
Operate time	0.05…300.00 s
Time multiplier	0.05…1.00
Operation mode	Not in use Definite time A curve B curve
Measuring mode	Phase-to-phase voltages; peak-to-peak measurement Phase-to-phase voltages; fundamental freq. measurement Phase-to-earth voltages; fundamental freq. measurement
Operation hysteresis	1.0...5.0%
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	±2.5% of set value
Start time	Injected voltages = 1.1 x start voltage: internal time < 42 ms total time < 50 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the trip output)
Reset ratio	0.96 (range 0.95...0.99)
Retardation time	< 50 ms
Operate time accuracy at DT mode	±2% of set value or ±20 ms
Accuracy class index E at IDMT mode, typically	±20 ms

Three-phase overvoltage protection, high-set stage, OV3High, 3U>>	
Start voltage	0.10…1.60 x Un
Operate time	0.05…300.00 s
Operation mode	Not in use Definite time
Measuring mode	Phase-to-phase voltages; peak-to-peak measurement Phase-to-phase voltages; fundamental freq. measurement Phase-to-earth voltages; fundamental freq. measurement
Operation hysteresis	1.0...5.0%
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	±2.5% of set value
Start time	Injected voltages = 1.1 x start voltage: internal time < 42 ms total time < 50 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the trip output)
Reset ratio	0.96 (range 0.95...0.99)
Retardation time	< 50 ms
Operate time accuracy at DT mode	±2% of set value or ±20 ms

Three-phase undervoltage protection, low-set stage, UV3Low, 3U<	
Start voltage	0.10…1.20 x Un
Operate time	0.1…300.0 s
Time multiplier	0.1…1.0
Operation mode	Not in use Definite time C curve
Measuring mode	Phase-to-phase voltages; peak-to-peak measurement Phase-to-phase voltages; fundamental freq. measurement Phase-to-earth voltages; fundamental freq. measurement
Operation hysteresis	1.0...5.0%
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	±2.5% of set value or ±0.01 x Un
Start time	Injected voltages < 0.5 x start voltage: internal time < 32 ms total time < 40 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the trip output)
Reset ratio	1.04 (range 1.005...1.05)
Retardation time	< 60 ms
Operate time accuracy at DT mode	±2.5% of set value
Accuracy class index E at IDMT mode, typically	±35 ms

Three-phase undervoltage protection, high-set stage, UV3High, 3U<<	
Start voltage	0.10…1.20 x Un
Operate time	0.1…300.0 s
Operation mode	Not in use Definite time
Measuring mode	Phase-to-phase voltages; peak-to-peak measurement Phase-to-phase voltages; fundamental freq. measurement Phase-to-earth voltages; fundamental freq. measurement
Operation hysteresis	1.0...5.0%
	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	±2.5% of set value or ±0.01 x Un
Start time	Injected voltages < 0.5 x start voltage: internal time < 32 ms total time < 40 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the trip output)
Reset ratio	1.04 (range 1.005...1.05)
Retardation time	< 60 ms
Operate time accuracy at DT mode	±2.5% of set value

Phase-sequence voltage protection, PSV3St1 and PSV3St2, U_1<, U_2>, U_1>	
Start value U2>	0.01…1.00 x Un
Start value U1<	0.01…1.20 x Un
Start value U1>	0.80…1.60 x Un
Operate time U2>	0.04…60.00 s
Operate time U1<	0.04…60.00 s
Operate time U1>	0.04…60.00 s
Operation mode	Not in use; U1< & U2> & U1>; U1< & U2>; U2> & U1>; U1< & U1>; U2>; U1<; U1>
Dir. selection	Forward; Reverse; Input ROT_DIR

	Note! The values below apply when f/fn = 0.95...1.05
Operation accuracy	± 2.5% of set value or ± 0.01 x Un
Trip time	U2> operation: Injected negative-seq. voltage = 1.1 x start value: internal time < 42 ms total time < 50 ms U1< operation: Injected positive-seq. voltage = 0.50 x start value: internal time < 32 ms total time < 40 ms U1> operation: Injected positive-seq. voltage = 1.1 x start value: internal time < 42 ms total time < 50 ms
Reset time	70...1030 ms (depends on the minimum pulse width set for the TRIP output)
Reset ratio, typically	U2> operation: 0.96 U1< operation: 1.04 U1> operation: 0.99
Retardation time	< 45 ms (for all operations)
Operate time accuracy	± 2% of set value or ± 20 ms

Underfrequency or overfrequency protection, 5 stages, Freq1St1… Freq1St5, f</f>, df/dt	
Operation mode	Not in use f</f> 1 timer f</f> 2 timers f</f> OR df/dt> f</f> AND df/dt> f</f> OR df/dt< f</f> AND df/dt<
Undervoltage limit for blocking	0.30…0.90 x Un
Start value for under-/overfrequency prot.	25.00…75.00 Hz
Operate time for under-/overfrequency prot.	0.10…120.00 s
Start value for df/dt protection	0.2…10.0 Hz/s
Operate time for df/dt protection	0.12…120.00 s
Operation accuracy	Under-/overfrequency (f</f>): ±10 mHz Frequency rate of change (df/dt); real df/dt < ±5 Hz/s: ±100 mHz/s real df/dt < ±15 Hz/s: ±2.0% of real df/dt Undervoltage blocking: ±1.0% of set value
Start time	Total start times at fn = 50 Hz: Frequency measurement < 100 ms Df/dt measurement < 120 ms
Reset time	140...1000 ms (depends on the minimum pulse width set for the trip output)
Operate time accuracy	±2% of set value or ±30 ms

Start-up supervision for motors, MotStart, I_s^2t, n<	
Start current (for motor)	1.0...10.0 x In
Start time (for motor)	0.3...250.0 s
Time-based restart inhibit limit	1.0...500.0 s
Countdown rate of the time counter	2.0...250.0 s/h
Stalling time permitted for rotor	2.0...120.0 s
Operation mode	Not in use I^2t I^2t & Stall
Start counter (Read-only parameter)	0...99999
Time to restart enable (Read-only parameter)	0...99999 min
Stall input (signal for motor stalling indication; read-only parameter)	Not active Active

Operation accuracy Start time Reset ratio, typically Retardation time	f/fn = 0.95...1.05: ±2.5% of set value or ±0.01 x In f/fn = 0.95...1.50: internal time < 22 ms total time < 30 ms f/fn = 0.50...0.95: internal time < 32 ms total time < 40 ms 0.95 < 50 ms

Three-phase overload protection for shunt capacitor banks, OL3Cap, 3I>, 3I<			
Operate times of the overload stage Ib>			
I/Ib>	t [s]	Standard durations [s]	Standard
1.15	1799	1800	IEC 60871-1
1.20	299	300	IEC 60871-1
1.30	58	60	ANSI/IEEE 37.99, IEC 60871-1
1.40	13.5	15	ANSI/IEEE 37.99
1.70	0.9	1	ANSI/IEEE 37.99
2.00	0.29	0.3	ANSI/IEEE 37.99
2.20	0.1	0.12	ANSI/IEEE 37.99
Note! The minimum operate time is 100 ms			
Start current of trip stage Time multiplier k for trip stage Start current of alarm stage Operate time of alarm stage Start current of undercurrent stage Operate time of undercurrent stage Setting of reconnection inhibit time t_{rec}		0.30...1.50 x In 0.05...2.0 0.80...1.20 x Ib 0.5...6000.0 s 0.10...0.70 x Ib 0.1...120 s 0.5...6000 s	
Operation accuracies Start time Reset time Reset ratio Retardation time Operate time accuracy at definite time mode (alarm stage I_a>, undercurrent stage I<) Operate time accuracy at inverse time mode (trip stage I_b>)		Note! The values below apply when f/f_n=0.95...1.05 ±2.5% of set value or ±0.01 x I_n Injected currents = 2.0 x start current internal time < 32 ms total time < 40 ms 40...1000 ms (depends on the minimum pulse width set for the TRIP output) Overload stages: Typ. 0.95 Undercurrent stage: Typ. 1.05 Total retardation time when the current exceeds the start value: < 50 ms ±2% of set value or ±20 ms Depends on the frequency of the current measured: ±10% of theoretical value or ±40 ms	

Current unbalance protection for shunt capacitor banks, CUB1Cap, ∆I>	
Operation mode Alarm mode Start current of the tripping stage Operate time of the tripping stage in DT mode Time multiplier k for the tripping stage in IDMT mode Start current of the alarm stage Operate time of the alarm stage Disallowed number of faulty elements Level of natural unbalance compensation Recording of the natural unbalance phasor Location of capacitor fuses	Not in use; Definite time; Extremely inv.; Very inv.; Normal inv.; Long-time inv.; RI-type inv.; RD-type inv. Normal mode; Element counter 1.0...100.0%dIn 1.0...300 s 0.05...2.0 1.0...100.0%dIn 1.0...300 s 1...100 0.0...20.0%dIn Do not activate; Activate External; Internal

Faulty elements counter	
Amount of faulty elements in branch 1 of phase IL1	0...100
Amount of faulty elements in branch 2 of phase IL1	0...100
Amount of faulty elements in branch 1 of phase IL2	0...100
Amount of faulty elements in branch 2 of phase IL2	0...100
Amount of faulty elements in branch 1 of phase IL3	0...100
Amount of faulty elements in branch 2 of phase IL3	0...100
Operation accuracies	Note! The values below apply when f/f_n=0.95...1.05 ±2.5% of set value + 0.001 x dI_n Phase angle measurement: ±2°
Start time	Injected currents = 2.0 x start current internal time <32 ms total time <40 ms
Reset time	40...1000 ms (depends on the minimum pulse width set for the TRIP output)
Reset ratio	Typ. 0.95
Retardation time	< 45 ms
Operate time accuracy at definite-time mode	±2% of set value or ±20 ms
Operate time accuracy at inverse-time mode	Class index E = 5.0 or ±20 ms

Auto-reclosure function, AR5Func, O → I	
Number of reclosures	0…5
Initiation mode	Trip Start
AR1, AR2, AR3, AR4 starting line operation mode	No operation AR shot initiated Initiation of AR shot blocked
AR1 AR2, AR3, AR4 start delay	0…10.00 s
Dead time	0.20…300.00 s
Synchro-check	Not in use; ARSYNC in use
Discriminating time td	0…30.00 s
Operation accuracy	±1% of setting value or ±30 ms

Synchro-check/voltage check function stage 1 and stage 2, SCVCSt1 and SCVCSt2, SYNC	
Upper threshold voltage Umax	0.50…1.00 x Un
Lower threshold voltage Umin	0.10…0.80 x Un
Voltage difference ΔU	0.02…0.60 x Un
Phase angle difference Δphase	5…90°
Frequency difference Δf	0.02…5.00 Hz
Operation accuracy	Note! The values below apply when f/fn = 0.95...1.05 ±2.5% of set value or ±0.01 x Un ±10 mHz ±2°
Reset time	< 50 ms
Reset ratio	0.975 x Un
Operate time accuracy	±2% of set value or ±20 ms

Three-phase transformer inrush and motor start-up current detector Inrush3, $3I_{2f}$>	
Ratio I_{2f}/I_{1f}>	5…50%
Start current	0.10…5.00 x In
Operation mode	Not in use Inrush mode Start-up mode

 Operation accuracy Start time	Note! The values below apply when f/fn = 0.95...1.05 Current meas.: ±2.5% of set value or ±0.01 x In Ratio I_{2f}/I_{1f} measurement: ±5.0% of set value Internal time < 32 ms Total time < 40 ms

Phase discontinuity protection, CUB3Low, 3ΔI>	
Start unbalance Operate time Operation mode	10.0…95.0% 1.0…300.0 s Not in use Definite time
 Operation accuracy Start time Reset time Reset ratio, typically Retardation time Operate time accuracy at DT mode	Note! The values below apply when f/fn = 0.95...1.05 ±2.5% of set value or ±1% unit internal time < 95 ms total time < 100 ms 40...1000 ms (depends on the minimum pulse width set for the trip output) 0.95 Total time for blocking: < 25 ms Total time when current drops below start value: < 50 ms ±2% of set value or ±50 ms

Table 7: Power quality functions

Current waveform distortion measurement, PQCU3H	
The current waveform distortion measurement PQCU3H is used for measurement and statistical analysis of current waveform distortion. The standards concerning voltage distortion measurement are applied to current distortion measurement in PQCU3H. Data collection and analysis is done according to EN 50160. Measuring principles for individual harmonics and THD are adapted from the International standard IEC 61000-4-7. The American standard IEEE Std 1159 is also partly supported. Analysis can be done for one selected phase current or most distorted phase current can be tracked.	
Measuring modes Measurement activation Triggering mode Distortion factor	Not in use; L1; L2; L3; Worst phase Triggering by: setting parameter, binary input, date & time setting Single; Continuous; Periodic THD; TDD
Monitored values THD (3 sec and 10 min mean values) Harmonic components from 1st to 13th (3 sec mean values) Harmonic components from 2nd to 13th (10 min mean values)	 0.0 ... 1000.0% 0.0 ... 1000.0% In 0.0 ... 1000.0% In
Statistics Observation times for statistics Percentile setting Percentiles for each harmonic and THD Five fixed percentiles (1,5,50,95,99) for one selectable harmonic or THD Maximum values for each harmonic and THD Recorded data	 1 hour; 12 hours; 1 day; 2 days; 3 days; 4 days; 5 days; 6 days; 1 week 90.0 ... 99.5% 0.0 ... 1000.0% In 0.0 ... 1000.0% In 0.0 ... 1000.0% In One data set for updating; One data set from the previous observation period
Harmonic limit supervision Limit for THD Limits for each harmonic Recorded data	 0.0 ... 60.0% 0.0 ... 40.0% In If any limit should be exceeded, the whole harmonic set will be recorded during the maximum THD (3 sec values)

Table 7: Power quality functions

Current waveform distortion measurement, PQCU3H	
Operation criteria Fundamental frequency Frequency deviation Amplitude of the fundamental wave	 0.9 ... 1.1 Fn ≤ 0.5 Hz (difference between max and min values within one second) ≥ 1% In
Measurement accuracy Measured harmonic Im = 1st, ... , 10th Measured harmonic Im = 11th, ... , 13th	 In accordance with IEC 61000-4-7 ± 1.0% In, if Im < 10% In; ± 10% Im, if Im ≥ 10% In

Voltage waveform distortion measurement, PQVO3H	
The voltage waveform distortion measurement PQVO3H is used for measurement and statistical analysis of voltage waveform distortion. Data collection and analysis is done according to EN 50160. Measuring principles for individual harmonics and THD are adapted from the International standard IEC 61000-4-7. The American standard IEEE Std 1159 is also partly supported. Analysis can be done for one selected phase or phase-to-phase voltage or most distorted phase or phase-to-phase voltage can be tracked.	
Measuring modes Measurement activation Triggering mode	Not in use; L1; L2; L3; Worst phase; L1-L2; L2-L3; L3-L1; Worst main Triggering by: setting parameter, binary input, date & time setting Single; Continuous; Periodic
Monitored values THD (3 sec and 10 min mean values) Harmonic components from 1st to 13th (3 sec mean values) Harmonic components from 2nd to 13th (10 min mean values)	 0.0 ... 120.0% 0.0 ... 120.0% Un 0.0 ... 120.0% Un
Statistics Observation times for statistics Percentile setting Percentiles for each harmonic and THD Five fixed percentiles (1,5,50,95,99) for one selectable harmonic or THD Maximum values for each harmonic and THD Recorded data	 1 hour; 12 hours; 1 day; 2 days; 3 days; 4 days; 5 days; 6 days; 1 week 90.0 ... 99.5% 0.0 ... 120.0% Un 0.0 ... 120.0% Un 0.0 ... 120.0% Un One data set for updating; One data set from the previous observation period
Harmonic limit supervision Limit for THD Limits for each harmonic Recorded data	 0.0 ... 30.0% 0.0 ... 20.0% Un If any limit should be exceeded, the whole harmonic set will be recorded during the maximum THD (3 sec values)
Operation criteria Fundamental frequency Frequency deviation Amplitude of the fundamental wave	 0.9 ... 1.1 Fn ≤ 0.5 Hz (difference between max and min values within one second) ≥ 0.7 Un
Measurement accuracy Measured harmonic Um = 1st, ... , 10th Measured harmonic Um = 11th, ... , 13th	 In accordance with IEC 61000-4-7 ± 0.3% Un, if Um < 3% Un; ± 10% Um, if Um ≥ 3% Un

Table 8: Energizing inputs

Rated frequency	50.0/60.0 Hz

Table 8: Energizing inputs

Current inputs	rated current		0.2 A/1 A/5 A
	thermal withstand capability	continuously	1.5 A/4 A/20 A
		for 1 s	20 A/100 A/500 A
	dynamic current withstand, half-wave value		50 A/250 A/1250 A
	input impedance		<750 mΩ/<100mΩ/<20 mΩ
Voltage inputs	rated voltage		100 V/110 V/115 V/120 V (parameterization)
	voltage withstand, continuously		2 x U_n (240 V)
	burden at rated voltage		<0.5 VA
Sensor inputs, max 9	voltage range RMS		9.4 V RMS
	voltage range peak		±12 V
	input impedance		>4.7 MΩ
	input capacitance		< 1 nF

Table 9: Auxiliary power supplies

Type	PS1/240V (REF 541, REF 543)	PS2/240V (REF 545 only)	External display module	PS1/48V (REF 541, REF 543)	PS2/48V (REF 545 only)
Input voltage, ac	110/120/220/240 V			-	
Input voltage, dc	110/125/220 V			24/48/60 V	
Operating range	ac 85…110%, dc 80…120% of rated value			dc 80…120% of rated value	
Burden	<50 W				
Ripple in dc auxiliary voltage	max. 12% of the dc value				
Interruption time in auxiliary dc voltage without resetting	<50 ms, 110 V and <100 ms, 200 V				
Internal overtemperature indication	+78°C (+75…+83°C)				

Table 10: Digital inputs

Power supply version	PS1/240 V, PS2/240 V	PS1/48 V, PS2/48V
Input voltage, dc	110/125/220 V	24/48/60/110/125/220 V
Operating range, dc	80…265 V	18...265 V
Current drain	~2…25 mA	
Power consumption/input	<0.8 W	
Pulse counting (specific digital inputs), frequency range	0…100 Hz	

Table 11: RTD/analogue inputs

Supported RTD sensors	100 Ω Platinum 250 Ω Platinum 1000 Ω Platinum	TCR 0.00385 (DIN 43760) TCR 0.00385 TCR 0.00385
	100 Ω Nickel 120 Ω Nickel 250 Ω Nickel 1000 Ω Nickel	TCR 0.00618 (DIN 43760) TCR 0.00618 TCR 0.00618 TCR 0.00618
	10 Ω Copper	TCR 0.00427
Max lead resistance (three-wire measurement)	200 Ω per lead	
Accuracy	±0.5% of full scale ±1.0% of full scale for 10 Ω Copper RTD	
Isolation	2 kV (inputs to outputs and inputs to protective earth)	
Sampling frequency	5 Hz	
Response time	≤Filter time + 30 ms (430 ms...5.03 s)	
RTD/ Resistance sensing current	max 4.2 mA RMS 6.2 mA RMS for 10 Ω Copper	
Current input impedance	274 Ω ±0.1%	

Table 12: Signal outputs

Max system voltage	250 V ac/dc
Continuous carry	5 A
Make and carry for 0.5 s	10 A
Make and carry for 3 s	8 A
Breaking capacity when control circuit time-constant L/R <40 ms, at 48/110/220 V dc	1 A/0.25 A/0.15 A

Table 13: Power outputs

Max system voltage		250 V ac/dc
Continuous carry		5 A
Make and carry for 0.5 s		30 A
Make and carry for 3 s		15 A
Breaking capacity when control circuit time constant L/R <40 ms, at 48/110/220 V dc		5 A/3 A/1 A
Minimum contact load		100 mA, 24 V ac/dc (2.4 VA)
TCS (Trip Circuit Supervision)	Control voltage range	20…265 V ac/dc
	Current drain through the supervision circuit	approx. 1.5 mA (0.99…1.72 mA)
	Minimum voltage (threshold) over a contact	20 V ac/dc (15…20 V)

Table 14: Analogue outputs

Output range	0...20 mA
Accuracy	±0.5% of full scale
Max load	600 Ω
Isolation	2 kV (output to output, output to inputs and output to protective earth)
Response time	≤85 ms

Table 15: Environmental conditions

Specified service temperature range		-10…+55°C
Transport and storage temperature range		-40…+70°C
Degree of protection by enclosure	Front side, flush-mounted	IP 54
	Rear side, connection terminals	IP 20
Dry heat test		according to IEC 60068-2-2
Dry cold test		according to IEC 60068-2-1
Damp heat test, cyclic		according to IEC 60068-2-30 r.h. = 95%, T = 20°…55°C
Storage temperature tests		according to IEC 60068-2-48

Table 16: Standard tests

Insulation tests	Dielectric test IEC 60255-5	Test voltage	2 kV, 50 Hz, 1 min.
	Impulse voltage test IEC 60255-5	Test voltage	5 kV, unipolar impulses, waveform 1.2/50 µs, source energy 0.5 J
	Insulation resistance measurements IEC 60255-5	Insulation resistance	> 100 MΩ, 500 V dc
Mechanical tests	Vibration tests (sinusoidal)		IEC 60255-21-1, class I
	Shock and bump test		IEC 60255-21-2, class I

Table 17: Electromagnetic compatibility tests

The EMC immunity test level fulfills the requirements listed below		
1 MHz burst disturbance test, class III, IEC 60255-22-1	common mode	2.5 kV
	differential mode	1.0 kV
Electrostatic discharge test, class III, IEC 61000-4-2 and IEC 60255-22-2	for contact discharge	6 kV
	for air discharge	8 kV
Radio frequency interference test	conducted, common mode IEC 61000-4-6	10 V (rms), f = 150 kHz…80 MHz
	radiated, amplitude-modulated IEC 61000-4-3	10 V/m (rms), f = 80…1000 MHz
	radiated, pulse-modulated ENV 50204	10 V/m, f = 900 MHz
	radiated, test with a portable transmitter IEC 60255-22-3, method C	f = 77.2 MHz, P = 6 W; f = 172.25 MHz, P = 5 W
Fast transient disturbance test (IEC 60255-22-4 and IEC 61000-4-4)	power supply	4 kV
	I/O ports	2 kV
Surge immunity test (IEC 61000-4-5)	power supply	4 kV, common mode 2 kV, differential mode
	I/O ports	2 kV, common mode 1 kV, differential mode
Power frequency (50 Hz) magnetic field, IEC 61000-4-8	100 A/m	
Voltage dips and short interruptions, IEC 61000-4-11	30%, 10 ms >90%, 5000 ms	
Electromagnetic emission tests EN 55011 and EN 50081-2	conducted RF emission (mains terminal)	EN 55011, class A
	radiated RF emission	EN 55011, class A
CE approval	Complies with the EMC directive 89/336/EEC and the LV directive 73/23/EEC	

Table 18: Data communication

Rear interface, connector X3.3	RS-485 connection	
	LON bus or SPA bus, selectable	
	the fibre-optic interface module RER 103 is needed for galvanic isolation	
	data transfer rates	SPA bus: 4.8/9.6/19.2 kbps LON bus: 78.0 kbps/1.2 Mbps
Rear interface, connectors X3.1 and X3.2	not used, reserved for future purposes	
Rear interface, connector X3.4	RJ45 connection	
	galvanically isolated RJ45 connection for an external display module	
	communication cable	1MRS 120511.001
Front panel	optical RS-232 connection	
	data code	ASCII
	data transfer rates	4.8 or 9.6 kbps, selectable
	serial communication cable	1MKC 9500011
Serial communication parameters	data bits	7
	stop bits	1
	parity	even
	baud rate	9.6 kbps (default)
Communication protocols	SPA-bus protocol LON-bus protocol	

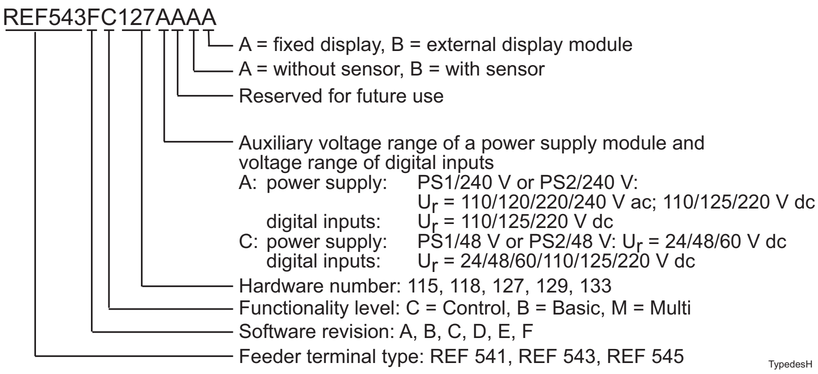
Table 19: General

Toolboxes	CAP 501 CAP 505 LNT 505	
Event recording	all events are recorded in higher level syntax: reason, time, date the last 100 events are recorded	
Data recording	records operate values	
Protection functions Control functions Condition monitoring functions Measurement functions Power quality functions	see Technical Descriptions of Functions, CD-ROM (1MRS 750889-MCD)	
Self-supervision	RAMs ROMs EEPROMs all analogue reference voltages automatic test sequences for I/Os and MMI modules output contact condition monitoring (all contacts)	
Mechanical dimensions	Width: 223.7 mm (1/2 of a 19” rack) Height, frame: 265.9 mm (6U) Height, box: 249.8 mm Depth: 235 mm	
	External display module	Width: 223.7 mm Height: 265.9 mm Depth: 74 mm
Weight of the unit	~8 kg	

Ordering

The following is to be specified when ordering REF 54_ terminals: order number, display language combination and quantity of feeder terminals.

Each REF 54_ feeder terminal has a specific order number that identifies the feeder terminal type as well as the hardware and the software as described below. The order number is labelled on the marking strip on the front panel of the feeder terminal delivered, e.g. Order No: REF543FC127AAAA.



The display language combination (see table below) is identified by a three-digit suffix in the software number labelled on the front panel of the feeder terminal, e.g. Software 1MRS110015-001.

Language combinations

Suffix	Language combination
001	English-German
002	English-Swedish
003	English-Finnish

The REF 541, REF 543 and REF 545 feeder terminals differ from each other as to the number of digital inputs and outputs as follows.

Number of inputs/outputs

Number of inputs/outputs	REF 541	REF 543	REF 545
Digital inputs	15	25	34
Trip circuit supervision inputs	2	2	2
Power outputs (NO single-pole)	0	2	3
Power outputs (NO double-pole)	5	9	11
Signal outputs (NO)	2	2	4
Signal outputs (NO/NC)	5	5	8
Self-supervision outputs	1	1	1

The functionality level determines the extent of the selection of function blocks available for the feeder terminal. For more detailed information on the separate function blocks included in each selection, please consult your relay supplier.

Functionality levels, protection functions

				FUNCTIONALITY LEVELS		
ANSI Code	**IEC Symbol**	**Function**	**Code**	**REF541/3/5 CONTROL**	**REF541/3/5 BASIC**	**REF541/3/5 MULTI**
		SHORT CIRCUITS				
51	3I >	Three-phase non-directional overcurrent, low-set stage	NOC3Low		X	X
50/ 51/ 51B	3I >>	Three-phase non-dir. overcurrent, high-set stage / blockable overcurrent	NOC3High		X	X
50/51B	3I >>>	Three-phase non-dir. overcurrent, inst. stage / blockable overcurrent	NOC3Inst		X	X
67	3I > ->	Three-phase directional o/c, low-set stage	DOC6Low		X	X
67	3I >> ->	Three-phase directional o/c, high-set stage / blockable overcurrent	DOC6High		X	X
67	3I >>> ->	Three-phase directional o/c, high-set stage / blockable overcurrent	DOC6Inst		X	X
		EARTH-FAULTS				
51N	Io > / SEF	Non-directional earth-fault, low-set stage	NEF1Low		X	X
50N/51N	Io >>	Non-directional earth-fault, high-set stage	NEF1High		X	X
50N	Io >>> / Io-o >	Non-directional earth-fault, instantaneous stage	NEF1Inst		X	X
67N/51N	Io > / SEF ->	Directional earth-fault, low-set stage	DEF2Low		X	X
67N	Io >> ->	Directional earth-fault, high-set stage	DEF2High		X	X
67N	Io >>> ->	Directional earth-fault, instantaneous stage	DEF2Inst		X	X
59N	Uo >	Residual overvoltage, low-set stage	ROV1Low		X	X
59N	Uo >>	Residual overvoltage, high-set stage	ROV1High		X	X
59N	Uo >>>	Residual overvoltage, instantaneous stage	ROV1Inst		X	X
		OVERLOAD				
49F	3[illegible]	Three-phase thermal overload (feeders & cables)	TOL3Cab		X	X
		OVER / UNDERVOLTAGE				
59	3U >	Three-phase overvoltage, low-set stage	OV3Low			X
59	3U >>	Three-phase overvoltage, high-set stage	OV3High			X
27	3U <	Three-phase undervoltage, low-set stage	UV3Low			X
27	3U <<	Three-phase undervoltage, high-set stage	UV3High			X
		LOAD SHEDDING AND RESTORATION				
81U/81O	f < / f > / df/dt	Underfrequency or overfrequency inc. rate of change, stage 1	Freq1St1			X

Functionality levels, protection functions

				FUNCTIONALITY LEVELS		
ANSI Code	**IEC Symbol**	**Function**	**Code**	**REF541/3/5 CONTROL**	**REF541/3/5 BASIC**	**REF541/3/5 MULTI**
81U/81O	f < / f > / df/dt	Underfrequency or overfrequency incl. rate of change, stage 2	Freq1St2			X
81U/81O	f < / f > / df/dt	Underfrequency or overfrequency incl. rate of change, stage 3	Freq1St3			X
81U/81O	f < / f > / df/dt	Underfrequency or overfrequency incl. rate of change, stage 4	Freq1St4			X
81U/81O	f < / f > / df/dt	Underfrequency or overfrequency incl. rate of change, stage 5	Freq1St5			X
		ADDITIONAL FUNCTIONS				
79	O → I	Auto-reclosure	AR5Func	X	X	X
25	SYNC	Synchro-check/voltage check, stage 1	SCVCSt1			X
25	SYNC	Synchro-check/voltage check, stage 2	SCVCSt2			X
68	3I2f >	Three-phase inrush detector	Inrush3		X	X
46	I >	Phase discontinuity	CUB3Low		X	X
62BF	CBFP	Circuit breaker failure	-	X	X	X
49M/ 49G/49T	3	Three-phase thermal overload protection for devices	TOL3Dev			X
48, 14, 66	Is2t, n<	Start-up supervision for motors	MotStart			X
27,47,59	U1< & U2> & U1>	Three-phase phase-sequency voltage protection, stage 1	PSV3St1			X
27,47,59	U1< & U2> & U1>	Three-phase phase-sequency voltage protection, stage 2	PSV3St2			X

Functionality levels, other functions

			FUNCTIONALITY LEVELS		
IEC Symbol	**Function**	**Code**	**REF541/3/5 CONTROL**	**REF541/3/5 BASIC**	**REF541/3/5 MULTI**
	MEASUREMENT FUNCTIONS				
	CURRENT				
3I	Three-phase current	MECU3A	X	X	X
3I	Three-phase current, B stage	MECU3B	X	X	X
Io	Neutral current	MECU1A	X	X	X
Io	Neutral current, B stage	MECU1B	X	X	X
	VOLTAGE				
3U	Three-phase voltage	MEVO3A	X	X	X
3U	Three-phase voltage, B stage	MEVO3B	X	X	X
Uo	Residual voltage	MEVO1A	X	X	X
Uo	Residual voltage, B stage	MEVO1B	X	X	X
	ENERGY / POWER				
E / P / Q / pf	Three-phase power and energy (incl. cos φ)	MEPE7	X	X	X
	FREQUENCY				

Functionality levels, other functions

			FUNCTIONALITY LEVELS		
IEC Symbol	**Function**	**Code**	**REF541/3/5 CONTROL**	**REF541/3/5 BASIC**	**REF541/3/5 MULTI**
f	System frequency	MEFR1	X	X	X
	RECORDING				
	Transient disturbance recorder	MEDREC16	X	X	X
	RTD -MODULE				
	Measurement of RTD/analogue inputs, general measurement	MEAI1…8	X	X	X
	Measurement of analogue outputs (Note! Only in products with an RTD/ analogue module)	MEAO1…4	X	X	X
	CONDITION MONITORING FUNCTION				
	CIRCUIT BREAKER				
CBCM	CB electric wear 1	CMBWEAR1	X	X	X
CBCM	CB electric wear 2	CMBWEAR2	X	X	X
CBCM	Operate Time Counter 1 (e.g. motors)	CMTIME1	X	X	X
CBCM	Operate Time Counter 2 (e.g. motors)	CMTIME2	X	X	X
CBCM	Gas pressure supervision	CMGAS1	X	X	X
CBCM	Gas pressure supervision for three poles	CMGAS3	X	X	X
CBCM	Spring charging control 1	CMSPRC1	X	X	X
CBCM	Breaker travel time 1	CMTRAV1	X	X	X
CBCM	Scheduled maintenance	CMSCHED	X	X	X
	TRIP CIRCUIT				
TCS	Trip Circuit Supervision 1	CMTCS1	X	X	X
TCS	Trip Circuit Supervision 2	CMTCS2	X	X	X
	MEASURING CIRCUIT				
MCS	Supervision of the energizing current input circuit	CMCU3	X	X	X
MCS	Supervision of the energizing voltage input circuit	CMVO3	X	X	X
	CONTROL FUNCTION				
	CIRCUIT BREAKERS, DISCONNECTORS / EARTHING SWITCH				
	Circuit breaker 1, 2 (2 state inputs / 2 control outputs)	COCB1...2	X	X	X
	Disconnector 1….5 (2 state inputs / 2 control outputs)	CODC1…5	X	X	X
	Three state disconnector 1, 2 (3 state inputs / 4 control outputs)	CO3DC1...2	X	X	X
	Object indication 1…8 (2 state inputs)	COIND1…8	X	X	X
	MIMIC dynamic data point 1…5 on MMI (single line diagram)	MMIDATA 1…5	X	X	X
	Alarm 1…8 on MMI (alarm view)	MMIALAR 1…8	X	X	X
	On/off switch 1…4 on MMI (single-line diagram)	COSW1…4	X	X	X
	Direct open for CBs via MMI	COCBDIR	X	X	X
	Logic control position selector	COLOCAT	X	X	X

Functionality levels, other functions

			FUNCTIONALITY LEVELS		
IEC Symbol	**Function**	**Code**	**REF541/3/5 CONTROL**	**REF541/3/5 BASIC**	**REF541/3/5 MULTI**
	ADDITIONAL FUNCTIONS				
	Interlocking	-	X	X	X
	Command control	-	X	X	X
	STANDARD FUNCTIONS				
	Operation indication, relay and register reset	INDRESET	X	X	X
	Activation of MMI backlight	MMIWAKE	X	X	X
	Switchgroups SWGRP1...SWGRP20	SWGRP 1....20	X	X	X
	PLC logics (AND, OR, timers etc.) acc. to IEC 61131-3	-	X	X	X
	DATA COMMUNICATION				
	Event to be defined by the customer, E0...E63	EVENT230	X	X	X
	SPA bus	-	X	X	X
	LON bus	-	X	X	X
	GENERAL FUNCTIONS				
	Main / secondary setting		X	X	X
	Remote setting		X	X	X
	Self-supervision		X	X	X
	Annunciating, event generating and value recording		X	X	X
	Measurement, parameter and switching device status display		X	X	X
	Remote-end binary signal transfer		X	X	X
	Binary signal interbay transfer		X	X	X

Optional functionality

Function	**Code**	**Ordering number**
CAPACITOR BANK PROTECTION		
Three-phase overload protection for shunt capacitor banks	OL3Cap	1MRS100116
Current unbalance protection for shunt capacitor banks	CUB1Cap	1MRS100117
CAPACITOR BANK CONTROL		
Power factor controller (Only available with the Control-level functionality)	COPFC	1MRS100143
POWER QUALITY		
Current waveform distortion measurement	PQCU3H	1MRS100512
Voltage waveform distortion measurement	PQVO3H	1MRS100513

Overview of REF hardware configurations

Hardware modules of REF 541	**Order number**											
	REF541C_115AAAA	REF541C_115CAAA	REF541C_115AABA	REF541C_115CABA	REF541C_115AAAB	REF541C_115AABB	REF541A_118AAAA	REF541A_118CAAA	REF541A_118AABA	REF541A_118CABA	REF541A_118AAAB	REF541A_118AABB
Analogue interface												
Sensor channels (current or voltage)			9	9		9			9	9		9
Current transformer 1/5 A	4	4	4	4	4	4	4	4	4	4	4	4
Current transformer 0.2/1 A	1	1	1	1	1	1	1	1	1	1	1	1
Voltage transformer 100 V	4	4	4	4	4	4	4	4	4	4	4	4
Main processor boards												
CPU module	1	1	1	1	1	1	1	1	1	1	1	1
Power supply boards												
Type 1: 80...265 Vdc/Vac	1		1		1	1	1		1		1	1
Type 1: 18...80 Vdc		1		1				1		1		
Type 2: 80...265 Vdc/Vac												
Type 2: 18...80 Vdc												
Digital I/O boards												
Type 1: threshold voltage 80 Vdc	1		1		1	1	1		1		1	1
Type 1: threshold voltage 18 Vdc		1		1				1		1		
Type 2: threshold voltage 80 Vdc												
Type 2: threshold voltage 18 Vdc												
Analogue I/O board												
RTD/analogue module							1	1	1	1	1	1
Display boards												
Graphic MMI display, fixed	1	1	1	1			1	1	1	1		
Graphic MMI display, external					1	1					1	1
Mechanical design												
1/2 enclosure	1	1	1	1	1	1	1	1	1	1	1	1
Digital inputs	15						15					
Power outputs, single-pole	0						0					
Power outputs, double-pole	5						5					
Signal outputs (NO)	2						2					
Signal outputs (NO/NC)	5						5					
Supervised trip circuits	2						2					
IRF outputs	1						1					
RTD/analogue inputs	0						8					
Analogue outputs	0						4					

Hardware modules of REF 543	**Order number**											
	REF543F_127AAAA	REF543F_127CAAA	REF543F_127AABA	REF543F_127CABA	REF543F_127AAAB	REF543F_127AABB	REF543A_129AAAA	REF543A_129CAAA	REF543A_129AABA	REF543A_129CABA	REF543A_129AAAB	REF543A_129AABB
Analogue interface												
Sensor channels (current or voltage)			9	9		9			9	9		9
Current transformer 1/5 A	4	4	4	4	4	4	4	4	4	4	4	4
Current transformer 0.2/1 A	1	1	1	1	1	1	1	1	1	1	1	1
Voltage transformer 100 V	4	4	4	4	4	4	4	4	4	4	4	4
Main processor boards												
CPU module	1	1	1	1	1	1	1	1	1	1	1	1
Power supply boards												
Type 1: 80...265 Vdc/Vac	1		1		1	1	1		1		1	1
Type 1: 18...80 Vdc		1		1				1		1		
Type 2: 80...265 Vdc/Vac												
Type 2: 18...80 Vdc												
Digital I/O boards												
Type 1: threshold voltage 80 Vdc	1		1		1	1	1		1		1	1
Type 1: threshold voltage 18 Vdc		1		1				1		1		
Type 2: threshold voltage 80 Vdc	1		1		1	1	1		1		1	1
Type 2: threshold voltage 18 Vdc		1		1				1		1		
Analogue I/O board												
RTD/analogue module							1	1	1	1	1	1
Display boards												
Graphic MMI display, fixed	1	1	1	1			1	1	1	1		
Graphic MMI display, external					1	1					1	1
Mechanical design												
1/2 enclosure	1	1	1	1	1	1	1	1	1	1	1	1
Digital inputs	25						25					
Power outputs, single-pole	2						2					
Power outputs, double-pole	9						9					
Signal outputs (NO)	2						2					
Signal outputs (NO/NC)	5						5					
Supervised trip circuits	2						2					
IRF outputs	1						1					
RTD/analogue inputs	0						8					
Analogue outputs	0						4					

Hardware modules of REF 545	Order number					
	REF545C_133AAAA	REF545C_133CAAA	REF545C_133AABA	REF545C_133CABA	REF545C_133AAAB	REF545C_133AABB
Analogue interface						
Sensor channels (current or voltage)			9	9		9
Current transformer 1/5 A	4	4	4	4	4	4
Current transformer 0.2/1 A	1	1	1	1	1	1
Voltage transformer 100 V	4	4	4	4	4	4
Main processor boards						
CPU module	1	1	1	1	1	1
Power supply boards						
Type 1: 80...265 Vdc/Vac						
Type 1: 18...80 Vdc						
Type 2: 80...265 Vdc/Vac	1		1		1	1
Type 2: 18...80 Vdc		1		1		
Digital I/O boards						
Type 1: threshold voltage 80 Vdc	2		2		2	2
Type 1: threshold voltage 18 Vdc		2		2		
Type 2: threshold voltage 80 Vdc	1		1		1	1
Type 2: threshold voltage 18 Vdc		1		1		
Analogue I/O board						
RTD/analogue module						
Display boards						
Graphic MMI display, fixed	1	1	1	1		
Graphic MMI display, external					1	1
Mechanical design						
1/2 enclosure	1	1	1	1	1	1
Digital inputs	34					
Power outputs, single-pole	3					
Power outputs, double-pole	11					
Signal outputs (NO)	4					
Signal outputs (NO/NC)	8					
Supervised trip circuits	2					
IRF outputs	1					
RTD/analogue inputs	0					
Analogue outputs	0					

Hardware versions of REF 541, REF 543 and REF 545

For the number of digital inputs and outputs of REF 54_ feeder terminals, refer to the tables above. The number of matching transformers, sensor inputs and analogue inputs and outputs, and the auxiliary voltage range vary between the different hardware versions of REF54_. Each hardware version of REF 541 and REF 543 can be supplied with an RTD/analogue module.

Software configuration

Each REF 54_ feeder terminal allows various software configurations based on separate functions. Functions included in the selected functionality level can be activated within the scope of the I/O connections and considering the total CPU load of the functions.

Parts and assembly descriptions

To achieve the best possible operation accuracy, all parts of a REF 54_ product have been calibrated together. Thus, each product forms a whole for which no separate spare parts can be supplied. In the event of malfunction, please consult your feeder terminal supplier.

Application examples

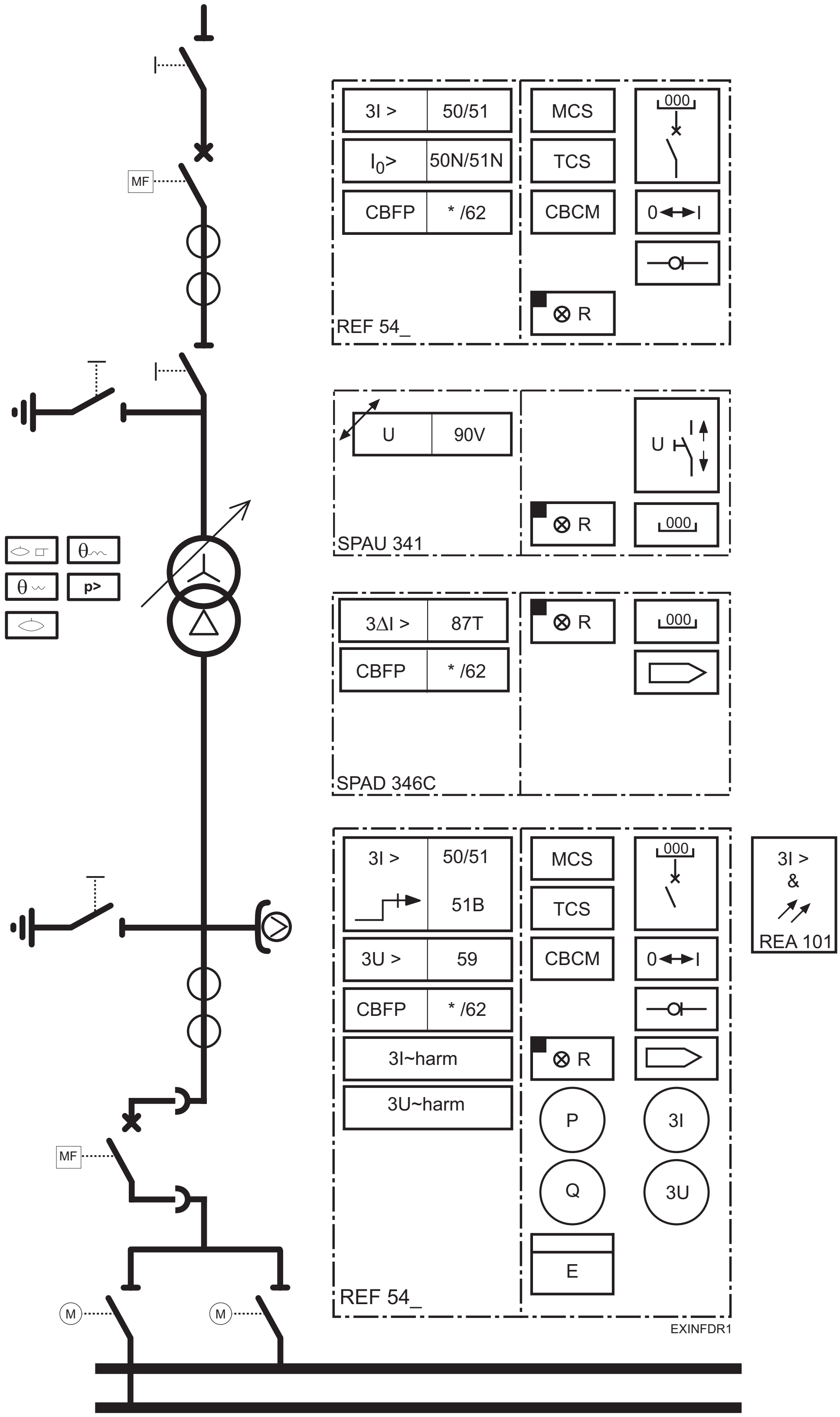


Fig. 5 Protection, control, measurement and supervision functions of a utility infeeder, implemented with REF feeder terminals, an REA arc monitoring system and SPACOM differential relay and voltage regulator (main single-line diagram presentation). The neutral point of the MV network supplied by the infeeder is isolated.

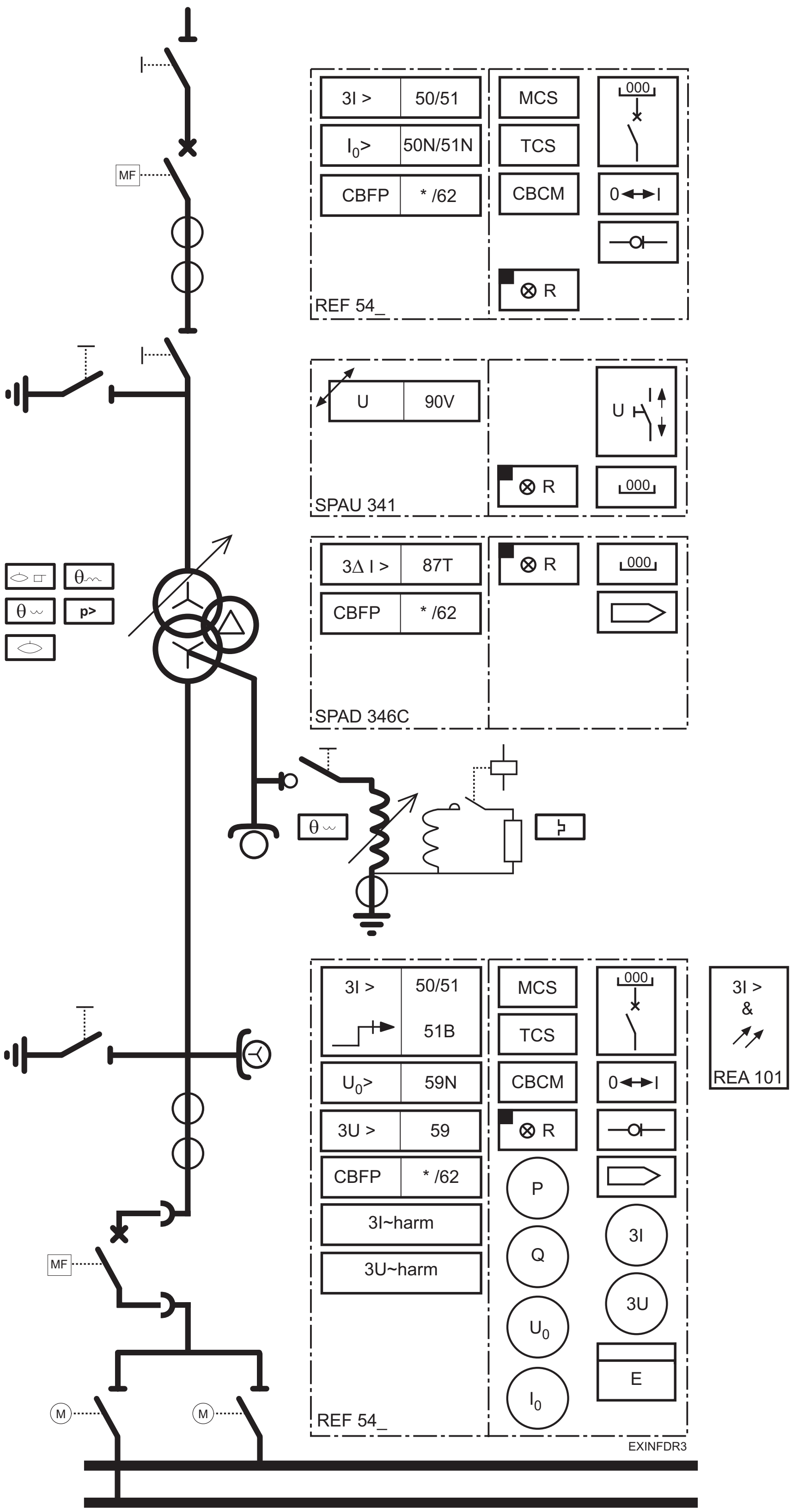


Fig. 6 Protection, control, measurement and supervision functions of a utility infeeder, implemented with REF feeder terminals, an REA arc monitoring system and SPACOM differential relay and voltage regulator (main single-line diagram presentation). The neutral point of the MV network supplied by the infeeder is earthed via the Petersen coil.

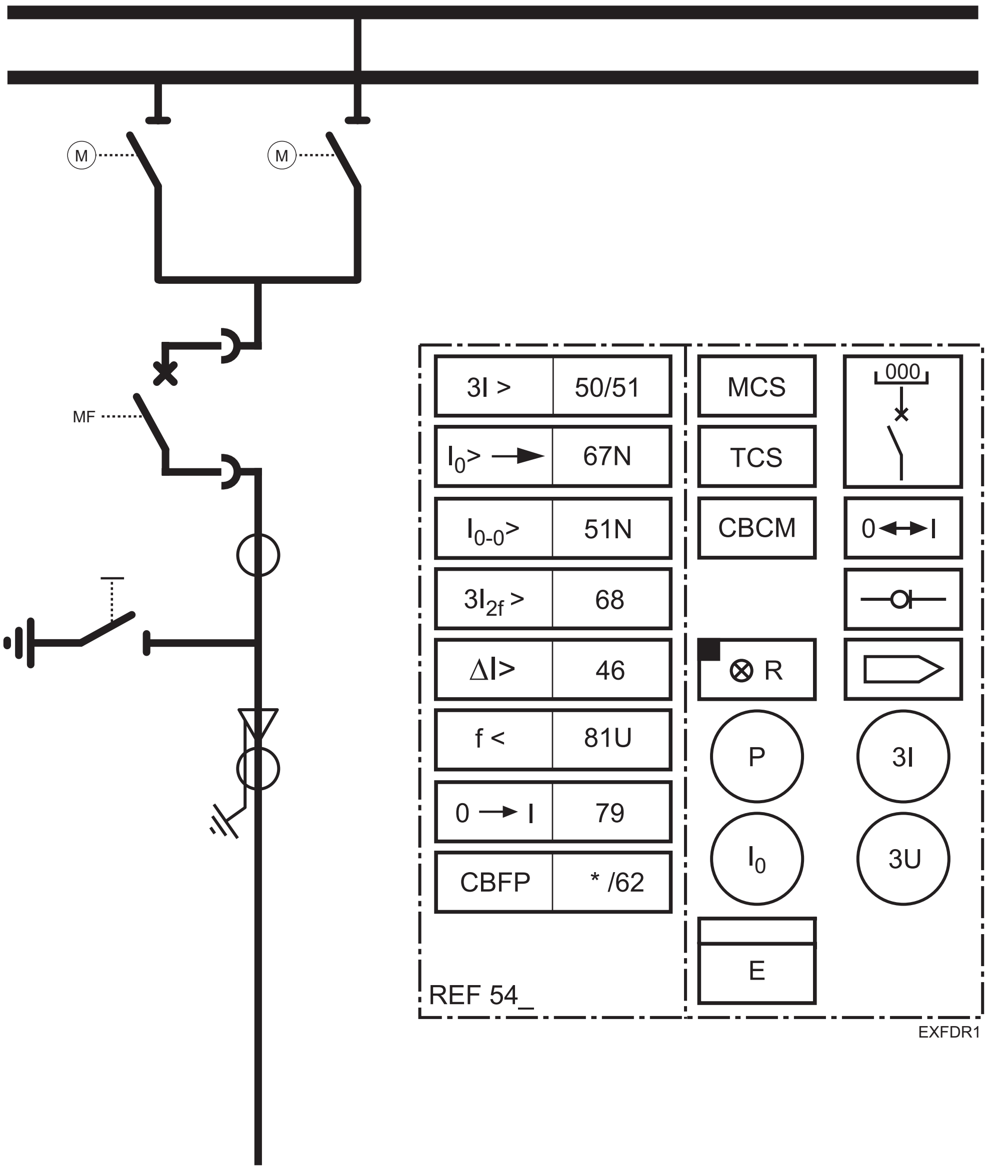


Fig. 7 An REF feeder terminal used for the protection, control, measurement and supervision functions of a utility feeder (main single-line diagram presentation). The neutral point of the supplying network is isolated. The scheme is also fully applicable in high-impedance earthed networks, where the neutral point is earthed via a high resistance or a Petersen coil.

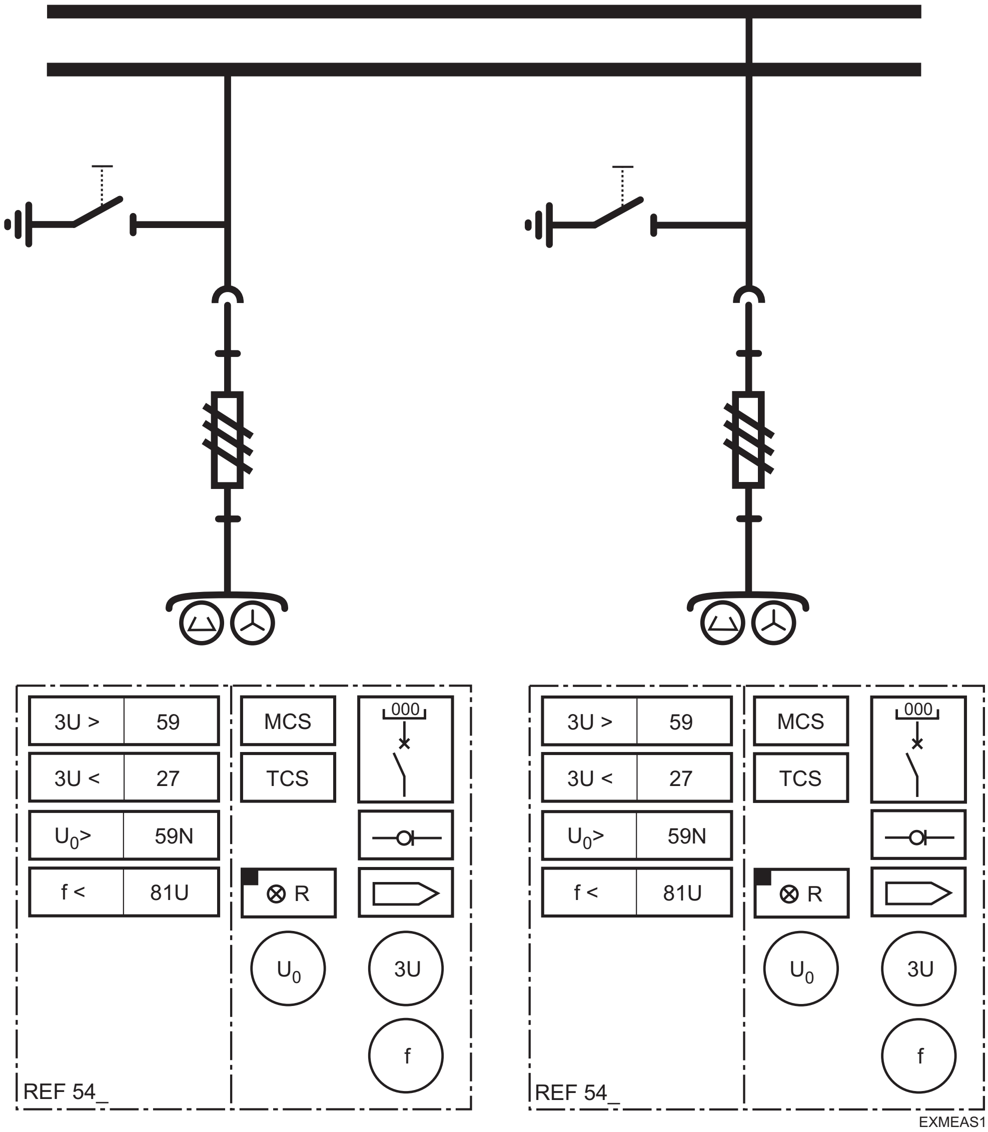


Fig. 8 REF feeder terminals used for the protection, control, measurement and supervision functions of a utility/industrial measurement cubicle (main single-line diagram presentation). The neutral point of the supplying network is isolated. The scheme is also fully applicable in high-impedance earthed networks, where the neutral point is earthed via a high resistance or a Petersen coil.

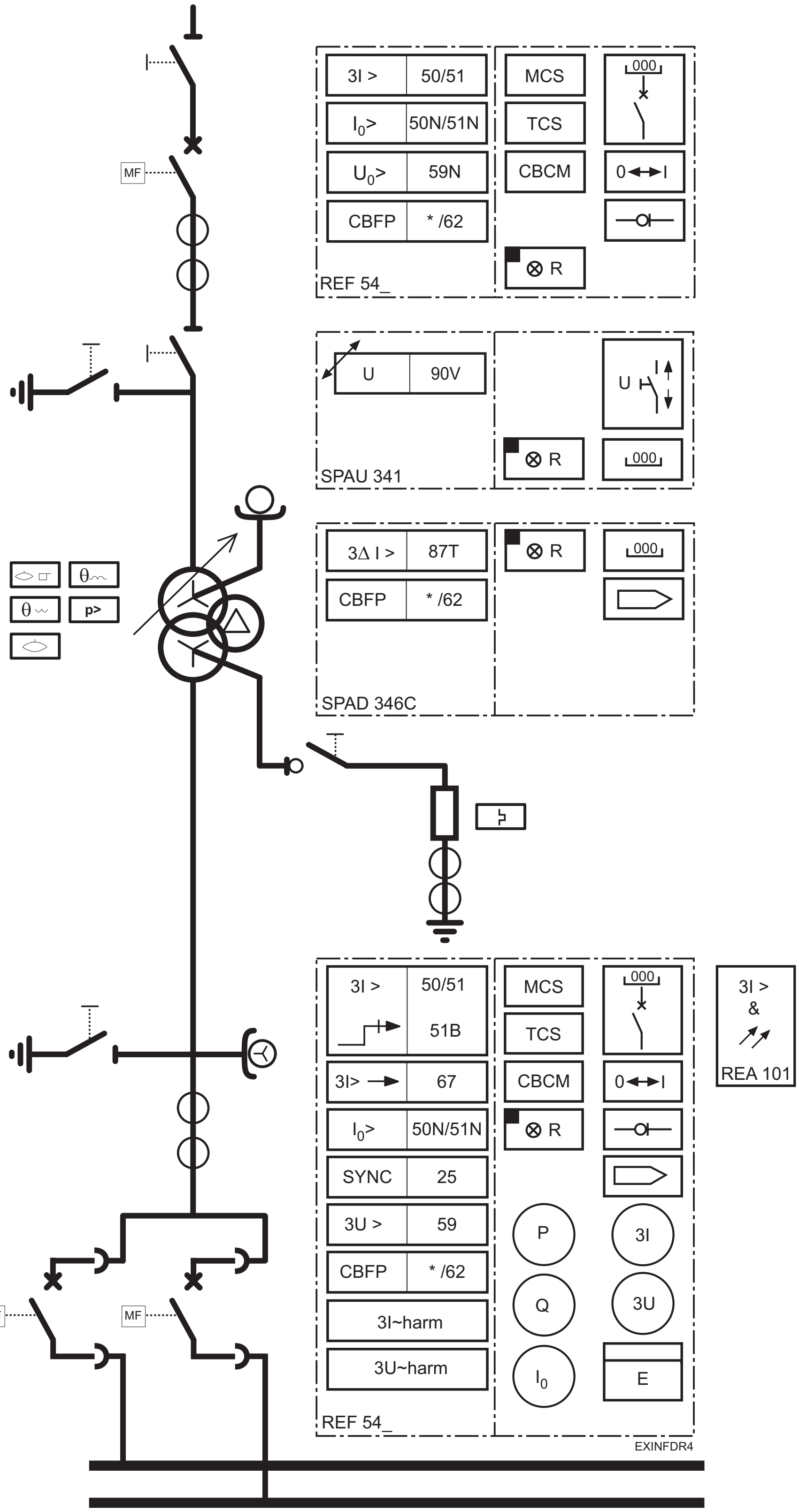


Fig. 9 Protection, control, measurement and supervision functions of a utility/industrial infeeder, implemented with REF feeder terminals, an REA arc monitoring system and SPACOM differential relay and voltage regulator (main single-line diagram presentation). The neutral point of the MV network supplied by the infeeder is earthed via a high resistance.

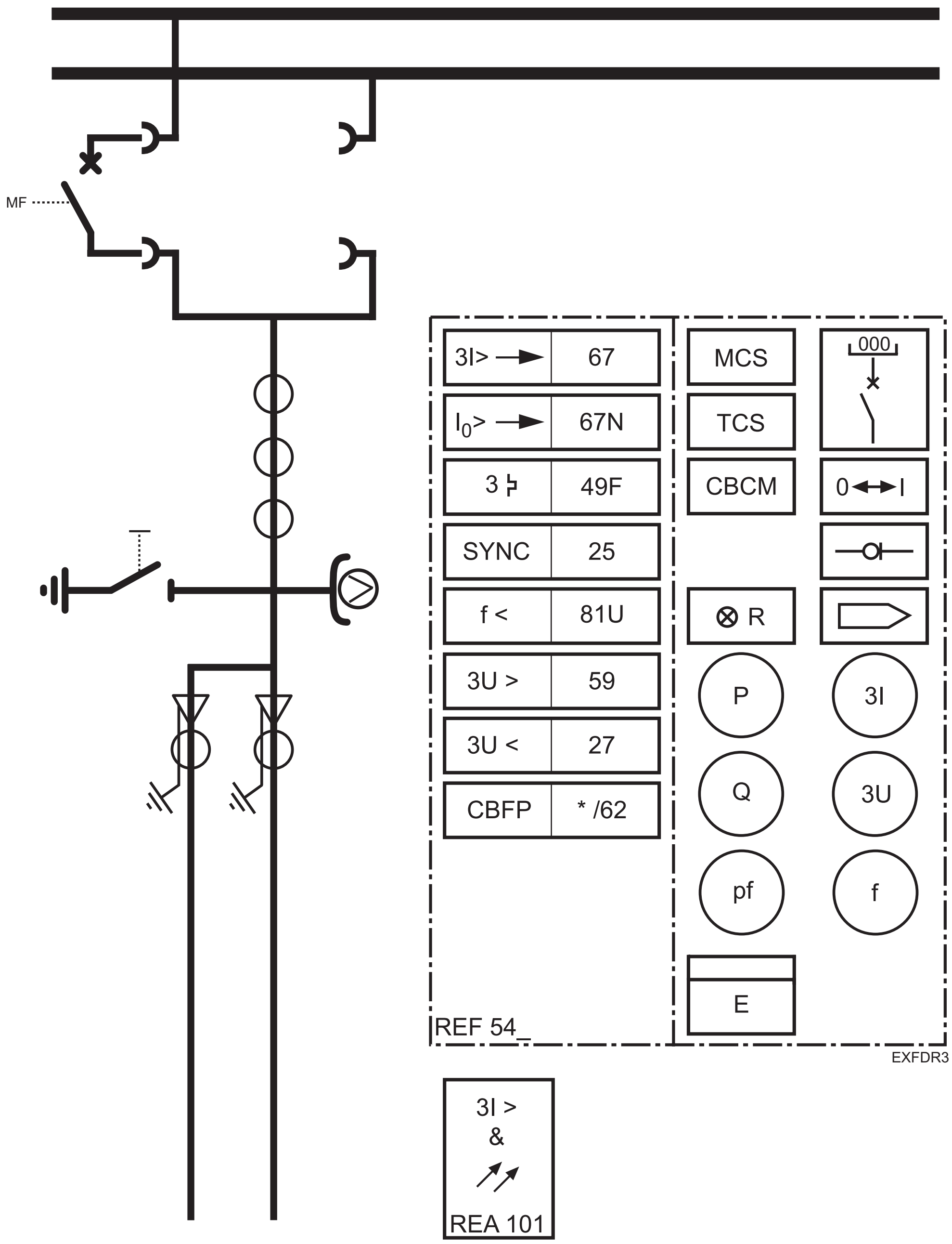


Fig. 10 An REF feeder terminal and an REA arc monitoring system (main single-line diagram presentation) used for the protection, control, measurement and supervision functions of a utility/industrial ring/meshed network cable feeder. The earthing of the supplying network can be of low or high impedance type.

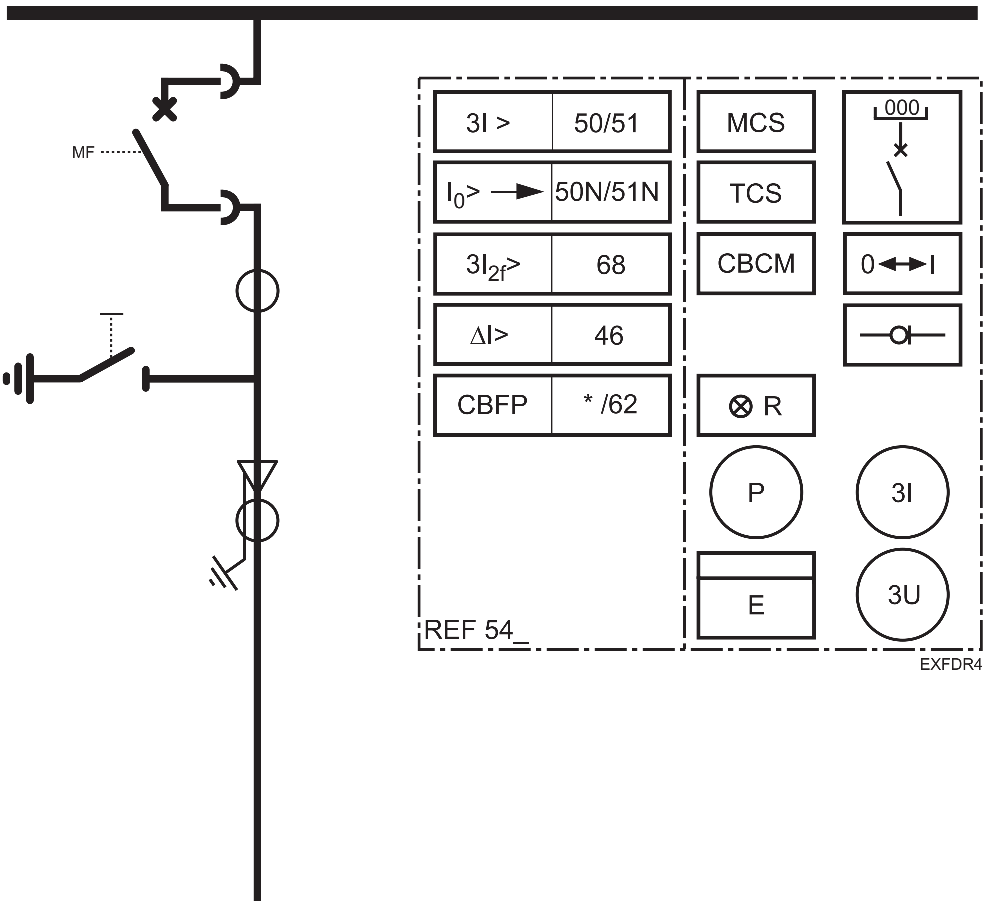


Fig. 11 An REF feeder terminal used for the protection, control, measurement and supervision functions of a utility/light industrial cable feeder (main single line diagram presentation). The earthing of the supplying network can be of low or high impedance type.

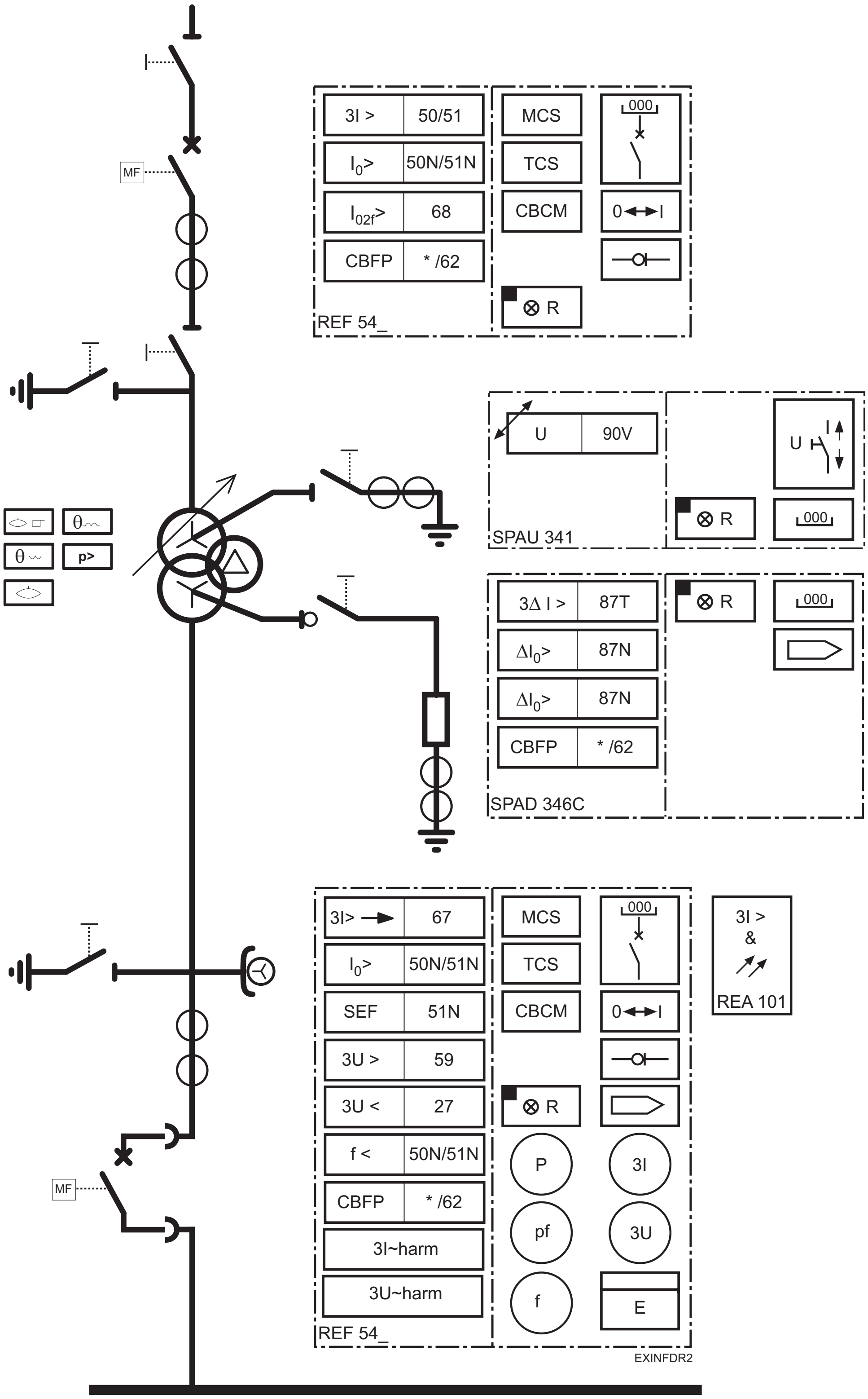


Fig. 12 Protection, control, measurement and supervision functions of a utility infeeder, implemented with REF feeder terminals, an REA arc monitoring system and SPACOM differential relay and voltage regulator (main single-line diagram presentation). The neutral point of the MV network supplied by the infeeder is earthed via a low resistance. The scheme is also fully applicable to other types of low-impedance earthed networks, where the neutral point is earthed effectively or via a low reactance.

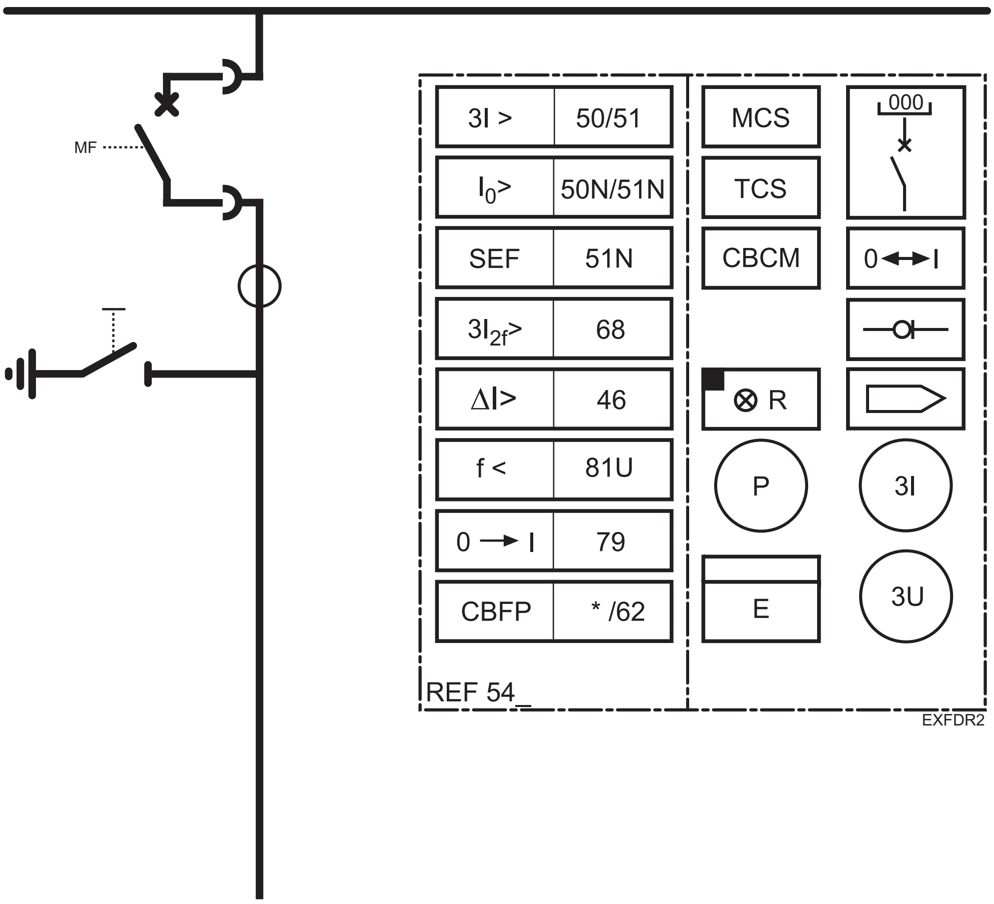


Fig. 13 An REF feeder terminal used for the protection, control, measurement and supervision functions of a utility feeder (main single-line diagram presentation). The neutral point of the supplying network is earthed via a low resistance. The scheme is also fully applicable to other types of low-impedance earthed networks, where the neutral point is earthed effectively or via a low reactance.

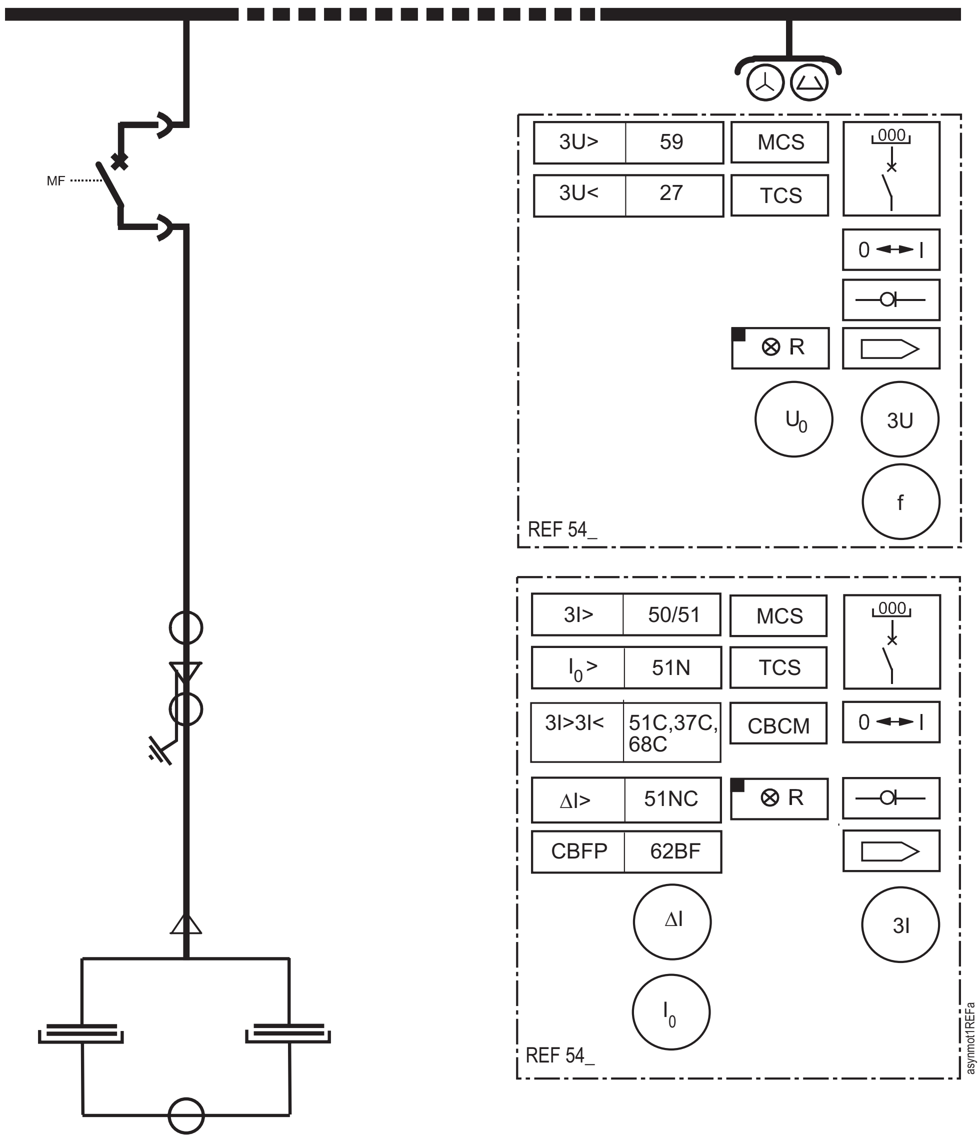


Fig. 14 REF 54_ used for the protection of a double **Y** connected capacitor bank

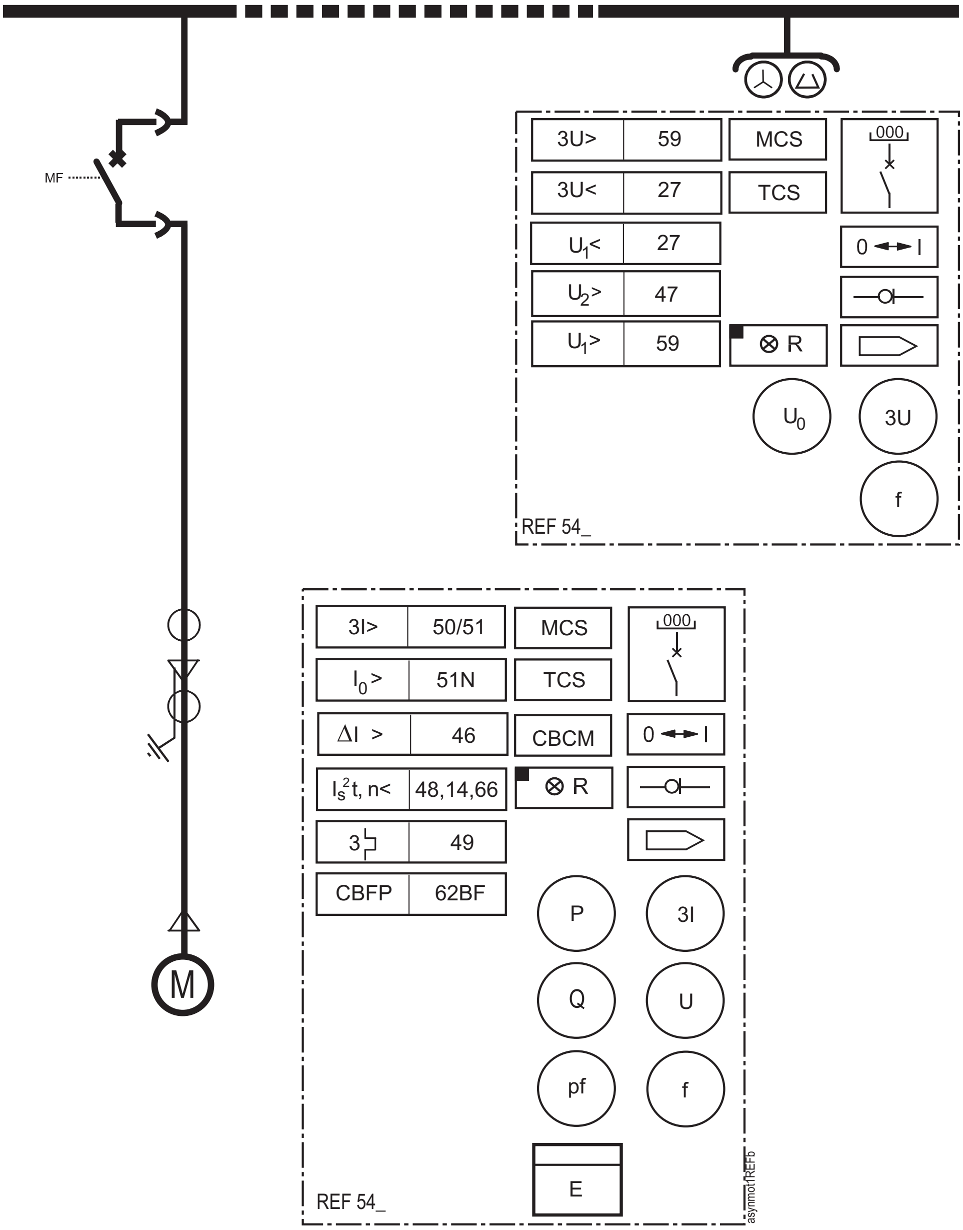


Fig. 15 REF 54_ used for the protection of a motor with direct-on-line starting

3I >	50/51	= multiple-stage three-phase overcurrent protection, low-set, high-set and instantaneous stage available
3I> →	67	= multiple-stage three-phase directional overcurrent protection, low-set, high-set and instantaneous stage available
I_0> →	67N	= multiple-stage directional earth-fault protection, low-set, high-set and instantaneous stage available
I_{0-0}>	51N	= instantaneous stage for earth-fault protection, to operate in the event of a double earth fault in isolated or impedance earthed networks
I_0>	50N/51N	= multiple-stage earth-fault protection, low-set, high-set and instantaneous stage available
SEF	51N	= low-set stage for sensitive earth-fault protection, to operate in the event of a high resistive earth fault in effectively or low-impedance earthed networks
3I >	50/51 51B	= multiple-stage three-phase overcurrent protection, one stage dedicated for blockable busbar overcurrent protection
3U >	59	= three-phase overvoltage protection, low-set and high-set stage available
3U <	27	= three-phase undervoltage protection, low-set and high-set stage available
U_0>	59N	= multiple-stage residual overvoltage protection, low-set, high-set and instantaneous stage available
$3I_{2f}$ >	68	= inrush detection based on the 2nd harmonic content of phase currents, applied for preventing possible unnecessary operation of overcurrent or earth-fault protection during transformer switching-in or to start cold load pick-up logic
ΔI>	46	= phase discontinuity protection
f <	81U	= underfrequency protection/load shedding scheme
3	49F	= thermal overload protection for feeders
0 → I	79	= multiple-shot auto-recloser
SYNC	25	= circuit breaker synchro-check/direction of energizing check function
3Δ I >	87T	= differential protection for transformers
ΔI_0>	87N	= restricted earth-fault protection, low- or high-impedance type
I_{02f}>	68	= inrush detection based on the 2nd harmonic content of neutral current, applied to prevent possible unnecessary operation of the earth-fault protection during transformer switching-in
CBFP	* /62	= circuit-breaker failure protection

SYMNOT1

Fig. 16 Symbol notations, part I

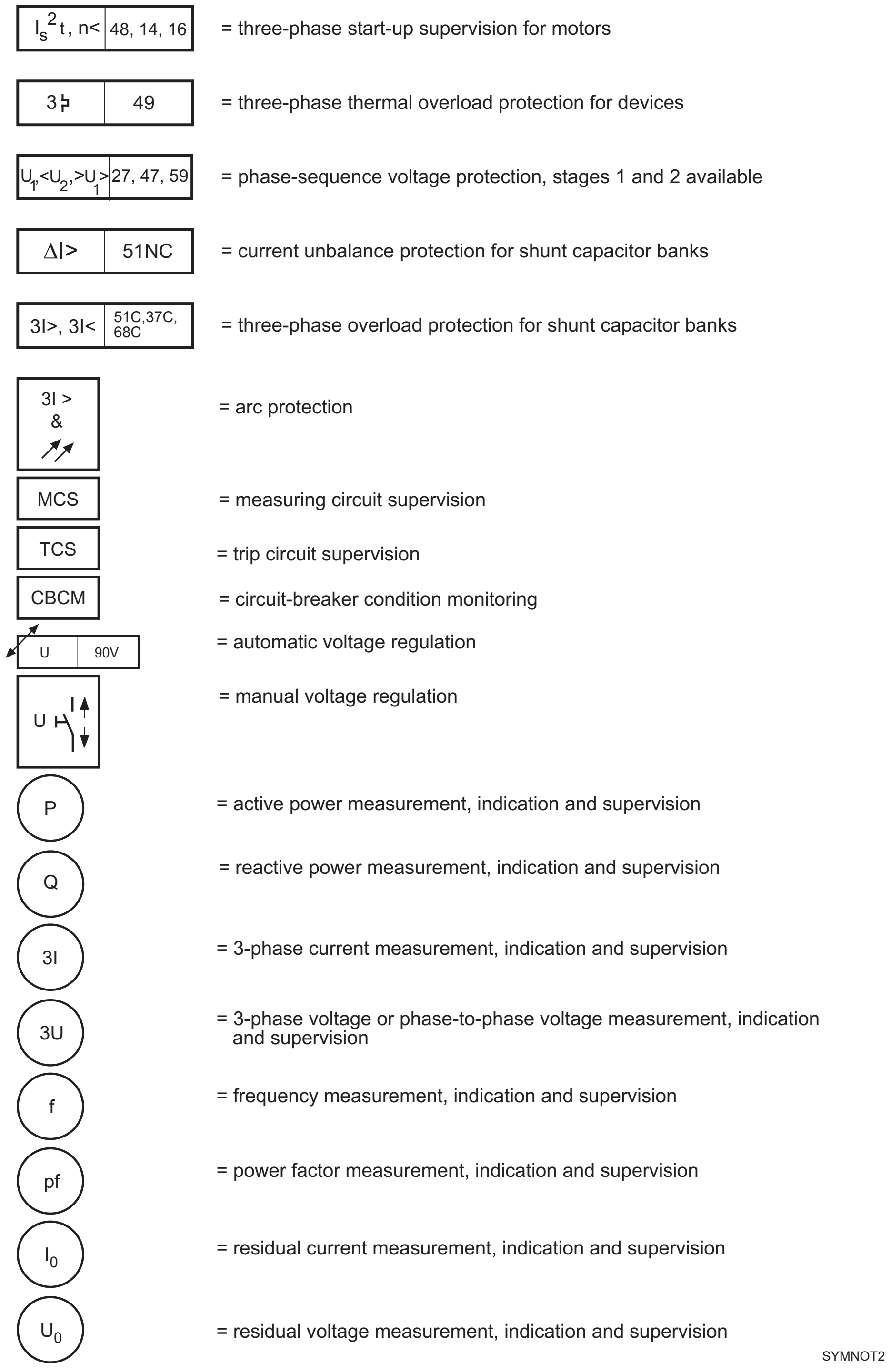


Fig. 17 Symbol notations, part II

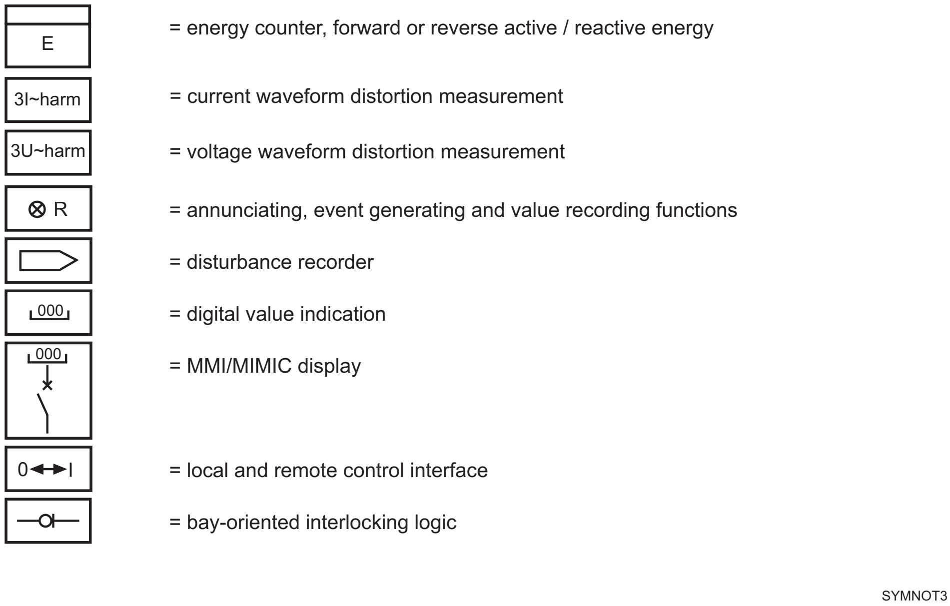


Fig. 18 Symbol notations, part III

Application selection tables for REF 541, REF 543 and REF 545 functions

Table 20: Protection functions

Types of fault	IEEE Device No.	IEC Symbol	Protection function	Function block code
Short circuits	51	3I>	Three-phase non-directional overcurrent, low-set stage	NOC3Low
	50/51/51B	3I>>	Three-phase non-directional overcurrent, high-set stage	NOC3High
	50/51B	3I>>>	Three-phase non-directional overcurrent, instantaneous stage	NOC3Inst
	67	3I>→	Three-phase directional o/c, low-set stage	DOC6Low
	67	3I>>→	Three-phase directional o/c, high-set stage	DOC6High
	67	3I>>>→	Three-phase directional o/c, instantaneous stage	DOC6Inst
Earth faults	51N	Io>/SEF	Non-directional earth-fault, low-set stage (or SEF = sensitive earth-fault protection)	NEF1Low
	50N/51N	Io>>	Non-directional earth-fault, high-set stage	NEF1High
	50N	Io>>>	Non-directional earth-fault, instantaneous stage	NEF1Inst
	67N/51N	Io>→/SEF	Directional earth-fault, low-set stage (or SEF = sensitive earth-fault protection)	DEF2Low
	67N	Io>>→	Directional earth-fault, high-set stage	DEF2High
	67N	Io>>>→	Directional earth-fault, instantaneous stage	DEF2Inst
	59N	Uo>	Residual overvoltage, low-set stage	ROV1Low
	59N	Uo>>	Residual overvoltage, high-set stage	ROV1High
	59N	Uo>>>	Residual overvoltage, instantaneous stage	ROV1Inst
Overload/ unbalanced load	49F	3	Three-phase thermal protection for cables	TOL3Cab
	49M/49G/49T	3	Three-phase thermal protection for devices (motors, generators and transformers)	TOL3Dev

Table 20: Protection functions

Types of fault	IEEE Device No.	IEC Symbol	Protection function	Function block code
Overvoltage/ undervoltage	59	3U>	Three-phase overvoltage, low-set stage	OV3Low
	59	3U>>	Three-phase overvoltage, high-set stage	OV3High
	27	3U<	Three-phase undervoltage, low-set stage	UV3Low
	27	3U<<	Three-phase undervoltage, high-set stage	UV3High
	27, 47, 59	$U_1<$ $U_2>$ $U_1>$	Phase-sequence voltage protection, stage 1	PSV3St1
	27, 47, 59	$U_1<$ $U_2>$ $U_1>$	Phase-sequence voltage protection, stage 2	PSV3St2
Overfrequency/ underfrequency	81U/81O	f</f>, df/dt	Underfrequency or overfrequency, stage 1 (incl. rate of change)	Freq1St1
	81U/81O	f</f>, df/dt	Underfrequency or overfrequency, stage 2 (incl. rate of change)	Freq1St2
	81U/81O	f</f>, df/dt	Underfrequency or overfrequency, stage 3 (incl. rate of change)	Freq1St3
	81U/81O	f</f>, df/dt	Underfrequency or overfrequency, stage 4 (incl. rate of change)	Freq1St4
	81U/81O	f</f>, df/dt	Underfrequency or overfrequency, stage 5 (incl. rate of change)	Freq1St5
Motor protection	48, 14, 66	I_s^2t, n<	Three-phase start-up supervision for motors (incl. I_2t and speed device modes, and start-up counter)	MotStart
Capacitor bank protection	51C, 37C, 68C	3I> 3I<	Three-phase overload protection for shunt capacitor banks	OL3Cap
	51NC	Δ I>	Current unbalance protection for shunt capacitor banks	CUB1Cap
Additional functions	79	O → I	Auto-reclosure	AR5Func
	25	SYNC	Synchro-check/ voltage check, stage 1	SCVCSt1
	25	SYNC	Synchro-check/ voltage check, stage 2	SCVCSt2
	68	$3I_{2f}>$	Three-phase transformer inrush and motor start-up current detector	Inrush3
	46	ΔI>	Phase discontinuity	CUB3Low

Table 21: Measurement functions

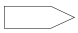
Types of measurement	**IEC Symbol**	**Measurement function**	**Function block code**
General measurement/ analogue input or analogue output	mA/V/°C/Ω	General measurement/ analogue input on RTD/ analogue module	MEAI1...8
	mA	Analogue output on RTD/analogue module	MEAO1...4
Current	3I	Three-phase current measurement, stage A	MECU3A
	3I	Three-phase current measurement, stage B	MECU3B
	Io	Neutral current measurement, stage A	MECU1A
	Io	Neutral current measurement, stage B	MECU1B
Voltage	3U	Three-phase voltage measurement, stage A	MEVO3A
	3U	Three-phase voltage measurement, stage B	MEVO3B
	Uo	Residual voltage measurement, stage A	MEVO1A
	Uo	Residual voltage measurement, stage B	MEVO1B
Energy / Power	E, P, Q, pf	Three-phase power and energy measurement	MEPE7
Frequency	f	System frequency measurement	MEFR1
Recording		Transient disturbance recorder	MEDREC16

Table 22: Power quality functions

Type of power quality measurement	Symbol	Power quality function	Function block code
Current	3I~harm	Current waveform distortion measurement	PQCU3H
Voltage	3U~harm	Voltage waveform distortion measurement	PQVO3H

Table 23: Control functions

Types of control	**Symbol**	**Control function**	**Function block code**
Circuit breaker	0 ⟷ 1	Circuit breaker 1 (2 state inputs / 2 control outputs)	COCB1
	0 ⟷ 1	Circuit breaker 2 (2 state inputs / 2 control outputs)	COCB2
	0 ⟷ 1	Direct open for CBs via MMI	COCBDIR
Disconnector	0 ⟷ 1	Disconnector 1...5 (2 state inputs / 2 control outputs)	CODC1...CODC5
	0 ⟷ 1	Three state disconnector 1 (3 state inputs/ 4 control outputs)	CO3DC1
	0 ⟷ 1	Three-state disconnector 2 (3 state inputs/ 4 control outputs)	CO3DC2

Table 23: Control functions

Types of control	Symbol	Control function	Function block code
Other control functions		Object indication 1...8 (2 state inputs)	COIND1...COIND8
		On/off switch 1...4 (1 output)	COSW1...COSW4
		Logic control position selector	COLOCAT
		Power factor controller	COPFC
		MIMIC dynamic data point 1...5	MMIDATA1...MMIDATA5
		Alarm 1...8 (MMI, remote)	MMIALAR1...MMIALAR8

Table 24: Condition monitoring functions

Types of condition monitoring	Symbol	Condition monitoring function	Function block code
Circuit breaker	CBCM	CB electric wear 1	CMBWEAR1
	CBCM	CB electric wear 2	CMBWEAR2
	CBCM	Operate time counter 1 for used operate time (motors)	CMTIME1
	CBCM	Operate time counter 2 for used operate time (motors)	CMTIME2
	CBCM	Gas pressure monitoring	CMGAS1
	CBCM	Three-pole gas pressure monitoring	CMGAS3
	CBCM	Spring charging control 1	CMSPRC1
	CBCM	Breaker travel time 1	CMTRAV1
	CBCM	Scheduled maintenance	CMSCHED
Trip circuit	TCS	Trip Circuit Supervision 1	CMTCS1
	TCS	Trip Circuit Supervision 2	CMTCS2
Measuring circuit	MCS	Supervision function of the energizing current input circuit	CMCU3
	MCS	Supervision function of the energizing voltage input circuit	CMVO3

References

Additional information

Technical Reference Manual	1MRS750527-MUM
Technical Descriptions of Functions	1MRS750889-MCD (CD-ROM only)
Installation Manual	1MR 750526-MUM
Operator’s Manual	1MR 750500-MUM
Technical Reference Manual RER 103	1MRS750532-MUM
Configuration Guideline	1MRS750745-MUM

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ABB Substation Automation Oy
P.O.Box 699
FIN-65101 VAASA Finland
Tel. +358 10 224 000
Fax. +358 10 224 1094
http://www.abb.com/substationautomation