Technical Specification code: MAT-NT&I-SGD-2020-0020-GIN
Version no.04 dated 09/09/2020

Subject: **GSTP001 -** Global Infrastructure and Networks Global Standard - Protection and control device for MV substation – RGDAT control unit

Application Areas
Perimeter: *Global*
Staff Function: -
Service Function: -
Business Line: *Infrastructure & Networks*

CONTENTS

THE HEAD OF SMART GRID DEVICES
Fabio Giammanco

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1. DOCUMENT AIMS AND APPLICATION AREA

This document describes the functional, construction and testing requirements for the Protection and control devices for MV substation – RGDAT control unit.

1.1 RELATED ORGANIZATIONAL DOCUMENTS TO BE IMPLEMENTED AT COUNTRY LEVEL

This document applies within Global Infrastructure and Networks and each Company must not issue additional documents.

2. DOCUMENT VERSION MANAGEMENT

Version	Date	Main changes description
4	[09/09/2020]	Issuing of Global Infrastructure and Networks Global Standard - Protection and control device for MV substation – RGDAT control unit

3. UNITS IN CHARGE OF THE DOCUMENT

Responsible for drawing up the document:

- Global Infrastructure and Networks: Network Technology and Innovation / Smart Grid Devices / Smart Grid Devices Development and Technical Support unit;

Responsible for authorizing the document:

- Global Infrastructure and Networks: Head of Smart Grid Devices;
- Global Infrastructure and Networks: Head of Quality Systems and Processes Unit.

4. REFERENCES

- Enel Group Code of Ethics;
- The Enel Group Zero Corruption Tolerance (ZCT) Plan;
- Organizational and management model as per Italian Legislative Decree no. 231/2001 or equivalent documents adopted in the Countries;
- Enel Human Rights Policy;
- Stop Work Policy;
- Enel Global Compliance Program (EGCP);
- Global Infrastructure and Networks RACI Handbook;
- IEC 60255 series: Measuring relays and protection equipment;

- IEC 61000-4-12: Electromagnetic compatibility (EMC) - Part 4-12: Testing and measurement techniques - Ring wave immunity test;
- IEC 61000-4-18: Electromagnetic compatibility (EMC) - Part 4-18: Testing and measurement techniques - Damped oscillatory wave immunity test;
- IEC 61000-4-4: Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test;
- IEC 61000-4-5: Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test;
- IEC 61000-4-8: Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test;
- IEC 61000-4-10: Electromagnetic compatibility (EMC) - Part 4-10: Testing and measurement techniques - Damped oscillatory magnetic field immunity test;
- IEC 61000-4-3: Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test;
- IEC 61000-4-29: Electromagnetic compatibility (EMC) - Part 4-29: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests;
- IEC 61000-4-16: Electromagnetic compatibility (EMC) – Part 4-16: Testing and measurement techniques – Test for immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz;
- IEC 61000-4-6: Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields;
- IEC 60068-2-2: Environmental testing - Part 2-2: Tests - Test B: Dry heat;
- IEC 60068-2-78: Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state;
- IEC 60068-2-1: Environmental testing - Part 2-1: Tests - Test A: Cold;
- IEC 60068-2-14: Environmental testing - Part 2-14: Tests - Test N: Change of temperature;

- IEC 60068-2-6: Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal);
- IEC 60068-2-64: Environmental testing - Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance;
- IEC 60529: Degrees of protection provided by enclosures (IP Code);
- IEC 60332-3-10: Tests on electric and optical fibre cables under fire conditions - Part 3-10: Test for vertical flame spread of vertically-mounted bunched wires or cables – Apparatus;
- IEC 60695-11-10: Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods;
- Cybersecurity guideline 12: INDUSTRIAL CONTROL SYSTEMS OT SECURITY GUIDELINE;
- GSGC002: Technical Conformity Assessment (TCA);
- GSCT005: Technical characteristics of LPITS for RGDM/RGDAT;
- GSTX001: Quality Control Activities – Contractual requirements for Automatic Test Systems (ATS).

5. ORGANIZATIONAL PROCESS POSITION IN THE PROCESS TAXONOMY

Value Chain /Process Area: Networks Management

Macro process: Materials management

Process: Network components standardization

6. DEFINITIONS AND ACRONYMS

Acronym and Key words	Description
ATS	Automatic Testing System
CT	Current transformer
Global Standard (GS)	Enel Group Technical Specification
Intelligent Electronic Device (IED)	Devices that perform one or more of functions of protection, measurement, fault recording and control.
Medium Voltage (MV)	Any set of nominal voltage levels exceeding 1 kV and below a value between 30 kV and 100 kV. NOTE: The boundary value between medium

	voltage and high voltage depends on local and historical circumstances or on common usage. Nevertheless the band 30 kV to 100 kV normally contains the accepted boundary.
RGDAT	Directional fault passage and voltage indicator for MV network
RGDM	Protection and Measurements device for MV network
Remote Terminal Unit (RTU)	Remote Terminal Unit
UP	Remote Terminal Unit for the remote control and automation functions for SS and pole mounted installations
VT	Voltage transformer

7. DESCRIPTION

7.1 LIST OF COMPONENTS, PRODUCT FAMILY OR SOLUTIONS TO WHICH THE GS APPLIES

The RGDAT described in this GS is a product of the family provided in **Table 1**.

Table 1 – GSTP00X product family and description

GSTP01X type	**Product family code**	**Description**
GSTP001- RGDAT	GSTP00X	Protection and control device for MV substation – RGDAT control unit.
GSTP021 – Sensors for RGDAT and RGDM	GSTP02X	Sensor for the RGDM and RGDAT control unit

7.2 APPLICATION FIELDS

The RGDAT is a device provided to be installed in MV line bays of remote controlled MV/LV substations, to locate the presence of faults and the absence of voltage signal on the line.

The RGDAT shall detect the following events:

- passage of phase over-currents exceeding a settable threshold, whose default value is 500A (overcurrent function);
- passage of residual currents in the presence of homopolar voltage due to a ground single-phase fault (function of directional measurement of ground fault);
- passage of residual current in the presence of homopolar voltage due to double-phase to ground fault (over homopolar current function);
- voltage presence/absence on MV line;
- presence of generic ground fault (homopolar overvoltage Vo);
- presence of two-phase fault (positive undervoltage Vd, negative overvoltage Vi).

Security by design is mandatory for any devices developed to be installed in the ENEL premises. The requirements from Cybersecurity guideline 12 must be adopted.

7.3 RGDAT GENERAL REQUIREMENTS

This chapter presents all the mandatory requirements for the RGDAT hardware.

7.3.1 Environmental Operating Conditions

The device shall operate accurately in the following conditions:

- operating temperature	-25 ÷ +70°C
- relative humidity (RH, non-condensing)	0% ÷ 95%
- altitude level	0 ÷ 3000 m
- atmospheric pressure	67 ÷ 106kPa

7.3.2 Enclosure

The RGDAT device shall be placed in a case made of steel or another metal/metal alloy equivalent in terms of electromagnetic compatibility.

The size of RGDAT shall be less than 250x200mm and the chassis shall be realised for protruding mounting. RGDAT shall be mounted perpendicular with 4 screws M5 according to the fixing template shown in Figure 1. RGDAT shall be equipped with a lid easily removable.

RGDAT shall be equipped with 4 fixing screws M5, made of stainless steel, with a suitable length to protrude between 5 and 10mm from the bottom of the container; it shall have a suitable earth bolt M10 located on corner bottom right side of the device.

In correspondence of each LED shall be printed with permanent ink the relative function.

On the bottom side of RGDAT shall be provided the terminal block for the analogue inputs with a suitable cable guide for the connections toward the current transducer and the connections toward the capacitive dividers (plug of the voltage presence lights).

The enclosure of RGDAT shall satisfy the protection level IP31 code (IEC 60529).

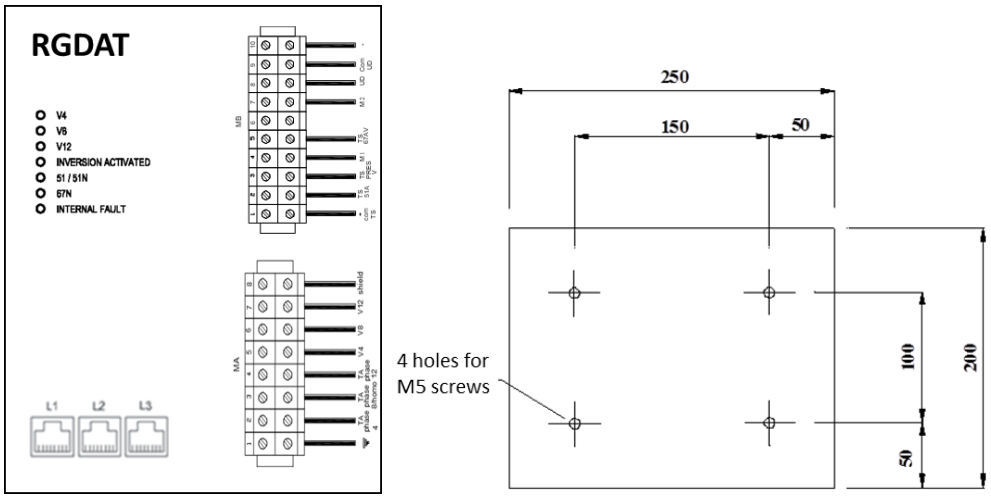


Figure 1 – Maximum dimensions and installation template of RGDAT for using on MV cells.

7.3.3 LED signals

It shall be locally signalled, through the lighting of the LED on the front of the device, the conditions of:

- recognition of fault events,
- inversion activated
- presence of voltage on the single phases
- internal fault

according with what below specified:

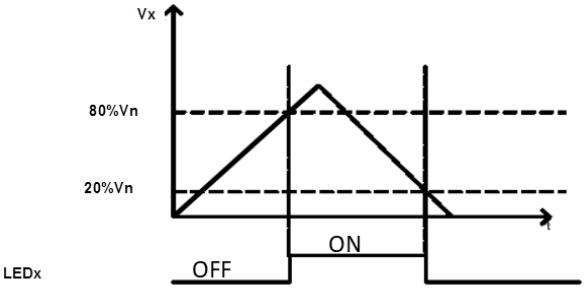
- an orange LED to signalize the phase overcurrent or residual overcurrent intervention;
- a red LED to signal the directional earth fault intervention;

- a white LED to signalize the active inversion;
- three green LEDs to identify the presence of voltage on the three phases of MV line;
- a red LED (flashing) to identify internal malfunction.

The first two LEDs (orange and red), that identify the fault of overcurrent and/or directional earth fault shall memorize the last occurred intervention.

The later intervention of one of the two thresholds (TS67 or TS51A) resets the precedent memorized if it is of a different type. In case of turning off the device each memorizations will be cancelled.

Each of any three green LEDs is associated with the presence of voltage on the corresponding phase, according to what is described in the following figure.



7.3.4 Network conditions

The networks where RGDAT will be installed can be operated with insulated neutral, neutral earthed through impedance/resistance or neutral directly earthed.

The characteristics of the reference networks are:

- Rated voltage: **from 6kV to 24kV (36kV)±10%**
- Maximum current of three-phase short circuit: **16kA**
- Maximum value of time constant τ of the phase unidirectional component decay: **20ms**
- Maximum single phase ground fault current (insulated neutral earth): from **500A to 8kA**
- Peak value of the unidirectional component of the current added to single-phase ground fault current (neutral compensated): **707A**
- Maximum value of time constant τ of the residual unidirectional component decay: **150ms**
- Presence of homopolar Voltage in healthy network condition: **0-3V**
- Harmonic content in current: **within prescribed limits by EN50160**
- network rated frequency **50Hz or 60Hz**
- frequency range fn=50Hz **47,5Hz÷51,5Hz**
- frequency range fn=60Hz **57,5Hz÷61,5Hz**

7.3.5 Installation conditions

The installation layouts of RGDAT device are illustrated in the following figures:

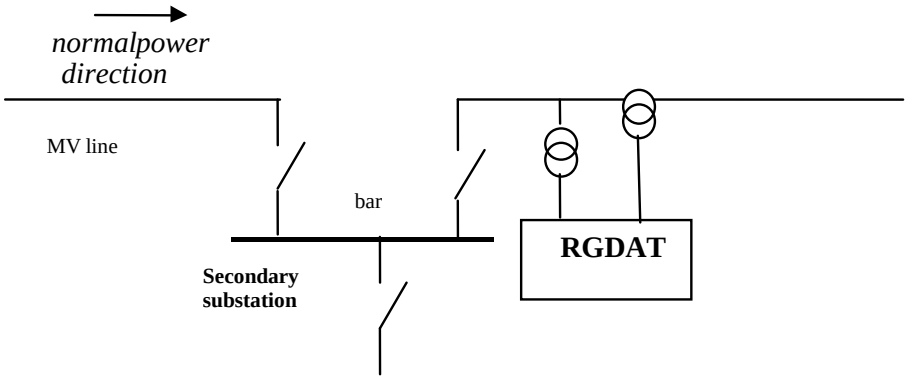


Figure 2 – RGDAT installed on output busbar

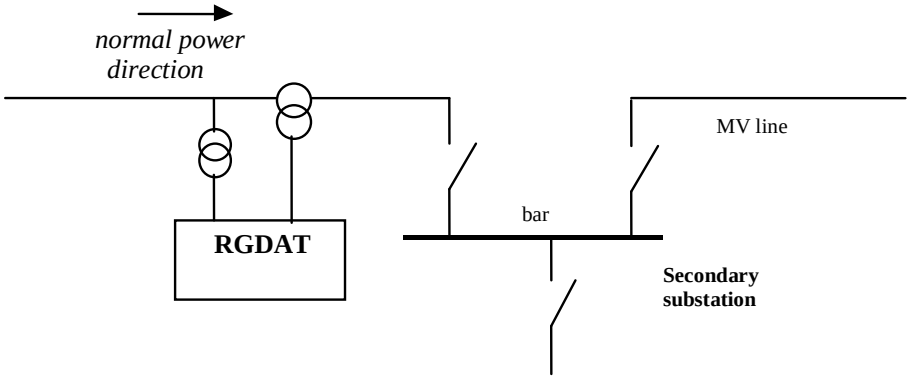


Figure 3 – RGDAT installed on input busbar

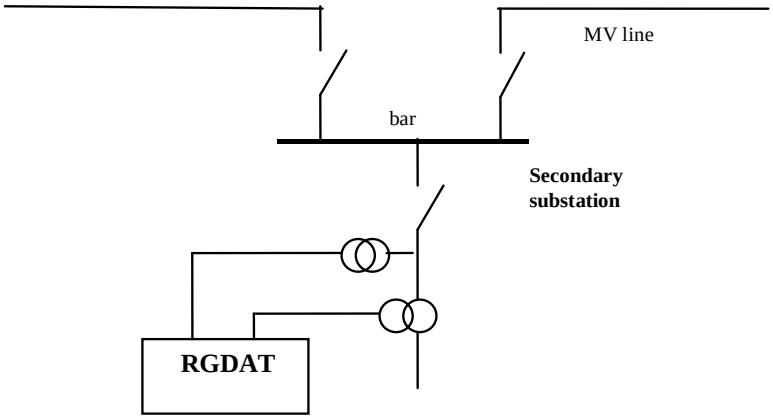


Figure 4 – RGDAT installed on shunt line.

The RGDAT device has to detect fault conditions downstream of its installation point, in relation to the direction of the power supply in the line. In order to satisfy this requirement, in all the cases listed in the previous figures, and for all power supply conditions for the MV line, a specific function is required, hereinafter referred to as inversion. Direction inversion is remotely controlled through the remote control unit device.

7.3.6 Electrical characteristics

RGDAT shall be assembled according to the principle diagram illustrated in Figure 2, Figure 3 and Figure 4. It can use two phase current transducers plus a residual current sensor or three phase current transducers.

The two configurations shall be selected by a suitable HW/SW selector (easily accessible from outside), which makes them perfectly equivalent from a functional point of view.

The firmware of the device shall be located on a non-volatile memory that can be totally update through the serial port whose device shall be equipped.

RGDAT, with no fault condition present (ground to phase or short circuit fault) shall have a consumption <3W.

The rated power supply voltage is 24 VDC with positive pole connected to the earth.

The correct operation shall be guarantee inside the range ±20% of the rated voltage, even in presence of alternating current component ≤10% on the voltage supply.

For values of the voltage supply that do not ensure the correct functioning, RGDAT device shall not emit any unwanted signal, local or remote.

RGDAT shall be protected against polarity inversion.

7.3.6.1 Terminal Boards MA and MB

The terminal boards called MA and MB must be of a screw-fixed extractable type and suitable for cable terminals, with a 5.08mm pitch. A cable marker must be indicated clearly next to these terminal boards, that identifies each input.

The MA (Figure 5), used for connections with current and voltage sensors, must be suitable for collecting section conductors until 2,5 mm^2.

In order to uniform the installation conditions and release them from the direction of energy from the time of installation of the device, it is agreed that the residual current sensor is always installed with the identification point of the Primary (P1) upwards – the side of the bars of the MV panel of the secondary substation. With such sensor positioning and in absence of inversion (Default), the RGDAT shall present a direction of output intervention from MV bars.

The remote control operator will provide for invert remotely the intervention verse according to the conditions of the substation alimentation.

The voltage signals are derived from capacitors already arranged on MV panels using the plug of the fixed part of the voltage presence/absence device.

The connections for this extraction shall be organised using six pins plug and three shielded wires of a section ≥ 0,5mm2 and a length equal to 3m. The six pins plug is included in the supply.

The abovementioned connections shall be attested on the terminal board MA. In order to ensure safety, in case of direct contacts from an operator in occurrence of insulation failure of the capacitors, shall be provided from the manufacturer an appropriate solution that will be subject to approval by Enel.

For the ground circuit part of the RGDAT shall be provided a cabling, realised in unipolar conductors with a section ≥1 mm^2, including:

- n°1 unipolar cable, for ground connection between the current node (ground bolt on the RGDAT chassis) and the earth of the substation (length ≥3 m);
- n°1 jumper in unipolar cable for the connection between the ground bolt on the RGDAT chassis and the ground terminal on the terminal block MA;

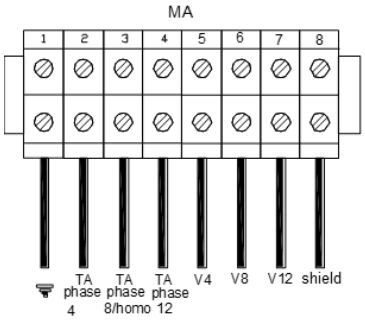


Figure 5 – MA terminal board

It must be used conductor of 1 mm^2 with a yellow-green insulator and a ring termination to the ground for bolts ϕ 10.

The MB (Figure 6), used for connection with the remote control peripheral unit, must be suitable for collecting section conductors until 2,5 mm^2.

For the electrical connection between RGDAT and the remote monitoring unit (power of device and transfer of messages) shall be provided a cable (Figure 7), with a length defined during the procurement process (par.7.5.17) and structure 9x1mm^2; the cable must have a special anti-rodent coating. One end of the cable shall be equipped with the flying part of the rectangular connector shown in Figure 8; the other one shall be prepared for the connection to the terminal board MB of the RGDAT; each cable conductor shall be equipped with tip terminations and also identification marks and references to the cabling diagram realised by the manufacturer.

The connector shall be realised with insulating material with adequate electric and mechanical characteristics; it shall be complete with strain relief and equipped with the contacts described in Figure 8.

The contacts, male type (the female type fitted to the installed fixed part on the UP not included in the supply), shall be able to receive the section conductors until 2 mm^2 and assure the characteristics indicated below:

- rated voltage: 24V
- current carrying capacity (ampacity): 13A
- Voltage drop on male-female pair traversed by a current of 5A: ≤50mV
- Insertion-extraction power: 0,40÷10N/contact

Cable characteristics shall be the following:

- rated voltage: 300/500V
- composition: 9x1mm^2
- flexible cable conductor in untinned annealed copper
- PVC insulator with R2 quality
- external diameter (on the insulator) of the cores: ≤3mm
- Distinction of the cores by marked numbers (according to CENELEC HD 186 S2), connecting the marked numbers with the identifying numbers on the conductor's pins
- PVC sheath of Rz quality
- Flameproof characteristics in accordance with IEC 60695-1-10.

On both the end of the cable shall be attached a mark strap device, in PVC, on which will be placed, during the commissioning, the indication of the number and the denomination of the compartment to which it relates.

All the connection component described above shall be dimensioned and realised to ensure the passing of the tests contained in paragraph 7.5.

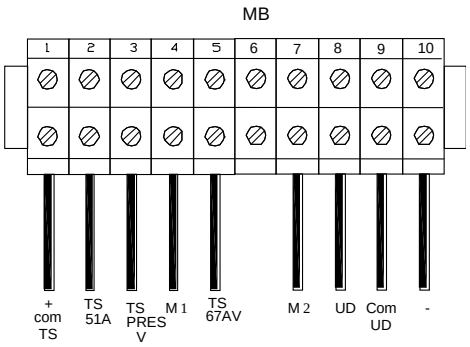


Figure 6 – MB terminal board

Table 2 – MB pin-out	
+24 Vcc/Com TS	Power supply (+24Vcc) e Common remote signals
TS 51 A	Multiphase or ground double phase fault signal
TS PRES V	Voltage presence MV signal (level)
M1	Measurement of line current (pole 1)
M2	Measurement of line current (pole 2)
TS 67AV	Single-phase ground fault signal downstream of the device
UD	Reverse direction command **67AV 8**
com UD	Common reverse direction command **67AV**
-24 Vcc	Power supply (-24 Vcc)

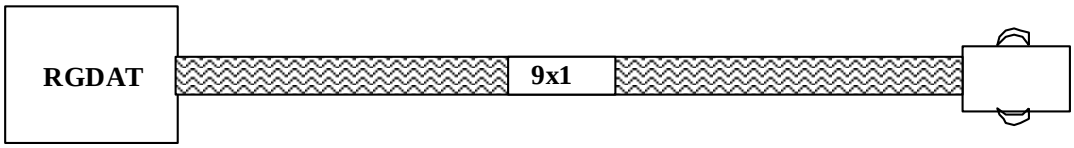


Figure 7 – Remote control unit connecting cable

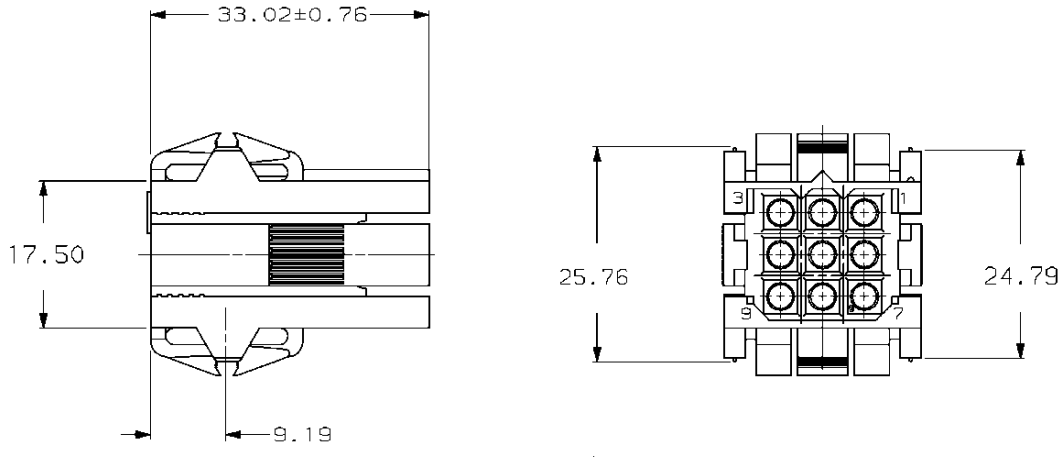


Figure 8 – Rectangular connector (UP side)

7.3.6.2 Signal relay contacts

The relay contacts for remote signalling of the exceeding of the thresholds shall be able to commute the small currents and have the following characteristics:

- nominal capacity ≥2A
- breaking capacity at 24Vcc (con L/R = 40ms) ≥0,1A
- number of electrical cycles ensured $\geq 10^5$
- number of mechanical cycles ensured $\geq 10^6$

7.3.7 Measurement circuits

7.3.7.1 Inputs for voltmetric sensors

The RGDAT must provide the possibility to measure voltages from three capacitive dividers (one for each phase with the same characteristics) with the following parameters:

- Equivalent capacitive reactance XC1 included between 100 MΩ and 700 MΩ (impedance a 50 Hz)
- Partial voltage V2 (detectable to the plug through an impedance of a measure of 1 MΩ) included between 25 V and 250 V
- Voltage variation (V2) to the plug, due to differences of capacitive values and/or to parasitic coupling between the three dividers:

Δamplitude <30%

Δdisplacement angle <15°

During the commissioning the device must be able to actuate a calibration of the measurements gained to the inputs of the 3 capacitive dividers to compensate voltage variations V2 above mentioned. Such calibration shall be performed on demand through a SW automatic procedure from the configuration terminal. It is not foreseen the possibility that such procedure becomes active periodically in an automatic mode.

The output of the capacitive dividers must be connected to the terminal board MA using the plug of the fixed part of the voltage presence/absence device.

7.3.7.2 Inputs for amperometric sensors

Regarding the current measurement (through the MA terminal board), the RGDAT can use:

- 2 Current sensors for measuring two-phase current and 1 current sensor for measuring residual current;
- 3 Current sensors for measuring three-phase current, from which obtain also the residual current.

Depending on the measurement mode chosen, the RGDAT will have the following ranges of variation of the primary current and relative secondary input voltage:

- case 1, linear, with a primary secondary ratio of $\frac{1000\text{A}}{100\text{mV}}$;
- case 2, linear, with a primary secondary ratio of $\frac{1000\text{A}}{300\text{mV}}$;
- case 3 derivative, with a primary secondary ratio of $\frac{1000\text{A}}{100\text{mV}}$;
- case 4 derivative, with a primary secondary ratio of $\frac{1000\text{A}}{300\text{mV}}$;

7.3.7.3 Inputs for sensors according to GSCT005

The RGDAT must have the possibility to be connected to sensors with the characteristics indicated in the GSCT005. The device must be equipped with 3 female RJ45 connectors, which will be used to collect the CT-VT signals, according to the pin-out indicated in GSCT005.

7.3.7.4 Measurement converters

The measurement of current sent to the Remote Control Peripheral Unit (UP) shall be derived from one of phase current transducer and converted in a current analogue value between one of the two ranges listed below:

- output level (terminals 4 and 7 in Figure 6) ± 5mA (overload ± 20%);
- output level (terminals 4 and 7 in Figure 6) 6-20mA (overload+20%);
- accuracy: ± 10%.

Both of the two output poles toward the UP shall be insulated from the earth and from the power supply. (24 V_{DC}).

7.3.8 Self-diagnosis

RGDAT shall include a self-diagnosis that at start-up and cyclically, according to the requirements of operation, checks the correctness of data and program, and also of its hardware. In case of anomaly RGDAT shall produce:

- The opening of all outputs, including that relating to the signal of Voltage Presence (TS PRES V) that, in that case, is forced to OFF condition;
- The local signal of fault through the lighting of the specific flashing red LED.

7.3.9 Device configuration and programming

RGDAT shall provide a serial interface RS232 on DB9 connector that allow the connection to a PC for configuration, monitoring and diagnosis of the device.

The programming SW includes in the supply (with a no limited number of user licenses) shall be compatible with the operating systems WINDOWS 10,7, XP.

In particular, it shall be verified all the SW functionality using an USB/RS232 converter interface.

<u>Configuration functionality</u>

The programming SW shall allow:

- the launch of the calibration procedure of voltage inputs. In the event that the calibration procedure is not successful, the program shall supply the information about the type of error identified;
- display the voltage measurements before and after the calibration procedure;
- the setting of current threshold value in field 1÷4A with a step of 0.5A (default value: 2A);

- the setting of homopolar voltage value in the range 1÷16% of phase voltage with a step 1% (default value: 6%).

Monitoring and diagnosis functionality

The programming SW shall allow:
- the monitoring of homopolar voltage measured before and after the calibration procedure;
- the monitoring of phase current and residual current in amplitude and phase;
- the launch of a diagnostic test of the device;
- the simulation of intervention of each expected device signals toward the Remote Control Peripheral Unit;
- Firmware upgrade.

7.3.10 Event Recorder

The RGDAT shall be able to record at least 100 events including time references with the following characteristics:
- the memory for data capture shall be circular type;
- each event shall include date and time;

each record concerning the single event shall containing the information concerning the fault characteristics.

7.4 PROTECTION FUNCTIONS

7.4.1 Detection of phase to ground fault: functional requirements

The device shall detect downstream ground faults both on isolated neutral grid and on compensated neutral grid, without requiring changes to the arrangements in the passage from one network type to another.

Furthermore the device shall detect downstream ground faults occurring during the circuit breaker closing. The above-mentioned fault condition shall be recognised even in the absence of voltage in capacitive plug before the fault closure (energization of the grips resulting from the closure of the control device).

The detection of the ground fault shall be guaranteed for fault resistance values able to generate:
- a homopolar voltage equal to a settable value at least in the phase voltage range of 1-40%, with a step of 1% (±15% accuracy on the set value);
- a residual current equal to a settable value from 1A to 20A (primary values) with a step of 0,5 (±15% accuracy on the set value) default 1A;
- a related phase shift between homopolar voltage and residual current that falls within the following intervention area.

The intervention condition shall correspond to the contemporary presence of the three previous conditions (logical AND).

For ground faults that don't need the intervention condition, the device should not emit any signal.

The tripping times connected with this function are the following:

- insensitivity (fault duration to not detect)	40ms
- fault duration to detect starting from energised capacitive plug (both operated with isolated neutral networks and neutral solidly earthed)	80ms
- tripping time in case of fault starting from energised capacitive plug.	≤150ms
- fault duration to detect starting from non-energised capacitive plug (both with isolated neutral operated networks and neutral solidly earthed)	150ms
- tripping time in case of fault starting from non-energised capacitive plug (closure on fault)	≤170ms
- release time	≤100ms

- time error 3%±20ms

Tripping time shall be measured from the starting fault time to the emission time of the output signal. The fault starting time is defined as the time in which the three conditions above-mentioned are verified.

RGDAT shall have two earth directional protection thresholds, 67NS1 and 67NS2, each one excludable through the configuration SW. The default for the device shall consider the 67NS2 threshold as excluded.

Considering α the lagging angle of the residual voltage respect to homopolar voltage, with the insertion modes specified in the following paragraphs the tripping area sectors shall be the following:

DEFAULT

67NS1 $60°\leq\alpha\leq255°$;

67NS2 $60°\leq\alpha\leq120°$;

The inverted sectors for this threshold (UD input = TRUE)

INVERTED SECTORS

67NS1 $240°\leq\alpha\leq75°$;

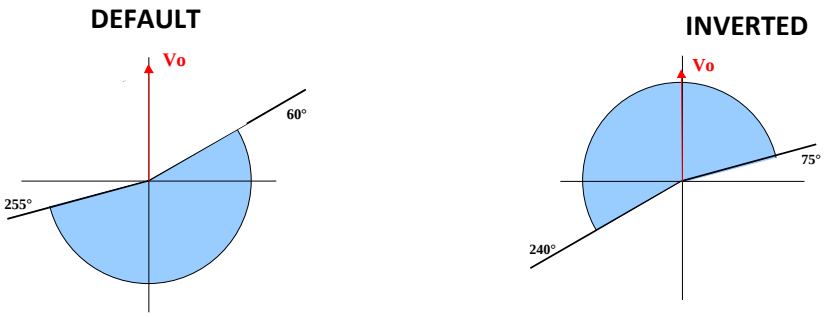
67NS2 $240°\leq\alpha\leq300°$;

Faults in 67NS2 sector shall cause the contemporaneous closure of the output contacts 51 and 67.

Faults in 67NS1 sector shall cause only the closure of the output contact 67.

- accuracy homopolar voltages in the range 1-120% and residual currents in the range 1–150A ± 2°;
- hysteresis in leaving the sector 3°

As example reports the inversion effect for the threshold 67NS1, this effect shall be that of rotating the intervention sector by an angle equal to 180° (cf. Fig.).



RGDAT shall be able to recognize intermittent type faults. The function shall be able to detect the presence of an earth voltage arc with intermittent characteristics, activating a suitable integrator, and, in this case, it have to render the output signal on relay 67, permanent during the fault duration.

The measurement function of the single phase ground fault current is not mandatory for faults with intermittent arc characteristics. In any case, the device shall not give wrong signals.

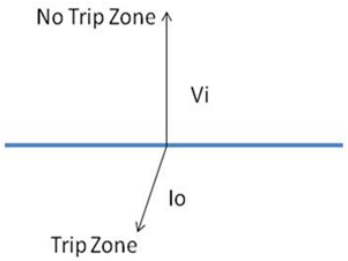
RGDAT shall permit, through a SW flag, to choose instead of the homopolar Voltage Vo, the negative sequence Voltage Vi as reference for intervention sectors.

In configuration mode, it has to be possible to disable, via software, the 67NS1 and 67NS2 functions, leaving only the 50N and 51N.

- a negative sequence voltage equal to a settable value at least in the phase voltage range of 1-40%, with a step of 1% (±15% accuracy on the set value);

- a residual current equal to a settable value from 1A to 200A (primary values) with a step of 0,5 (±15% accuracy on the set value) default 1A;

a related phase shift between negative sequence voltage and residual current that falls within the following intervention area:



7.4.2 Phase overcurrent function: functional requirements

The device shall detect over-current that exceed the tripping threshold set, even in case of closure on fault (current and voltage absent in the RGDAT installation point before closing).

Such function shall satisfies the following requirements:

- tripping threshold (Iint) — (50÷900)A step 10A default 500A ± 10%
- fault duration to not detect — 40 ms
- fault duration to detect (both starting from energized MV line, and in case of closure on fault starting from no-energized MV line) — 80ms
- maximum tripping time (Imis = 1,2 Iint) — 120 ms
- maximum tripping time (Imis = 2 Iint) — 80 ms
- closure on fault, tripping time: — no change compared with above-mentioned.
- release time — ≤80 ms
- time error — 3%±20ms
- starting time (with no intentional delay) — 45 ms ± 10ms

7.4.3 Residual overcurrent function: functional requirements

The device shall detect over-current that exceed the tripping threshold set, even in case of closure on fault (current and voltage absent in the RGDAT installation point before closing).

Such function, typical of cross-country fault, shall satisfies the following requirements:

- no-directional tripping threshold on residual current (Iint) — (10 ÷ 200) A step 2A default 150A ±10%
- fault duration to not detect — 40 ms
- fault duration to detect (both starting from energized MV line, and in case of closure on fault starting from no-energized MV line) — 80 ms
- maximum tripping time (Imis= ,2Iint) — 120 ms
- maximum tripping time (Imis=2Iint) — 100 ms
  - closure on fault, tripping time — no change compared with above-mentioned
  - release time — ≤80ms
  - time error — 3%±20ms
  - starting time (with no intentional delay) — 45 ms ± 10 ms

The settings default for phase overcurrent and residual overcurrent functions shall be such that functions are operative at the same time with the earth directional fault function (67N). Furthermore RGDAT shall allow the exclusion of 67N function, leaving operative the two no-directional overcurrent functions (even the calibration possibility of voltage inputs is disabled). In that case RGDAT will operate without the protection function 67N. To evidence this mode, the indication LED 67 located on front to the device will flash.

7.4.4 Optional timers for protection functions

Normally the timers for the functions: 51, 51N and 67N shall be set on the default values.

RGDAT shall permit, through a flag (see red circle in Figure 9), the setting on others timer values as showed in the Figure 9.

Farther RGDAT shall permit the changing of the current full-scale associated (see yellow circle in Figure 9) with remote measurement.

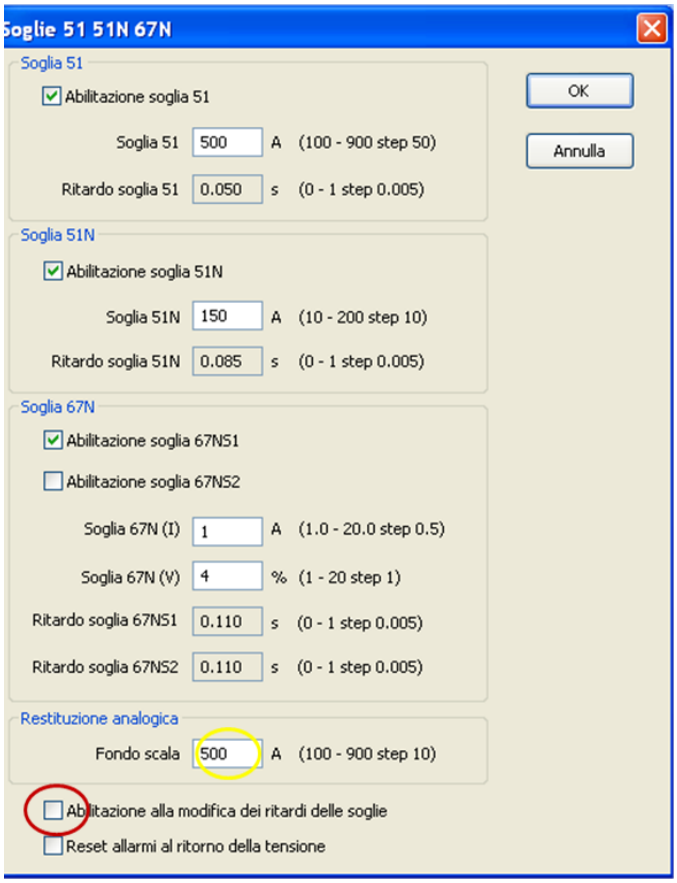


Figure 9 -Example of setting window for timers.

7.4.4.1 Optional timers signaling

Normally the behaviour of the signalling TS67 and TS51 is as above described.

RGDAT shall permit, through a flag (see red circle in Figure 10), the switch on other behaviour.

In detail:

- The command of relay 51 must be issued only when, after tripping of thresholds 51, 51N or 67NS2, the condition of "Voltage Absent" is detected within a certain time (T1, programmable, default setting: 0.5 s).
- The command of relay 67 must be issued only when, after tripping of thresholds 67NS1 or 67NS2, the condition of "Voltage Absence" is detected within a certain time (T1, programmable, default setting: 0.5 s).
- The return to quiescent status of relays 51 and 67 must occur when "Voltage Presence" condition is detected and that condition holds for a certain time (T2, programmable, default setting: 10 s).

- If there is no return of power within a certain time (T3, programmable, default setting: 4 hours), output contacts 51 and 67 return to quiescent status anyway.
- The signal of present voltage and absence voltage must be instantaneous value

According to the previous points:

- LEDs 51 and 67 must follow the state of respective relay.
- Event logging must also records the issuance of commands to relays 51 and 67, in addition to tripping of various thresholds.

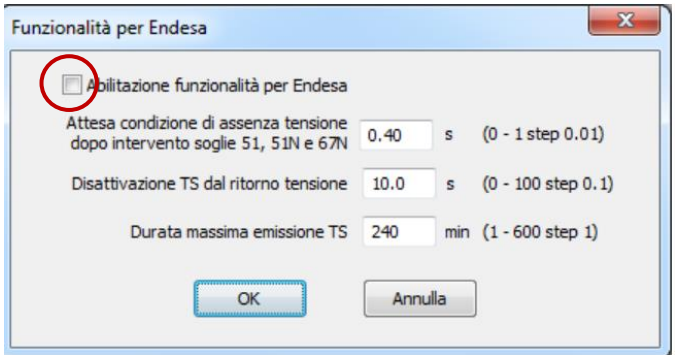


Figure 10 -Example of timers signalling.

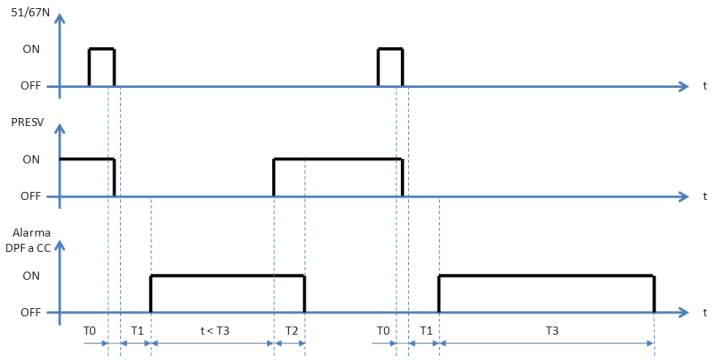


Figure 11 -Behaviour of the signalling.

7.4.5 Protection functions: 59Vo, 59Vi and 27Vd

RGDAT device shall have 59Vo functions (homopolar overvoltage function), 59Vi (overvoltage negative sequence function) and 27Vd (undervoltage positive sequence function), with the following characteristics:

- Setting ranges shall be the ones expressed in Table 3,
- The functions shall be excluded through configuration SW, the default configuration is EXCLUDED for all the three thresholds,
- Each of the function of protections 59Vo, 59Vi e 27Vd shall have an intentional time delay configurable with a setting range 0÷60s with a step 0,1s and with a tripping time with no intentional delay equal to 45ms,
- The exceeding of one of the 59Vo or 59Vi threshold (when the measured value exceed the set threshold) or the when positive sequence voltage is under then the setting threshold (27Vd) shall act on the closing/opening mode of relay contact used for the function 67N,
- Through the SW, it shall be possible change the normal status of the 67 output relay: closed, when there are no faults, or opened when there are no faults. The contact shall be always opened when the RGDAT is not powered.
- The equations for quantity calculus to sequences are given below:

$$Vo = \frac{\vec{V}_4 + \vec{V}_8 + \vec{V}_{12}}{3} \quad Vd = \frac{\vec{V}_4 + \vec{\alpha}\vec{V}_8 + \vec{\alpha}^2\vec{V}_{12}}{3} \quad Vi = \frac{\vec{V}_4 + \vec{\alpha}^2\vec{V}_8 + \vec{\alpha}\vec{V}_{12}}{3}$$

Where alpha is $\alpha = \cos(120) + jsen(120) = -0{,}5 + j0{,}866$

Protection function	Regulation ranges	Step
59Vo	1%En÷40%En	1%
59Vi	1%En÷40%En	1%
27Vd	110%En÷20%En	1%

- **Table 3**

7.4.6 Vss function

RGDAT shall include a maximum homopolar voltage function that can be activated via SW.

In case a Vss adjustable threshold is exceeded the RGDAT locks the 67N function leaving activated those 51 and 51N for an adjustable time TVss. The contact RVL shall be opened. When the homopolar voltage becomes lower than the threshold Vss, the functions 67N and RVL shall be restored to the normal operation.

Protection function	Regulation ranges	Step
Vss	1%En÷40%En	1%
TVss	(1÷600)s	1s

7.4.7 Voltage presence: functional requirements

RGDAT device shall be able to detect the presence of voltage on the line considering the following threshold:

- 20% of rated voltage (accuracy 4%);
- 80% of rated voltage (accuracy 4%).

Such threshold distinguish the passages between presence/absence voltage conditions as specified below:

- starting from voltage absence condition on the line, the logical state of Voltage Presence is recognised if, for at least 250 ms, the following condition applies:

  (VR > 80%Vn) OR (VS > 80%Vn) OR (VT > 80%Vn)

- starting from the condition of Voltage Presence ON, the logical state is no longer recognised, if, the condition applies:

  (VR < 20%Vn) AND (VS < 20%Vn) AND (VT < 20%Vn)

without intentional delays.

In case of drop and rise of 24 Vdc of power supply, the variable starts from voltage absence state. In case the below condition is TRUE the variable starts from voltage presence.

(VR > 80%Vn) OR (VS > 80%Vn) OR (VT > 80%Vn)

The signal of voltage presence, can become OFF state even if is verified the condition of voltage presence when internal logical diagnostic of the device detect an internal fault.

7.4.8 Logical Outputs

The identification of fault events shall be remotely reported through the temporary closure of the two different electrical contacts:

- A contact for the overcurrents due to faults between phases or ground double-phases (functions of phase overcurrent or residual overcurrent) as in following TS51A described;
- A contact for the downstream single-phase fault from the point of installation (directional earth fault function) as in following TS67AV described.

The remote signal shall endure for a time equal to that of fault condition and, in any case not less than 150ms.

Voltage presence shall be remotely reported by closing an additional electric contact, following indicated as TS PRES V.

The lack of power supply of the device (+24Vdc) shall not cause the emission of the signal.

TS PRES V signal shall be forced in OFF state in case of internal fault of the device.

The signals are sent to the Remote Control Peripheral Unit that elaborates them in order to select (locally) the fault section, records them chronologically and sends to the center for searching and isolating the fault section or for direct the maintenance action on MV network.

The three output relays shall be in normally opened contact with RGDAT unpowered from auxiliary voltage.

Through three appropriate pre-setting devices SW, it shall be possible to set them:

- Each single relay normally opened when monitored function is in a “FALSE” state, the relay is closed when function becomes “TRUE”,
- Each single relay normally closed when monitored function is in a “FALSE” state, the relay is opened when function becomes “TRUE”.

7.4.9 Logical inputs

It shall be provided a logical input that, if active (from an external signal level), inverts the intervention sector in the sense specified in par. 7.4.1. with the absence of activation signal, hereinafter indicated with UD, the intervention sector is that of default.

UD signal is transmitted through Remote Control Peripheral Unit according to the model in Figure 12.

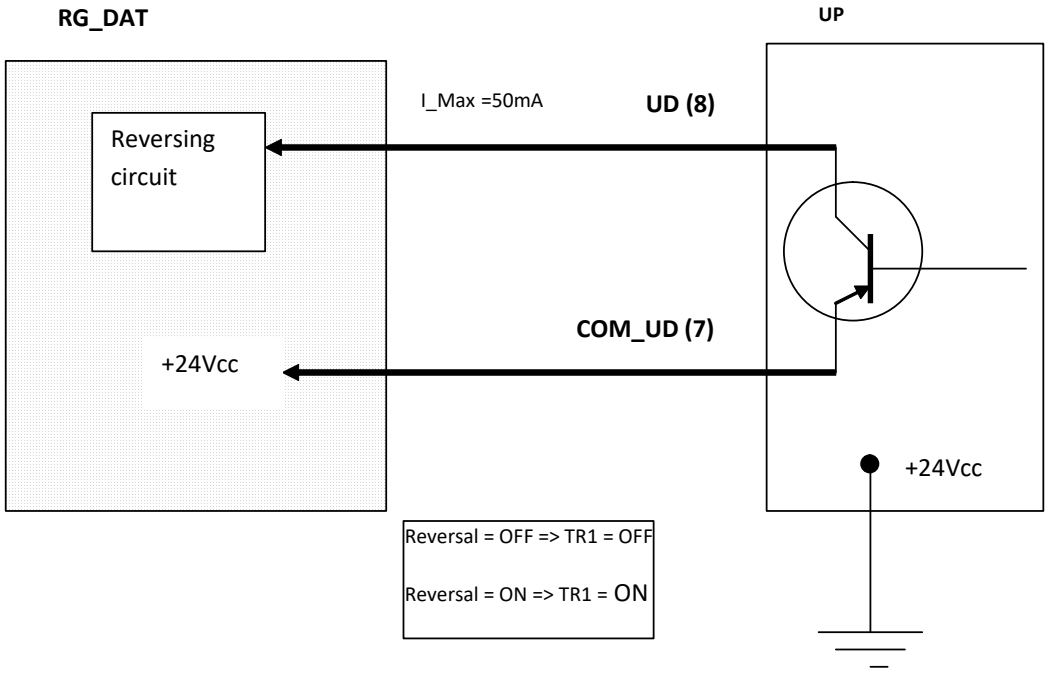


Figure 12 – Diagram of reversal of the direction command single phase to ground fault detection.

7.4.10 Voltage Monitoring Procedure

Through the setting of a configuration flag, RGDAT shall commute its mode of function from the standard one (RGDAT) to that of Voltage Monitoring. In such mode all protection functions defined beforehand shall be disabled and, furthermore, shall be redefined the meanings of logical inputs and outputs as specified below:

RGDAT shall monitoring voltage presence following an external trigger, the trigger signal will act on input used in inversion standard mode for the protection function 67N (UD). Therefore, when input is high UD, RGDAT shall check the voltage, verifying the voltage presence and signalling through the contacts of auxiliary relays (V PRESENCE).

In particular, with trigger present if is verified voltage presence, RGDAT shall close the relay contact “V PRESENCE” with a pulse (pulse duration time settable between 0 and 5000ms with a step of 10ms). “V PRESENCE” contact shall be normally opened during voltage absence.

The “line voltage presence” is a boolean variable and shall be a logic OR between the voltage presence of the three phases, whereas the voltage absence is a logic AND between the voltage absence of the three phases, as described in 7.4.7.

In parallel with the command of the V PRESENCE relay and with the same modes to actualize (pulse mode) shall be also controlled the output that in normal configuration of RGDAT is named “TS51”.

Lastly the output that in normal mode is named as “TS67” shall be bistable, that is: the output contact shall be opened if there is "voltage absence" and shall be closed if there is "voltage presence".

In the absence of enabling signal (low signal on UD) the Monitoring function, RGDAT shall command the instantaneous opening of “V PRESENCE” relay contact.

All the signals “V PRESENCE”, “TS67” and “TS51” shall be able to be filtered by a timer that will add a delay that shall be settable in a range from 0 to 5000ms with a step of 10ms.

Applying three voltage signals starting from voltage absence, with zero time delay set, the maximum delay of the voltage presence signal shall be less than 50ms.

The voltage measurement shall be anyway active, even when the digital monitoring signal is absent, in this case only the signal functions are inhibited.

Timers	Time ranges	Step
Delay filter (only for outputs “TS51” and “V PRESENCE”)	0÷5000ms	10ms
Pulse duration closing contacts “TS51” and “V PRESENCE”	0÷5000ms	10ms

Table 4 V presence: timer settings.

7.5 TESTING AND CERTIFICATION

All the requirements from this chapter must be respected. ENEL has the right to ask a prototype for any kind of verification testing. These tests must be performed in the provider factory or third party laboratories (by according to ENEL or relevant standards provision), with no cost participation by ENEL.

The sensors will be subjected to an ENEL Technical Conformity Assessment (TCA) process, by according to GSCG002 that is intended to verify if the supplied device meets regulatory standards and specifications.

7.5.1 Overview Technical Conformity Assessment (TCA) Process

The information of this paragraph are only indicative and may change by according with ENEL TCA management; final TCA organization will be discussed during the TCA kick off meeting.

7.5.1.1 TCA documents

The ENEL technical organization unit in charge of the Technical Conformity Assessment of the sensors will supervise the technical documentation and the execution of the tests required to receive the “Statement of Conformity”, according to GSCG002 prescriptions.

All the technical documentation required during that process shall be in English or in the local language of ENEL technical organization unit in charge of the TCA.

The TCA documents that shall be delivered include:

a. Type A documentation (Not confidential documents used for product manufacturing and management from which it is possible to verify the product conformity to all technical specification requirements, directly or indirectly).

b. Type B documentation (Confidential documents used for product manufacturing and management where all product project details are described, in order to uniquely identify the product object of the TCA). This type of documentation must be delivered **only to the ENEL technical organization unit in charge of the TCA**

c. TCA dossier (Set of final documents delivered by the Supplier for the TCA)

d. The supplier shall provide the TCA Dossier on digital support.

7.5.2 Test list

1. Visual inspection
2. Insulation and dielectric strength tests
3. Functional tests
4. Out of range power supply tests
5. Immunity test to electromagnetic interferences
6. Thermal performance test
7. Mechanical compatibility tests
8. Climatic tests
9. Final check of functioning

7.5.3 Type tests

The type tests are all those mentioned in the previous paragraph.

The supplier must keep and provide ENEL access to the documentation which attests to the success of the execution of the type tests.

At the discretion of ENEL such tests may be repeated all or in part during the supplies, as evidence of type conformity.

ENVIRONMENTAL COMPATIBILITY TESTS

TYPE	DETAIL		NOTES/TEST LEVELS	STANDARD
Insulation and EMC test	Impulse test		Overvoltage category IV	IEC 60255-27
	Dielectric test		AC test voltage 2 kV	IEC 60255-27
	Insulation resistance		≥100 MΩ to 500 V_{DC}	IEC 60255-27
	Electrostatic discharges		Contact discharge level 3 Air discharge level 3	IEC 61000-4-2
	Ring Wave		level 3	IEC 61000-4-12
	Damped oscillatory waves		level 2	IEC 61000-4-18
	Fast transient/burst		level 4	IEC 61000-4-4
	Surge 1,2-50/8-20		level 3	IEC 61000-4-5
	Power frequency magnetic field		level 5	IEC 61000-4-8
	Damped oscillatory magnetic field		level 4	IEC 61000-4-10
	Radiated, radio-frequency, electromagnetic field		level 3	IEC 61000-4-3
	Radiated, radio-frequency, electromagnetic field (digital radio telephones)		level 3	
	Short interruptions on d.c. input power ports		level 0% t = 0,05 s	IEC 61000-4-29
	Voltage dips		level 50% t = 0,1 s	
	Voltage variations on d.c. input power ports		Un ± 20%; t = 10 s	
	Test voltage level at main frequency		level 3	IEC 61000-4-16
	Conducted common mode disturbances in the frequency range 0 Hz to 150 kHz		level 3	
	Conducted disturbances induced by radio-frequency fields		level 3	IEC 61000-4-6
Climatic test	No-powered equipment	Dry heat	+70 °C ± 2 °C (16 hours)	IEC 60068-2-2
		Damp heat	+40 °C ± 2 °C, RH = 93% ± 3% (4 days)	IEC 60068-2-78
		Cold	(-25 ± 3)°C (16 hours)	IEC 60068-2-1
		Change of temperature	TA = -25°C; TB =70°C; (3 hours+3 hours)	IEC 60068-2-14
	Powered equipment	Dry heat	+70 °C ± 2 °C (16 hours)	IEC 60068-2-2
		Damp heat	+40 °C ± 2 °C, RH = 93% ± 3% (4 days)	IEC 60068-2-78
		Cold	(-25 ± 3)°C (16 hours)	IEC 60068-2-1
		Change of temperature	TA = -25°C; TB =70°C; (3 hours+3 hours)	IEC 60068-2-14
Mechanical test	Vibration (sinusoidal)		lower frequency 10 Hz upper frequency 500 Hz acceleration amplitude 10 m/s^2 displacement amplitude 0,075 mm	IEC 60068-2-6
	Vibration, broad-band random (digital control) and guidance			IEC 60068-2-64

- **Table 5 Test levels for environmental tests.**

7.5.4 Acceptance tests

Acceptance tests are that indicated in par. 7.5.2, points 1, 2 (except for the impulse voltage withstanding test) and 3. In case of solutions that adopt 3 phase sensors for the detection of residual current, acceptance test shall also include sensor phase tests described in par. 7.5.14, test 2c (for Holmgreen connection) or an equivalent test to be agreed, according to par. 7.5.15.

The acceptance tests must be carried out using specifically designed and automated test equipment according to GSTX001 (ATS). Each device must be accompanied by a report stating that all ATS tests have been concluded successfully.

7.5.5 Visual inspection

It is mandatory to verify the absence of visible manufacturing defects, the accuracy of construction, the compliance of the dimensions of the cabinet container with those indicated in the present specification, as well as the prescribed IP degree of protection.

7.5.6 Insulation and dielectric strength tests

The objective of tests is that to verify dielectric strength between the three independent circuits of RGDAT described below; each test shall be performed by applying the voltage (with the corresponding value to the level specified for each circuit) between each of the three circuits and the two connected to ground.

7.5.7 Verification of all functions

All the functions shall be checked with three different conditions of power supply: 80%, 100% and 120% of the power supply voltage.

The tests to perform concern:

Tests on current transducers. Measurement of offset current induced due the assembling conditions of residual current transducer (par. 7.5.14).

Check the phase error relating to the voltage channel of the RGDAT when it is connected to a signal generator (which emulates the function of an ideal generator). This error must be ≤ 2°.

Tests on the detection of voltage presence/absence. Tests on the detection of voltage presence/absence. Variation of the voltage on both directions near of the threshold voltages. It shall be tested the behaviour in all possible case in the changing of voltage on three phases.

Check of the angular sector of intervention concerning the detecting function of the phase to ground fault. Such check shall be performed considering both senses of rotation of the vector in steps of 1°, and shall be performed with and without inversion.

Verification of the intervention thresholds. In static conditions (that is steady sinusoidal wave) shall be verified all the thresholds (voltage and current) previously specified. In particular:

- Verification of thresholds of maximum current and maximum homopolar current, both at the tripping and the release;
- Verification of thresholds (from 1% to 16%) of homopolar voltage both at the tripping and the release;
- Verification of thresholds (from 1A to 4 A) of homopolar current both at the tripping and the release.

Transient tests. Feeding RGDAT device with voltage and current waveforms obtained from fault simulations or default field recordings, it is possible to make a functional test of the device in transient conditions. In particular transients refer to the following conditions:

Fault tests between phases. Multi-phase faults with current equal to 1.2 Iint, 2 Iint, 10 Iint, (3 cases)

Fault tests for phase to ground fault. Faults for isolated neutral earth networks and neutral current compensation networks with variable compensation, with a network extension from 100 A to 500 A, with zero fault resistances with a value of 15% inferior and higher to the limit corresponding to the calibration reported in par. 7.5.15 (24 cases)

Fault tests for country cross fault. Faults for a network with a compensation of 100%, with an extension of 300 A and with fault resistances corresponding to residual current (on the two lines with the fault) from 120 A to 180 A respectively (4 cases). Holding stable the threshold value of intervention for the maximum homopolar current (value specified 150 A) RGDATs of the lines affected by the faults, it is required to intervene with trip 51 for currents over the above-mentioned threshold; it could intervene with trip 67 (according to the active angular sector) for currents below the same threshold.

Test closure on fault . Closure transients (and rapid reclosing) on faulty line for isolated neutral earth and neutral current compensation networks in the conditions of existing line voltages (RGDAT upstream of the operating organ) and absent (RGDAT downstream of the operating organ) (12 cases).

Evolutionary fault tests. Transients of evolutionary fault (closure on single-phase fault and reclosing on double-phase and vice versa) (2 cases).

Re-striking faults. Simulation of re-striking faults on network with 100% compensation and extension 300A (4 cases). In case of faults as shown in fig. 8 is expected a behaviour as shown in the same figure.

Fault recordings (only in type tests): Transients obtained by field oscilloperturbographyc recordings, related to single-phase fault events with an intervention of SHUNT switch and re-striking faults for isolated neutral earth networks (6 cases) and neutral current compensation networks (6 cases)

A detailed description of the test cases and of the expected results is described in par. (par. 7.5.15). It will be made available from ENEL the file in COMTRADE format needed to verify the above-mentioned functional test.

In case of type tests, the tests shall be repeated five times.

7.5.8 Out of range supply tests

It shall be verified that all functions of RGDAT are inhibited by feeding the device with the values of the supply voltage that don't provide the proper function.

7.5.9 Electromagnetic compatibility tests

The RGDAT must comply with the EMC requirements defined in IEC 60255-26.

The objective of the tests is to verify the correct functioning of RGDAT subject to the application of various electromagnetic disturbance.

- the function of RGDAT is intended as "protection";
- the environment installation is intended as "MV/LV station";
- the signal port is intended as "local connections".

The interferences shall be applied on the terminal board MA, with reference to voltage inputs, and to current transducers (primary signals) for what concerns the current inputs.

The procedure for verifying the correct functioning of RGDAT during this tests shall be agreed with ENEL.

7.5.10 Thermal behavior tests

It shall be revealed the thermal map of the RGDAT feeding with maximum values of the nominal range; the test shall be performed under the following normal environmental conditions:

- temperature: -25 ÷ 70 °C
- atmospheric pressure: 86 ÷ 106 kPa
- relative humidity: 0 ÷ 95%

The values of over temperature, collected near the individual components, shall be used for verifying that, at the higher temperature of the expected operating, the maximum permissible temperature of functioning for the same components is not exceeded.

Moreover, the thermal map shall be used for the definition of thermal time constant in view of the temperature variation test.

7.5.11 Mechanics compatibility tests

The tests and are divided in:

- immunity tests to sinusoidal type vibrations (working device)
- resistance tests to transport and handling stresses (non working device)

The requirements to apply are the following:

- immunity to sinusoidal vibrations V.H.3
- resistance to transport and handling stresses test type broadband random vibrations

The procedures for verifying the correct operation of RGDAT during this tests shall be agreed with ENEL.

7.5.12 Climatic tests

The referring levels of the single group of tests are indicated in the Table 5.

The procedures for verifying the correct operation of RGDAT during this tests shall be agreed with ENEL.

7.5.13 Functional final test

In order to check that RGDAT operates regularly after the execution of all the prescribed type tests, they shall be repeated, with the characteristics of the acceptance tests, those indicated in sections 1, 2 and 3 of par. 7.5.2.

7.5.14 Checking tests for current sensors

We assume that sensors present a linear characteristic, in the contrary case the manufacturer shall supply the characteristic curve.

The supplier shall specify the input impedance of the inputs used to acquire the quantities concerning currents of RGDAT, and indicate the magnitude that used by the device for its algorithm (voltage and/or current).

The tests that should be performed are of two types: a first sequence planned for the sensor of residual currents for the case of RGDAT that uses two sensors for phase currents and one sensor for residual currents, a second sequence for evaluate the behaviour of RGDAT that uses three sensors of phase current.

Tests for the sensor of residual current

1a. Determination of the characteristic

The residual sensor is charged with the impedance provided by the manufacturer is determined the typical primary current/output signal (voltage) up to 200A.

1b. Test to highlight the behaviour of the sensor of residual current to centering and symmetry mismatch of the three passing cable.

Instead of considering a set of three currents, to simplify, it is used a coil at least of 1500mm with axes of conductors distant each other 45mm.

The coil is inserted in the centre of residual current sensor, applying a current of about 200A. The coil is moved along a specific direction from the centre to touch the inner side of the sensor, recording the value of the quantity transduced and bringing back to primary current.

Such measurement shall be repeated for the eight directions placed at 45° relative to each other, that cover the entire round angle. At least two directions shall correspond with the axis of air gaps.

The test is considered passed if in all conditions the detected residual current does not exceed (in terms of primary current) 0,6A (and 0,2A in the case of a coil perfectly centred).

1c. Test to highlight the behaviour of residual current sensor in presence of an external current.

This test has the objective to evaluate the influence over the residual current sensor to residual current that flows on a set of three placed near the same sensor.

To simplify, the test is performed with a coil of, at least, 1500mm high and, at least, with a width of 1000mm, based a current equal to 200A.

Placing the coil outside of the sensor of the residual current, starting from the contact position between the sensor and the coil, the latter is progressively separated measuring the translated magnitude and obtaining the equivalent primary current.

The test shall be repeated for the same eight directions considered in point 1b.

The test is considered passed if, in all conditions, the detected residual current for distance between the coil and the transducer >= 5cm does not exceed (in terms of primary current) 0,3A.

Tests for phase current sensors (configuration that consists on 3 phase current sensors)

2a. Determination of feature

A sensor is charged with the impedance provided by the manufacturer is determined the typical primary current / output signal (voltage) up to 750A.

2b. Test to highlight the behaviour to centering and symmetry faults of the three passing cable.

The three current sensors shall be connected to detect a single secondary magnitude sum of the three translated quantities.

Instead of considering a set of three currents, to simplify, it is used only a conductor with a current equal to 600A that flows two sensors in order to invalidate the residual current.

The conductor shall remain perfectly centred inside the first sensor and for what concern the second sensor it shall be moved along the eight directions as required in the similar test set for the point 1b.

The test is considered passed if, in all conditions, the detected residual current does not exceed (in terms of primary current) 0,6A (and 0,2A in case of both conductors perfectly centred).

2c. Test to verify the correct translation of homopolar current.

Considering the three sensors connected as in point 2b. two of them are crossed by a centred conductor with a current of 600 A; inside the third transducer is passed another conductor with a current of 4 A. The conductor is moved along the eight positions as required in point 1b. and the secondary magnitude is measured to obtain the equivalent primary current.

The test is considered passed if, in all conditions, the error of the detected residual current does not exceed (in terms of primary current) 0,6 A.

Remark:

The tests 2b and 2c evaluate the behaviour of RGDAT that employs three phase-current sensors in Holmgreen configuration.

In the event of adopting three phase current sensors, but with detection of residual current through mathematical calculations, the tests to perform on sensor shall be agreed with ENEL according to the planned modality.

7.5.15 Description of test cases for RGDAT device – Functional test

The objective of the following functional tests is to check through additional tests the RGDAT conformity to functional requirements enclosed in this specification.

The tests will verify the ability to recognize electrical faults and the presence/absence of line voltage.

The tests to perform concern the recognizing of fault events (phase to ground fault, cross-country fault, and phase to phase fault) and reclosing on fault, and also the detection of voltage presence, during opening and closing of line switch and/or IMSs in Substation.

In order to check the detection of **fault transients** shall be applied the following sequence of events:

- Pre-fault healthy voltage signal (duration about 5 seconds);
- Electrical fault;
- Opening of the line with fault (after an appropriate period of time, higher than the time of recognition specified for RGDAT device);
- Removal of the fault;
- Reclosing of the line (with voltage return to the value previous to the fault itself);
- Post-fault healthy voltage signal (duration about 2 seconds).

For **closing** cases **(and rapid reclosing) on fault** the sequence is, on the other hand the following:

- Pre-fault healthy voltage signal (duration about 3 seconds);
- Closing on fault;
- Opening of the line with fault (after an appropriate period of time, higher than the time of recognition specified for RGDAT device);
- Rapid reclosing of the line (while remains the fault condition).

Concerning the cases of **re-striking fault**, have assumed some cases with a duration of less than 80 ms and other ones with a higher duration, to verify the possible detection capacity and insensitivity towards intermittent faults.

Finally, the fault recordings concern single-phase faults and arc events, as described in detail hereinafter.

The network structure supposed for the tests acquired from simulations is shown in Figure A-1 and represents a simplified network diagram, but adequate for the purposes of the same tests.

It is a MV network to 20 kV composed of three equivalent lines; the network extension in terms of fault single-phase current changes, according to the cases, from 100A to 500A. Unless otherwise specified, the line shown in fig. as L1 is supposed of a length that represents about the 40 % of the entire network (maximum value allowed), while the remaining two lines are supposed of a length corresponding respectively to 10% and to 50% of the entire network.

In cases of compensated network has supposed the diagram with the coil connected to the neutral point of transformer.

The three-phase short-circuit current to MV bus-bars is approximately 10kA.

The faults (ground single-phase) are supposed around the zero crossing of the phase voltage; this condition, although unlikely, represents, in general, a more critical condition for RGDAT device (in case of compensated network the fault current - then residual measured on the line with the fault - displays the maximum unidirectional component).

The cases of single-phase fault supposed a different fault resistances according to what specified hereinafter.

The output values of RGDAT to control for the evaluation of the result of the described tests are the signals TS67AV, TS51A, TSPRESV.

All the cases described represent the type tests for RGDAT device; the acceptance tests are represented, on the other hand, by a little subset of the above-mentioned type tests, identified in the column “test” with the symbol “T+A” (Type+Acceptance).

Multiphase fault tests

20 kV network isolated neutral earth, extension 200A. These are ground bi-phase fault with an appropriate fault resistance supposed in point p1 of line L1 (about 25% of the length)

Referring to Figure A-1, for these fault transients are provided:

- Phase voltage in point 1;
- Phase current in point 1;

for each transient, the functional test consists in the test obtained feeding the device with phase voltage and, respectively, phase current R+S, R+T, S+T. Then, each test shall be repeated launching in the device the direction reversal (the test result shall be independent from the presence of reversal signal).

event	name	fault current	test
1	gupol1	≈4 kA (8 In)	T
2	gupol2	≈800 A (1.6 In)	T+A
3	gupol3	≈550 A (1.1 In)	T

Fault tests for ground single-phase.

Referring to Figure A-1, for these transients of single-phase fault are provided:

- Phase voltage and homopolar current[1] in point 1 (faulty line);
- Phase voltage and homopolar current in point 2[2] (healthy line);

For each transient, the test consists in two tests, obtained feeding the device, respectively, with quantities in point 1 and with quantities in point 2. Then, each test shall be repeated launching in the device the direction reversal.

Tests with 20 kV network, isolated neutral

event	name	network extension	calibration	Rfault [Ω]	α (Lfault)	Test
1	gm01ni	100 A	Vo=9% Io=1 A	0.	90°	T+A
2	gm02ni	100 A	Vo=9% Io=1 A	1250.	90°	T
3	gm03ni	100 A	Vo=9% Io=1 A	1060.	90°	T
4	gm04ni	100 A	Vo=9% Io=1 A	1450.	90°	T
5	gm05ni	200 A	Vo=1% Io=1 A	0.	90°	T
6	gm06ni	200 A	Vo=1% Io=1 A*	5000.	90°	T
7	gm07ni	200 A	Vo=1% Io=1 A*	4000.	90°	T
8	gm08ni	200 A	Vo=1% Io=1 A*	6000.	90°	T

* Additional test – Verify the NON-intervention of RGDAT for adjustment of Io=2A.

EXPECTED RESULTS

		without reversal	with reversal

[1] Intended as the sum of three phase current (so it is the primary residual current of the current sensor of the RGDAT).

[2] In case of RGDAT assembled with three phase sensors will be supplied, as an alternative to residual current, the three phase currents.

event	name	faulty line	healthy line	faulty line	healthy line
1	gm01ni	trip 67	no trip	no trip	trip 67
2	gm02ni	trip 67 (possible)	no trip	no trip	trip 67 (possible)
3	gm03ni	trip 67	no trip	no trip	trip 67
4	gm04ni	no trip	no trip	no trip	no trip
5	gm05ni	trip 67	no trip	no trip	trip 67
6	gm06ni	trip 67 (possible)*	no trip	no trip	trip 67 (possible)*
7	gm07ni	trip 67*	no trip	no trip	trip 67*
8	gm08ni	no trip	no trip	no trip	no trip

* Additional test – Verify the NON-intervention of RGDAT for adjustment of Io=2A.

Tests with 20 kV network, compensated neutral

event	name	network extension	Compensation degree	Set calibration	Rg [Ω]	α (Lfault)	Test
1	gm01nc	300 A	50 %	Vo=6% Io=1 A	≈0 Ω	130,5°	T+A
2	gm02nc	300 A	50 %	Vo=6% Io=1 A	1000.	130,5°	T
3	gm03nc	300 A	75 %	Vo=7% Io=1 A	1500.	210,5°	T
4	gm04nc	300 A	75 %	Vo=7% Io=1 A	1800.	210,5°	T
5	gm05nc	500 A	95 %	Vo=1% Io=1 A	≈0 Ω	184°	T
6	gm06nc	500 A	100 %	Vo=1% Io=1 A*	17 kΩ	251°	T
7	gm07nc	500 A	100 %	Vo=1% Io=1 A*	14 kΩ	251°	T
8	gm08nc	500 A	100 %	Vo=1% Io=1 A*	20 kΩ	251°	T
9	gm09nc	300 A	135 %	Vo=12% Io=1 A	≈0 Ω	252°	T
10	gm10nc	300 A	135 %	Vo=12% Io=1 A	790 Ω	252°	T
11	gm11nc	300 A	135 %	Vo=12% Io=1 A	670 Ω	252°	T
12	gm12nc	300 A	135 %	Vo=12% Io=1 A	910 Ω	252°	T
13	gm13nc	500 A	150 %	Vo=15% Io=1 A	≈0 Ω	255,5°	T
14	gm14nc	500 A	150 %	Vo=15% Io=1 A	280 Ω	255,5°	T
15	gm15nc	500 A	150 %	Vo=15% Io=1 A	230 Ω	255,5°	T
16	gm16nc	500 A	150 %	Vo=15% Io=1 A	330 Ω	255,5°	T

* Additional test – Verify the NON-intervention of RGDAT for adjustment of Io=3A.

EXPECTED RESULTS

		without reversal	with reversal	without reversal	with reversal
event	name	faulty line	healthy line	faulty line	healthy line
1	gm01nc	trip 67	no trip	no trip	trip 67
2	gm02nc	trip 67	no trip	no trip	trip 67
3	gm03nc	trip 67 (possible)	no trip	no trip	trip 67 (possible)
4	gm04nc	no trip	no trip	no trip	no trip
5	gm05nc	trip 67	trip 51	no trip	trip 51
6	gm06nc	trip 67 (possible)	no trip	trip 67 (possible)	trip 67 (possible)
7	gm07nc	trip 67	no trip	trip 67 *	trip 67
8	gm08nc	no trip	no trip	no trip	no trip
9	gm09nc	trip 67 o 51	trip 51	trip 51 (possible)	trip 51
10	gm10nc	trip 67 (possible)	no trip	trip 67 (possible)	trip 67 (possible)

11	gm11nc	trip 67	no trip	trip 67	trip 67
12	gm12nc	no trip	no trip	no trip	no trip
13	gm13nc	trip 51	trip 51	trip 51	trip 51
14	gm14nc	trip 67 (possible)	no trip	trip 67 (possible)	trip 67 (possible)
15	gm15nc	trip 67 (possible)	no trip	trip 67	trip 67
16	gm16nc	no trip	no trip	no trip	no trip

* Additional test – Verify the NON-intervention of RGDAT for adjustment of Io=3A.

Fault tests for cross-country fault

Referring to Figure A-1, for these transients of double-phase fault are provided:

- Phase voltages, phase currents and residual current[3] in point 1 (fault on first line);
- Phase voltages, phase currents and residual current in point 3 (fault on second line);

For each transient, the test consists in two tests, obtained feeding the device, respectively, with quantities in point 1 and with quantities in point 3. Then, each test shall be repeated launching in the device the direction reversal.

Tests with 20 kV network, 300 A, compensated neutral with a compensation degree of 100%

The faults are supposed (on different phases) in points p1 and p2, Figure A-1.

event	denomination	Iomo line 1	α 1	Iomo line 2	α 2	test
1	gdomo1	250 A	101°	350 A	275°	T
2	gdomo2	150 A	99.5°	265 A	272°	T
3	gdomo3	37 A	107°	135 A	268°	T
4	gdomo4	63 A	103°	165 A	270°	T

EXPECTED RESULTS

		without reversal		with reversal	
event	name	faulty line 1	faulty line 3	faulty line 1	faulty line 3
1	gdomo1	trip 51	trip 51	trip 51	trip 51
2	gdomo2	trip 51 or trip 67	trip 51	trip 51 (possible)	trip 51
3	gdomo3	trip 67	no trip	no trip	trip 67
4	gdomo4	trip 67	trip 51	no trip	trip 51

Closed tests (and rapid re-closure) on permanent fault

Referring to Figure A- 2 for transients of fault closure and re-closure are provided:

- Phase voltages Va (quantities 1,2,3 of comtrade file)
- Phase voltages Vb (quantities 4,5,6 of comtrade file)
- Residual current Iomo1 (quantity 7 of comtrade file)
- Residual current Iomo3 (quantity 8 of comtrade file)

For each transient, the functional test consists in four tests, obtained feeding the device respectively:

- With Va voltages and Iomo1 current (with these quantities is reproduced a condition of closure on the downstream fault, with presence of voltages before the closure (capacitive panels already fed);

[3] Intended as the sum of three phase current (so it is the primary residual current of the sensor of the RGDAT).

- with Vb voltages and Iomo1 current (with these quantities is reproduced a condition of closure on the downstream fault, with absence of voltages before the closure (capacitive panels not fed);
- With Va voltages and Iomo3 current (with these quantities is reproduced a condition of closure on the upstream fault, with presence of voltages before the closure (capacitive panels already fed);
- with Vb voltages and Iomo3 current (with these quantities is reproduced a condition of closure on the upstream fault, with absence of voltages before the closure (capacitive panels not fed);

the tests shall be conducted setting up for the RGDAT a **voltage calibration equal to 6% and a value of minimal current equal to 1A** (except as further specified), and without reversal signal.

6 events with isolated neutral network

rich_01ni zero resistive fault with “synchronous” closure of IMS poles;

rich_01nibis as previous, but the fault lasts only 150ms (time limit of fault duration to recognize);

rich_02ni zero resistive fault with IMS poles discrepancy equal to 2ms.

rich_03ni resistive fault (Vomop about 7%: shall intervene) with IMS poles discrepancy equal to 2ms.

rich_04ni resistive fault (Vomop about 5%: shall not intervene) with IMS poles discrepancy equal to 2ms.

rich_05ni resistive fault (Vomop about 7%: shall intervene) with IMS poles discrepancy equal to 5ms.

rich_05nibis as previous, but the fault lasts only 150ms (time limit of fault duration to recognize);

rich_06ni zero resistive fault with IMS poles discrepancy equal to 10ms.

event	Name	Va – Iomo1	Va – Iomo3	Vb – Iomo1	Vb – Iomo3
1	rich_01ni	trip 67	trip 51	trip 67	trip 51
2	rich_01nibis	trip 67	trip 51	trip 67	trip 51
3	rich_02ni	trip 67	trip 51	trip 67	trip 51
4	rich_03ni	trip 67	no trip	trip 67	no trip
5	rich_04ni	no trip	no trip	no trip	no trip
6	rich_05ni	trip 67	no trip	trip 67	no trip
7	rich_05nibis	trip 67	no trip	trip 67	no trip
8	rich_06ni	trip 67	trip 51	trip 67	trip 51

The event **rich_04ni** shall be repeated for downstream cases (line 1) setting up a voltage adjustment equal to 2% and in current equal to 4A : trip shall not occur because Iomo is inferior to 4A.

6 events with Compensated Neutral network

rich_01nc zero resistive fault with “synchronous” closure of IMS poles;

rich_01ncbis as previous, but the fault lasts only 150ms (time limit of fault duration to recognize);

rich_02nc zero resistive fault with IMS poles discrepancy equal to 2ms.

rich_03nc resistive fault (Vomop about 7%: shall intervene) with IMS poles discrepancy equal to 2ms.

rich_04nc resistive fault (Vomop about 5%: shall not intervene) with IMS poles discrepancy equal to 2ms.

rich_05nc resistive fault (Vomop about 7%: shall intervene) with IMS poles discrepancy equal to 5ms.

rich_05ncbis as previous, but the fault lasts only 150 ms (time limit of fault duration to recognize);

rich_06nc zero resistive fault with IMS poles discrepancy equal to 10 ms.

EXPECTED RESULTS

event	name	Va – Iomo1	Va – Iomo3	Vb – Iomo1	Vb – Iomo3
1	rich_01nc	trip 67	trip 51	trip 67	trip 51
2	rich_01ncbis	trip 67	trip 51	trip 67	trip 51
3	rich_02nc	trip 67	trip 51	trip 67	trip 51
4	rich_03nc	trip 67	no trip	trip 67	no trip
5	rich_04nc	no trip	no trip	no trip	no trip
6	rich_05nc	trip 67	no trip	trip 67	no trip
7	rich_05ncbis	trip 67	no trip	trip 67	no trip
8	rich_06nc	trip 67	trip 51	trip 67	trip 51

The event **rich_04nc** shall be repeated for downstream cases (line 1) setting up a voltage adjustment equal to 2% and in current equal to 4A: trip shall not occur because Iomo is inferior to 4A.

Tests of closure (and rapid reclosure) on evolutionary fault

- with the same test procedures of the fault closing and reclosure tests above described will have:

2 events (with Compensated Neutral network) of evolutionary fault

evol_01nc single-phase fault (Iomo<150A) that at the second reclosure returns as double-phase (Iomo>150A);

evol_02nc double-phase fault (Iomo>150 A) that at the second reclosure returns as simple single-phase (Iomo<150A);

EXPECTED RESULTS

event	name	Va – Iomo1	Va – Iomo3	Vb – Iomo1	Vb – Iomo3
1	evol_01nc	trip 67+ trip 51	no trip	trip 67+ trip 51	no trip
2	evol_02nc	trip 51+ trip 67	trips 51 (possible)	trip 51+ trip 67	trips 51 (possible)

Tests relating to intermittent arc simulations.

Referring to Figure A-1 for transients of fault closure are provided:

- phase voltages and residual current[4] in point 1;
- phase voltages and residual current in point 2;

For each transient, the functional test consists in two tests, obtained feeding the device respectively with quantities in point 1 and quantities in point 2. Each test shall be then repeated by activating in the device the directional reversal. The adjustments to set for the RGDAT will be **Vomo=2%, Iomo=1A** for all the tests.

The tests in question refer only to the directional detection function of the single-phase fault, in the event that fault current is not continuous but, for further arc extinctions and restriking, indeed intermittent.

[4] Intended as the sum of three phase current (so it is the primary residual current of the sensor TA of the RGDAT).

The used arc modeling, relatively simple, consists in a fault that, activated for an appropriate ground-phase voltage, it keeps a certain resistance for a part of the cycle; such resistance is later increased very rapidly, leading to about 1 millisecond to extinction of the same fault.

The simulations differ in the duration of the event and in the hypothesis of the arc priming.

Tests refer to a network of 20 kV, 300 A.

event	denomination	Network type	Event duration	test
1	arc1	NI	<40 ms	T
2	arc2	NI	>80 ms	T
3	arc3	NI	1 s	T
4	arc4	NI	1 s	T
5	arc5	NC	<40 ms	T
6	arc6	NC	>80 ms	T
7	arc7	NC	1 s	T
8	arc8	NC	1 s	T

EXPECTED RESULTS

With device without reversal

- For tests with quantities in point 1 (faulty line): trip 67 or no trip;
- For tests with quantities in point 2 (healthy line): no trip.

With device with active reversal

- For tests with quantities in point 1 (faulty line): no trip;
- For tests with quantities in point 2 (healthy line): trip 67 or no trip.

Fault recordings (only for type tests)

Transients obtained by field oscilloperturbographyc recordings, related to single-phase and/or intermittent fault events.

For these cases are available wave forms of secondary phase voltages, of homopolar voltage (not necessary for the test) and residual currents of two secondary lines (one of which with the fault): so it will possible to feed RGDAT directly with these quantities on MB terminal board or through current transducers and capacitor dividers after a recalculation of the values on the primary side.

For each transient, the functional test consists in two tests, obtained feeding the device with bar voltages and, respectively, with the residual current of the faulty line and of the healthy line. Then each test shall be repeated activating in the device the direction reversal.

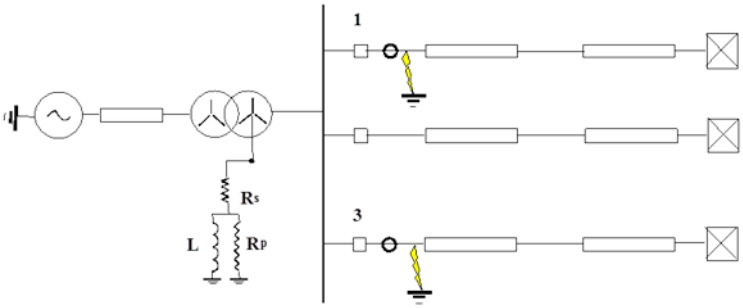
Isolated neutral network

Recordings of single-phase fault with the intervention of SHUNT switch (3 cases) and intermittent arc events (3 *cases*).

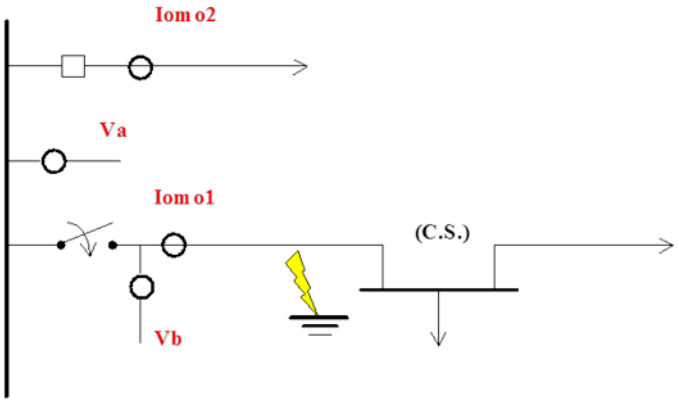
Compensated neutral network

Recordings of single-phase fault (3 cases) and intermittent arc (3 *cases*).

At last, there are two field recordings, concerning an intermittent arc event on compensated neutral network.



- **Figure A-1 Reference network for TEST events of RGDAT**



- **Figure A- 2: Events for fault closure.**

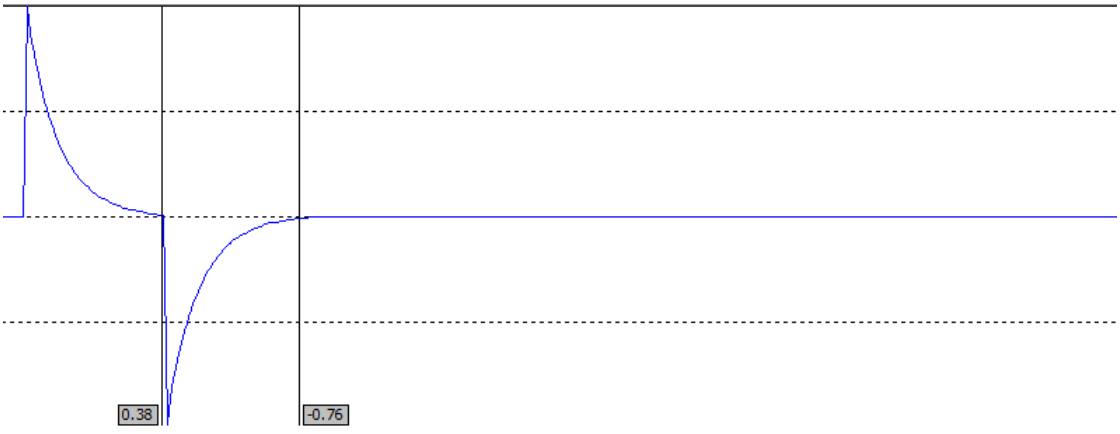
Impulse response of integrator Rogowski

RGDAT shall have some output measurement points of the Rogoswski integrated signal.

With the Rogoswski coils connected to the RGDAT, will injected a primary positive impulse of current (duration 20ms; amplitude 20A).

The time constant (τ) of the impulse response shall be less than 4ms (Figure 13).

It's allowed a time constant less than 60ms but in that case the amplitude of the impulse response must be less than 1/20 of the injection.



- **Figure 13 -Example of impulse response.**

During a simulation of a re-striking fault RGDAT shall record the intervention measurement values on a log file.

Examples of a correct functioning following a ground-phase fault and intermittent arc (both with resistance within specification limits).

In Figure 14 is showed a waveform of residual current and of fault detection signal at the output of the device.

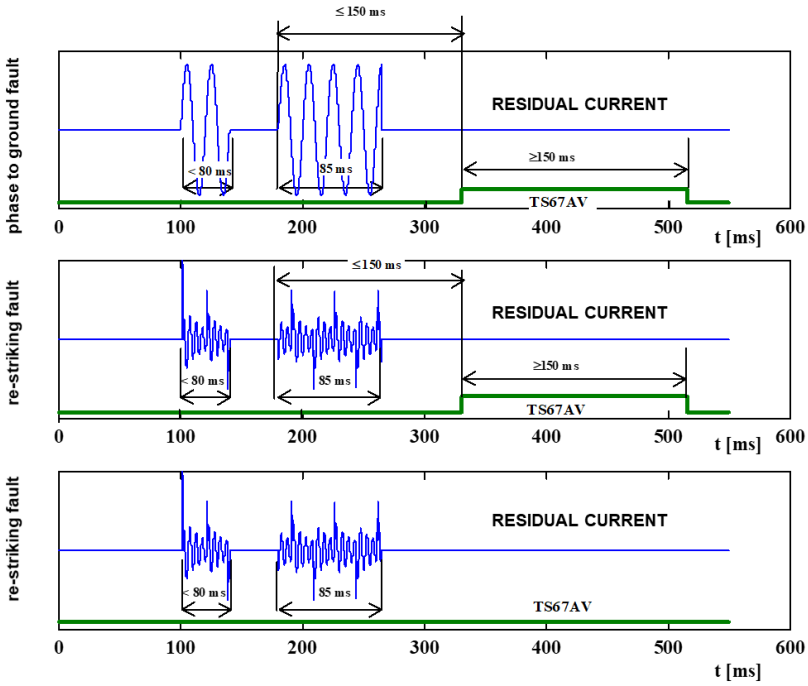


Figure 14 -Examples of a ground-phase fault and intermittent arc

Upper diagram: phase to ground fault in case of isolated neutral network. The first fault remains less than 80ms, then is not detected by the device; the second fault remains more than 80ms and it is detected. The output signal changes the state after no more than 150 ms from the beginning of the fault and it has a duration not less than 150ms.

Following diagrams: intermittent arc for isolated neutral network. With presence of intermittent fault that remains for the same times of the previous example, the device shall give a correct signal (middle diagram, same signal of single-phase fault) or, at most, give no signal (lower diagram).

7.5.16 Checking tests for Par. 7.4.4.1

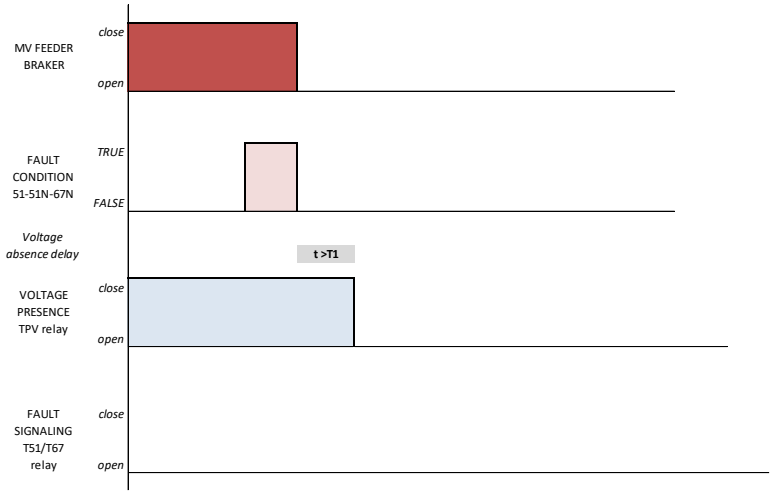


Figure 15 –test 1

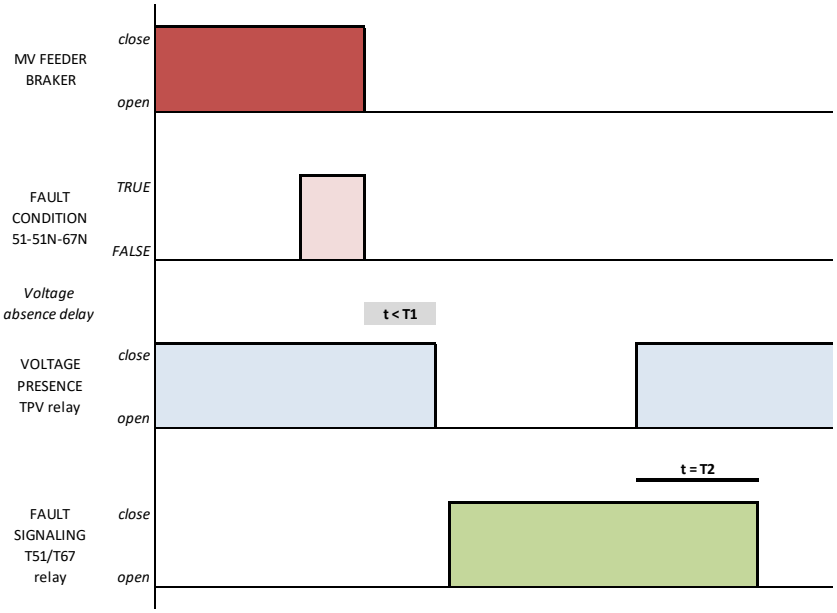


Figure 16 - test 2

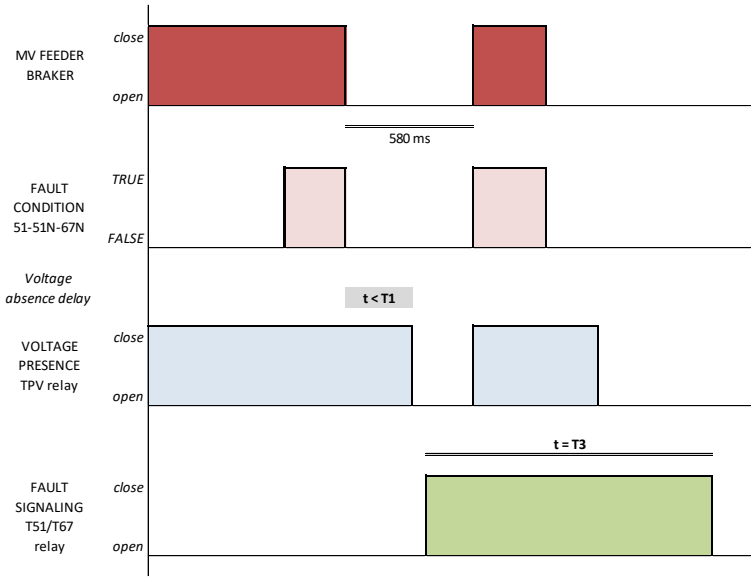


Figure 17 - test 3

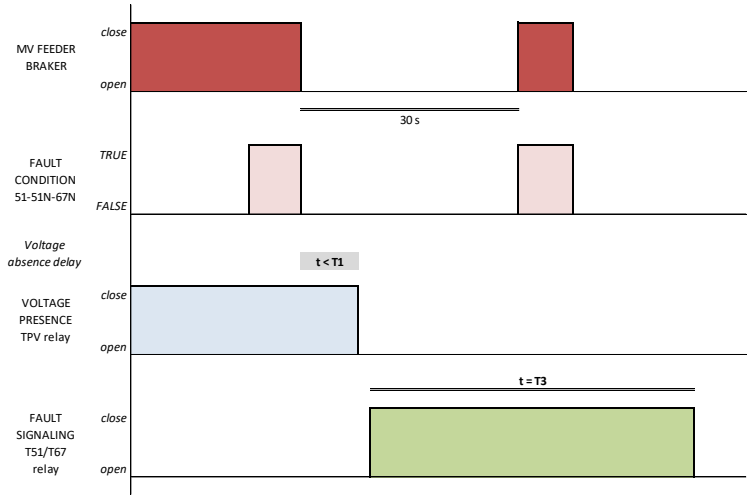


Figure 18 - test 4

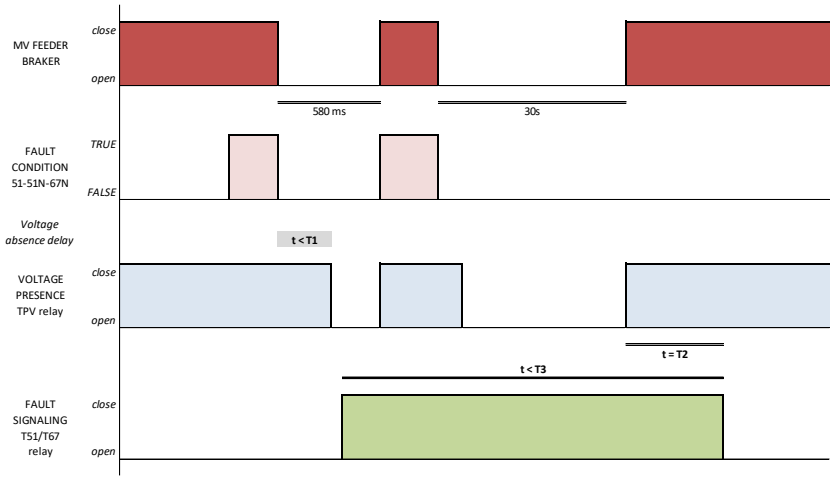


Figure 19 - test 5

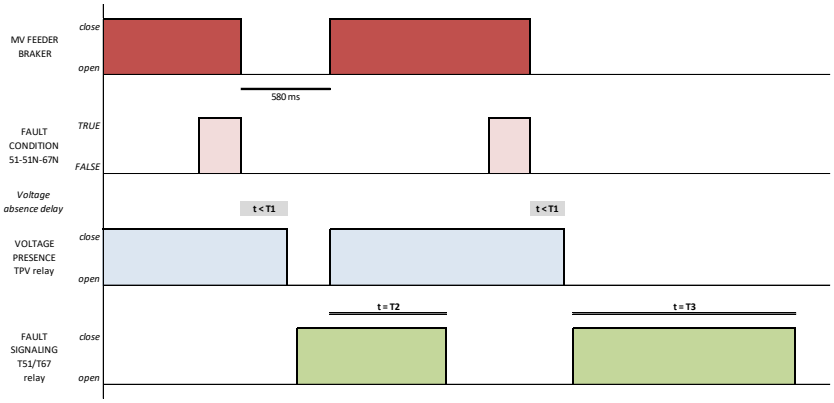


Figure 20 - test 6

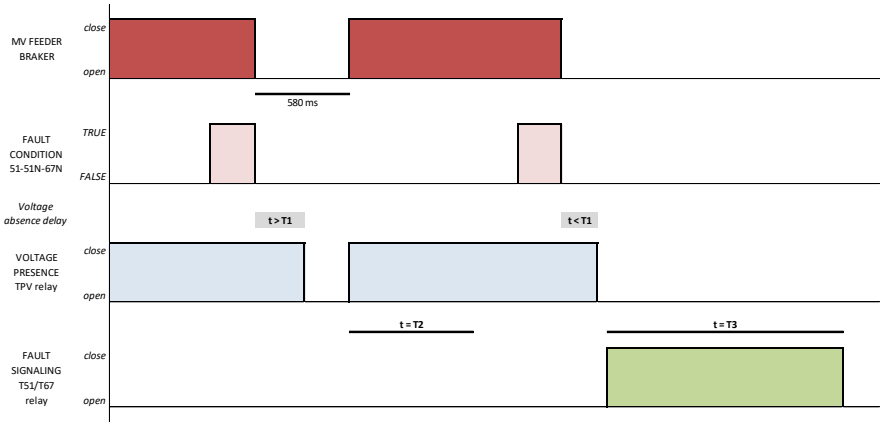


Figure 21 - test 7

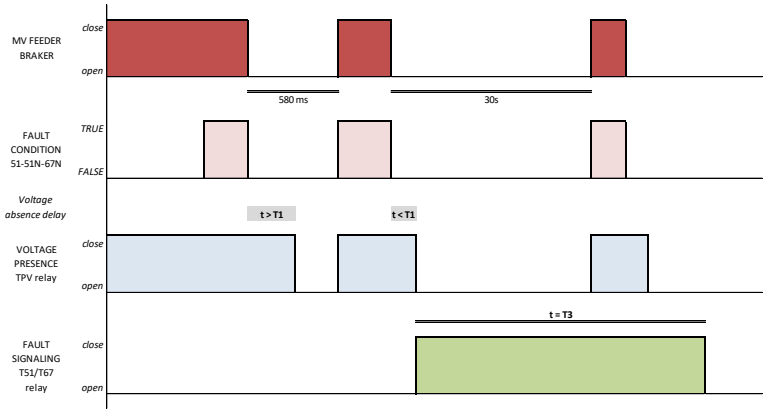


Figure 22 - test 8

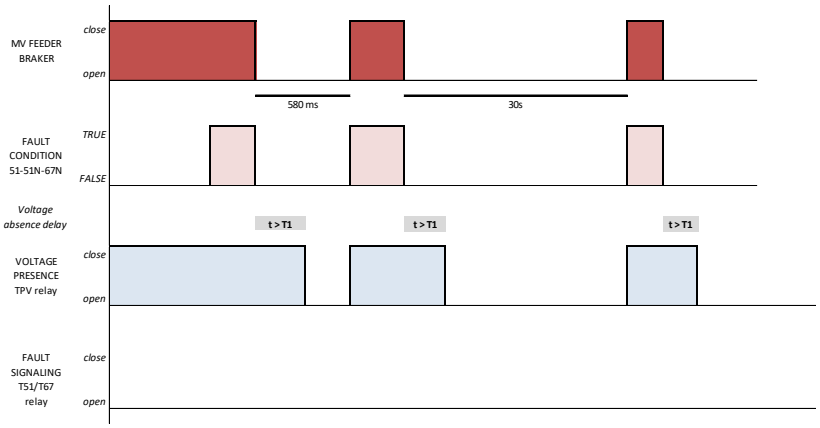


Figure 23 - test 9

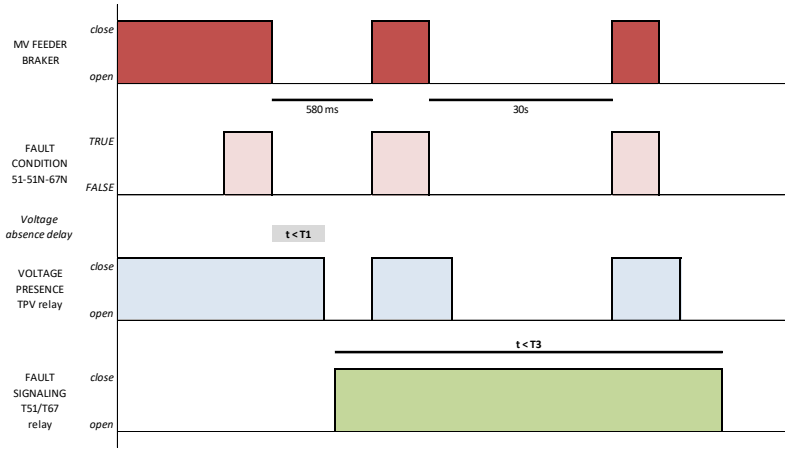


Figure 24 - test 10

7.5.17 Clarification during the procurement process

During the procurement process the following clarification will be provided to the supplier:

a. Choice about the length of the cable for the connection with the RTU (**Figure 7**):
   - L ≥ 8 m for indoor installation
   - L = 1,5 m for outdoor installation.

7.5.18 Warranty

The manufacturer will commit to providing a guarantee of the device for a minimum period of 24 months, which will commence immediately following a successful reception.

The guarantee will be legally binding for any device/component faults and/or defects that occur within the guarantee period: accordingly, the devices and/or components will be replaced.

If during the contract term the manufacturer fails to address in a prompt and timely manner any functional anomalies or defects in the device behavior or manufacture (hardware or firmware), ENEL reserves the right to block the necessary positions on the contract, staged payments and/or alter the payment schedules as necessary until the anomalies have been resolved to the complete satisfaction of ENEL.