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## RGDAT

This document has the objective to specify the functions and provide for construction and testing instruction of Directional Fault Passage Indicator (DFPI/RGDAT).

Countries' I&N – NTI	Elaborated by	Verified by	Approved by
Argentina			<b>Mario Colonnello</b>
Brazil			<b>Victor Manuel Galvao Macedo Costa</b>
Chile			<b>Hans Christian Rother Salazar</b>
Colombia			<b>Cesar Augusto Rincon Alvarez</b>
Iberia			<b>Maria Avery Fernandez</b>
Italy			<b>Gianluca Sapienza</b>
Peru			<b>Roberto Leonidas Sanchez Vargas</b>
Romania			<b>Ivano Bonfanti</b>

	Revision	Elaborated by	Collaborations	Verified by	Approved by
<b>Global I&amp;N – NTI/SGS</b>	03	Pietro Paulon		Luca Delli Carpini	Giorgio Di Lembo
<b>Global I&amp;N – NTI/SGS</b>	02	Pietro Paulon		Luca Delli Carpini	Giorgio Di Lembo
<b>Global I&amp;N – NTI/SGS</b>	00	Giorgio Di Lembo Roberto Calone	Countries' I&N – NT	Maria Avery Carmen Ranea Jaume Badia	Giorgio Di Lembo

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Revision	Date	List of modifications
00	15.12.2015	First version
01	10.02.2016	Par. 6.3 and 6.4: reduction to 10A and to 2A the steps in the setting of phase overcurrent and residual overcurrent respectively. Editorial amendments.
02	08.08.2017	Insert appendix 6; Chapter 4.1 added, with Enel Product family codes of the components adopted in each Company within Enel Group; editorial amendment.
03	11-12-2017	Editorial amendments, chapter 15 better detailed

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## 1 ACRONYMS

- RGDAT** directional fault passage and voltage indicator
- UP** Remote Terminal Unit for the remote control of the secondary substations
- DFPI** Directional Fault Passage Indicator

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## 2 SCOPE

This document intends to specify the functions and provides the requirements for the construction and testing of the Directional Fault Passage Indicator and voltage detector (RGDAT) for remote controlled MV/LV substations.

## 3 REFERENCE STANDARDS

IEC 60255-27:2013 (former IEC 60255-5)	Measuring relays and protection equipment - Part 27: Product safety requirements
IEC 61000-4-2:2008	Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test
IEC 61000-4-12:2006	Electromagnetic compatibility (EMC) - Part 4-12: Testing and measurement techniques - Ring wave immunity test
IEC 61000-4-18:2006+AMD1:2010 CSV	Electromagnetic compatibility (EMC) - Part 4-18: Testing and measurement techniques - Damped oscillatory wave immunity test
IEC 61000-4-4:2012 RLV	Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test
IEC 61000-4-5:2014	Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test
IEC 61000-4-8:2009 RLV	Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test
IEC 61000-4-10:1993+AMD1:2000 CSV	Electromagnetic compatibility (EMC) - Part 4-10: Testing and measurement techniques - Damped oscillatory magnetic field immunity test
IEC 61000-4-3:2006+A1:2007+A2:2010	Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test
IEC 61000-4-29:2000	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 61000-4-16:2015 PRV	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 61000-4-6:2013	Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields
IEC 60068-2-2:2007	Environmental testing - Part 2-2: Tests - Test B: Dry heat
IEC 60068-2-78:2012 RLV	Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state
IEC 60068-2-1:2007	Environmental testing - Part 2-1: Tests - Test A: Cold
IEC 60068-2-14:2009	Environmental testing - Part 2-14: Tests - Test N: Change of temperature
IEC 60068-2-6:2007	Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)

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IEC 60068-2-64:2008	Environmental testing - Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance
IEC 60529:1989+AMD1:1999+AMD2:2013 CSV	Degrees of protection provided by enclosures (IP Code)
IEC 60332-3-10:2000+AMD1:2008 CSV	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 60507:2013	Artificial pollution tests on high-voltage ceramic and glass insulators to be used on a.c. systems
IEC 60383-2:1993	Insulators for overhead lines with a nominal voltage above 1000 V - Part 2: Insulator strings and insulator sets for a.c. systems - Definitions, test methods and acceptance criteria
IEC 60695-11-10:2013	Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods
IEC 1109:1992+AMD:1995	Insulators for overhead lines - Composite insulator for a.c. overhead lines with a nominal voltage greater than 1 000 V - Definitions, test methods and acceptance criteria

#### 4 COMPONENTS IDENTIFICATION

TYPE	DEVICE	SERIAL NUMBER
DY1059-A70	Multifunction Directional Fault Passage Indicator –electronic control unit and accessories for voltage collection-	160000
DY 1059-A70/C	Multifunction Directional Fault Passage Indicator for cable lines	160001
DY 1059-A70/M	Multifunction Directional Fault Passage Indicator for mixed lines	160002
DY 1059-A70/A	Multifunction Directional Fault Passage Indicator for overhead lines	160003
DY 1059-A70/O-24	Multifunction Directional Fault Passage for OUTDOOR installations (24kV max)	160004
DY 1059-A70/O-36	Multifunction Directional Fault Passage for OUTDOOR installations (36kV max)	160035

Example of short description:

R G D A T   A 7 0   F A U L T   D E T E C T O R   M V - O   2 4 k V

R G D A T   A 7 0   F A U L T   D E T E C T O R   M V - O   3 6 k V

R G D A T   A 7 0   F A U L T   D E T E C T O R   M V - C

R G D A T   A 7 0   F A U L T   D E T E C T O R   M V - M

R G D A T   A 7 0   F A U L T   D E T E C T O R   M V - A

R G D A T   A 7 0   C O N T R O L   U N I T

#### 4.1 Enel Product family codes of the components adopted in each Company within Enel Group



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Description	Global Product Family	Argentina	Brazil	Chile	Colombia	Italy	Peru	Romania	Spain
DY 1059-A70/C - Multifunction Directional Fault Passage Indicator for cable lines	160001	0131-0408		6808324	6808346	160001	6808346	160001	510259
DY 1059-A70/O-24 - Multifunction Directional Fault Passage for OUTDOOR installations (24kV max)	160004	0131-0405	6808357	6808325	6808357	160004	6808357	160004	510260
DY 1059-A70/O-36 - Multifunction Directional Fault Passage for OUTDOOR installations (36kV max)	160035	0131-0407			6812238	160035		160035	510261

#### 4.2 Components tracking

All the RGDAT-A70 samples shall be provided with rating plate as specified in the ENEL standard PVR06.

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## 5 FUNCTIONS

RGDAT-A70 is a device provided to be installed in correspondence of MV line bays of remote controlled MV/LV substations, to locate the presence of faults and the absence of voltage signal on the line.

### 5.1 Characteristics of the reference network

The networks where RGDAT-A70 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) $\pm$ 10%**
- Maximum current of three-phase short circuit: **16kA**
- Maximum value of time constant  $\tau$  of the phase unidirectional component decay: **20ms**
- Maximum single phase ground fault current (insulated neutral earth): **500A**
- Peak value of the unidirectional component of the current added to single-phase ground fault current (neutral compensated ): **707A**
- Maximum value of time constant  $\tau$  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  $f_n=50\text{Hz}$  **47,5Hz-51,5Hz**
- frequency range  $f_n=60\text{Hz}$  **57,5Hz-61,5Hz**

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## 5.2 Analogical Inputs

RGDAT-A70 shall measure:

- phase current and residual current, through current transducer installed in correspondence of MV line bays;
- line voltage, using voltage signals supplied by capacitor divider that, usually are installed on panel to detect the voltage presence.

Regarding the current measurement, RGDAT-A70 can use:

2 Current sensors for measuring two-phase current and 1 current sensor for measuring residual current or alternately:

3 Current sensors for measuring three-phase current, from which obtain also the residual current.

The sensors must be Rogoswki coils with rated ratio 1000A/100mV.

## 5.3 Events to be detected

RGDAT-A70 shall detect, through the measurements on the previous paragraph, 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  $V_o$ );
- presence of two-phase fault (positive undervoltage  $V_d$ , negative overvoltage  $V_i$ ).

In paragraphs 7.2, 7.3, 7.4, 7.6, 7.8, 7.9 are specified the requirements relating to the detection functions of the aforementioned events.

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## 6 TYPE OF DEVICES

There are different versions of the device depending on the system type on which they should be installed. Particularly, it should refer to the following 4 versions:

### RGDAT-A70

It is formed by a single electronic control part, along with the accessories for UP connection and the collection of the single voltage signals. It will be installed near the MV cells on panels endowed with capacitor divider voltage transducer DJ1054 (approved by ENEL). In this case, the supplied device is constituted by:

- RGDAT-A70;
- wiring and accessories for installation.

### RGDAT-A70/C

Suitable to install on MV cable lines connected with panels endowed with capacitor divider voltage transducer DJ1054 (approved by ENEL). In this case, the supplied device is constituted by:

- RGDAT-A70;
- opening current transducer for cables;
- wiring and accessories for installation.

### RGDAT-A70/M

Suitable to install on MV cable lines connected with busbar systems with bare conductors. In this case, the supplied device is constituted by:

- RGDAT-A70;
- mounting plate and assembling accessories;
- DJ1054 current transducer assembled on a crossbeam;
- Transducer crossbar to secure on a station case shelf (Figure 22);
- opening current transducer for cables;
- wiring and accessories for installation.

### RGDAT-A70/A

Suitable to install on bare conductor MV lines connected with busbar systems with bare conductors. In this case, the supplied device is constituted by:

- RGDAT-A70;
- mounting plate and assembling accessories;
- DJ1054 voltage transducer assembled on a crossbeam;
- Crossbeam transducer for fixing on the wall (Figure 20);
- Closed type current transducer to install on the cross-wall insulators present in the upper part of the substation (Figure 21);
- wiring and accessories for installation.

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### RGDAT-A70 /O

Suitable for OUTDOOR. In this case, the supplied device is constituted by:

- RGDAT-A70;
- crossbeam for fixing and mounting accessories;
- current/voltage transducers mounted on crossbar;
- wiring and accessories for installation.

RGDAT-A70 is the control system electronic part, shall be the same for each of the four versions. Therefore it shall allow the right configuration in case of presence of 2 phase current sensors + 1 residual current sensor or 3 phase current sensors (RGDAT-A70/ O).

## 7 FUNCTIONS

### 7.1 Installation layouts

The installation layouts of RGDAT-A70 device are illustrated in the following figures:

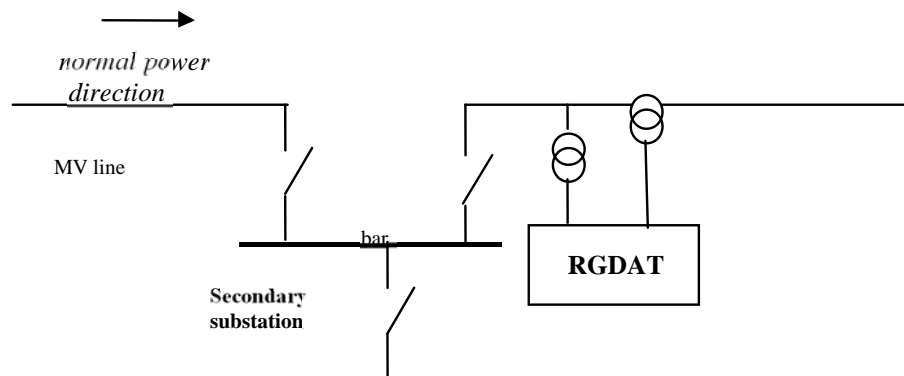


Figure 1 -RGDAT-A70 installed on output backbone line.

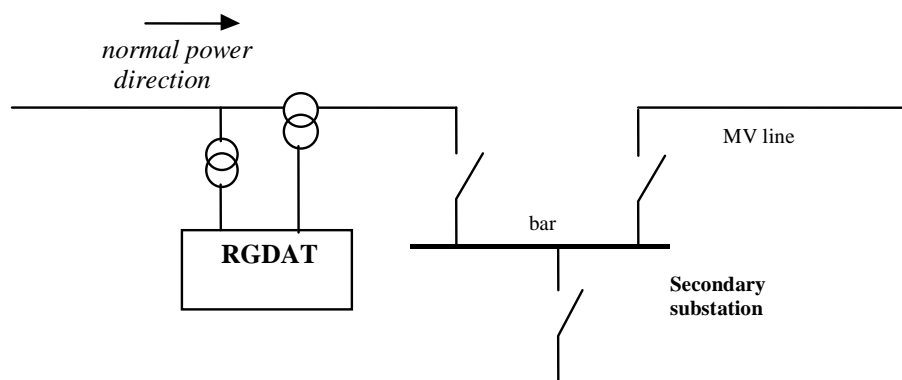
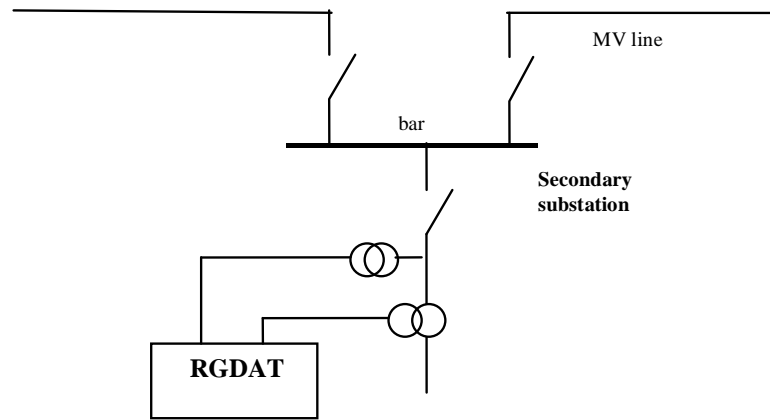


Figure 2 –RGDAT-A70 installed on input backbone line.

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**Figure 3 -RGDAT-A70 installed on shunt line.**

With reference to the line power source direction, RGDAT-A70 device shall detect fault conditions on the downstream sector of the installation point. In order to satisfy this requirement in any case listed in the previous figures and in any power source condition of the MV line, is required a specific feature, following called “inversion”. Direction inversion is remotely controlled through the remote control unit device.

## 7.2 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% ( $\pm 15\%$  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 ( $\pm 15\%$  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.  $\leq 150$ ms
- fault duration to detect starting from non-energised capacitive plug (both with isolated neutral operated)

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networks and neutral solidly earthed)	150ms
- tripping time in case of fault starting from non-energised capacitive plug (closure on fault)	$\leq 170\text{ms}$
- release time	$\leq 100\text{ms}$
- time error	$3\% \pm 20\text{ms}$

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-A70 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  $\alpha$  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  $60^\circ \leq \alpha \leq 255^\circ$ ;

67NS2  $60^\circ \leq \alpha \leq 120^\circ$ ;

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

#### INVERTED SECTORS

67NS1  $240^\circ \leq \alpha \leq 75^\circ$ ;

67NS2  $240^\circ \leq \alpha \leq 300^\circ$ ;

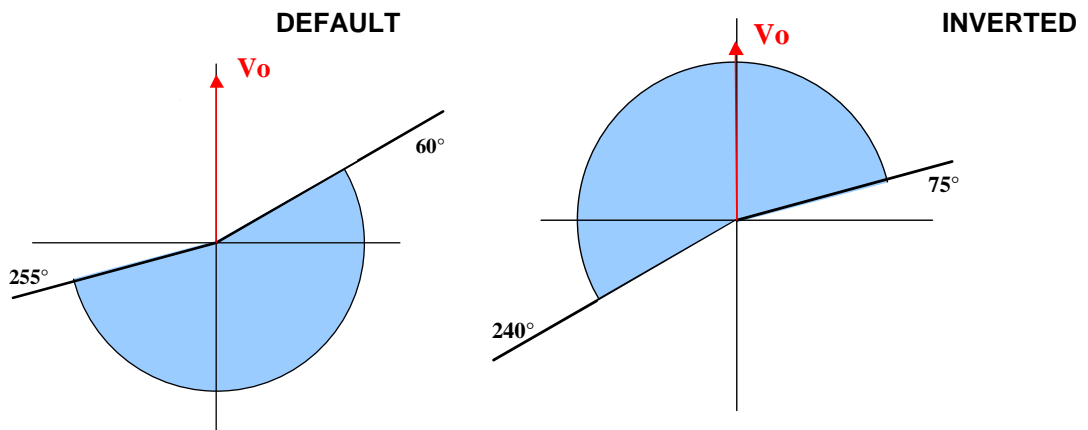
Faults in 67NS2 sector shall cause the contemporaneous closure of the output contacts 51 and 67.

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  $\pm 2^\circ$ ;
- hysteresis in leaving the sector  $3^\circ$

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  $180^\circ$  (cf. Fig.).

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RGDAT-A70 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 has 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.

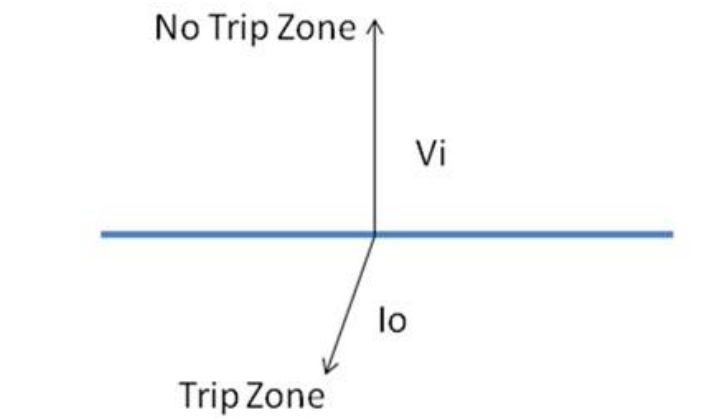
RGDAT-A70 shall permit, through a SW flag, to choose instead of the homopolar Voltage  $V_o$ , the negative sequence Voltage  $V_i$  as reference for intervention sectors.

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

The detection of the ground fault shall be guaranteed for fault resistance values able to generate:

- a negative sequence voltage equal to a settable value at least in the phase voltage range of 1-40%, with a step of 1% ( $\pm 15\%$  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 ( $\pm 15\%$  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:





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### 7.3 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-A70 installation point before closing).

Such function shall satisfies the following requirements:

- |  |   |
|--|---|
| - tripping threshold (lint)  | (100÷900)A step 50A<br>default 500A ± 10% |
| - fault duration to not detect   | 40 ms                                     |
| - fault duration to detect<br>(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 lint)  | 120 ms                                    |
| - maximum tripping time (Imis = 2lint)   | 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 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-A70 installation point before closing).

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

- |  |   |
|--|---|
| - no-directional tripping threshold on residual current (lint)   | (10 ÷ 200)A step 10A<br>default 150A ±10% |
| - fault duration to not detect   | 40 ms                                     |
| - fault duration to detect<br>(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= ,2lint)   | 120 ms                                    |
| - maximum tripping time (Imis=2lint)   | 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-A70 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-A70 will operate without the protection function 67N. To evidence this mode, the indication LED 67 located on front to the device will flash.

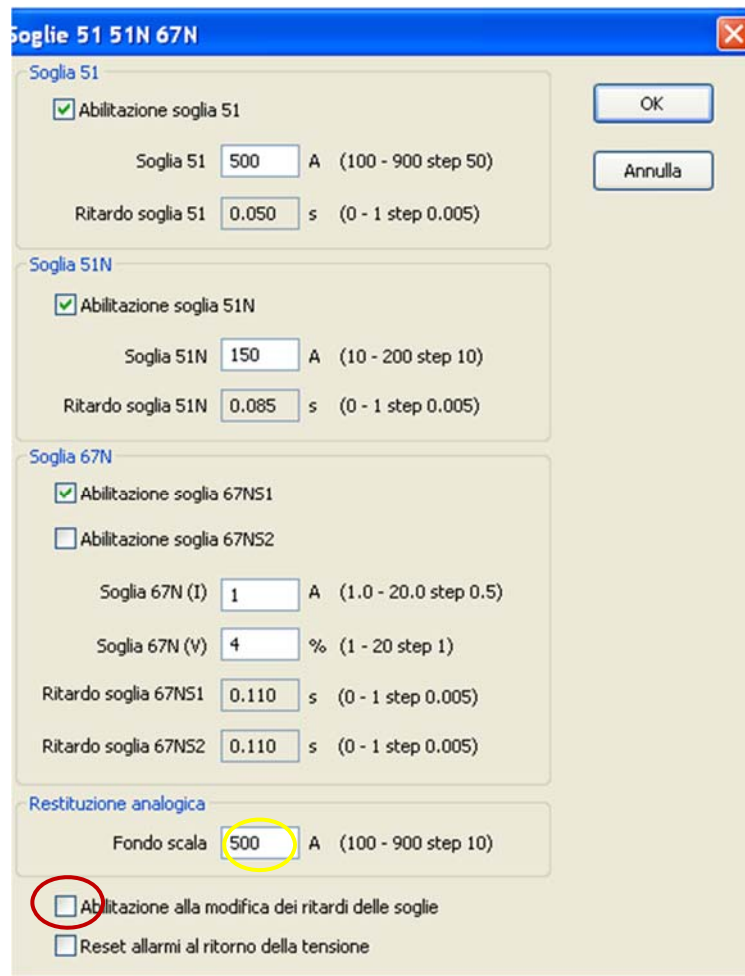
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## 7.5 Optional timers for protection functions

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

RGDAT-A70 shall permit, through a flag (see red circle in Figure 4), the setting on others timer values as showed in the Figure 4.

Farther RGDAT-A70 shall permit the changing of the current full-scale associated (see yellow circle in Figure 4) with remote measurement.



**Soglie 51 51N 67N**

**Soglia 51**

Abilitazione soglia 51

Soglia 51:  A (100 - 900 step 50)

Ritardo soglia 51:  s (0 - 1 step 0.005)

**Soglia 51N**

Abilitazione soglia 51N

Soglia 51N:  A (10 - 200 step 10)

Ritardo soglia 51N:  s (0 - 1 step 0.005)

**Soglia 67N**

Abilitazione soglia 67NS1

Abilitazione soglia 67NS2

Soglia 67N (I):  A (1.0 - 20.0 step 0.5)

Soglia 67N (V):  % (1 - 20 step 1)

Ritardo soglia 67NS1:  s (0 - 1 step 0.005)

Ritardo soglia 67NS2:  s (0 - 1 step 0.005)

**Restituzione analogica**

Fondo scala:  A (100 - 900 step 10)

Abilitazione alla modifica dei ritardi delle soglie

Reset allarmi al ritorno della tensione

Figure 4 -Example of setting window for timers.

## 7.6 Optional timers signaling

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

RGDAT-A70 shall permit, through a flag (see red circle in Figure 5), 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 ( $T_1$ , 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 ( $T_1$ , 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 ( $T_2$ , programmable, default setting: 10 s).
- If there is no return of power within a certain time ( $T_3$ , 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.

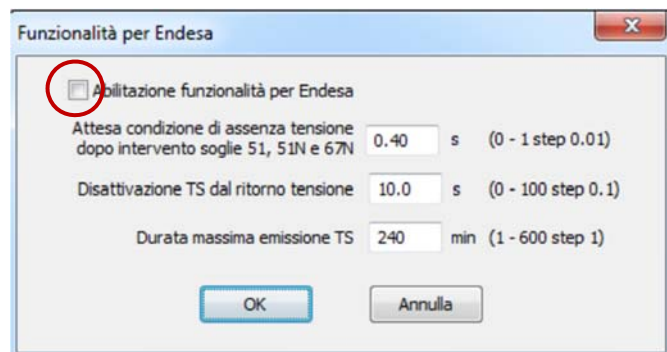


Figure 5 -Example of timers signalling.

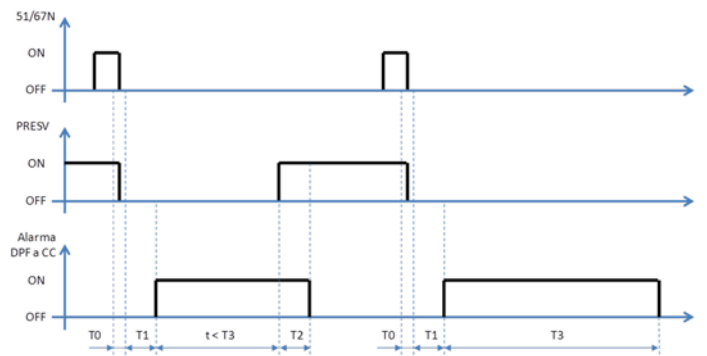


Figure 6 -Behaviour of the signalling.

### 7.7 Protection functions: 59Vo, 59Vi and 59Vd

RGDAT-A70 device shall have 59Vo functions (homopolar overvoltage function), 59Vi (over negative sequence voltage function) and 27Vd (under positive sequence voltage function), with the following characteristics:

- Setting ranges shall be the ones expressed in Table 1,
- 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-A70 is not powered.
- The equations for quantity calculus to sequences are given below:

$$V_o = \frac{\vec{V}_4 + \vec{V}_8 + \vec{V}_{12}}{3} \quad V_d = \frac{\vec{V}_4 + \alpha\vec{V}_8 + \alpha^2\vec{V}_{12}}{3} \quad V_i = \frac{\vec{V}_4 + \alpha^2\vec{V}_8 + \alpha\vec{V}_{12}}{3}$$

Where alpha is  $\alpha = \cos(120) + j\sin(120) = -0,5 + j0,866$

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

**Table 1**

### 7.8 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

### 7.9 Voltage presence: functional requirements

RGDAT-A70 device shall be able to detect the presence of voltage on the line considering the following threshold:

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

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- 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:

$$(VR > 80\%V_n) \text{ OR } (VS > 80\%V_n) \text{ OR } (VT > 80\%V_n)$$

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

$$(VR < 20\%V_n) \text{ AND } (VS < 20\%V_n) \text{ AND } (VT < 20\%V_n)$$

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.

$$(VR > 80\%V_n) \text{ OR } (VS > 80\%V_n) \text{ OR } (VT > 80\%V_n)$$

In APPENDIX 4 are reported some diagrams that describe the function mode above described.

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 (see 7.10 and **Errore. L'origine riferimento non è stata trovata.**).

## 7.10 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 (see 7.9 and **Errore. L'origine riferimento non è stata trovata.**).

The signals are sent to the Remote Control Peripheral Unit (DX 1215) 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-A70 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",

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

### 7.11 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. 7.2. 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 (DX1215) according to the model in Figure 18.

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## 7.12 Local 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

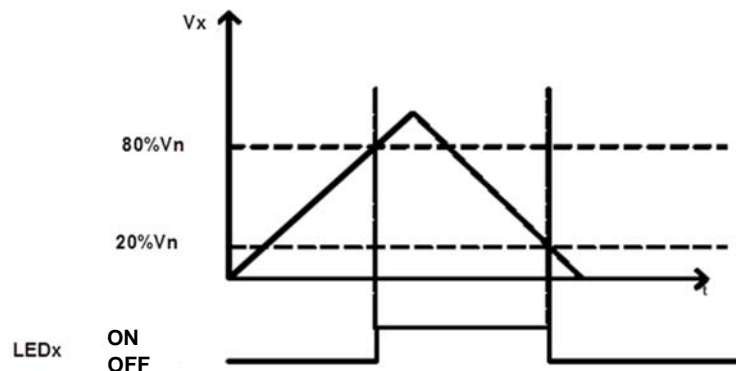
according with what below specified:

- 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.



## 7.13 Voltage Monitoring Procedure

Through the setting of a configuration flag, RGDAT-A70 shall commute its mode of function from the standard one (RGDAT-A70) 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-A70 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-A70 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-A70 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.

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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 7.9.

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-A70 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-A70 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 2 V presence: timer settings.**



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## 7.14 Event Recorder

RGDAT-A70 shall be able to record at least 20 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.

## 8 ENVIRONMENTAL OPERATING CONDITIONS

The device shall operate accurately in the following conditions:

- |  |           |
|--|-----------|
| - operating temperature                            | -10÷+55°C |
| - relative humidity (without condensation nor ice) | ≤93%      |
| - atmospheric pressure                             | 70÷106kPa |

## 9 CONSTRUCTIVE CHARACTERISTICS

RGDAT-A70 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-A70 shall be less than 250x200mm and the chassis shall be realised for protruding mounting. RGDAT-A70 shall be mounted perpendicular with 4 screws M5 according to the fixing template shown in Figure 11. RGDAT-A70 shall be equipped with a lid easily removable.

RGDAT-A70 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-A70 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-A70 shall satisfy the protection level IP31 code (IEC 60529).

## 10 ELECTRICAL CHARACTERISTICS

RGDAT-A70 shall be assembled according to the principle diagram illustrated in Figure 1, Figure 2 and Figure 3. 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-A70, 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.

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

For values of the voltage supply that do not ensure the correct functioning, RGDAT-A70 device shall not emit any unwanted signal, local or remote.

RGDAT-A70 shall be protected against polarity inversion.

## 11 RGDAT-A70

### 11.1 Connections for collecting voltage signals

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 ENEL standard DY 1811.

The connections for this extraction shall be organised using six pins pursuant to the unification table DY 1811 and three shielded wires of a section  $\geq 0,5\text{mm}^2$  and a length equal to 3m.

The abovementioned connections shall be attested on the terminal board MA as shown in Figure 12.

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.

### 11.2 Measurement circuits

#### 11.2.1 Capacitive plug characteristics of secondary substation panels

The device derives network voltages from three capacitive dividers (one for each phase with the same characteristics) with the following parameters (see Figure 16):

- Equivalent capacitive reactance  $X_{C1}$  included between  $100\text{ M}\Omega$  and  $700\text{ M}\Omega$  (impedance a 50 Hz)
- Partial voltage  $V_2$  (detectable to the plug through an impedance of a measure of  $1\text{ M}\Omega$ ) included between 25 V and 250 V
- Voltage variation ( $V_2$ ) to the plug, due to differences of capacitive values and/or to parasitic coupling between the three dividers:

$$\Delta\text{amplitude} < 30\%$$

$$\Delta\text{displacement angle} < 15^\circ$$

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  $V_2$  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.

## 12 RGDAT-A70/C

### 12.1 Current transducers connections

Inside RGDAT-A70 shall be provided a terminal block, called MA on Figure 12, suitable for collecting section conductors until  $2,5\text{ mm}^2$ , in which will be applied the connections with current transducers.

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For the electric connection of current transducers with RGDAT-A70 shall be provided a cabling (Figure 14), realised in unipolar conductors with a section  $\geq 1 \text{ mm}^2$ , including:

- n°1 unipolar cable, for ground connection between the current node (ground bolt on the RGDAT-A70 chassis) and the earth of the substation (length  $\geq 3 \text{ m}$ );
- n°1 jumper in unipolar cable for the connection between the ground bolt on the RGDAT-A70 chassis and the ground terminal on the terminal block MA;
- n°2 conductors for each current transducer signals. A conductor will be connected to the RGDAT-A70 terminal board MA (live conductor) the other conductors will be connected to , the ground by the bolt on the RGDAT-A70 enclosure.  
Such conductors shall have at least a length of 3,5m (suitable for installation of the current transducer on the bottom of the MV panel) and be all six gathered and inserted, at least for a length of 3,0m starting from the chassis of RGDAT-A70, within a flexible protective device ("rilsan" braided sleeves or similar).

All the used cables shall have a nominal voltage  $\geq 450/750\text{V}$  and fire retardant characteristics according to IEC 60332 standards.

Conductors shall be provided of pre-insulated terminals suited to the type of expected connection (faston, cylindrical, ring, etc.) and also identification marks and references to the realized wiring diagram.

The insulation of conductors shall be black and on the terminations of the terminal board shall be provided a white numbering indicating the caption of the terminal board and the terminal number (ex. MA 1).

For the ground circuit part shall use a conductor of  $1 \text{ mm}^2$  with a yellow-green insulator and a ring termination to the ground for bolts  $\phi 10$ .

The connections on the current transducers shall be encapsulated in resin if fixed, otherwise shall be provided a polarized connector, with golden contacts, and provided with a protection against accidentally disconnections.

To render 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), l'RGDAT-A70 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.

## 12.2 Connections for collecting voltage signals

Voltage signals are derived from capacitors already arranged on MV panels using the plug of the fixed part of the voltage presence/absence device ENEL Standard DY 1811.

The connections for this extraction shall be organised using six pins pursuant to the ENEL Standard DY 1811 and three shielded wires of a section  $\geq 0,5\text{mm}^2$  and a length equal to 3 m.

The abovementioned connections shall be attested on the terminal board MA as shown in Figure 12.

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.

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## 12.3 Measurement circuits

### 12.3.1 Capacitive plug characteristics of secondary substation panels

The device derives network voltages from three capacitive dividers (one for each phase with the same characteristics) with the following parameters (see Figure 16):

- Equivalent capacitive reactance  $X_{C1}$  included between 100 M $\Omega$  and 700 M $\Omega$  (impedance a 50 Hz)
- Partial voltage  $V_2$  (detectable to the plug through an impedance of a measure of 1M $\Omega$ ) included between 25V and 250V
- Voltage variation ( $V_2$ ) to the plug, due to differences of capacitive values and/or to parasitic coupling between the three dividers:

$$\Delta \text{amplitude} < 30\%$$

$$\Delta \text{displacement angle} < 15^\circ$$

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  $V_2$  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.

### 12.3.2 Current transducer characteristics

Current transducers and accessories for their correct installation are integral part of the supply. The type of transducer (Rogowsky coil) shall be to permit an easy assembling also on cables already installed.

The transducer shall be in corrosion- resistant material compatible with the provided opening system.

#### 12.3.2.1 Phase current transducers

Current transducers for detection of phase current shall be installed on MV cables that have a diameter between 25mm and 52mm and to each of them, during installation, will be joined a unipolar cable of 25 mm<sup>2</sup> (for the grounding of the MV cable shield).

The diameter of the transducer shall be equal to 90mm $\pm$ 10%.

For their size, it shall be taken into account the stresses resulting the following functioning conditions:

- |  |        |
|--|--------|
| - Permanent current on each cable        | 500A   |
| - Short circuit thermal current (for 1s) | 16kA   |
| - Dynamic current (peak)                 | 31,5kA |

#### 12.3.2.2 Residual current transducers

Residual current transducer should be installed on set of three MV cables with a diameter of the circumscribed circle between 75 and 170 mm.

The diameter of the transducer shall be equal to 240mm $\pm$ 10%.

The characteristics of the residual current transducer (or the phase ones if used for measuring residual current) shall be able to detect the failure even with residual current having the following characteristics:

- |                                      |      |
|--------------------------------------|------|
| - Unidirectional component amplitude | 707A |
|--------------------------------------|------|

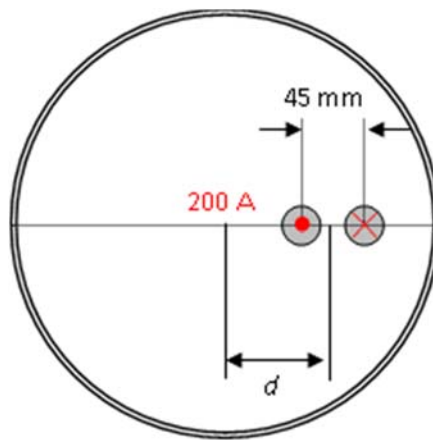
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- Unidirectional component time constant 150ms
- Symmetrical component 50A

Residual current transducer could produce output error current, for null residual current, due to:

a) *Centring and balancing errors of the 3 passing cables respect to the toroid axis*

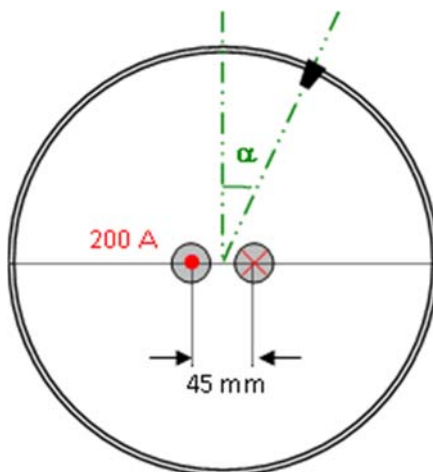
With a single conductor that enters and exits from the Rogowsky coil applying a current of 200 A, the output signal from the sensor shall correspond to a primary current not higher to 0.6A, (maximum error) independently from the distance “d” between the torus centre and the centre of symmetry of the 2 conductors and independently from the angular position (□) of the air gap on coil closure.



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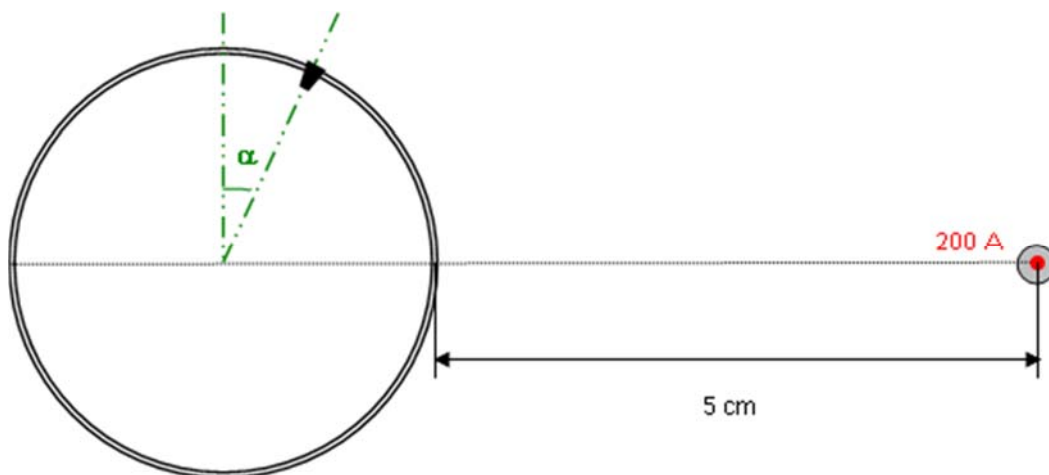
b) *Angular position of air gap on the orthogonal plane to the passing cables*

With single conductor that enters and exits from the Rogowsky coil and positioned to the centre of the same sensor with an applied current of 200 A, the output signal from the sensor shall correspond to a primary current not higher to 0.2A, (maximum error), independently from the angular position ( $\alpha$ ) of the air gap.



c) *Induced currents from parallel cables of the adjacent lines to the outer sensors*

With a conductor carrying a current of 200 A, external to the sensor and parallel to its axis, the output signal from the sensor shall correspond to a primary current not higher to 0.3A, (maximum error), at a distance of 5 cm between the outer edge of the sensor and the axis of the conductor, independently from the angular position ( $\alpha$ ) of the air gap on the sensor plane.



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## 13 RGDAT-A70/M

It has to be installed on MV cable lines connected to bus-bar systems in bare conductors.

The RGDAT-A70 device is identical to C model and it is fixed to the wall through a plate provided with threaded holes according to the fixing template (Figure 11). The plate shall be installed through expanding rawlplug and shaped so as to remain enough distant from the wall. RG-DAT plate, the attachment screws and the expanding rawlplug shall be included in the supply.

### 13.1 Connections toward current transducers

The connections with current transducers, that are integral part of the supply, shall have the same characteristics shown in fig. 8.1 The encumbrance and the installation methods are shown in Fig. 10.

In particular, the 2 conductors from each current transducer shall have a length of 3,5 m and head to a suitable wall socket equipped with a ground bolt.

In the socket is grafted a 6 pin male connector connected to the terminal board MA of RGDAT-A70 through 6 shield conductors of section  $\geq 1 \text{ mm}^2$  and with a length of 0,5 meters as shown in the detail 11 of Figure 19.

As in RG-DAT/C, the ground node of the three transducers shall be realized on the ground bolt of RGDAT-A70 and not on the socket.

However, the female socket, when is not connected to the male one, shall provide automatically for ground short circuiting (through its bolt) the currents from transducers.

### 13.2 Connections for collecting voltage signals

The voltage signals are derived from phase voltage transducers assembled on a suitable crossbar (Figure 22). The encumbrance and the installation modality are shown in Figure 19; transducer characteristics are listed below.

For transducer connections shall be arranged three shield conductors with section  $\geq 0,5 \text{ mm}^2$  and with a length of 3,5 meters, headed to a wall socket equipped with a ground bolt.

In the socket is grafted a 4 pin male connector connected to the terminal board MA of RGDAT-A70 through 4 shield conductors of section  $\geq 1 \text{ mm}^2$  and with a length of 0,5 meters as shown in fig. 10.

The female socket, when is not connected to the male one, shall provide automatically for ground short circuiting (through its bolt) the voltages of the transducers.

The proper RGDAT-A70, voltage transducers, the crossbar, current transducers, sockets and male connectors, cables and accessories for the installation are included in the supply.

**To ensure the safety (direct contacts by an operator on the equipment, in case of failure of the insulation of capacitors) shall be provided by manufacturer an appropriate device, placed at the bottom of the same capacitive detectors (surge arresters, ...) that prevent the transfer of dangerous voltages on RGDAT-A70 circuits; such device will be subject for approval by Enel Distribuzione.**

### 13.3 Measurement circuits

#### 13.3.1 Capacitive divider characteristics

See par. 12.3.1 (RGDAT-A70).

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### 13.3.2 Current transducer characteristics

See par. 12.3.2 (RG-DAT-A70 /C).

## 14 RGDAT/A

It has to be installed on MV cable lines in bare conductors connected to bus-bar systems also in bare conductors.

The RGDAT-A70 device is the same of C model and shall be fixed to the wall through a plate provided with threaded holes according to the fixing template (Figure 11). The plate shall be installed through expanding rawplug and shaped so as to remain enough distant from the wall. RG-DAT plate, the attachment screws and the expanding rawplug shall be included in the supply.

### 14.1 Connections toward current transducers

The connections with current transducers, that are integral part of the supply, shall have the same characteristics shown in par. 12.1 The encumbrance and the installation modality are shown in Figure 19.

The two conductors from each current transducer shall have a length of 6,5m and head to a suitable wall socket equipped with a ground bolt.

In the socket is grafted a 6 pin male connector connected in turn to the terminal board MA of RGDAT-A70 through 6 shield conductors of section  $\geq 1\text{mm}^2$  and with a length of 0,5 meters as shown in the detail 11 of Figure 19.

As in RGDAT/C, the ground node of the three transducers shall be on the ground bolt of RGDAT-A70 and not on the socket.

The female socket, when is not connected to the male one, shall provide automatically for ground short circuiting (through its bolt) the currents from transducer.

### 14.2 Connections for collecting voltage signals

The voltage signals are derived from phase voltage transducers assembled on a suitable crossbar (Figure 20). The encumbrance and the installation modality are shown in Figure 19; transducer characteristics are listed below.

For transducer connections shall be arranged three shield conductors with section  $\geq 0,5\text{mm}^2$  and with a length of 6,5 meters, headed to a wall socket equipped with a ground bolt.

In the socket is grafted a 4 pin male connector connected in turn to the terminal board MA of RGDAT-A70 through 4 shield conductors of section  $\geq 1\text{mm}^2$  and with a length of 0,5 meters as shown in Figure 19.

The female socket, when is not connected to the male one, shall provide automatically for ground short circuiting (through its bolt) the voltages of the transducers.

The RGDAT-A70, voltage transducers, the crossbar, current transducers, sockets and male connectors, cables and accessories for the installation shall be included in the supply.

**To ensure the safety (direct contacts by an operator on the equipment, in case of failure of the insulation of capacitors) shall be provided by manufacturer an appropriate device, placed at the bottom of the same capacitive detectors (surge arresters, ...) that prevent the transfer of dangerous voltages on RGDAT-A70 circuits; such device will be subject for approval by Enel.**



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### 14.3 Measurement circuits

#### 14.3.1 Capacitive divider characteristics

See par. 12.3.1 (RG-DAT/C).

#### 14.3.2 Current transducer characteristics

Current transducers for the collection of phase and residual current (integral part of the supply) should be installed in correspondence with wall-bushing insulator (ENEL standard DJ 1055 – July 1989), according to what shown in Figure 19 and Figure 21.

The Rogowsky coil shall have a point operable in order to permit an easy assembling also on cables already installed. The assembling system of transducers and all the required accessories are integral part of the supply.

For other functional characteristics and performances worth as expressed in par. 12.3.2.1 and 12.3.2 (RG-DAT/C).

To render 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 current sensors are always installed with the identification point of the Primary (P1) toward 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 direction according to the conditions of the substation alimentation.

## 15 RGDAT-A70/O

It has to be installed on pole where are installed driven switch or recloser. The sensors shall be suitable for Outdoor installation.

RGDAT-A70/O shall measure:

- The phase currents and the residual current, by means of three suitable phase current transducers for installation on overhead bare conductors;
- The phase voltages and the homopolar voltage, by means of three suitable phase voltage transducers for installation on overhead bare conductors.

All the measurements shall be carried out with reference to r.m.s.

For each phase the current and voltage sensors, shall be integrated in one piece combined component. The sensor can be active, but the power supply shall be supplied only from RGDAT-A70.

RGDAT-A70 shall be the same RGDAT-A70/C type and shall be installed inside the box containing the UP for pole installation.

The combined sensor shall provide a proportional voltage signal to the primary voltage such that with a 9kV primary voltage, the output signal shall be at least of 1V.

### 15.1 RGDAT-A70/O: Installation on pole

The following figure shows an example of installation layout for 20kV network (the forbidden area and all the distances depend from the network rated voltage).

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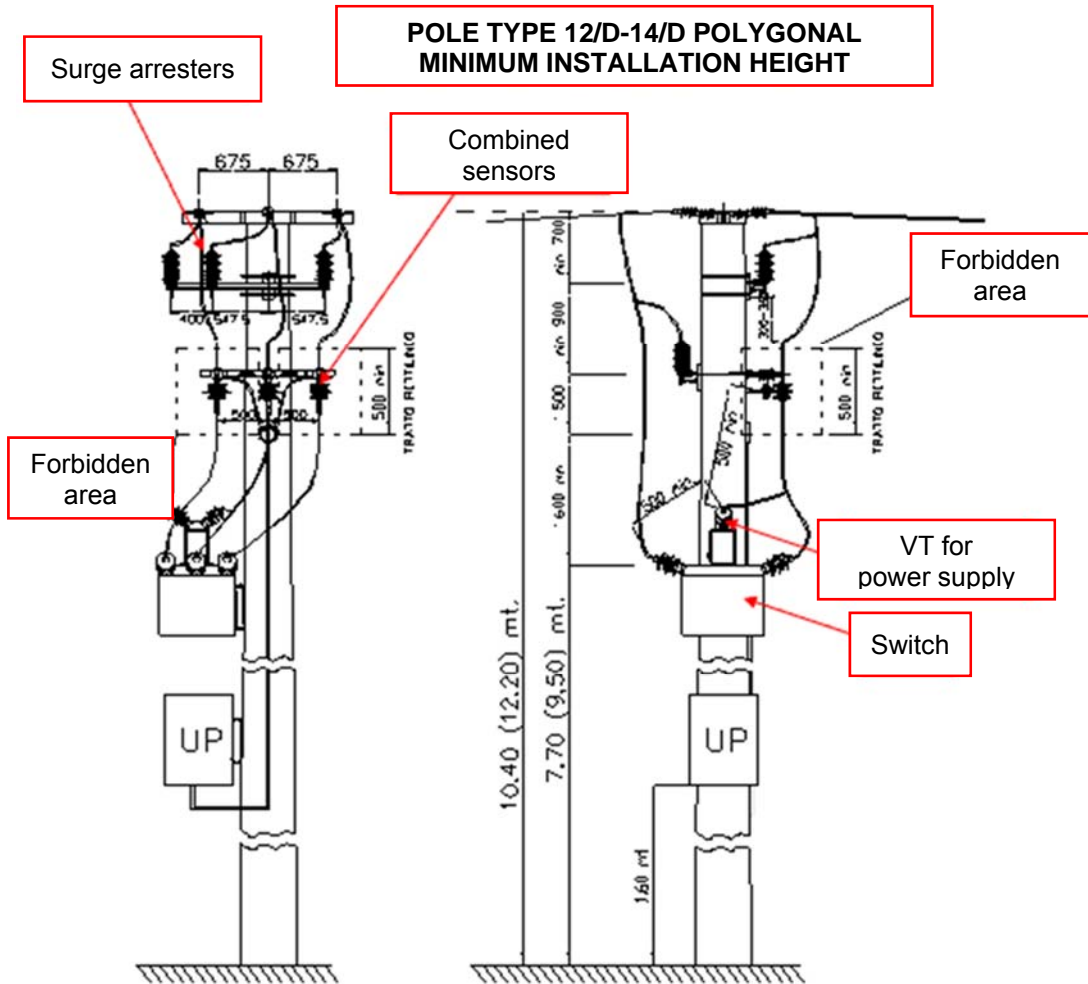
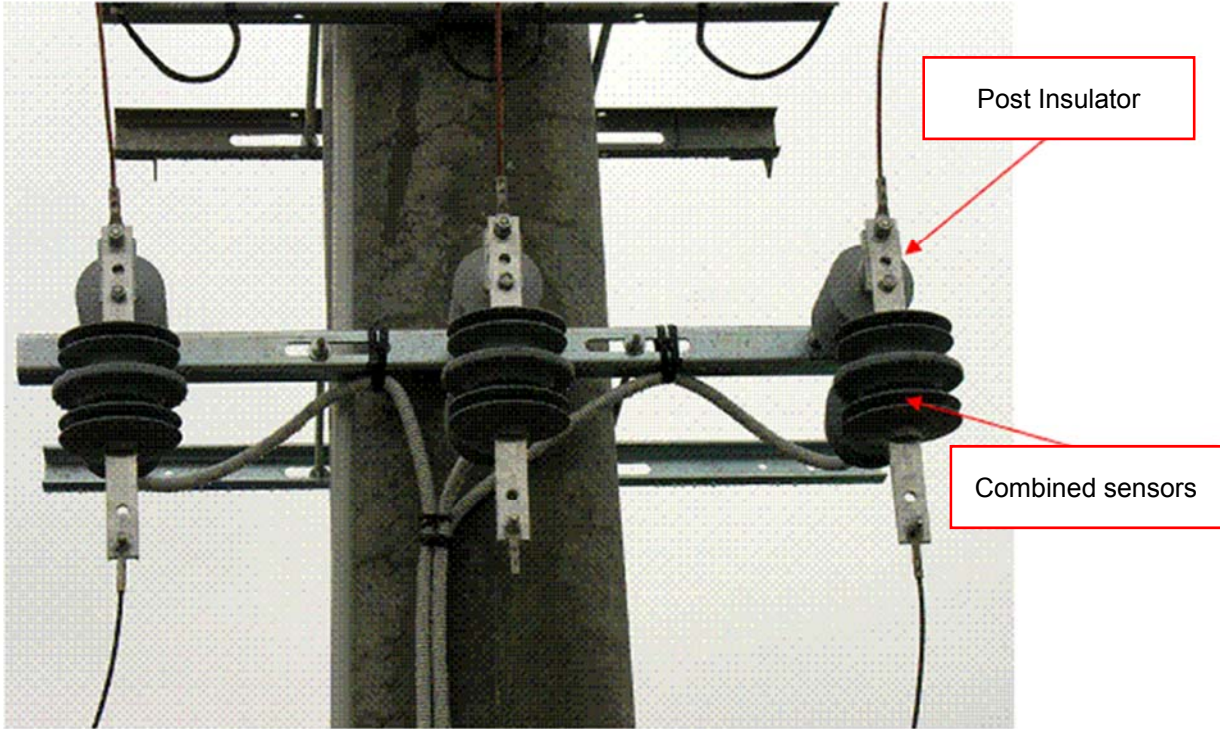


Figure 7 -Example of RGDAT-A70/O installation.

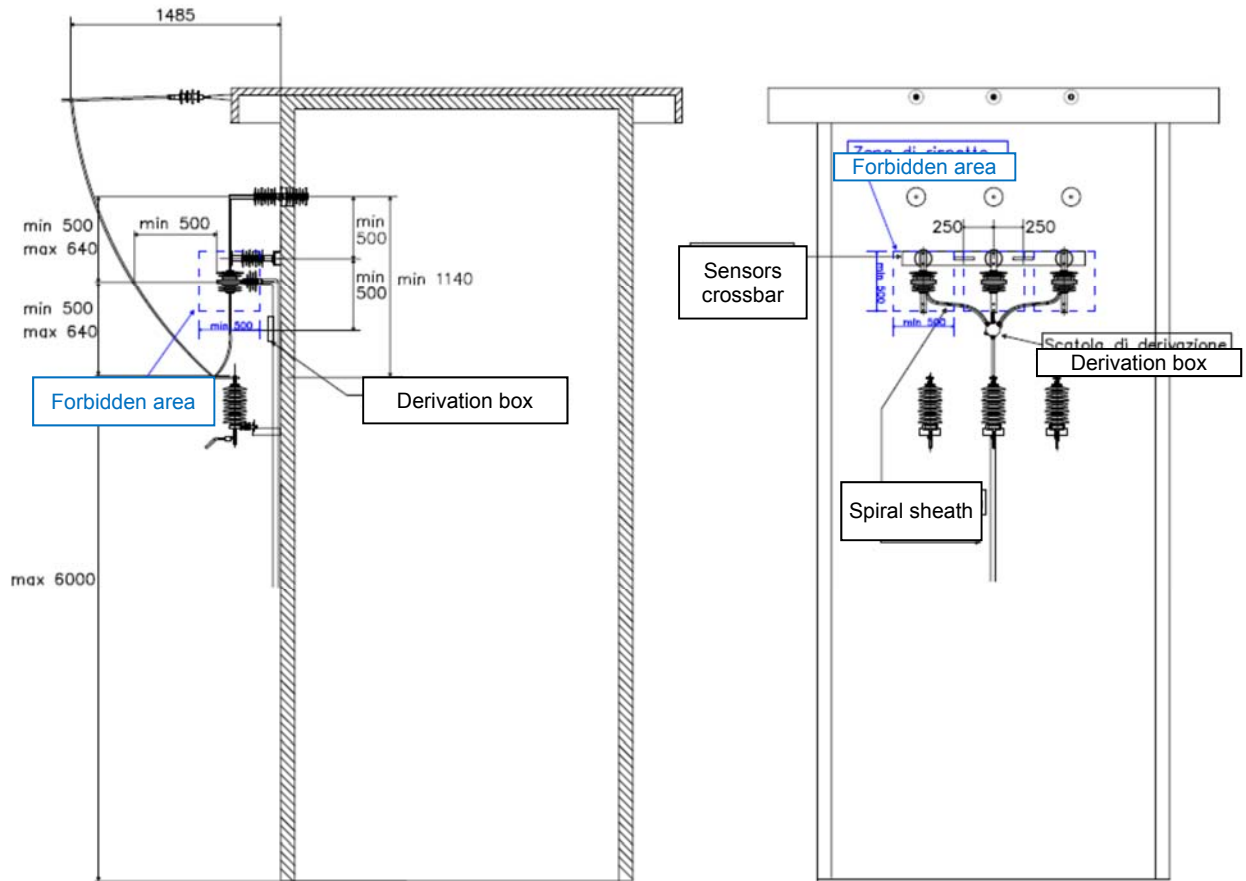
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**Figure 8 -Example of RGDAT-A70/O installation on pole.**

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### 15.2 RGDAT-A70/O: Installation on raised MV/LV substation



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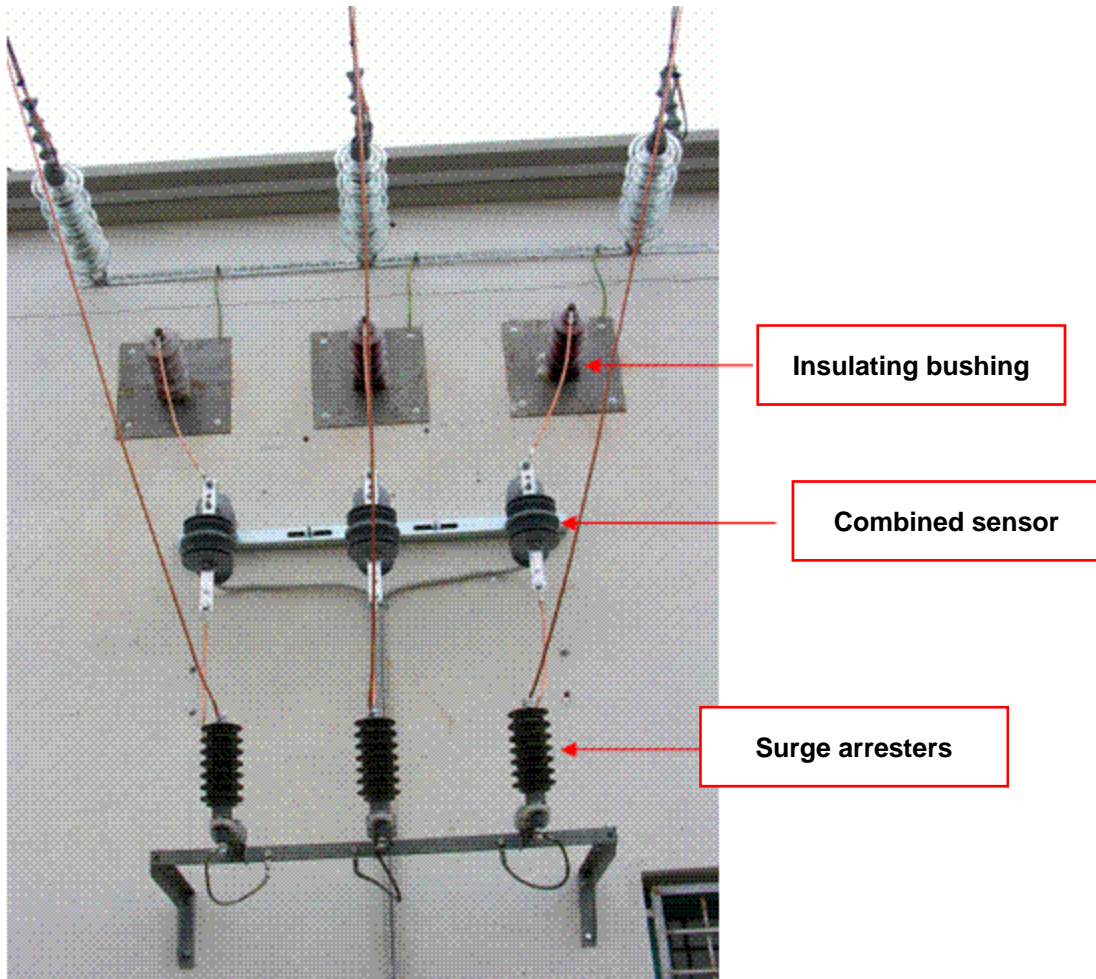


Figure 9 --Example of RGDAT-A70/O installation on raised MV/LV substation.

### 15.3 Combined sensors 24kV (36kV)

#### 15.3.1 Combined sensors Outdoor TYPE 1 (24kV)

The combined current/voltage sensor shall be resistant to the severe environmental conditions.

With reference to the CEI EN 60529 standard, the sensors shall have a IP65 level protection.

The creepage distance between the live conductor and the part connected to the earth shall be at least 700mm.

Between the earth and the sensor shall be installed a suitable insulator (included in the package) with the following mechanical features:

- Specified mechanical load (STL):  $\geq 10\text{kN}$
- Specified bending load (SCL):  $\geq 2\text{kN}$
- Specified bending load designed (MDCL):  $\geq 2,5\text{kN}$

Dimensional requirements:

- Maximum diameter of external covering: 120mm

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- Minimum rated creepage distance: 700mm
- Minimum distance between metallic parts: 210mm

Electrical requirements:

- Rated Voltage 24kV
- Dielectric insulation level in the rain (50Hz and 60Hz): 70kV
- Dielectric insulation level to atmospheric pulse (dry environment): 150kV
- Dielectric voltage level (salt spray): Up=18kV 224kg/m<sup>3</sup>

In case that the combined sensors perform also outdoor post insulator functions, the mechanical features of the insulator shall be as above listed and, if is present a junction between the post insulator and combined sensor it's mechanical features shall be as listed below:

- Bending load between on the junction:  $\geq 0,95\text{kN}$

Considering a maximum combined sensor weight of 3,5kg and its maximum encumbrance less than 400X400mm.

For the design, it shall be taken into account the stresses resulting the following functioning conditions:

- Permanent current on each phase 500A
- Short circuit thermal current (for 1s) 16kA
- Dynamic current (peak) 31,5kA

For each sensor a 8 meters connection cable (for RGDAT-A70 wiring) shall be included in the supplied package.

### 15.3.2 Combined sensors TYPE-2 (36kV)

The combined current/voltage sensor shall be resistant to the severe environmental conditions.

With reference to the CEI EN 60529 standard, the sensors shall have a IP65 level protection.

The creepage distance between the live conductor and the part connected to the earth shall be at least 1000mm.

Between the earth and the sensor shall be installed a suitable insulator (included in the package)

with the following mechanical features:

- Specified mechanical load (STL):  $\geq 10\text{kN}$
- Specified bending load (SCL):  $\geq 2\text{kN}$
- Specified bending load designed (MDCL):  $\geq 2,5\text{kN}$

Dimensional requirements:

- Maximum diameter of external covering: 120mm
- Minimum rated creepage distance: 1000mm
- Minimum distance between metallic parts: 400mm

Electrical requirements:

- Rated Voltage 36kV
- Dielectric insulation level in the rain (50Hz and 60Hz): 70kV
- Dielectric insulation level to atmospheric pulse (dry environment): 170kV
- Dielectric voltage level (salt spray): Up=18kV 224kg/m<sup>3</sup>

In case that the combined sensors perform also outdoor post insulator functions, the mechanical features of the insulator shall be as above listed and, if is present a junction between the post insulator and combined sensor it's mechanical features shall be as listed below:

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- Bending load between on the junction:  $\geq 0,95\text{kN}$

Considering a maximum combined sensor weight of 3,5kg and its maximum encumbrance less than 400X400mm.

For the design, it shall be taken into account the stresses resulting the following functioning conditions:

- Permanent current on each phase 630A
- Short circuit thermal current (for 1s) 20kA
- Dynamic current (peak) 50kA

For each sensor a 20 meters connection cable (for RGDAT-A70 wiring) shall be included in the supplied package.

#### 15.4 Residual current calculation

The RGDAT-A70/O type shall calculate the residual current by the sum of the three phase currents.

In order to compensate the error due the composition of the three phase errors, RGDAT-A70 shall valuate continually the residual current offset ( $I_{OPRE}$ ), in healthy network conditions. During a fault RGDAT-A70 shall subtract the vector  $I_{OPRE}$  from the vector  $I_O$  measured (continually current compensation).

In details:

- the above mentioned  $I_{OPE}$  shall be calculated using a mobile window, with 100ms of width and with 10ms of update time. This functionality shall be activated via SW;
- in case that the setting homopolar voltage threshold is exceeded<sup>1</sup>, the calculation of  $I_{OPE}$  shall be frozen and subtracted to the  $I_O$  measured, this compensation shall be active during the period in which the setting homopolar voltage threshold is exceeded;
- the calculation of  $I_{OPE}$  restarts after 30s while the homopolar voltage is less than the setting threshold.

#### 15.5 Voltage inputs

In order to avoid unwanted starts of the protection in case of disconnection of a single voltage plug, RGDAT-A70/O shall be able to detect this occurrence and block the protection functions.

In order to reduce the homopolar voltage error due to the differences between the three voltage sensors, RGDAT-A70/O shall permit an individual compensation of the sensors via three compensation coefficients. This compensation shall acts only on the voltage amplitude. This compensation coefficients<sup>2</sup> shall be provided by the manufacturer.

In order to compensate homopolar voltage presence in healthy network conditions, RGDAT-A70 shall valuate continually the homopolar voltage ( $V_{OPRE}$ ), this value (amplitude and phase) shall be subtracted to  $V_O$  during a fault (continually compensation).

---

<sup>1</sup> Minimum  $V_o$  threshold set between 67.S1 and 67.S2.

<sup>2</sup> In case of replacement of a single sensor, a new coefficient shall be settable in RGDAT-A70.



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In details:

- the above mentioned  $V_{OPE}$  shall be calculated using a mobile window, with 100ms of width and with 10ms of update time. This functionality shall be activated via SW;
- in case that the setting homopolar voltage threshold is exceeded<sup>3</sup>, the calculation of  $V_{OPE}$  shall be frozen and subtracted to the  $V_O$  measured, this compensation shall be active during the period in which the setting homopolar voltage threshold is exceeded;
- the calculation of  $V_{OPE}$  restarts after 30s while the homopolar voltage  $V_O$  is less than the setting threshold.
- The compensation shall be activated until  $V_{OPE}$  is less than 3V, at exceeding of this threshold RGDAT-A70/O shall stop the updating of  $V_{OPE}$ .

## 16 CONNECTION TO REMOTE MONITORING PERIPHERAL UNIT

Inside RGDAT-A70 shall be provided a terminal block, in addition to that one mentioned in par. 12.1, called MB (Figure 12) suitable for collecting section conductors until 2,5 mm<sup>2</sup>, in which will be applied the connecting cable with the remote control peripheral unit.

For the electrical connection between RGDAT-A70 and the remote monitoring unit (power of device and transfer of messages) shall be provided a cable (Figure 13), with a length of  $\geq 8m$  and structure 9x1mm<sup>2</sup>; one end of the cable shall be equipped with the flying part of the rectangular connector shown in Figure 15; the other one shall be prepared for the connection to the terminal block MB of the RGDAT-A70; 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 15 required to perform the functions specified on the wiring diagram of Figure 10.

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<sup>2</sup> 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: | $\leq 50mV$      |
| - Insertion-extraction power:                                    | 0,40÷10N/contact |

Cable characteristics shall be the following:

- |  |                    |
|--|--------------------|
| - rated voltage:                                       | 300/500V           |
| - composition:   | 9x1mm <sup>2</sup> |
| - flexible cable conductor in untinned annealed copper |                    |
| - PVC insulator with R2 quality                        |                    |
| - external diameter (on the insulator) of the cores:   | $\leq 3mm$         |

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<sup>3</sup> Minimum  $V_O$  threshold set between 67.S1 and 67.S2.



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- distinction of cores, through colours<sup>4</sup>, according to CEI-UNEL00725
- PVC sheath of Rz quality
- characteristics of fire retardant according to CEI 20-22

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 17.

### 16.1 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         | ≥10 <sup>5</sup> |
| - number of mechanical cycles ensured         | ≥10 <sup>6</sup> |

### 16.2 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 analog value between one of the two ranges listed below:

- |   |                         |
|---|-------------------------|
| - output level (terminals 4 and 7 in Figure 10) | ± 5mA (overload ± 20%); |
| - output level (terminals 4 and 7 in Figure 10) | 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<sub>DC</sub>).

### 16.3 Self-diagnosis

RGDAT-A70 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-A70 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.

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<sup>4</sup> Cores of the same colour are accepted on the condition that the numbers that indicate the reference to the terminal board MB are imprinted on the core itself.

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## 16.4 Device configuration and programming

RGDAT-A70 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 7, XP.

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

### Configuration functionality

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.

## 17 TEST

### 17.1 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

### 17.2 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.

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### ENVIRONMENTAL COMPATIBILITY TESTS

TYPE	DETAIL		NOTES/TEST LEVELS	STANDARD
Insulation and EMC test	Impulse test		Overvoltage category IV	IEC 60255-27:2013
	Dielectric test		AC test voltage 2 kV	IEC 60255-27:2013
	Insulation resistance		$\geq 100 \text{ M}\Omega$ to $500 \text{ V}_{\text{DC}}$	IEC 60255-27:2013
	Electrostatic discharges		Contact discharg level 3 Air discharge level 3	IEC 61000-4-2:2008
	Ring Wave		level 3	IEC 61000-4-12:2006
	Damped oscillatory waves		level 2	IEC 61000-4-18:2006+AMD1:2010
	Fast transient/burst		level 4	IEC 61000-4-4:2012
	Surge 1,2-50/8-20		level 3	IEC 61000-4-5:2014
	Power frequency magnetic field		level 5	IEC 61000-4-8:2009
	Damped oscillatory magnetic field		level 4	IEC 61000-4-10:1993+AMD1:2000
	Radiated, radio-frequency, electromagnetic field		level 3	IEC 61000-4-3:2006+A1:2007+A2:2010
	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 61000-4-29:2000
	Voltage dips		level 50% t = 0,1 s	
	Voltage variations on d.c. input power ports		Un $\pm$ 20%; t = 10 s	
	Test voltage level at main frequency		level 3	IEC 61000-4-16:2015
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 61000-4-6:2013	
Climatic test	No-powered equipment	Dry heat	+70 °C $\pm$ 2 °C (16 hours)	IEC 60068-2-2:2007
		Damp heat	+40 °C $\pm$ 2 °C, RH = 93% $\pm$ 3% (4 days)	IEC 60068-2-78:2012
		Cold	(-25 $\pm$ 3)°C (16 hours)	IEC 60068-2-1:2007
		Change of temperature	TA = -25°C; TB =70°C; (3 hours+3 hours)	IEC 60068-2-14:2009
	Powered equipment	Dry heat	+70 °C $\pm$ 2 °C (16 hours)	IEC 60068-2-2:2007
		Damp heat	+40 °C $\pm$ 2 °C, RH = 93% $\pm$ 3% (4 days)	IEC 60068-2-78:2012
		Cold	(-25 $\pm$ 3)°C (16 hours)	IEC 60068-2-1:2007
		Change of temperature	TA = -25°C; TB =70°C; (3 hours+3 hours)	IEC 60068-2-14:2009
Mechanical test	Vibration (sinusoidal)		lower frequency 10 Hz upper frequency 500 Hz acceleration amplitude 10 m/s <sup>2</sup> displacement amplitude 0,075 mm	IEC 60068-2-6:2007
	Vibration, broad-band random (digital control) and guidance			IEC 60068-2-64:2008

**Table 3 Test levels for environmental tests.**

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### 17.3 Acceptance tests

Acceptance tests are that indicated in par. 17.1, points 1, 2 (except for the impulse voltage withstanding test) and 3, limited to a significant set of tests including those prescribed in APPENDIX 2. 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 APPENDIX 5, test 2c (for Holmgreen connection) or an equivalent test to be agreed, according to APPENDIX 3.

Acceptance tests shall be realised through a specific device for automatic test (SCA).

A report attesting the overcoming of SCA tests shall be attached on each device.

The procedures for preparation and certification of SCA device are included in the document ENEL Distribuzione SQ/P/0101 – August 2001.

Any test relating phase current sensor shall be performed also outside of the SCA, attaching on each set of three current sensors the related test report.

### 17.4 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.

### 17.5 Insulation and dielectric strength tests

The objective of tests is that to verify dielectric strength between the three independent circuits of RGDAT-A70 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:

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## 17.6 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 (see cap. 12.3.2.2 and APPENDIX 5).

**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-A70 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 lint, 2 lint, 10 lint, (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 Appendix. (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) RGDAT-A70s 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-A70 upstream of the operating organ) and absent (RGDAT-A70 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.

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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 presented in Appendix to the present specification. 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.

### 17.7 Out of range supply tests

It shall be verified that all functions of RGDAT-A70 are inhibited by feeding the device with the values of the supply voltage that don't provide the proper function.

### 17.8 Immunity tests (Electromagnetic interferences)

The objective of the tests is to verify the correct functioning of RGDAT-A70 subject to the application of various electromagnetic disturbance.

- the function of RGDAT-A70 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-A70 during this tests shall be agreed with ENEL.

### 17.9 Thermal behaviour tests

It shall be revealed the thermal map of the RGDAT-A70 feeding with maximum values of the nominal range; the test shall be performed under the following normal environmental conditions:

- temperature: 15÷35 °C
- atmospheric pressure: 86÷106 kPa
- relative humidity: 45÷75%

The values of overtemperature, 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.

### 17.10 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

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The procedures for verifying the correct operation of RGDAT-A70 during this tests shall be agreed with ENEL.

### 17.11 Climatic tests

The referring levels of the single group of tests are indicated in the Table 3.

The procedures for verifying the correct operation of RGDAT-A70 during this tests shall be agreed with ENEL

### 17.12 Functional final test

In order to check that RGDAT-A70 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. 17.1.

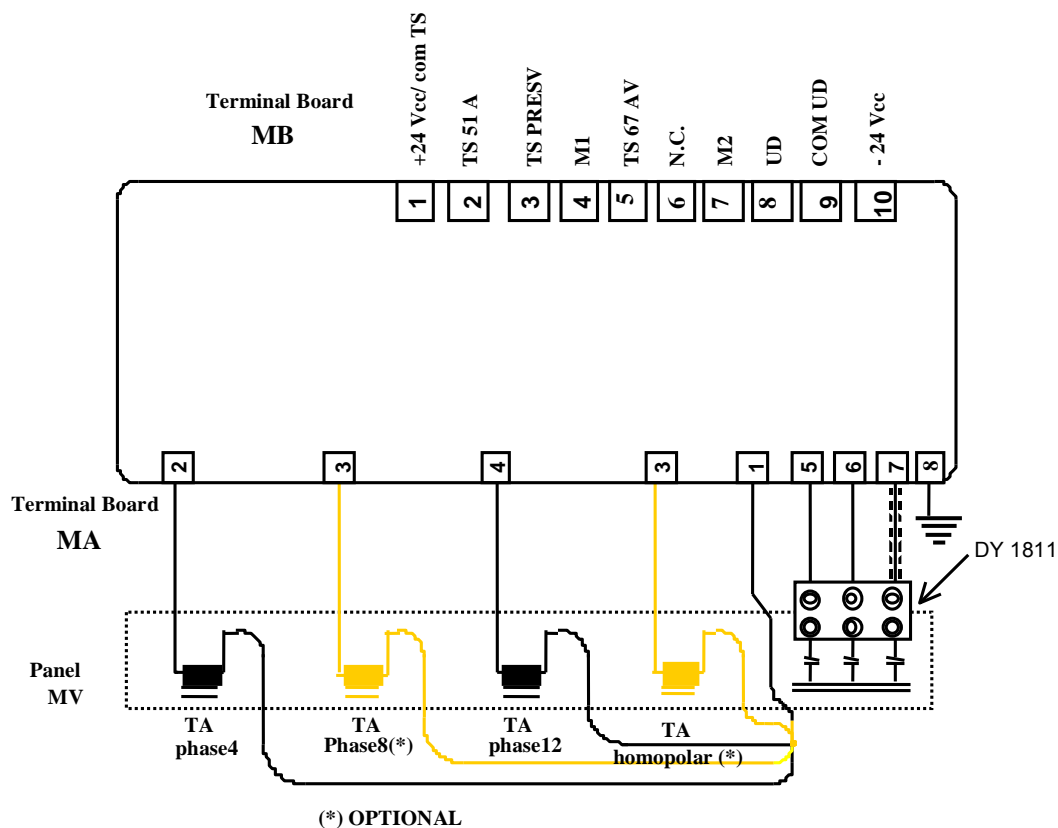


Figure 10 -Circuit diagram of Directional Fault Passage Indicator (RGDAT-A70)

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



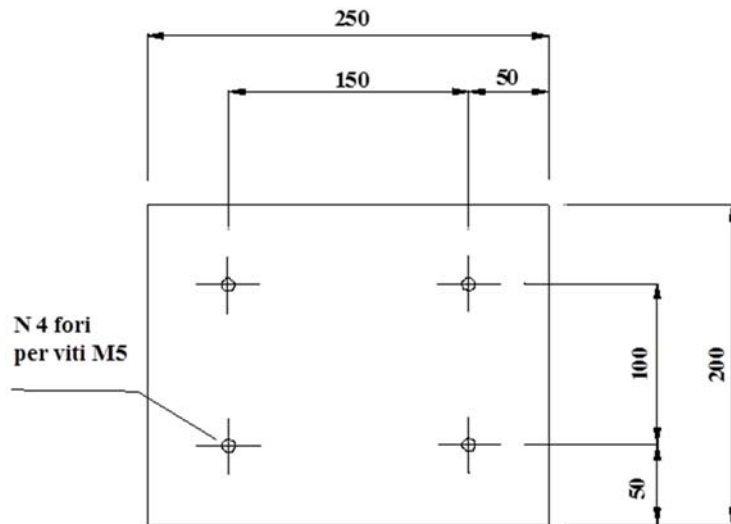


Figure 11 -Maximum dimensions and installation template of RGDAT-A70 for using on MV cells.

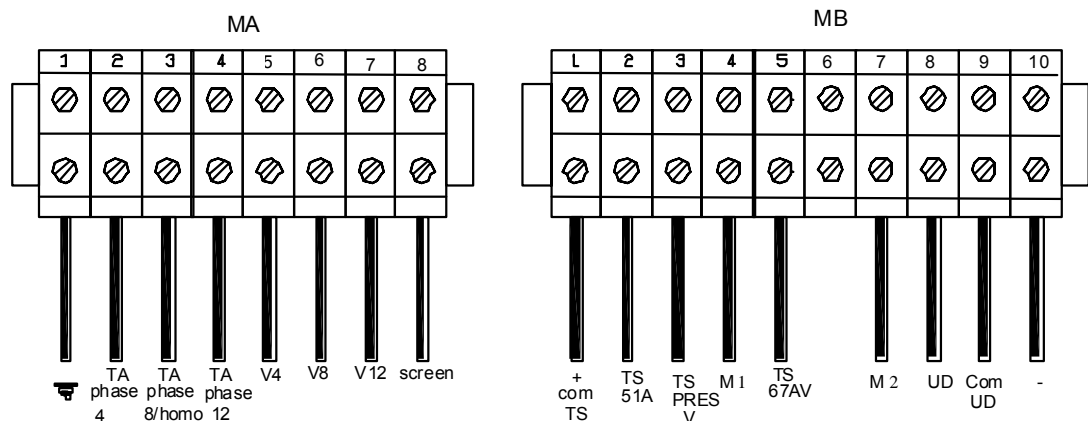


Figure 12 -Terminal blocks for input voltages and currents (MA) and output signals (MB).

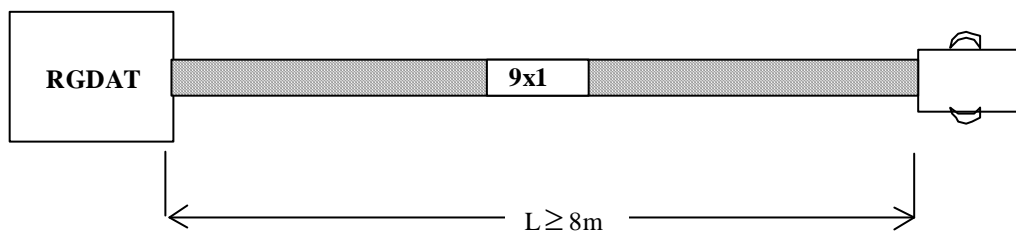


Figure 13 -Remote control unit connecting cable.

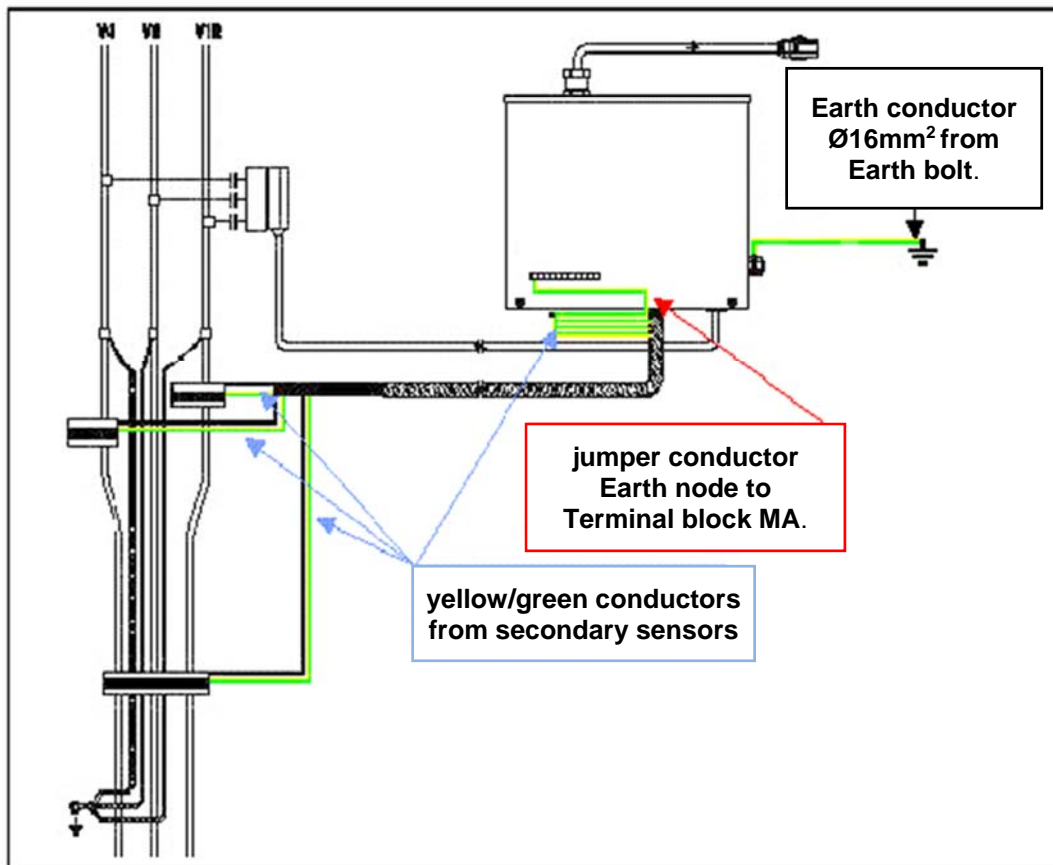
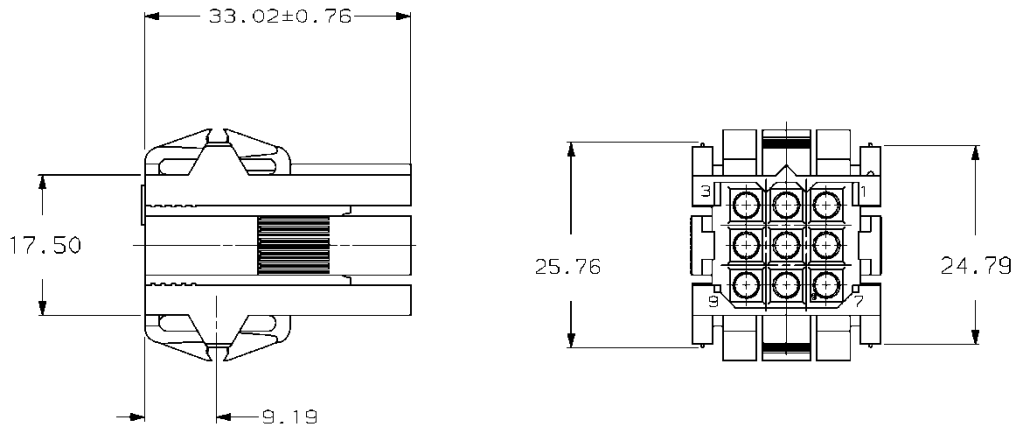


Figure 14 -Cabling scheme RGDAT/C.

1	Com TS	Power supply (+24Vcc) and Common remote signals
2	TS 51 A	Multiphase or double-phase fault
3	TS PRES V	Voltage presence MV (level)
4	M1	Measurement - pole 1
5	TS 67AV	Ground to phase fault (downstream)
6	M2	Measurement - pole 2
7	COM UD	Reverse direction command 67 AV (common)
8	UD	Reverse direction command 67 AV
9	-	Power supply (-24 Vcc)



**Figure 15 -Rectangular connector (UP side).**

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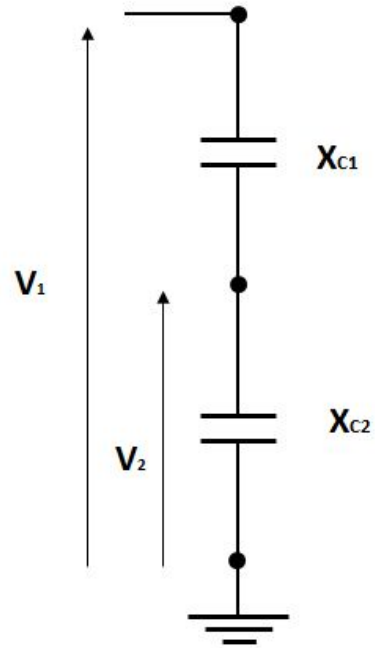
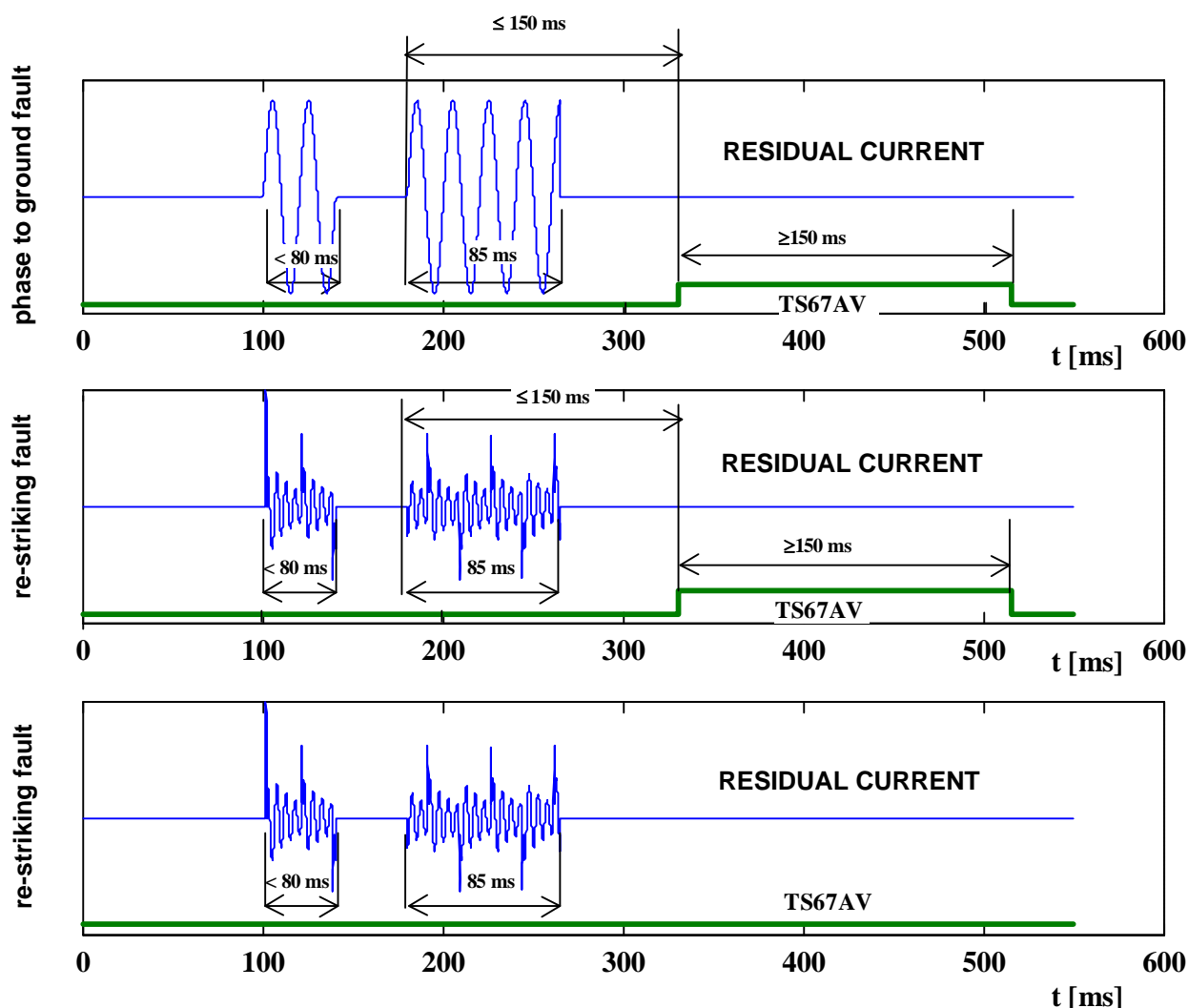


Figure 16 -Single phase equivalent diagram of a capacitive divider.



**Figure 17 -Examples of a correct functioning following a ground-phase fault and intermittent arc (both with resistance within specification limits). It's showed a waveform of residual current and of fault detection signal at the output of the device.**

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).

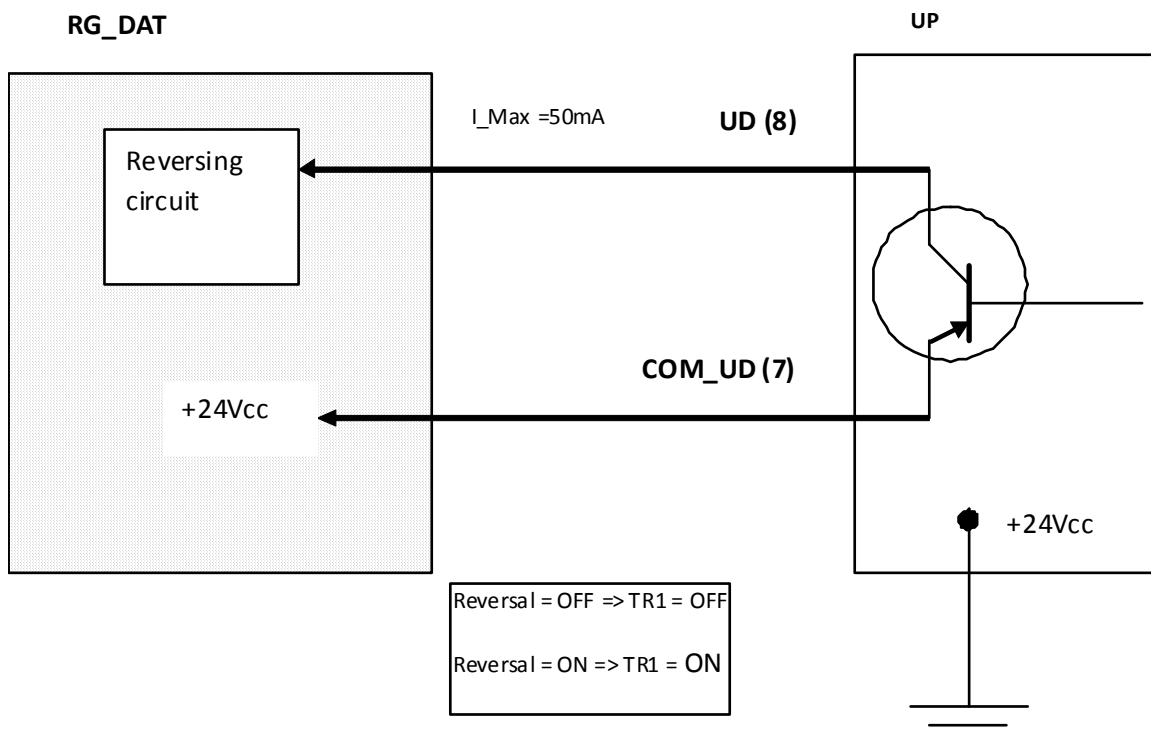


Figure 18 -Diagram of reversal of the direction command single phase to ground fault detection.

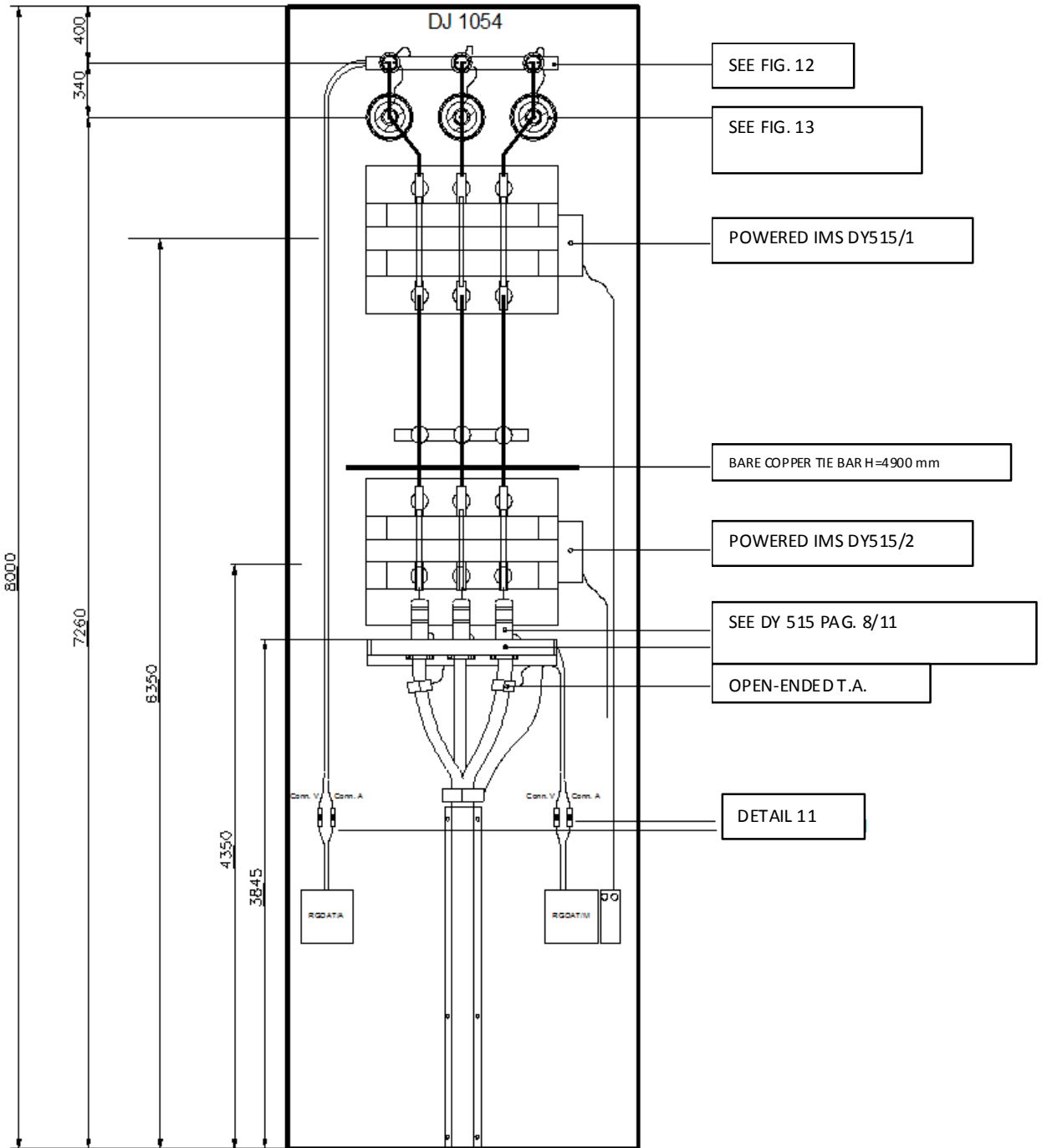
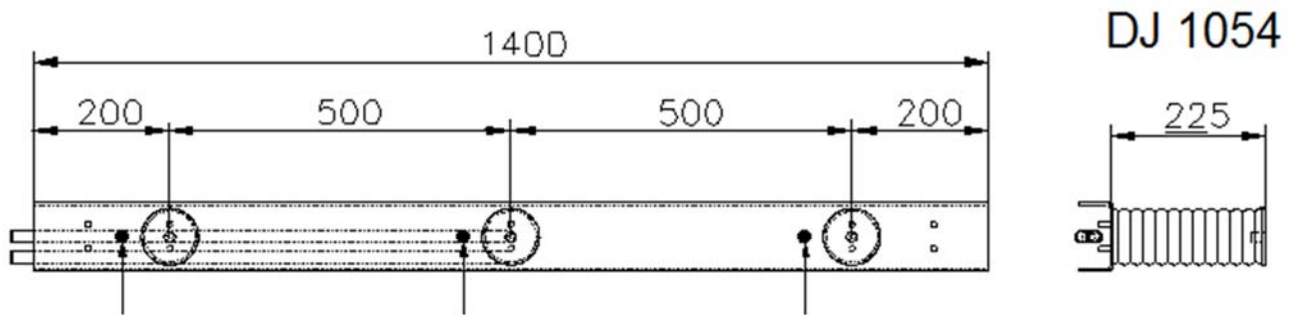
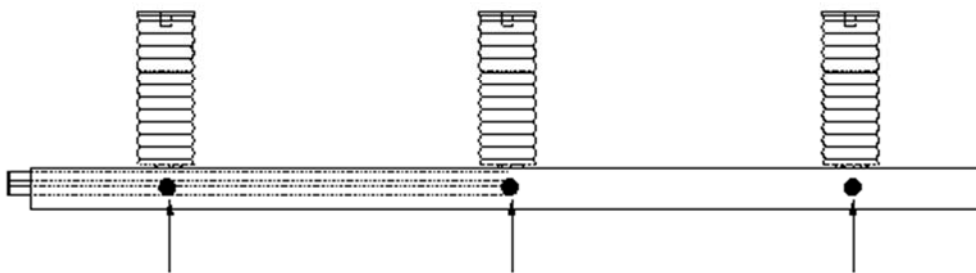


Figure 19 -Front view of a substation for overhead lines.

**18 COMPONENTS AND ACCESSORIES FOR RGDAT-A70/A**

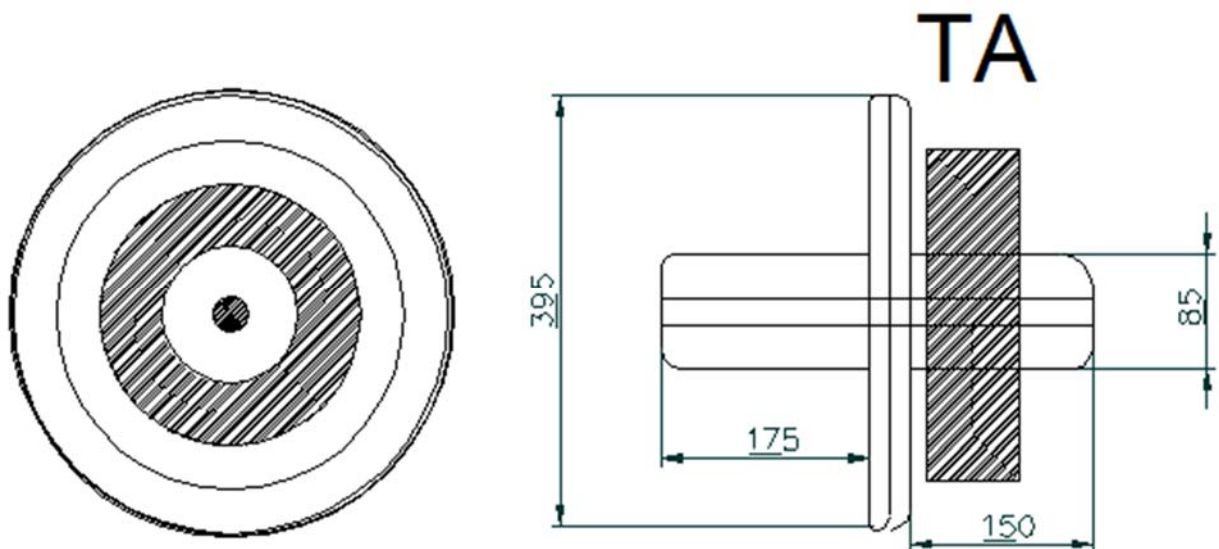


**WIRING INPUT CAPACITIVE DIVIDERS**



**WIRING INPUT CURRENT SENSORS**

**Figure 20 -High crossbar for insulators with capacitive dividers.**



**Figure 21 -Feed through insulator with current sensor.**



### 19 COMPONENTS AND ACCESSORIES FOR RGDAT-A70/M

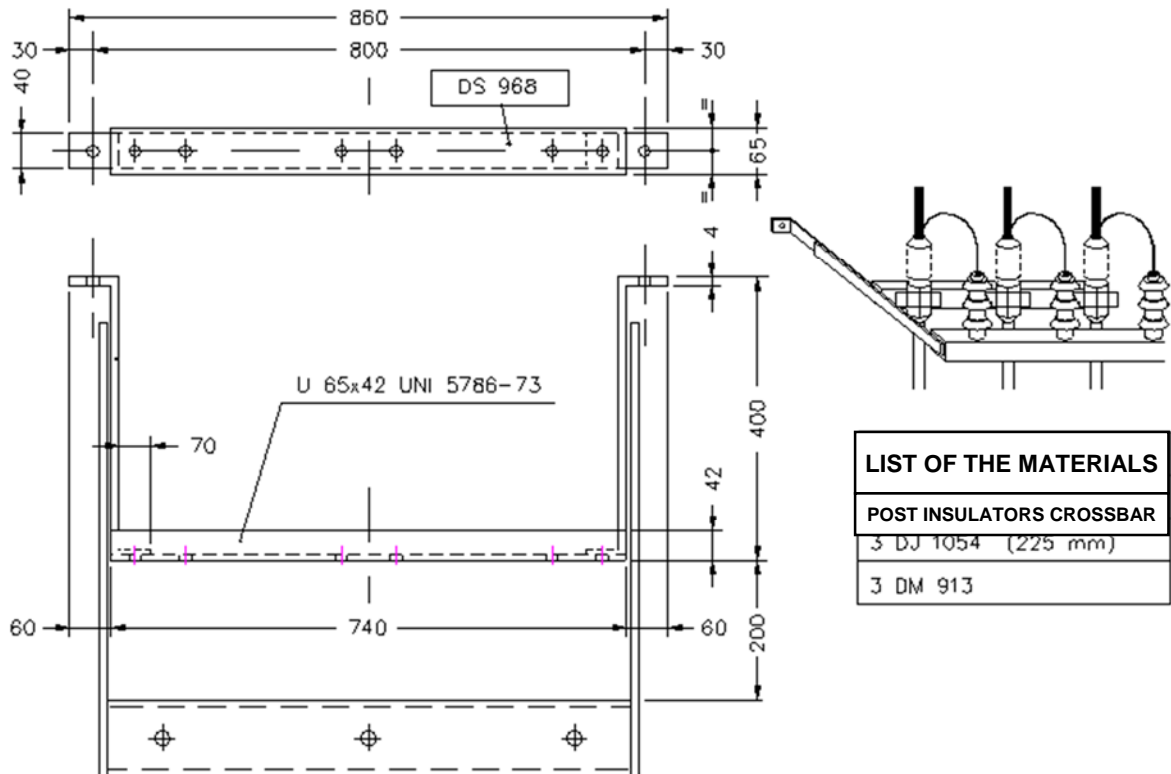
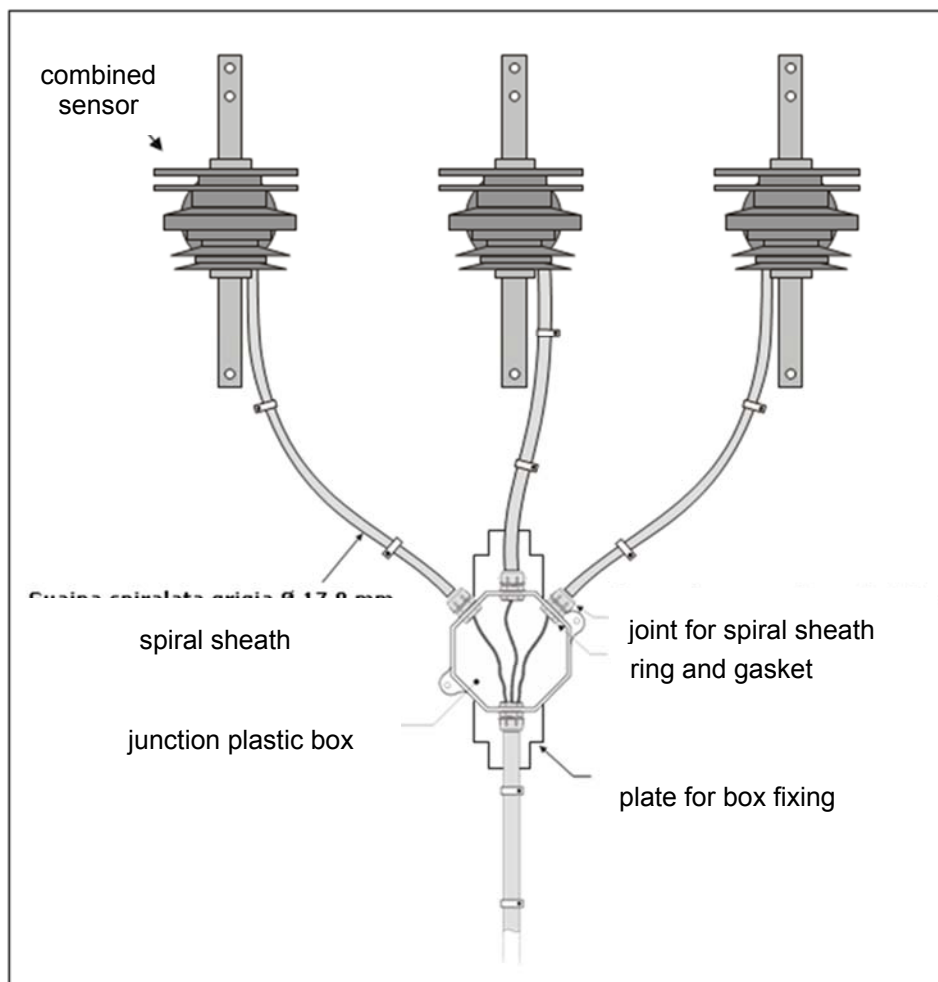


Figure 22 -Low crossbar for insulators with capacitive dividers.

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## 20 COMPONENTS AND ACCESSORIES FOR RGDAT-A70/O



**Figure 23 -Combined sensors installation kit.**

### Components:

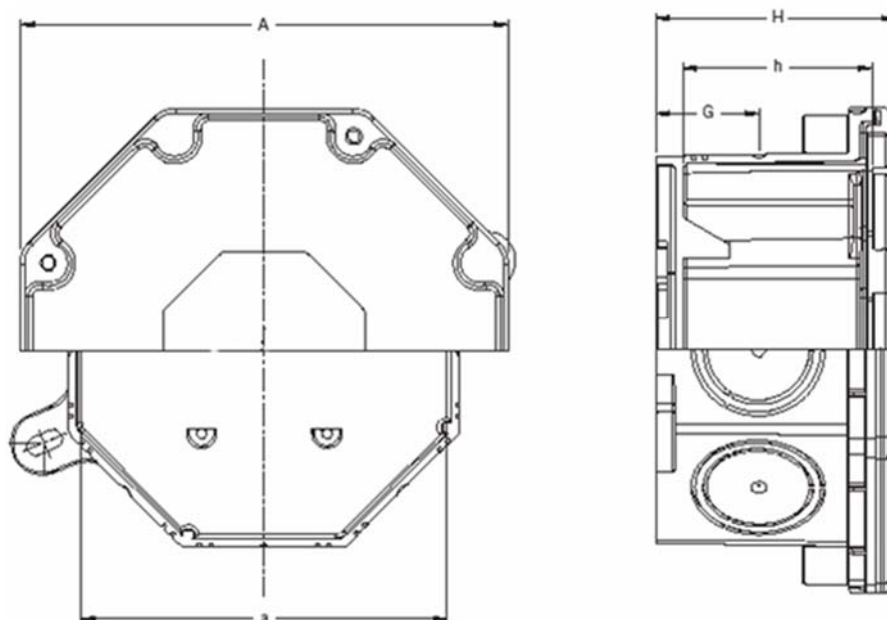
- spiral sheath: Ø17mm
- junction plastic box
- plate for box fixing
- joint for spiral sheath
- ring and gasket for mounting fitting
- screws, washers, nuts for medium voltage connections

The following document will describe all the parts. Other solutions may be allowed only if equivalent in terms of resistance to solar radiation, the functionality and waterproofness.

### Junction plastic box

Technical requirements:

- Height: 128mm
- Effective height: 94mm
- IP level protection: 54 (EN 60529, IK09 EN 50102)
- Base width: 128mm
- Effective base width: 94mm
- Depth: 63mm
- Effective depth: 50mm
- Material: reinforced polyamide resin
- Color: RAL 7035 (gray)
- Box type: empty
- Mounting type: on wall



A [mm]	H [mm]	G [mm]	A [mm]	H [mm]
128	63	26,5	94	50

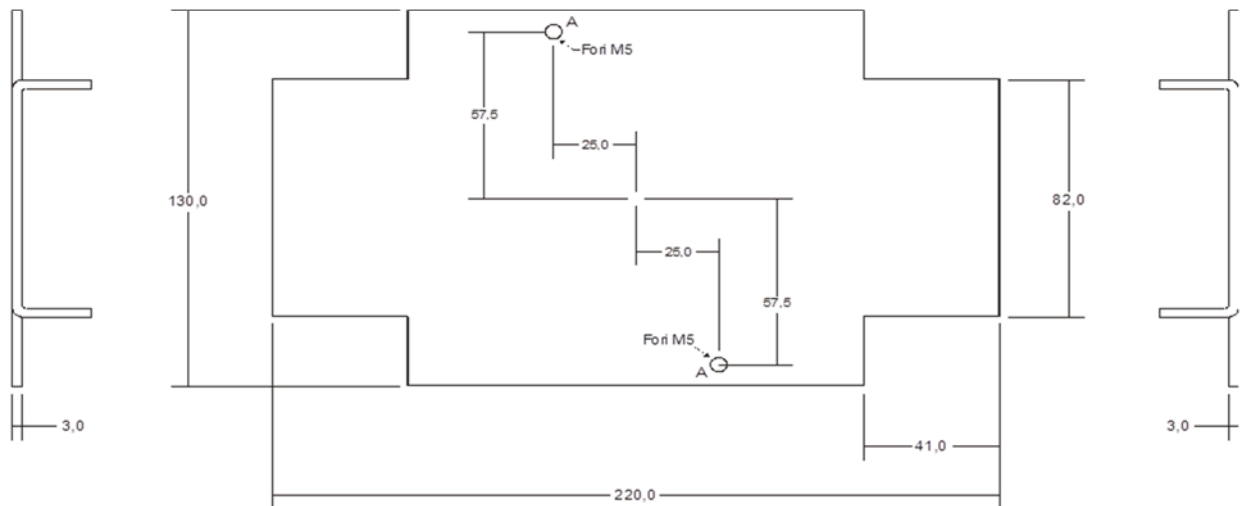


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**Plate for box fixing**

The plate is used only in case of mounting on pole.

Profiled anodized aluminium, thickness 3mm

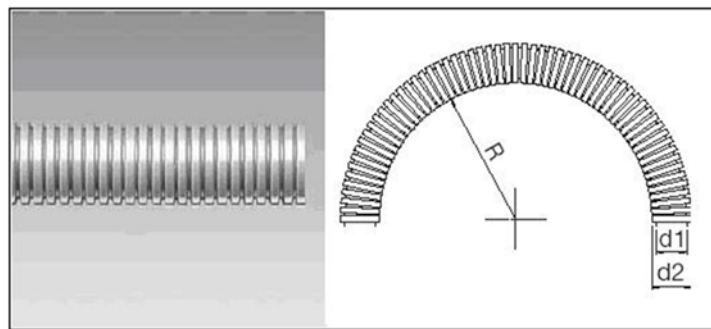


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### Spiral sheath

*Technical requirements:*

- Material: polyamide
- Resistance to bending: good
- Resistance to crushing: 400N/100mm
- Impact test: 6J
- Temperature: -40°C/+105°C
- Class self-extinguishing: V2
- Colour: grey



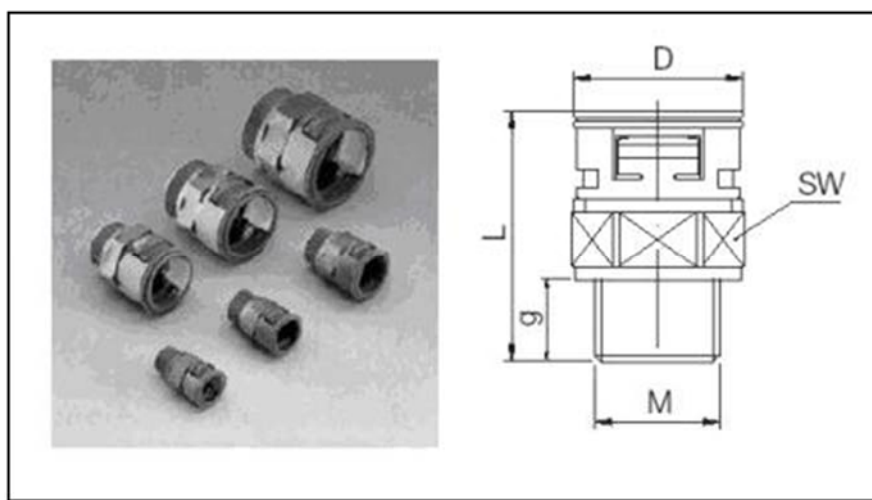
Nominal diameter (mm)	d2 (mm)	d1 (mm)	Bending radius
17	21,5	15,5	40

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### Joint for spiral sheath

Technical requirements:

- Material: composite polyamide
- IP level protection: 67
- Colour: grey
- metric thread: metric



Nominal diameter (mm)	M (mm)	g (mm)	D (mm)	L (mm)	SW (mm)
17	20x1,5	13	33	43	27

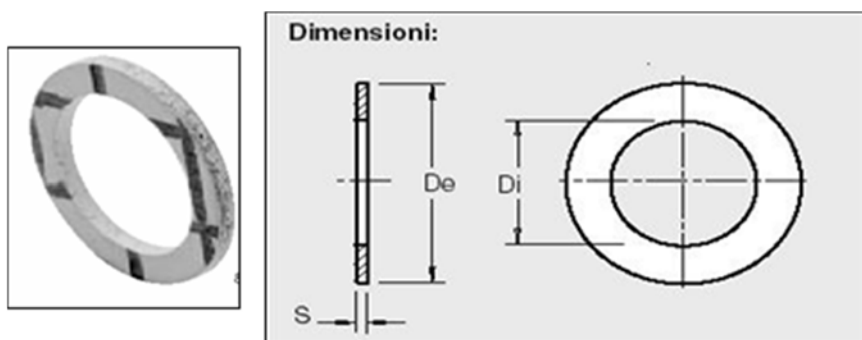
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### Ring and gasket

Gasket for isometric thread, PG and Gas.

*Technical requirements:*

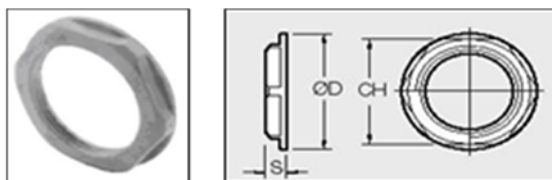
- Max temperature: +150°C
- Thread: M20X1,5 e PG13,5 e G ½"



Ø Di (mm)	Ø De (mm)	S (mm)
21	27	2

### Ring for fitting

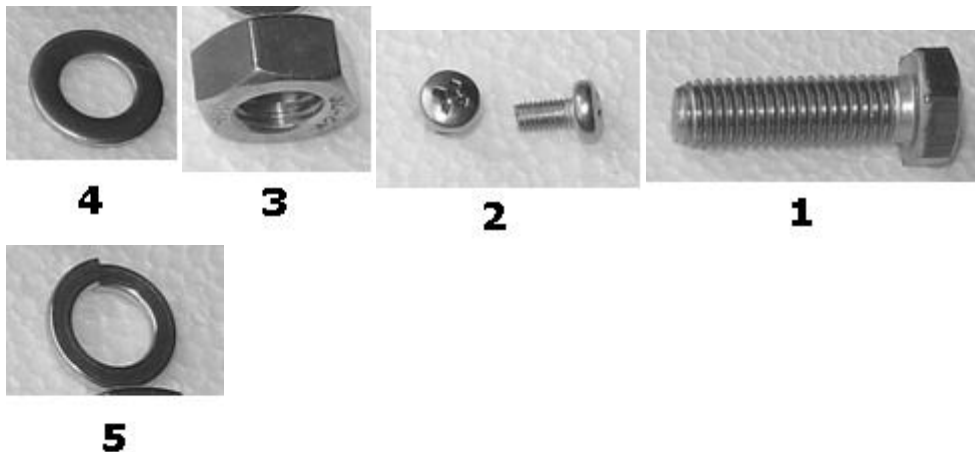
Ring for fitting with isometric thread, colour gray RAL7001 and thread M20X1,5.



CH (mm)	Ø D (mm)	S (mm)
26	28	6

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**Screws, washers, nuts for medium voltage connections**



- 1 Hexagonal screw INOX M12X40 UNI/DIN 5739
- 2 Screw TCB M5X10 Steel INOX DIN 7985 ZB
- 3 Nut steel INOX M12 UNI/DIN 5588
- 4 Flat washer INOX M12 UNI/DIN 6592
- 5 Washer grower INOX M12 UNI/DIN 1751

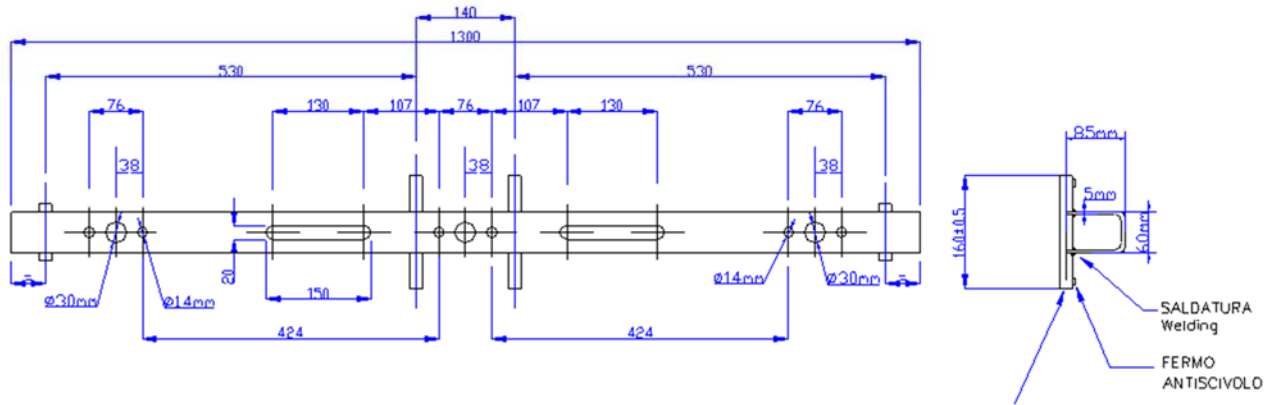


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### Support Bracket

Ries. / Treat. ZINCATURA - Zinced : SECONDO NORMA CEI7-6 e UNI EN ISO 1461  
 Protec. / Treat. - According to CEI 7-6 and UNI EN ISO 1461 -

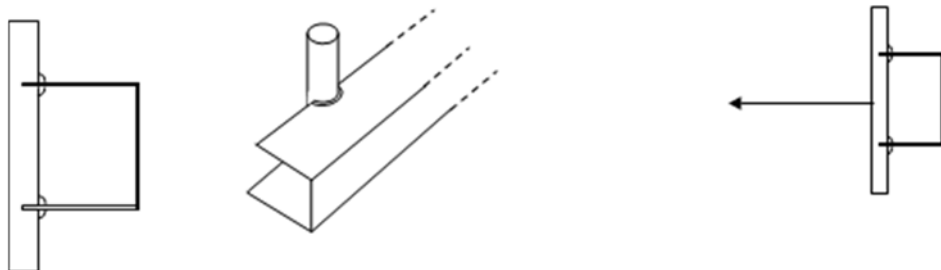
Materiale Material ACCIAIO - Steel : Fe 360 UNI EN 10025 CL.1



N°2 TONDI  $\varnothing 18$  O TUBI  $\varnothing 27 \times 5.5$  h 70 IN ACCIAIO SECONDO UNI 7070-27 (posti agli estremi)  
 Nr.2 rods  $\varnothing 18$  or pipes  $\varnothing 27 \times 5.5$  h 70 steel according to UNI 7070-27

N°2 TONDI  $\varnothing 18$  O TUBI  $\varnothing 27 \times 5.5$  h 160 IN ACCIAIO SECONDO UNI 7070-27 (posti al centro della mensola)  
 Nr.2 rods  $\varnothing 18$  or pipes  $\varnothing 27 \times 5.5$  h 160 steel according to UNI 7070-27

The round profiles (or tubes) must be soldered to the support in galvanized sheet metal as shown in the figures herein, and each of the 4 round profiles must be subjected to tensile test.



The test consists of applying a horizontal force  $F$  of 100 daN to each individual round profile (not simultaneously) for one minute and verify that they are not subsequently occurred chipping, breakage or cracks of all the welding bead

Test Requirements:

- Type tests and construction:  
 ENEL Standard DS 3850 for bracket metallic parts  
 ENEL Standard DJ 3955 for insulators
- Acceptance tests:  
 Visual inspection and The supplier upon delivery must ensure, with a declaration of conformity, the full compliance of the product to the technical requirements above.

On each item will be marked the following data:

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- On the metal support:  
Identification number of support, trademark of the manufacturer, year of manufacture.
- On the insulators:  
In a suitable position to be agreed with ENEL must be marked the Specified Mechanical Load insulator in kN, the term constructive assigned by the manufacturer to the type of insulator, the name or trademark of the manufacturer, year and month of manufacture.

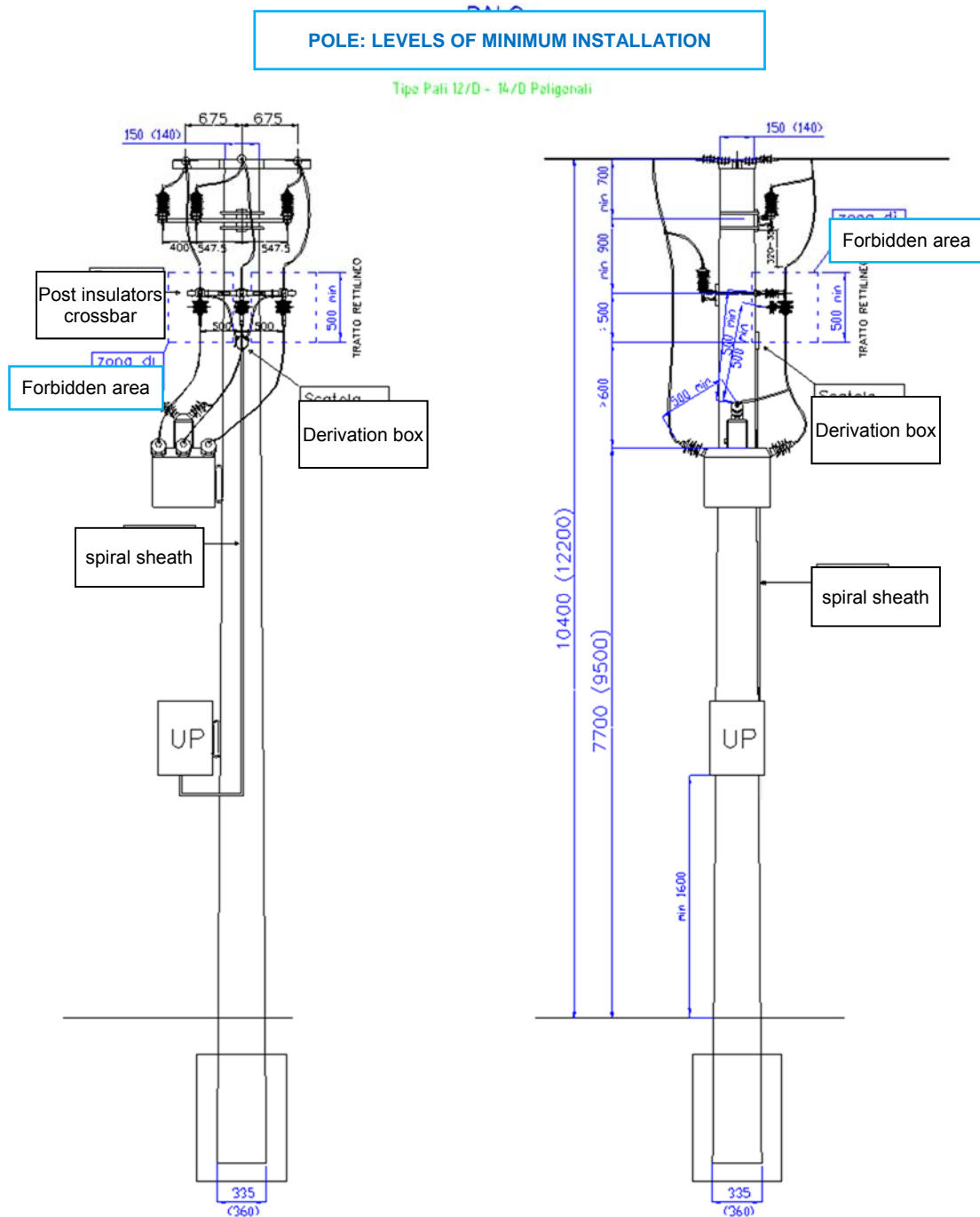
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## 20.1 Quantity

<b>Combined sensors for RGDAT-A70/O installation on pole/substation</b>	
Quantity	<i>Description</i>
9 Pcs	Hexagonal screw INOX M12X40 UNI/DIN 5739
9 Pcs	Flat washer INOX M12 UNI/DIN 6592
9 Pcs	Washer grower INOX M12 UNI/DIN 1751
9 Pcs	Nut steel INOX M12 UNI/DIN 5588
5 Pcs	Ring nylon M20 gray
2 Pcs	Screw TCB M5X10 Steel INOX DIN 7985 ZB
4 Pcs	Gasket 1/2" - PG13,5 - M20
8 Pcs	Joint for spiral sheath
1 Pcs	Junction plastic box
1 Pcs	Plate for box fixing
10 m	Spiral sheath

<b>Assembly support (crossbar+insulators) for combined sensors</b>	
Quantity	<i>Description</i>
1 Pcs.	Support bracket
6 Pcs.	Hexagonal screw INOX M12X40 UNI/DIN 5739
6 Pcs.	Flat washer INOX M12 UNI/DIN 6592
6 Pcs.	Washer grower INOX M12 UNI/DIN 1751
6 Pcs.	Nut steel INOX M12 UNI/DIN 5588
3 Pcs.	Post insulators (only in case not integrated in the combined sensors)

**APPENDIX 1 EXAMPLE OF INSTALLATION LAYOUT RGDAT-A70/O (UP OUTDOOR)**



**Figure 24 -Minimum distances for pole installation polygonal type 12/D and 14/D.**

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## APPENDIX 2 ADDITIONAL ENVIRONMENTAL TESTS FOR COMBINED SENSORS

- **AGING:** the sensor must withstand environmental stresses, electrical and the combination thereof, under normal operating conditions, without giving rise to processes of degradation (tracking, drilling, etc.) that could affect the functionality of the insulator. For this purpose the combined sensor will stand the test of accelerated aging electrical environment than 5,000 hours as specified in Annex C of IEC 1109. In case the sensor contains electronic board, shall be performed some functional tests with RGDAT-A70/O connected to three sensors before and after the test cycle, with the expected results of the tests virtually equal. The electronics that uses the sensors not will be tested;
- **LIQUID TIGHTNESS:** It needs the check of liquid tightness of the interface between the conductor sensor output and the insulation as required by section 7.4 of the "Amendment" 1 of IEC 1109. Instead of applying a tensile load it is possible apply a bending moment to be agreed after the examination of the final prototype for 1 minute. The test will be considered passed if, after the release of the load, the liquid in the area of the interface will not be entered for more than 10mm along the conductor. At the same test he will have to be subjected compass hollow in which is housed the tube mounting, at both ends, with the hose inserted inside the bush;
- **SALINITY TIGHTNESS:** the combined sensor must have a profile of the fins and a creepage such as to ensure the sealing surface in conditions of pollution, the salinity values and voltage given in the tables of unification (to be defined after the examination of the prototype). The aim must be realized a test salinity sealing. The verification test salinity sealing must be carried out properly after washing the insulators in the manner indicated in the Standard IEC 60507, taking into account the following details and indications:
  - The cleaning of the insulator must be carried out by wiping the entire surface with a soft sponge soaked in a solution, at a temperature of 50 ° C, water and trisodium phosphate. The isolator must therefore be thoroughly rinsed with tap water;
  - The process of pre-conditioning as indicated in the standard mentioned above should not be done; in its stead the insulator must be subjected, for a period of 3 hours, to a preconditioning consisting in the application of a voltage equal to 80% of 18 kV, simultaneously with the salinity of 224 kg/m<sup>3</sup>;
  - The isolator must therefore be subjected to the series of tests of one hour. The number of tests of the series is equal to 12, carried out at the voltage of 18 kV and to salinity of 224 kg/m<sup>3</sup>;
  - The time interval between the end of the pre-conditioning and the start of the tests of the series must not be greater than 30min. Said interval must also be respected between the end of a single test and the beginning of the next. At the end of each test, the insulator must be rinsed with a simple jet of tap water;
  - The test is positive if there is tight during preconditioning and in at least 8 of the Test Series.

In case the sensor contains electronic board, shall be performed some functional tests with RGDAT-A70/O connected to three sensors before and after the test cycle, with the expected results of the tests virtually equal. The electronics that uses the sensors not will be tested.

- **LEAK TEST IMPULSE ATMOSPHERIC DRY - IEC 60383-2;** par. 6, 9, 12.1 (as applicable): the test will carried out on 3 sensors connected to the electronic part powered and active. The test will be considered passed if the three sensors are not damaged and are not emitted tripping signals;
- **LEAK TEST FREQUENCY INDUSTRIAL UNDER RAIN - IEC 60383-2;** par. 6, 7, 10.1, 12.1 (as applicable): the test will carried out on 3 sensors connected to the electronic part powered

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and active. The test will be considered passed if the three sensors are not damaged and are not emitted tripping signals;

- **INFLAMMABILITY:** the material used for the coating of the sensors must pass the flammability test scheduled in IEC 60695- 11-10 (former IEC 60707), and be in class V0, using method B (formerly FV).

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## APPENDIX 3 DESCRIPTION OF TEST CASES FOR RGDAT-A70 DEVICE – FUNCTIONAL TEST

The objective of the following functional tests is to check through additional tests the RGDAT-A70 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-A70 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-A70 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-A70 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.

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The output values of RGDAT-A70 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-A70 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<sup>5</sup> in point 1 (faulty line);
- Phase voltage and homopolar current in point 2<sup>6</sup> (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

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<sup>5</sup> Intended as the sum of three phase current (so it is the primary residual current of the current sensor of the RGDAT-A70).

<sup>6</sup> In case of RGDAT-A70 assembled with three phase sensors will be supplied, as an alternative to residual current, the three phase currents.



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event	name	network extension	calibration	Rfault [ $\Omega$ ]	$\alpha$ (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-A70 for adjustment of Io=2A.

#### EXPECTED RESULTS

event	name	without reversal		with reversal	
		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-A70 for adjustment of Io=2A.

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Tests with 20 kV network, compensated neutral

event	name	network extension	Compensation degree	Set calibration	Rg [ $\Omega$ ]	$\alpha$ (Lfault)	Test
1	gm01nc	300 A	50 %	Vo=6% Io=1 A	$\approx 0 \Omega$	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	$\approx 0 \Omega$	184°	T
6	gm06nc	500 A	100 %	Vo=1% Io=1 A*	17 k $\Omega$	251°	T
7	gm07nc	500 A	100 %	Vo=1% Io=1 A*	14 k $\Omega$	251°	T
8	gm08nc	500 A	100 %	Vo=1% Io=1 A*	20 k $\Omega$	251°	T
9	gm09nc	300 A	135 %	Vo=12% Io=1 A	$\approx 0 \Omega$	252°	T
10	gm10nc	300 A	135 %	Vo=12% Io=1 A	790 $\Omega$	252°	T
11	gm11nc	300 A	135 %	Vo=12% Io=1 A	670 $\Omega$	252°	T
12	gm12nc	300 A	135 %	Vo=12% Io=1 A	910 $\Omega$	252°	T
13	gm13nc	500 A	150 %	Vo=15% Io=1 A	$\approx 0 \Omega$	255,5°	T
14	gm14nc	500 A	150 %	Vo=15% Io=1 A	280 $\Omega$	255,5°	T
15	gm15nc	500 A	150 %	Vo=15% Io=1 A	230 $\Omega$	255,5°	T
16	gm16nc	500 A	150 %	Vo=15% Io=1 A	330 $\Omega$	255,5°	T

\* Additional test – Verify the NON-intervention of RGDAT-A70 for adjustment of Io=3A.

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EXPECTED RESULTS

event	name	without reversal	with reversal	without reversal	with reversal
		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-A70 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<sup>7</sup> 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	lomo line 1	$\alpha$ 1	lomo line 2	$\alpha$ 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

E

**XPECTED RESULTS**

event	name	without reversal		with reversal	
		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

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<sup>7</sup> Intended as the sum of three phase current (so it is the primary residual current of the sensor of the RGDAT-A70).

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### **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 lomo1 (quantity 7 of comtrade file)
- Residual current lomo3 (quantity 8 of comtrade file)

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

- With Va voltages and lomo1 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);
- with Vb voltages and lomo1 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 lomo3 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 lomo3 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 l'RGDAT-A70 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.

EXPECTED RESULTS

event	Name	Va – lomo1	Va – lomo3	Vb – lomo1	Vb – lomo3
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 lomo 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 – lomo1	Va – lomo3	Vb – lomo1	Vb – lomo3
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 lomo is inferior to 4A.

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**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 ( $I_{omo} < 150A$ ) that at the second reclosure returns as double-phase ( $I_{omo} > 150A$ );

**evol\_02nc** double-phase fault ( $I_{omo} > 150 A$ ) that at the second reclosure returns as simple single-phase ( $I_{omo} < 150A$ );

EXPECTED RESULTS

event	name	Va – I <sub>omo</sub> 1	Va – I <sub>omo</sub> 3	Vb – I <sub>omo</sub> 1	Vb – I <sub>omo</sub> 3
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<sup>8</sup> 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-A70 will be **V<sub>omo</sub>=2%**, **I<sub>omo</sub>=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.

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.

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<sup>8</sup> Intended as the sum of three phase current (so it is the primary residual current of the sensor TA of the RGDAT-A70).

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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.



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**Fault recordings (only for type tests)**

Transients obtained by field osciloperturbographic 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-A70 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.

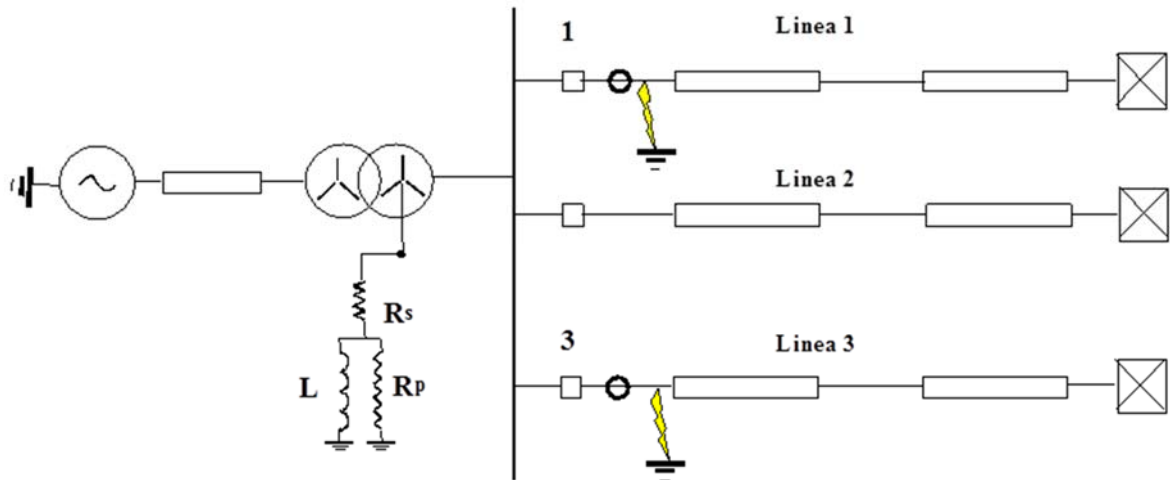
Isolated neutral network

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-A70**

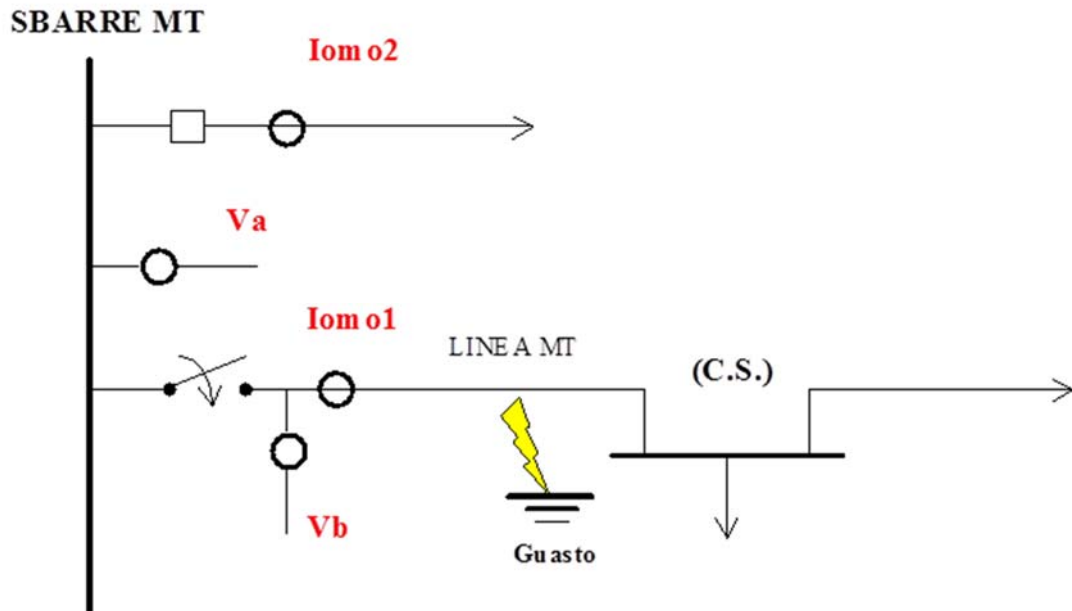


Figure A- 2: Events for fault closure.

**Impulse response of integrator Rogowski**

RGDAT-A70 shall have some output measurement points of the Rogowski integrated signal.

With the Rogowski coils connected to the RGDAT-A70, will injected a primary positive impulse of current (duration 20ms; amplitude 20A).

The time constant ( $\tau$ ) of the impulse response shall be less than 4ms (Figure 25).

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.

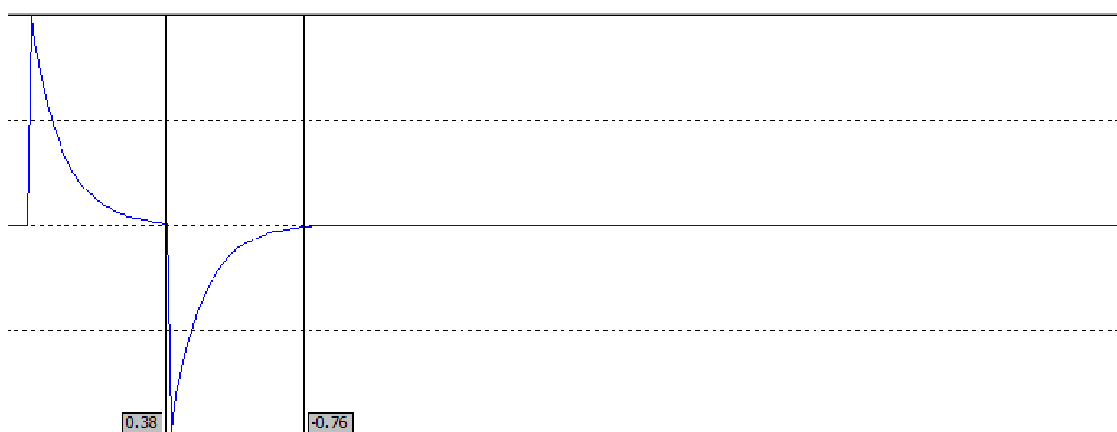
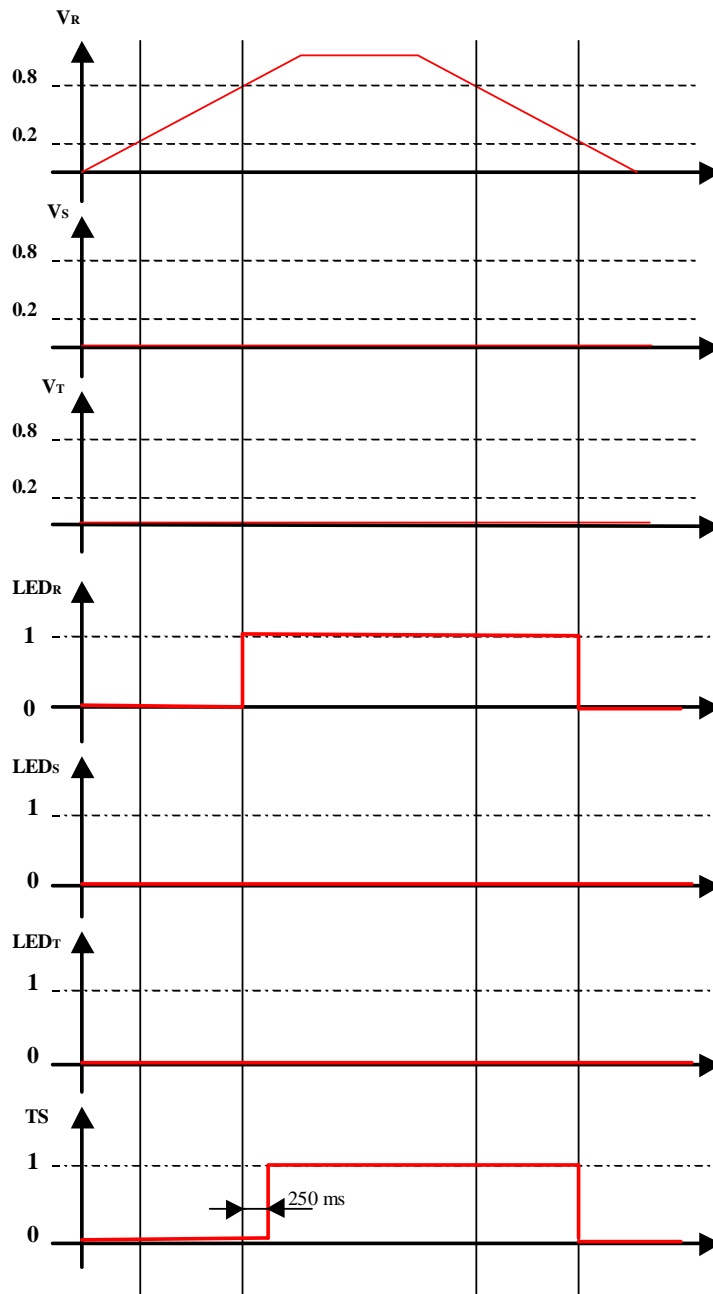


Figure 25 -Example of impulse response.

During a simulation of a re-striking fault RGDAT-A70 shall record the intervention measurement values on a log file.

**APPENDIX 4 SOME EXAMPLES FOR DETECTION OF VOLTAGE PRESENCE/ABSENCE**



**PRESENCE/ABSENCE VOLTAGE MODE**

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## APPENDIX 5 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-A70, 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-A70 that uses two sensors for phase currents and one sensor for residual currents, a second sequence for evaluate the behaviour of RGDAT-A70 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  $\geq 5\text{cm}$  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.

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**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-A70 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.

## APPENDIX 6 CHECKING TESTS FOR CHAPTER 7.6

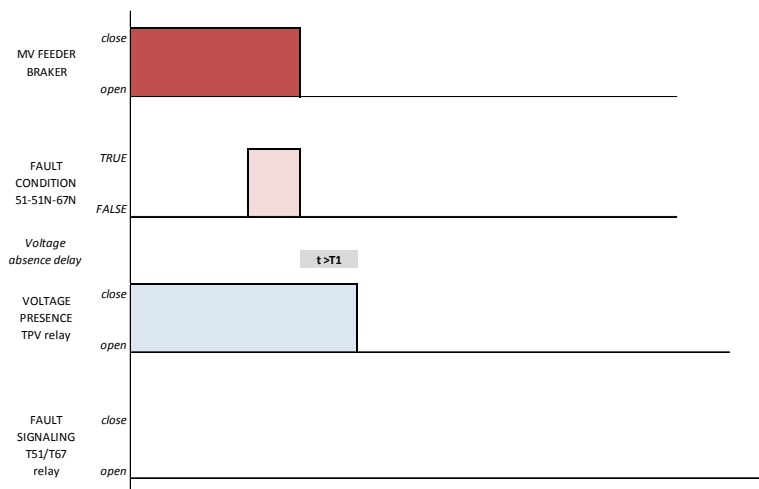


Figure 1 - test 1

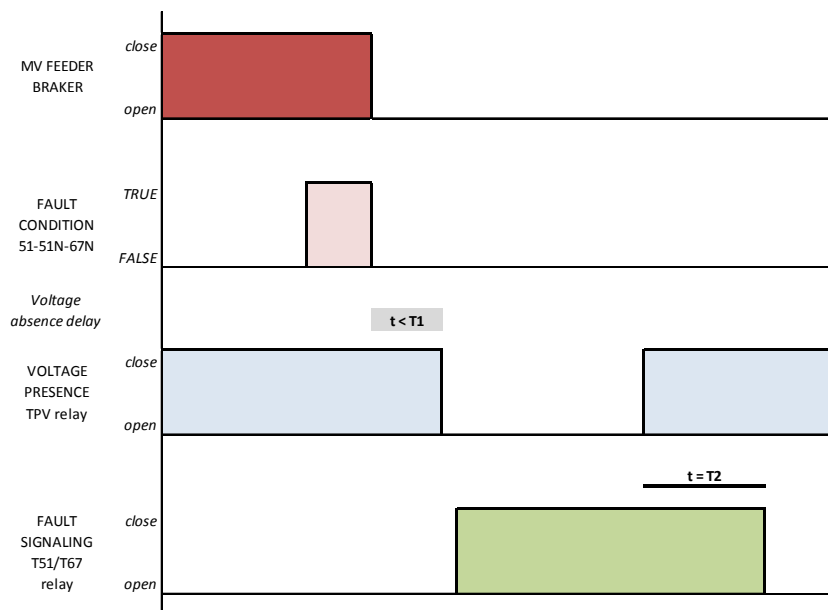
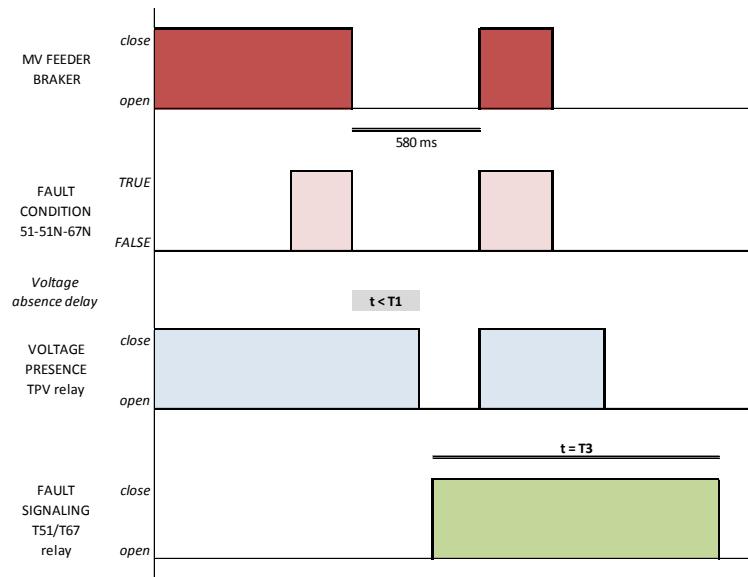
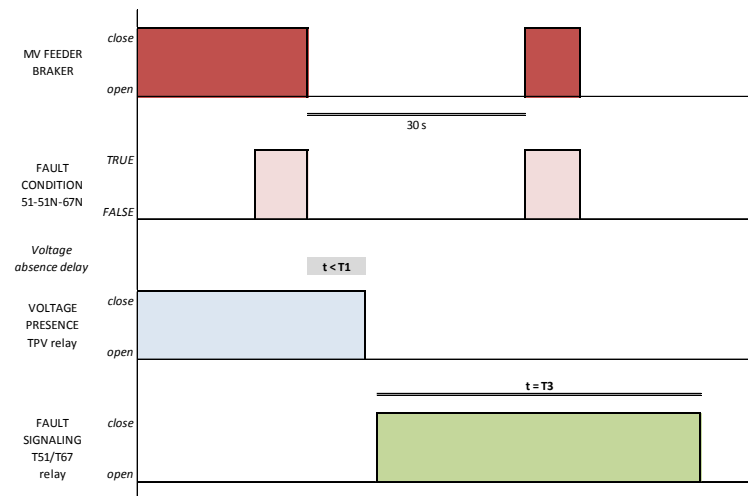


Figure 2 - test 2



**Figure 3 - test 3**



**Figure 4 - test 4**

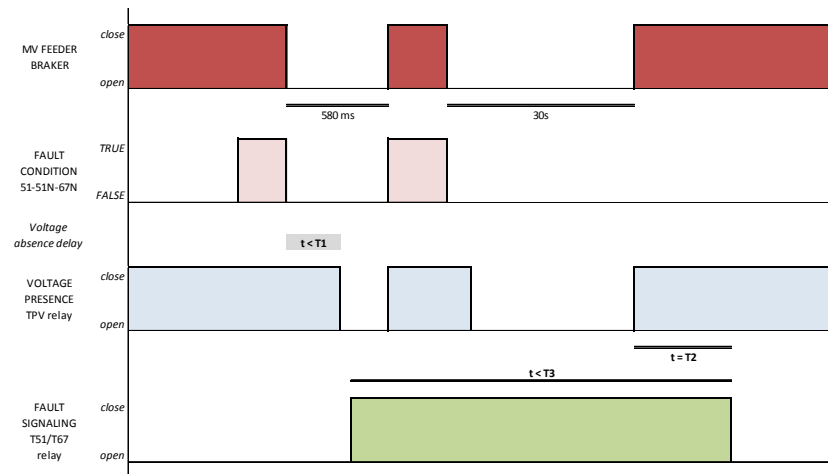


Figure 5 - test 5

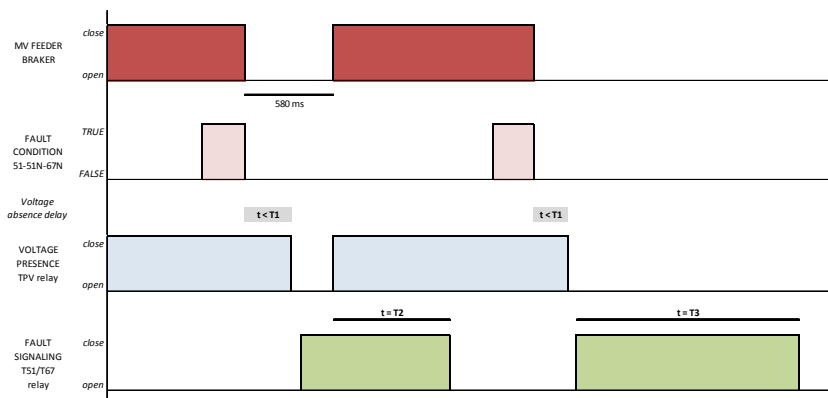


Figure 6 - test 6

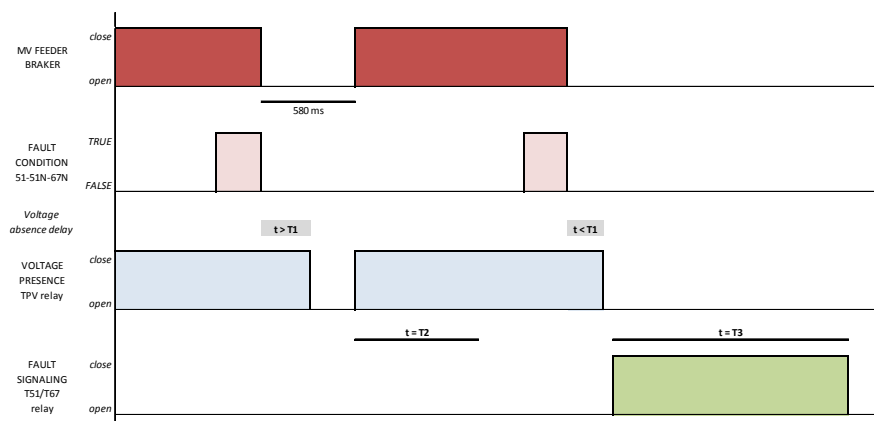


Figure 7 - test 7



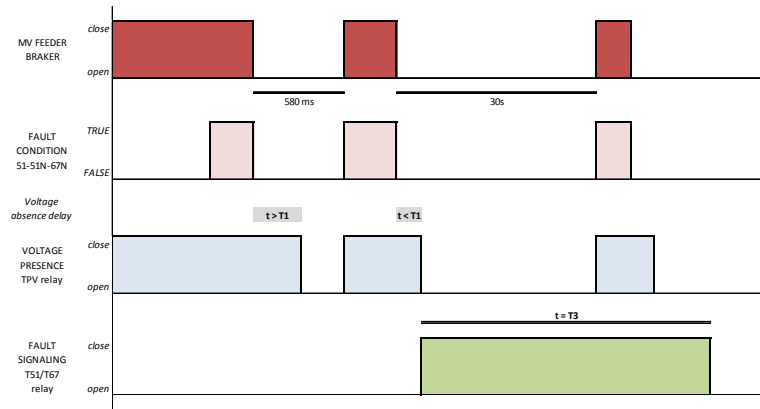


Figure 8 - test 8

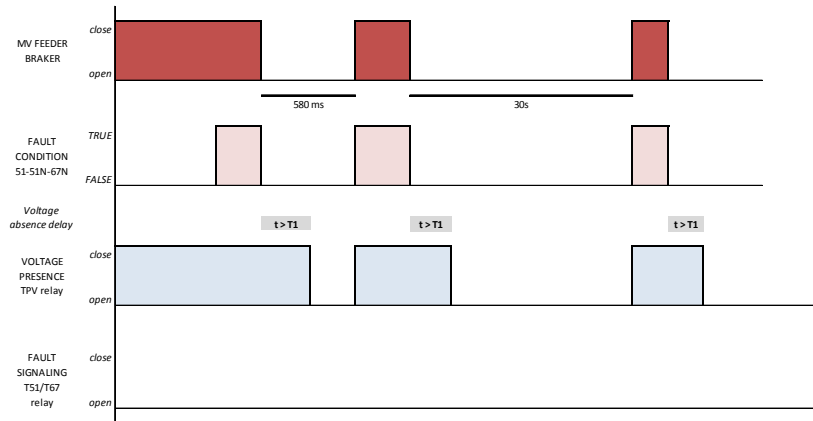


Figure 9 - test 9

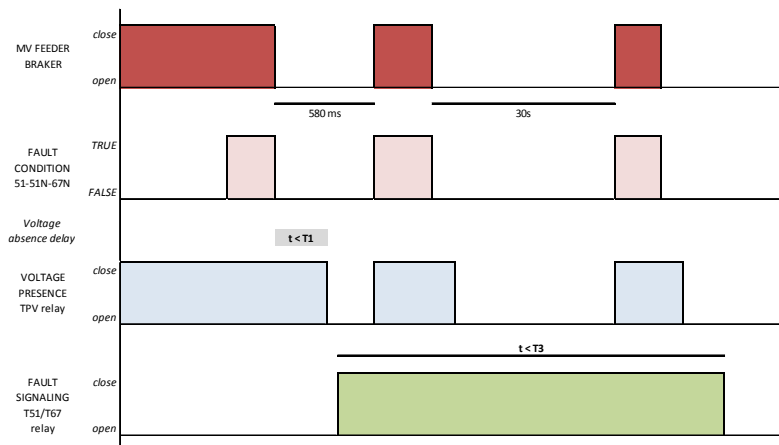


Figure 10 - test 10