

White paper

# Double Ground Fault Protection Implementation



# Double Ground Fault Protection

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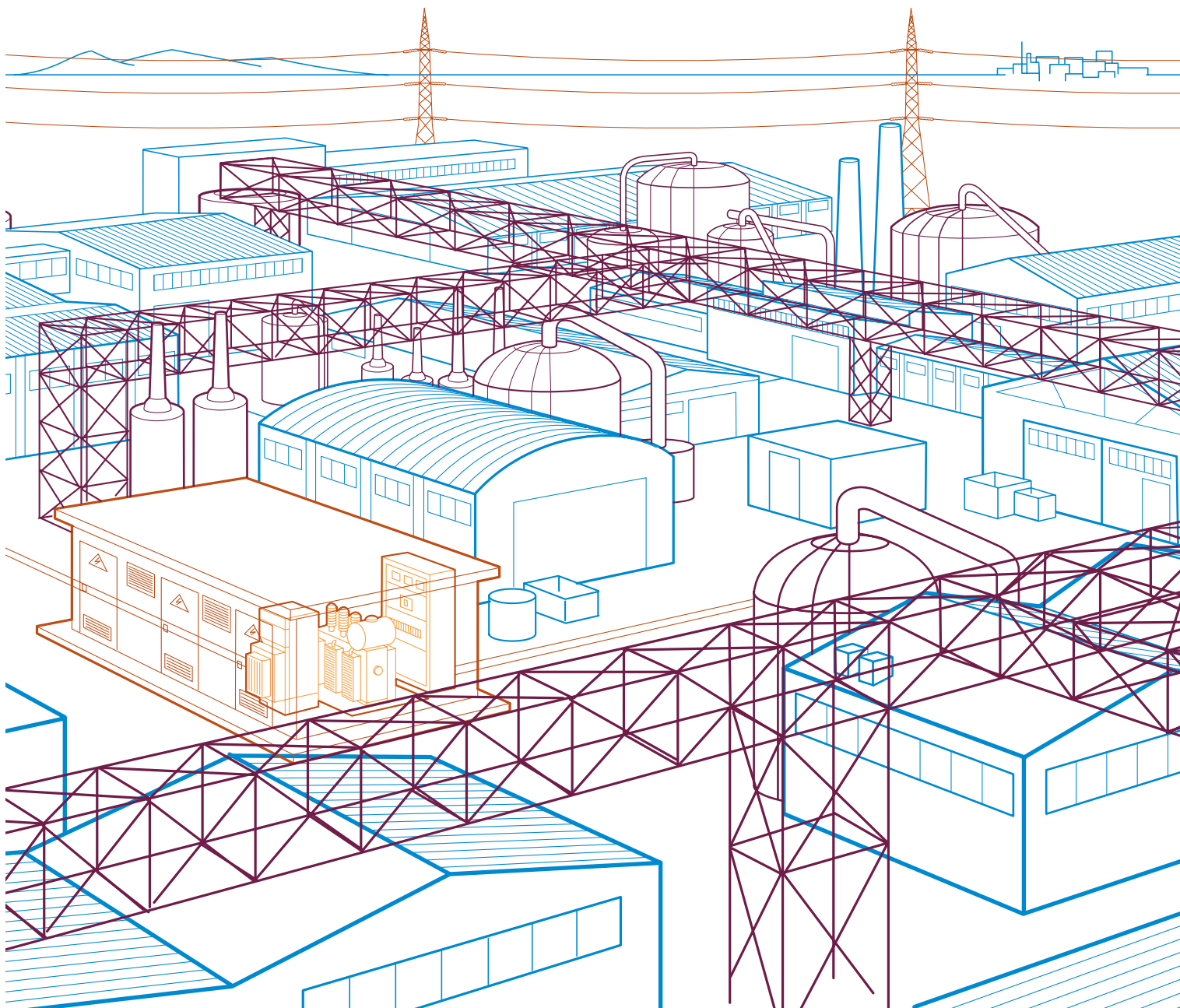
# 1. Generalities

The purpose of this White Paper is to offer the necessary guidelines for the correct implementation of the “Double G” function of ABB SACE low voltage circuit-breakers. With this function it is possible to ensure protection against:

- earth faults downstream the circuit-breaker on the secondary side of the Medium/Low voltage (MV/LV) transformer (unrestricted earth faults or downstream earth faults);
- earth faults between the transformer secondary windings and its cables connected to the circuit-breaker terminals (restricted earth faults or upstream earth faults).

The “Double G” is able to distinguish between each type of fault, restricted and unrestricted, thanks to a chrono-amperometric discrimination and to the MV/LV integration.

It is always available on New Emax circuit-breakers equipped with PR123/P LSIG trip units and on X1 circuit-breakers equipped with PR333/P LSIG trip units. The “Double G” function is easy to install and doesn't require special wiring.



## 2. Application Description

### 2.1 Introduction

The loss of insulation between normally live conductors and exposed-conductive-parts may generate a fault which is generally called earth fault; it represents a danger for electrical systems and for people safety.

Taking as example a typical MV/LV distribution substation, it is possible to identify three different areas where an earth fault could take place and three different kinds of earth protection that can be used:

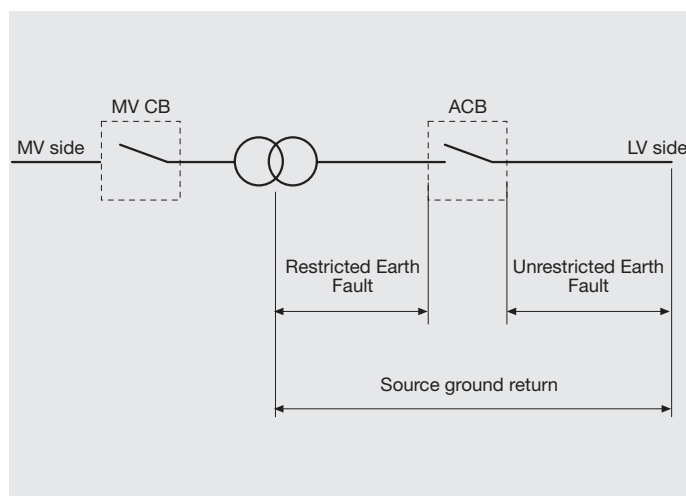


Figure 1

- unrestricted earth fault protection: it is the protection against earth faults on the load side of the air circuit-breaker (ACBs) put on the secondary of the transformer. This protection is obtained by using a circuit-breaker equipped with a trip unit that has earth fault protection G (or with a circuit-breaker equipped with an homopolar toroid for residual current protection or, only in the presence of high ground faults, with the normal phase protections of the circuit-breaker);
- restricted earth fault protection: it is the protection against earth faults in the section between the secondary of the transformer and the upstream terminals of the air circuit-breaker. This earth fault is not easily detectable by protections on the primary of the transformer, because the current value of this fault type is very reduced;
- source ground return: it is the protection against all earth faults either on the load side of the circuit-breaker or from the circuit-breaker terminals to the secondary of the transformer. This protection is obtained by using an external toroid on the conductor connecting the star center of the transformer to earth. In this case the toroid is able to detect all earth faults either on the supply side or on the load side of the circuit-breaker (restricted and unrestricted, but indiscriminately).

With “Double G” function, it is possible to detect and discriminate between restricted and unrestricted faults.

### 2.2 Application solution

Thanks to the PR123/P-LISG and PR333/P-LSIG trip units by ABB SACE and to the external toroid on the conductor connecting the star center of the transformer to earth<sup>1</sup>, the unrestricted and restricted faults are always detectable<sup>2</sup>.

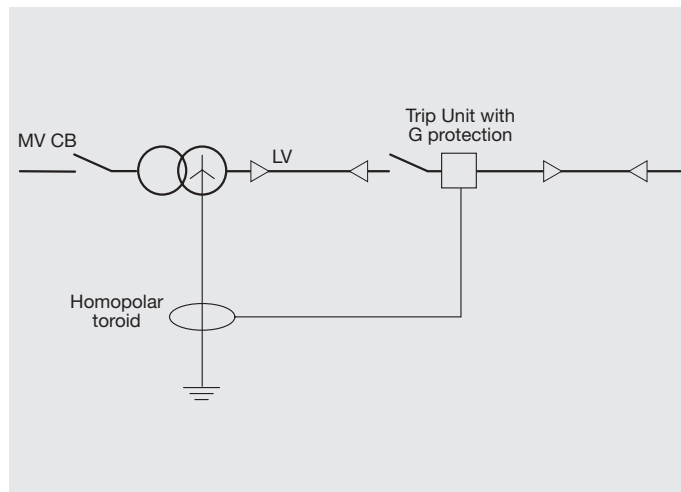


Figure 2

These trip units allow two independent curves for G protection<sup>3</sup>:

- Internal G only for the unrestricted fault (G protection of the trip unit).
- External G for both restricted and unrestricted faults (Gext protection of the trip unit).

This offers the possibility to achieve a chrono-amperometric discrimination between the two G protection functions as shown, for example, in the time-current diagram below (Figure 3). In this way, it is possible to distinguish the restricted and unrestricted faults.

<sup>1</sup> The external homopolar toroid, placed on the conductor connecting the transformer star centre to earth, must be located between the neutral conductor and PE conductor. In this way the currents that flow in the neutral don't pass through the homopolar toroid; on the contrary the currents that flow in the PE conductor are detected by homopolar toroid.

<sup>2</sup> The trip unit is able to measure earth fault currents in a range from 0.05 In to 4 In. The standard operation range is from 0.3 In to 4 In with a tolerance equal to +/- 1.5%.

<sup>3</sup> With PR122/P-LSIG or PR332/P-LSIG it is possible to set only either internal G protection (activated by ACB's current sensors) or external G protection (with the external homopolar toroid). In this case, by using Gext protection, it is not possible to distinguish between restricted earth fault and unrestricted earth fault.

## 2. Application Description

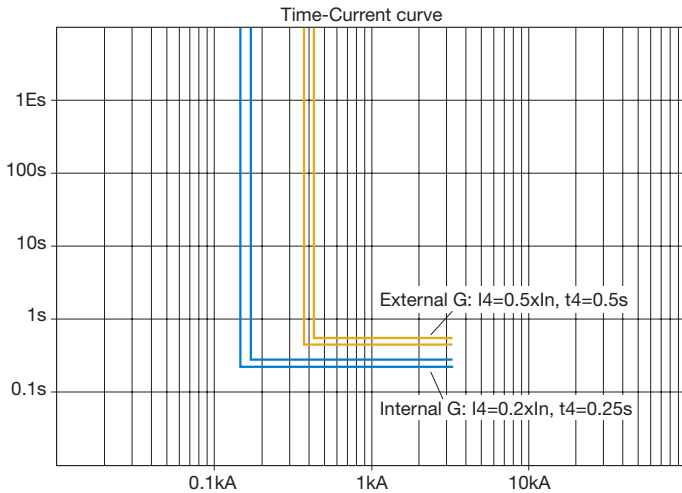


Figure 3 – Possible curves of the External and Internal G protections.

The settings of G and Gext protections must guarantee the discrimination: the Gext curve has always to be set at a higher value than G curve.

Now, let's suppose that a restricted fault - upstream fault - occurs in the plant.

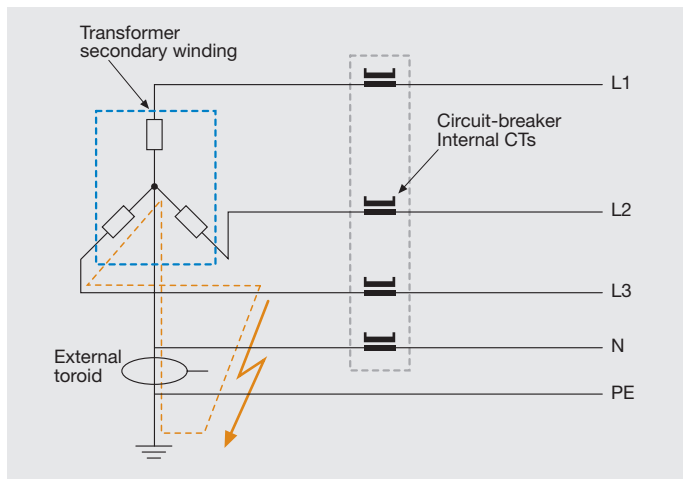


Figure 4

Firstly the Gext protection is activated and, after the Gext protection timing, the low voltage circuit-breaker can open: in fact, in the trip unit, it is possible to select if the breaker must open or remain closed after Gext protection timing; hence

only the case in which the trip unit is programmed to allow the opening is taken into consideration.

This possible trip cannot guarantee the complete plant protection because the fault occurs between the secondary of the transformer and the circuit-breaker terminals.

In order to guarantee the complete protection of the plant, it is necessary to involve the protection device installed on the primary, that is the medium voltage circuit-breaker – MVCB.

Once the fault has been detected, the trip unit can make available an output signal to the MV circuit-breaker. The MV circuit-breaker detects the signal and commands the opening of the breaker ensuring the complete protection of the plant.

Let's suppose that an unrestricted fault - downstream fault - occurs in the plant:

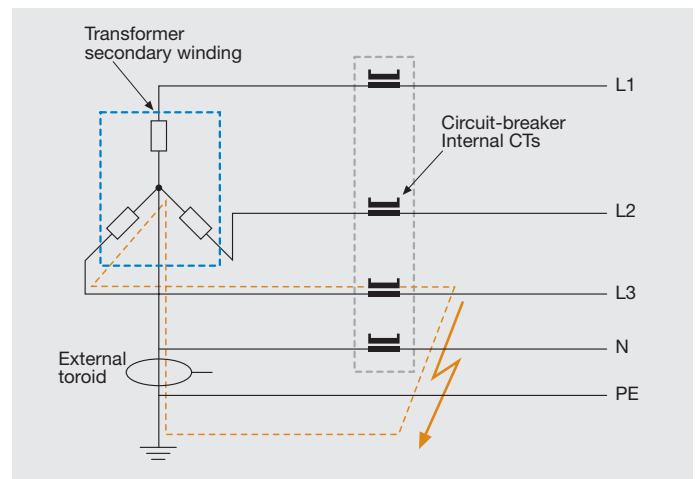


Figure 5

Both G, external and internal, are activated and go into the “timing” phase. By opposite current and time settings of both protections (Internal G and External G), the low voltage circuit-breaker trips thanks to the internal G protection, assuring fault extinction and avoiding unnecessary opening of MV circuit breaker.

Therefore, thanks to the time-current discrimination between the two G protection functions, before the MV breaker receives the opening command, the low voltage breaker is able to trip and eliminate the unrestricted earth fault.

# 3. References

## 3.1 Application example

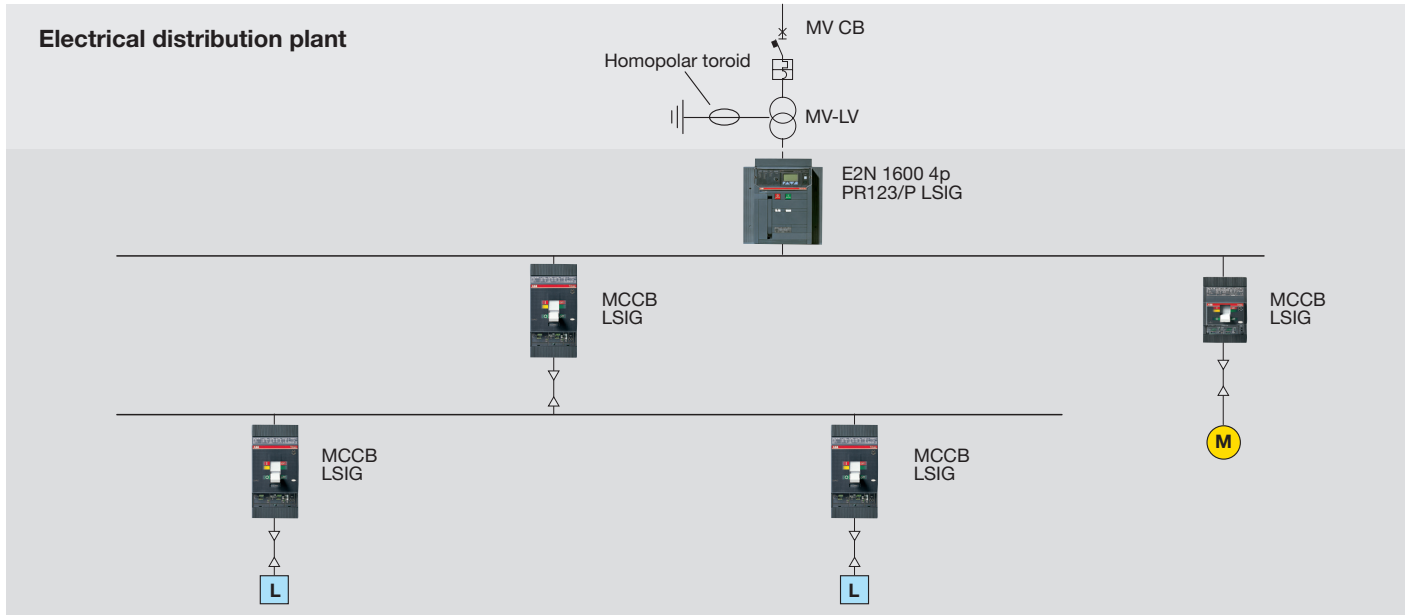


Figure 6 – Electrical distribution plant

Consider an electrical distribution plant composed by:

- a MV circuit-breaker;
- a MV-LV transformer;
- an incoming LV air circuit-breaker as an E2N 1600 4p equipped with PR123/P LSIG trip unit (or X1N 1600 4P equipped with PR333/P LSIG);
- several supply-side circuit-breakers as MCCBs, equipped with G (or Rc residual current) protection;

In order to guarantee the protection of the plant, “Double G” implementation requires:

- to apply a homopolar toroid connected to the star center of the transformer to earth<sup>1</sup>;
- to apply and set the signalling module as PR120/K, PR021/K or LD030 DO in order to make available one contact to command the opening of the MV circuit-breaker. This contact must be programmed so that the contact, normally open, shall close when the trip unit of the LV circuit-breaker detects the fault thanks to the external G protection. The circuit diagrams below show the contacts available in the PR120/K (Figure 7-8), PR021/K (Figure 9) and LD030 DO (Figure 10) signalling units;

<sup>1</sup> The external homopolar toroid, placed on the conductor connecting the transformer star centre to earth, must be located between the neutral conductor and PE conductor. In this way the currents that flow in the neutral don't pass through the homopolar toroid; on the contrary the currents that flow in the PE conductor are detected by homopolar toroid.

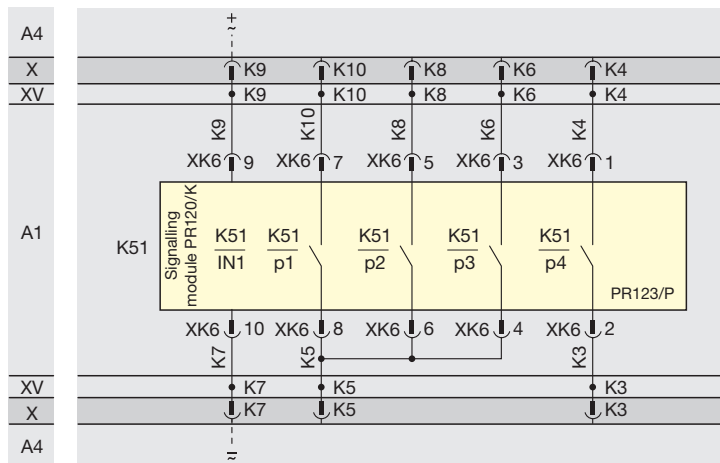


Figure 7 – PR120/K (4 Outputs + 1 Input with common terminal)

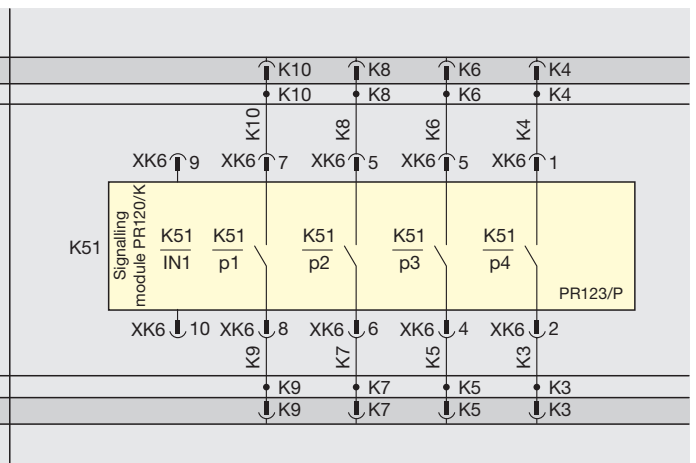


Figure 8 – PR120/K (4 Outputs with independent terminals)

### 3. References

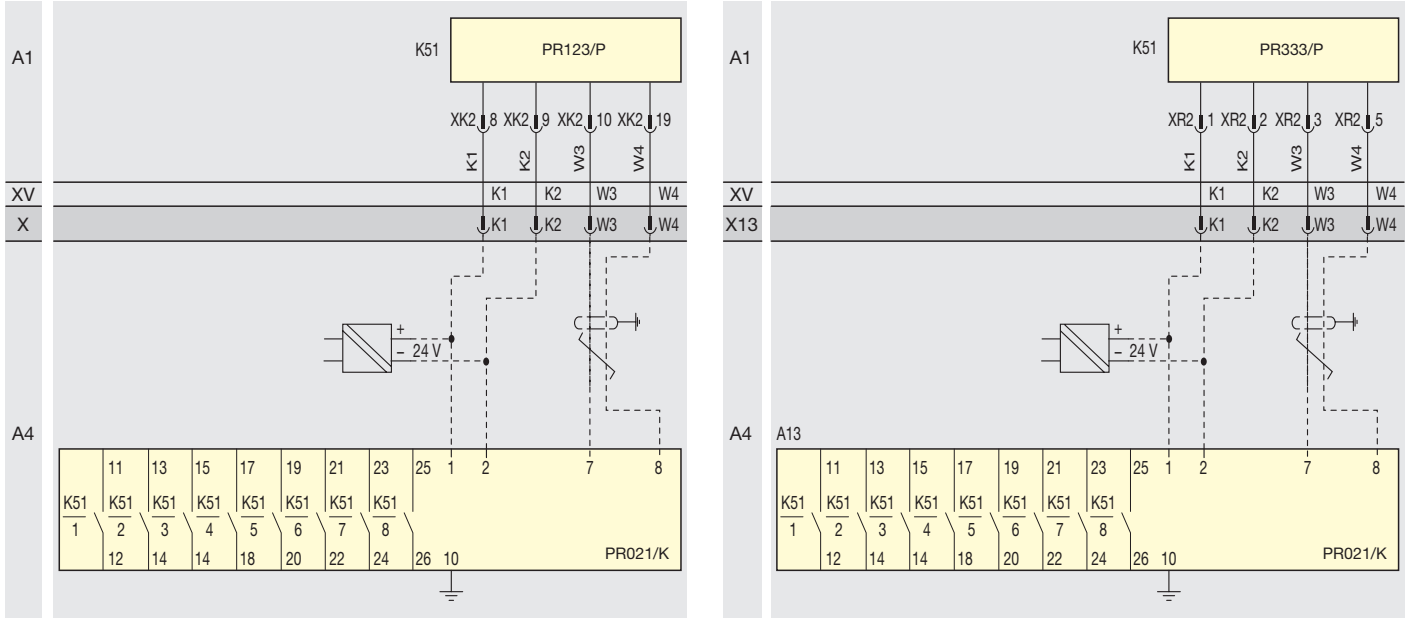


Figure 9 – PR021/K signalling unit

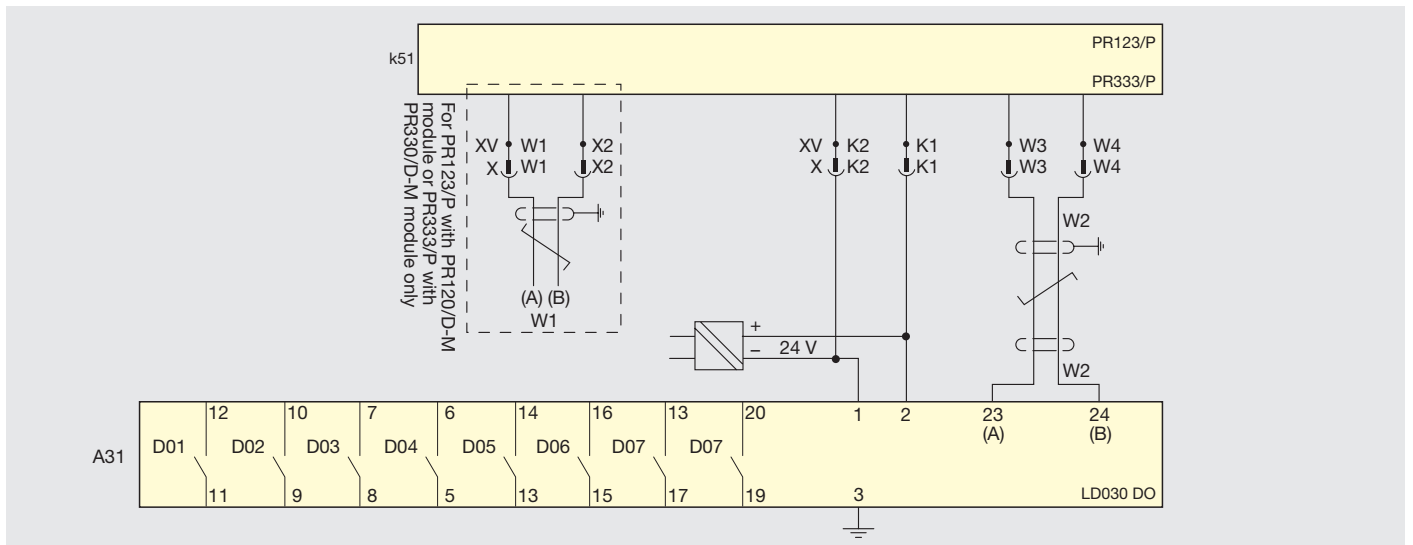


Figure 10 – LD030 DO

PR120/K – PR021/K contact	Monostable STDP
Maximum switching power (resistive load)	100W / 1250 VA
Maximum switching voltage	130 V DC / 250 V AC
Maximum switching current	5 A
Breaking capacity (resistive load)	@ 30V DC 3.3 A
	@ 250V AC 5 A
Contact/coil insulation	2000V r.m.s. (1min@50Hz)

LD030 DO contact	Monostable SPDT
Maximum switching power (resistive load)	150W, 2000VA
Maximum switching voltage	30V DC, 250V AC
Breaking capacity (resistive load)	@ 30V DC 5 A
	@ 250V AC 8 A

- and finally, to make the interlocking cabling between the signalling unit and the shunt opening release of the medium voltage circuit-breaker. For example, when the K51/P1 contact (PR120K) closes, the medium voltage shunt opening release receive the signal and command the opening of the MV circuit-breaker (Figure 11).

For more detailed information about the way to interlock the medium and low voltage side, please consult the White Paper “Integration between the MV protection and control unit REF 542 and LV protection trip unit PR123: selectivity and earth fault”.



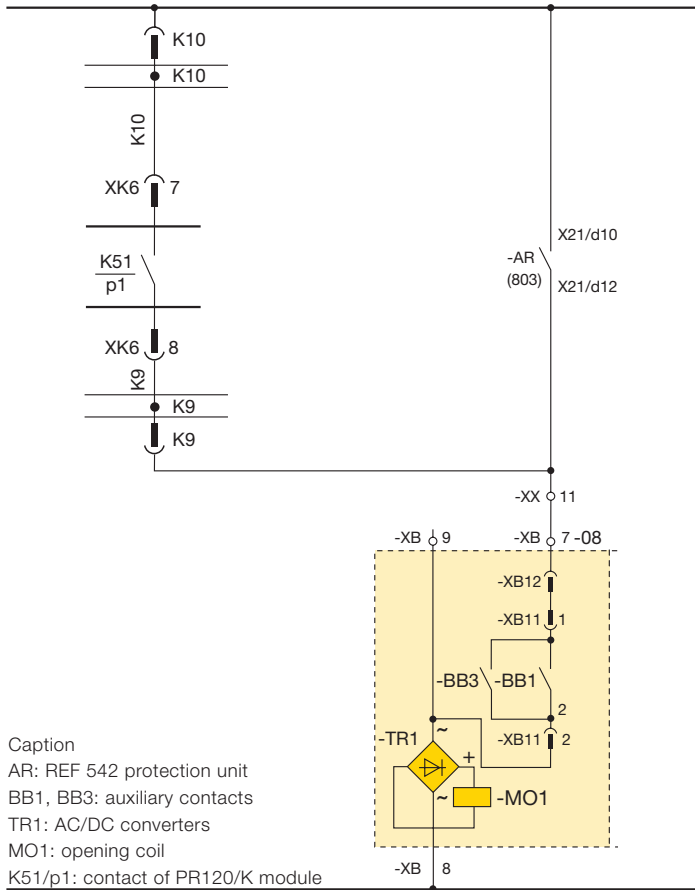


Figure 11  
 Caption  
 AR: REF 542 protection unit  
 BB1, BB3: auxiliary contacts  
 TR1: AC/DC converters  
 MO1: opening coil  
 K51/p1: contact of PR120/K module

Figure 11

Three different scenarios might occur in the electrical plant:

**Case 1 - Restricted fault:** in case of earth fault occurring in the installation area comprised between the MV-LV TRAFO and the incoming ACB, the MV circuit-breaker must trip.

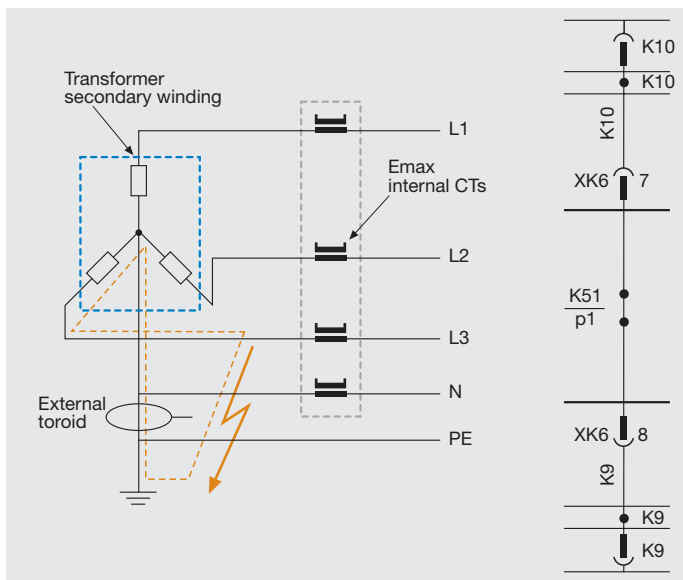


Figure 12 – Restricted fault

Restricted fault is only detected by the homopolar toroid; the LV circuit-breaker could open due to the “Gext” protection and the contact switches from the open to the closed condition.

It follows that:

- the MV CB opens, since it is activated by the contact;
- the LV CB opens. As already described above, the trip unit is enabled to open the LV circuit-breaker because of Gext protection. In the most common plants, the LV circuit-breaker must to open when the MV circuit breaker trips due to the Gext protection.

**Case 2 - Unrestricted fault:** in case of earth fault occurring in the installation area downstream the air circuit-breaker ACB, the incoming air circuit-breaker trips due to the internal G protection.

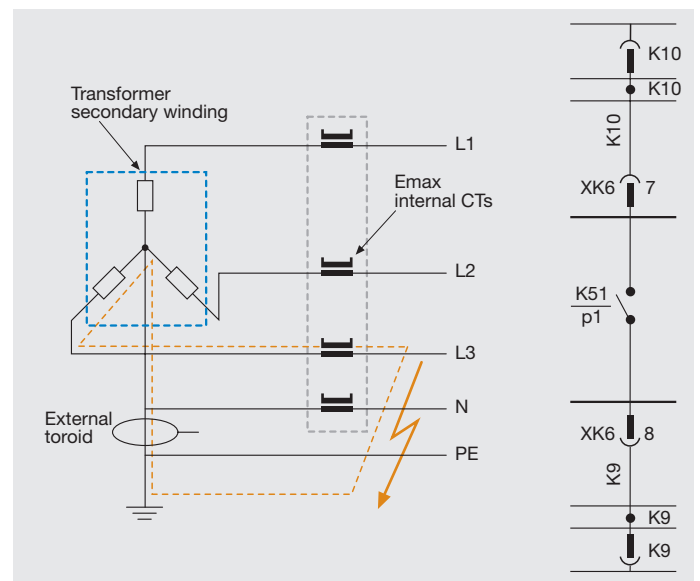


Figure 13 – Unrestricted fault

Unrestricted fault is detected by both the homopolar toroid and by the internal G, but, because of the settings, internal G protection is faster than external G protection (Gext). The contact remains open because the protection “Gext” goes into protection timing but the fault is extinguished before the protection timing phase ends.

It follows that:

- the LV ACB opens because of internal G protection trip;
- the MV CB does not open, since it is not activated by the contact.

### 3. References

**Case 3:** In case of an earth fault occurring in the installation area downstream the MCCB load side, only the moulded-case circuit-breaker trips due to G, Rc, L, S, I protection activation.

Unrestricted fault is detected by the homopolar toroid, by the internal G of the ACB and by the internal G (or Rc) of the MCCB. By appropriate settings, the internal G (or Rc) protection of the MCCB should be faster than the internal G protection and the external G protection of the ACB.

It follows that:

- the G (or Rc) protection of the downstream MCCB is activated to extinguish the earth fault;
- the LV ACB does not open;
- the MVCB does not open, because it is not activated by the contact.

If the MCCB has not G (or Rc) protection, it must open before the LV ACB due to selectivity. In this case the time to extinguish the earth fault depends on the earth fault intensity.

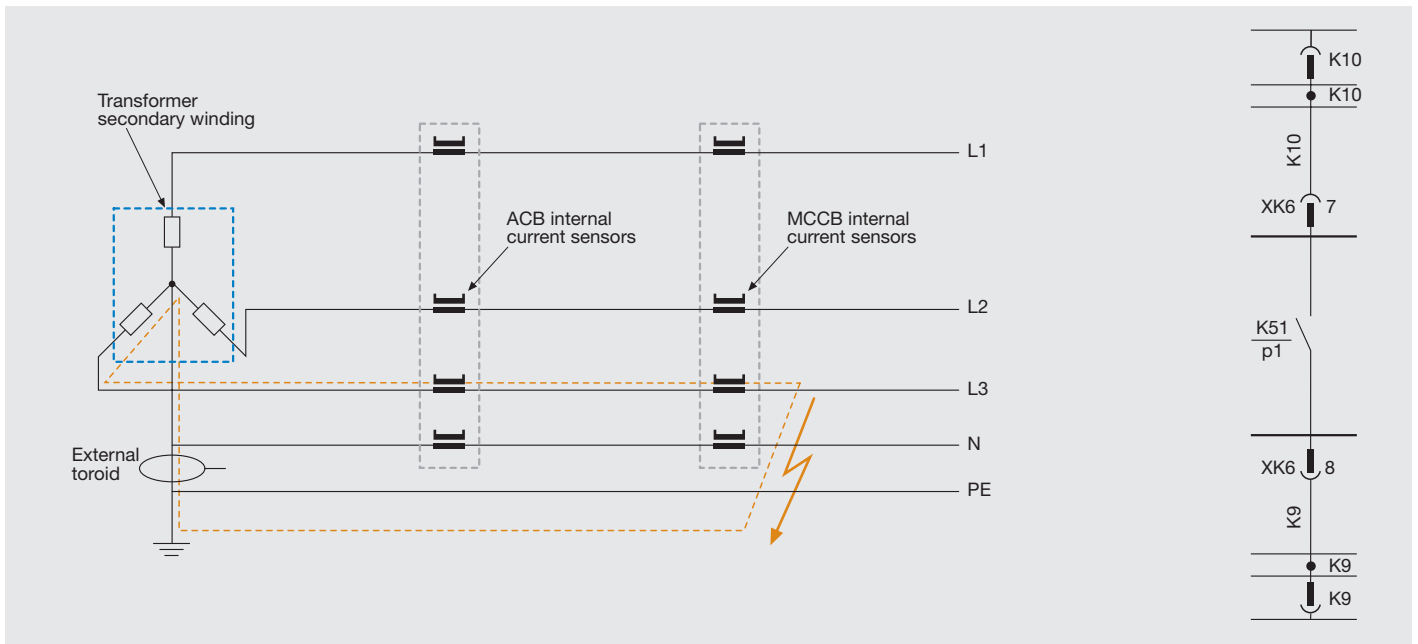


Figure 14 – Earth fault downstream the MCCB

## 4. Practical Guide

### 4.1 Shopping list section

As already shown in the previous paragraphs, the “Double G” needs specific equipment:

1. the new Emax with PR123/P-LSIG trip unit or Emax X1 with PR333/P-LSIG trip unit;
2. the homopolar toroid for the main power supply grounding conductor;
3. the signalling module: PR120/K only for New Emax circuit-breakers. Otherwise it is possible to use the PR021/K or LD030 DO with a separate 24VDC auxiliary power supply. If you have a low voltage air circuit-breaker Emax X1, the PR021/K or LD030 DO are always needed because the PR120/K is not available.

As regards the PR120/K, PR021/K and LD030 DO signalling units, it is possible to set them by:

- programming Free-Software SD-TestBus2 or SD-Pocket that can be downloaded (free) from the “Business On Line” website – <http://bol.it.abb.com>;
- the configuration Test Unit PR010/T.

When choosing SD-TestBus2 or SD-Pocket, a communication network is needed and one of these components may be chosen:

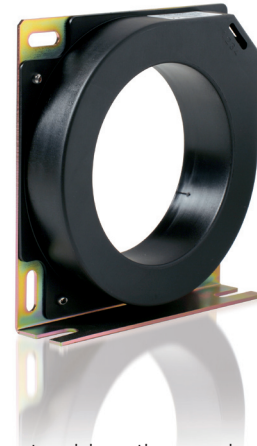
- communication module PR120/D-M (Modbus RTU) for New Emax or PR330/D-M for Emax X1;
- internal wireless communication module PR120/B-T;
- external wireless/usb communication module BT030.

### 4.2 Testing field section

In this section it is shown how to set each device in order to make available the “Double G” function. The customer has to follow three easy steps:

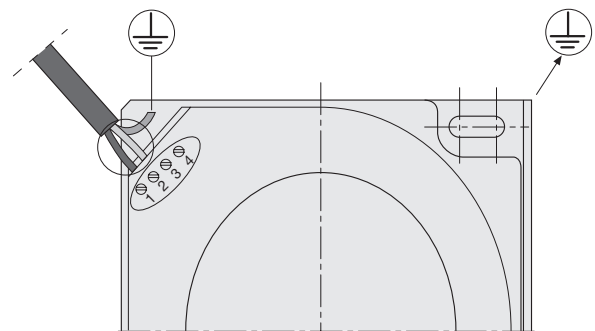
1. external homopolar toroid installation and settings;
2. setting of signalling module PR120/K, PR021/K and LD030 DO;
3. trip unit protection settings.

### 1. External homopolar toroid installation and settings



Apply the homopolar toroid on the conductor connecting the star centre of the transformer to earth and connect it to the terminal box or to the fixed part sliding contacts. The external toroid must be connected to the trip unit by means of a cord shielded two-wire cable with length not exceeding 15 m. The shield must be earthed both on the circuit-breaker side as well as on the toroid side. More details are available in the instruction sheet and are summarized below:

- cable and set the external homopolar toroid according to the rated service current range. For example, in order to obtain a current range<sup>3</sup> of 400/800A, choose clamps 1 and 3;



Homopolar Toroid clamp	Terminal Box on CB	In range
1	T7	
2	T8	100 / 250A
3	T8	400 / 800 A
4	-	

Figure 15 – External homopolar toroid

- connect the cables to the terminal box of the breakers into the opposite contacts T7-T8. In the pictures below, the example of the terminal box for Emax fixed version.

<sup>3</sup>The accurate current value of the homopolar toroid is set through the trip unit settings.

## 4. Practical Guide

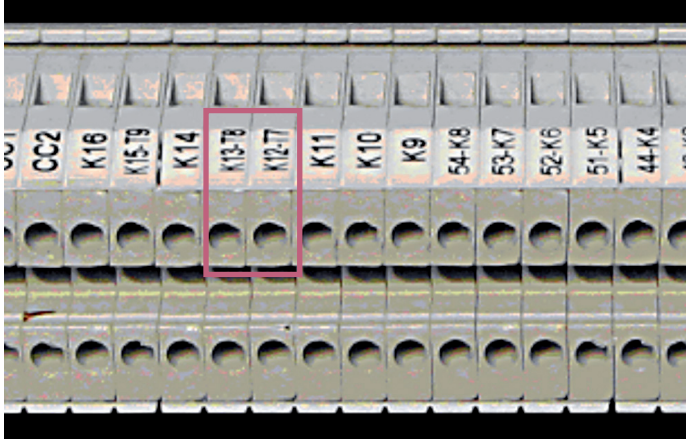


Figure 16 – Emax terminal box – fixed version

In order to set the external toroid (and consequently Gext), from the Main Menu of PR123/P or PR333/P trip units:

1. choose “Settings”
2. select “Circuit Breaker”
3. select “Ground Protection”
4. select “External Toroid”
5. enter the trip unit password
6. select “Source Ground Return”
7. select “Toroid size”. Four thresholds are available: 100A, 250A, 400A and 800A
8. press “ESC” until you get the confirmation message
9. press “Confirm”. The settings are updated.

### 2. Setting of the signalling module PR120/K, PR021/K and LD030 DO

To regulate the programmable contacts of PR120/K or PR021/K, it is necessary to use one of the following external devices:

- SD-TestBus2
- SD-Pocket
- PR010/T

### SD-TestBus2

In the presence of PR120/D-M for New Emax or PR330/D-M for Emax X1, follow these instructions:

1. choose “settings” from “MENU” page of PR123/P (or PR333/P)
2. select “Modules”
3. select “COM Module”
4. select “Local/Remote”
5. after password input, select “Remote”
6. write down the “Serial Address” and “Baudrate”
7. start SD -Testbus2 software in your PC
8. in the “Bus” menu, select “Scan”
9. select “EvenParity”
10. select “Serial Address” and “Baudrate” from PR123/P (or PR333/P) menu.

In the presence of PR120/D-BT or BT030/USB (wireless mode):

1. start SD -Testbus2 tool
2. in the “Bus” menu, select “Bluetooth”
3. select your PR123/P (or PR333/P).

Once the connection is available, it is possible to set the signalling unit PR120/K (or PR021/K or LD030 DO):

1. in the browse menu of the SD-TestBus2 that appears on the left, select “PR120/K configuration” (or “PR021/K configuration”)<sup>1</sup>,
2. in the “P1 contact” area, as shown in the figure below, (or “K51/1 contact” for PR021/K), press “Custom” in the “Function field”,
3. move to “Byte Offset #8”

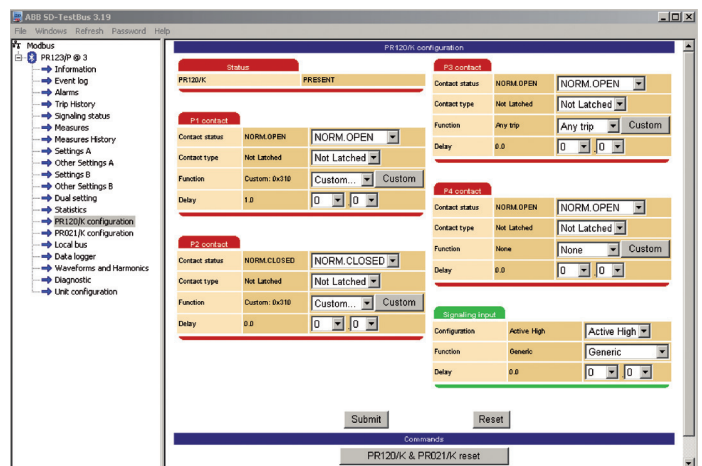
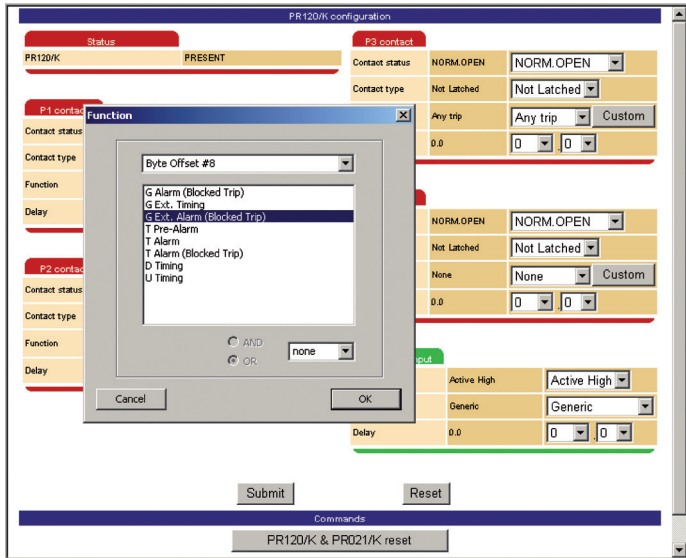


Figure – 17

<sup>1</sup> In SD-TestBus2, in order to set the LD030 DO, use the PR021/K page configuration.



4. select "Gext alarm (blocked trip)"
5. set this contact to "NO" (normally open)
6. press "Submit"

It is also possible to choose:

- contact "Latched" or "Not latched". Contact "latched" is activated when the associated event happens; they are reset only by the reset of the circuit-breaker or of trip unit;
- it is possible to set a delay time, i.e. a time shift respect to the event that changes the normal status of the contact.

### SD-Pocket

1. Start SD-pocket tool
2. Log-in as Administrator
3. Select the device PR123/P or PR333/P (on the trip unit a device type PR120/D-BT or BT030 must be installed)
4. Press "Connect", press "Enter"
5. In the toolbar, select "Menu" ⇔ select "PR120/K configuration" (or PR021/K or LD030 DO configuration)
6. In Function, select "Custom"
7. Move to "Byte Offset #8"
8. Select "Gext alarm (blocked trip)"
9. Set this contact to "NO" (normally open)
10. In order to accept the configuration, press "SET"
11. "Yes" to save.

It is also possible to choose:

- contact "Latched" or "Not latched";
- it is possible to set a delay time, i.e. a time delay respect to the event that changes the normal status of the contact.

### PR010/T

A) Instruction to set PR120/K Signalling module

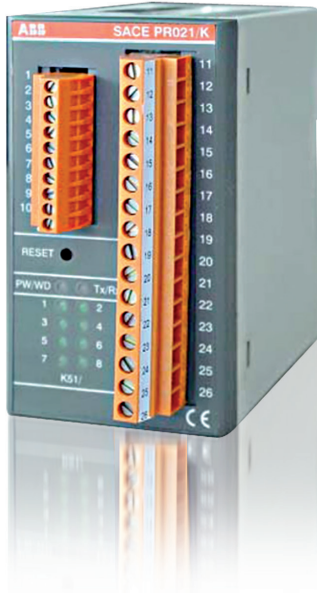


Connect the PR010/T to the trip unit:

1. select "Operation mode" and press "Enter"
2. select DUT "PR123" for New Emax CB or "PR333" for X1 and press "Enter"
3. select "4. Config/Param" and press "Enter"
4. choose "1. Configurations" and press "Enter"
5. select "9. Modules" and press "Enter"
6. select "3. Signalling" and press "Enter"
7. select "1. Relay 1" and press "Enter"
8. select "1. Signal source" and press "Enter"
9. insert Password (if required) and then press "Enter"
10. select, by ⇐ ⇒ , the signal source "Custom" and press "Enter"
11. move, by ⇕, to "Alarm 2 1...3"
12. set the blinking cursor to "Gext alarm", scroll ⇕ and select "Gext alarm", press ⇐ ⇒ and press "Enter".
13. enter in "Configuration", select NO (Normally Open).
14. press "Esc" until you have the possibility to save the configuration
15. save Configuration.

## 4. Practical Guide

B) Instruction to set PR021/K and LD030 DO signalling modules.



The signalling unit must be connected to the trip unit. Connect PR010/T to the trip unit and repeat the steps from 1 to 4 of the PR120/K setting, and afterwards:

1. select "10. Local Bus Unit" and press "Enter"
2. select "2. Relay 1" and press "Enter"

Follow the instructions of PR120/K from the 8th step.

It is also possible to choose:

- contact "Latched" or "Not latched".
- it is possible to set a delay time, i.e. a time delay with respect to the event that changes the normal status of the contact.

### 3. Trip unit protection settings

The parameters of internal G protection and external G protection (Gext) have to be set in order to guarantee a chrono-ampereometric discrimination between the two curves: protection Gext settings must have both trip thresholds and trip time parameters higher than those set for protection G.



Please note:

- the rated service current ( $I_n$ ) for G protection is the rated service current of the circuit-breaker, while the rated service current for function G ext is the rated service current of the toroid (100A, 250A, 400A or 800A);
- a minimum 20% difference between the current parameters of the two thresholds is needed;
- as regards the trip times, a difference of 100 ms between the two parameters is needed;
- the trip unit is able to measure earth fault currents in a range from  $0.05 I_n$  to  $4 I_n$ . The standard operation range is from  $0.3 I_n$  to  $4 I_n$  with a tolerance equal to  $\pm 1,5\%$ .

For example, a possible configuration for a New Emax E1N800 PR123  $I_n$  800A and a toroid with  $I_n$  equal to 800 A, is the following one:

G protection	Trip threshold $I_4 = 0.2 \times I_n = 160A$	Trip Time $t = 0.25s$	$t=k$
Gext protection	Trip threshold $I_4 = 0.5 \times I_n = 400A$	Trip Time $t = 0.5s$	$t=k$

In order to avoid the opening of the low voltage circuit-breaker after the Gext protection trip, in case of restricted earth fault, follow these instructions:

1. select "Protection" in the Main Menu of the trip unit
2. select "Gext Protection"
3. press "Enable" and enter the password
4. select "On"
5. select "Trip Enable"
6. select "OFF"
7. press "Esc" and confirm the changes.

## 5. Bibliography

Distribution system and protection against indirect contact and earth fault (1SDC007102G0201)

New Emax Technical Catalogue (1SDC200006D0205)

Emax X1 Technical Catalogue (1SDC200009D0203)

New Emax Installation and Service Instructions (1SDH000460R0002)

Operating instructions for T7-T8-X1 low voltage air circuit-breaker protection releases (1SDH000587R0002)

Instruction sheet for homopolar toroid for the main power supply grounding conductor (star center of the transformer) (1SDH000460R0507)

Instructions sheet for PR120/K, PR120/D-M (1SDH000460R0509)

Instructions sheet for PR333 X1 microprocessor-based electronic release and module (1SDH000529R0504)

Instructions sheet for PR021/K (1SDH000559R0002)

White Paper "Integration between the MV protection and control unit REF 542 and LV protection trip unit PR123: selectivity and earth fault" (1SDC007402G0201)

Signalling unit LD030 DO (1SDH000671R0001).





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