White paper

Directional protection and directional zone selectivity

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1. Introduction

White paper
Directional protection and directional
zone selectivity

1. Generalities

This White Paper describes the sense, the potentials and the use of directional protection and directional zone selectivity functions, hereafter called "D" and "SdZ D" respectively.

1.1 Directional Protection: different trip times according to the direction of the fault

> **Directional Protection is a PR123/P and PR333/P advanced function**

> **Directional Protection is useful in all those cases when there is more than one power supply source**

> **Directional Protection doesn't need either auxiliary power supply or a specific own cabling**

The PR123/P and the PR333/P units carry out excludable directional protection ("D") against short-circuit with adjustable fixed time active both with self-powering and with auxiliary supply. This protection functionality is very similar to protection "S" with fixed time, with the capacity to recognize the current direction during the fault period as well.

The "D" makes it possible to determine whether the fault is on the supply side or load side of the circuit-breaker, and then to obtain selectivity ("directional time selectivity", see *Application Paper QT1, "Low voltage selectivity with ABB circuit breakers"*).
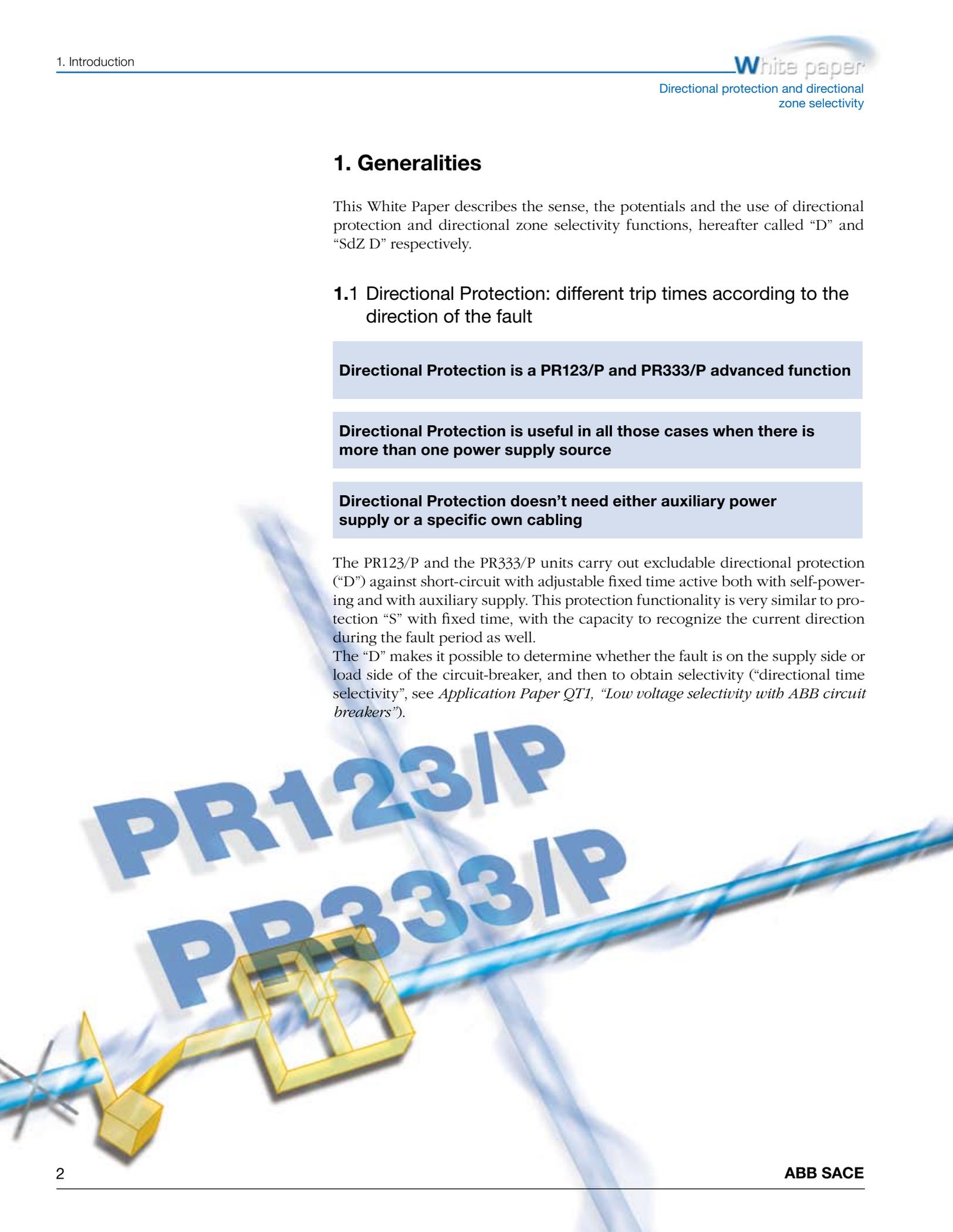
In order to use D function, you have to set a reference direction for the current. Then it is possible to set two different trip times on the relay:
- a time (t7FW) in a direction concordant with the reference direction set;
- a time (t7BW) in a direction discordant with the reference direction set.
These times are enabled when the only current threshold (I7) set on the relay is exceeded.

1.2 Directional Zone Selectivity: the combination of Zone Selectivity and Directional Protection

Directional Zone Selectivity is a PR123/P and PR333/P advanced function

By means of Directional Zone Selectivity can be obtained selectivity in mesh and ring networks

Implementing the Directional Zone Selectivity is simple: you don't need special external devices

SdZ D function is useful in ring and grid type systems where, in additional to the zone, it's essential to define the direction of the power flow that supplies the fault.
This function is available exclusively on PR123/P and PR333/P relays, and it can be only set to "on" when zone selectivity S and G are set to off and there is an auxiliary power supply (at 24 V DC).

To define the zone and the power flow, each relay has two inputs (DFin and DBin: i. e. Directional Forward in and Directional Backward in) and two outputs (DFout and DBout: i. e. Directional Forward out and Directional Backward out), that must be suitably connected to the other relays.
Each output is a "block" signal. The breaker that receives the signal will open within the backward or forward time prescribed; the breaker that doesn't receive a block signal will open within a set time t7s.
Thus the relays will behave in two different ways, depending on the direction of the power flowing across them.

2. Application Description

2.1 Theoretical introduction

The definition of selectivity is given by the IEC 60947-1 Standard "Low voltage equipment – Part 1: General rules for low voltage equipment".
"Trip selectivity (for overcurrent) (441-17-15)
Coordination between the operating characteristics of two or more overcurrent protection devices, so that when an overcurrent within established limits occurs, the device destinated to operate within those limits trips whereas the others do not trip".
Selection of the protection system of the electrical installation is fundamental both to guarantee correct economical and functional service of the whole installation and to reduce to a minimum the problems caused by abnormal service conditions or actual faults.
Particularly, a good protection system must be able to:
- sense what has happened and where, discriminating between abnormal but tolerable situations and fault situations within its zone of competence, avoiding unwanted trips (mal-trips) that cause unjustified stoppage of an undamaged part of the installation.
- act as rapidly as possible to limit the damage (destruction, accelerated ageing, etc...) safeguarding power supply continuity and stability.

2.2 An outline of D
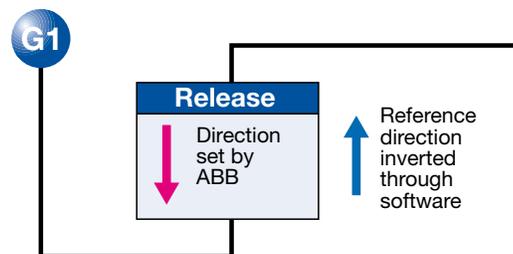
There is a power flow reference direction set by default on the circuit-breaker, indicated by a red arrow. If it is necessary, it is possible to invert the reference direction through the software of the relay. Working in this way all the values measured with the PR123 and PR333 trip units will be assessed as they actually flow in the installation.
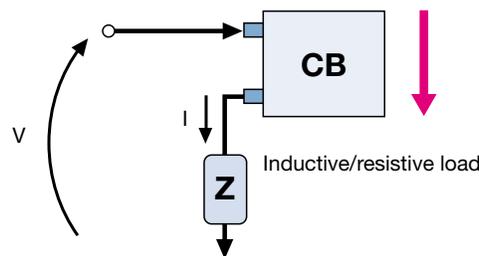
Once the power flow reference direction has been chosen, the flow of the positive reactive power towards the load (refer to the picture above) is the defined "forward" direction; on the contrary, the flow of the negative reactive power towards the load is the defined "backward direction". In this manner, because of the bond between reactive power and current, the forward and the backward directions are defined also for the currents.

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With the D activated, if the direction of the power cannot be established, the
relay takes effect considering shorter of the programmed times between t7Fw
and t7Bw.
To determine the direction of the current the value of the phase reactive power
has to be higher than 2% of the nominal phase power.

2.3 An outline of SdZ D

In order to obtain selectivity even in mesh networks and ring networks it is neces-
sary to use a protection that combines zone and directional selectivity: the SdZ D.
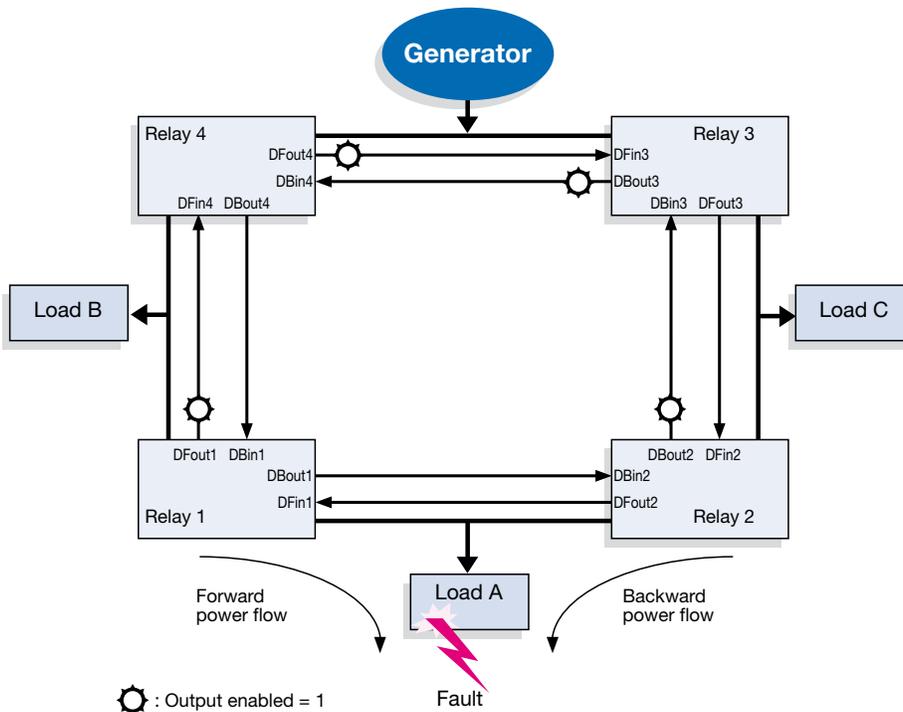
An example (theoretical) of configuration for which the SdZ D is likely to be used
is illustrated in the previous figure.
If a fault is detected in one of the section of the system (Load A), the final circuit-
breakers of the interested section (relay 1 and relay 2), communicate the presence
of the fault to the connected circuit-breakers (relay 3 and relay 4) by setting the
output signals DFout or DBout, depending on the direction of the current (in our
case both DFout of relay 1 and DBout of relay 2 are on).
So, the circuit-breaker relay 1 and relay 2, delimiting the section affected by the
fault, are tripped with the set selectivity time t7s, while the circuit-breakers fur-
ther away from the fault count down the delay time set, t7FW (relay 4) and t7BW
(relay 3), before opening: in this way the system is isolated, within the time t7s, to
exclude only the part affected by the fault.
In the event of lack of auxiliary power supply, the breakers will open in t7fw or
t7bw times (i. e. SdZ is reduced to being a simple D: this fact must be considered
by plant designers).
If, for some reasons, one of the circuit-breakers required to open does not oper-
ate, a specific function will activate the opening of the first circuit-breaker imme-
diately upstream of it, after further 100 ms approx. In the above example, if the
circuit-breaker does not open with the relay 1, only the circuit-breaker with relay
4 will open after a time t7s+100 ms.

2.4 D application example: Two generators linked at the same busbar
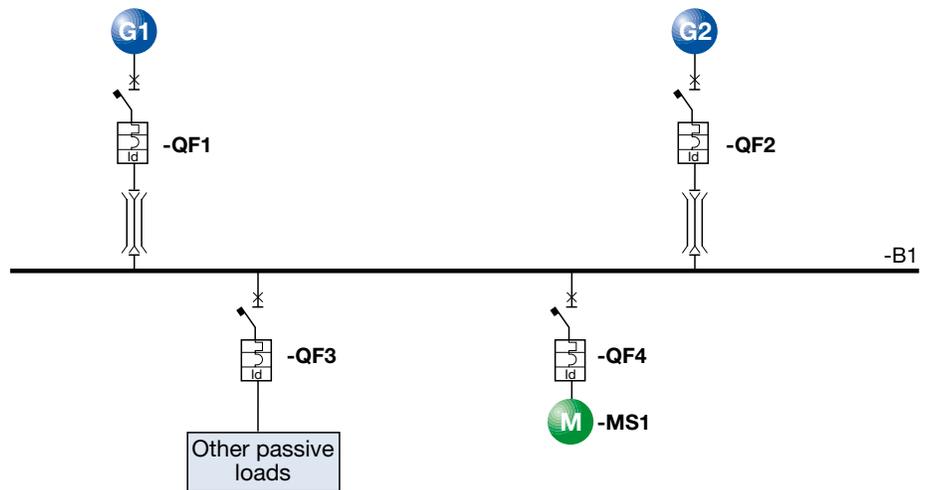
Let we consider an electrical scheme like the above one. The contribution of the motor to the maximum short-circuit current is about 5 kA. The contribution to the short-circuit by each (exactly alike) generator is about 10 kA.

As a consequence, it is not sure that QF1 and QF2 can be able to distinguish between an upstream and a downstream fault.

In order to guarantee selectivity between QF1 and QF2 in the event of a fault and to maintain the supply to the other passive loads, it's necessary to use D. Hereunder, an analysis of the two faults on the supply sides taken into consideration:
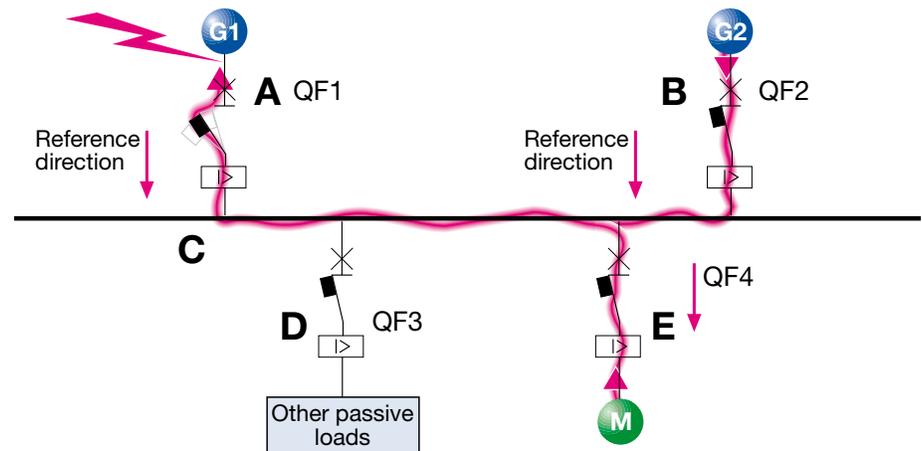
Let we have chosen reference directions for QF1, QF2 and QF3 breakers.

In this first case (fault on the supply side of QF1), only QF1 must trip:

1 - QF1 detects a current from 10 kA to 15 kA discordant with its reference direction, and shall therefore trip in t7BW1 time

2 - QF2 detects a current of 10 kA concordant with its reference direction, and shall therefore trip in t7FW2 time.

3 - QF3 does not detect any fault current

4 - QF4 detects a current of maximum 5 kA discordant with its reference direction, and shall therefore trip in the t7BW4 time.
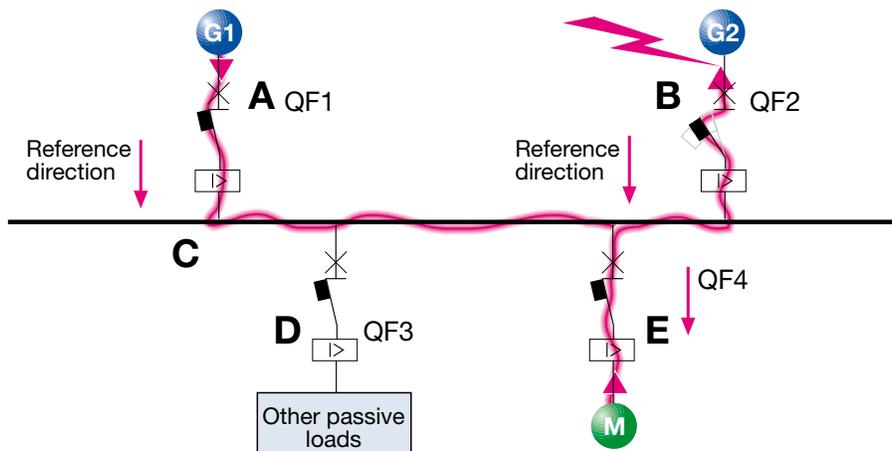
In this first case (fault on the supply side of QF2), only QF2 must trip:

1 - QF1 detects a current of 10 kA concordant with its reference direction, and shall therefore trip in t7FW1 time

2 - QF2 detects a current from 10 kA to 15 kA discordant with its reference direction, and shall therefore trip in t7BW2 time.

3 - QF3 does not detect any fault current

4 - QF4 detects a current of maximum 5 kA discordant with its reference direction, and shall therefore trip in the t7BW4 time.

By repeating the consideration above for any other possible fault, it's possible to give an example of settings (protection S, D and I) for the installation in question (where I7 is the current threshold for D).

| Protection functions | S | | D | | | I |
CB	I2	t2	I7	t7FW	t7BW	I3
QF1	OFF		3kA	300ms	200ms	OFF
QF2	OFF		3kA	300ms	200ms	OFF
QF3	3kA	200ms	-	-	-	OFF
QF4	OFF		3kA	200ms	300ms	OFF

2.5 SdZ application example 1: MV/LV transformer substation with bus tie

Reference direction
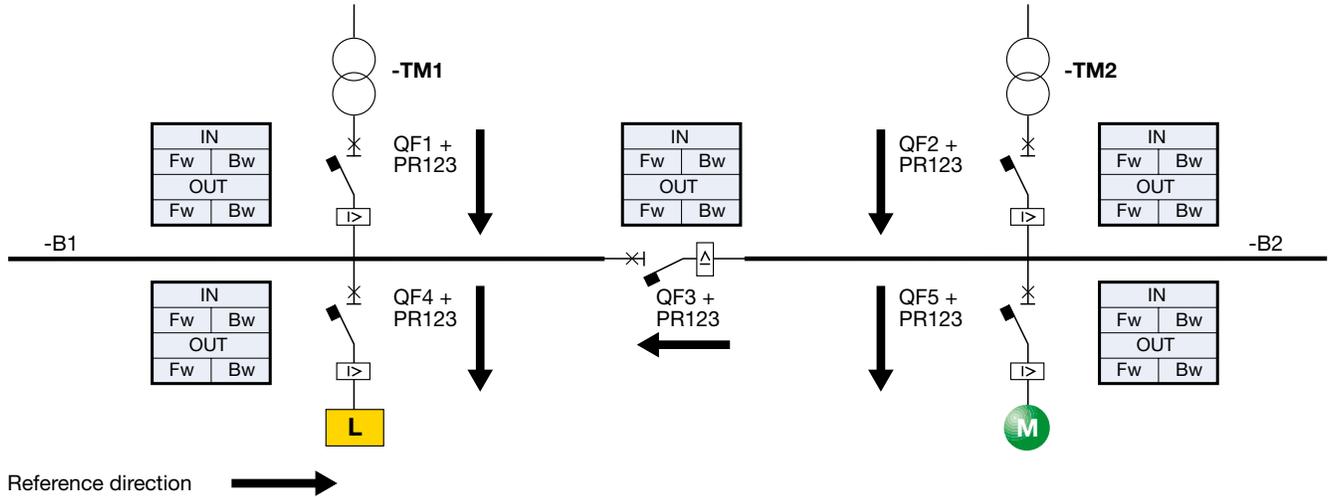
The presence of two or more MV/LV transformers and a bus tie closed on the LV busbars in a transformer substation allows the network to be managed with the transformers in parallel (this kind of configuration has the main advantage of allowing power supply even in the case of outage of one of the transformer). Thanks to SdZ D it is possible to keep a half-busbar supplied with voltage even in the case of a fault on the other half-busbar.

This example also shows which procedure must be used to determine the cabling required between the various releases.

The faults analyzed now are:

Fault in B1
Fault in B2

Fault in B1

Only QF1 and QF3 circuit-breakers must interrupt the fault: in particular the QF3 circuit-breaker is passed through by a current in a direction concordant with the one set; the DFout sends a lock signal to the DFin of QF2 circuit-breaker and to the DBin of QF5 circuit-breaker .
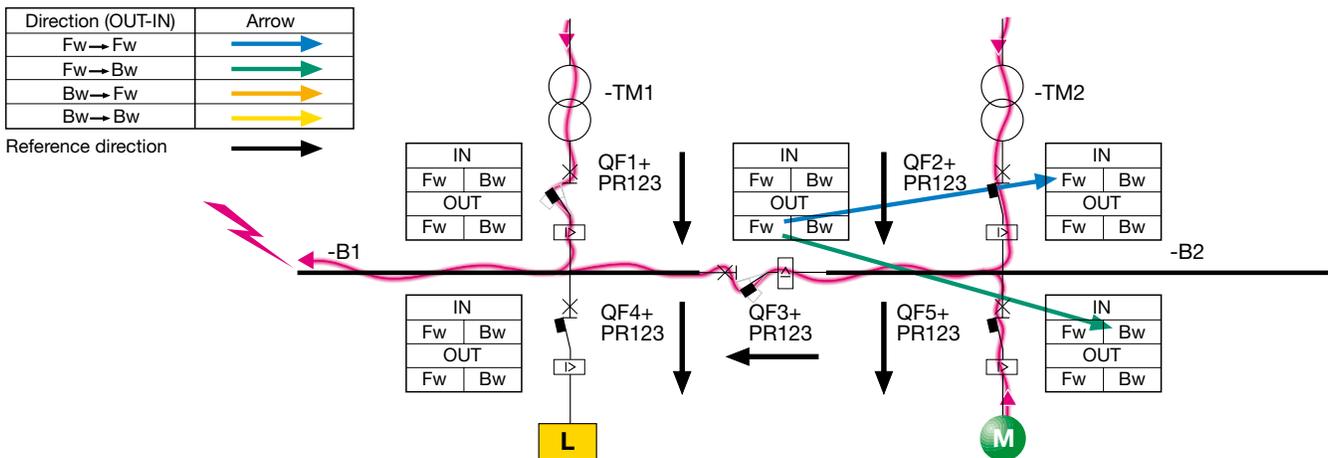
Fault in B2

QF2 and QF3 and QF5 circuit-breakers must interrupt the fault: in particular the
QF3 circuit-breaker is passed through by a current coming from busbar B1 (there-
fore in a direction discordant with the one set); the DBout sends a lock signal to
the DFin of QF1 circuit breaker.
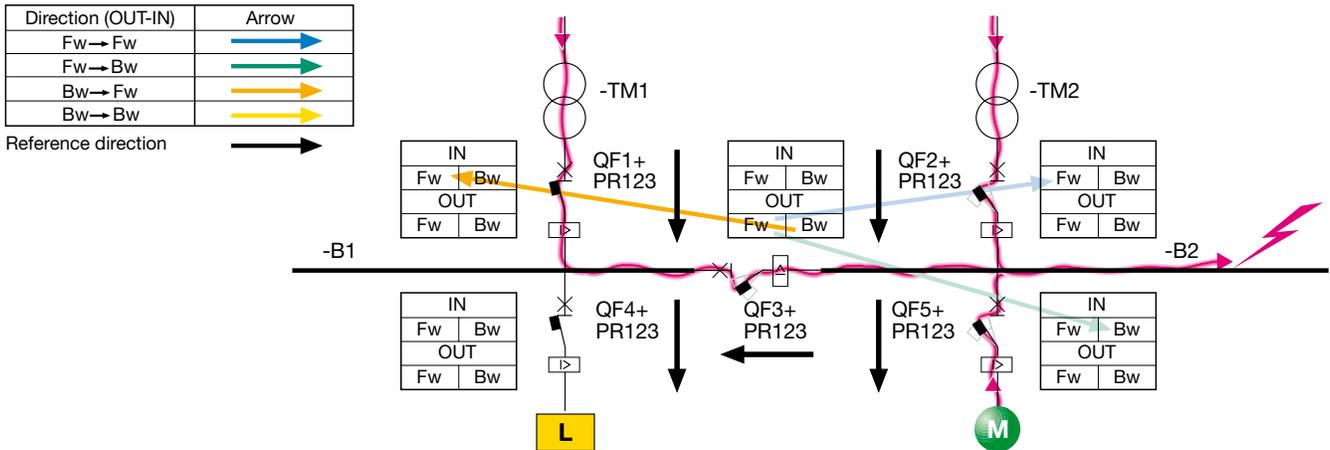
The remarks described above are to be resumed in the following table that helps
to manage the cabling of the system:

Cabling			OUT									
			QF1		QF2		QF3		QF4		QF5	
			FW	BW	FW	BW	FW	BW	FW	BW	FW	BW
IN	QF1	FW						■				
		BW										
	QF2	FW					■					
		BW										
	QF3	FW										
		BW										
	QF4	FW										
		BW										
	QF5	FW										
		BW					■					

Repeating this reasoning for the three others kind of possible fault (load side of
QF4, load side of QF5, supply side of QF1 and supply side of QF2), it is possible
to establish a global table of the system:

Cabling			OUT									
			QF1		QF2		QF3		QF4		QF5	
			FW	BW	FW	BW	FW	BW	FW	BW	FW	BW
IN	QF1	FW						■	■			
		BW										
	QF2	FW					■				■	
		BW										
	QF3	FW							■			
		BW				■					■	
	QF4	FW										
		BW										
	QF5	FW										
		BW				■	■					

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An example of settings (protection S, D and I) for the installation in question is given (where I7 is the current threshold for SdZ D protection and IK the minimum short-circuit current calculated).

Protection function	S		D				I
CB	I2	t2	I7	t7FW	t7BW	Selectivity time	I3
QF1	OFF		$<Ik_{min}$	350ms	250ms	150ms	OFF
QF2	OFF		$<Ik_{min}$	350ms	250ms	150ms	OFF
QF3	OFF		$<Ik_{min}$	300ms	300ms	150ms	OFF
QF4	OFF		$<Ik_{min}$	250ms	350ms	150ms	OFF
QF5	OFF		$<Ik_{min}$	250ms	350ms	150ms	OFF

Selectivity time t7s (remember that selectivity time t7s is the trip time of the "unlocked" circuit breakers which must open) can be adjusted form 130 to 500 ms, while t7FW/BW (i. e. trip time of the "locked" circuit-breakers which mustn't open) is to be adjusted (from 200 to 800 ms) so as to comply with the relationship: *t7FW/BW>t7s+70 ms.*

That is because 70 ms is the minimum difference between the trip times of two CBs in series, in auxiliary power supply, to guarantee that the CB on the supply side does not trip.

It's important to consider that if the function I is enabled, and the short-circuit current exceeds the value set I3 the circuit-breaker will open instantaneously and regardless of directions and signals received; moreover, even if the function I is disabled, however there is always enabled the Iinst protection, auto-protection of the CB.
In the same way, if the function S is enabled and the short-circuit current exceeds the value set I2, the circuit breaker will open in the t2 time, if this is shorter than the other times, regardless of the directions and signals received.

2.6 SdZ application example 2: Presence of low voltage generators

SdZ D may be very useful when in the network low voltage generators are present. This is a situation that will happen more and more frequently in the future, in consequence of diffusion of distributed energy resources.

Let TM1 be the MV/LV transformer, QF1 its LV protection, G1 the low voltage generator, QF2 its protection, B1 the low voltage busbar, M a motor load, QF3 its protection.
In the case of fault in A, circuit-breaker QF1 is passed through by a current that flows in a direction discordant with the one set (black arrow). The DBout of QF1 "blocks" the DFin of QF2 and the DBin of QF3: in fact, current flows through QF2

in the same direction as the setting, whereas QF3 is passed through by a current discordant with the setting (the active "block" signals are indicated by wider arrows).
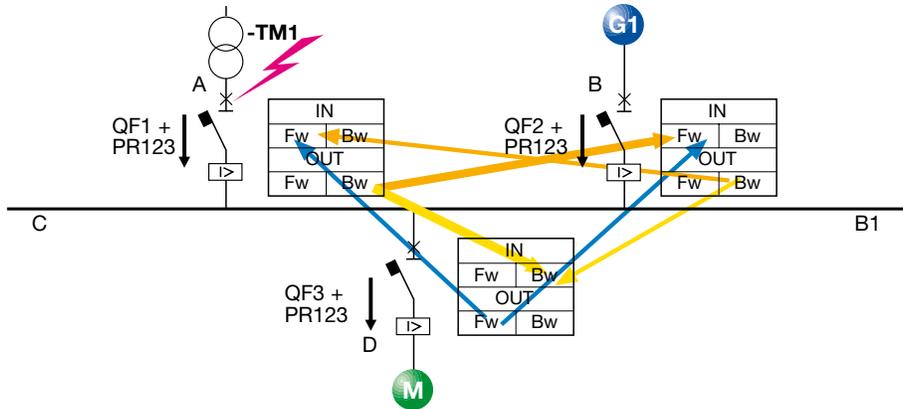
In the case of a fault in B, the circuit breaker QF2 is passed through by a current from busbar B1; this current flows in a direction discordant with the one set. The DBout of QF2 "blocks" the DFin of QF1 and the DBin of QF3: in fact, current flows through QF1 in the same direction as the setting, whereas QF3 is passed through by a current discordant with the setting.
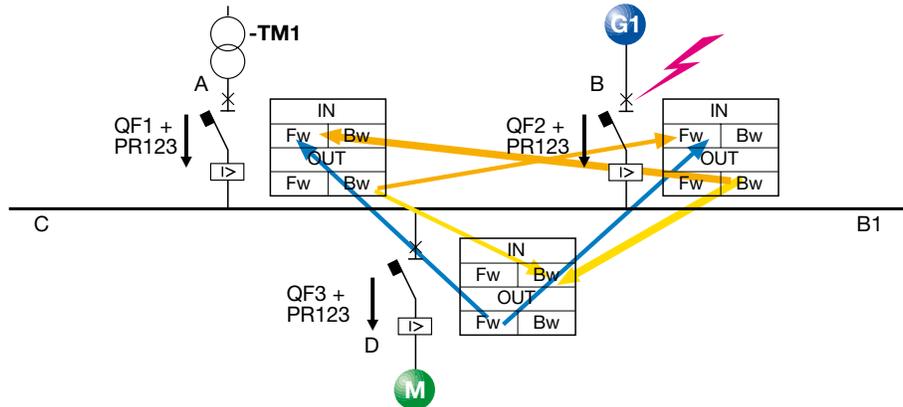
In case of fault in C, QF1 and QF2 are passed through by a current flowing in the same direction as the one set, whereas QF3 is passed through by a current with discordant direction. No CB is blocked and consequently all the CBs affected by the fault will trip according to the time settings of the protection S or I.

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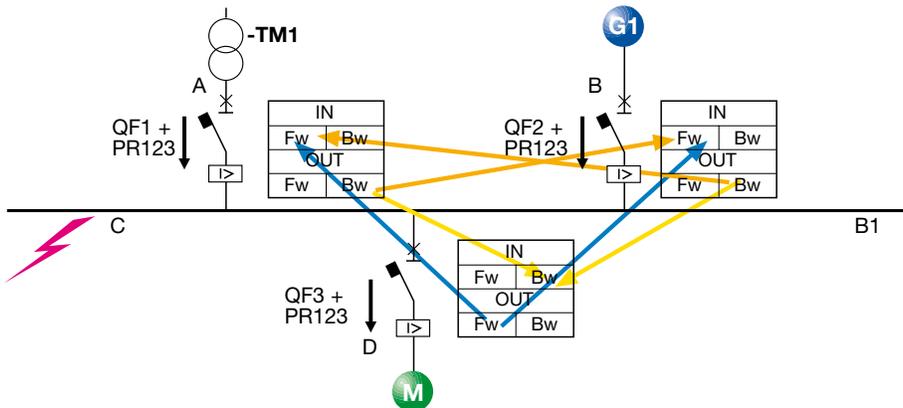
3. References

3.1 Reference for D

D is commonly used in order to guarantee selectivity between ACB in substations with two transformers which operate in parallel on the same busbar

-U1
Vrif = 20000V
LLL/IT->TT
P = 885kW
Q = 462 kvar

-TM1
Vn2 = 400V
Sn = 630kVA
Sec.: LLLN/TT

-TM2
Vn2 = 400V
Sn = 630kVA
Sec.: LLLN/TT

A

B

-QF1
E1B 1000 PR123/P-LSIG In=1000A
RCQ

-QF2
E1B 1000 PR123/P-LSIG In=1000A
RCQ

-MS1
M3GP 315 MLA 8 - 110 kW
T4N320 PR221-I

-MS2
M2BAT 315 SMB 2 - 132 kW
T5N400 PR221-I

-QF3
T5N 630 PR221DS-LS/I
RCQ

-QF4
T5N 630 PR221DS-LS/I
RCQ

Cont. LD A210
Relay E320DU
Pn = 110.00 kW
Cosphi = 0.83

Cont. LD A260
Relay E320DU
Pn = 132.00 kW
Cosphi = 0.887

-L1
Sn = 350 kWA
Cosphi = 0.90

-L2
Sn = 350 kWA
Cosphi = 0.90

-M1

-M2

Plant main features	
Operating voltage	400 V
Rated frequency	50 HZ
Installed power	850 kW
Busbar short-circuit current	28 kA

Here above a sketch of an electrical plant for a food industry.
Let we assume reference direction as in the picture above (red arrows).
From each transformer a contribution to proceeds of about 13 kA low voltage busbar short-circuit current. The two motors together give a contribution to maximum short-circuit current of about 2 kA.
We have two possible faults near sources, a fault at load side of TM1 and a fault at load side of TM2.

In the first case (fault in **A**), QF1 is passed through by a current of a value included between 13 kA and 15 kA, while QF2 is passed through by a current of about 13 kA. Only QF1 must trip: in this manner, shedding the low priority load L2, it is possible to keep on load L1, M1 and M2. Owing to the fact that there could be no difference between the two short-circuit values, it is no possible to use a protection S setting in order to guarantee selectivity between QF1 and QF2. The second case (fault in B) is exactly specular. So, only using D (with t7FW times longer than t7BW times) selectivity between QF1 and QF2 is always saved.

Hereunder, the setting of the protection functions (values of I threshold guaranteed as multiple of In).

Protection function	S		D			I
CB	I2	t2	I7	t7FW	t7BW	I3
QF1	OFF		4	300 ms	200 ms	OFF
QF2	OFF		4	300 ms	200 ms	OFF
QF3	4.5	100 ms	-	-	-	OFF
QF4	4.5	100 ms	-	-	-	OFF
MS1	-	-	-	-	-	9
MS2	-	-	-	-	-	9

To be sure that everything functions as foreseen in case of a fault, i. e. the CBs set with D protection always trip with D protection, the choice of the circuit-breakers and the relevant settings has been established following these three simple rules:

1 The CBs must have a short-wihtstand current value higher than the maximum prospective short-circuit current which can occur at the point where they are installed: Icw>Ikmax

2 The trip threshold of D protection must be set at a lower value than the minimum prospective short-circuit current which can occur at the point where that release is installed: I7<Ikmin

3 The trip threshold of protections S and I must be set in such a way so as not to create trip overlapping with function D.

3.2 References for SdZ

SdZ D has been just implemented in several applications, three of these are listed below.

3.2.1 Naval electrical plant (civil)

Hereunder (look at next page) the electrical plant of a large ferryboat:

-GS1
Vn = 440 V
Vrif = 440 V
Cosphi = 0.80
P = 625 kW
Q = 604 kvar
LLL/IT->TT

-WC1
10x4G300/150
Ib = 1009.9 A
Iz = 1695.0 A
dV = 0.02%
L = 6 m

-QF1
T7L 1600 PR332/P LSI

-GS2
Vn = 440 V
Vrif = 440 V
Cosphi = 0.80
P = 888 kW
Q = 302 kvar
LLL/IT->TT

-WC2
14x4G300/150
Ib = 1230.8 A
Iz = 2373.0 A
dV = 0.02 %
L = 8 m

-QF2
T7L 1600 PR332/P LSI

-GS3
Vn = 440 V
Vrif = 440 V
Cosphi = 0.80
P = 625 kW
Q = 605 kvar
LLL/IT->TT

-WC3
10x4G300/150
Ib = 1010.0 A
Iz = 1695.0 A
dV = 0.02 %
L = 6 m

-QF18
T7L 1600 PR332/P LSI

-GS4
Vn = 440 V
Vrif = 440 V
Cosphi = 0.80
P = 625 kW
Q = 605 kvar
LLL/IT->TT

-WC4
10x4G300/150
Ib = 1010.0 A
Iz = 1695.0 A
dV = 0.02 %
L = 6 m

-QF18
T7L 1600 PR332/P LSI

-B1
V = 439.9 V
Ib = 2216.5 A
Cosphi = 0.90
I''k LLL = 76.0kA

-B2
V = 439.9 V
Ib = 2216.6 A
Cosphi = 0.89
I''k LLL = 76.0kA

-QF5
T2L 160

-QF6
E2S 1600
PR122/P-LSI

-QF7
E2S 1600
PR122/P-LSI

-QF8
E1B 1250
PR 123/P-LSI
Bus Tie

-QF9
E1B 1250
PR 123/P-LSI
Bus Tie

-QF10
T2L 160

-QF19
E2S 1600
PR122/P-LSI

-QF20
E2S 1600
PR122/P-LSI

-WC5
4G10
Ib = 27.6 A
Iz = 46.0 A
dV = 0.14 %
L = 7 m

-BW1
SC 1200 A 4 cond. Al
L = 30 m
dV = 0.59 %
Ib = 860.0 A
Iz = 1260,0 A

-BW2
SC 1200 A 4 cond. Al
L = 10 m
dV = 0.22 %
Ib = 950.2 A
Iz = 1260,0 A

-B3
V = 439.9 V
Ib = 756.0 A
Cosphi = 0.90
I''k LLL = 76.0kA

-QF13
E2S 1250
PR122/P-LSI

-WC6
4G10
Ib = 29.4 A
Iz = 46.0 A
dV = 0.14 %
L = 7 m

-BW3
SC 1200 A 4 cond. Al
L = 30 m
dV = 0.59 %
Ib = 860.0 A
Iz = 1260,0 A

-BW2
SC 1200 A 4 cond. Al
L = 10 m
dV = 0.22 %
Ib = 950.2 A
Iz = 1260,0 A

-TM1
Vn2 = 220 V
Sn = 50 kVA

-MS1
M2JA 400 MB 4
Pn = 560.00 kW
Cosphi = 0.89
FU = 100 %
dV = 0.62 %

-MS2
M2JA 400 LKA 4
Pn = 630.00 kW
Cosphi = 0.86
Cosphi = 0.90
FU = 100 %
dV = 0.24 %

-BW5
MR 1000 A 4 cond. Cu
L = 10 m
dV = 0.26 %
Ib = 756.0 A
Iz = 1050,0 A

-MS5
M3KP 355 MLB 4
Pn = 500.00 kW
Cosphi = 0.87
Cosphi = 0.90
FU = 100 %
dV = 0.28 %

-TM2
Vn2 = 220 V
Sn = 50 kVA

-MS3
M2JA 400 MB 4
Pn = 560.00 kW
Cosphi = 0.89
FU = 100 %
dV = 0.62 %

-MS2
M3KP 400 LKA 4
Pn = 630.00 kW
Cosphi = 0.86
Cosphi = 0.90
FU = 100 %
dV = 0.24 %

-WC7
4G95/50
Ib = 55.3 A
Iz = 179.0 A
dV = 0.07 %
L = 7 m

-WC8
4G95/50
Ib = 55.8 A
Iz = 179.0 A
dV = 0.07 %
L = 7 m

-QF14
T1B 160

-QF15
T1B 160

-MS6
M3AA 180 L 6
Pn = 17.00 kW
Cosphi = 0.79
Cosphi = 0.90
FU = 100 %
dV = 1.90 %

-MS7
M2BA 100 L2 A
Pn = 17.00 kW
Cosphi = 0.79
Cosphi = 0.85
FU = 100 %
dV = 1.98 %

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Plant main features	
Operating voltage	440 V
Rated frequency	60 HZ
Installed power	3 MW
Busbar short-circuit current	76 kA

There are two bus ties that connect the central 3-phase 500 kW Ms5 motor to the two LV busbars.

This motor be supplied on both in the event of a fault on busbar B1 (red one) and of a fault on busbar B2 (green one). Default directions for the two Emax E1 bus-ties have been imposed as the picture below:
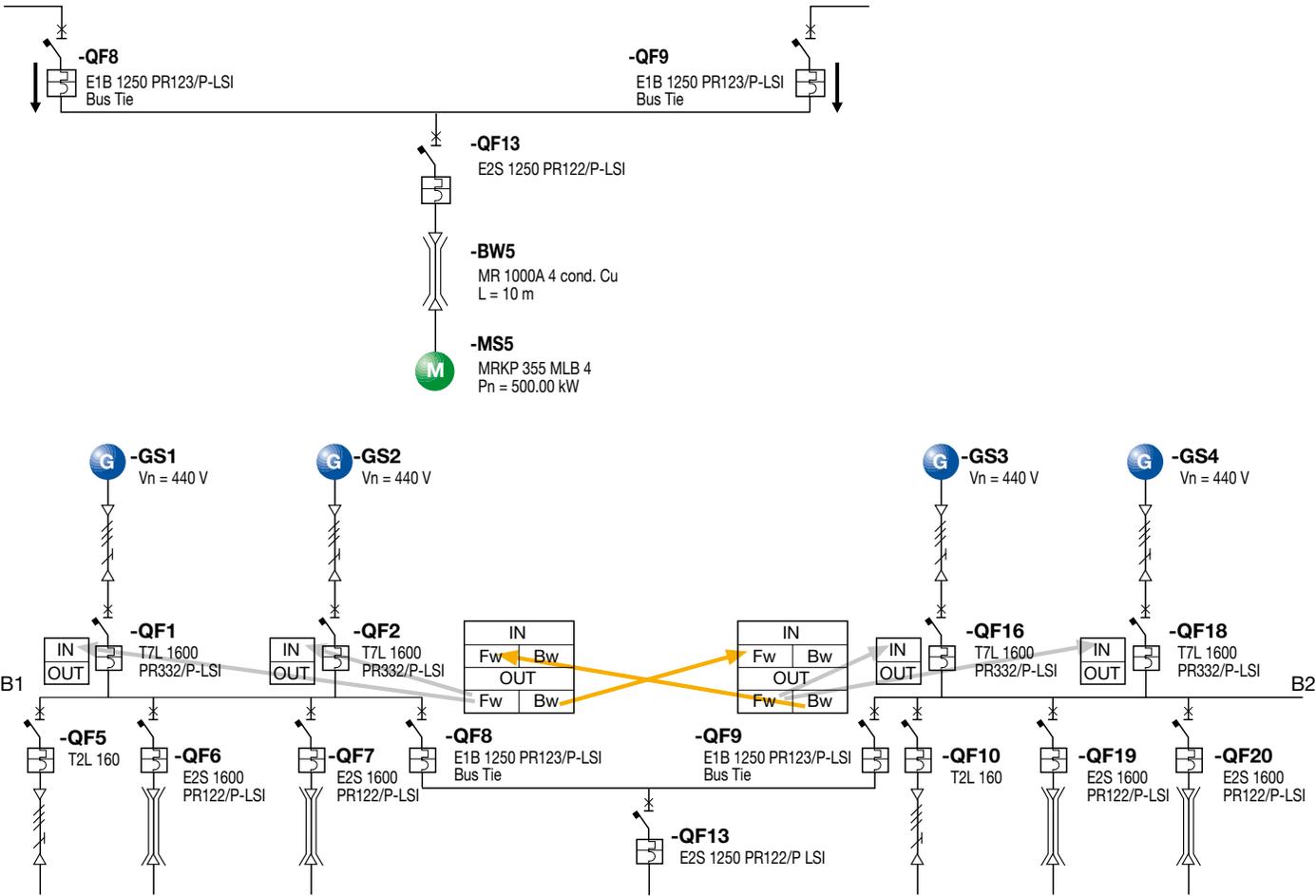
In the event of a fault on the busbar B2 the bus tie of busbar B1 must remain close, while bus tie B2 must trip so that the fault is isolated.

Moreover, also QF1 and QF2 breakers must remain close, and do not trip unless they are passed through by a considerable current.

At the same time, QF1 and QF2 must suitably protect the generators, and then their S protection function has to intercept the decrement curve of the generator in the event of a fault on busbar B1.

Because of this two antithetical issues, QF1 and QF2 have been equipped with PR332/P relays, with which it is possible to implement the zone selectivity.

So, in the event of a fault on the busbar B2, QF8 provides to block QF1 and QF2 that will open in S time t2 (set at 0.25 s), but in the event of a fault on the busbar B1

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they will quickly open in t7s time (set at 0.15 s, so that it intercepts the decrement curve of the generator): in this manner both the issues are respected (see the diagram and the table in the next page).
In the event of fault on the busbar B1, it is needed to act in a quite similar way.
So, in the picture above, it is summarized the plant logic, hinged on the two PR123/P relays with SdZ D.

Time-Current Curve LLL
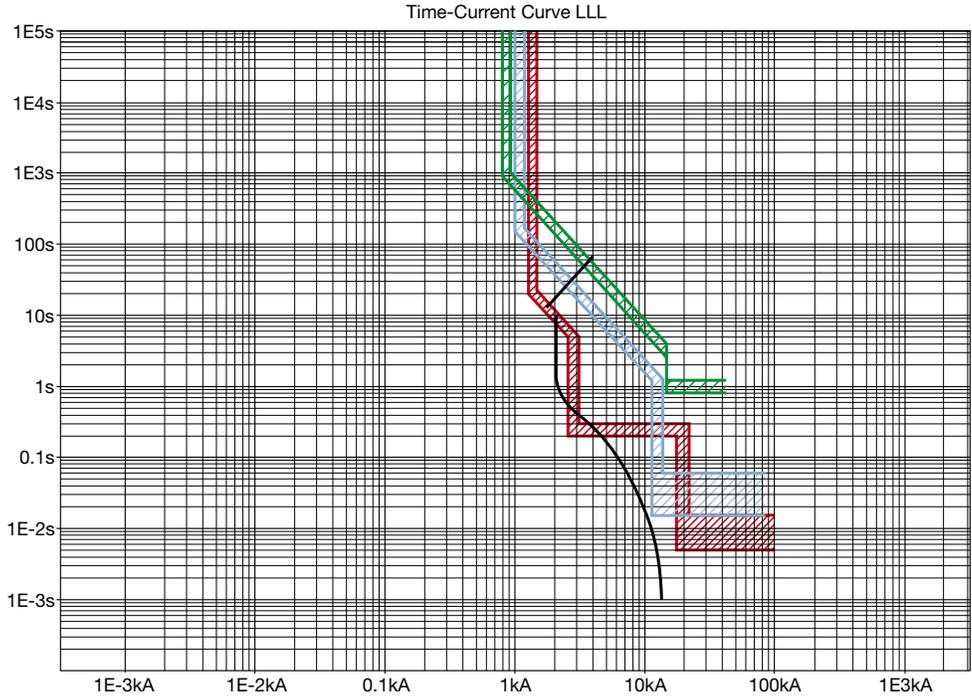
Here above, the set time-current curves for generator GS2 (black line), generator protection QF2 (red), motor protection QF7 (blue) and bus tie QF8 (green).

Hereunder a brief table with the chosen settings of the breakers considered in the time-current graph.

Protection function	S		D			I
CB	I2	t2	t7FW	t7BW	t7SEL	I3
QF2	1.8	250 ms	-	-	150 ms	OFF
QF7	OFF	OFF	-	-	-	8
QF8	OFF	OFF	250 ms	-	150 ms	OFF

3.2.2 Military ship electrical plant
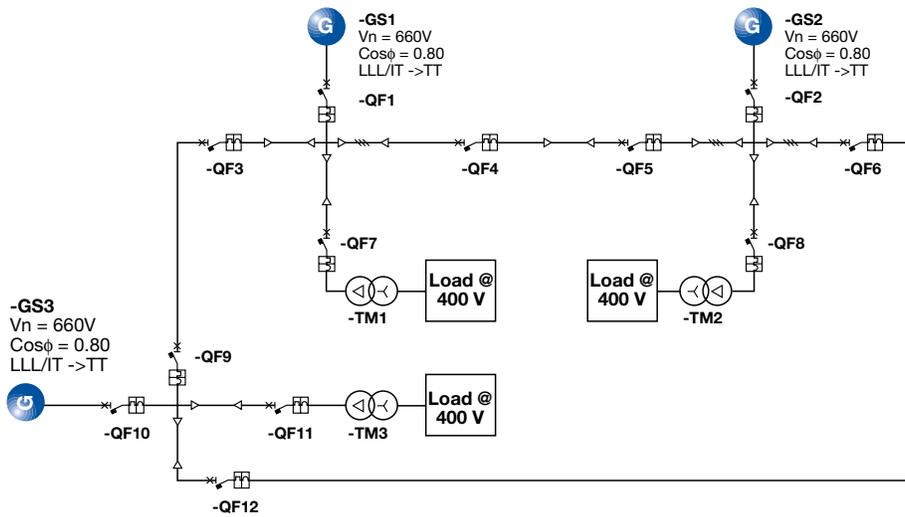
Plant main features	
Operating voltage	660 V
Rated frequency	50 HZ
Installed power	7.5 MVA
Ring short-circuit current	65 kA

Here above a simplified sketch of a part of a military ship electrical plant. The topology of the plant is characterized by the presence of a ring which the loads are linked to. In this case, only using SdZ D it is possible to reach a satisfying selectivity (look at paragraph 2.1).

3.2.3 High reliability military electrical plant
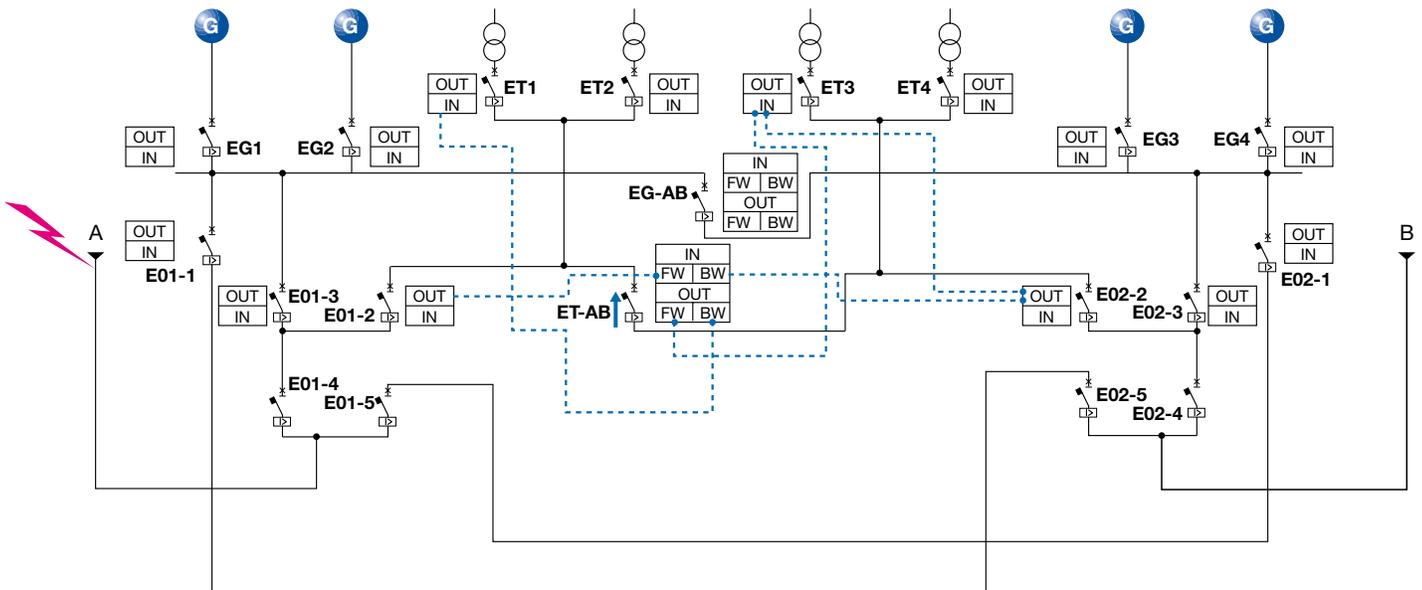
Plant main features	
Operating voltage	400 V
Rated frequency	50 HZ
Installed apparent power	7.5 MVA
Max busbar short-circuit current	65 kA

EMAX	Number of breakers
All EMAX	20
With PR123/P relay and SdZ D	2
With PR122/P relay and SdZ	14
With PR121/P relay	4
Withdrawable version	20
With interblock	4

Let we focus on ET-AB bus tie. The plant layout foresees that it is not possible to have more than two transformers parallel connected on the same busbar, therefore:
- ET-AB will be always open when ET1, ET2, ET3 and ET4 are all closed
- ET-AB will be closed only if one among the couple ET1/ET2 and one among the couple ET3/ET4 are be closed at the same time.

Moreover, the generators can't operate in parallel with the transformer, except for few minutes.
Let we analyzed two different fault types:

1) Fault in the main switchboard A with only TR1 and TR3 on duty
   In this case let we have:
   - ET1 and ET3 close
   - ET2 and ET4 open
   - ET-AB close
   - E01-3 open
   - E01-2 close
   - E01-4 close (E01-5 open)

The fault path affects E01-2, ET1, ET-AB, ET3 breakers.
E01-2 senses the fault and blocks ET1 and ET-AB (simple zone selectivity); ET-AB is passed through by a current coming from the busbar supplied by TR3 (therefore in a direction concordant with the one set, see the blue arrow), so the DFout sends a lock signal to the DFin of ET3.

2) Fault in the main switchboard B with only TR1 and TR3 on duty
   In this case let we have:
   - ET1 and ET3 close
   - ET2 and ET4 open
   - ET-AB close
   - E02-3 open
   - E02-2 close
   - E02-4 close (E02-5 open)

The fault path affects the E02-2, ET3, ET-AB, ET1 breakers.
E02-2 feels the fault and blocks ET3 and ET-AB (simple zone selectivity); ET-AB is passed through by a current coming from the busbar fed by TR1 (therefore in a direction discordant with the one set), so the DFout sends a lock signal to the DFin of ET1.

It is quite clear that only using a SdZ D for the ET-AB relay it is possible to reach a good degree of selectivity in this plant.

4. Pratical Guide

## 4.1 About SdZ

4.1.1 An overview

To set up the SdZ D function you have to suitably connect the K11...K15 terminals
on EMAX terminal box. For example, if you have to realize the cabling needed
in the picture hereunder (sketch of a part of a real electrical plant of an electronic
equipment industry):
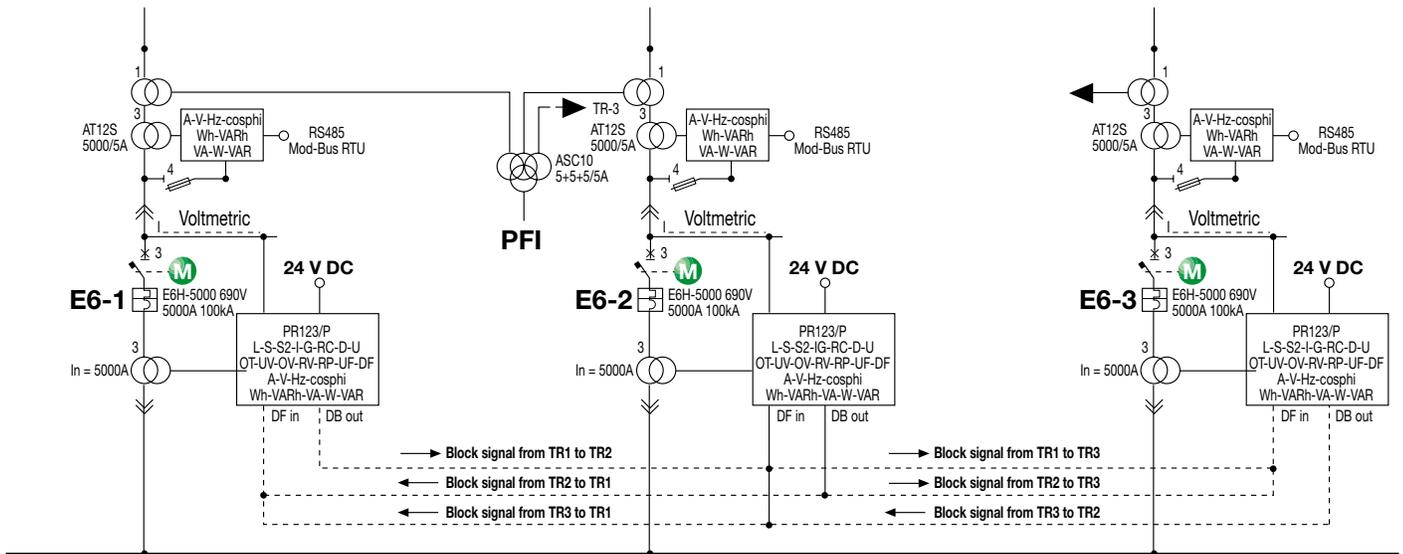
in this illustrative scheme you can find the cabling:

Star connected K11 terminals, not earthed
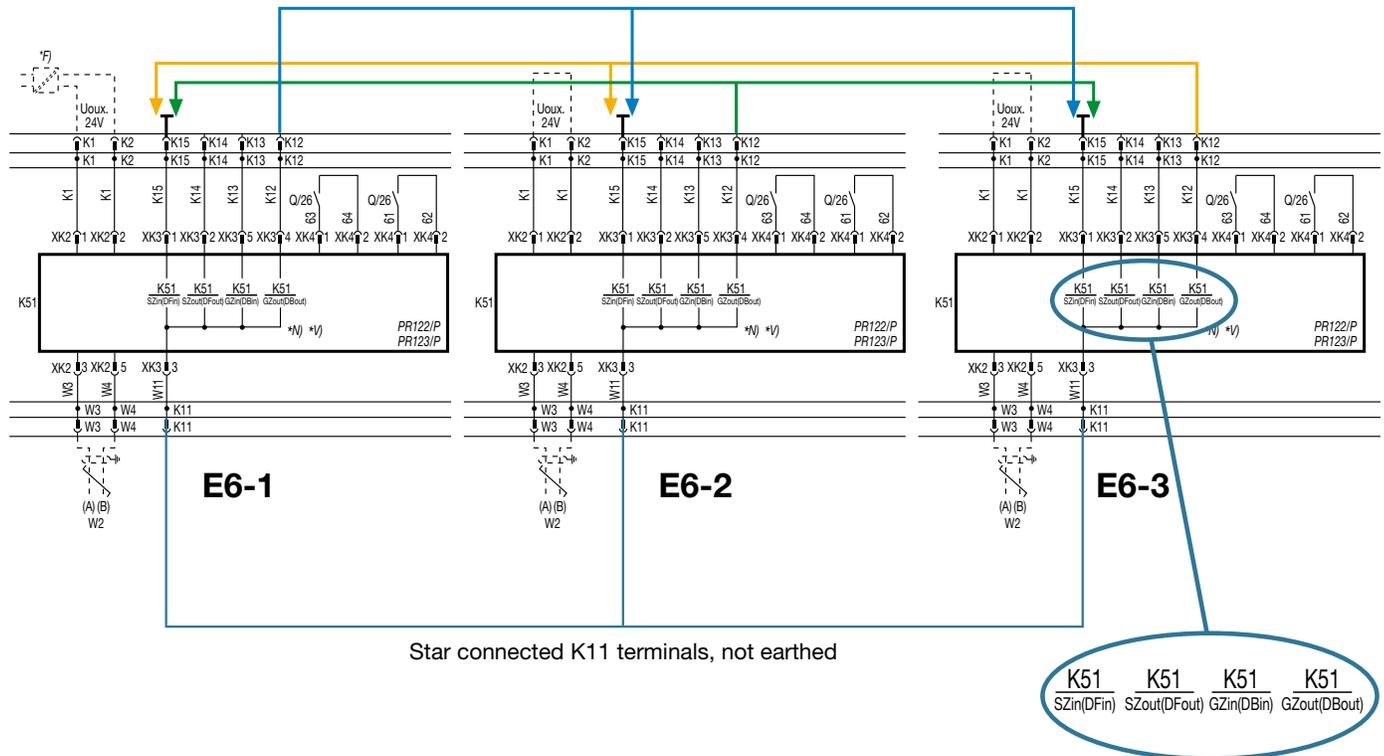
The terminals that have to be connected (look at the scheme above) are physi-
cally present (and clearly identified) in EMAX terminal box.
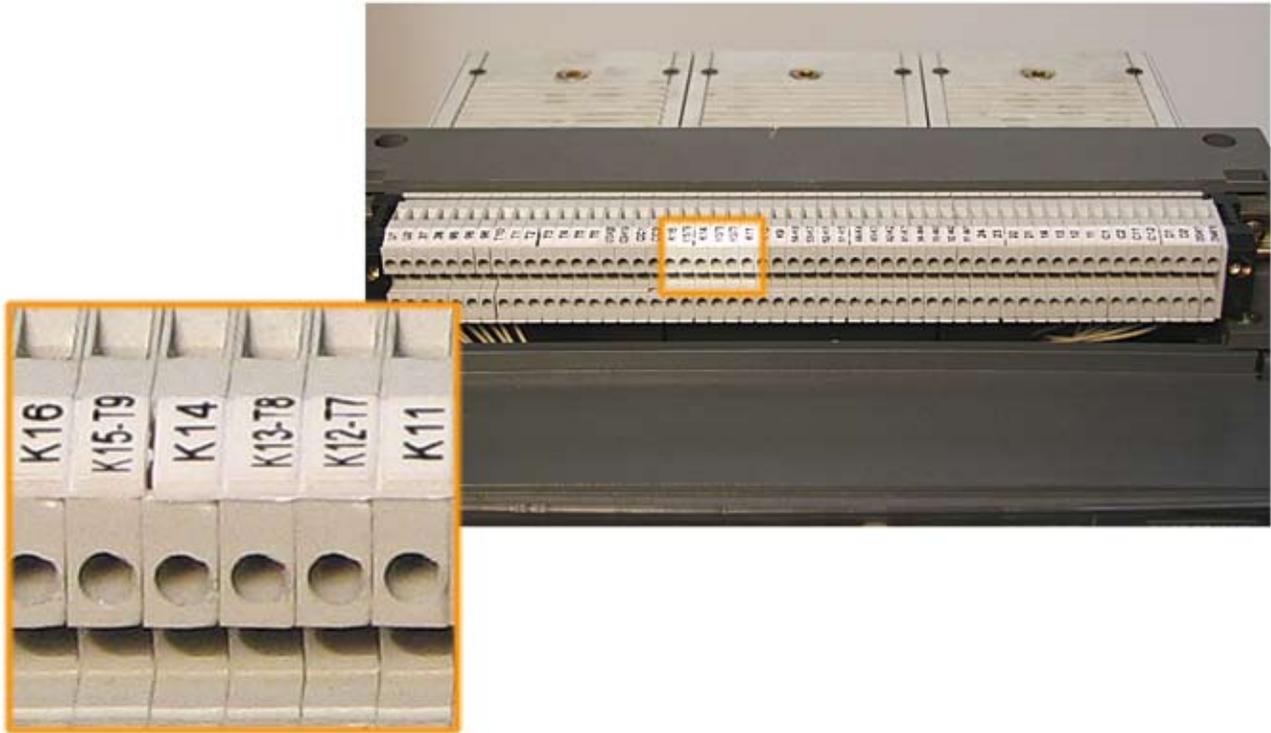
4.1.2 "Shopping list" section

To use SdZ D it is needed:

1) An EMAX ACB with PR123/P or an EMAX X1 with PR333/P

All EMAX can be used to realize SdZ D.

2) A cable

A two-wire shielded corded cable can be used to carry out the cabling.
A cable feasible for the application is the "Belden 3105A", manufactured by BELDEN (some characteristics: conductor diameter 0.30 inch, characteristic impedance 120 Ohm, max. operating voltage-UL 300 V RMS, max. recommend current 2.7 A per conductor @ 25°C).
The shield of the cable must only be connected to earth in correspondence with one of the two releases. When it is possible to find a CB further "to the supply side" between the two, it is advisable to connect the shield to earth in correspondence with the release which equips the CB.

The maximum length of cabling between two units for zone selectivity is *300 meters*. This limit can be increased using special mechanism.

3) A power pack

The external auxiliary power supply is provided using a galvanically-separated power pack.
You may use an ABB CP-24 power supply unit (supply voltage: max. 260 V): it is recommended to provide an output current of 0.5 A per breaking unit supplied.

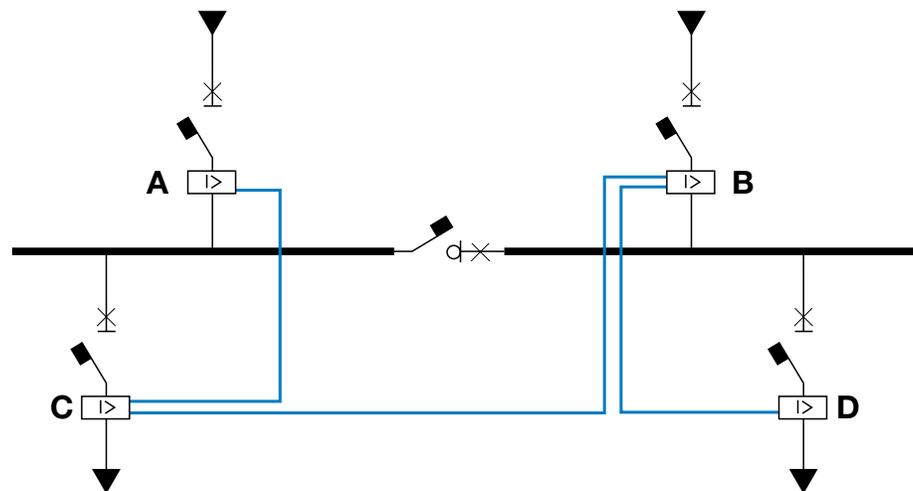**4)** Some special devices... for some particular applications

4a) Zone Selectivity Array

With reference to the figures below, let us suppose that, in a specific case of current flow:

C must lock A and B

D must only lock B

With the cabling made as in the figure below, it would not be possible to obtain the desired solution.


In fact, the lock signal coming from D would also be transmitted to A by means of the electrical continuity which is created between the different B-C and C-A interlocking connections.

By means of suitable cabling of ZSA (the acronym is for Zone Selectivity Array) module (cabling is carried out by ABB on customer's request) the lock signal is made one-way so that a signal coming form D towards B is not transmitted to A as well (see the picture below).
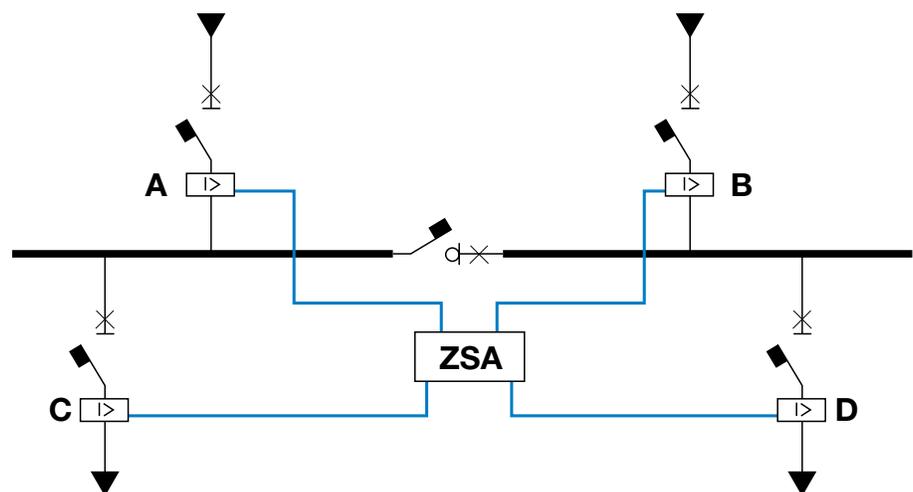
In fact, ZSA is a diode matrix that allows distributing the input blocking signal to the correct output, without undesired signal returns. Look at the example below:
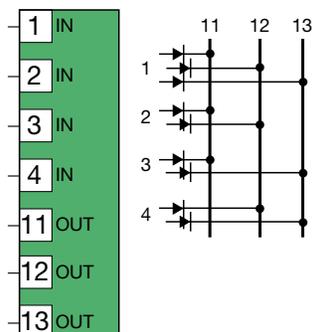
Blocking signal	11	12	13
1	X	X	X
2	X	X	
3	X		X
4		X	X

1 blocks 11,12 and 13, 2 blocks 11 and 12…. and so on.

The maximum number of CB which can be connected to the outputs of a trip unit is 20 in the case of a PR123 that blocks other PR123s. But, if you have old devices type PR113, there are less connections available: 3 in the case of a PR123 that blocks PR113s; 3 in the case of PR113 that blocks other PR113s.
The maximum number of CB which can be connected to the inputs of a PR123 trip unit is indefinetely high.

4b) Zone Selectivity Buffer
As above, the maximum number of CB which can be connected to the outputs of a trip unit is 3 in the case of a PR113 that blocks PR113s. If it is necessary to block 4 or more PR113, it's possible to use a Zone Selectivity Buffer (ZSB) unit.

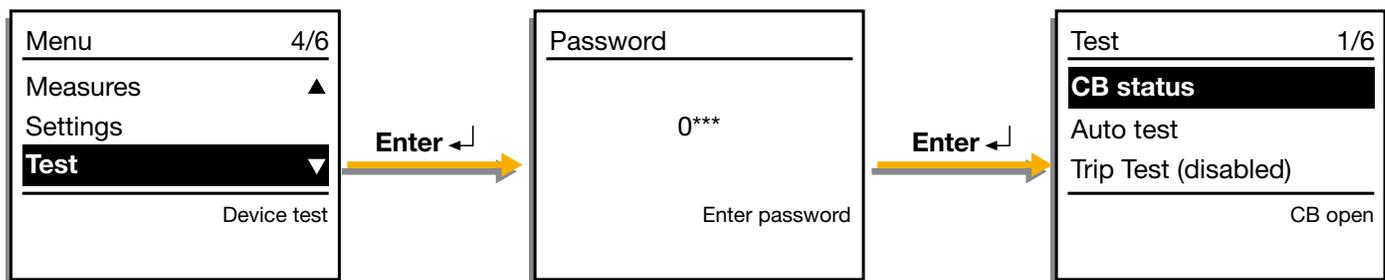ZSB is an amplifier and needs to be supplied with auxiliary voltage.

4.1.3 Testing field

There are two different kinds of test that can be performed in order to verify the correct functioning of the SdZ D. The first one (see clause 4.1.3.1) shall be performed when the electrical system is working under normal operating conditions, while the second one (see clause 4.1.3.2) simulates a fault in the plant. Between the two, only the first one can be carried out by the customer: the other one is carried out on demand by ABB technicians.

4.1.3.1 Testing with the PR123 test function

Testing SdZ D using PR123 test function is simple. In order to test whether the implemented system works properly, it is possible to force the output signals DFout and DBout of one breaker and then proceed to verify the status of the breakers connected.
This specific function may be activated under the relay Test Menu selecting the "Zone selectivity" menu.

```
Menu              4/6
Measures           ▲
Settings
Test               ▼

         Device test
```

Enter ↵

```
Password
_____


        0***


      Enter password
```

Enter ↵

```
Test              1/6
CB status
Auto test
Trip Test (disabled)
_____
           CB open
```
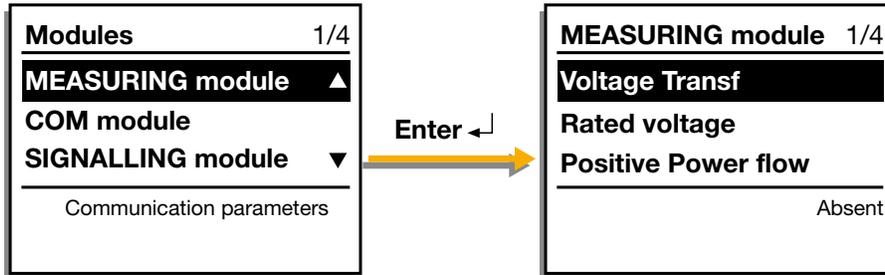
4.1.3.2 Testing with Ts3 unit

By using a special testing unit named Ts3, it is possible to simulate short-circuit current on several breakers, and then to test the correct working of SdZ D function.
The verb "simulate" means that, using the Ts3 unit, it is possible to apply a suitable current to the secondary of the PR113/P CS or to set a suitable voltage in the Rogowski coil of the PR123/P, so that the PR1x3/P sees a fault current. If you need this kind of test, ask ABB for details.

4.2 About D

D doesn't need either a terminal connection or an external power supply. Once
it has been decided to use D, the customer has just to choose the power flow
direction.

Modules 1/4
MEASURING module ▲
COM module
SIGNALLING module ▼
Communication parameters

Enter ↵ →

MEASURING module 1/4
Voltage Transf
Rated voltage
Positive Power flow
Absent

Choosing the power flow direction is simple. Entering in the measuring module
menu (you can find it in the settings menu) and selecting "positive power flow" is
possible to make a choice between

Bottom -> Top

Or

Top -> Bottom.

It's possible to test D protection only using Ts3 unit (look at 4.1.3.2 paragraph).

5. Index of abbreviations

D	Directional protection
SdZ D	Directional zone selectivity function
t7FW	Trip time in a direction concordant with the reference direction set
t7BW	Trip time in a direction discordant with the reference direction set
I7	Current threshold for D and SdZ D
DFin	Directional Forward input
DBin	Directional Backward input
DFout	Directional Forward output
DBout	Directional Backward output
t7s	Selectivity time, i. e. the trip time of the "unlocked" circuit-breakers

6. Bibliography

Technical Application Paper No. 1, "Low voltage selectivity with ABB circuit-breakers", February 2006, code 1SDC007100G0202.

IEC 60947-1 Standard "Low voltage equipment – Part 1: General rules for low voltage equipment".

Electrical Installation Handbook volume 1, "Protection and control device", March 2007, code 1SDC008001D0205

Electrical Installation Handbook volume 2, "Electrical device", March 2007, code 1SDC010001D0205.

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A division of ABB S.p.A.

L.V. Breakers
Via Baioni, 35
24123 Bergamo - Italy
Tel.: +39 035.395.111 - Telefax: +39 035.395.306-433

http://www.abb.com