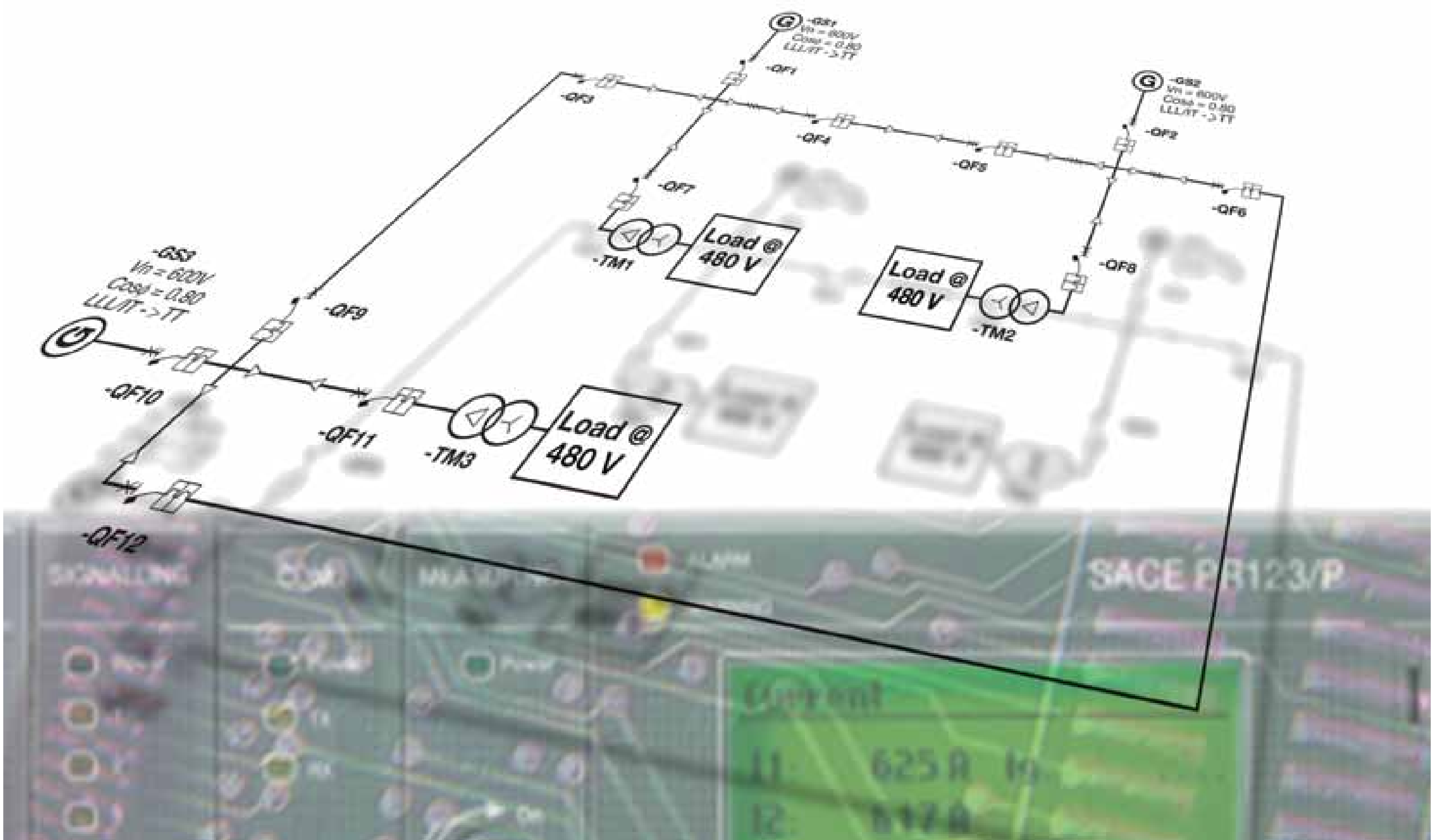

Directional protection and directional zone selectivity

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1. Generalities

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

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

- Directional Protection is an advanced function of trip units PR123/P and PR333/P
- Directional Protection is useful in cases when there is more than one power supply source
- Directional Protection does not need an auxiliary power supply or its own specific cabling

The PR123/P and the PR333/P trip units offer excludable directional protection ("D") against short-circuits with adjustable fixed time. This protection function 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, "Low voltage selectivity with ABB circuit breakers")*.

In order to use the D function, you have to set a reference direction for the current. Then it is possible to set two different trip times on the trip unit:

- time (t7FW) in the same direction as the reference direction set;
- time (t7BW) in a different direction as the reference direction set.

These times are enabled only when the 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 an advanced function of the PR123/P and PR333/P trip units
- By means of Directional Zone Selectivity, selectivity can be obtained in mesh and ring networks
- Implementing the Directional Zone Selectivity is simple: you do not need special external devices

The SdZ D function is useful in ring and grid type systems in addition to its zone where it is essential to define the direction of the power flow that supplies the fault.

This function is available exclusively on PR123/P and PR333/P trip units and 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 trip units.

Each output is a “block” signal. The breaker that receives the signal will open within the time set; the breaker that doesn’t receive a block signal will open within a set time t7s.

Thus the trip units 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 ANSI C37.17 Standard, “American National Standard for Trip Devices for AC and General Purpose DC Low voltage Power Circuit Breakers”.

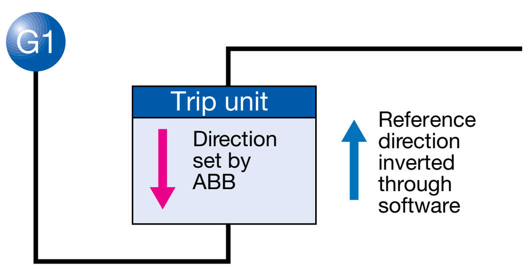
Zone protective interlocking provides a selective trip system which obtains shorter tripping times for upstream circuit breakers for faults located between two or more circuit breakers, while providing coordination of upstream and downstream circuit breakers for through faults. Zone protective interlocking may operate on the short-time-delay trip function and/or the ground fault trip function. It requires communication between the direct-acting trip devices comprising the zone protective interlocking system.

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.

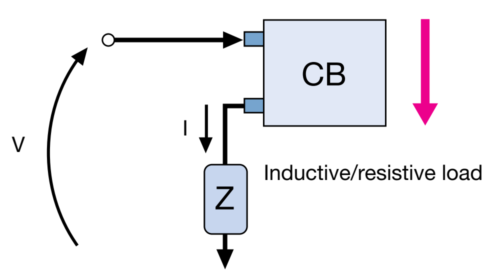
Particularly, a good protection system must be able to:

- sense what has happened and where, discriminating between abnormal but tolerable situations and fault situations within its zone of competence, avoiding unwanted trips 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



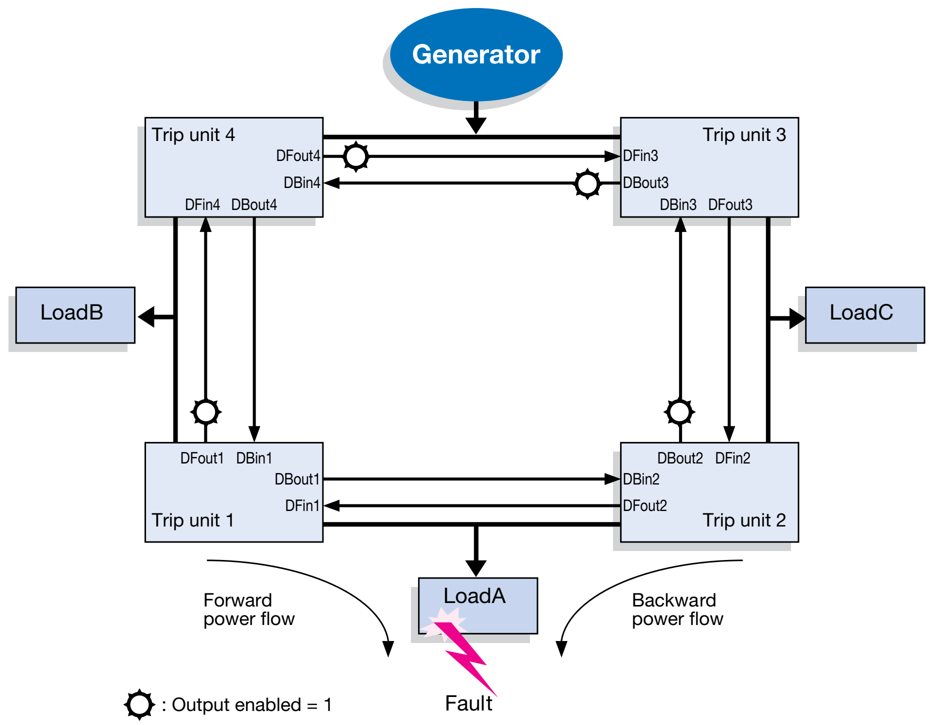
There is a default power flow reference direction on the circuit breaker, indicated by a red arrow. If it is necessary, it is possible to invert the reference direction through the software of the trip unit. Working in this way all the values measured with the PR123 and PR333 trip units will be assessed 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 also defined for the current.

With the D activated, if the direction of the power cannot be established, the trip unit takes effect considering the shorter 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

Even in mesh networks and ring networks, in order to obtain selectivity it is necessary to use a protection that combines zone and directional selectivity: the SdZ D.

An example configuration for which the SdZ D is likely to be used is illustrated in the above figure.

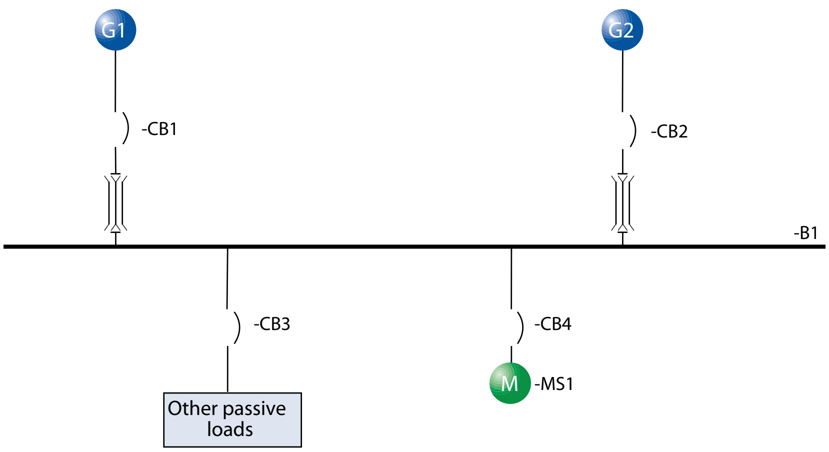
If a fault is detected in one section of the system (Load A), the final circuit breakers of the interested section (trip unit 1 and trip unit 2), communicate the presence of the fault to the connected circuit breakers (trip unit 3 and trip unit 4) by setting the output signals DFout or DBout, depending on the direction of the current (in our case both DFout of trip unit 1 and DBout of trip unit 2 are on).

So the circuit breaker trip unit 1 and trip unit 2, confining the section affected by the fault, are tripped with the set selectivity time t7s, while the circuit breakers further away from the fault count down the delay time set, t7FW (trip unit 4) and t7BW (trip unit 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 a 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 one of the circuit breakers required to open does not operate, a specific function will activate the opening of the first circuit breaker immediately upstream of it, after another approx. 100 ms. In this example, if the circuit breaker does not open with the trip unit 1, only the circuit breaker with trip unit 4 will open after a time t7s+100 ms.

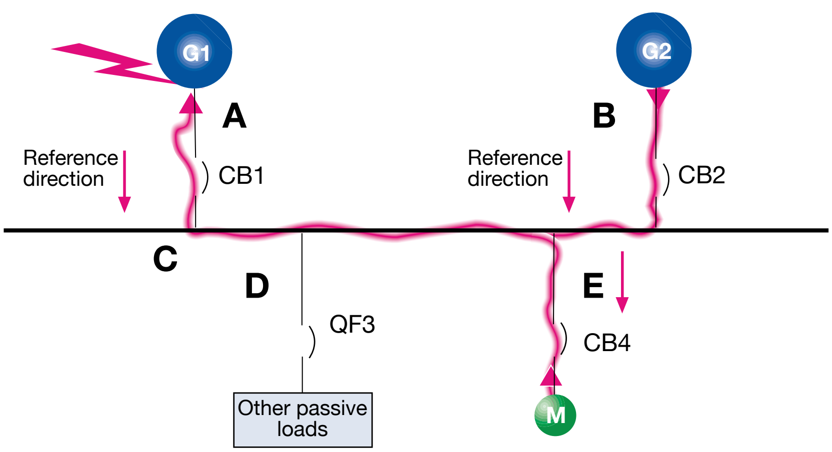
2.4 D application example: Two generators linked at the same busbar



Consider an electrical scheme like the one above. The contribution of the motor to the maximum short circuit current is about 5 kA. The contribution to the short circuit by each generator is about 10 kA.

As a consequence, it is not sure that CB1 and CB2 will be able to distinguish between an upstream and a downstream fault.

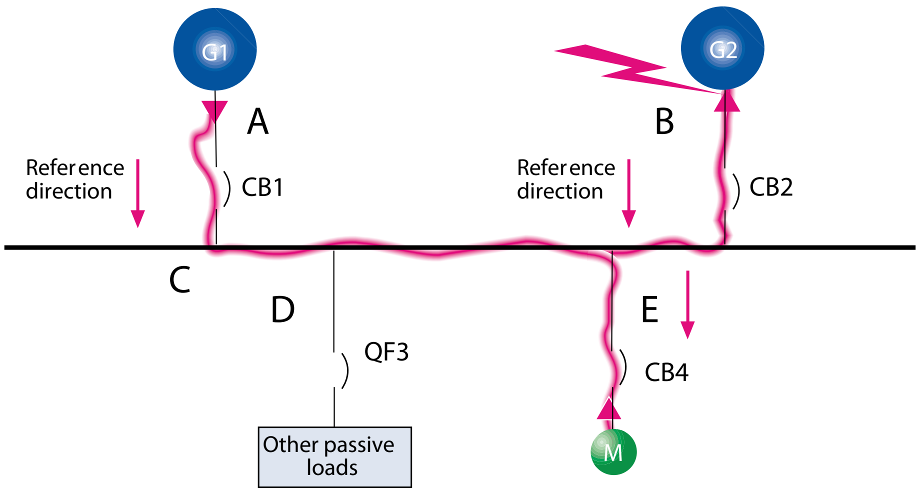
In order to guarantee selectivity between CB1 and CB2 in the event of a fault and to maintain the supply to the other passive loads, it is necessary to use D. Hereunder, an analysis of the two faults on the supply sides taken into consideration:



Let's chose reference directions for CB1, CB2 and CB4 breakers.

In this first case (fault on the supply side of CB1), only CB1 must trip:

1 CB1 detects a current from 10 kA to 15 kA different from with its reference direction, and therefore shall trip in t7BW1 time
2 CB2 detects a current of 10 kA the same as its reference direction, and therefore shall trip in t7FW2 time.
3 CB3 does not detect any fault current
4 CB4 detects a current of maximum 5 kA different from with its reference direction, and therefore shall trip in the t7BW4 time.



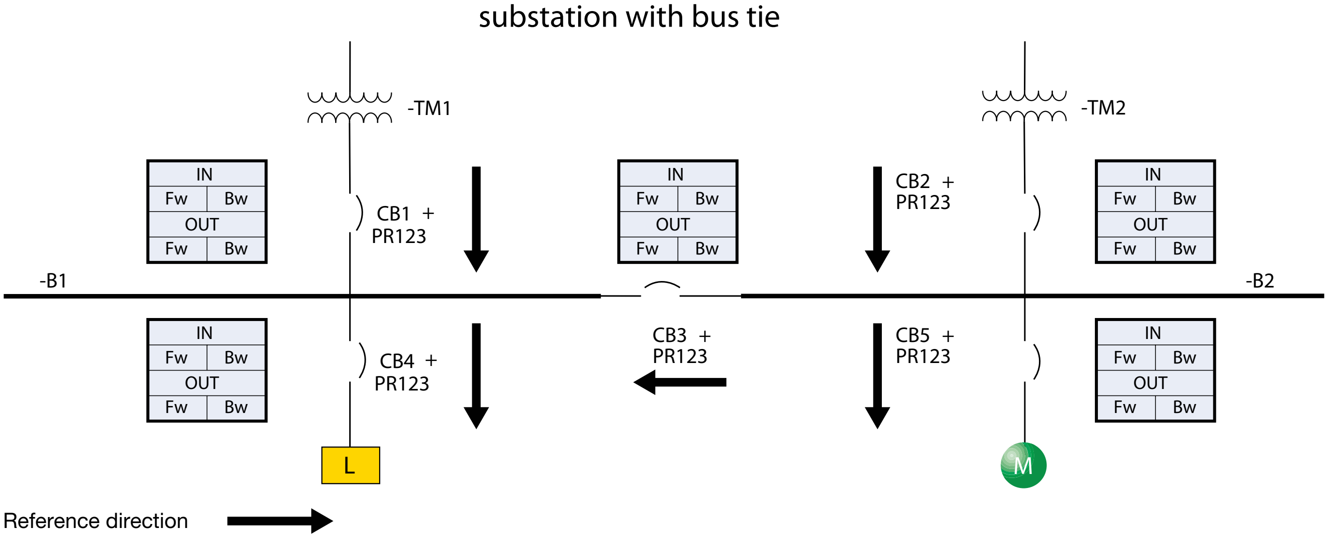
In this second case (fault on the supply side of CB2), only CB2 must trip:

1 CB1 detects a current of 10 kA in the same direction as its reference direction, and therefore shall trip in t7FW1 time
2 CB2 detects a current from 10 kA to 15 kA different from its reference direction, and therefore shall trip in t7BW2 time.
3 CB3 does not detect any fault current
4 CB4 detects a current of maximum 5 kA different from its reference direction, and therefore shall trip in the t7BW4 time.

By repeating the consideration above for any other possible fault, it is 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
CB1	OFF		3 kA	300 ms	200 ms	OFF
CB2	OFF		3 kA	300 ms	200 ms	OFF
CB3	3 kA	200 ms	-	-	-	OFF
CB4	OFF		3 kA	200 ms	300 ms	OFF

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



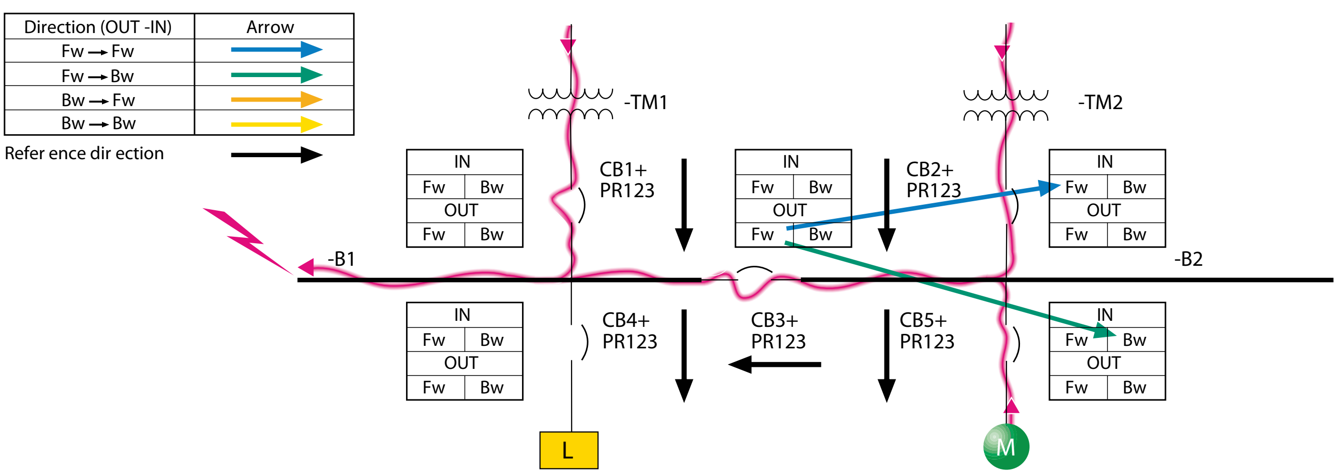
The presence of two or more MV/LV transformers and a bus tie closed on the LV busbars in a transformer substation allows the network to be managed with the transformers in parallel. This kind of configuration has the main advantage of allowing power supply even in the case of outage of one transformer.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

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

The faults now analyzed are: Fault in B1, Fault in B2

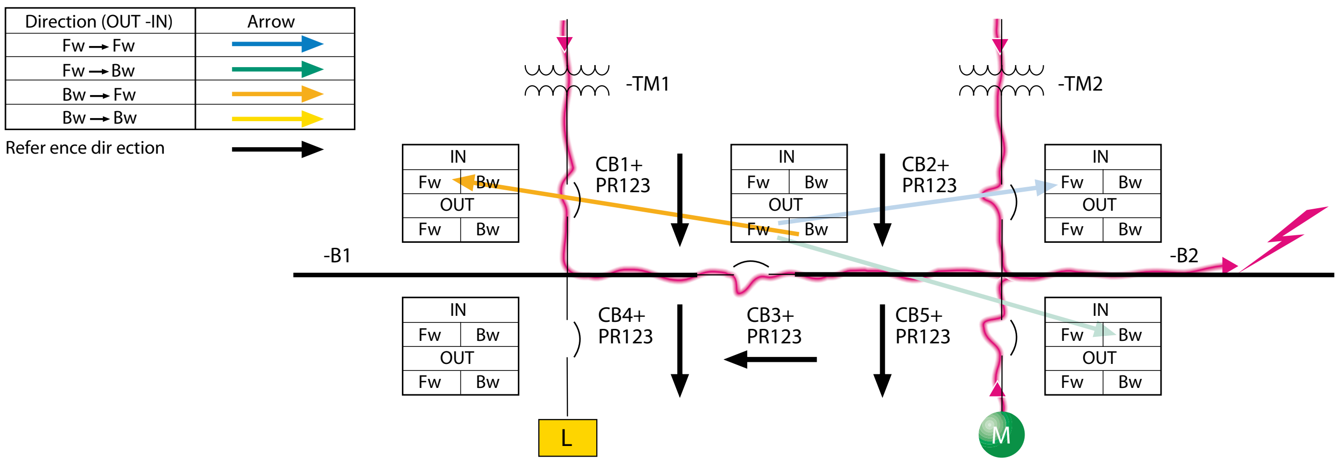
Fault in B1

Only CB1 and CB3 circuit breakers must interrupt the fault: in particular the CB3 circuit breaker is passed through by a current in the same direction as the one set; the DFout sends a lock signal to the DFin of CB2 circuit breaker and to the DBin of CB5 circuit breaker.



Fault in B2

CB2 and CB3 and CB5 circuit breakers must interrupt the fault: in particular the CB3 circuit breaker is passed through by a current coming from busbar B1 (therefore in the opposite direction from the one set); the DBout sends a lock signal to the DFin of CB1 circuit breaker.



The remarks described above are summarized in the following table on the cabling of the system:

Cabling			OUT									
			CB1		CB2		CB3		CB4		CB5	
			FW	BW	FW	BW	FW	BW	FW	BW	FW	BW
IN	CB1	FW						■				
		BW										
	CB2	FW					■					
		BW										
	CB3	FW										
		BW										
	CB4	FW										
		BW										
	CB5	FW										
		BW					■					

Repeating this reasoning for the four other kinds of possible fault (load side of CB4, load side of CB5, supply side of CB1 and supply side of CB2), it is possible to establish a global table for the system:

Cabling			OUT									
			CB1		CB2		CB3		CB4		CB5	
			FW	BW	FW	BW	FW	BW	FW	BW	FW	BW
IN	CB1	FW						■	■			
		BW										
	CB2	FW					■				■	
		BW										
	CB3	FW							■			
		BW				■					■	
	CB4	FW										
		BW										
	CB5	FW										
		BW				■	■					

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
CB1	OFF		$<Ik_{min}$	350 ms	250 ms	150 ms	OFF
CB2	OFF		$<Ik_{min}$	350 ms	250 ms	150 ms	OFF
CB3	OFF		$<Ik_{min}$	300 ms	300 ms	150 ms	OFF
CB4	OFF		$<Ik_{min}$	250 ms	350 ms	150 ms	OFF
CB5	OFF		$<Ik_{min}$	250 ms	350 ms	150 ms	OFF

Selectivity time t7s can be adjusted from 130 to 500 ms, while t7FW/BW is to be adjusted from 200 to 800 ms 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 circuit breakers in series in auxiliary power supply, to guarantee that the circuit breaker on the supply side does not trip.

It is 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, the line protection is always enabled, the auto-protection of the circuit breaker.

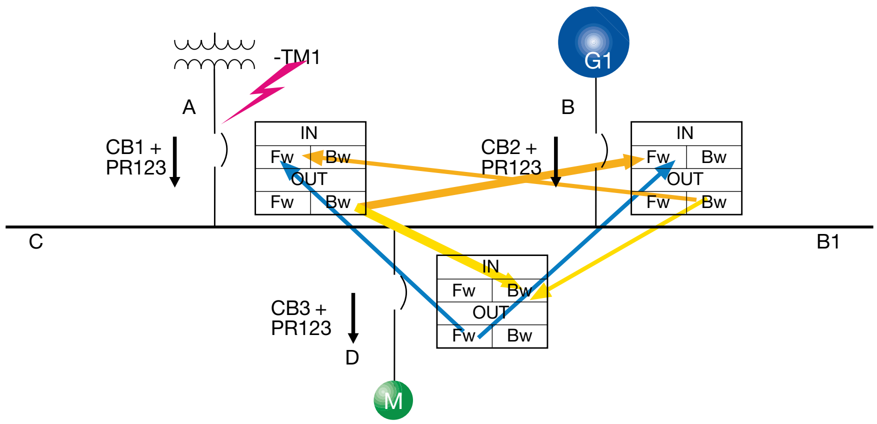
In the same way, if the function S is enabled and the short circuit current exceeds the value set I2, the circuit breaker will open in the t2 time if this is shorter than the other times, regardless of the directions and signals received.

2.6 SdZ application example 2: Presence of low voltage generators

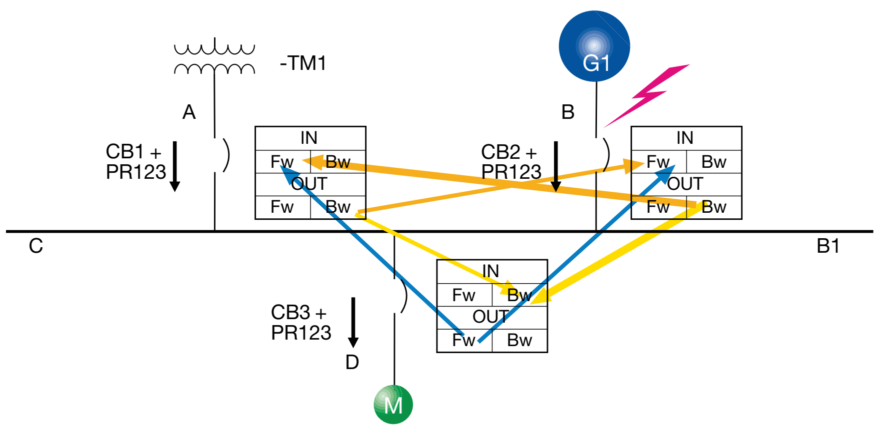
SdZ D may be very useful when generators are present in the low voltage network. This is a situation that will happen more and more frequently in the future, due to the diffusion of distributed energy resources.

Let TM1 be the MV/LV transformer, CB1 its LV protection, G1 the low voltage generator, CB2 its protection, B1 the low voltage busbar, M a motor load, CB3 its protection.

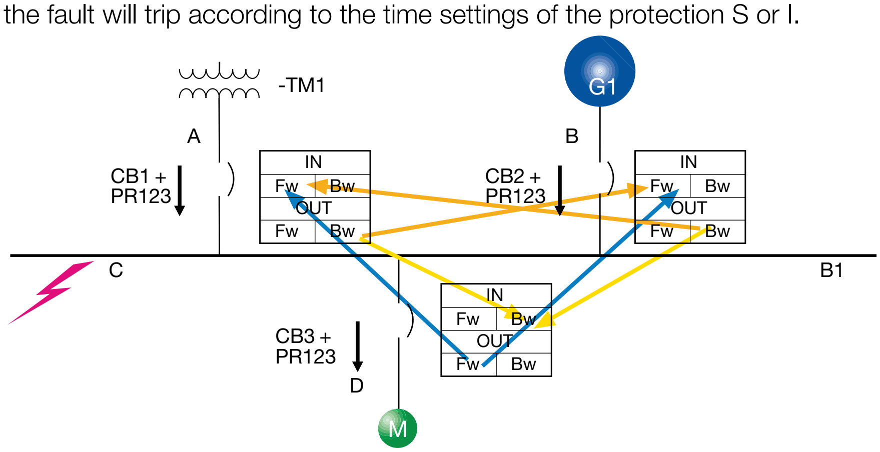
In the case of fault in A, circuit breaker CB1 is passed through by a current that flows in a direction against with the one set (black arrow). The DBout of CB1 “blocks” the DFin of CB2 and the DBin of CB3. Current flows through CB2 in the same direction as the setting, whereas CB3 is passed through by a current against the setting (the active "block" signals are indicated by wider arrows).



In the case of a fault in B, the circuit breaker CB2 is passed through by a current from busbar B1. This current flows in a direction against the one set. The DBout of CB2 "blocks" the DFin of CB1 and the DBin of CB3. In fact, current flows through CB1 in the same direction as the setting, whereas CB3 is passed through by a current opposite from the setting.



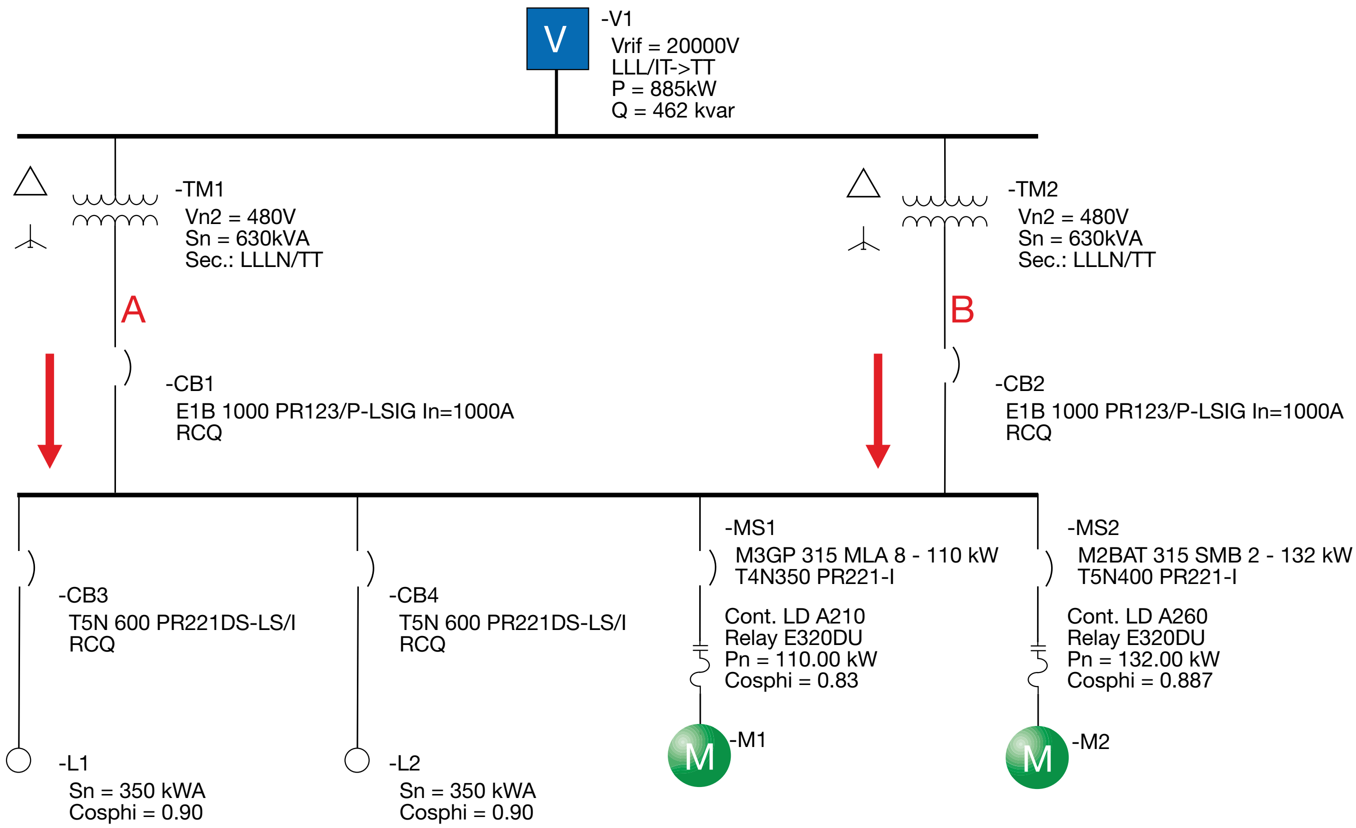
In case of fault in C, CB1 and CB2 are passed through by a current flowing in the same direction as the one set, whereas CB3 is passed through by a current with the opposite direction. No circuit breaker is blocked and consequently all the circuit breakers affected by the fault will trip according to the time settings of the protection S or I.



3. References

3.1 Reference for D

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



Plant main features	
Operating voltage	480 V
Rated frequency	60 HZ
Installed power	850 kW
Busbar short-circuit current	28 kA

Above is a sketch of an electrical plant for a food plant.

Assume reference direction as in the picture above (red arrows).

From each transformer a contribution to the short circuit current equal to about 13 kA flows to the low voltage busbar. The two motors together give a contribution to maximum short circuit current of about 2 kA.

We have two possible faults near the sources, a fault at load side of TM1 and a fault at load side of TM2.

In the first case (fault in A), CB1 is passed through by a current of a value included between 13 kA and 15 kA, while CB2 is passed through by a current of about 13 kA. Only CB1 must trip: in this manner, shedding the low priority load L2, it is possible to keep on load L1, M1 and M2. Because there may be no difference between the two short circuit values, it is not possible to use a protection S setting in order to guarantee selectivity between CB1 and CB2. The second case (fault in B) is exactly the same. So, only using D (with t7FW times longer than t7BW times) selectivity between CB1 and CB2 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
CB1	OFF		4	300 ms	200 ms	OFF
CB2	OFF		4	300 ms	200 ms	OFF
CB3	4.5	100 ms	-	-	-	OFF
CB4	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 circuit breakers 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 circuit breakers must have a short withstand current value higher than the maximum prospective short circuit current that 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

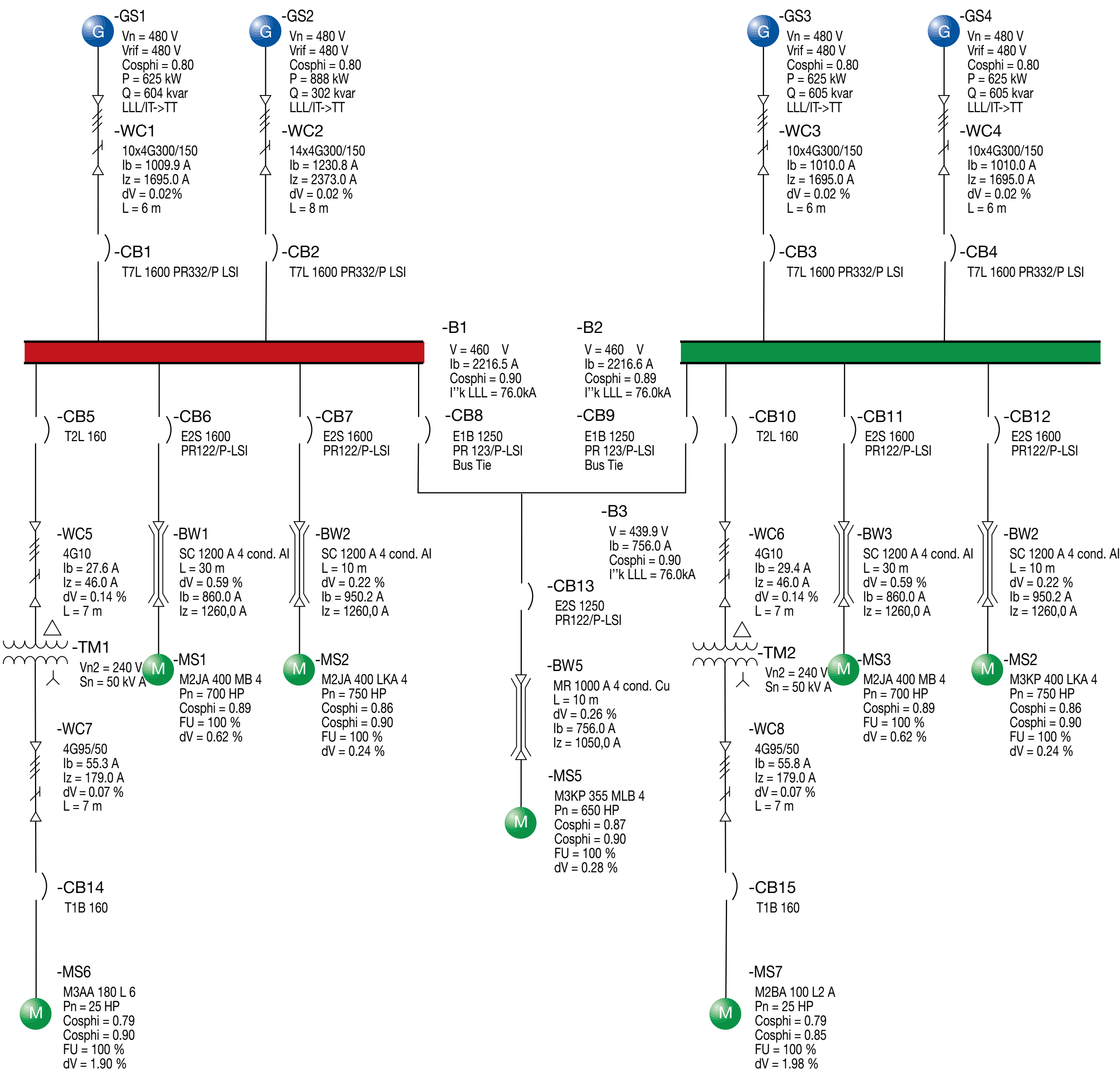
3. The trip threshold of protections S and I must be set in such a way so as not to create trips overlapping with function D.

3.2 References for SdZ

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

3.2.1 Marine electrical plant (civilian)

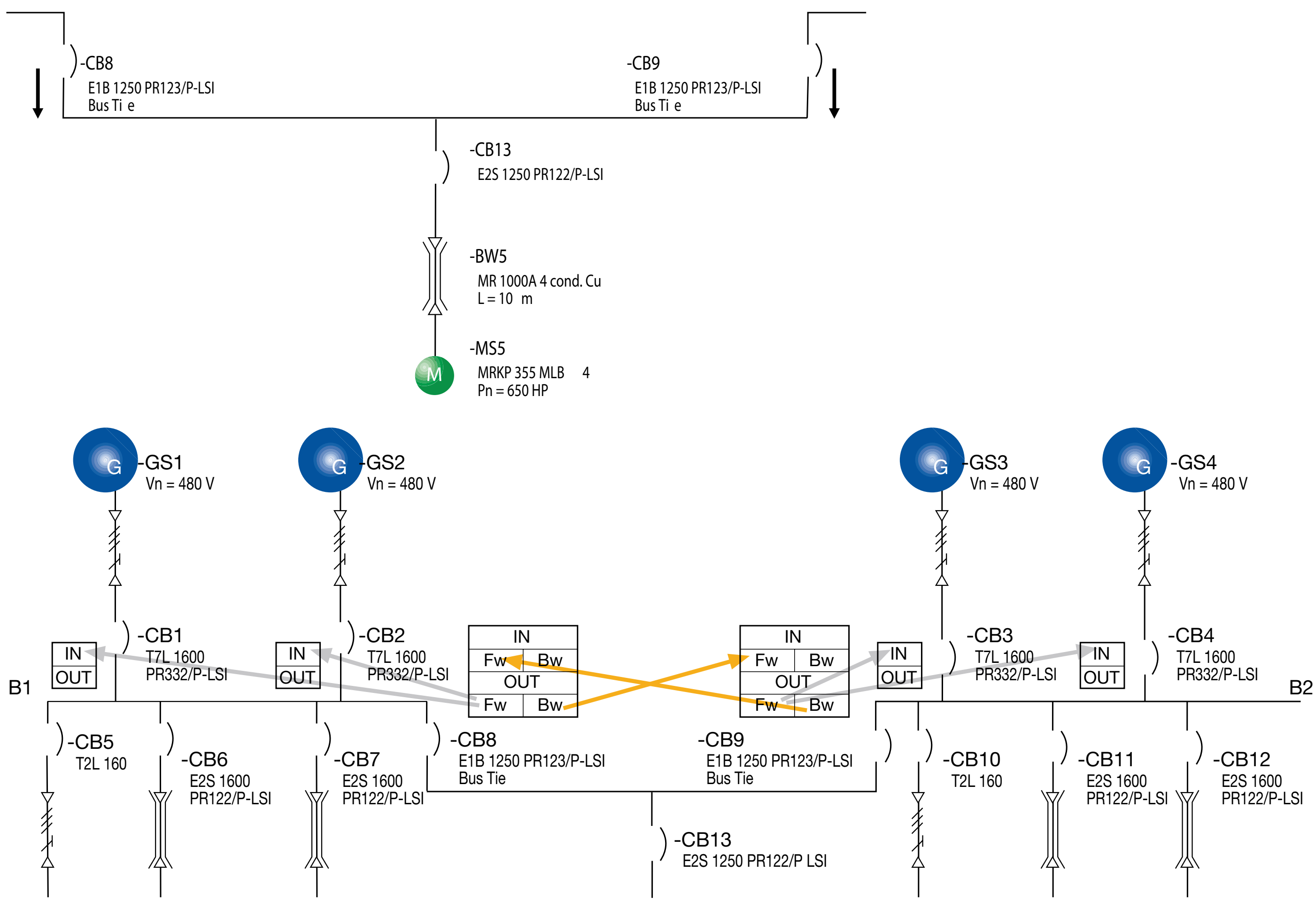
An IEC electrical plant of a large ferryboat:



Main plant features	
Operating voltage	480 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 shall be supplied 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 are indicated in the picture below:



In the event of a fault on the busbar B2 the bus tie of busbar B1 must remain closed, while bus tie B2 must trip so that the fault is isolated.

Moreover, CB1 and CB2 breakers must also remain closed and not trip even if they are passed through by a considerable current.

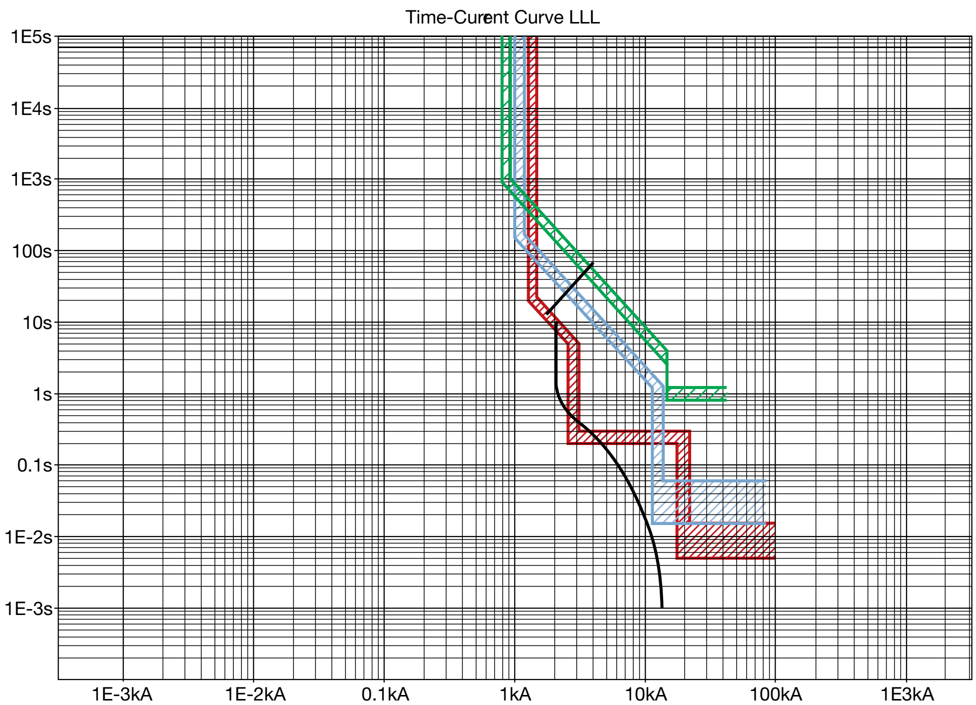
At the same time, CB1 and CB2 must suitably protect the generators, and their S protection function has to intercept the curve of the generator in the event of a fault on busbar B1.

Because of these two opposing issues, CB1 and CB2 have been equipped with PR332/P trip units, with which it is possible to implement the zone selectivity.

In the event of a fault on the busbar B2, CB8 will block CB1 and CB2, which will open in S time t2 (set at 0.25 s). However, in the event of a fault on the busbar B1 they will quickly open in t7s time (set at 0.15 s, so that it intercepts the decreasing 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 necessary to act in a similar way.

In the picture above, the plant logic is summarized, hinged on the two PR123/P trip units with SdZ D.

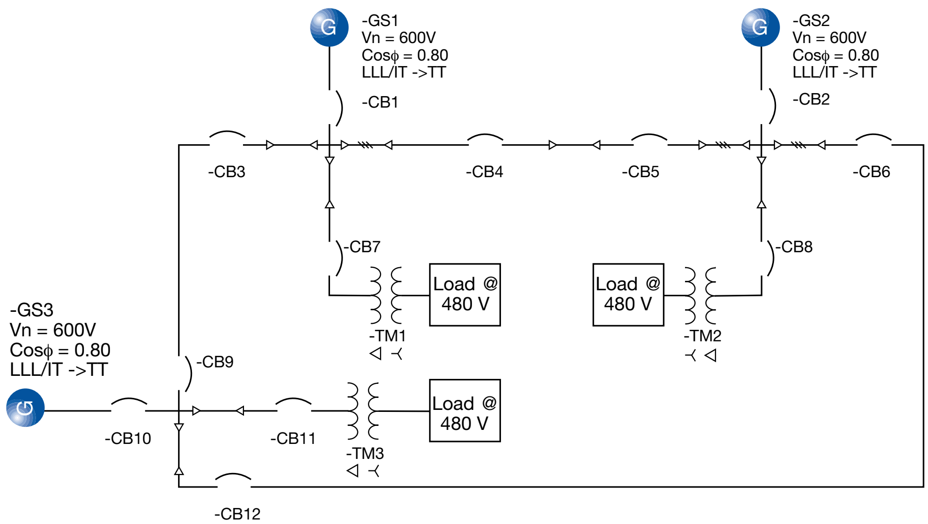


Here above, the set time-current curves for generator GS2 (black line), generator protection CB2 (red), motor protection CB7 (blue) and bus tie CB8 (green) are indicated.

This brief table shows the chosen settings of the breakers considered in the time-current graph.

Protection function	S		D			I
CB	I2	t2	t7FW	t7BW	t7SEL	I3
CB2	1.8	250 ms	-	-	150 ms	OFF
CB7	OFF	OFF	-	-	-	8
CB8	OFF	OFF	250 ms	-	150 ms	OFF

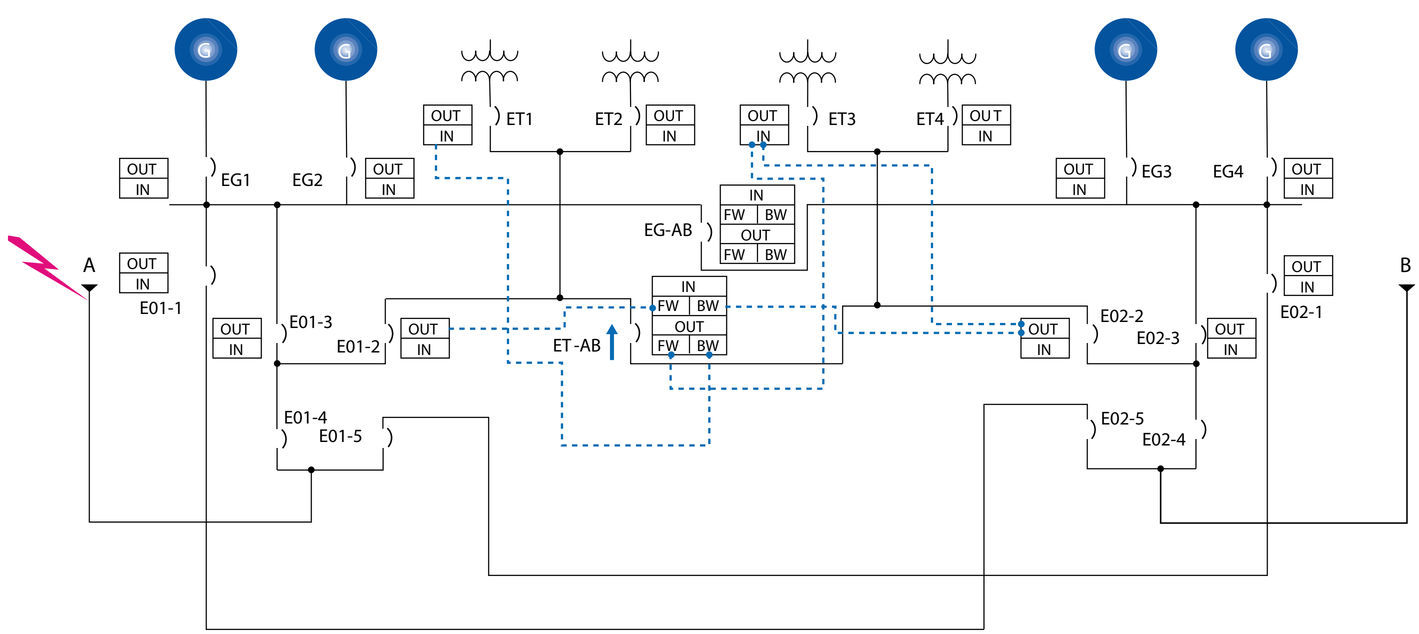
3.2.2 Military naval electrical plant



Main plant features	
Operating voltage	480 V
Rated frequency	60 HZ
Installed power	7.5 MVA
Ring short-circuit current	65 kA

Above is a simplified sketch of a part of a 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 by using SdZ D it is possible to reach selectivity (see paragraph 2.1).

3.2.3 High reliability military electrical plant



Main plant features	
Operating voltage	480 V
Rated frequency	60 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's focus on the 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 closed at the same time.

Moreover, the generators cannot operate in parallel with the transformer, except for few minutes.

Let's analyze two different fault types:

1) Fault in the main switchboard A with only TR1 and TR3 on duty

In this case:

- 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 the same direction as 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:

- 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 the opposite direction as the one set), so the DFout sends a lock signal to the DFin of ET1.

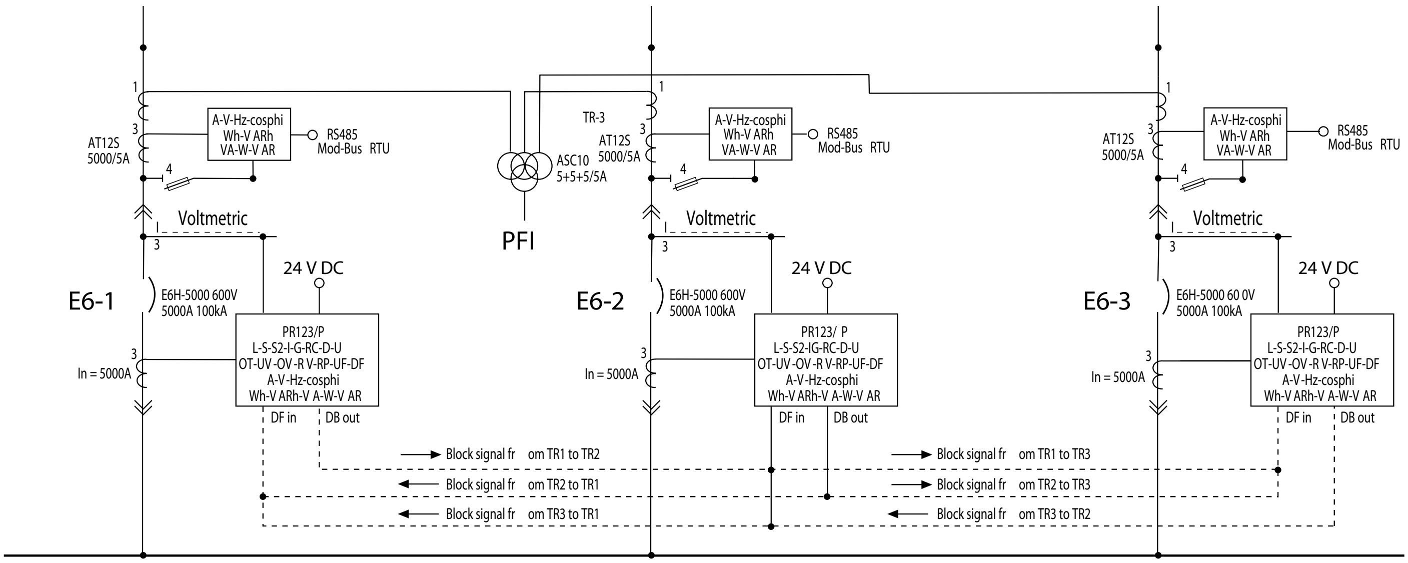
It is quite clear that only using a SdZ D for the ET-AB relay it is possible to reach a good degree of selectivity in this plant.

4. Practical Guide

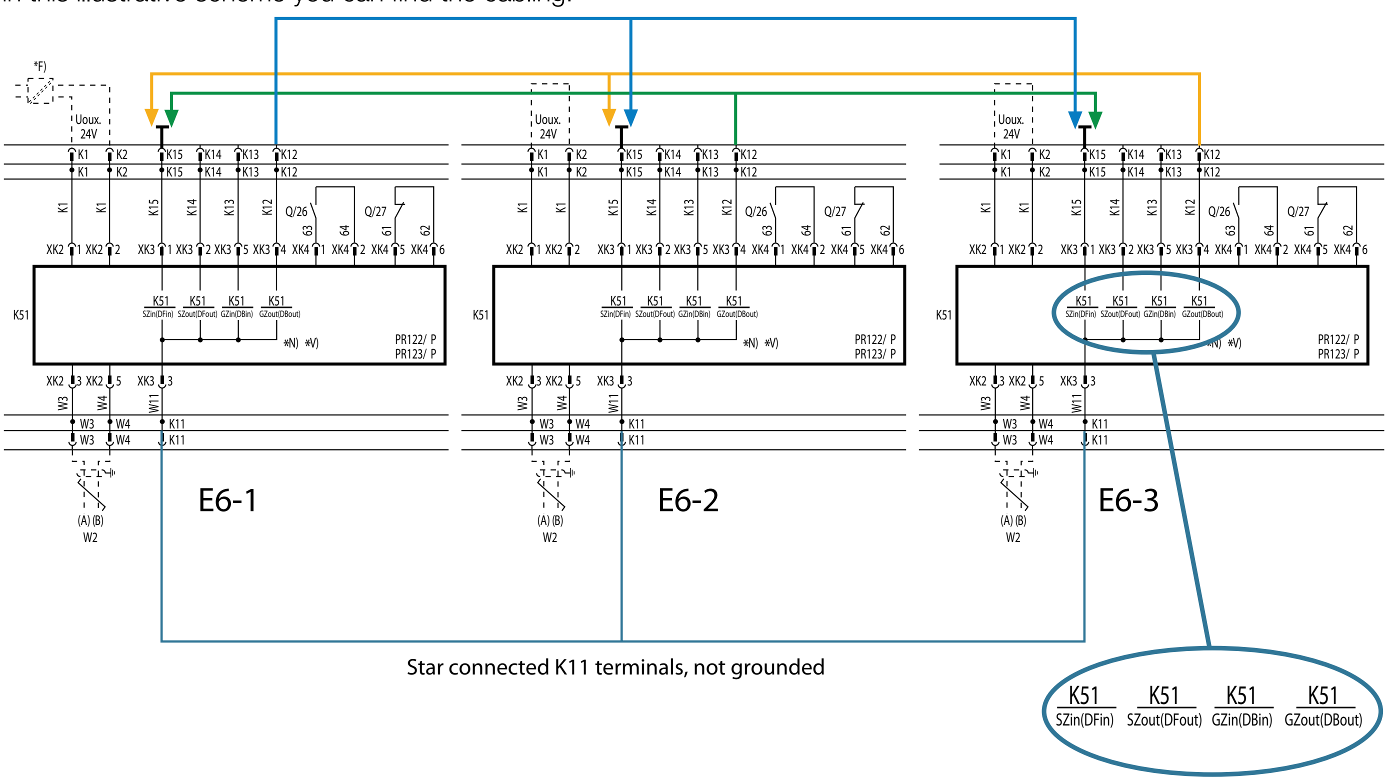
4.1 About SdZ

4.1.1 An overview

To set up the SdZ D function you must suitably connect the K11 – K15 terminals on EMAX terminal box. For example, if you have a system like the following (sketch of a part of a real electrical plant of an electronic equipment factory):



in this illustrative scheme you can find the cabling:



The terminals that must be connected are physically present (and clearly identified) in EMAX terminal box.

4.1.2 "Shopping list" section

To use SdZ D the following is needed:

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

All EMAX frames 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 that can be used for the application is the “Belden 3105A”, manufactured by BELDEN. The conductor diameter is 0.30 inch, characteristic impedance is 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 ground in correspondence with one of the two trip units. When it is possible to find an additional circuit breaker “on the supply side” between the two, it is advisable to connect the shield to ground in correspondence with the trip unit of the circuit breaker.

The maximum length of cabling between two units for zone selectivity is 300 meters. This limit can be increased using a 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 circuit breaker supplied.

4) Some special devices for some particular applications

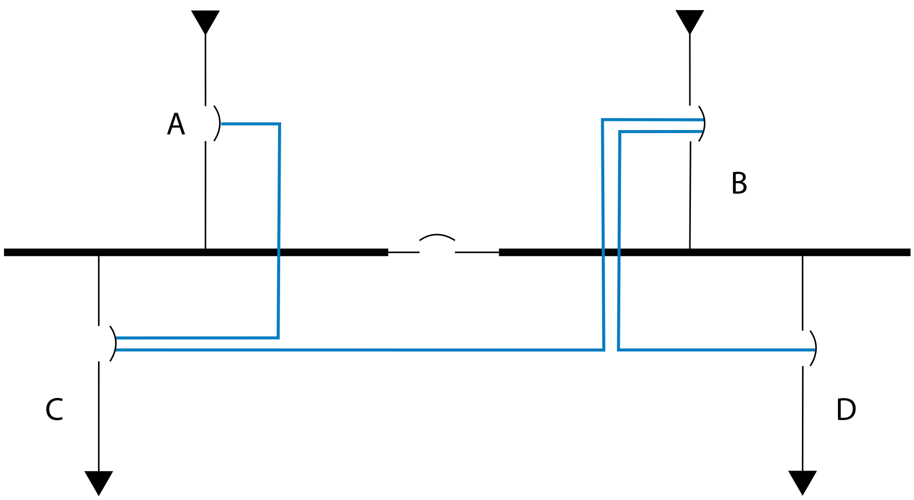
4a) Zone Selectivity Array

With reference to the figures below, in a specific case of current flow:

C must lock A and B

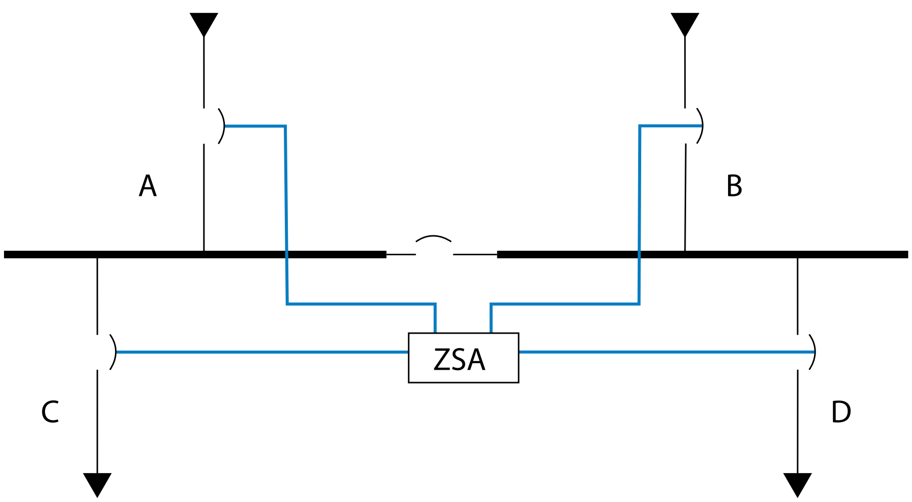
D must only lock B

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

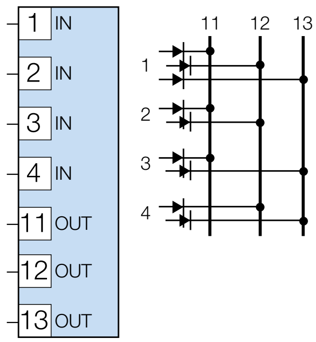


In fact, the lock signal coming from D would also be transmitted to A by means of the electrical continuity which is created between the different B-C and C-A interlocking connections.

By means of suitable cabling of the Zone Selectivity Array module (ZSA). 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 circuit breakers which can be connected to the outputs of a trip unit is 20, for PR123 that blocks other PR123s. 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 circuit breakers which can be connected to the inputs of a PR123 trip unit is indefinitely high.

4b) Zone Selectivity Buffer

As above, the maximum number of circuit breakers 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 is possible to use a Zone Selectivity Buffer (ZSB) unit.

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

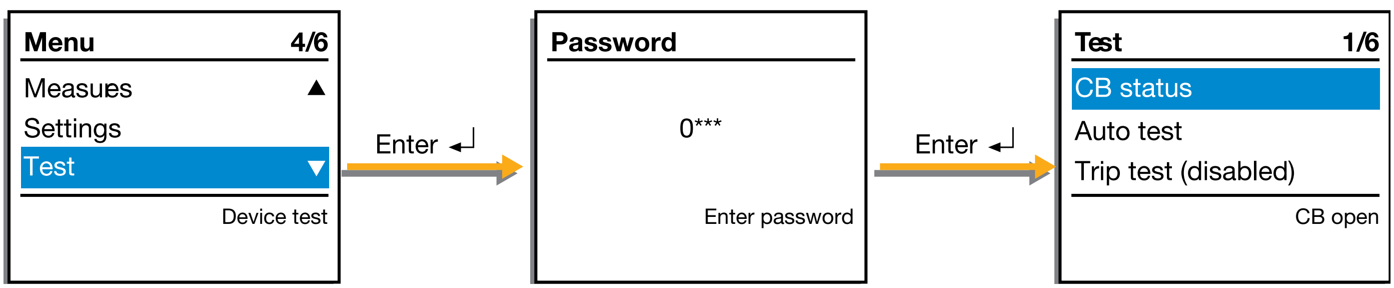
4.1.3 Testing field

There are two different kinds of tests 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 by ABB technicians.

4.1.3.1 Testing with the PR123 test function

Testing SdZ D using the 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 trip unit's Test Menu selecting the "Zone selectivity" menu.



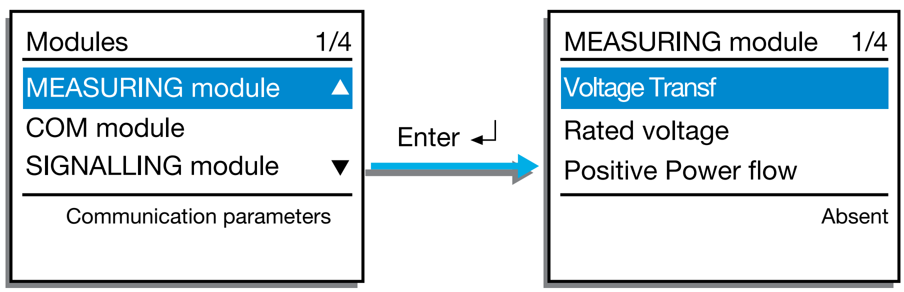
4.1.3.2 Testing with the Ts3 unit

By using the special Ts3 testing unit, it is possible to simulate short circuit current on several breakers, and then to test the correct working of the SdZ D function.

To simulate the test, the Ts3 unit applies a suitable current to the secondary of the PR113/P CS or sets a suitable voltage in the Rogowski coil of the PR123/P, so that the PR1x3/P sees a fault current.

4.2 About D

D does not need a terminal connection or an external power supply. Once the customer has decided to use D, they just have to choose the power flow direction.



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 is only possible to test D protection using the Ts3 unit (see paragraph 4.1.3.2).

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, “Low voltage selectivity with ABB circuit breakers”, May 2008, code 1SDC007100G0204.

ANSI C37.17 “American National Standard for Trip Devices for AC and General Purpose DC Low Voltage Power Circuit Breakers”

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

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Notes

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1SXU210200G0201 March 2010

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