TECHNICAL GUIDE

COORDINATION

BETWEEN PROTECTION DEVICES

THE GLOBAL SPECIALIST IN ELECTRICAL AND
DIGITAL BUILDING INFRASTRUCTURES

legrand®

Coordination between protection devices against overcurrents consists of coordinating the characteristics of several protection devices installed in series, with two different objectives:

Selectivity, which prevents the entire installation being put out of service when a fault occurs on one part of the installation,
for performance reasons

Back-up (or more generally back-up protection, if the protection devices are not circuit breakers), which increases the breaking capacity Icu of the downstream protection, for economic reasons

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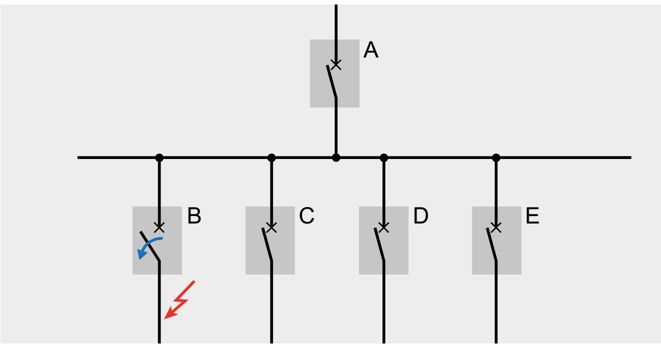
THE SELECTIVITY

Definitions

Selectivity means that, when a fault occurs, only the part of the installation concerned by this fault is isolated.
It is required when several protection devices are installed in series and when it is justified by safety or operating requirements. Selectivity is based on coordinating the operating characteristics of protection devices so that the intended device operates when overcurrents occur within the given limits, whereas the other devices, located upstream, do not operate.



■ Example

As a result of the selectivity between protection devices A and B, the fault which occurs downstream of B does not affect the other parts of the installation.

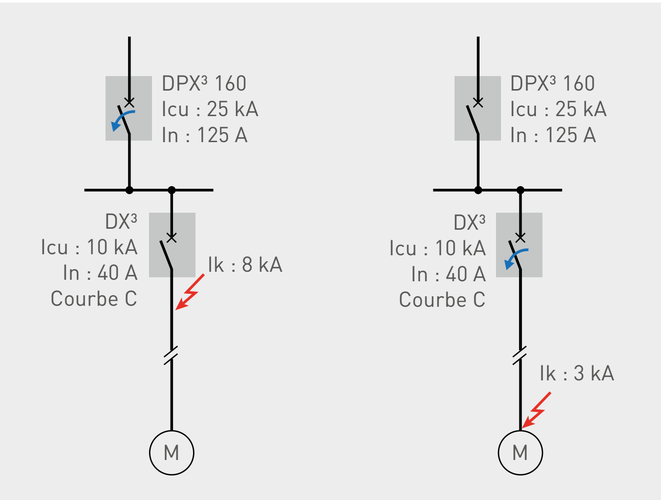
Selectivity improves the continuity of service and safety of the installation. There are two types of selectivity: **partial selectivity** and **total selectivity**.

PARTIAL SELECTIVITY

Selectivity between two protection devices installed in series is said to be "partial" when the downstream protection device provides protection up to a given overcurrent level without triggering operation of the upstream protection device. Above this overcurrent level, the upstream device will provide the protection.

Since almost all faults occur during use, partial selectivity may be adequate if the selectivity limit is higher than the value of the maximum short circuit which may occur at the point of use (or at the end of the trunking). This is referred to as "operating selectivity".

This technique is very often adequate, more economical and less restricting in terms of implementation.

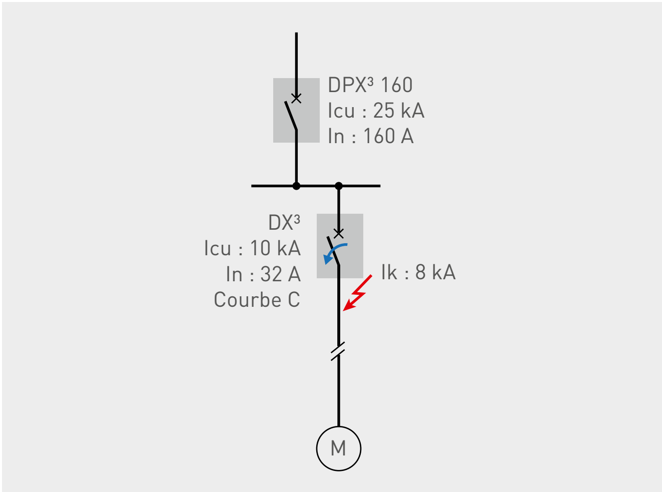


■ Example

The selectivity limit for coordination of the DPX³ 160 - 25 kA - 125 A with the DX³ 10 kA - 40 A - C curve is 6 kA. As the maximum short-circuit level (Ik max) at the installation point is 8 kA, the selectivity is not total. However, there is total selectivity at the point of use where the prospective short-circuit current is only 3 kA.

TOTAL SELECTIVITY

Selectivity between two protection devices installed in series is said to be "total" when the downstream protection device provides protection up to the value of the maximum prospective short circuit at its installation point without triggering operation of the upstream protection device.



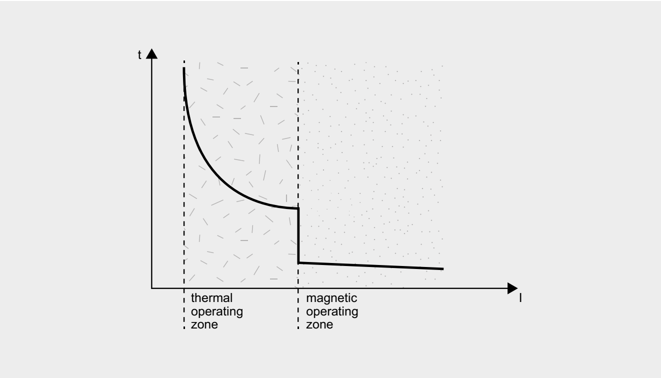
■ Example

The selectivity limit for coordination of the DPX³ 160 - 25 kA - 160 A with the DX³ 10 kA - 32 A - C curve is 10 kA.

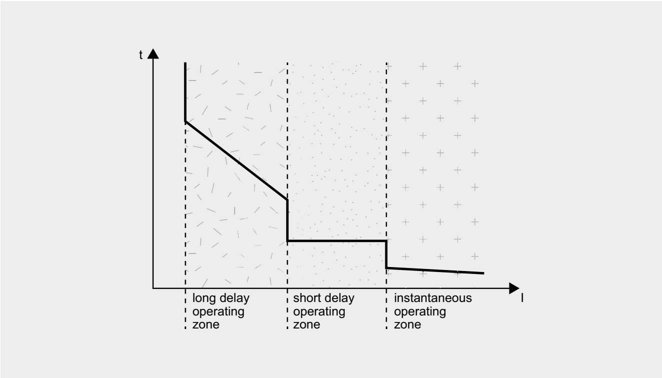
As the maximum short-circuit level (Ik max) at the installation point is 8 kA, the selectivity is total.

Methods of checking the selectivity level

To confirm whether the selectivity level for two circuit breakers installed in series is total or partial, **the selectivity must be checked for the various trip zones of the devices.**

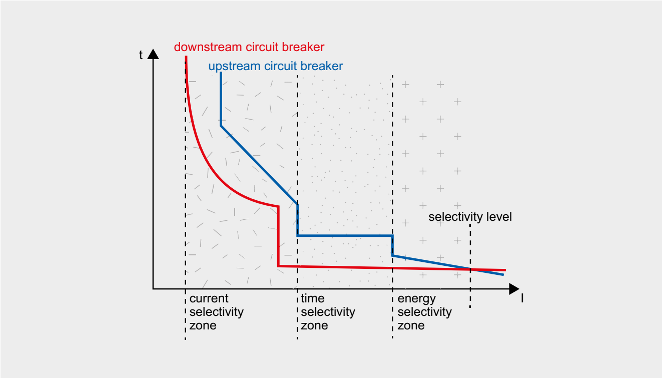


Trip zones of a thermal magnetic circuit breaker



Trip zones of an electronic circuit breaker

Three checking methods must be used in sequence:
- Current selectivity
- Time selectivity
- Energy selectivity



The check consists of ensuring that that the curves do not intersect before the required selectivity level.

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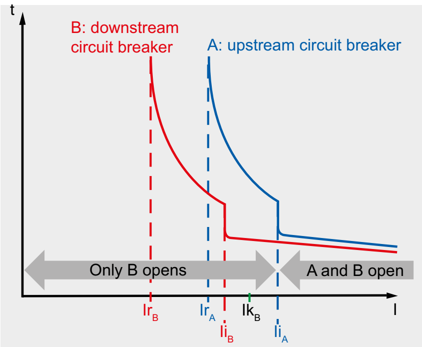
CURRENT SENSING SELECTIVITY

This technique is based on the difference in the intensity of the tripping curves of the upstream and downstream circuit breakers. It is checked by comparing these curves and ensuring that they do not overlap.



Ik_B: maximum short circuit at the installation point of circuit breaker B

It applies for the overload zone and the short-circuit zone, and the further apart the ratings of the devices, the better the selectivity.

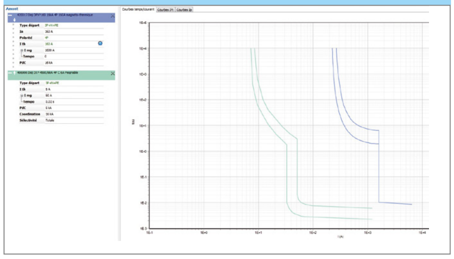
■ **Application rules**

- To obtain selectivity in the overload zone, the ratio of the setting currents (Ir) must be at least 1.6.
- To obtain selectivity in the short-circuit zone, it is generally adequate for the ratio of the magnetic setting currents (Ii) or short delay currents (Isd) for electronic circuit breakers to be at least 1.6. The selectivity limit is then equal to the magnetic tripping current Ii_A (or short delay current Isd_A for an electronic circuit breaker) of the upstream circuit breaker. The selectivity is therefore total as long as $Ik_B < Ii_A$ (Isd_A).

Current sensing selectivity is therefore very suitable for final circuits where the short circuits are relatively weak.

CHECKING SELECTIVITY WITH THE XLPRO³ BACK-UP/SELECTIVITY TOOL

The selectivity is checked using tables or by comparing the tripping curves of the protection devices using the Legrand "XLPRO³ BACK-UP/SELECTIVITY TOOL" software. This tool can be downloaded from the Legrand website free of charge. It is an additional option for XLPRO³ CALCUL which makes it easy for users to obtain the required level of selectivity.
Product benefits:
- Can be used to adjust values to match customer requirements as closely as possible
- Automatic updating of the software and the selectivity tables



(Valeurs en kA)			DPX 1600;EL#DPXSHA				DPX 250;EL#DPXSHA				DP
		In (A) >=	630	800	1250	1600	40	100	160	250	25
	In (A) <=	Ir (A)									
DPX 125 25kA	25		T	T	T	T	T	T	T	T	T
	63		T	T	T	T		T	T	T	T
	125		T	T	T	T			T	T	T
DPX 125 36kA	25		T	T	T	T	25	25	25	25	T
	63		T	T	T	T		25	25	25	T
	125		T	T	T	T			25	25	T
DPX 1250	630			36	36	36					
	1000				36	36					
	1250					36					
DPX 160 25kA	63		T	T	T	T		T	T	T	T
	100		T	T	T	T			T	T	T
	160		T	T	T	T				T	T
	250		T	T	T	T					
DPX 160 50kA	25		T	T	T	T	25	25	25	25	36
	63		T	T	T	T		25	25	25	36
	100		T	T	T	T			25	25	36
	160		T	T	T	T				25	36
	250		T	T	T	T					
DPX 1600;EL	630			36	36	36					

Refer to the technical guide "Logical selectivity" available on the Legrand website.

Legrand provides tables detailing the three selectivity zones for its circuit breakers. These tables can be accessed in some technical data sheets or in the XLPRO³ BACK-UP/SELECTIVITY TOOL application.

The letter "T" (for "Total") indicates that there is selectivity up to the breaking capacity of the downstream device. When a value is given, it must be compared with the prospective short-circuit current at the installation point of the downstream device to check whether the selectivity is total.

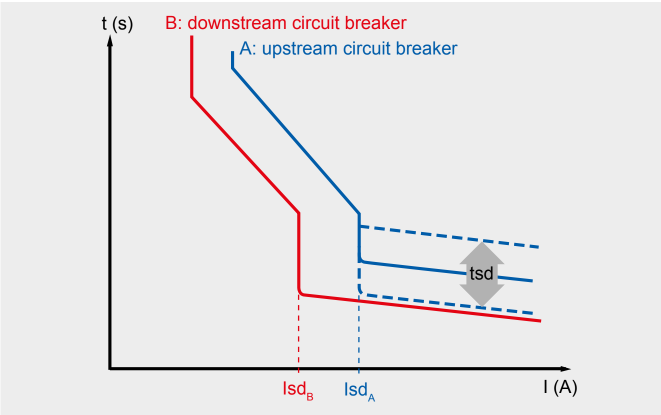
NB: The current settings of the circuit breakers given in the tables are assumed to be their maximum values. If the settings are different, it is advisable to check the selectivity in the current and time zones, while the values given remain true in the energy zone.

If it is not possible to obtain the required selectivity level using conventional methods, there are two additional techniques with Legrand electronic circuit breakers:
- Dynamic selectivity
- Logical selectivity

TIME SELECTIVITY

This technique is based on the difference in the times of the tripping curves of the circuit breakers in series. It is checked by comparing the curves and is used for selectivity in the short-circuit zone.

It is used for selectivity in the medium intensity short-circuit zone.



It is used in addition to current selectivity in order to obtain selectivity beyond the magnetic setting (or short delay) current of the upstream circuit breaker (IiA or IsdA).

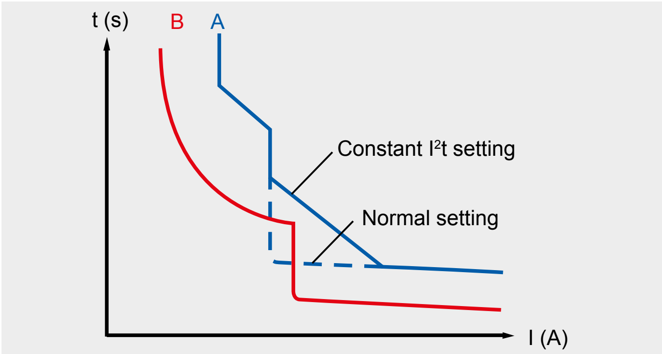
■ **Application rules**

The non-tripping time of the upstream device must be longer than the breaking time (including any time delay) of the downstream device.

The following conditions must be met for this:

- It must be possible to set a time delay on the upstream circuit breaker
- The upstream circuit breaker must be able to withstand the short-circuit current and its effects for the whole period of the time delay
- The conductors through which this current passes must be able to withstand the thermal stresses (I^2t).

Using circuit breakers with electronic releases set at constant I^2t improves the selectivity.

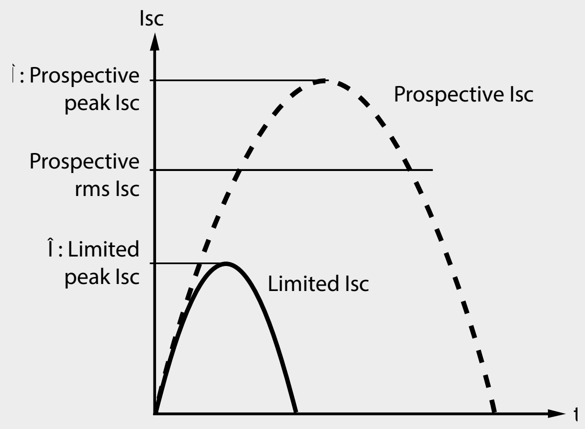


Removal of the short delay section of the tripping curve avoids overlapping of the tripping curves. This option is available on electronic DPX and DPX³, and on DMX³.

DPX, DPX³ and DMX³ circuit breakers have a number of time delay setting positions for implementing selectivity with a number of stages.

ENERGY SELECTIVITY

This is based on the capacity of the downstream protection device to limit the energy flowing through it to a value lower than that required to cause tripping of the upstream device.
It is checked by reading the manufacturers' selectivity tables.



If there is a short circuit, without any protection, the current that would flow through the installation is the prospective short-circuit current. When a short-circuit current crosses a circuit breaker, the circuit breaker has the capacity, to a greater or lesser extent, to allow only part of this current to flow. The short circuit is then limited in amplitude and duration.

When the downstream circuit breaker B is a limiting device, the short-circuit current is limited in terms of both time and amplitude. The selectivity is therefore total if the limited current (IkB) which device B allows to pass is lower than the tripping current of device A.

Energy selectivity is used in the high intensity short-circuit zone.
The selectivity tables give the short-circuit current limit value for total selectivity between two circuit breakers. When this value is at least equal to the breaking capacity Icu of the downstream circuit breaker, it is simply marked "T".

Additional selectivity techniques

DYNAMIC SELECTIVITY

Dynamic selectivity is a particular type of selectivity developed by Legrand. It is based on making maximum use of the limitation characteristics of moulded case circuit breakers and extends the concept of time coordination to the highest short-circuit currents.

Dynamic selectivity operates between an electronic DPX/DPX³ circuit breaker installed upstream and an electronic or thermal magnetic DPX/DPX³ circuit breaker installed downstream.

Electronic DPX and DPX³ have a 2-position setting:

- "High" for a higher selectivity level
- "Low" for a normal selectivity level

Electronic circuit breakers set to "High" have a slight tripping delay which enables a high selectivity level to be obtained even for the highest short-circuit currents.

■ **Application rules**

Before considering dynamic selectivity, the time selectivity must be checked for medium intensity short-circuit currents by comparing the tripping curves.
When this has been checked, the following rules can be applied:

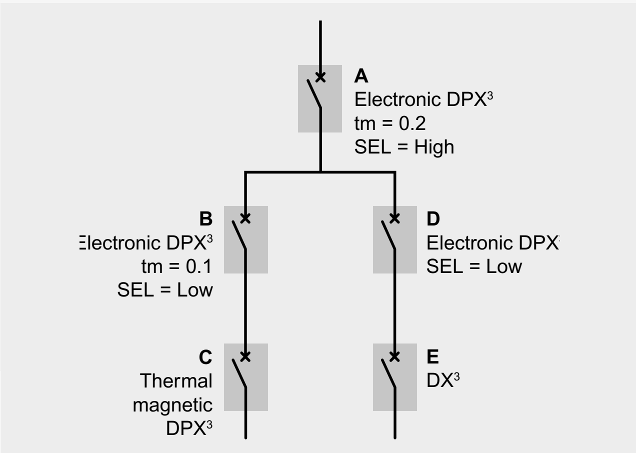
- The upstream circuit breaker must be set to "High"
- The downstream circuit breaker can be an electronic DPX or DPX³ set to "Low", or a thermal magnetic DPX³

Dynamic selectivity does not apply to the S1 electronic trip units of the DPX³ 630/1600.

On DPX³ dynamic selectivity is set on the LCD screen in the same way as the other settings

■ **Exemple**

Dynamic selectivity between 2 levels



Dynamic selectivity is particularly useful for installations characterised by a high intensity short-circuit current, when the circuit breakers concerned are in the same distribution board.

Dynamic selectivity enables:

- The selectivity limit for high intensity short-circuit currents to be increased in comparison with conventional energy selectivity
- The continuity of service and safety to be increased simply and economically

When there is no specific requirement for selectivity or the device is protecting a final circuit, it is not necessary to activate this function.

■ **Upstream**

A : electronic DPX or DPX³ with "S2" release and the SEL selector switch set to High (tm = 0.2, considered to be the result of the previous time selectivity study on medium intensity short circuits)

■ **Downstream**

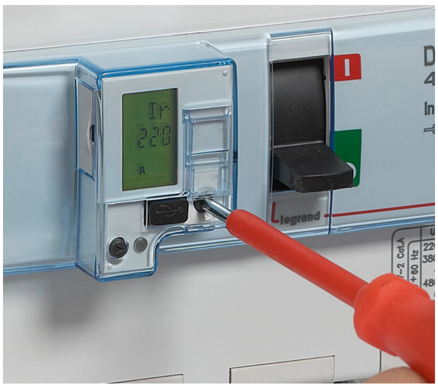
B : electronic DPX or DPX³ with "S2" release and the SEL selector switch set to Low (tm = 0.1, considered to be the result of the previous time selectivity study on medium intensity short circuits)

D : electronic DPX or DPX³ with "S1" release and SEL selector switch set to Low

It is possible to install other circuit breakers downstream of the two dynamic selectivity levels :

C (thermal-magnetic DPX or DPX³) and **E** (DX³).

For high intensity short-circuit currents downstream of **C** or downstream of **E**, the selectivity with the upstream devices is no longer dynamic but current selectivity.



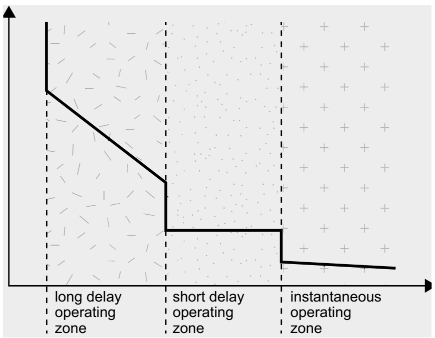
Setting dynamic selectivity on a DPX³

THE SELECTIVITY

LOGIC SELECTIVITY

Logic selectivity is an "intelligent" type of selectivity performed by exchanging data between electronic DPX/ DPX³/ DMX³ linked by an external connection.

Logical selectivity is used on the short delay and instantaneous zones of the activation curve I = f(t). **It concerns medium and high intensity short circuits** (energy part).
It does not operate on the long delay part of the curve (current selectivity) dealing with overloads.

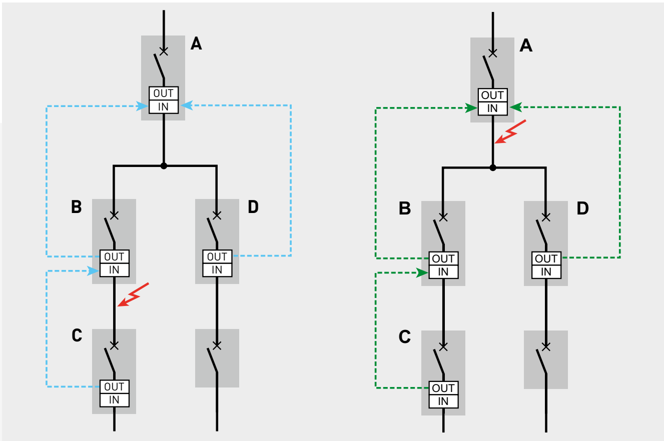


The operating principle of logical selectivity is as follows:
• The circuit breakers which detect the short-circuit current or a high starting current send a signal, via the connecting cable, to the circuit breaker(s) at the next level up, and at the same time they check the presence of a signal coming from one or more circuit breakers located at the level immediately below them.
• The circuit breaker located in the logical selectivity system which detects the short circuit and does not receive any signal from the downstream circuit breakers operates immediately, resetting any programmed delays (Tsd and/or HIGH) to zero.
• The circuit breaker which detects the short circuit and confirms the presence of a signal from a downstream circuit breaker remains closed, keeping to the programmed time delays (Tsd and/or HIGH).

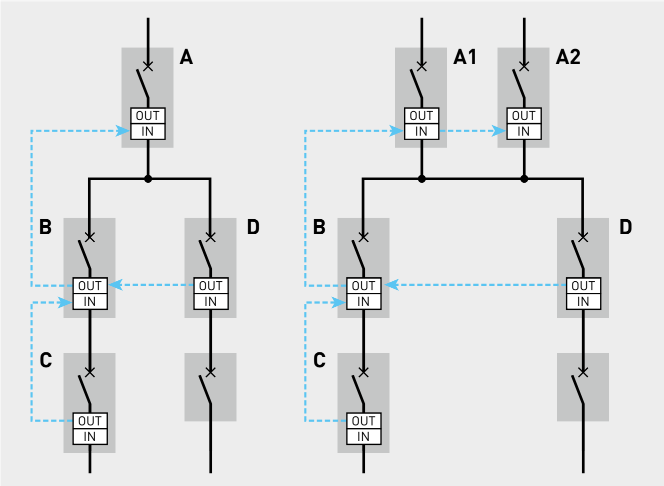
In this way, if there is a short circuit, only the part of the installation affected by the fault is isolated by the circuit breaker immediately upstream. This circuit breaker operates immediately, inhibiting the programmed settings, thus ensuring that the time taken to eliminate the fault is minimised.
This:
• Ensures that good selectivity is obtained on several levels, in addition to the various time delays
• Reduces the thermal and electrodynamic stresses on the cables or the bars, thus optimising the dimensions of the installation

■ **Fault 1: short circuit downstream of B**
Circuit breakers A and B detect the fault. Circuit breaker A receives a signal from downstream circuit breaker B and therefore remains closed, keeping to the programmed delays. As it does not receive any signal from the circuit breakers at the lower levels, circuit breaker B trips immediately, resetting any programmed delays (Tsd and/or HIGH) to zero.

■ **Fault 1: short circuit downstream of B**
Only circuit breaker A detects the fault. As it does not receive any signal from the circuit breakers at the lower levels, circuit breaker A trips immediately, resetting any programmed delays (Tsd and/or HIGH) to zero.



In both the cases described above, to prevent a double connection to circuit breaker A, it is also possible to use the following wiring:



APPLICATION RULES

To ensure correct time selectivity for medium intensity short circuits, the time/current curve with constant time (tsd) is used. Using the time/current curve with constant I^2t prevents correct operation of logical selectivity.

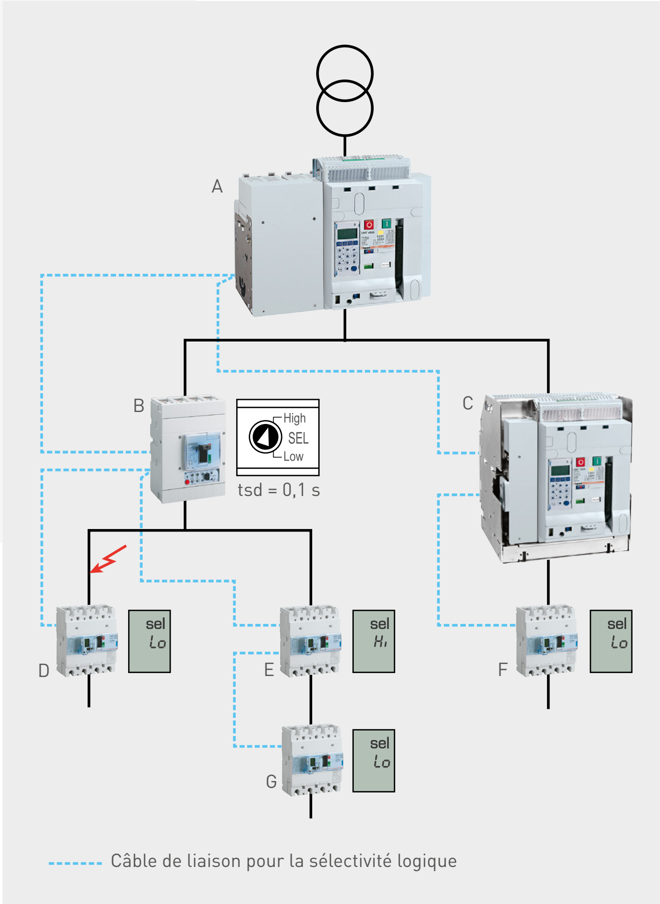
All the circuit breakers occupying the levels of the logical selectivity system, apart from the last level, must be set to "High" and must have a tsd ⩾ 100 ms.

All the circuit breakers at all levels of the logical selectivity system, apart from the last level, must have the same tsd setting.

All the circuit breakers in the last level of the logical selectivity system must be set to "Low" and must have a tsd setting lower than that of the circuit breakers at the higher levels.

■ **Example**

Circuit breaker B, concerned by the fault, trips immediately, without waiting for the set delay. Upstream circuit breaker A remains closed.



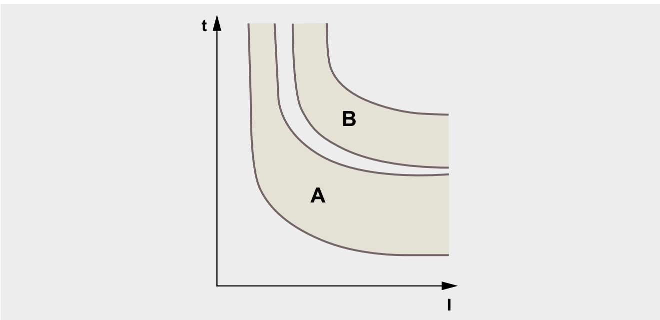
Selectivity of residual current devices

The conditions for coordinating residual current protection devices (RCDs) are defined by standard IEC 60364 part 5-53 (ch. 535.2).
Selectivity between several RCDs in series ensures maximum safety and enables the power supply to be maintained to the parts of the installation which are not affected by any fault.
Selectivity between residual current protection devices can be total or partial.

TOTAL SELECTIVITY

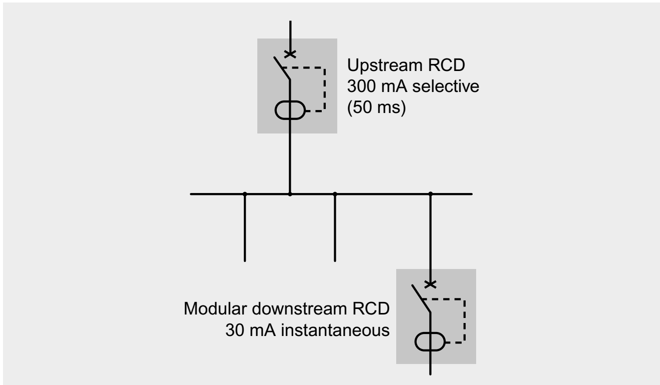
Total selectivity can be specified for safety or operational reasons.
To obtain total selectivity between two RCDs, the time/current non-tripping characteristic of the upstream device must be greater than that of the downstream device.
This requires two conditions to be met:

- The residual operating current of the upstream RCD must be higher than that of the downstream RCD
- The operating time of the upstream RCD must be greater than that of the downstream RCD for all currents

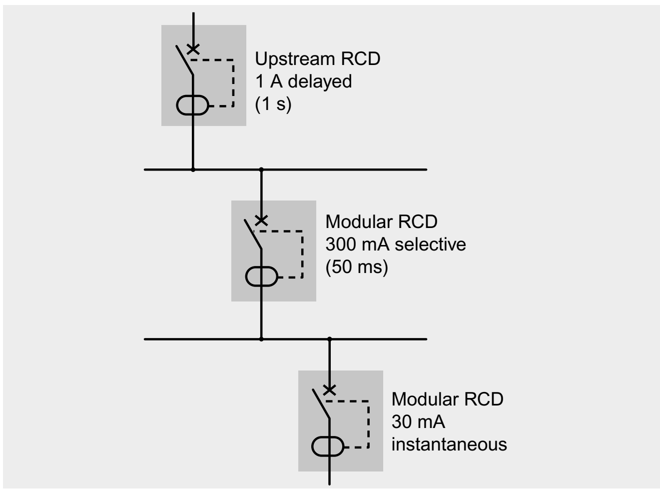


The selectivity between downstream device A and upstream device B is total
In practice, the sensitivity level of the upstream device must be 2 to 3 times higher than that of the downstream device, and must be type S or delayed. The breaking time must be at least 3 times longer than that of the downstream device.

Caution: a check must be carried out to ensure that the maximum breaking time of each device satisfies the protection conditions. A delay of more than 1 s is not usually permitted.



Total selectivity at two levels



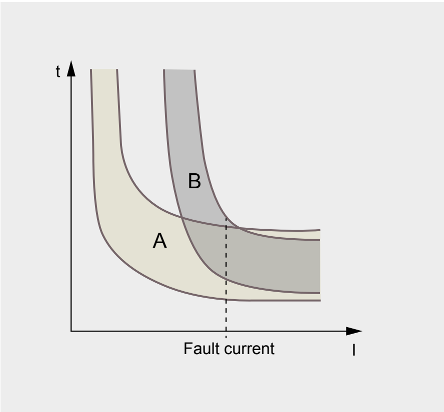
Total selectivity at three levels

PARTIAL SELECTIVITY

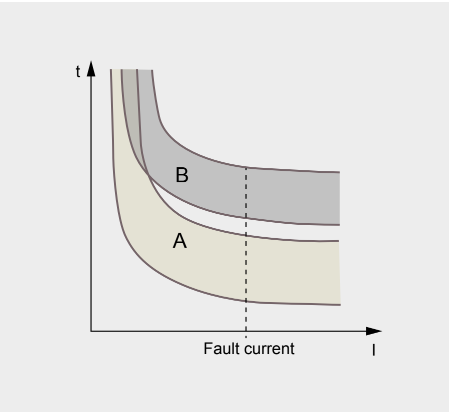
When the conditions for total selectivity are not met, the selectivity is partial.

Selectivity between two devices with different sensitivity levels and no time delay is virtually zero. The intensity of the fault current is generally enough to trip the upstream device.

However partial selectivity between two RCDs with similar sensitivity levels (for example, 500 mA and 300 mA) but with a type S or delayed upstream device, is much more efficient. The delay on the upstream device generally allows the downstream device to eliminate the fault. In practice, uncertainty concerning the values of the fault currents means that this type of selectivity is rarely practicable.

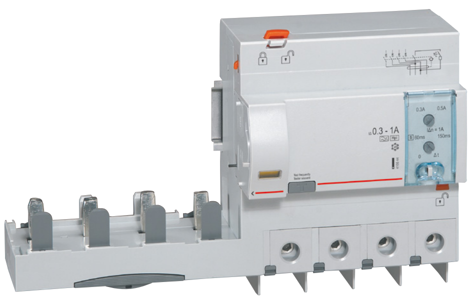


Partial selectivity between two non-delayed RCDs with different sensitivity levels: incorrect selectivity



Partial selectivity between two RCDs with similar sensitivity levels with device B delayed: better selectivity

DPX³ with electronic earth leakage module: tripping adjustable from 0 to 3s.



DX³ add-on module: tripping adjustable from 0 to 3s.

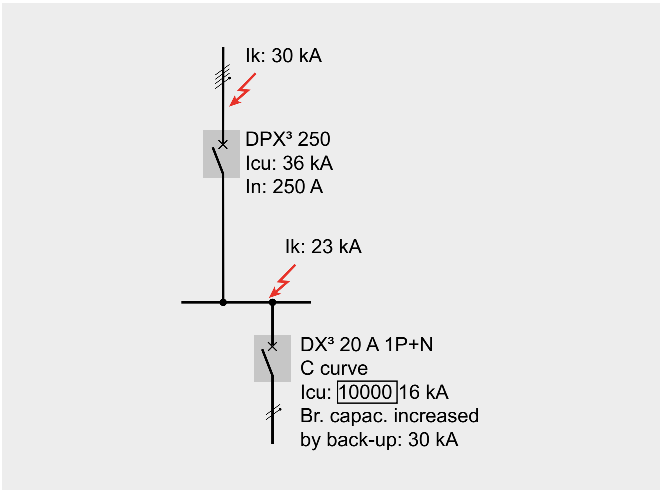
BACK-UP PROTECTION

Back-up is the technique by which the breaking capacity of a circuit breaker is increased by coordinating it with another protection device, placed upstream.
This coordination makes it possible to use a protection device with a breaking capacity which is lower than the maximum prospective short-circuit current at its installation point.
It can be used even if the devices are located in different distribution boards.

TWO-LEVEL BACK-UP

The breaking capacity of a protection device must be at least equal to the maximum short circuit which may occur at the installation point of this device. For economic reasons, it is however possible to combine a number of protection devices to obtain high operational performance on several levels, as long as:

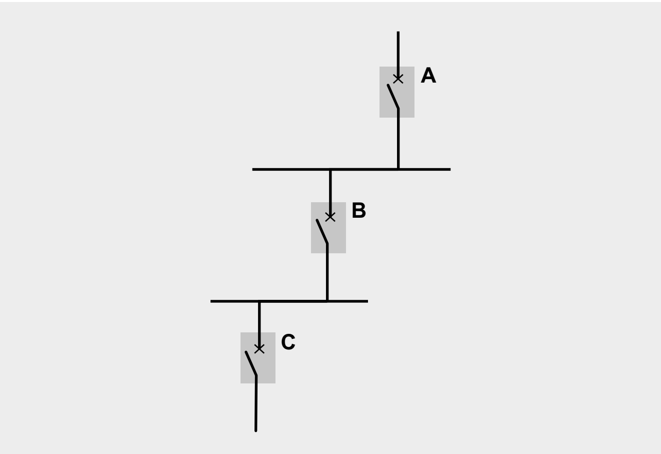
• It is backed up by an upstream device that has the necessary breaking capacity at its own installation point
• The downstream device and the protected trunking can withstand the energy limited by the two devices in series
Substantial savings can therefore be made by using back-up protection.



The back-up values given in the tables are based on laboratory tests carried out in accordance with IEC 60947-2.

NB: For single phase circuits (protected by 1P+N or 2P circuit breakers) in a 400/415 supply, supplied upstream by a 3-phase circuit, it is advisable to use the back-up tables for 230 V.

THREE-LEVEL BACK-UP



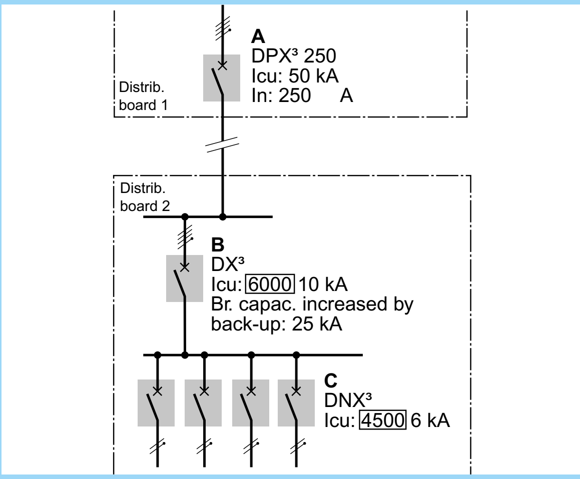
Three-level back-up is possible if one of the following conditions is met.

■ **Back-up with the main protection device**
Devices B and C are coordinated with device A. Upstream device A must have an adequate breaking capacity at its installation point. It is then simply a matter of checking that the B + A and C + A back-up values have the necessary breaking capacities. In this case, there is no need to check the back-up between devices B and C.

■ **Successive cascading**
Coordination is implemented between two successive devices. Upstream device A must have an adequate breaking capacity at its installation point. It is then simply a matter of checking that the C + B and B + A back-up values have the necessary breaking capacities. In this case, there is no need to check the back-up between devices A and C.

BACK-UP BETWEEN DISTRIBUTION BOARDS

Back-up protection can also be obtained when the devices are installed in different distribution boards. It is therefore generally possible to benefit from the advantages of back-up between devices, for example when one of the devices is located in the main distribution board and the other in a secondary board.



The upstream device must always have the necessary breaking capacity at its installation point.

It is also possible to have back-up on distribution board 2 between device B and the secondary devices C. In this example, the DX³ + DNX³ back-up has an increased breaking capacity of 25 kA.

Back-up protection of switches

A switch must be protected against overload and short circuit type overcurrents. It can be protected upstream, downstream or both, as detailed opposite.

Upstream protection

■ Situation 1: Same brand of switch and circuit breaker
When the switch and its upstream back-up protection device are the same brand, the back-up data provided by the manufacturer should be used. This is referred to as a switch combination.
The nominal current of the switch must be at least the same as its upstream protection. The back-up value of the switch must be greater than the short-circuit currents in question at the installation point of the switch (Ik1, Ik2 or Ik3).

■ Situation 2: Different brand of switch and circuit breaker
The back-up tables for the switches cannot be used. To check whether the switch can withstand the electrical stresses, the limitation curves of the upstream protection device must be known and the peak current value limited by this device for a maximum short circuit at the installation points of the switch must be established. For a thermal magnetic circuit breaker, this limited peak value must be below the Icm current of the switch.
For an electronic circuit breaker, which may be delayed, the breaking time will be longer: refer to situation 3.

■ Situation 3: details of upstream protection device not known
The details of the upstream protection device are not known or it is an electronic version from another brand. The rating of the switch must at least be higher than the continuous current-carrying capacity Iz of the cable connected to it or higher than the nominal current of the upstream protection device. The 1s Icw current of the switch must be higher than the possible short-circuit current Ik1, Ik2 or Ik3 at the installation point of the switch. It is generally accepted that any type of protection device has a short-circuit breaking time of less than 1 second (reference time for Icw).

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Downstream protection

In order to protect a switch downstream, all the protection devices supplied by the switch should be taken into consideration.

■ **Protection against overloads**

The sum of the nominal currents of the downstream protection devices distributed by phase must not exceed the nominal current of the switch (care must be taken with regard to the distribution by phase).
As the installation is only true at instant t, it is advisable to keep a minimum reserve or provide for a future extension.

■ **Protection against short circuits**

The most important point is to know the type of electrical connection that is to be used between the downstream terminals of the switch and the upstream terminals of the protection devices. If there is little or no risk of a short circuit due to the perfect control of the distribution system (for example, optimised distribution) then it is possible to use:

- Either the switch back-up tables, as though the switch were located downstream of the most restrictive protection device (situation 1 on the previous page), this value being compared to the short-circuit currents at the installation point of the switch (Ik1, Ik2 or Ik3). The back-up value must be greater than the short-circuit currents in question.

- Or the maximum short-circuit current limited by the downstream protection devices according to the prospective Isc at the installation point of these protection devices, the highest value being chosen. This short-circuit current is compared in the same way as in situation 2 on the previous page.
Like overloads, as the installation is only true at instant t, it is advisable to keep a minimum reserve or provide for a future extension.

Upstream and downstream protection

The upstream protection mainly protects the switch against the risks of short-circuit currents (use the switch back-up tables). The protection devices located downstream of the switch protect it against overloads by the sum of the In not exceeding the nominal current of the switch. The reverse may also be possible if there is a lack of electrical data.

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