Electrical protection
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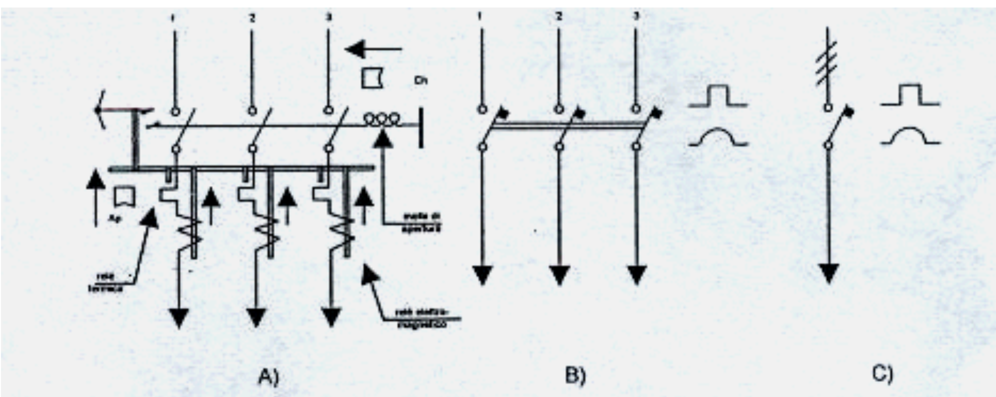
Topic: Educational Lighting Site

Protections normally used in industrial and civilian plants are essentially of two kinds: thermo-magnetic and residual current devices. Thermo-magnetic devices are used to protect from overloads and short-circuits while residual current devices safeguard systems and people from earth leakage currents. A thermo-magnetic device contains two distinct protections, i.e. magnetic protection and thermal protection.

The former has the essential task of protecting the line below the device from very abrupt and intense overloads like short circuits. As the name itself reveals, it comprises a few coils placed in series to the load, and then travelled by the current that goes through the device. This reel has the task of causing the release of the device when the current exceeds a value that is many times higher than the nominal value. The release of the device, in this case, takes place because the reel, run through by the fault current, generates a very intense magnetic field which can open the contacts of the device itself by means of the precharged springs. These devices require a higher effort to be charged than to be opened: this is due to the presence of the springs that are compressed and store up the energy necessary to keep the contacts compressed during the functioning and to open the device in case of a malfunction.

The thermal protection, on the contrary, intervenes with currents that are just above the nominal one (starting from 1.2 Volts) and is not as immediate as the magnetic protection. It normally comprises an element passed through by the current and sensible to the thermal expansion due to the heating caused by the current going through it. In fact, a conductor travelled by a current heats up and by heating up it expands, this phenomenon is not very evident in many metals, but there are particular metals that get deformed even with very few degree of thermal variation. An example of this behaviour can be seen in the thin bimetallic plates used for thermostats. The figure below shows the side view of a thermo-magnetic device in which the various elements that comprise it are clearly visible:



1) Arc quenching chamber, 2) Fixed contact; 3) Mobile contact; 4) Control mechanism; 5) Instantaneous electromagnetic releaser; 6) Delayed thermal releaser.

To facilitate a reliable and stable functioning of the device, thermal protection is compensated with ambient temperature, this is done to avoid that more current than the nominal is let pass through the devices in cold premises. In reality, though, this compensation is never perfect but still valid for normal use. Many of you have probably noticed that after the first overload release, the device is much more sensible to the subsequent overloads. This is due to the fact that the sensible element, still quite hot (because the device has just been released), takes a shorter time to reach the same temperature (i.e. the expansion) again that is necessary to be released. The magnetic protection occurs in the presence of very strong currents such as short-circuits and it is instantaneous, while thermal protection is released even with currents that slightly exceed the nominal one ,and requires a specific time. Does the thermal trip depend on time? For instance, if a 10A circuit breaker is released with a 14A current applied for 10 minutes, which current will cause its release after 7 minutes? In fact, we have the so called "trip curves", that is graphs that allow us to get to know the nominal current - time release of the device. It is possible to buy devices with any current value (or calibre) with different curves. The better known are K, U, C, L curves, the L curve is very sensible, it is released in short times with currents that are just above the nominal one and are appropriate, like the C curve, for domestic use or the service sector or for loads with a reduced peak current or even in all those cases in which the line below the device does not tolerate even modest overloads. The K curve is indeed more appropriate for loads with a strong starting (e.g. power supply of end racks). To choose the circuit breaker with the right trip curve means to have a valid protection with no use-related inconvenience.

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Let's go back to the example of the rack of ends with an inadequate residual current device above. Let's suppose that in the rack there are three finals and the plant processor, two finals are switched on and one is switched off as a supply. During the show one of the two finals that are switched on fails and you think of using the third as a substitute. It is very likely that you won't be able to switch it on without causing the untimely release of the general circuit breaker of the rack. On the other hand it is not possible to substitute the device with a bigger one because the connecting cable has a 16A inlet and must thus be protected for 16A and not more. The only solution is to choose an appropriate trip curve. It is only necessary to choose with care when purchasing one, the cost of the circuit breaker being the same. Unfortunately, there is another characteristic of residual current devices that must be checked, i.e. the "breaking power". With what breaking power is your service equipped ? During a short-circuit the current takes on extremely high values that the circuit breaker must be able to break efficiently without suffering any damage (otherwise it would become a fusible). The short-circuit current, i.e. the maximum current that goes into the short-circuited conductors, varies according to the point in which we take it into consideration, that is a connection effected directly from an ENEL booth will have a higher value than one effected after many metres of cable and many branchings. The circuit breakers of electric boards must be able to break the short-circuit current in order to avoid the gluing of the contacts or damages to the residual current device itself. The value of the short-circuit current by ENEL network usually varies from 3 to 16 KA (1KA equals 1000A), small circuit breakers usually have a breaking power of 3KA; surely insufficient in many cases.

An example: in general the services do not know which connection they will have in each place in which they will be working, they may work with hundreds of ENEL KW, supplied by a generator set, with small connections in theatres, depending on the work that is being prepared. However, boards, especially small ones will always remain the same. Let's take for instance an audio service that's been called for a convention or a theatre performance in a big congress centre or a theatre. The assimilation of the medium service requires a 32A triphase inlet (at least with regard to audio services) and a small distribution board with 16A singlephase outlets. The breaking power of 16A residual current devices will normally be of 3KA, the standard size that is generally sold when no specific features are required. The transformation booth of the theatre or the conference centre will probably have a normal power having been built for an assimilation of hundreds of KWs. Short-circuit current varies from point to point even in the same electrical system and it is often difficult to determine, but it increases according to the enhancement of the power of the power supply network.: the more powerful the distribution booth or the generator set, the higher the short-circuit current will be. This phenomenon must be kept into consideration and does not depend on our power supply needs, even if the service absorbs only 16A, in the case of a fault in the board a huge current will circulate and it will have to be efficiently broken by the residual current device on the failed line. A 250KVA transformation booth has a short-circuit current of about 7-8KA (the exact datum depends on the transformer and on the system of the premises) whereas a 400KVA one reaches 14KA (with a Vcd of 6%). Probably, the values will often be lower, but there are places where the short-circuit current will be extremely high, e.g. during big events when many parallel generator sets are used. Moreover, the short-circuit current depends a lot on the length of the lines and on their section; the services plants employ huge powers (e.g. the light plant on a stage) with a cable development that is sometimes limited to a few tens of metres which allow the short-circuit current to reach extremely high values. Often big main distribution boards have 16A service lines that are derived directly from power lines and that are protected with residual current devices that have a breaking power of 3KA, when the real sort-circuit current to the board would be 8-9KA. It is recommended to use devices with at least 6KA of breaking power in any case ,and to go up to 10KA and more in the critical cases described above.

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On the other hand, the absence of precise calculations (difficult to elaborate in the case of mobile systems because of the variety of the materials employed), the only possible solution is to exceed by foreseeing the most critical cases. Unfortunately, the increase of breaking power of a residual current device coincides with a substantial raise of its cost. As an alternative, it is possible to use fuses that have an extremely high breaking power (up to 100KA and more) and present the tendency of limiting short-circuit current, they also have a very contained initial price; the shortcoming is represented by the fact that they need to be replaced if they burn and they do not allow, anyway, to eliminate residual current devices because they are not manoeuvrable. Short circuits are not a very common event for a service, therefore this replacement would be quite a rare event in any case.

Finally, the "selectivity of breaking", that is the characteristic that any system should have and which, if respected, entails the release of the right residual current device and not of others at the right moment. In other words, often a few devices are placed in cascade, from the general one to increasingly smaller secondary branchings; selectivity will cause the release only of the device involved in the fault and not of the immediately preceding one, thus limiting inefficiencies. In practice: a fault on a rack of ends or on a dimmer will involve only the release of the residual current device of the broken machine and not of the general one above it. By taking care of this aspect it will be possible to limit a lot of damages and poor services (particularly feared by those who work in the live sector who are always hoping that in the failed rack the DSP of the plant or the DMX distributor are not included!). In this case, selectivity will only be useful in finding the failure sooner; breaking selectivity is not easy to obtain and it is advised to diversify the calibrations of the residual current devices by lowering them in secondary branchings and, whenever, possible to diversify breaking times, this, however, is only applicable on big adjustable residual current devices. In this case it is recommended never to push the breaking time of these devices beyond 0.2 seconds; in practice there are devices with a breaking time that reaches a few seconds: it is the same as taking away the residual current device of the board, in the case of a fault of the line there will be such an amount of energy going through that it the cable will be seriously damaged and a fire will start. It is a matter of your own safety and that of your machinery. Similarly, it does not make any sense for the general circuit breaker to have a calibration of 30mA, it is better to regulate it at 300-500mA and to leave the value of 30mA for the small circuit breakers of secondary boards. In this case too, it is recommended not to exaggerate the breaking time, the consequences are not always easily evaluated.