COURSE 11

LV circuits' protection

RECAP:

An **overcurrent** occurs each time the value of current exceeds the maximum load current for the load concerned. This current must be cut off with a rapidity that depends upon its magnitude, if permanent damage to the cabling (and appliance if the overcurrent is due to a defective load component) is to be avoided.

Overcurrents of relatively short duration can however, occur in normal operation; two types of overcurrent are distinguished:

- Overloads

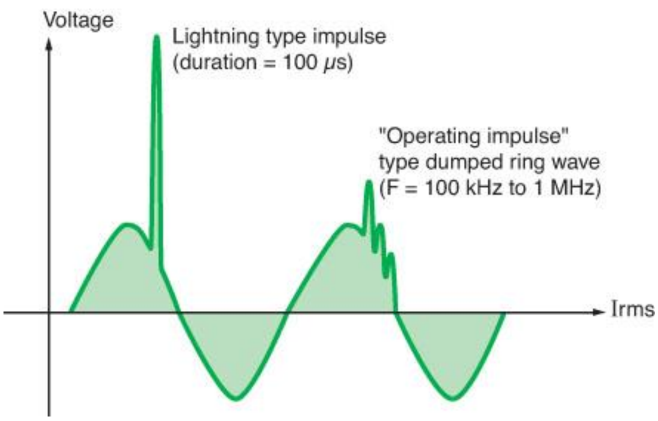
These overcurrents can occur in healthy electric circuits, for example, due to a number of small short-duration loads which occasionally occur co-incidentally: motor starting loads, and so on. If either of these conditions persists however beyond a given period (depending on protective-relay settings or fuse ratings) the circuit will be automatically cut off.

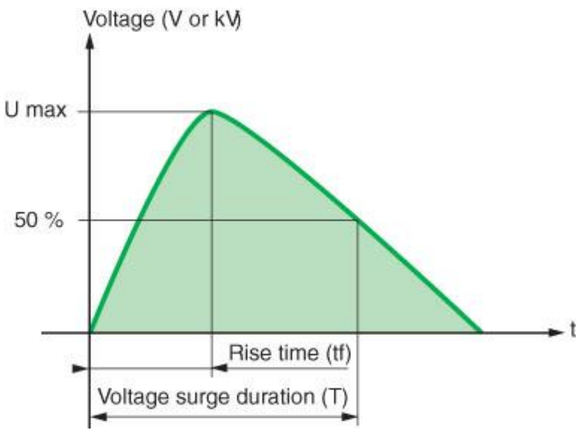
- Short-circuit currents

These currents result from the failure of insulation between live conductors or/and between live conductors and earth (on systems having low-impedance-earthed neutrals) in any combination:

  - 3 phases short-circuited (and to neutral and/or earth, or not)
  - 2 phases short-circuited (and to neutral and/or earth, or not)
  - 1 phase short-circuited to neutral (and/or to earth) Influence of neighbouring circuits

An **overvoltage** (in a system) is any voltage between one phase conductor and earth or between phase conductors having a peak value exceeding the corresponding peak of the highest voltage for equipment. An overvoltage disturbs equipment and produces electromagnetic radiation. Moreover, the duration of the overvoltage (T) causes an energy peak in the electric circuits which could destroy equipment.





Overvoltage is characterized by the rise time t_f (in µs) and the gradient S (in kV/µs).

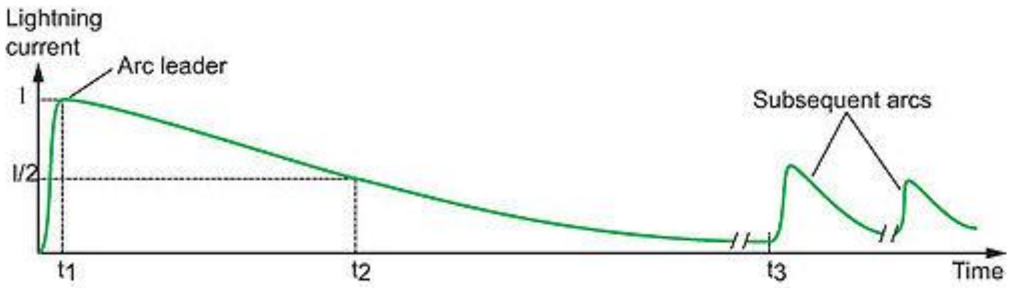
Transient overvoltages are short duration surges in voltage between two or more conductors (L-PE, L-N or N-PE) which can reach up to 6kV on 230 V power lines and generally results from:

- Atmospheric origin (lighting activity) through resistive or inductive coupling
- Electrical switching of inductive loads.

Overvoltages of atmospheric origin arise from uncontrollable sources and their severity for the load depends on many parameters that are determined according to where the lightning strikes and the structure of the electrical network. A lightning strike creates overvoltages that propagate along any type of electrical cabling (electrical distribution mains, telephone connections, communication bus, etc.), metallic wiring systems or conducting elements of significant length.

For direct lightning strikes, the overvoltages are caused by the flow of lightning current in the structure concerned and its earth connections. For near lightning strikes, overvoltages are created in the loops and are in part linked to rises in earth potential due to the flow of lightning current.

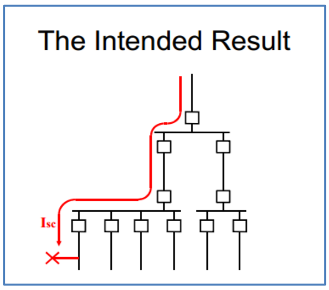
For distant lightning strikes, the overvoltages are limited to those created in the loops. The occurrence of overvoltages due to lightning and their characteristics are statistical in nature and much data remains uncertain.



1. Generalities. Proprieties.

Selection of protective devices is made from distribution networks and continuing with the power lines, to achieve selective protection.

Complete selectivity means that the protective devices will minimize effect of a short circuit or other undesirable event on the power system. The amount of the power system that must be shut down in response to the event is kept to the absolute minimum. For the purposes of this article, we'll focus on short circuits, also referred to as "faults". While several devices may respond to the fault, we want the first protective device in the path leading toward the power source to operate and clear the fault. If the next one beyond that one were to open, then other loads not fed by the unfaulted circuit might be turned off unnecessarily.



- an example of a short circuit in a radial system where four circuit breakers could be sensing the current flow caused by the short circuit. The circuit breaker immediately upstream of the fault is the most desirable breaker for isolating this fault.

Selectivity can be achieved with devices that are "inherently selective." That is, they operate only on faults within their "zone of protection" and do not ordinarily sense faults outside that zone. When a fault occurs inside the zone, the device typically responds instantaneously and trips breakers on the edge of the zone that are associated with short circuit contributors into the zone. If a fault occurs outside the zone, fault current may flow through the zone but the device will not operate for this “through-fault”. Examples of inherently selective systems are current differential relays (typically applied on busses, motors, generators, transformers), pilot wire relays, and transformer sudden pressure relays. While these devices offer the best in circuit protection, they can add significant cost to the power system expense. These protective devices tend to be much more expensive than overcurrent devices, but the cost may be worthwhile if it reduces the amount of damage to a critical piece of equipment or reduces the amount of lost production resulting from a fault. For this reason they tend to be used sparingly, usually when the protected equipment is critical, or if an extended outage to repair the system causes significant economic loss.

In most other cases, a simple overcurrent device is used in the form of a circuit breaker, fuse, or overcurrent relay. In a properly designed power system, these devices can provide selective coordination under most circumstances at a reasonable cost. They are currently the workhorses of electrical protection.

Active conductors of LV installations must be protected against overcurrent owed to overloads or short circuits:

a) Overload protection (current exceeding the value of $I_{max\ adm}$ and when its long duration may cause damage to conductor insulation) is made by: thermal relays, circuit breakers, overcurrent protection relays, fuses[1].

b) Short-circuit protection is made by: circuit breakers, fuses.

c) Overload and short circuit protection is made by: circuit breakers equipped with overcurrent protection relays and rapid triggers, fuses.

E.g. related to (c): Thermal-magnetic (inverse time) circuit breakers provide both thermal (overcurrent) and magnetic (short-circuit) protection within a single device. For thermal overcurrent protection, thermal elements (bimetallic or electronic) are used to protect the circuit components from damage caused by continuous levels of high overcurrent. As current passes through the thermal elements, they will deflect until a trip point is reached, at which time the circuit breaker will trip, opening the motor circuit. The thermal action is also associated with the characteristic of “inverse time” since low overcurrents require longer trip times and high overcurrents result in shorter trip times. For short-circuit protection, thermal-magnetic circuit breakers incorporate a magnetic trip element. During a short-circuit condition, the high fault current causes the magnetic trip element to release a latching mechanism, tripping the circuit breaker and opening the motor circuit.

The IEC (international circuit breaker) type circuit protector incorporates several functions within a single device including On-Off push buttons for local control and motor circuit isolation, adjustable bimetallic elements for overload protection, and magnetic trip elements for short-circuit protection.

Type 2 Coordination is a term used to describe a level of protection that can be achieved by properly “coordinating” the selection of the short-circuit protection device with the withstand capability of the motor controller and overload protection device in the circuit. The concept of Type 2 Coordination

[1] **Fuses** are over-current protective devices that are placed in an electrical circuit to protect the control components, wiring, insulation, and motor from damage caused by excessive current and associated heat. Overcurrents are considered any increase in continuous current above the normal operating current level.

originated from the IEC (International Electrotechnical Commission) standard 947-4-1. In this standard, two levels of short-circuit coordination are identified.

Type 1 Coordination is defined as follows: “Under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and may not be suitable for further service without repair and replacement of parts.” In other words, contact welding is allowed in the contactor and overload burnout is acceptable. In either case, replacement of the control components are required.

Type 2 Coordination on the other hand, limits the effect of a short-circuit on the control components. Type 2 Coordination is defined as follows: “Under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and shall be suitable for further use. The risk of contact welding is recognized, in which case the manufacturer shall indicate the measures to be taken in regard to the maintenance of the equipment.”

2. Choosing protective and switching devices for equipment’s and receiver’s circuits

A protective device is provided at the origin of the circuit concerned:

- cuts-off the current in a time shorter than that given by the I^2t characteristic of the circuit cabling;
- allows the maximum load current IB to flow indefinitely.

The characteristics of insulated conductors when carrying short-circuit currents can, for periods up to 5 seconds following short-circuit initiation, be determined approximately by the formula which shows that the allowable heat generated is proportional to the squared cross-sectional-area of the conductor:

$$I^2t = k^2*S^2$$

t: Duration of short-circuit current (seconds)

S: Cross sectional area of insulated conductor (mm^2)

I: Short-circuit current (A r.m.s.)

k: Insulated conductor constant (values of k_2).

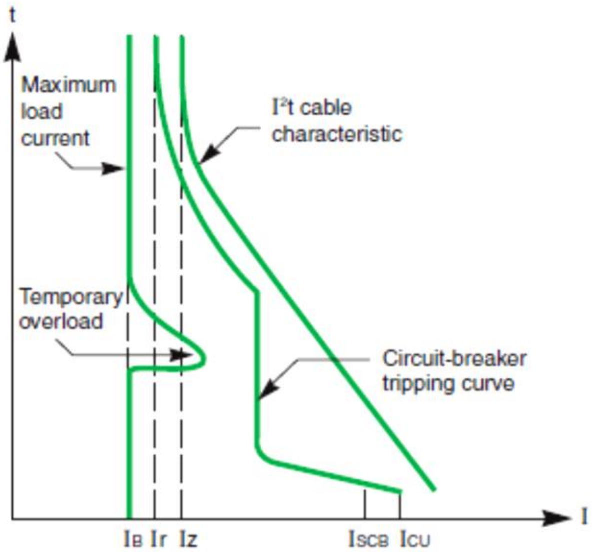


Figure 1 – Circuit protection by circuit breaker

* ISCB: rated 3-ph. short-circuit breaking current of the circuit-breaker

* Ir (or Irth) : regulated “nominal” current level; e.g. a 50 A nominal circuit-breaker can be regulated to have a protective range, i.e. a conventional overcurrent tripping level similar to that of a 30 A circuit-breaker.

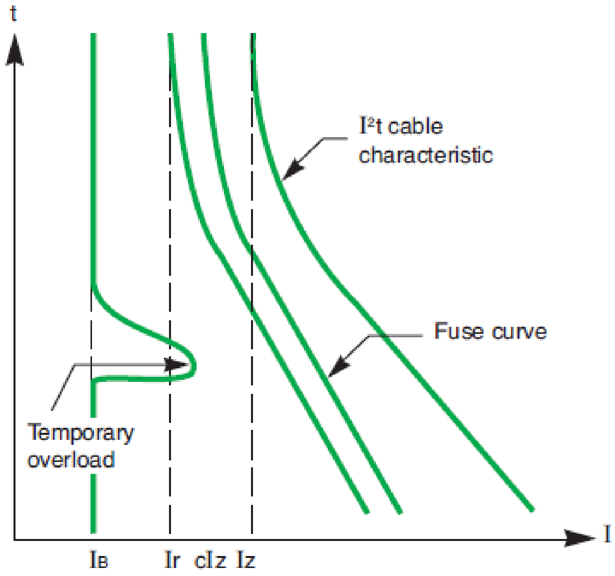


Figure 2 – Circuit protection by fuses

A protective device functions correctly if:

- its nominal current or its setting current is greater than the maximum load current I_B, but less than the maximum permissible current I_z, corresponding to zone "a" from figure 3.
- Its tripping current "conventional" setting is less than 1,45*I_z , which corresponds to zone "b" in figure 3. For fuses, the tripping current is I_f.
- Its three-phase short-circuit fault-current braking rating is greater than the three-phase short-circuit current existing at its point of installation. This corresponds to zone "c" in figure 3.

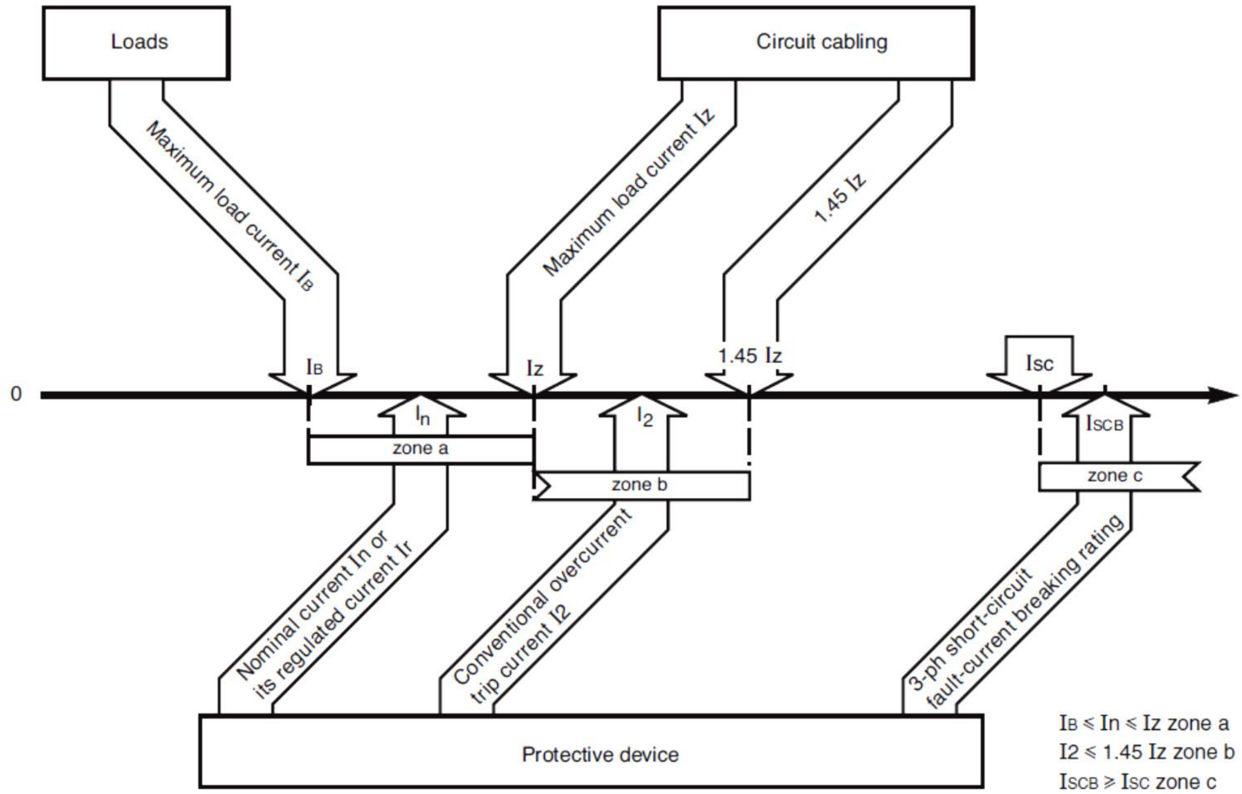


Figure 3 – Practical current levels for protective devices

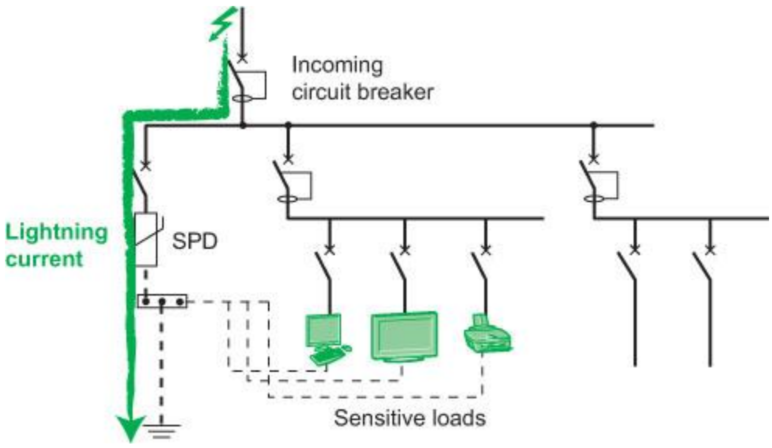
When evaluating and comparing time current curves, you should keep in mind the following. It is assumed that the fault current is constant up until the time that the fault is cleared; the graphical evaluation of curves may not necessarily reflect the true characteristics when the fault current is varying. In the real world, the fault may vary depending on the contact area of the fault, the degree of arcing that is occurring and a number of other factors. In most cases, the fault current tends to escalate upwards from its initial value, but this is not always the case.

3. Overvoltage protection

The protective principle is to attempt control of the point of impact by attracting the lightning on to one or several specified points (the lightning conductors) that are placed away from the places to be protected and by letting the pulse current flow to earth.

Several lightning conductor technologies exist and can be of the following types: stem, meshed cage, taut wire or even priming device. The presence of lightning conductors on a facility increases the risk and amplitude of pulse currents in the earthing network.

The use of SPD‘S (surge protection device) is therefore necessary to avoid increasing damage to the installation and equipment. This device is connected in parallel on the power supply circuit of the loads that it has to protect (figure 4). It can also be used at all levels of the power supply network. This is the most commonly used and most efficient type of overvoltage protection.



SPD provides protection against transient overvoltages as well as protection against the effects of indirect lightning strikes.

Connections of a SPD to the loads should be as short as possible in order to reduce the value of the voltage protection level on the terminals of the protected equipment.

The total length of SPD connections to the network and the earth terminal block should not exceed 50 cm and the cross section area of the cable must be of 4 mm^2 Cu (for SPDs with Nominal Discharge Current Rating of 10kA or 20kA) and 16 mm^2 Cu (for SPDs with Nominal Discharge Current Rating of 3 kA, 5 kA, 10 kA, or 20 kA).