INTRODUCTION TO PROTECTION

1. TWO TYPES OF FAULT (OR OVERCURRENT)

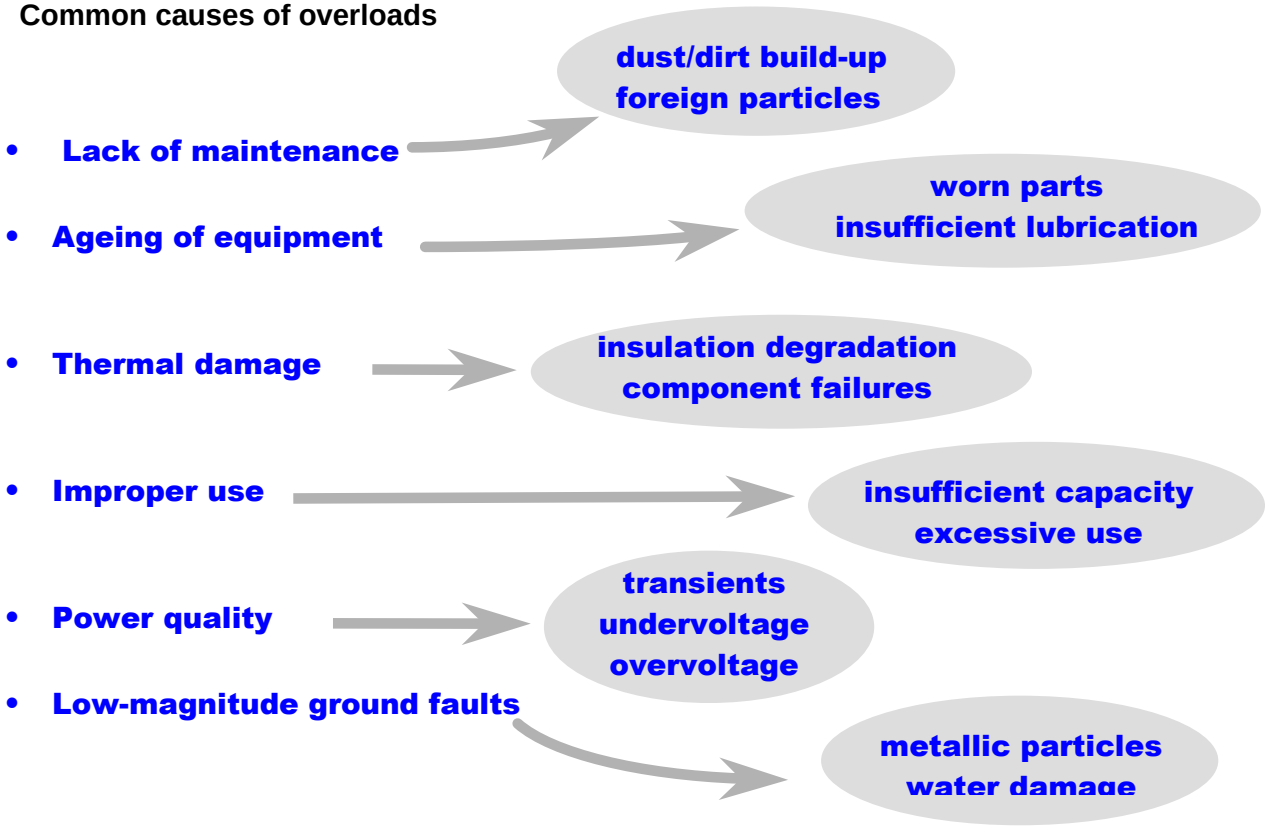
There are 2 types of overcurrents:

- Overload
- Short circuit

Figure 1 : danger of the arc flash energy

1.1. Overload

- **Common causes of overloads**



- **Characteristics**

the term "overload" is used for excess current flowing in a circuit which is electrically sound. Overload currents are usually not much greater than the normal full-load current of the system, but if allowed to persist will eventually cause damage. Damage to the system, especially to insulating materials in contact with the circuit conductors, can result, due to the heating effect of the current. The heating time is relatively long (from seconds up to several hours), and the overload can therefore be characterized by the **r.m.s. value** of the overload current. For overload protection, the requirement for a protective device is that it should limit the duration of the overload current.

Some fuse ranges are designed for this type of protection.

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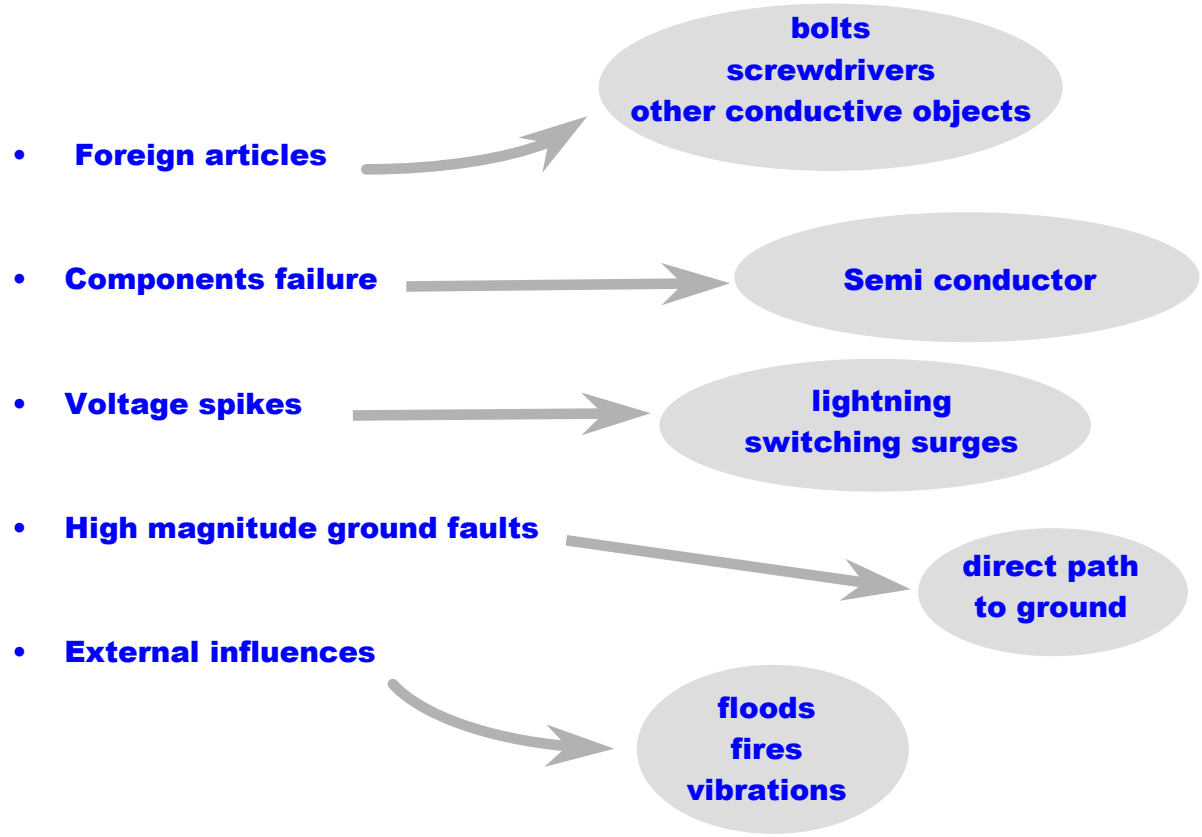
1.2. Short circuit

- **Common causes of short- circuits**



- **Characteristics**

Short-circuits are usually due to a catastrophic electrical failure, such as insulation breakdown or accidental conditions, and the resulting r.m.s. value of the prospective (available) short-circuit current is high, typically more than 10 times the normal full-load current of the system. The heating effect is so rapid that damage to the system can occur within milliseconds, which is of the same order as the duration of an a.c. half-cycle. The heating effect cannot be characterized by the r.m.s. value of the prospective (available) current, as in the case of overloads, because it depends upon the **waveform** of the current.

In this case the protective device must limit the energy associated with the fault, which depends upon the value of the following parameter:

$$I^2t$$

where **i** is the instantaneous current. This parameter value is a measure of the thermal energy delivered to each ohm of the circuit by the short-circuit current during the time *t*.

An additional requirement for a short-circuit protective device is that it should also limit the **peak value** of current permitted to flow in the circuit.
Electromagnetic forces are dependent on the square of the instantaneous current and may produce mechanical damage to equipment when short circuit currents are not « limited » very quickly.
The welding of circuit breakers contacts as well as contactors and disconnectors contacts can occur when the peak value of the current is not limited down to a low enough value

Melting of circuit conductors can occur and be followed by arcing between the molten fragments, possibly causing fires and hazards to personnel as well as the further destruction of the electrical system.

Very fast fuses for the semi conductor protection provide excellent protection in case of short circuit.

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- **Short circuit currents can reach very high values**

Large plants have a lot of motors becoming generators when a short circuit occurs. Sometimes there are several transformers or generators in parallel. Protection devices must have a large breaking capacity.

Short circuits current can reach 300 KA r.m.s. (about 750 KA peak !!)

Therefore protection systems must have a very large breaking capacity. A fuse can provide such large breaking capacities.

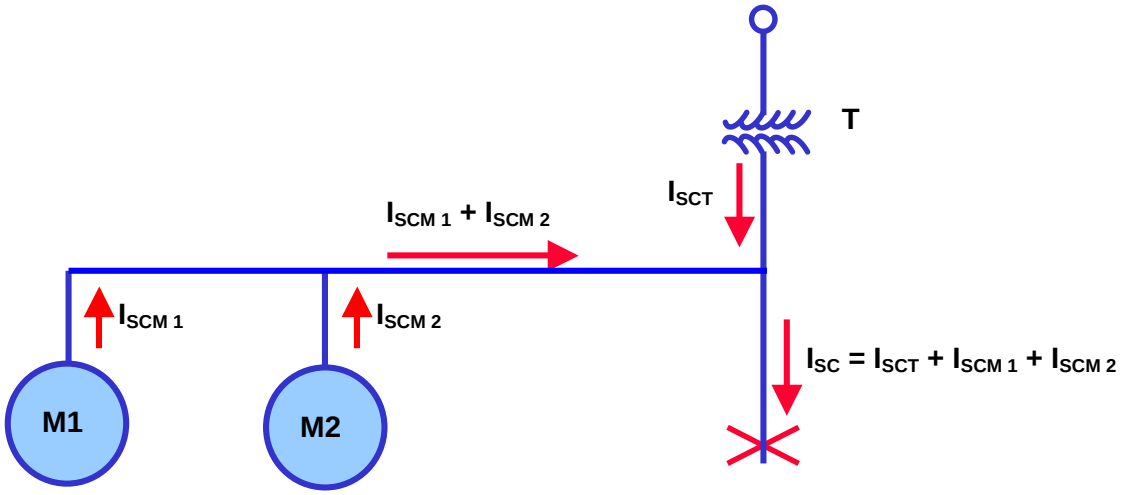

Figure 2 : short circuit current

1.3. Consequences of overcurrents

It is usually a combination of these results !

- **Injury** → - loss of life - burns - flash blindness
- **Downtime** → thousands of dollars or euros per minute
- **Loss of process control** → - continuous process - steel in arc furnace - non-conforming parts
- **Mechanical effect** → - equipment damage - destruction from magnetic movement
- **Thermal effect** → - equipment damage - destruction from energy arcs

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2. PROTECTION LEVEL / PROTECTION COORDINATION IEC 60947 § 8.2.5.1.

IEC 60947- 4 - 1 belongs to: contactors and motor-starters electromechanical contactors et motor-starters

§ 8.2.5.1. : Performance under short circuits conditions

In this paragraph coordination types are defined as follows:

type 1 coordination:
requires that, under short circuit conditions, the contactor or starter shall cause no danger to persons or installations and may not be suitable for further service without repair and replacement of parts.

type 2 coordination:
requires that, under short circuit conditions, the contactor or starter shall cause no danger to persons or installations 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 as regards the maintenance of the equipment.

3. PROTECTIVE DEVICE CHARACTERISTICS TO PROTECT AGAINST OVERLOADS

- Allow temporary, harmless overloads to avoid needless circuit disruption under normal operation of the equipment (starting current of a motor)
- Interrupt sustained, damaging overloads (minimize thermal damage to equipment)

4. PROTECTIVE DEVICE CHARACTERISTICS TO PROTECT AGAINST SHORT CIRCUITS

4.1. Short circuit current limitation

La limitation du courant crête dans le circuit permet d'obtenir:

- Maximize reduction of magnetic forces (proportional to I^2_C)
- Maximize reduction of thermal energy (proportional to I^2t)

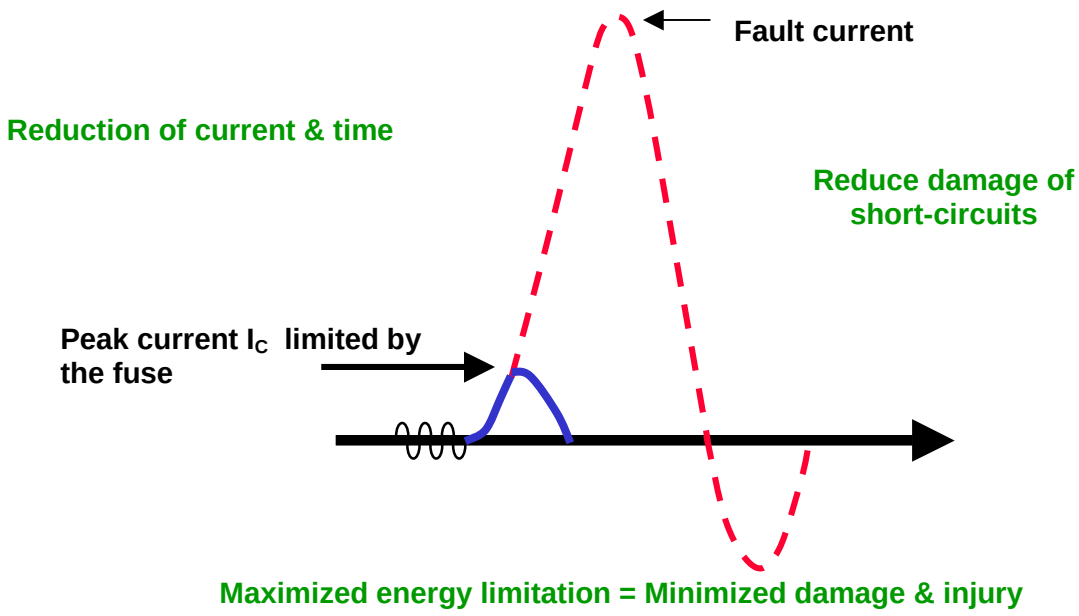

Figure 3

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4.2. Additional considerations for choosing a protective device

- safety and reliability

- Speed

- High breaking capacity

- Minimum maintenance : low cost operation

- Selectivity (or discrimination) : only one protection operates , the one in the faulty branch (example in figure 3)

- Electric energy quality

- General purpose: simplicity (for example a gG or gR type fuse can interrupt all fault levels.)

- Price

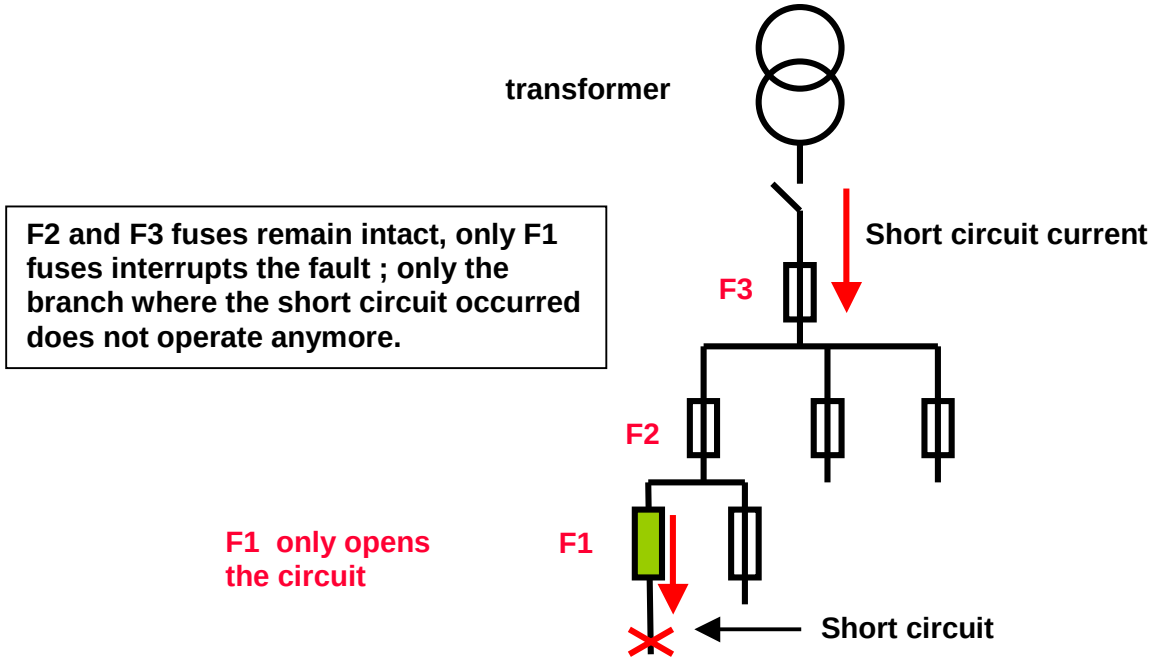

Figure 3 : selectivity

4.3. Comparison of protective devices

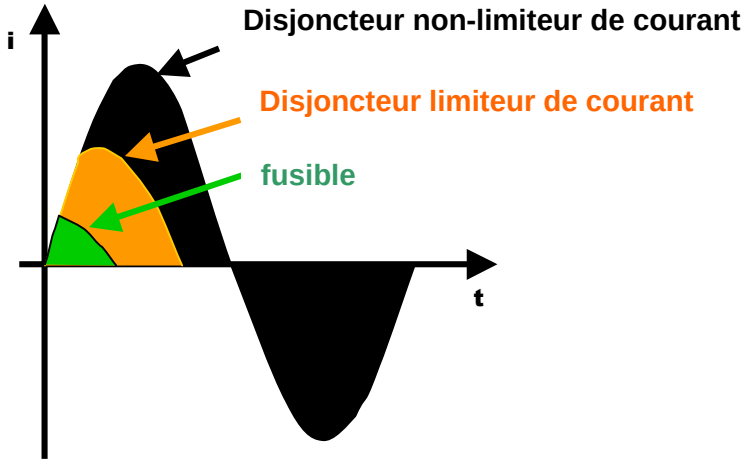

Figure 4: comparaison de plusieurs dispositifs de protection

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4.4. The ideal protective device ... a fuse

Time-Delay: minimized needless openings
Fast or very fast: best **protection choice**
The best current limiting device: minimized damage & injury
Safe and reliable: fail-safe thermal device
High interrupting rating: safe operation, future growth
Minimum Maintenance: trouble free protection
Selectivity ratio 1,6 and 2 : design simplicity

Simply perfect !

5. LEGAL CONSIDERATIONS

5.1. Global convergence of legal considerations

Codes & Standards: harmonization... IEC, UL, NEC…
Product liability (legal precedents having worldwide impact)
New French law (98-388) holds manufacturers responsible for personnel & product liability for «less-than-expected» product performance... disclaimers are null and void for users!

5.2. Impact of legal considerations

- Manufacturers are fully responsible for their components
- OEM's are fully responsible for their assemblies / equipment
- «Limited liability» is a thing of the past!
- Cost of settlements are growing astronomically! (personnel injury, equipment, downtime, mental anguish, punitive damages)

6. CONCLUSION

The fuse, alone or associated to another protection system is an ideal solution to protect and ensure safety in low voltage and medium voltage distribution circuits, power electronic equipments and DC fed circuit.

F	**F**ull overcurrent protection, **F**idelity of operation
U	**U**niversal use (gM or gD ideal all-purpose fuse)
S	**S**electivity, **S**implicity, **S**afety
E	**E**conomical, **E**nergy-limiting, **E**asy-to-use

Simply perfect !

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