Power Dissipation of Fuses –afflicted with prejudice

The commonly used term "power loss" suggests a loss of energy and money. As a matter of fact, fuses, like any other overcurrent protective devices, require a certain amount of electric energy to operate. Fuse operation is based on a defined temperature rise and melting of the fuse-element by electric heat. The heating process requires electric energy that will be dissipated to the environment.

Depending on the point of view, this energy may be considered as

- operating costs or "power loss", by network operators, as far as non-metered energy is concerned,
- physical necessity, by fuse engineers, who have to balance the speed of current interruption against power dissipation under normal load,
- design parameter, by switchgear design engineers, who have to take into account the temperature rise inside enclosures.

The technical community does therefore prefer the standardized term "power dissipation" as a physical quantity to deal with.

1. Economic aspects

The bulk of power distribution system losses is generated on the l. v. level and amounts to about 4 % of the power and 3 % of the energy distributed in an fully fuse-protected urban network. Higher values may apply to rural networks.

Under the assumption that the connecting conductors will be loaded with fuse rated current, the contribution of fuses to the l. v. system loss compares approximately to the loss of 0,5 m to 1 m of the connected cable.

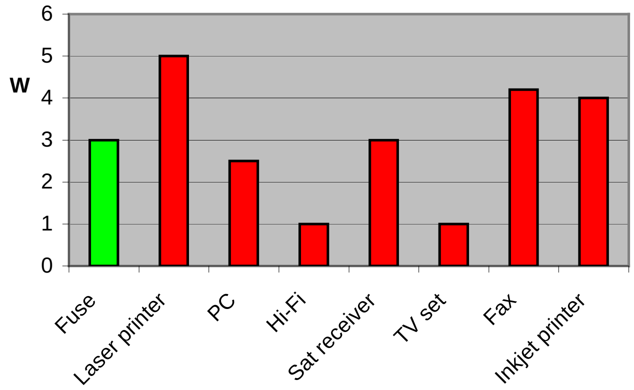

Fig. 1 - Stand-by power of electronic devices

Consequently, fuses may represent an estimated 5 % to 10 % share of l. v. power loss in an urban network and significantly less in rural networks.

Some utilities, running fully fuse-protected l. v. networks, assume a load independent average power consumption of 3 W per fuse. Real network modelling with load dependent power loss results in somewhat lower values.

One may compare the power loss of fuses with the standby power of contemporary electronic devices, available in every household and widely neglected (fig. 1). But one may also keep in mind the different importance of these devices:

While stand-by power can be considered dispensable comfort, fuses are necessary safety items. Still, some rules to minimize excess energy consumption by fuses may be considered.

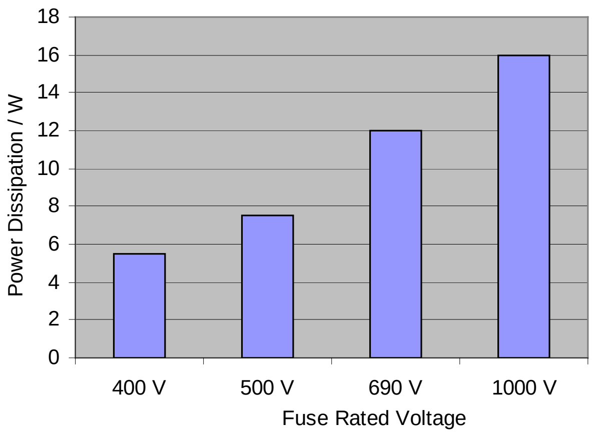

Fig. 2 - Power dissipation and rated fuse voltage

2. Fuse rated voltage shall not be greater than required

Fuse length and the number of restrictions in the fuse-elements govern the power dissipation of a fuse-link. Both depend on the recovery voltage, i. e. on the fuse rated voltage. Consequently, the same operating current generates more power the higher the voltage rating of the fuse-link. Figure 2 shows the rated power dissipation of 100 A fuse-links having different rated voltages. Of course, fuses with higher voltage ratings may safely be used at lower operating voltage. For minimum power dissipation however, the fuse rated voltage shall be selected equal or insignificantly greater than the system operating voltage. Using a 690 V fuse in a 400 V network would more than double the power dissipation and at least one half thereof could with reason be called a “power loss”.

3. Selecting greater fuse rated currents reduces power dissipation

The power dissipated by fuses and other electric devices arranged in an enclosure may increase the inside temperature and reduce the loading factor of the equipment. Lowering power dissipation is therefore a desirable task. Fuses are assigned rated power dissipations that relate to and inherently increase with rated fuse currents. The power actually dissipated under operating conditions is not necessarily reflected by the rated value but follows the operating current in a non-linear relationship (see fig. 3). As power dissipation goes approximately by the square of the load current, actual values for temperature rise considerations may significantly deviate from rated power dissipation. This is especially true with back-up fuses that are operated well below their rated current.

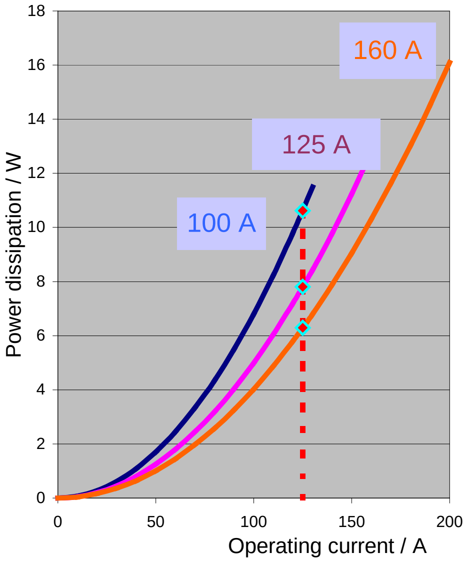

Fig. 3 - Power dissipation of fuses having different rated currents

An attempt to reduce power dissipation in an enclosure may likely end up in selecting a fuse having higher rated power dissipation.

This seemingly contradictory result is due to the above-mentioned non-linear relationship between load current and power dissipation. As can be seen from fig. 3, at the same operating current of 125 A, the 100 A fuse would dissipate more than 10 W, while the 125 A and the 160 A fuses would only dissipate less than 8 W and 6 W respectively.

Likewise, thermal problems in h.v. fuse enclosures may be less severe under normal load than they appear based on rated power dissipation (fig. 4). Figure 4 illustrates the example of back-up fuse selection for the protection of a 20 kV, 1.000 kVA distribution type transformer. The power dissipation of all suitable fuses ranging from 50 A to 80 A exceed by far the maximum 60 W power acceptance of the fuse container. At transformer rated load however, the power dissipation of all three fuse ratings is far below the thermal limit of the container. In case the transformer shall be loaded up to 150 % of its rated current, the 50 A fuse would not meet the requirement.

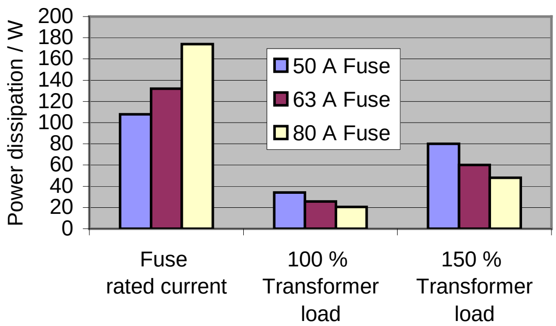

Fig. 4 - Power dissipation of h.v. fuses

That’s why greater fuse rated currents shall be selected whenever possible in order to eliminate or ease thermal problems. Typical examples for the application of this rule are. -

- h.v. back-up fuses in containers of SF_6 insulated switchgear,
- capacitor circuits with high contents of harmonics,
- densely packed l.v. fuse boxes.

4. Fuses can cope with other protective devices

The maximum power dissipation values of power fuses has been well defined and standardized in IEC 60269. Quality products usually end up well below the upper limits. Unfortunately there is no related definition for mechanical protective devices in the corresponding switchgear standard IEC 60947. This standard does not even mention power dissipation though switchgear builders need this information to properly design their products. The non-existence of information on power dissipation in the relevant International Standard may suggest to users that this quantity was negligible.

In reality, circuit-breakers exhibit a wide range of power dissipation values that might be higher or lower than the power dissipation of fuses. Figure 5 shows a range of published c.b. values and by no means conclusive. For higher current ratings the power dissipation of circuit-breakers depends on the type of overcurrent release: Generally, circuit-breakers with electronic tripping units represent the lower values, while the power dissipation of circuit-breakers with thermal-magnetic tripping units often exceed the power dissipation of fuse-combination units. Fully electronic circuit-breakers, based on semiconductors, are still way above the values shown in figure 5.

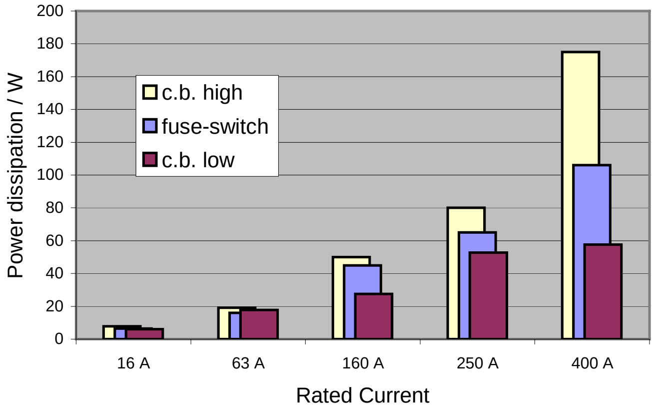

Fig. 5 - Power dissipation of protective devices
(Typical values published by manufacturers)

Special high performance selective circuit-breakers, thought to replace fuses and fuse-combination units in counter cabinets of buildings, dissipate even twice as much power as common fuse solutions (fig. 6). Figure 6 shows the power dissipation per phase.

The increasing energy costs and growing concern about the influence of human energy consumption on the world climate give fuses a competitive position, if not a leading edge, among electric circuit protective devices. Power dissipation has still to be accepted as a necessity of all overcurrent protective devices. The term "power loss" however, seems to be inappropriate for energy efficient devices like fuses and should be reserved to products that dissipate more power than necessary to fulfil their duty.

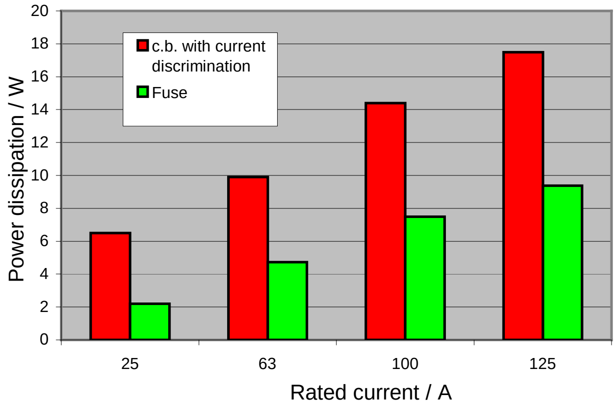

Fig. 6 - Fuses and discriminating main circuit-breakers
(Typical rated values published by manufacturers)

More information on energy efficient fuse application may be obtained from the experts of fuse manufacturers organised in Pro Fuse International.