

## **FUSES –Outdated or CONTEMPORARY PROTECTIVE DEVICES**

### **“Fuse” –synonym for protective devices**

Fuses belong to the first products in history of electricity. They are named after their physical principle of operation: melting of a metal conductor. A metallic conductor, representing the smallest cross section in an electric circuit, is melted by currents exceeding the circuit's current carrying capacity, thus interrupting overcurrents and protecting the circuit. The physical principle of fuse operation is still the same after more than a century of dramatic development in other fields of electricity.

Generally, products do not survive in a competitive market because of their mode of operation but because of their benefits in application. So there must be at least some product features and advantages over competitive products to make people using fuses till now and in the future.

While in English and some other languages fuses are named by their physical principle of operation, the German term “Sicherheit” is synonymous for “safety” and describes best the paramount benefits of fuses in electric circuits: Protecting property and saving human's health or even lives in case of faulted or overloaded electric circuits.

Unlike in the early days, when fuses were sole devices available for circuit protection, today's design engineers of electrical equipment and distribution networks have the privilege to select the best solution among a range of technical alternatives.

### **Fuses –associated with unpleasant moments in life**

The image of fuses has widely been established on personal experience. In spite of the fact that fuses are not thought to be end-user products but part of the electric infrastructure, hidden behind the scene, almost everybody, laymen and engineers alike, gathered some personal experience with fuses. Most of the time people become aware of the existence of fuses in literally dark moments of life, using the shine of a candle or flashlight in search of a replacement fuse. That may explain the fuse's image of a non-perfect product and a deep and sustained desire for resettable protective devices, impelling the search of alternative technical solutions. Consequently, a number of alternative overcurrent protective devices have been developed during past decades, e.g. –

- circuit-breakers (c.b.),
- self-resetting polymer-based PTCs (PPTC),
- electronic controls,

but fuses are still unsurpassed and irreplaceable in many applications. Most interestingly, “fuse“ has widely become a generic term for overcurrent protection devices based on completely different technologies, e.g. “automatic fuses” for miniature circuit-breakers or “polymeric fuses” or “resettable fuses” for resettable polymer-based PTCs.

### Fuse selection –a real challenge

Fuse performance and fuse characteristics have been laid down in IEC-Publications 60127, 60269 and 60282 and are now worldwide standardized. Fuses have historically been developed in different designs and for many specific applications. To read



the fuse markings and pick the proper fuse among the huge variety of sizes, shapes and characteristics can be a real challenge, not only for amateurs (see Fig 1). There is a certain risk that fuses may be wrongly used by people checking the current rating only (which is usually printed in bold letters!) and not respecting or not understanding the meaning of utilization category. More information and guidance may be helpful to select the appropriate fuse for a specific protection job and to

Fig. 1 Utilization categories of low voltage fuses (IEC and other common categories)

prevent potentially dangerous misinstallation. Pro Fuse International undertakes to support fuse solutions, give advice and provide information to better understand fuse protection.

### Fuses or alternative solution?

A general overview on what type of protection can best be achieved by the different devices is given in Table I. (Table I and Fig. 2 are not meant to be comprehensive but to give some guidance as to what protective device may provide best technical performance in different applications.) Other than technical criteria e.g., operating conditions, physical dimensions, price or availability of products and information may however also be honoured and finally govern selection.

- Short-circuit protection

High fault levels define the application field dominated by fuses (see Fig. 2). No other protective device having similar physical dimensions could so far reach the breaking capacity of fuses. This is because of their physical principle of operation: The higher the fault current the faster the fuse operates.

Table I – Preferred selection of overcurrent protection devices

Type of protection	fuse	circuit-breaker	polymer PTC	electronic control
overload protection	+	+	++	++
short-circuit protection	++	+	o	o
cascaded protection	++	o	-	o

Ratings: ++ excellent, + good, o fair, - not recommended

## Fuses –contemporary protective devices

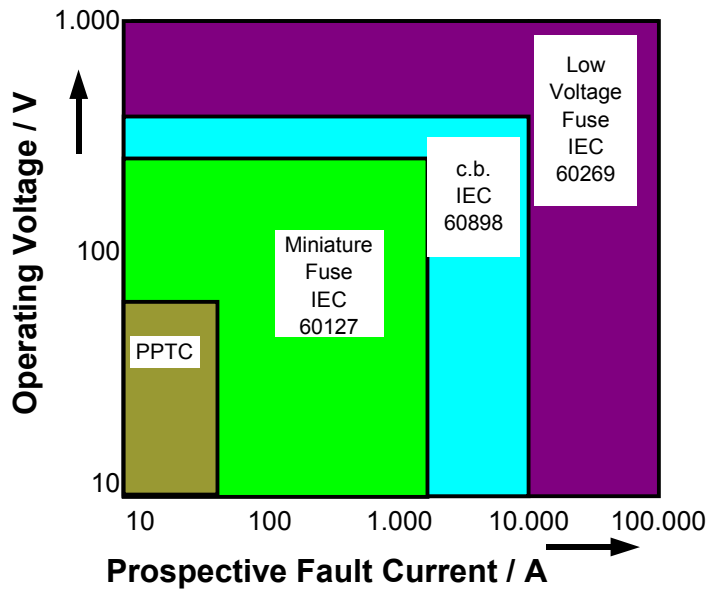


Fig. 2 – Application fields of Protective devices

Due to the high internal arcing voltage generated by short-circuit currents, fuses are able to interrupt a.c. currents much before they could reach their prospective peak values. This current-limitation gives very efficient protection of electric equipment against mechanical and thermal damage. No similar performance could so far be achieved by means of other overcurrent protection devices. After clearing a short-circuit current, fuse replacement does not represent a serious disadvantage as the fault needs anyhow repair work by skilled craftsmen.

### ▪ Overload protection

Overload current levels to be interrupted and breaking conditions are usually very moderate and as a rule no damage needs to be repaired. Rather than breaking capacity, quick restoration of service is therefore the determining factor. Consequently, resettable devices have widely replaced fuse-links in overload protection.

Fuses are still used for overload protection of cables and lines in l.v. power distribution networks. This is for their high breaking capacity, but also for a number of additional features and corresponding benefits:-

- Fuses are maintenance-free over decades of service life,
- Fuses enable low-cost and compact sized distribution boards,
- Fuses allow for easy segmentation of distribution networks,
- Fuses provide selective disconnection of faulted branches in a cascaded network.

### ▪ Cascaded protection

Discrimination of protective devices is essential to minimize the effects of a fault in hierarchical distribution networks. Only the faulted circuit shall be disconnected by the relevant protective device while all other circuits shall remain in service.

Fuses are highly discriminating. All fuses, from miniature to high voltage fuses, follow the same principle of operation. Their time-current characteristics form therefore more or less parallel lines. This is especially true under high-fault conditions when fuses require a constant energy ( $I^2t$ ) to operate. Discrimination between fuses can simply be achieved by choosing a minimum ratio of rated currents as defined in the applicable fuse standards.

## Fuses –contemporary protective devices

Circuit-breakers follow different time-current characteristics in the overload range and require a constant mechanical opening time under short-circuit conditions. Discrimination between circuit-breakers and between circuit-breakers and fuses is therefore more difficult to achieve.

### **Fuses and alternative protection!**

Fuses are unparalleled short-circuit protection devices. There are other devices available having more advantages in overload protection. In many applications the optimum protection will not be found by answering the question “fuses or other devices?” but by a combination of fuses and other devices.

As mentioned above, resettable or self-resetting devices are usually of limited breaking capacity. They can be backed-up by current-limiting fuses, restricting any higher fault currents to the breaking capacity of the overload protection device. This combination offers the benefits of reliable fault protection with the comfort of easy service restoration in case of overloads.

### **Fuse quality and safety aspects**

Selection of fuses as well as of other overcurrent protection devices is not for unskilled persons. Unless defined by product standards or local regulations, fuse selection requires proper circuit evaluation and expert's advice. Wrong fuse selection may not only result in failure to prevent damage, but may even cause damage or be dangerous to people.

Once properly selected, the irreversible nature of operating mechanism and the simple construction without moving parts makes fuses highly dependable. That's why fuses qualify for protection of important equipment with the highest level of safety required. The continuing discussion on whether or not circuit-breakers need regular inspections and whether or not electronic devices could be trusted does not apply to fuses, as their reliability has been proven for many decades. In case of deterioration of melting-elements -if any- fuses do not tend to malfunction but to fail safe. That's why fuses are very often installed as a “last line of defence” to back-up other less dependable devices.

Fuses are simple but high precision devices. Materials used, manufacturing technology and quality assurance need to be on a high level of expertise and are essential for the fuses to perform as expected. Care should be taken when transporting and handling fuses, as the robust body contains fragile melting elements.

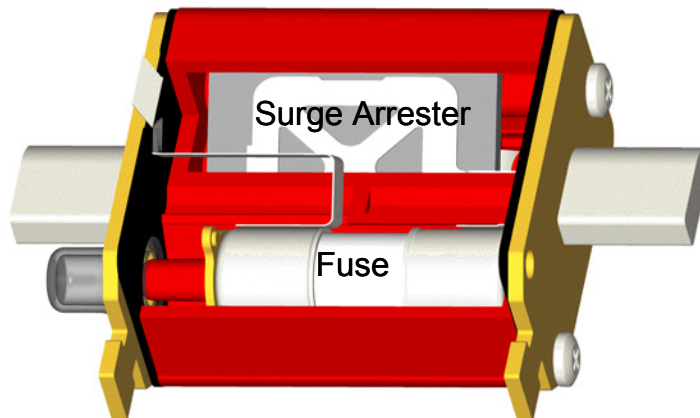
### **Integrated fuse protection**

One very common myth about fuses is that they need to be accessible for replacement. This is certainly true for fuses intended to prevent damage from cable and lines. In many applications however, fuses are not meant to protect the equipment itself but to limit the amount of damage in case of equipment failure. Fuses for this type of protection are specifically selected or custom designed back-up fuses which are never replaced unless the equipment would fail. Consequently, these fuses can be integrated in the equipment and be invisible to users. Integrated fuses offer all the benefits of fuse protection without showing from the inherent weaknesses:

## Fuses –contemporary protective devices

- Fuse selection by experts reduces the risk of misinstallation and malfunction,
- Factory installation rather than on site, enables proper quality assurance,
- No nuisance tripping, no replacement fuses required,
- Fuses are replaced during equipment repair or disposed with the equipment,

Well known applications of integrated fuses are under-oil high voltage fuses installed in transformer tanks or bushings or surface mounted miniature fuses on printed circuit boards.



One later very unique development concerning special fuse and surge arrester in a standard fuse body is shown in Fig. 3. Fuses qualify specifically for integrated protection by their compact size combined with high breaking capacity and durability. With their tendency to fail safe, inbuilt fuses make intrinsically safe products.

Fig 3: Surge arrester with integrated HRC fuse  
*Courtesy of Dehn + Söhne, Germany*

## Conclusion

Fuses are pioneer products of electricity and by no means outdated. Though they have been replaced by alternative protection devices in many applications, primarily overload protection, there are still plenty of protection jobs dominated by fuses. This is because of their paramount advantages in

- fault current limitation
- selectivity and
- reliability.

Fuses are very simple devices, but their mode of operation isn't simple at all. Fuse design and fuse manufacturing does therefore require long-term experience, superior manufacturing technology and a high level of consciousness for product quality. Fuse selection isn't for amateurs but for experts as can be found among the members of **Pro Fuse International**.