THE FUTURE OF FUSES

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1. Introduction

Fuses belong to the first devices of commercial electricity and they still use the same physical principle since their invention much more than a hundred years ago. In fact, many fuses don't appear to have changed in design over decades. Just the fact of an extremely long product history in a rapidly developing technical environment seems to be reason enough for people of different interests to question the future of fuses.-

- Customers, driven by the desire of a perfect convenient protective device
- C.b. manufacturers, wishfully thinking of ousting a nuisant competitive device
- Fuse manufacturers, being concerned about future business

The author intends to discard his admittedly positive attitude to fuses and to develop an unbiased scenario of fuses and applications that may enable the fuses to survive in a growingly competitive environment. Three methods of prognostication are used.-

- Chart technique
- Technical facts
- Market psychology

2. Chart technique

One very common attempt to predict the future development of markets is the extrapolation of past figures. In conjunction with an estimation of future development in technology this may give a reasonable prediction of the future of fuses as well. Looking at the demand of electronic fuses in Fig. 1 it can be seen that there has been an approximately linear growth of about 6 % per year until now. There is not too much prophetic skill necessary to predict a similar growth rate for the years to come as the major fields of application are still to be seen in growing markets like computer hardware, cellular phones and consumer electronics. Unfortunately the sales value cannot be expected to grow in line with the number of fuses as significant price erosion has to be expected.

A second field of growing fuse application can be seen in the automotive market. Even if the number of new cars produced would not increase, the number of fuses used in cars has been increasing with each new model and can still be expected to grow further on. Fig. 2 shows how the number of fuses (not including electronic fuses) has increased in one popular compact size European car. Similar graphs can be drawn for almost every model of car.

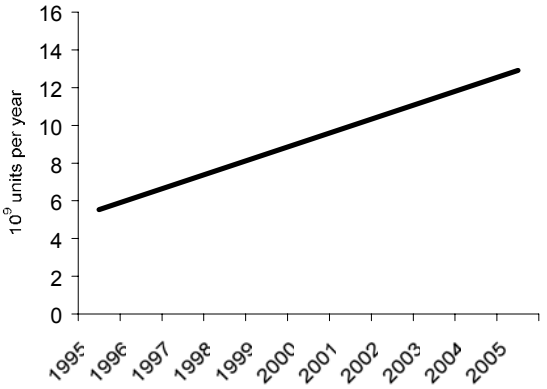

Fig. 1: Demand of electronic fuses

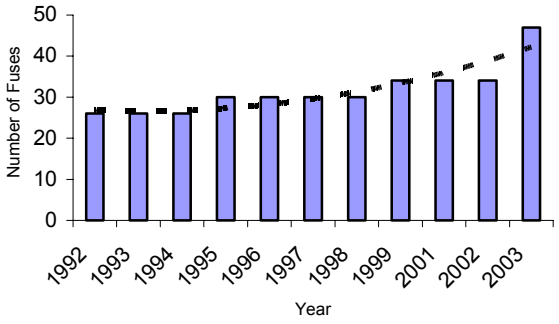

Fig. 2: Fuses in cars

Unfortunately, the author could not find any solid numbers on low voltage and high voltage power fuses but with increasing worldwide electric power consumption and huge future demand for electric power in developing countries, the number of power fuses can also be expected to grow with a remarkable pace.

Increasing power consumption and still growing markets for electronic devices and electric appliances means a growing number of electric circuits that need to be protected. While there is no doubt that the market for circuit protection devices will still be growing, there is no guarantee that future circuit protection will necessarily raise the need for electric fuses.

There are however, competitive devices using different technologies that have to be taken into

account and carefully watched. Fuses will only maintain or increase their share in circuit protection if they offer significant technical advantages and benefits over other protective devices.

3. Technical facts

Fuses exhibit a number of very positive attributes that make them technically superior to other protective devices. The current-limiting fuse provides complete protection against the effects of overcurrent by protecting both electric circuits and their components. Fuses offer a combination of exceptional features, for example:

a) High breaking capacity (current interrupting rating)
b) No need for complex short-circuit calculations
c) Easy and inexpensive system expansion involving increased fault currents
d) Mandatory fault elimination before resetting:- Unlike other short-circuit protective devices (SCPD), fuses cannot be reset, thus forcing the user to identify and correct the overcurrent condition before re-energizing the circuit.
e) Reliability
No moving parts to wear out or become contaminated by dust, oil or corrosion. Fuse replacement ensures protection is restored to its original state of integrity.
f) Cost effective protection
Compact size offers low cost overcurrent protection at high short-circuit levels.
g) No damage for type 2 protection according to IEC 60947-4-1
By limiting short-circuit energy and peak currents to extremely low levels, fuses are particularly suitable for type 2 protection without damage to components in motor circuits. This type of protection may be achieved without installing a fuse with a smaller ampere rating.
h) Safe, silent operation
No emission of gas, flames, arcs or other materials when clearing the highest levels of short-circuit currents. In addition, the speed of operation at high short-circuit currents significantly limits the arc flash hazard at the fault location.
i) Easy coordination
Standardized fuse characteristics and a high degree of current limitation ensure effective coordination between fuses and other devices.
j) Standardized performance
Fuse-links according to IEC 60269 ensure availability of replacements with standardized characteristics throughout the world.
k) Improved power supply quality
Current-limiting fuses interrupt high fault currents in a few milliseconds, minimizing dips in system supply voltage.
l) Tamperproof
Once installed, fuses cannot be modified or adjusted in order to change their level of performance, and thus malfunction is avoided.

There are, however, some weaknesses to be considered before adding up the fuse benefits to an unsurpassed product that would not need to fear any competition.

a) Fuses are single-action devices that need replacement after operation.
b) Replacement fuses may not always be at hand.
c) Too many different and incompatible fuse systems laid down in national and international standards round the world can be rather confusing to the customer and make fuse selection complicated (see fig. 3).
d) A lack of information on fuse application may cause misapplication and consequently malfunction

Fig. 3: Confusing utilisation categories

Malfunction of fuses is very rare and usually a consequence of lacking information and understanding of how fuses work. This applies to both, design engineers who have to select the proper fuses according to the equipment to be protected and even more to field operators who need to replace operated fuse-links.

Depending on the qualification of the user and the nature of the job performed when using fuses, the judgment of fuses as protective devices may vary from unsurpassed cost efficient safety device to a nuisant pain in the neck.

4. Market psychology

Commercial success or failure of a product is not only based on technical data and operational performance of a product as manufacturers and even more development engineers may believe.

Commercial success depends to a great deal on market psychology i.e., on what benefits the customer believes to enjoy when using a product. In the contrary even excellent technical solutions may fail if

potential users fear the product may be inconvenient or potentially dangerous to use. In this respect it is unimportant whether real danger or inconvenience exists or the benefits can be measured in currency. What counts is what the user believes or better to say the image of fuses that develops in the user's mind.

4.1 The image of fuses

Fuses are among the best known electrical devices to people around the world. Unfortunately, most people may have become aware that fuses exist after fuse operation and consequent power outage. The image of fuses is therefore widely dominated by the personal experience of the search for replacement fuses in literally dark moments of life.

These moments usually do not generate a lot of sympathy for fuses but trigger a deep desire for more convenient protective devices and more advanced (preferably electronic) devices replacing these dinosaurs of electricity. The long history of fuses and their wide spread use has also developed a not very sophisticated even martial language to describe the effect of fuses which associates a number of negative feelings to the use of fuses.-

- Danger: Fuse blows!
- Heat and fire: Fuse burns out!
- Nuisance defects: Fuse fails, fuse is defective.

Depending on local language and habits, you will find similar discriminative expressions describing fuses and their operation round the world. Even fuse experts use these expressions and laid them down in national and international standards.

The poor reputation of fuses and the need for replacement necessarily implies low value (throw-away product) and consequently low prices. Price pressure sometimes has got its impact on quality and operational reliability which again confirms and enhances a biased image of fuses. This way it seems the reputation of fuses is washed down the drain in a vicious circle of self fulfilling prophecy.

Strange to see that just competitive devices are called "fuses" e.g., "automatic fuses" for m.c.b., "resettable fuses" for PTC overcurrent protectors or "fuse board" for breaker panels. That means, the term "fuse" has become synonymous for "protective device" which is to be seen an extremely valuable asset fuses and fuse manufacturers can build their future upon.

4.2 Customer benefits

The benefits of fuses as listed above will only be honoured by the customer if he is fully aware of. This requires:-

- Availability of information
- Clarity of information
- Availability of suitable fuses and
- Positive field experience.

While service men and ordinary unskilled persons would usually suffer from a lack of suitable replacement fuses in case of line or equipment defects, laboratory engineers have to deal with the selection of the optimum fuse for their application out of a seemingly uncountable variety of fuses available in the market.

Without viable information and preferably professional technical assistance both are very likely to run into the vicious circle of misapplication and product failure that necessarily ends up in frustration, a poor esteem of fuses and search for believed to be better protective devices. These development and application engineers who know how to use fuses will usually experience positive results and likely continue using fuses whenever possible.

5. The future of fuses

5.1 Improving the image

The future of fuses will very much depend on their positive image among design engineers and users alike. There is a good chance to build upon the widespread awareness that "fuse" stands for "safety" and "protection". But to eliminate also existing prejudice and alleged weaknesses of fuses, the fuse industry will have to work hard making fuse application a common art to the technical community rather than preserving the "mystery of I^2t".

Significant effort has already been spent to work out an application guide for fuses, recently published as Technical Report IEC TR 61818.

The European fuse manufacturers founded "Pro Fuse International", an organization to promote the knowledge of fuses and fuse application.

The German fuse manufacturers established a recycling system (NH/HH Recycling e.V.) for fuses that have fulfilled their duty.

All activities of this nature that are not only thought to promote a single manufacturer's product but to promote the acceptance and improve the image of fuses are suited to sustain future fuse application.

5.2 Future fuse applications

5.2.1 Overload protection

The question about the future of fuses can only be answered based on knowledge or projections of their future applications. Most likely fuses will be replaced by other protective devices in applications where the weaknesses prevail and strengths do not offer enough benefits to the user. This happened widely in l.v. a.c. distribution systems up to 63 A rated current and up to about 6 kA prospective short-circuit current i.e., mainly cable and line overload protection.

Overload protection means that the protected electric circuit or equipment is still operational but the fuse-link needs to be replaced. A situation that may be troublesome and annoying suited to trigger a deep desire for resettable protective devices.

Fuses will therefore be most vulnerable in overload protection applications. Whenever resettable devices e.g., circuit-breakers, PTC or electronic controls fulfill the requirements of time-current characteristics and breaking capacity they will very likely be preferred.

5.2.2 Short-circuit protection

In fact, fuses cannot prevent short-circuits as they can prevent dangerous overloads, but they limit the effects of short-circuit currents very efficiently to the faulted circuit and prevent potentially catastrophic results of high faults and disturbing arcs.

As mentioned above, fuses show their strengths in high breaking capacity and by limiting short-circuit energy and peak currents to extremely low levels. They offer these benefits at an extremely compact physical size and unbeatable low costs.

A faulted circuit or equipment anyhow needs to be repaired before fuses are replaced. It may therefore even be a valuable benefit that fuses cannot be reset. I.e., if fuses are used to protect adjacent circuits or components from the effects of a faulty component, the need for replacement does no longer appear to be a disadvantage.

Short-circuit protection or more precisely "fault containment", specifically at high fault levels, does therefore seem to offer chances for future fuse application.

5.2.3 Semiconductor and c.b. protection

Semiconductor equipment is usually well protected against overload by electronic controls. The protection of semiconductors can therefore be seen as a specific type of short-circuit protection. Because of the fast and reliable response to short-circuit currents, no other devices can be seen to replace fuses in the near future.

Fuses backing up electro-mechanical switching devices e.g., circuit-breakers or motor starters can make a very cost efficient solution as they upgrade the fault current levels up to which these devices can be used. Increasing performance of these devices may however cannibalize the use of accompanying fuses.

5.3 Future fuse design

5.3.1 Integrated back-up fuses

Future fuses shall exhibit all strengths as listed above and not show any apparent weaknesses to the user. What appears to be utopian is in fact nothing unusual as it depends more on the application than on the design. Many of today's fuses are not intended to protect the equipment they are assigned to but to operate after the equipment has failed and to contain the fault i.e., to protect the adjacent circuits and other devices as well as the environment from further damage. Consequently, these fuses could be integral part of the assigned equipment and replaced during equipment repair or discarded with the demolished equipment.

Fig. 4 shows m.v. back-up fuses installed under oil in a distribution type transformer. The fuses are selected to operate in case of internal transformer faults only. No on site replacement does therefore need to be considered. For overload protection, fuses or circuit-breakers are installed on the l.v. transformer side.

Fig. 5 shows the integration of a custom designed cylindrical back-up fuse to protect the adjacent overvoltage protector enclosed in the same device.

Fig. 4: Under-oil m.v. back-up fuses in a transformer tank

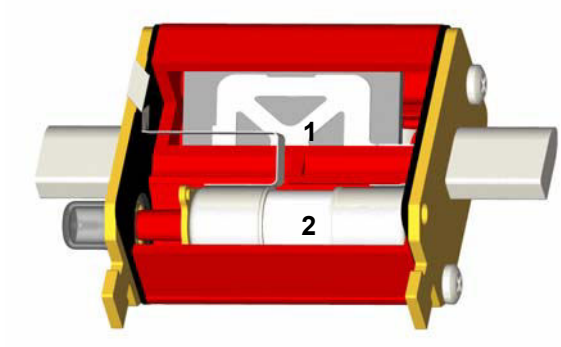

Fig 5: Back-up fuse (1) and overvoltage protector (2) integrated in NH fuse casing

Back-up fuses designed to application are ideal for devices with integrated protection. Integrated back-up protection seems to be the fuse application offering a maximum of benefits and a minimum of disadvantages in application.-

- fuse selection by design engineers, preferably assisted by manufacturer's application engineers, reduces the risk of misapplication
- no trouble with fuse replacement
- compact and cost efficient fuse design
- low power dissipation

5.3.2 Miniature dimensions

Following the general trend for more compact dimensions of electrical equipment, fuses will

continue to adopt smaller dimensions in the future. This is especially true with electronic fuses where miniaturization was a major development task in the past and will certainly be in the future (see figs. 6 and 7). This trend will also affect the future development of power fuses that are integral part of electrical equipment. By coincidence, back-up fuses allow for the most compact dimensions.

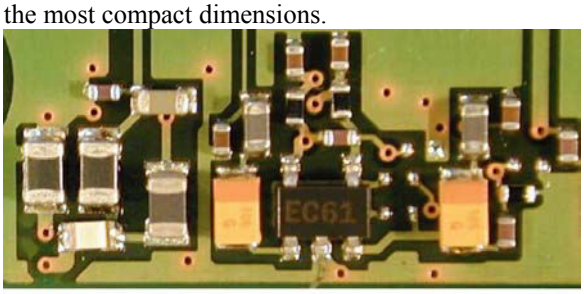

Fig. 6 –PCB with chip fuse (lower left corner)

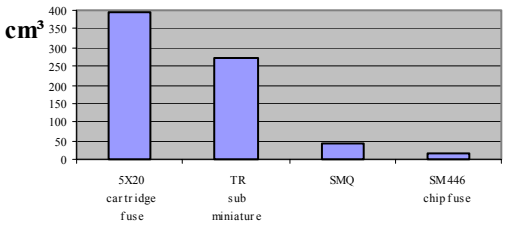

Fig. 7: Miniaturization of fuse dimensions

5.3.3 Intelligent fuses with additional functions

Fuses are simple technical devices that operate at a given current after a defined period of time. Fuses cannot be adjusted nor discriminate fault currents from operating currents. I.e., fuses will not always interrupt high impedance arc faults that may cause fire.

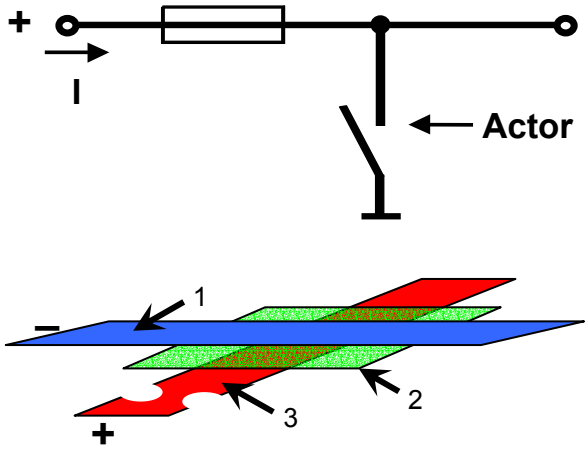

Fig. 8: Actor fuse
1 - Frame potential 2 - Actor layer 3 - Voltage plus

Ordinary fuses cannot transmit or receive signals or information i.e., fuses are all but intelligent.

Some types of fuses are equipped with strikers to indicate fuse operation and trigger switch releases or microswitch for remote indication including electronic fuse monitoring. It is also possible to integrate more functions in a fuse than just current dependent operation. Microchips applied to the melting element may be used to sense current and temperature for energy control and fault current or overload sensing.

No fuses have however been found to receive external signals and operate accordingly. Studies show that the characteristics of fuses can be adjusted within a broad range even below the rated current by the application of compact sized heaters to the melting elements (see fig.8).

This type of fuse can be externally triggered e.g., by a crash sensor and interrupt low fault currents to avoid fire after a car crash. In a further step, several fuses connected to a busbar can be combined to a distribution fuse-board including sensors for currents and temperatures as well as actors for external triggering of fuse operation. Fig. 9 shows a working prototype of such a complex device.

Fig. 9: Distribution board with sensor-actor fuses

Whether and when such protection systems will be included in cars is still uncertain and will finally depend on market needs.

6. Conclusions

A positive image will be necessary but not sufficient to ensure a prosperous future of fuses. Fuse benefits exceeding the advantages of competitive devices will be major key to success.

It seems that the features and advantages of fuses are somewhat difficult to communicate to users whose major subjects are others than fuses. In the contrary, the draw backs are deeply rooted in peoples mind. Consequently, successful fuses shall have eliminated all the weaknesses listed above, i.e. future fuses will be

- integrated in equipment
- designed to application
- invisible to users
- never replaced