

Fuses – still the best form of overload protection

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Often when I visit people to talk about circuit protection I hear the comments “fuses are a thing of the past” and “circuit breakers have made fuses obsolete”. I have come to believe that although some of these comments are based on some truth, the important role that fuses have in our electrical protection systems has slowly become misunderstood. So, are fuses less relevant these days? Which protective device is better? Do fuses have a future?

Before these questions can be answered, it is important to take a step back and explore what protective devices actually do. What do they protect us from and what are their respective advantages & disadvantages?

In recent years, we have seen the arrival of many new overload protection devices ranging from various mechanical circuit breakers, brake switches and expulsion devices to hi-tech chemical shunt mechanisms. One could be forgiven for believing that the old venerable fuse is on the way out.

The truth is that some of these devices have replaced fuses in some applications but the humble fuse is still the best form of overload protection and will be around for many years to come.

Why after over eighty years of service are fuses still the best?
Put simply, it's because fuses can do three things at once that the other protection devices cannot.

Electrical circuits & distribution systems can be quite complicated in design and can never be 100% fail-safe because they are exposed to the possibility of destructive over-currents.

Over-currents - What are they?

An over-current is either an overload or a short circuit current.

An overload current is an excessive current relative to the normal operating current, but one which is confined to the normal conductive paths provided by the conductors and other components and loads of the distribution system.

As the name implies, a short circuit current is one which flows outside the normal conducting path.

Over-currents can be caused by many factors. The most common factors are damage to the circuit, excessive overloading of the distribution system and general deterioration of components within the system. Circuits can be damaged by accident or by natural causes (eg. thunder storm).

Reliable protective devices prevent or minimise costly damage to transformers, conductors, motors and other components and loads that make up the complete distribution system.

Reliable circuit protection is essential to avoid the severe financial losses that can result from power blackouts and prolonged down time of facilities. More importantly, they also save people's lives.

Overloads (Nasty...)

Overloads are most often between one and six times the normal current level. They are usually caused by harmless temporary surges in current that occur when motors are started up or transformers are energised.

Such overloads, or transients, are normal occurrences. Since they are of brief duration, any temperature rise is trivial and has no harmful effects on the circuit components. It is important that the protective devices do not react to them.

Continuous overloads can result from defective motors (such as worn motor bearings), overloaded equipment or too many loads on the one circuit. Such sustained overloads are destructive and must be cut off by protective devices before they damage the distribution system.

However, since they are of relatively low magnitude, removal of the overload current within a few seconds will generally prevent equipment damage. A sustained overload current results in the overheating of conductors and other components and will cause deterioration of insulation, which may eventually result in severe damage and short circuits if not interrupted.

Short Circuits (Very Very Nasty...)

Short circuit currents occur when the current in a particular circuit is given the opportunity to flow through a shorter than normal path.

Whereas overload currents occur at rather modest levels, the short circuit or fault current can be many hundreds of times larger than normal operating current. If not cut off in a matter of a few milliseconds, damage and destruction can become rampant. There can be severe insulation damage, melting of conductors, vaporisation of metals, ionisation of gases, arcing and fires.

Simultaneous high level short circuit currents can develop huge magnetic field stresses. The magnetic forces between bus bars and other conductors can be extreme. Even heavy bracing cannot be adequate to keep them from being warped or distorted beyond repair. Because the load is bypassed a very large magnitude of fault current may occur.

In recent years many utilities have increased their generating capacity and consequently the available short circuit currents have also increased.

As well low impedance circuit components (transformers, busways, etc) have allowed for greater magnitudes of fault currents. These factors make the proper selection of a protection device with a proper interrupting rating extremely important.

Fuses

The fuse is a reliable over-current protective device. A 'fusible' element encapsulated in a tube and connected to contact terminals comprises the fundamental elements of the basic fuse.

Electrical resistance of the link is so low that it simply acts as a conductor. However, when destructive currents occur, the link melts quickly and opens the circuit to protect conductors and other circuit components.

Fuse characteristics are stable. Fuses do not require periodic maintenance and testing.

Fuses have three unique characteristics:

1. They are safe. Modern fuses have extremely high breaking capacities – Can withstand very high fault currents without rupturing.
2. Properly applied, fuses prevent 'blackouts'. Only the fuse nearest the fault opens without upstream fuses (feeders or mains) being affected. Fuses can provide selective co-ordination.
3. Fuses provide optimum component protection by keeping fault currents to a low value.....They are said to be current limiting.

Breaking Capacity (Interrupting Rating)

A protective device must be able to withstand the destructive energy of short circuit currents. If a fault current exceeds a level beyond the capacity of the protective device, the device may actually rupture or explode, causing additional damage and possibly catastrophic arcing.

Thus, it is important when applying a protection device to use one that can sustain the largest short circuit current. The rating which defines the capacity of a protective device to maintain its integrity when reacting to fault conditions is termed 'breaking capacity' or 'interrupting rating'. This value is printed on the fuse and is defined as the maximum fault current the fuse can be subjected to and safely interrupt without losing its physical integrity.

One of the most progressive areas of modern fuse design is in this area. New technology in materials composition & structural engineering have given modern fuse designs the ability to clear the highest and most onerous of fault conditions.

The maximum fault current that modern fuses can clear presents no problem. For example, many UK manufactured fuses to BS88 (AS2005) rated at 80kA at 415V have also been tested to Canadian CSA standard at 200kA at 660VAC.

High Breaking Capacity means that detailed fault level calculations with fuse protected systems are unnecessary. In addition, it allows for strengthening of the system at some later date.

The commonly used term 'HRC', meaning High Rupturing Capacity is derived from this concept.

It should be noted that where moulded case circuit breakers are used, another term must be defined and understood. 'Interrupting capacity' is the amount of short circuit current that the moulded case circuit breaker can safely interrupt.

Selective Co-ordination – The Prevention of Blackouts

The co-ordination of protective devices prevents blackouts caused by over-current conditions. When only the protective device nearest a faulted circuit opens and larger upstream fuses remain closed, the protective devices are selectively co-ordinated (they discriminate). The word 'selective' is used to denote total co-ordination (isolation) of a faulted circuit by opening of only the localised protective device.

Unlike electro-mechanical devices it is a simple matter to selectively co-ordinate fuses of modern design. By maintaining a minimum ratio of fuse current ratings between upstream and downstream fuse, selective co-ordination is achieved.

Co-ordination in fuse systems between major and minor fuse-links can readily be achieved on a 2:1 basis of current rating. This has been an industry standard for several decades and applies to any fault current and any fuse-link complying with BS88 Part 1 & 2 (AS2005).

The time/current zones given in these standards are based on this limiting requirement of a 1:6:1 ratio for most practical conditions.

Current Limiting

If a protective device cuts off a short circuit in less than one quarter cycle (ie. less than 5ms) before it reaches its total available (destructive) value, the device is termed as 'current limiting'.

HRC fuses to AS2005 part 10 & 20 are designed to be current limiting. Fuses restrict fault currents to such low values that a high degree of protection is given to circuit components against even very high short circuit currents.

The fundamental purpose of current limiting fuses is to limit the instantaneous peak current to as low a value as possible and clear quickly so as to limit the amount of damaging let-through energy to the circuit and components the fuse is protecting.

These fuses permit breakers with lower interrupting capacity to be used. Fuses can reduce bracing of busbar structures. Fuses minimise the need for other components to have high short-circuit withstand ratings.

If not limited, short circuit currents can produce heating in circuit components by the immense energy can cause insulation damage or even explosion. At the same time huge magnetic forces develop between the conductors that can crack insulators and distort bracing structures.

High Rupturing Capacity low voltage fuses have the ability to provide protection at all likely fault levels. No other protection device can aspire to such a claim.

Semiconductor Applications

In circuits containing sensitive semiconductor components such as thyristors & diodes, even small overloads can be catastrophic. Utilising pure silver elements and efficient design, semiconductor fuses are able to open a circuit in small fractions of a second, protecting the sensitive and often very expensive semiconductor components.

No other protection devices can be used in such applications.

Conclusion

So, let's see if we have answered our initial questions. Are fuses less relevant today? Circuit breakers have the advantage of being reset-able and operationally cheaper. They have certainly taken over the downstream protective role where the potential fault currents are lower. So they certainly sell in much larger quantities than fuses do. However, due to their unique qualities, fuses are still required upstream in the critical role. They are, in essence, the 'gatekeepers' of the protection system. They are actually the most important protective device in the system. I think that makes them very relevant.

Which protective device is better?

There is no doubt that as an over-current protection and safety device, fuses maintain their position as the world's premier option.

Do fuses have a future?

Circuit breaker technology will continue to improve and they will continue to take over some roles presently performed by fuses. However, fuses will always have a role in electrical protection systems due to their unique qualities and specialist capabilities. The answer is a resounding 'YES' with the further note that the fuse will one day become more specialised in its nature.

I hope that in exploring this topic, I have addressed the relevant questions, comparisons and any possible misunderstandings relating to fuses and their future.