Mechanical Products Company

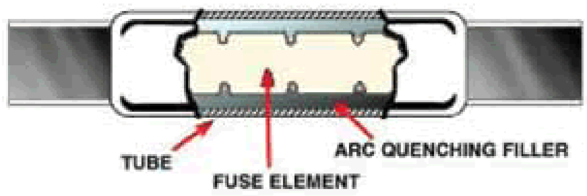
Circuit Protection Types

Advanced Design - Legendary Performance - Superior Circuit Protection - Count on it

There are two general categories of circuit protection:
1) Fuses
2) Electro-mechanical circuit breakers.

Each has its advantages which will be discussed here.

Fig 1 – Single element fuse



Fuses

Fuses break down into three convenient categories —fast-blow, slow-blow, and semiconductor. Each responds to fault current in different ways.

The principal function of a fuse is the resistance heating of a current-carrying element and its subsequent destruction under a fault condition, which results in an air gap. Basically this is a fault condition that is confined to a controlled environment. Such a condition requires that the fuse be the weakest point in the circuit design. This creates a situation when size can be exploited to its smallest constraints. Circuit interruption—especially under short circuit conditions—creates expanding powerful forces. Thus, the ingenuity of material sciences is critical to fuse design.

Fast-blow and semiconductor fuses are the quickest-response devices available because there is no lost time for mechanical motion related to contact separation. The trade-off for speed, however, is sensitivity to start-up inrushes commonly found in many applications. This, then, results in one of two compensatory actions: 1) the decision to either derate the fuse—increasing the amperage rating of the fuse beyond the circuit's steady-state current value, which impairs the quality of protection in overload fault conditions, or 2) the addition of a mechanism to override the start-up surge. It is not uncommon to use a combination of both of these steps.

The slow-blow fuse is an example of a device that adds a spring-loaded mechanism to artificially delay the opening function. Although this provides an answer, derating of a slowblow fuse still occurs because of the nuisance and expense associated with replacing blown fuses. Due to the materials utilized, a slowblow fuse is also more sensitive to ambient temperature extremes than the faster reacting devices, even though all fuses exhibit sensitivity to ambient temperatures.

Another issue in the use of fuses is thermal cycling —the continued, repetitive cycling of current flow through the fuse at or near its rated current. Thermal cycling will, over time, stress the mechanical connections within the fuse, which are usually soldered. This will increase the resistance at these critical points, causing added heat and eventual breakdown.

There have recently been improvements in the design of fuses, such as better indication of a faulted circuit through visual means. These adaptations include mechanical flags and lights of various designs. The indicator light also has improved the versatility of fuses. They still lack many of the options available on other devices, such as dual-voltage capabilities, shunt trip/relay trip functions which allow for remote control, and the ability to combine functions into a single device such as on/off switching.

The main drawback of fuses is that they must be replaced every time they open the circuit, creating downtime and inconvenience. Also, upon replacement, the opportunity exists to replace the fuse with an improper substitution that compromises the safe operation of a piece of equipment. Additionally, the replacement can be an expensive warranty item in many applications. The primary advantages of fuses are low cost and small package size.

Electro-Mechanical Circuit Breakers

The electro-mechanical circuit breaker category is broken down into two general sub-groups: 1) magnetically actuated devices, and 2) thermally actuated devices. In general, a magnetic device is based on a current flow through a coil generating a magnetic field that unlatches a contact. In a thermal device, mechanical motion, obtained by resistance heating of thermostatic metals, is used to unlatch a contact or pair of contacts.

There are also devices available, called thermal-mags, that utilize both types of technology within the same device. A very common usage of thermal-mags is found in most home-use circuit breakers.

Fig 2 – Dampening reaction time of magnetic breaker.

Magnetic devices have found wide usage today because of their versatility. They have provided designers with many options, i.e. multi-pole devices, various electrical configurations (shunt trip, relay trip, voltage trip), lighted indication, auxiliary contacts, and switchability. This has made them a very popular choice for circuit protection.

Magnetic devices are current-sensitive and are therefore used to detect electrical faults. These devices are sensitive to the type of applied voltage, AC vs. DC, and to the frequency of AC voltage. Additionally, it is difficult to precisely correlate the magnetic function to a rising current. This makes them extremely susceptible to fluctuations in power quality (i.e., minor surges and inrushes which generally are not harmful). To counter nuisance tripping, therefore, a means must be added to dampen the reaction time of the breaker to overloads. This is accomplished by means of a hydrostatic action against the magnetic core in the coil. The reaction time of the circuit breaker to overloads is then controlled by the viscosity of the liquid contained in the core tube. This allows for a diverse array of different trip profiles enlarged by the different frequencies 50/60 Hz; DC and 400 Hz. The additional mechanism, however, adds cost to the device, increases the number of moving parts, and increases its weight.

Many applications, especially at start-up, have significant inrush currents. The magnetic breaker, even with the dampening core, will exhibit nuisance tripping, although further dampening with magnetic flux inhibitors and inertia-impeding mechanisms can provide additional inrush let-through. The published specifications for withstanding inrush of magnetic breakers are only 33% to 50% that of thermal sensing devices.

Magnetics are affected by their environment and the mounting attitude in which they are placed. Environmentally, the magnetic breaker is impacted by the ambient temperature. Temperature will cause the viscosity index of the core tube fluid to change, thus increasing trip times in cold and decreasing trip times in warm ambients. Pre-loading a magnetic breaker, or operating it at 80% of its rating can also impact its performance, causing trip times to shift.

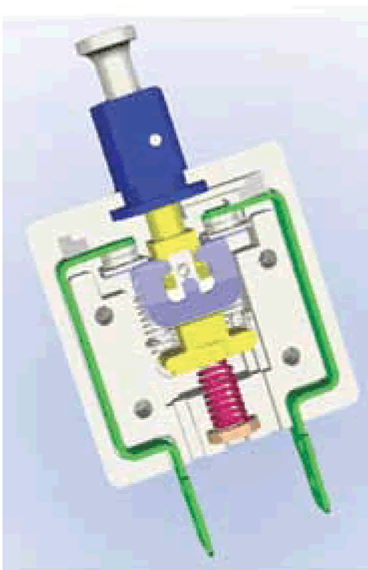
Magnetic breakers are also affected by vibration and shock. The attitude of the core tube when mounted also impacts the trip characteristics of the magnetic breaker. Because of these issues, the aerospace industry, including such sophisticated space vehicles as the U.S.-manned space shuttle, requires thermal sensing circuit breakers that exhibit more robust designs when considering such environmental issues. Even so, the magnetic circuit breaker has carved out a respectable market in circuit protection.

In the past, the lack of versatility of the thermal sensing breaker reduced its effectiveness in the commercial marketplace, even though it has enjoyed much success in high tech aerospace/military applications. This situation is now changing with the introduction of the standard options—multi-pole, auxiliary contacts, shunt, and relay trip variations.

In fact, the thermal sensing breaker is leading the industry with new innovations such as dual voltage (120/240 V in a single package) for the international market, two-pole devices in the package size of a single, and snap-in mounting features. These, combined with the package aesthetics exhibited by recent entries, make it the desirable circuit protection choice

The performance features of the thermal sensing device are also second to none. Thermals now offer double-contact interruption for superior short circuit protection; power on/off switching that competes with plain mechanical switches for endurance and reliability even under inductive load rating conditions, and an extensive range of amperage and voltage ratings.

Fig 3 – Cutaway view of a thermal circuit breaker



One of the key attributes of thermal sensing circuit breakers is their inherent ability to withstand harmless start-up and surge inrushes while protecting against overloads and short circuit faults. This feature of thermals makes them the protection of choice for the majority of today’s applications.

Additionally, the precise calibration available with the thermal device provides the design engineer with superb circuit protection.

Not unlike fuses and magnetic circuit breakers, thermal sensing devices also exhibit sensitivity to ambient temperature. Recent design innovations in the utilization of different bimetals and blade forming have improved these characteristics. The designer, being aware of this, can take steps to minimize the affect on the design, and even use these characteristics to the benefit of the design.

The electro-mechanical circuit breaker provides the design engineer with the most versatile product in circuit protection. Combined with the safe resetability function these devices offer, in most instances they represent the most economical circuit protection choice.

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