Evolution of the molded case circuit breaker trip units and their value to customers

Even though an 1879 patent filed by Thomas Edison provided a glimpse of the definition of what would become circuit beakers, fuses (use once and throw away) were the standard for the first 30-40 years in power distribution systems[1]. In 1924, German inventor Hugo Stotz created and patented what was marketed as a re-settable fuse (Figure 1). It was a direct retrofit into common fuse panels of the day. The Stotz fuse incorporated a thermal element to detect and open contacts to clear overloaded or shorted circuits[2]. This was a forerunner of the thermal-magnetic breaker (Figure 2) widely used in today's power distribution systems.

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01 First Circuit Breaker – Designed by Hugo Stotz

How have circuit breakers evolved since the Stotz?
More importantly, how can you take advantage of new circuit breaker technology to deliver your clients a better tailored and more user-friendly project? This brief article will focus specifically on the evolution of the breaker trip unit and the value this evolution provides to customers.

Circuit Breaker and Trip Unit
In order to understand what a trip unit is, let's revisit the definition of a circuit breaker. A circuit breaker is a mechanical switching device designed to automatically detect and eliminate short circuits and overload current. A trip unit, specifically, is the "brain" of the circuit breaker as its function is to measure physical parameters such as electrical current and decide when to "trip" or rapidly open the mechanical contacts of the circuit breaker. At the bare minimum, a trip unit needs to offer overload and short circuit protection. In regard to the topic of evolution, the trip unit can be as simple as a bi-metallic strip or now, as advanced as a computer. This evolution has opened the door to so much more than overload and short circuit protection, but a whole new world of protection, measurement and control.

Let's take a look at the evolution of the circuit breaker trip unit in four stages, starting with the basic thermal magnetic circuit trip unit (still the most widely used trip mechanism used today).

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Written by Andrew Legro, PE, ABB Field Applications Engineer

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02 Example of a Thermal Magnetic Trip Curve[3]
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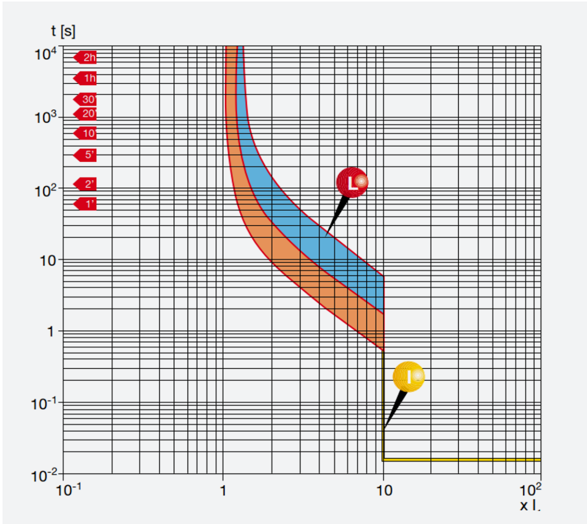
03 Early electronic trip unit[4]



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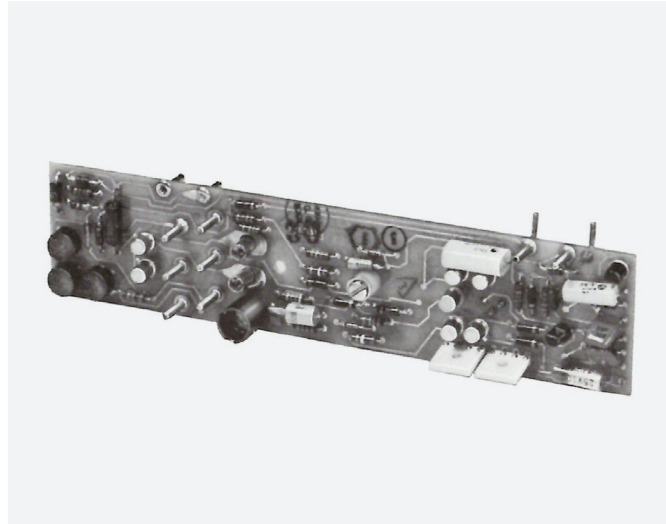

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Thermal magnetic circuit trip unit
The basic thermal magnetic circuit trip unit still provides a cost-effective solution for basic circuit protection and remains in widespread use. With the growth of critical electrical loads, the need for accurate and coordinated circuit protection has become much more important. However, the lower accuracy sensitivity offered by thermal magnetic breaker cannot fully address this increasing demand. These shortcomings are amplified when you need breakers to trip in a coordinated fashion where only the problematic circuit is taken out of service. This is called selectivity and was a primary driver in the evolution from the thermal magnetic trip unit to the electronic trip unit which can provide a much higher degree of accuracy in sensing and responding to trip events.

The illustration above (Figure 3) is a typical response of a thermal magnetic breaker in the form of a time current curve (TCC). The X axis represents current and Y axis represents time, in seconds. The grid is logarithmic on both X and Y axis. The breaker has two elements ‘L’ or long time for the thermal and ‘I’ for the magnetic. Note the width of the long-time element indicates a substantial lack of accuracy. Also note that the breaker’s response is significantly affected by temperature. There are two long time curve sections shown. The blue section is the ‘cold’ response and the orange section is the ‘hot’ response. The lack of accuracy makes coordination between thermal magnetic breakers difficult.

First generation electronic trip units
As noted earlier, this lack of accuracy, along with the growing need for coordinated circuit protection, drove the development of the electronic trip unit. First generation electronic trip units (Figure 4) were simple analog circuits comprised of resistors, capacitors, inductors, and transistors. However, they offered increased accuracy over their thermal-magnetic cousins. Electronic trip breakers could be reasonably coordinated and be used to build a selectively coordinated distribution system.

Over the years, electronic trip units underwent incremental improvements including:

- Limited adjustability – addition of the ability to make basic adjustments to instantaneous and overload response to improve selectivity
- True RMS sensing – improving accuracy bringing measurement much closer to the thermal response (not just looking at peak) of the current
- Thermal memory – ensuring (even lacking the inherent “heater” present in original thermal magnetic breakers) that trip data could be retained and remembered for reporting
- Overall improvement in equipment protection – these enhancements allowed more selectivity and eliminated nuisance or premature trips, which can damage the equipment

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04 Typical Thermal Magnetic Time Current Curve
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05 Typical LSIG Time Current Curve
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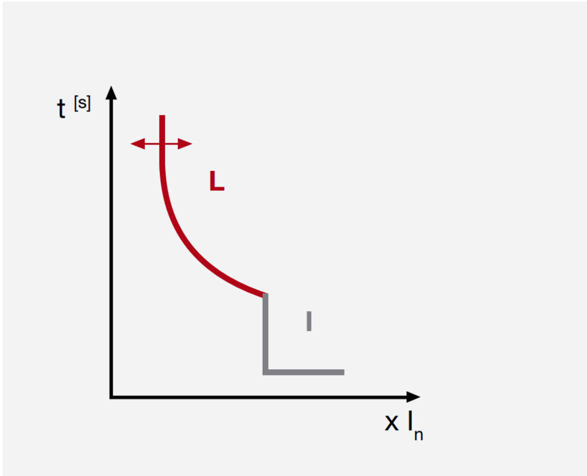
06 Example Time Current Curve with LSI trip unit



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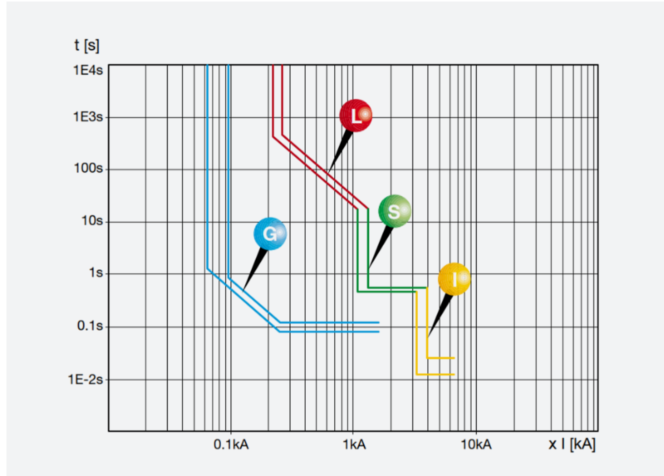

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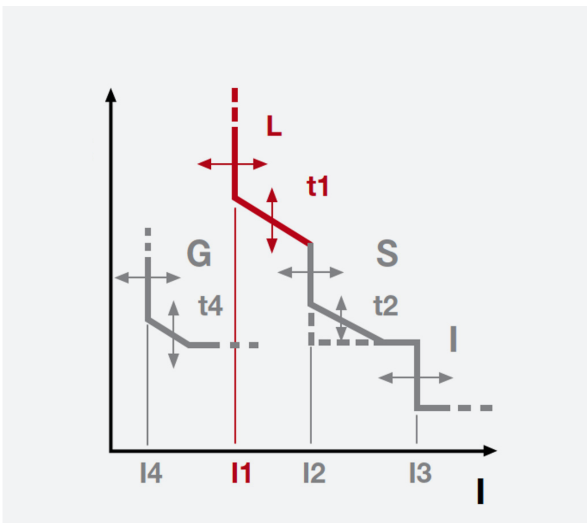

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Modern microprocessor trip units
As these electronic trip units continued to evolve, manufacturers used more and more sophisticated and integrated circuits, which slowly turned trip units into the modern microprocessor trip unit. The microprocessor trip unit provides even more improved protection accuracy and adjustability (ability to coordinate breakers closer together thus allowing additional breakers to operate in series). Electronic trip unit breakers are commonly referred to as ‘LSI’ or ‘LSIG’ where ‘L’ is the long-time trip (60-600 sec), ‘S’ is the short time trip (0.1 to 60 sec), and ‘I’ is the instantaneous trip. ‘G’ is the optional ground fault trip. The ‘L’ and ‘S’ functions replace the thermal element in the thermal magnetic circuit breaker and the ‘I’ replaces the magnetic element. Figure 5 and Figure 6 show the difference in response and adjustability between thermal magnetic and LSIG circuit breakers.

FIgure 7 shows an example time current curve of a typical breaker with microprocessor LSI trip unit. Note the increased accuracy and adjustability in comparison with the thermal magnetic breaker.

This Improved accuracy and adjustability of LSI breakers allowed for more advanced coordination of increasing layers of panels / circuit breakers in series.

Application example
A building with 2000A main switchboard and multiple power panels scattered throughout, thermal magnetic breakers may allow up to three levels of coordination: switchboard main to switchboard feeder to power panel branch. Suppose the power panels were then feeding lighting panels. The lighting panel branch circuits can not be coordinated as it is the fourth level of coordination. If LSI breakers were used, the same system could be coordinated through the lighting panel and possibly with an additional panel in between (5 levels).

These evolving microprocessor trip units also provide much improved coordination with different types of protective devices such as motor starters, fuses and relays as well as the key ZSI (Zone selective interlocking) ability which allows planned overlap to achieve maximum protection.

One big weakness that had yet to evolve was the advancement of sensors. So, while these electronic microprocessor trip units along with the right add-on equipment could provide early versions of metering from the circuit itself, the data were very poor (inaccurate).

As mentioned, the real leap in value is moving so many functions "on board" the breaker trip unit that, in the past, could only be delivered by purchasing, integrating and programming separate devices. A few examples (many more to explore) include:

- Built-in programmable logic – incorporating functions formerly available only through the addition of one or more PLCs, such as automatic source transfer, load shedding, load control and generator control
- Communications – standard network connections, additional communications technology such as IEC6185 / GOOSE to high-speed breaker-to-breaker communications and coordination, including serving as a bridge between LV/MV applications.
- Metering – ability to delivery revenue-class metering (typically 1% accuracy), harmonic measurement and reporting, and power quality monitoring
- Commissioning – direct access to trip units via HMI panel (one panel for multiple breakers), or USB device (just copy over the settings), or even Bluetooth®[5] connection (outside the arc-flash zone)

Today's advanced microprocessor trip units

Finally, we come to today's advanced microprocessor trip units which are still microprocessor based, but because of continued miniaturization in electronics, provide additional power, memory and storage. And, with a big change in the sensor technology, these new breakers are a quantum leap ahead of their predecessors.

Much of the new functionality is made possible by the replacement of the lower accuracy, non-linear iron core current transformers with highly accurate linear current sensors. These sensors are based on the Rogowski coil concept. With traditional iron core current transformers, there is a tradeoff between measurement range and accuracy. Circuit breakers require sensing a large range of currents and accuracy is not as important. Today's demands for metering require a smaller sensing range and much greater accuracy. The Rogowski coil sensor can cover a wide range of currents and has a very linear response. It is an ideal sensor for both protection and metering.

With the evolution of breaker trip units starting with basic overcurrent protection, now advanced capabilities that offer a host of additional protective functions nearly equal to functions offered by medium / high voltage multi-function relays are available. A few key features to look for include monitoring capabilities such as voltage, power quality, and even temperature of external sensors connected to the breaker.

The evolution will certainly continue

We've touched on the evolution of the circuit breaker trip unit across a century. Generally, three key technical advancements have opened up the possibilities of today's advanced circuit protection with a molded case breaker: increased processor power (intelligence) due to advances in circuit board/component miniaturization, increased sensor accuracy as advances allowed for the application of the Rogowski coil for linear measurement, and the continued improvements in high-speed communications both in the processor capabilities and communication protocols. Overall, these three things combine to deliver the key cornerstone values required in smarter, safer and more reliable power – and those values are enhanced accuracy and rapid control.

These capabilities will continue to evolve, and you and customers will continue to benefit from the advancement of cheaper and more available raw computing power and communications over time.

[1] Friedel, R., &amp. Israel, P. (1987). Edison's electric light biography of an invention. New Brunswick, NJ, NJ: Rutgers University.

[2] Riemensperger, S. (2014, October 31). Miniature Breakers Stop Overloads, Short Circuits. Retrieved July 22, 2020, from abb.com/conversations.

[3] Electrical installation handbook - Protection, control and electrical devices (Sixth ed., ABB Technical Guide). (2010). Bergamo Italy: ABB SACE.

[4] Figure 3-3. (n.d.). In A Working Manual on Molded Case Circuit Breakers (Third ed.). Beaver, PA: Westinghouse Electric Corporation.

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