Tech Trends: Selectively Coordinating Your Facility's Electrical Distribution System

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Keeping the power on is a critical task for an industrial facility's electrical maintenance personnel because a loss of power could result in lost production, translating to unhappy customers and deflated profit margins. However, there are other reasons why the power needs to stay on. An unplanned loss of power could result in a safety hazard in certain industrial processes, like chemical production, or worse, could occur at the same time the plant needs to be evacuated due to an emergency such as a fire.

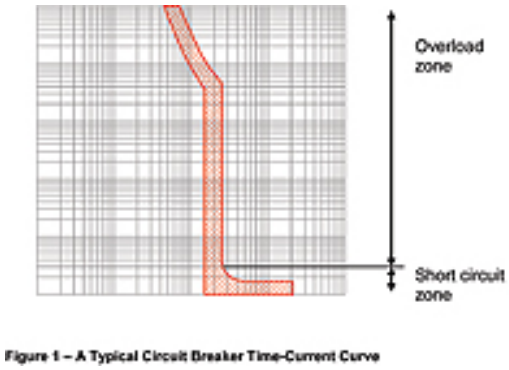

Figure 1. A typical circuit breaker time-current curve.

There are a number of steps that can be taken in power system design to ensure continuity of power, such as multiple utility feeds, standby generators, automatic transfer switches and uninterruptible power supplies (UPS). Another option is selective coordination, which is simply ensuring that when an overcurrent event occurs, only the overcurrent protective device (OCPD) closest to the problem (i.e., a circuit breaker or fuse) interrupts the flow of excessive current. Overcurrents can occur through an overload, short circuit or ground fault, and while all properly designed electrical systems are selectively coordinated to some degree, typically for overloads, they may not be for ground faults and high-level short circuits. A totally selective system is one that is coordinated for all levels and types of overcurrent.

NEC® Requirements

While the nature of an industrial process or the high cost of downtime may call for total selective coordination, the National Electrical Code® requires it in certain situations, such as for elevators (620.62), emergency power systems (700.27),

legally required standby systems (701.18), and in certain systems in healthcare facilities (517.26). Selective coordination is designed into systems using time-current curves such as those illustrated in Figure 1. A time-current curve describes how long it will take for an OCPD to operate during overcurrent conditions. Note that there are two different areas of the curve – the overload zone and the short circuit zone.

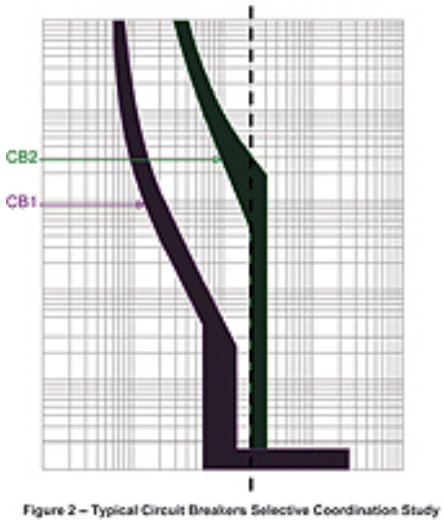

Figure 2. Typical circuit breakers selective coordination study.

The selective coordination of two or more OCPDs in series with one another can be evaluated by plotting their time-current curves on a single graph. They can be said to be selectively coordinated as long as their curves do not overlap. But in plotting the curves on a single graph, the instantaneous trip characteristics of circuit breakers sometimes overlap, particularly thermal-magnetic breakers. This might lead one to the conclusion that circuit breakers cannot be totally coordinated, but that is inaccurate.

In Figure 2, the curves of CB1 and CB2 overlap in the short circuit zone. While these two circuit breakers are selectively coordinated in the overload zone, it would appear that they are not at the highest fault levels in the short circuit zone; thus, we can say that they appear to not be totally selectively coordinated.

But in the short circuit zone, where both devices appear to be operating instantaneously, taking into account only time and current is an insufficient approach. To fully understand selective coordination in the short circuit zone, the let-through energy of the downstream circuit breaker needs to be considered. In other words, will the energy the downstream circuit breaker allows to pass before it completely interrupts the current flow cause the upstream circuit breaker to trip?

If the downstream circuit breaker responds faster than its upstream counterpart, either because it is smaller in ampacity or of a different type or construction, it may open faster. When this occurs, an arc will form, introducing significant impedance into the system (called dynamic impedance). This dynamic impedance will limit the current the upstream circuit breaker experiences. The more current limiting the

downstream circuit breaker, the less current the upstream circuit breaker will experience.

Let-Through Energy

In order to evaluate the selective coordination of circuit breakers in the short-circuit region, there needs to be a way to take the let-through energy of the downstream circuit breaker into account when evaluating the short circuit selective coordination of the pair. Circuit breaker manufacturers have begun publishing data tables that show how pairs of circuit breakers will respond under short circuit conditions by considering the effect of let-through energy. These tables, when used in conjunction with time-current curves, provide a means to achieve total selective coordination with circuit breakers.

Similar challenges exist when trying to achieve total selective coordination with fuses. Once again, using time-current curves alone is insufficient, as the let-through energy of the downstream fuse needs to be compared to the amount of energy required to melt the links in the upstream fuse. Fuse manufacturers provide ratio tables that state, depending on the class of fuse, how much larger an upstream fuse must be in order to totally coordinate with a downstream fuse.

The steps to follow in order to achieve total selective coordination in a low voltage system (600V and below) with circuit breakers are as follows:

- Determine the available short circuit currents at each point in the system.
- Evaluate the coordination of the initial circuit breaker selection with time-current curves, starting from the bottom of the system and working upstream towards the source of supply.
- If overlap is seen in the short circuit zone above the level of the available short circuit current at the downstream circuit breaker, consult the selective coordination tables provided by the circuit breaker manufacturer, making alternate selections as required.

For fuses:

- Determine the class of fuses to be used and make initial selections.
- Use selective coordination ratio tables provided by the fuse manufacturer, making alternate selections as required.

System Design

The Square D LAL MC Circuit Breaker.

When designing totally coordinated systems, it's important to verify all equipment has adequate current withstand ratings. Coordinating generator protective devices with the downstream OCPDs is also crucial. Only time-current curves can be used if circuit breakers from different manufacturers or a mix of circuit breakers and fuses are used in the system. Also, selective coordination may result in an increase in arc flash hazard levels. Make sure that the circuit breaker trip settings determined during the selective coordination study are actually set on the breakers.

Most fuse and circuit breaker manufacturers publish information about how to achieve total selective coordination with their products, but contacting those manufacturers with questions is also prudent.

Ed Larsen is responsible for activities relating to product standards for overcurrent protective devices at Square D/Schneider Electric. He is a member of technical committees in several organizations, including IEEE, UL and the National Electrical Manufacturers Association, is a member of the International Association of Electrical Inspectors, the National Fire Protection Association and the Standards Engineering Society, and has authored several technical publications and articles on circuit breaker applications and standards. He has worked for Square D/Schneider Electric for 33 years.

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