

KEEP THE POWER ON FOR VITAL LOADS

BY EVANGELOS STOYAS P.E.

What do *National Electrical Code*[®] (*NEC*[®]) Articles 700, 701, and 708 have in common? They all focus on keeping certain critical loads up and running. In some cases, the loads only need to run until the building can be safely evacuated. In others, the loads must remain energized until the emergency has passed, which could be hours or days.

It's that common goal of continued operation of certain vital loads that has been driving some changes in the *NEC*. Perhaps the biggest change that occurred during the 2008 revision cycle was the introduction of Article 708, **Critical Operations Power Systems**, designed to keep critical operations required for public health and safety running during emergencies.

But minor changes have also garnered attention. One of those changes concerns selective coordination, which is the operation of protective devices to isolate problem circuits from the remainder of the system without unnecessarily taking out parts of the system that are not in trouble.

The reliability of electrical systems supplying vital loads must be greater than that of the systems supplying power to normal loads. People's health and safety rely on the power to these critical loads, even under adverse conditions such as fires, earthquakes, hurricanes, and man-made catastrophes. Selective coordination of all the overcurrent protective devices for the circuits supplying these loads adds another assurance of reliability.

The best way to understand the reason for adding selective coordination requirements to the *NEC* is to review the code proposals, comment substantiations, and panel statements.

New selective coordination requirements went into the 2005 *NEC* as Sections 700.27 and 701.18. The substantiation for the original proposal for Section 700.27 provides the reasons:

"This article specifically mandates that the emergency circuits be separated from the normal circuits as shown in [Section] 700.9(B) and that the wiring be specifically located to minimize system hazards as shown in [Section] 700.9(C), all of which reduce the probability of faults, or failures to the system so it will be operational when called upon. With the interaction of this Article for emergency lighting for egress, it is imperative that the lighting system remain operational in an emergency. Failure of one component must not result in a condition where a means of egress will be in total darkness as shown in [Section] 700.16...Selectively coordinated overcurrent protective devices will provide a system that will support all these requirements and principles. With properly selected overcurrent protective devices, a fault in the emergency system will be localized to the overcurrent protective device nearest the fault, allowing the remainder of the system to be functional...Due to the critical nature of the emergency system uptime, selective coordination must be mandated for emergency systems. This can be accomplished by both fuses and circuit breakers based

on the system design and the selection of the appropriate overcurrent protective devices."

Similarly, the requirements of Article 708 were created to address national security and public safety needs arising from our dependence on certain vital electrical loads and the vulnerability of standard premises electrical systems. In summing up why selective coordination was included in this new Article, Code-Making Panel 20 (CMP-20), which was responsible for it, noted that "selective coordination is obviously essential for the continuity of service required in critical operations power systems. Selective coordination increases the reliability of the COPS [critical operations power systems]."

Selective coordination requirements first appeared in the Code for circuits supplying elevators in 1993. The 2005 edition of the Code expanded the selective coordination requirements to circuits supplying vital loads fed from an emergency system—Section 700.27—or from a legally required standby system—Section 701.18. This requirement became effective for health-care circuits supplying loads required on essential electrical systems—Section 517.26.

For the 2008 code cycle, CMP-20 was formed to develop requirements for COPS. The resulting Article 708 requirements apply to systems supplying loads that are vital for national security, public safety, or the economy. Selective coordination is required for all overcurrent protective devices in the circuits supplying COPS loads, according to Section 708.54. Whether the vital load is fed from the normal source or the alternate source doesn't matter. The selective coordination requirement applies to all overcurrent protective devices, whether they are in the normal source path or the alternate source path circuits.

What Is Selective Coordination?

So what is selective coordination and how can it be achieved?

In simple terms, selective coordination means that, if an overcurrent causes an overcurrent protective device to open, only the nearest upstream fuse or circuit breaker will open. No other, larger upstream fuse or circuit breaker should open. In this way, only the circuit with the overcurrent condition is interrupted. In a system in which all overcurrent protective devices are selectively coordinated, an overcurrent should only affect the loads where the problem has occurred. The other loads still have power.

According to Section 700.27, "Emergency system(s)," overcurrent devices shall be selectively coordinated with all supply side overcurrent protec-

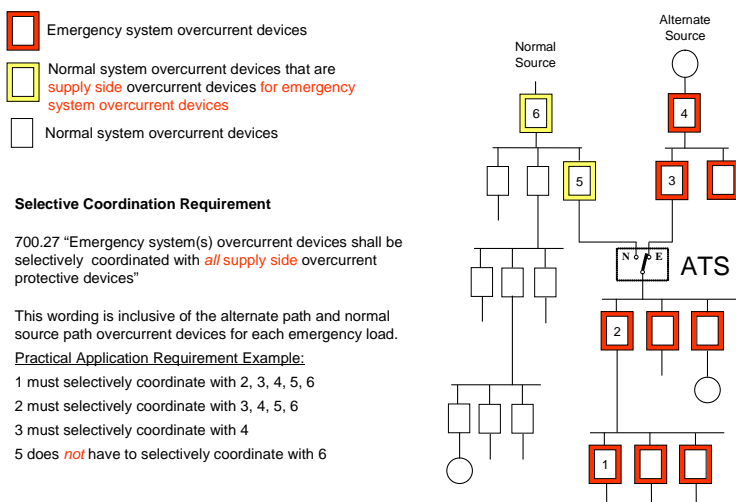
tive devices.” The requirements in Sections 701.18 and 708.54 are identical, except for the type of systems to which they apply. Sections 700.27 and 701.18 contain two exceptions that clarify selective coordination applications.

Todd Stafford, senior director with the National Joint Apprentice Training Center, is a member of CMP-13, which is responsible for Articles 700 and 701. In the 2005 and 2008 code cycles, CMP-13 discussed and debated selective coordination.

“The committee discussed this topic thoroughly,” he says. “The words were discussed and chosen to be specific, in that ‘Emergency system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.’ This means the overcurrent protective devices from the load branch circuit up through to the alternate source and from the load branch circuit up through to the main of the normal source. Both paths are important for a more reliable delivery of power. If a fault on the load side of the transfer switch caused the normal path feeder or main to unnecessarily open, we are looking at the alternate source and transfer switch needing to activate. There is some probability that the generator may not start or the transfer switch may not transfer, which reduces the system reliability. Also, the analysis should be done for the fault current supplied by the normal source and by the alternate source to ensure the worst case is analyzed.”

All emergency overcurrent protective devices must be selectively coordinated through to the alternate power source, and the emergency overcurrent protective devices on the load side of the transfer switch must selectively coordinate with the main and feeder overcurrent protective devices in the normal circuit path (see Figure 1). However, there is a difference on the minimum requirement for the overcurrent protective devices in the normal source path. Read the text adjacent to the one-line.

Figure 1. Selective Coordination of Overcurrent Devices



How to Achieve Selective Coordination

For many years, selective coordination of overcurrent protective devices has been a common system design practice for circuits that supply critical business, government, and military loads. In the financial and communications industries, for instance, where there are significant dollars at risk, many critical loads are designed with supply circuits that have selectively coordinated overcurrent protective devices. No less should be expected for the few important loads that are critical for life safety.

I have spent a career with the U.S. Army Corps of Engineers specifying and designing high-reliability electrical systems for mission-critical operations for all branches of the military and many government agencies. One thing that my experience has taught me is that selective coordination is important for powering critical loads for as long as possible, even under adverse physical circumstances. This can be done by either circuit breakers or fuses. Selective coordination of overcurrent protective devices is one of the most important studies that should be completed when designing systems for emergency or critical-operations power systems. Qualified electrical power system engineers competent in selective coordination can get the task accomplished efficiently.

This does not mean any circuit breaker or fuse can be used indiscriminately. In some cases, specific types of fuses or circuit breakers may be required. However, many have mischaracterized this as a fuse vs. circuit breaker issue. That is not the case.

As Alan Manche of Square D said on the floor of the NFPA’s 2004 World Safety Conference & Exposition®, “This is not a breaker/fuse issue. You can selectively coordinate with breakers and fuses.” In the 2008 code cycle, experts from several circuit breaker and fuse manufacturers presented to CMP-13 and each stated that circuit breaker and fuse systems can both be designed to comply.

A range of circuit breaker and fuse types and options can be used, depending on the specific application needs, including molded-case circuit breakers, insulated-case circuit breakers, low-voltage-power circuit breakers, and current-limiting fuses. In some situations, relays may be a suitable option.

The simplest circuit breaker solution is molded-case circuit breakers with instantaneous trips, if the available fault currents are sufficiently low. Circuit breaker manufacturers publish selective coordination tables for their molded-case circuit breakers that show selective coordination at higher values than obtainable by merely interpreting the time-current curves.

New molded-case circuit breakers with fixed high-magnetic instantaneous trips have been introduced for the very purpose of achieving selective coordination with downstream branch circuit breakers. These circuit breakers can achieve selective coordination at a much

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higher fault current than can be achieved by using the standard adjustable instantaneous trip circuit breakers.

Other alternatives include molded-case circuit breakers and insulated-case circuit breakers with a short-time delay option. These circuit breakers typically have an instantaneous override to protect the circuit breaker. With this option, the designer simply ensures that the fault current at the downstream circuit breaker does not exceed the instantaneous override on the upstream circuit breaker. If fault current does exceed this value, the designer might use low-voltage-power circuit breakers or insulated-case circuit breakers that have short-time delay settings without an instantaneous override. With these circuit breakers, it is relatively easy to achieve selective coordination.

In most cases, a study to determine the available short-circuit currents throughout the system will be required when designing with circuit breakers, as will plotting the circuit breakers' time-current curves for each circuit path and interpreting the results. If selective coordination is not achieved, adjustments will be required in the design or type of circuit breakers.

Some people have observed that using short-time delay settings on circuit breakers increases the arc-flash incident energy and resulting equipment damage. However, the industry has remedies, such as arc-flash reduction maintenance switches. When a worker needs to work on or near a circuit that is protected by a circuit breaker with a short-time delay, the arc-flash-reduction maintenance switch can be thrown to the position that puts the circuit breaker into an instantaneous trip setting. This lowers the clearing time, and incident energy, should an arc fault occur.

Another solution is zone-selective interlocking, in which the circuit breakers communicate with each other and use short-time delays to achieve selective coordination. The other benefit: if a fault occurs in a given circuit breaker's protection zone, the circuit breaker can open as fast as possible since the instantaneous setting overrides the short-time delay. Some designers include power inductors and isolation transformers in the system to choke the current down below the circuit breakers' instantaneous settings.

Designing selectively coordinated fuse systems is also relatively simple. Each low-voltage fuse manufacturer publishes selectivity ratio guides for its fuses. These ratios are based on the fuse type and the ampere rating of the fuses. Divide the ampere rating of the upstream fuse by the ampere rating of the downstream fuse. If this ampere rating ratio is greater than the ratio published by the fuse manufacturer, selective coordina-


tion is achieved up to the fuse's interrupting ratings. Typically, a short-circuit current analysis is not necessary, nor is plotting the time-current curves.

If selectivity ratios are not available, a coordination study is needed. And if the fuse types and ampere ratings do not have sufficient ratios adhering to the minimum published selectivity ratios, different types of fuses must be used or design changes implemented.

What About the Cost?

Many engineers and contractors routinely provide selectively coordinated systems for mission-critical business loads, and many already comply with the new requirements. As with any significant Code change, there were objections along the way, among them that they result in more work for the engineer and a higher price for the system. But all the requirements in Articles 700, 701, and 708 result in extra work and cost. An alternate power source with additional electrical distribution gear, often with sophisticated sensors, monitoring, and control, is warranted. It takes extra time and money to test, maintain, and retain records for these systems to provide a reliable system that can provide electrical power to designated vital loads. The extra cost is expected.

When selective coordination results in extra cost, the engineers who conduct a selective coordination study have to account for the extra time in their bids and negotiations with owners or architects. If the equipment an engineer chooses adds to the cost of the project, this money must be accounted for in the equipment bids. As the changes work their way through the industry, however, the playing field will level out as people become willing to pay for more reliable systems. Reliability and availability of systems and equipment will become a deciding factor in the future. With the use of availability data currently found in NFPA 70B, reliability-centered maintenance will be able to predict and determine maintenance requirements and cost. This, in turn, will be used to justify the need for selective coordination.

For life safety reasons, selective coordination requirements have expanded to increase the reliability of supplying power to a few critical loads. For the circuits supplying these loads, all overcurrent protective devices must be selectively coordinated. Both fusible systems and circuit breaker systems can be designed to comply. 

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