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Productivity Through Protection™

Update on 2008 Code Changes

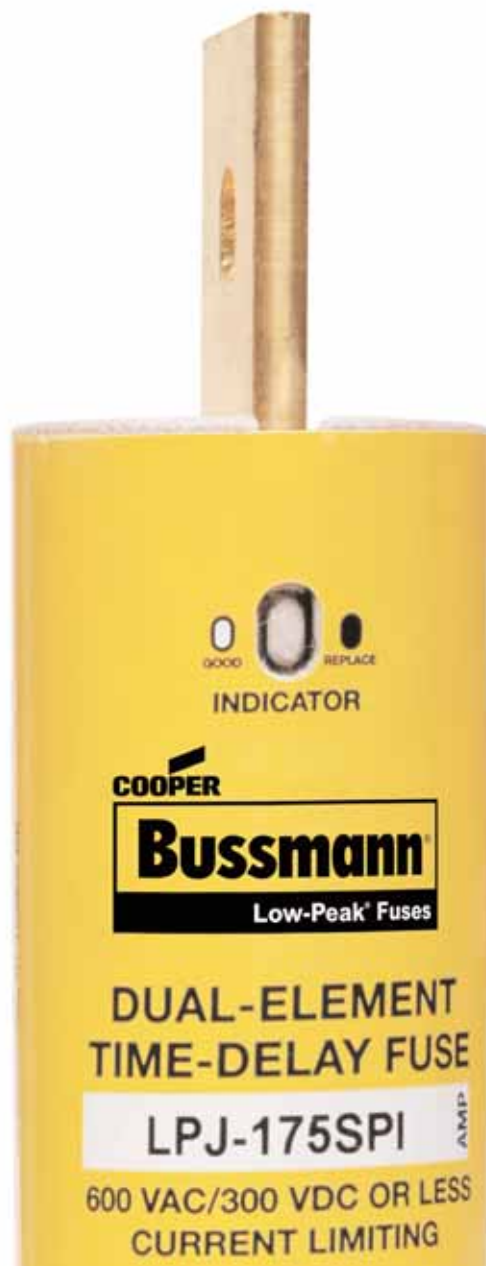


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Selective Coordination Requirements

Background

Selective coordination of all upstream overcurrent protective devices in the supplying circuit paths is required by the NEC® for a limited number of specific vital loads. These requirements increase system reliability and load availability for life safety. Requirements for selective coordination of all overcurrent protective devices supplying elevator circuits first appeared in the 1993 NEC®. The 2005 NEC® added selective coordination requirements for all overcurrent protective devices in the circuit paths supplying emergency system loads and legally required standby loads, plus in healthcare facilities, the essential electrical system loads. The 2008 NEC® retained the previous selective coordination requirements, plus added the selective coordination requirement for all overcurrent protective devices in circuit paths to loads of critical operations power systems (COPS - new Article 708). In addition, two exceptions were added to 700.27 and 701.18; however, these exceptions did not alter the requirements but rather provided clarification for two circumstances.

The 2008 Requirements

Article 100 Definitions Coordination (Selective).

Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings or settings.

Article 517 Healthcare Facilities 517.26 Application of Other Articles.

The essential electrical system shall meet the requirements of Article 700, except as amended by Article 517. (Note: Article 517 has no amendment to the selective coordination requirement, therefore selective coordination is required.)

Article 620 Elevators 620.62 Selective Coordination

Where more than one driving machine disconnecting means is supplied by a single feeder, the overcurrent devices in each disconnecting means shall be selectively coordinated with any other supply side overcurrent protective devices.

700.9(B)(5)(b), Exception.

Overcurrent protection shall be permitted at the source or for the equipment, provided the overcurrent protection is selectively coordinated with the down stream overcurrent protection.

Article 700 Emergency Systems 700.27 Coordination.

Emergency system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices. Exception: Selective coordination shall not be required in (1) or (2):

- (1) Between transformer primary and secondary overcurrent protective devices, where only one overcurrent protective device or set of overcurrent protective devices exist(s) on the transformer secondary,
- (2) Between overcurrent protective devices of the same size (ampere rating) in series.

Article 701 Legally Required Standby Systems 701.18. Coordination.

Legally required standby system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.

Exception: Selective coordination shall not be required in (1) or (2):

- (1) Between transformer primary and secondary overcurrent protective devices, where only one overcurrent protective device or set of overcurrent protective devices exist(s) on the transformer secondary,
- (2) Between overcurrent protective devices of the same size (ampere rating) in series.

Article 708 Critical Operations Power Systems 708.54 Selective Coordination

Critical operations power system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.

Why Selective Coordination is Important

The progressive inclusion of additional selective coordination requirements in the NEC® is the result of increased focus on life safety in the NEC®. Other recent notable life safety additions in the 2008 NEC® are the expansion of requirements for AFCIs and the addition of tamper-proof receptacles. Selective coordination is a requirement intended to keep certain vital loads powered as long as possible, especially in times of emergency or critical need. Our building systems have evolved to the point where certain electrical loads are absolutely vital for sustaining life, for the evacuation of facilities or for the safe continuous operation of facilities. Recent catastrophic events such as 9/11 and hurricane Katrina have highlighted the need to require a higher level of system reliability, thus ensuring higher availability for certain designated electrical loads. As part of a building is damaged or failing, the objective is to maintain power to each vital load as long as possible; whether the normal source is still powering the loads or the alternative source has been called upon to power these vital loads.

Vital Loads

Emergency systems are considered in places of assembly where artificial illumination is required, for areas where panic control is needed such as hotels, theaters, sports arenas, health care facilities, and similar institutions, and where interruption of power to a vital load could cause severe human safety hazards. Emergency loads may include emergency and egress lighting, ventilation and pressurization systems, fire detection and alarm systems, elevators, fire pumps, public safety communications, or industrial process loads where interruption could cause severe human safety hazards. Article 700 provides the requirements.

Legally required standby systems are intended to supply power to selected loads in the event of failure of the normal source. Legally required standby systems typically serve loads in heating and refrigeration, communication systems, ventilation and smoke removal systems, sewage disposal, lighting systems, and industrial processes where interruption could cause severe human safety hazards. Article 701 provides the requirements.

Where hazardous materials are manufactured, processed, dispensed, or stored, then the loads that may be classified to be supplied by emergency or legally required standby systems include ventilation, treatment systems, temperature control, alarm, detection, or other electrically operated systems.

Essential electrical systems in healthcare facilities are portions of the electrical system designed to ensure continuity of lighting and power to designated areas/functions during normal source power disruptions or disruptions within the internal wiring system. Essential electrical systems can include the critical branch, life safety branch, and equipment systems which are essential for life safety and orderly cessation of procedures during normal power disruptions. Article 517 provides the requirements and 517.26 refers to Article 700 requirements.

Critical Operations Power Systems (COPS) are systems intended to provide continuity of power to vital operations loads. COPS are intended to be installed in facilities where continuity of operations is important for national security, the economy, or public safety. These systems will be classified COPS by government jurisdiction or facility management. The type of loads may be any and all types considered vital to a facility or organization including data centers and communications centers. New Article 708 provides the requirements.

The objective of Article 700, 701, and 708 requirements is to ensure availability and reliability of electrical power to these

vital loads with the goal of safety of human life during emergencies, man made or natural catastrophic events, or loss of the normal power. These articles have numerous requirements that are intended to increase reliability, reduce the probability of faults, and minimize the effects of negative events to the smallest portion of system as possible: all to keep the vital loads up and running as long as possible. Selective coordination of overcurrent devices is another logical requirement that helps ensure a higher system reliability and availability of electrical power to vital loads. The following are examples of a few other Article 700 requirements with similar intent:

- 700.4 maintenance and testing requirements
- 700.9(B) emergency circuits separated from normal supply circuits
- 700.9(C) wiring specifically located to minimize system hazards
- 700.16 failure of one component must not result in a condition where a means of egress will be in total darkness

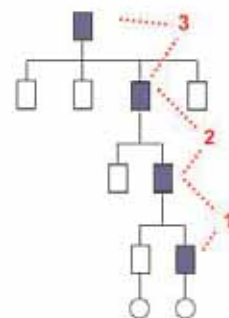
What is Selective Coordination?

Selective coordination can be defined as isolating an overloaded or faulted circuit from the remainder of the electrical system by having only the nearest upstream overcurrent protective device open. Overcurrent protective devices are deemed selectively coordinated only when the nearest upstream overcurrent protective device opens for any possible overcurrents (overload or fault current) that could occur in a specific application. For example, when a fault occurs on a branch circuit, only the branch-circuit fuse or circuit breaker should open. See Figure 1. Similarly, when a fault occurs on a feeder, only the nearest upstream feeder fuse or circuit breaker should open.

Selective Coordination Includes the Entire Circuit Path

Conditions for selective coordination:

1. Branch circuit OCPD selectively coordinated with sub-feeder OCPD
2. Sub-feeder OCPD selectively coordinated with feeder OCPD
3. Feeder OCPD selectively coordinated with main OCPD
4. 1, 2, & 3 above met for the full range of overcurrents, overloads and faults, for the application



■ Blue boxes represent one circuit path from main to branch circuit

Figure 1

The one-line diagrams in Figure 2 and Figure 3 demonstrate the concept of selective coordination. Figure 2 illustrates the circuit path for emergency loads powered by the normal power source and Figure 3 illustrates the circuit path for emergency loads powered by the alternate source. If overcurrent protective devices in circuit paths supplying emergency loads are not selectively coordinated, a fault at X1 on the branch circuit may unnecessarily open the sub-feeder; or even worse the feeder or possibly even the main. In this case, emergency loads are unnecessarily blacked out. With selective coordination as a requirement for emergency, legally required standby, and essential electrical loads, when a fault occurs at X1 only the nearest upstream fuse or circuit breaker supplying just that circuit would open. Other emergency loads would remain powered. The same analysis can be made for faults occurring at the feeder level.

Normal Path and Alternate Path

For these vital loads, selective coordination is required for both the normal power circuit path and the alternate power circuit path. The requirements state selective coordination is required, “with all supply side overcurrent protective devices”. Selective coordination is about the continuance of power to vital loads. These vital loads in the emergency systems, legally required standby systems, critical operations power systems, and essential electrical systems can be powered through the normal source or through the alternate source. The overcurrent protective devices must be selectively coordinated from each load branch circuit up through both the normal source main and alternative source. Code Panels 12, 13, and 20 carefully chose their words with all supply side overcurrent devices for this requirement, because they wanted to assure that these vital loads are not disrupted, whether fed from the normal source or the alternate source.

There are several reasons for this. If the overcurrent protective devices are not selectively coordinated in the normal path to the vital loads, a fault can cause the OCPDs to cascade thereby unnecessarily opening the feeder on the loadside of the transfer switch as well as the feeder and service on the lineside of transfer switch. This action reduces the reliability of the system since there is some probability that the generator may not start or the transfer switch may not transfer. In addition, when the generator starts and the loads transferred to the alternate source, some vital loads will be unnecessary blacked out due to the feeder OCPD's lack of selective coordination (it is still open unnecessarily). In assessing whether the overcurrent protective devices are selectively coordinated in the circuit path for these vital loads, it is important that the available short-circuit current from the normal source be considered since it may cause fault currents much higher than from the alternate source.

Full Range of Overcurrents

To comply, the overcurrent protective devices must selectively coordinate for the full range of overcurrents possible for the application. It is not selective coordination if the fuses or circuit breakers are coordinated only for overloads and low level fault currents. The fuses or circuit breakers must also be selectively coordinated for the maximum short-circuit current available at each point of application. In a Panel Statement during the 2008 ROP cycle, Code Panel 13 responded to a proposal to alter the selective coordination requirement: “...the instantaneous portion of the time current curve is no less important than the long time portion.” Higher level faults may not occur as frequently as lower level faults, but they can and do occur. Higher level faults will be more likely during fires, attacks on buildings, or building failures or more likely as the system ages, or if proper maintenance is not performed regularly. Also, all too often, the circuits for these vital loads may be worked on while energized and a worker-caused fault can be of a significant fault level.

Selective coordination has a very clear and unambiguous definition. Either overcurrent protective devices in a circuit path are selectively coordinated for the full range of over currents for the application or they are not. The words “optimized selective coordination”, “selectively coordinated for times greater than 0.1 seconds”, or other similar wording are merely attempts to not meet the selective coordination requirements. And terms like “selective coordination where practicable” is unenforceable. Code Panels 12, 13, and 20 have discussed and declined any wording that lessens the requirement from the full range of overcurrents or lessens the enforceability.

Faster Restoration & Increased Safety

Besides minimizing an outage to only the part of the circuit path that needs to be removed due to an overcurrent condition, selective coordination also ensures faster restoration of power when only the closest upstream overcurrent protective device opens on an overcurrent. When the electrician arrives to investigate the cause, correct the cause, ensure the integrity of the circuit components for re-energization, and restore power, the electrician does not have to spend time locating upstream overcurrent protective devices that unnecessarily opened. This also increases safety by avoiding unnecessary reclosing or replacing OCPDs.

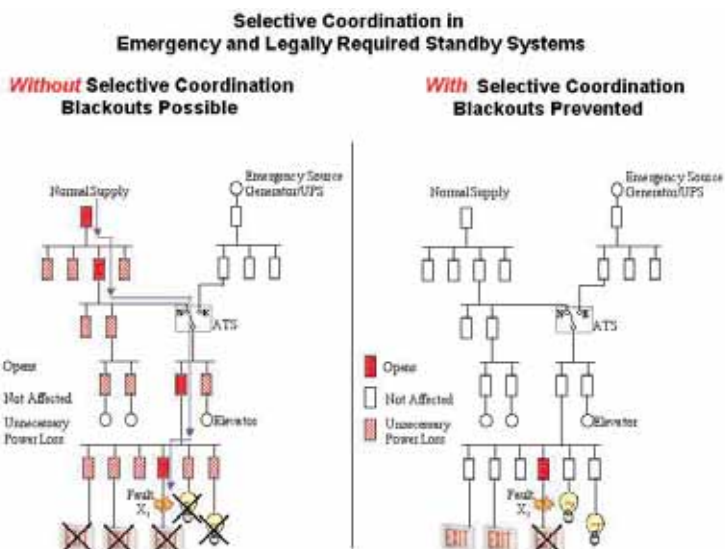


Figure 2 - Emergency loads powered by normal source

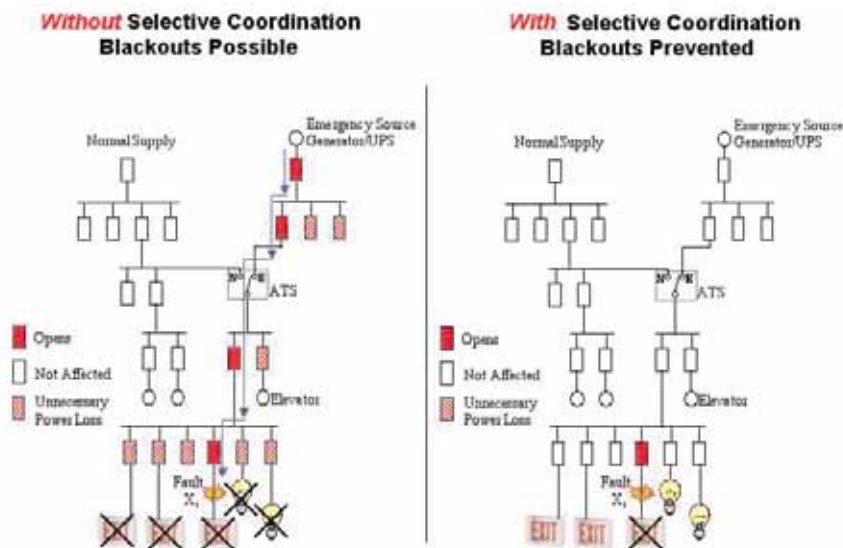


Figure 3 - Emergency loads powered by alternative source

Ensuring Compliance

Achieving the proper overcurrent protective device selective coordination requires proper engineering, specification and installation of the required overcurrent protective devices. It is possible for both fusible or circuit breaker systems to be selectively coordinated with proper analysis and selection. See the section Achieving Selective Coordination.

Authority Having Jurisdiction (AHJ): the AHJ does not have to be an expert at overcurrent device coordination to enforce the selective coordination requirements. It is a simple matter of requiring a professional engineer to provide his or her seal on documentation that states selective coordination is achieved. The documentation should include a selective coordination analysis and the specified

overcurrent devices with pertinent information on type, ampere ratings, and options/settings, if appropriate. During site inspection, the AHJ may choose to spot check the installation to see if the installation is as specified. It is advisable for the jurisdiction to proactively let the electrical community know that the requirements are being enforced. If the contractor installs a non-selectively coordinated system that gets red tagged, the cost and time to correct the system are often substantial.

Engineers: Selective coordination is best resolved in the design phase. Depending on the load needs and types of overcurrent protective devices, engineers have flexibility. It is the engineer's responsibility to provide documentation that verifies the overcurrent devices are selectively coordinated for the full range of overcurrents that can occur in the system.

If fuses are used, a circuit schedule with Cooper Bussmann fuse types and ampere ratings adhering to the Cooper Bussmann fuse selectivity ratios is the easiest verification analysis method. The selectivity ratios are valid for all over-current conditions up to the interrupting rating of the fuses.

If circuit breakers are used, it is necessary to do a short-circuit current study, plot the time-current characteristic curves, and interpret the data properly. In some cases, circuit breaker manufacturers publish tables showing at what values of short-circuit current their circuit breakers coordinate. A schedule is needed that shows the circuit breaker types, options, settings, and available short-circuit currents. The schedule should reference the corresponding time-current curve with interpretation analysis or the manufacturer's coordination tables showing how the circuit breakers are selectively coordinated for the full range of overcurrents. If alternatives are submitted, the same documentation as above should also be submitted so that the engineer can assess that selective coordination is achieved.

Installer: the contractor should install per the engineer's specifications or approved submittals. If the system is circuit breakers, the installer must ensure the circuit breaker settings (short-time delay and instantaneous trip) are set per the engineer's coordination analysis. Circuit breakers are shipped from the manufacturers with the short-time delay and instantaneous trip settings on low or the minimum; these settings may require adjustment.

Achieving Selective Coordination

Following is a brief overview of achieving selective coordination with fuses or circuit breakers. For more in-depth discussion, visit www.cooperbussmann.com or call application engineering at 636-527-1270. At the time of this publication, materials are being developed, so please check periodically, if interested in a more in-depth discussion. Also, publication SPD – Selecting Protective Devices, Based on the 2005 NEC has a more in-depth discussion. The 2008 NEC version of the SPD publication will be updated with more selective coordination information and is planned to be available in early 2008.

Fuse Systems

Cooper Bussmann makes it easy to design and install fusible systems that are selectively coordinated. For modern current-limiting, low voltage fuses, selectivity ratios are published. Figure 4 illustrates a Fuse Selectivity Ratio Table for the fuses in the example. It is not necessary to plot time current curves or do a short-circuit current analysis; all that is necessary is to make sure the fuse types and ampere rating ratios for the mains, feeders and branch circuits meet or

exceed the selectivity ratios. If the ratios are not satisfied, then the designer should investigate another fuse type or design change. These selectivity ratios are for all levels of overcurrent up to the interrupting ratings of the respective fuses. The ratios are valid even for fuse opening times less than 0.01 seconds. This means with current-limiting fuses, it is not necessary to do any analysis for less than 0.01 seconds when the fuse types and ampere rating ratios adhere to the selectivity ratios. The installer just needs to install the proper fuse type and ampere rating. There are no settings to adjust. The following example illustrates all that is necessary to achieve selective coordination with a fusible system.

Selective Coordination - Fuses

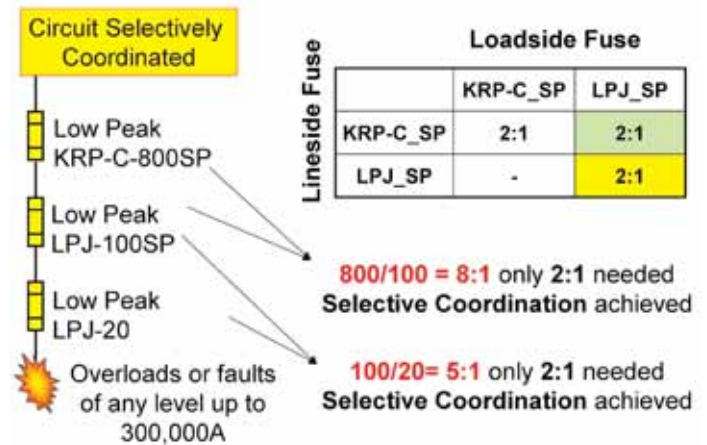
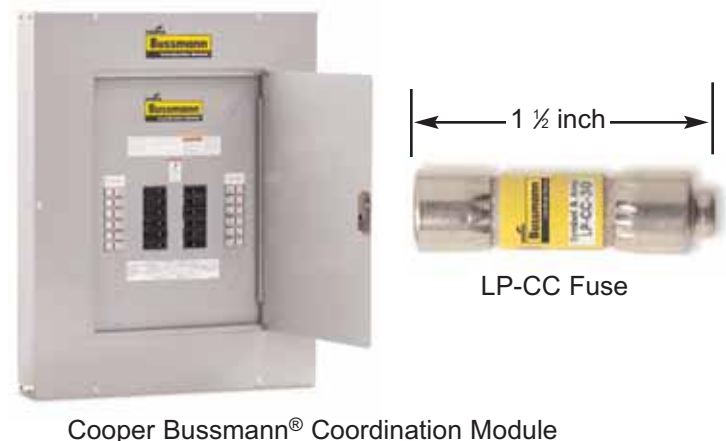


Figure 4 - Using the Fuse Selectivity Ampere Rating Ratios

In order to provide a selectively coordinated fusible system, fusible branch circuit lighting panels may be needed. To fulfill this need, Cooper Bussmann has the Coordination Module, a fusible branch circuit lighting panel. The Product Profile #3115 is located at www.CooperBussmann.com under product literature - sales literature. The coordination module branch circuits incorporate Class CC fuses (LP-CC) for branch circuit protection. Fuseholders with easyID Neon Indicator provide open fuse indication. Class CC fuses are available from 1/10 to 30A.



Circuit Breaker Systems

Systems can be designed with circuit breakers where selective coordination can be achieved. It is important that the curves and circuit breaker functionality are interpreted properly by a qualified person. Typically the steps necessary are:

1. Short-circuit current calculation study: Determine the available short-circuit current (both normal source and alternate source) at every point of application in order to select the proper interrupting rated circuit breakers and to interpret the curves as to whether a circuit breaker scheme is selectively coordinated for the specific application.
2. Time current characteristic analysis: Plot the curves for the circuit breakers of each circuit path, note the available short-circuit currents, and determine if the circuit breakers for that circuit path are selectively coordinated. If not, then,
3. Trial and error method: try various setting adjustments, CB types, options, or design change.

Figure 5 illustrates a circuit breaker system where the 20A branch circuit breaker is selectively coordinated with the 100A feeder circuit breaker as long as the available short circuit current at the branch panel does not exceed 900A. Also, this figure illustrates the 100A feeder circuit breaker is selectively coordinated with the 800A main circuit breaker, which has a short-time delay. Figure 6 illustrates a system where the 20A, 100A and 800A circuit breakers are selectively coordinated for all levels of available short-circuit current up to their respective interrupting ratings. This is achieved by using feeder and main circuit breakers with short-time delays (without any instantaneous override feature).

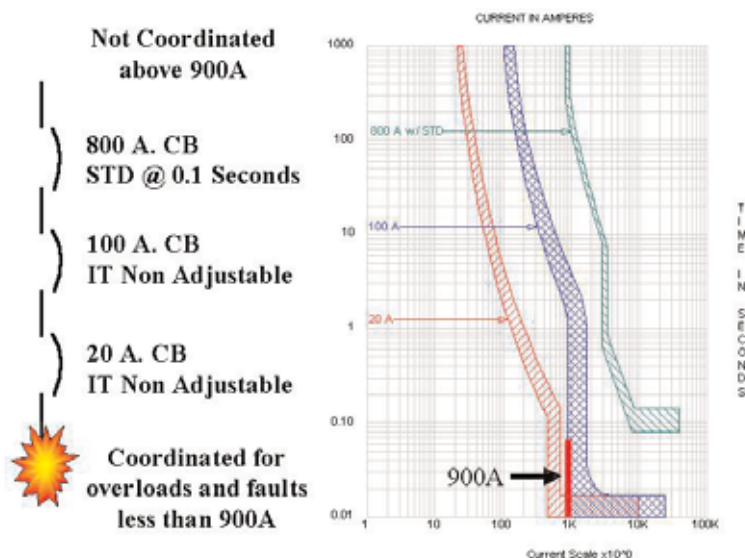


Figure 5

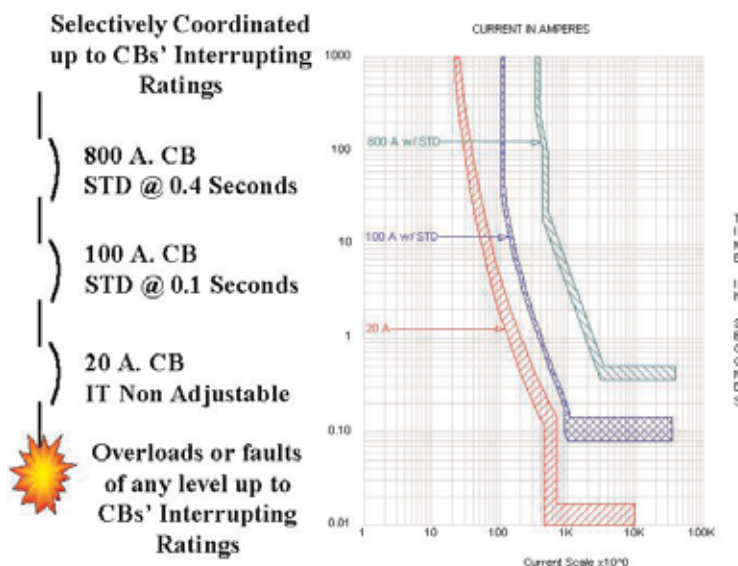


Figure 6

Circuit Breaker Selective Coordination Alternatives

1. MCCBs, ICCBs, and LVPCBs with instantaneous trip settings
2. MCCBs with fixed high magnetic trip or larger frame size may allow higher instantaneous trip
3. CBs coordinated to manufacturer's tested coordination tables
 - CB manufacturers have coordination testing on many MCCBs
 - These tables can enable circuit breakers to coordinate for fault currents higher than shown on the time current curves
4. CBs with short time delay having instantaneous trip override
 - MCCBs and ICCBs with short-time delay settings, typically have an instantaneous trip override that opens the CB instantaneously for higher fault currents (10X to 12X amp rating)
 - ICCBs and some LVPCBs may have higher instantaneous override settings than MCCBs
5. ICCBs and LVPCBs with short time delay (with no instantaneous override): allow sufficient separation between time current bands

Notes:

- The instantaneous trip of upstream circuit breakers must be greater than the available short-circuit current for alternatives 1, 2, and 4
- Interpret the time current curves properly
- Some options may require larger frame size or different type CBs
- Maintenance and testing should be performed periodically or after fault interruption to retain proper clearing times and the coordination scheme

Selective Coordination of Elevator Circuits

NEC® Requirement under Article 620 which includes Elevators

For these elevator circuits, a design engineer must specify, the contractor must install, and the inspector should enforce main, feeder, sub-feeder, and branch circuit protective devices that are selectively coordinated for all possible values of overloads and short-circuits for the system.

One of the reasons that selective coordination is so important is because firefighters commonly use the elevator to get closer to a fire during fire-fighting operations and elevators are a means of egress in emergencies. When more than one driving machine is fed from a single feeder, selective coordination is required between the overcurrent protective device (OCPD) in each disconnecting means and any other supply side overcurrent protective devices. This requires all the overcurrent protective devices from the elevator disconnect to the main to be selectively coordinated with one another.

For example, in Figures 1 and 2, if a fault were to occur on B1, B2, B3 or B4 (or F4) that would cause overcurrent protective devices F2 or M1 to open in Figure 1 and F1, F2, F3, or M1 to open in Figure 2. If M1 opens, the entire system is blacked out; most are all of the elevators in the building would lose power. If a fault were to occur on F2 that would cause M1 to open, all of the elevators in the building would lose power. These conditions described are a lack of selective coordination and not in compliance with 620.62. Note, in attempt to get around the 620.62 requirement for Figure 1, some designers incorrectly believe the scheme in Figure 2 does not require selective coordination. For the layout in Figure 2, 620.62 requires F1, F2, F3, and F4 to be selectively coordinated with M1.

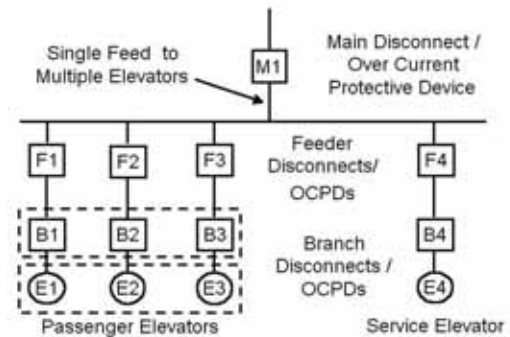


Figure 2

Power Module™

Besides helping in providing a selectively coordinated system, the Power Module™ can simplify the process and ensure consistent practices. There are three disciplines involved in the design, installation, and inspection of elevator systems; this can result in complications and even improper installations. When sprinklers are installed in elevator hoistways, machine rooms, or machinery spaces, ANSI/ASME A17.1 requires that the power be removed to the affected elevator upon or prior to the activation of these sprinklers. The electrical installation allows this requirement to be implemented by a shunt-trip option for the elevator disconnecting means in NEC® 620.51(B). In addition, interface with the fire alarm system along with the monitoring of components required by NFPA 72 must be accomplished in order to activate the shunt trip action when appropriate and as well as making sure that the system is functional during normal operation. This requires the use of interposing relays that must be supplied in an additional enclosure.

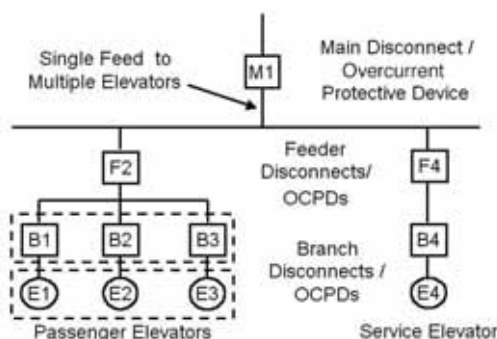


Figure 1



Cooper Bussmann® Power Module

Short-Circuit Current Ratings

Background

The 2008 NEC® has a new definition of “short-circuit current rating”. Previously there was no definition of short-circuit current rating (sometimes referred to as “withstand rating”), although it was referenced in several sections on the marking and proper application of various types of equipment. Because the term is referenced in multiple locations of the Code, it was necessary to add a definition to Article 100 of the NEC®.

Article 100 Definitions

Short-Circuit Current Rating. The prospective symmetrical fault current at a nominal voltage to which an apparatus or system is able to be connected without sustaining damage exceeding defined acceptance criteria.

What is Short-Circuit Current Rating?

Short-circuit current rating (SCCR) is the maximum short-circuit current a component or assembly can safely withstand when protected by a specific overcurrent protective device(s) or for a specified time. Adequate short-circuit current rating is required per 110.10.



Figure 1

SCCR: When using (1) gauge wire protected by a (2) ampere maximum Class J fuse. This power distribution block is rated for use on a circuit capable of delivering no more than (3) kA rms sym. or dc amperes 600V maximum. Otherwise 10kA. Other SCCR options see datasheet.

(1) Wire range	(2) Max. Ampere	(3) SCCR
2-6 AWG	400	200kA
2-14 AWG	200	50kA
2-14 AWG	175	100kA

Figure 1 illustrates a power distribution block that has a default SCCR of 10kA per UL508A SB4 Table SB4.1. However, this PDB has been combination tested and UL Listed with higher SCCRs when in combination with specific types and maximum ampere rating current-limiting fuses. The label is marked with a 200kA SCCR when protected by 400A or less Class J fuses and the conductors on the line side and load side are in the range of 2 to 6 AWG.

For more on Cooper Bussmann® High SCCR PDBs see data sheet 1049.

“Short-circuit current rating” is not the same as “interrupting rating” and the two must not be confused.



Figure 2

Interrupting rating is the maximum short-circuit current an overcurrent protective device can safely interrupt under standard test conditions; it does not ensure protection of the circuit components or equipment. Adequate interrupting rating is required per 110.9. The fuse in Figure 2 has a UL Listed interrupting rating of 300kA at 600Vac or less.

When analyzing assemblies for short-circuit current rating, both the interrupting rating of overcurrent protective devices and the short-circuit current rating of all other components affect the overall equipment short-circuit current rating. For instance, the short-circuit current rating of an industrial control panel typically cannot be greater than the lowest interrupting rating of any fuse or circuit breaker, or the lowest short-circuit current rating of all other components in the enclosure.

Why is Short-Circuit Current Rating Important?

Short-circuit current ratings provide the level of fault current that a component or piece of equipment can safely withstand (based on a fire and shock hazard external to the enclosure). Without knowing the available fault current and short-circuit current rating, it is impossible to determine if components or equipment can be safely installed.

Specification and installation of new equipment with higher short-circuit current ratings, such as 200,000 amperes, makes it easy to meet the requirements of the NEC®. In addition, when equipment is later moved within a facility or from plant to plant, equipment with the highest ratings can be moved without worrying about unsafe situations that might

arise from placing the equipment in a new location where the available short-circuit current is higher than the old location and now above the rating of the equipment.

How to Determine Short-Circuit Current Rating?

For components, the short-circuit current rating is typically determined by product testing. For assemblies, the marking can be determined through the equipment product listing standard or by an approved method. With the release of the UL508A, UL Standard for Safety for Industrial Control Panels, an industry-approved method is now available. UL 508A, Supplement SB, provides an analytical method to determine the short-circuit current rating of an industrial control panel. This method is based upon the weakest link approach. In other words, the assembly marked short-circuit current rating is limited to the lowest rated component short-circuit current rating or the lowest rated overcurrent protective device interrupting rating.

How to Increase Short-Circuit Current Rating?

Protection with current-limiting fuses is the easiest, lowest cost and most effective way to achieve higher short-circuit current ratings. For components, a motor controller can be used to illustrate this point very well. The Cooper Bussmann® compact, non-fused disconnect, the CDNF63, is a Listed UL 508 Manual Motor Controller with a maximum horsepower rating of 40hp at 480V. It is marked with a short-circuit current rating of 5kA when protected by a 150A (or less) Class H fuse or circuit breaker. However, the short-circuit current rating for the CDNF63 is marked 100kA when protected by a 100A (or less) Class J or T fuse (Cooper Bussmann LPJ-110SP or JJS-100).

When using UL 508A Supplement SB, there are significant advantages to using current-limiting fuses in industrial control panels.

1. The high interrupting rating (typically 200kA) of current-limiting fuses increases the ability to achieve higher short-circuit current ratings. If using typical circuit breakers, interrupting ratings are often only 10,000 or 14,000 amperes, which limits the short-circuit current rating of the individual control panel to 10,000 or 14,000 amperes.
2. The use of current-limiting fuses in industrial control panels can also increase component short-circuit current ratings through combination ratings (higher fault current ratings of components when a specific overcurrent protection device is provided). Currently, the only method to achieve high short-circuit current ratings with terminal and power distribution blocks is through the use of current-limiting fuses.

3. If current limiting fuses are used in the feeder circuit of an industrial control panel, the let-through values in UL508A Supplement SB can be used to raise downstream branch circuit component short-circuit current ratings.

What are the Short-Circuit Current Rating Marking Requirements?

The NEC® has requirements for certain components and equipment to be marked with their short-circuit current rating. The important sections of the Code that require the marking of the short-circuit current rating include:

Industrial Control Panels

409.110 requires that an industrial control panel be marked with its short-circuit current rating; see Figure 3.



Figure 3

Industrial Machinery Electrical Panel

670.3(A) requires the nameplate on industrial machinery to include the short-circuit current rating of the machine industrial control panel. In previous editions of the NEC® (2002 Edition) and NFPA 79 (2002 Edition), the industrial machine nameplate was required to include only the interrupting rating of the machine overcurrent protective device, if furnished. This marking was misleading as it did not represent the short-circuit current rating of the machine industrial control panel, but could be misinterpreted as such.



Air Conditioning and Refrigeration Equipment with Multimotor and Combination-Loads

440.4(B) requires the nameplate of this equipment to be marked with its short-circuit current rating. There are three exceptions for which this requirement does not apply: one and two family dwellings, cord and attachment-plug connected equipment, or equipment on a 60A or less branch circuit. So for most commercial and industrial applications, air conditioning and refrigeration equipment with multimotor and combination loads must have the short-circuit current rating marked on the nameplate.

Meter Disconnect Switches (rated up to 600V)

230.82(3) permits a meter disconnect switch ahead of the service disconnecting means, provided the meter disconnect switch has a short-circuit current rating adequate for the available short-circuit current.

Motor Controllers

430.8 requires that motor controllers be marked with their short-circuit current rating. There are three exceptions for fractional horsepower motor controllers, 2 horsepower or less general-purpose motor controllers, and where the short-circuit current rating is marked on the assembly.

How to Assure Compliance?

To assure proper application, the designer, installer, and inspector must assure that the marked short-circuit current rating of a component or equipment is not exceeded by the calculated available fault current.

In order to assure compliance it is necessary to:

- Determine the available short-circuit current or fault current at the point of installation of the component or equipment.
- Assure the component or equipment marked short-circuit current rating is equal to or greater than the available fault current. (See Figure 4 for example).

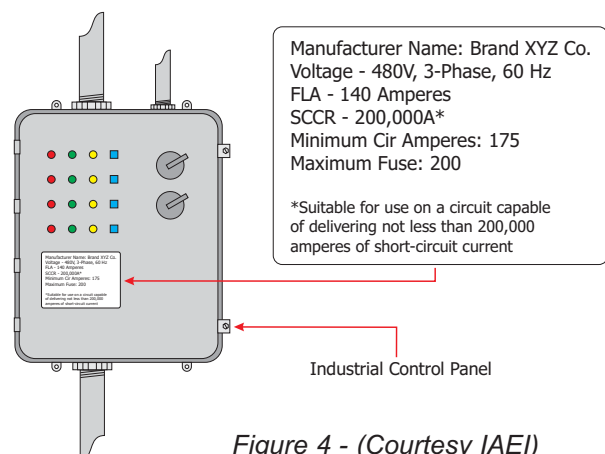


Figure 4 - (Courtesy IAEI)

Any installation where the component or equipment marked short-circuit current rating is less than the available fault current is a lack of compliance and violation of 110.10. In these cases, the equipment cannot be installed until the component or equipment short-circuit current rating is sufficient or the fault current is reduced by an acceptable method.

What Resources are Available?

Cooper Bussmann offers tools to assist with the proper application of short-circuit current ratings including:

Simplified Guide to SCCR – Basic Understanding of short-circuit current ratings and tools to determine the “weakest-link” for industrial control panels.

Advanced Guide to SCCR – In depth discussion of short-circuit current ratings, UL 508A Supplement SB, and how to fix weak-links of industrial control panels.

High SCCR Products

- Current-limiting fuses – high interrupting rating does not limit assembly SCCR and can increase other component ratings within industrial control panels.
- High SCCR Power Distribution and Terminal Blocks – high SCCR is available for feeder circuits (with UL 508A required feeder circuit spacings) and branch circuits. Open and enclosed (IP-20) power distribution blocks.
- Fuse holders, fused disconnects and non-fused disconnects with high SCCR

OSCAR™ (On-Line Short-circuit Current per UL508A Rating Calculator Software) – On-line calculator used to determine and document the short-circuit current rating of industrial control panels.

SPD (Selecting Protective Devices) – Details how to understand, determine and comply with short-circuit current ratings and other overcurrent protection issues.

Short-Circuit Calculator Program – free software download to calculate the available fault current at different points within the electrical distribution system.

For more information on the above see:

<http://www.bussmann.com/2/IndustrialMachineryandControl.html>

Note: There are other companion ratings that must be verified for compliance when installing or inspecting assemblies. These include:

1.Voltage Rating: be sure the voltage rating for an assembly is equal to or greater than the system voltage. When devices such as slash rated circuit breakers or motor controllers (ie 480/277) are used, the entire assembly is also limited. Per 240.85 and 430.83(E), a device, which is slash voltage rated, limits the application of that device to only solidly grounded wye systems where the voltage of any conductor to ground does not exceed the lower value and the voltage between any two conductors does not exceed the higher value. Similarly, an entire assembly would have the same limitation, if one or more devices in the assembly were slash voltage rated devices. For instance, if equipment is marked 480/277V due to the use of slash rated motor controllers, it can only be applied on 480/277V (or less) solidly grounded systems. It cannot be applied on 480V ungrounded, impedance grounded, or corner grounded systems. More information can be found on Voltage Rating on the Cooper Bussmann® website at www.cooperbussmann.com/2/ProtectiveDeviceRatings.html.

Article 240 VII. Circuit Breakers

240.85 Applications.

A circuit breaker with a slash voltage rating, such as 120/240V or 480Y/277V, shall be permitted to be applied in a solidly grounded circuit where the nominal voltage of any conductor to ground does not exceed the lower of the two values of the circuit breaker's voltage rating and the nominal voltage between any two conductors does not exceed the higher value of the circuit breaker's voltage rating.

Article 430 VII. Motor Controllers

430.83 Ratings

(E) Voltage Rating.

A controller with slash rating, for example, 120/240 volts or 480Y/277 volts, shall only be applied in a solidly grounded circuit in which the nominal voltage to ground from any conductor does not exceed the lower of the two values of the controller's voltage rating and the nominal voltage between any two conductors does not exceed the higher value of the controller's voltage rating.

2.Single Pole Interrupting Capability: Where higher fault currents are present, the single pole interrupting capability of circuit breakers and self-protected combination controllers can be of concern as indicated in the fine print notes of 240.85 and 430.52(C)(6). This is because the single pole interrupting capability is not always equal to the

three-pole rating. For instance, a 480V, 100A circuit breaker may have a three pole interrupting rating of 65,000A, but its single pole interrupting capability, based on UL 489 testing requirements, is only 8,660A. This single-pole interrupting capability becomes very critical for ungrounded, corner-grounded, and impedance grounded systems where full voltage can be seen by only one pole of the device. More information can be found on Single-Pole Interrupting Capability on the Cooper Bussmann® website at

www.cooperbussmann.com/2/ProtectiveDeviceRatings.html.

240.85 (added in 2002 NEC®)

FPN: Proper application of molded case circuit breakers on 3-phase systems, other than solidly grounded wye, particularly on corner, grounded delta systems, considers the circuit breakers' individual pole-interrupting capability.

430.52(C)(6) (added in 2005 NEC®)

FPN: Proper application of self-protected combination controllers on 3-phase systems, other than solidly grounded wye, particularly on corner grounded delta systems, considers the self-protected combination controllers' individual pole-interrupting capability.

Other Considerations

Applying components or equipment within their short-circuit current rating does not mean the components can not sustain damage. UL Standards have evaluation criteria for acceptance to SCCR testing. Components and assemblies are tested in an enclosure with the bolted short-circuits external to the enclosure and door closed or cover fastened. The typical evaluation acceptance criteria by UL is

- The enclosure cannot become energized (shock hazard)
- The door or cover cannot blow open and there cannot be any large holes in the enclosure (fire hazard external to the enclosure). However, extensive damage may be permitted to the internal components.

Applying components or equipment within their short-circuit current rating, does not mean the equipment does not pose an arc flash hazard. Equipment certification tests are not run with arcing faults inside the enclosure. An arcing fault within a closed enclosure is a potentially serious hazard with the doors closed or open; incidents have been reported of doors being blown open, or off, due to arcing faults. A marked short-circuit current rating for an assembly does not signify that someone working on or near energized equipment will be uninjured if an arcing fault occurs with the doors either open or closed and latched.

Branch-Circuit Overcurrent Devices

Background

A definition for branch-circuit overcurrent device has been added to the 2008 edition of the National Electrical Code® to provide clarity to users of the Code as to what the devices are and how they can be used.

New Definition

NEC® Article 100

Branch-Circuit Overcurrent Device. A device capable of providing protection for service, feeder, and branch circuits and equipment over the full range of overcurrents between it's rated current and it's interrupting rating. Branch-circuit overcurrent protective devices are provided with interrupting ratings appropriate for the intended use but no less than 5,000 amperes.

With the added definition for 2008, it becomes clear that a branch-circuit overcurrent protective device is suitable for use at any point in the electrical system to protect branch circuits, as well as feeder circuits and mains. The definition also illustrates that a branch-circuit overcurrent device must be capable of protecting against the full range of overcurrents which includes overloads and short-circuits as well as have an interrupting rating sufficient for the application (this reflects the interrupting rating requirements of 110.9). In addition to the traits described in the new definition, branch-circuit overcurrent devices meet minimum common standardized requirements for spacings and operating time-current characteristics.

Overcurrent protective device types fall into two main categories; "Branch-circuit overcurrent devices" and "Application-limited" devices. Table 1 lists acceptable branch-circuit overcurrent device types along with Cooper Bussmann branch-circuit fuse part numbers. These devices meet the new NEC® definition.



Branch-Circuit Fuses

Table 1

Device Type	Acceptable Devices	Cooper Bussmann® Branch-Circuit Fuses
UL 248 Fuses	Class J Fuse	LPJ_SP, JKS, DFJ*
	Class RK1 Fuse	LPN-RK_SP, LPS-RK_SP
	Class RK5 Fuse	FRN-R, FRS-R
	Class T Fuse	JJN, JJS
	Class CC Fuse	LP-CC, KTK-R, FNQ-R
	Class L Fuse	KRP-C_SP, KLU, KTU
	Class G Fuse	SC
	Class K5 Fuse	NON, NOS (0-60A)
	Class H Fuse	NON, NOS (61-600A)
UL 489 Circuit Breakers	Molded Case CBs, Insulated Case CBs	
UL 1066 Circuit Breakers	Low Voltage Power CBs	

*DFJ fuse listed as Class J and provides high speed fuse protection

Application-limited devices all have some limitations that restrict their usage. The NEC® permits some devices for specific branch-circuit applications under limited conditions. Other devices, such as supplementary overcurrent devices, can never be used as branch-circuit overcurrent protection. When applied both categories must have an adequate interrupting rating (NEC® 110.9) and must protect the circuit components (NEC® 110.10). The two categories are further summarized with the following:

(1) Permitted for specific branch circuit applications under limited conditions per the specific reference in the NEC®:

These OCPDs have some limitation(s) and are not true branch-circuit devices but may be permitted if qualified for the use in question. For example, most high speed fuses are not branch circuit OCPDs, however high speed fuses are allowed to be used for short circuit protection on motor circuits utilizing power electronic devices by 430.52(C)(5). Motor Circuit Protectors (MCP) are recognized devices (not listed) and can be used with the intent of providing short circuit protection for motor branch circuits, if used in combination with a listed combination starter for which the MCP has been tested and recognized by a NRTL (per 430.52(C)(3)). Both of these examples are only suitable for use on motor branch circuits, they cannot be used on other branch-circuit types or for service or feeder protection. Special attention must be paid to the circuit type, NEC® requirements, and the devices in question when considering the use of application specific devices.

Branch-Circuit Overcurrent Devices

In other words these types of overcurrent devices are only acceptable for use under special conditions.

(2) Supplementary overcurrent protective devices:

These devices have limited applications which are discussed further on the next page but must always be in compliance with 240.10. The definition for supplementary overcurrent protective device was added to the 2005 NEC®.

Application Limited Devices	
High Speed Fuses ¹	Supplementary Fuses ⁴
Motor Circuit Protector ²	Limiters ⁵
Self Protected Starter ³	UL 1077 Protectors ⁴

1. HS Fuses w/ marked replacement per 430.52(C)(5)
2. MCP if part of listed combination starter per 430.52(C)(3)
3. SPS if listed as self protected combination controller per 430.52(C)(6)
4. Supplementary protection per 240.10
5. Cable Limiters per 230.82

The use of supplementary overcurrent protective devices allowed by 240.10 is for applications such as lighting and appliances shown in Figure 1. The supplementary protection is in addition to the branch-circuit overcurrent protection provided by the device protecting the branch circuit (located in the lighting panel in Figure 1).

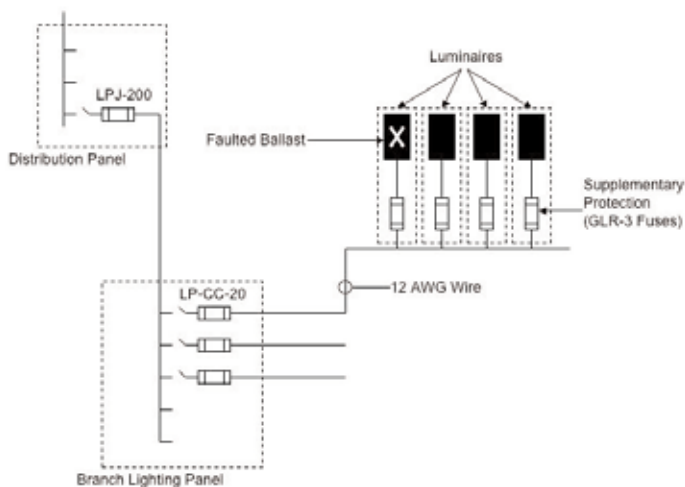


Figure 1

Branch circuit overcurrent protective devices can also be used to provide the additional protection that a supplementary overcurrent protective device provides: see Figure 2. Rather than using a supplementary overcurrent protective device for supplementary protection of the luminaire, a branch-circuit overcurrent protective device is used. The fact that a branch-circuit overcurrent device is used where a supplementary device is permitted does not turn the circuit between the lighting panel and the fixture from a branch-circuit to a feeder. In the case of Figure 2, the branch circuit starts on the loadside of the 20A fuse in the lighting panel.

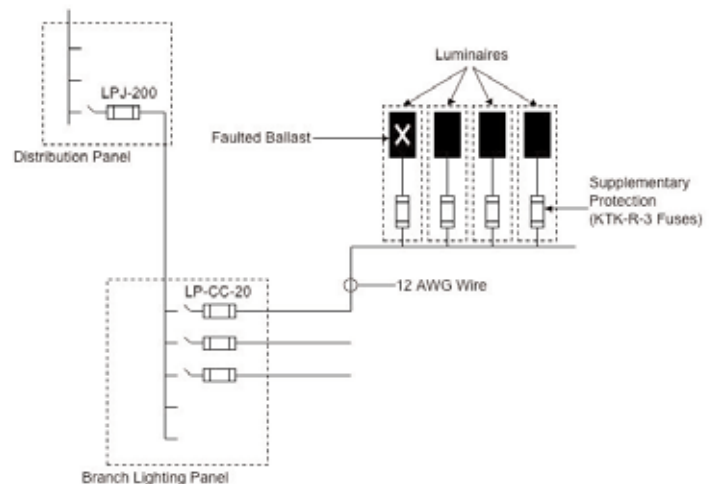


Figure 2

How to Comply

It is vital to know how a device is listed to its respective product standard. If listed as a branch-circuit overcurrent device it is easier to apply. For circuits where the overcurrent protective device is one shown in Table 1, the device suitability as a branch-circuit overcurrent protective device is not in question. So if the overcurrent device is an LPJ-SP fuse for example, or a listed UL 489 Circuit Breaker, it is permissible for overload and short-circuit protection on any service, feeder or branch-circuit where properly applied. Other types of protective devices have to be qualified for the use in question. Caution should always be used to assure that the proper overcurrent device is being used for the application at hand. Cooper Bussmann publication SPD-Selecting Protective Devices has a section titled "Devices for Motor Circuits" that discusses the listing for various devices and how they can be applied.

Supplementary Overcurrent Protective Devices

Background

A definition for “Supplementary overcurrent protective device” was added into Article 100 for the 2005 NEC®. The definition was added to help avoid serious misapplication of devices that may have limitations for general usage. Supplementary protective devices can only be used as additional protection when installed on the load side of a branch-circuit overcurrent device. Supplementary devices must not be applied where branch-circuit overcurrent protective devices are required; unfortunately this unsafe misapplication is prevalent in the industry. Supplementary devices are properly used in some appliance applications and where branch-circuit overcurrent protection is not needed.

NEC® Article 100

Supplementary Overcurrent Protective Device.

A device intended to provide limited overcurrent protection for specific applications and utilization equipment such as luminaires (lighting fixtures) and appliances. This limited protection is in addition to the protection provided in the required branch circuit by the branch-circuit overcurrent protective device.

Supplementary overcurrent protective devices are not general use devices, as are branch-circuit overcurrent devices, and must be evaluated for appropriate application in every instance where they are used. Supplementary overcurrent protective devices are extremely application oriented and prior to applying the devices, the differences and limitations for these devices must be investigated and found acceptable.

Examples of supplementary overcurrent protective devices include, but are not limited to the following:



UL248-14
Supplemental Fuses



UL1077 Supplemental
Protectors (Mini Circuit Breakers)

One example of the difference and limitations is that a supplementary overcurrent protective device may have creepage and clearance spacings that are considerably less than that of a branch-circuit overcurrent protective device.

Example:

- A supplementary protector, UL1077, has spacings that are $\frac{3}{8}$ inch through air and $\frac{1}{2}$ inch over surface at 480V.
- A branch-circuit rated UL489 molded case circuit breaker has spacings that are 1 inch through air and 2 inches over surface at 480V.

Another example of differences and limitations is that branch-circuit overcurrent protective devices have standard overload characteristics to protect branch-circuit, feeder, and service entrance conductors. Supplementary overcurrent protective devices do not have standard overload (time-current) characteristics and may differ from the standard branch-circuit overload characteristics. Also, supplementary overcurrent protective devices have interrupting ratings that can range from 32 amps to 100,000 amps. When supplementary overcurrent protective devices are considered for proper use, it is important to be sure that the device's interrupting rating equals or exceeds the available short-circuit current and that the device has the proper voltage rating for the installation (including compliance with slash voltage rating requirements, if applicable).

Reasons Why Supplementary Protectors (UL1077 Devices) can not be used to Provide Branch-Circuit Protection

1. Supplementary Protectors are not intended to be used or evaluated for branch-circuit protection in UL1077
2. Supplementary protectors have drastically reduced spacings, compared to branch-circuit protective devices, and depend upon the aid of a separate branch circuit protective device upstream
3. Supplementary protectors do not have standard calibration limits or overload characteristics performance levels and cannot assure proper protection of branch-circuits
4. Multipole supplementary protectors for use in 3 phase systems are not evaluated for protection against all types of overcurrents
5. Most supplementary protectors are short-circuit tested with a branch-circuit overcurrent device ahead of them and rely upon this device for proper performance
6. Supplementary protectors are not required to be tested for closing into a fault
7. Recalibration of a supplementary protector is not required and depends upon manufacturer's preference. There is no assurance of performance following a fault or resettability of the device.
8. Considerable damage to a supplemental protector is allowed following short-circuit testing.
9. Supplementary protectors are not intended be used as a disconnecting means.
10. Supplementary protectors are not evaluated for short circuit performance criteria, such as energy let through limits or protection of test circuit conductors

Protection of Small Conductors

Background

Up until now, 14 AWG was the smallest branch-circuit conductor allowed for general building systems use in the NEC®. 2008 NEC® added requirements for overcurrent protection of 16 and 18 AWG CU insulated conductors for power circuits in 240.4(D). This action in itself does not permit the use of these smaller conductors; it provides the criteria for the proper overcurrent protection if other articles of the NEC® permit these smaller conductors for the circuits/equipment covered by a given article.

Requirement

240.4(D) Small Conductors. Unless specifically permitted in 240.4(E) or (G), the overcurrent protection shall not exceed that required by (D)(1) through (D)(7) after any correction factors for ambient temperature and number of conductors have been applied.

(1) 18 AWG Copper. 7 amperes, provided all the following conditions are met:

- (1) Continuous loads do not exceed 5.6 amperes
- (2) Overcurrent protection is provided by one of the following:
 - a. Branch-circuit rated circuit breakers listed and marked for use with 18 AWG copper wire
 - b. Branch-circuit rated fuses listed and marked for use with 18 AWG copper wire
 - c. Class CC, Class J, or Class T fuses

(2) 16 AWG Copper. 10 amperes, provided all the following conditions are met:

- (1) Continuous loads do not exceed 8 amperes
- (2) Overcurrent protection is provided by one of the following:
 - a. Branch-circuit rated circuit breakers listed and marked for use with 16 AWG copper wire
 - b. Branch-circuit rated fuses listed and marked for use with 16 AWG copper wire
 - c. Class CC, Class J, or Class T fuses

(3) 14 AWG Copper. 15 amperes

(4) 12 AWG Aluminum and Copper-Clad Aluminum. 15 amperes

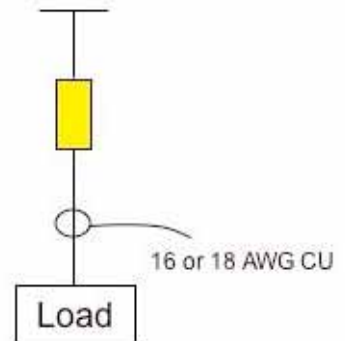
(5) 12 AWG Copper. 20 amperes

(6) 10 AWG Aluminum and Copper-Clad Aluminum. 25 amperes

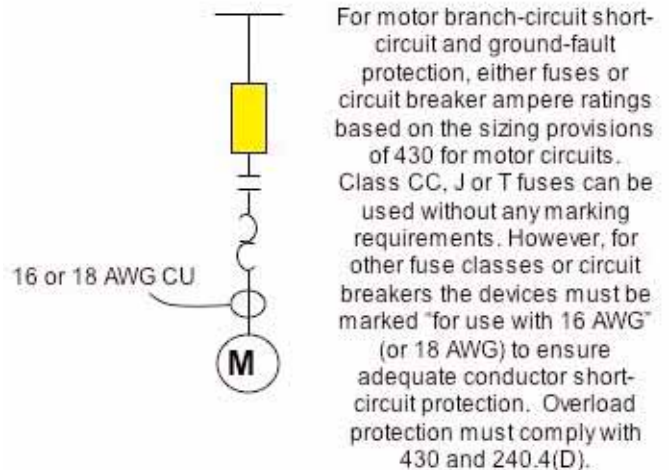
(7) 10 AWG Copper. 30 amperes

In future, if permitted in another Article

Either fuses or circuit breaker must have maximum ampacity of 7A for 18 AWG and 10A for 16 AWG. In addition, Class CC, J or T fuses can be used without any marking requirements. However, for other fuse classes or circuit breakers the devices must be marked "for use with 16 AWG" (or 18 AWG) to ensure adequate conductor protection.



In future, if permitted in Article 430



Why

Short-circuit currents can quickly damage insulated conductors. The level of damage can vary from slight insulation damage, to annealing of the copper, to vaporization of the copper. Under short circuit conditions the level of damage sustained is a factor of a specific insulated conductor's withstand capability, the level of short-circuit current, and the time the short-circuit current is permitted to flow. Smaller conductors such as 16 AWG and 18 AWG have very low short circuit current withstands and in many instances, the generally acceptable overcurrent protective devices do not have the operating characteristics to provide adequate protection as required in 110.10.

Small Wire Report

In August, 2001 there was an investigation by the Small Wire Working Group of the NFPA 79 Electrical Standard for Industrial Machinery. The investigation focused on the protection of 16 and 18 AWG CU conductors for use in Industrial Machinery applications and resulted in similar requirements as 240.4(D). The basis of this study compared the conductor short-circuit current withstand to the overcurrent device let-through energy under short-circuit conditions. The Small Wire Working Group studied the critical application considerations for small conductors, proposed the requirements and conducted UL witnessed tests to prove the proposed requirements are acceptable. After considering several damage criteria, the group decided to use the ICEA damage levels because they were the most conservative. All other methods allowed certain levels of damage. A testing program with insulation damage evaluation criteria was conducted to prove the engineering analysis as valid. This study determined that small conductors could be sufficiently protected by certain overcurrent protective devices, but not all the standard commercially available overcurrent protective devices provided acceptable levels of protection.

In this study, Class CC, J and T fuses, 30A and smaller, were found to provide short-circuit protection for these conductors. The very current limiting characteristics of these fuses provide the necessary level of protection under short-circuit conditions. For Class CC, J, or T fuses, the maximum short-circuit current energy permitted by UL for the 30A or less ampere ratings is below the ICEA thermal energy damage criteria. In the testing, special fuse limiters that purposely exceed the short-circuit current I^2t umbrella limits for the applicable class fuses from UL 248 Fuse Standard were tested with 16 and 18 AWG CU insulated conductors. After the tests, the insulated conductors were evaluated by a set criteria including dielectric testing. The conclusion was that Class CC, J and T 30A or less fuses protect 16 and 18 AWG CU insulated conductors simply by complying with UL 248 performance required for listing and follow-up testing. The

UL 248 30A or less Class CC, J, and T fuse let-thru energy limits are less than the 16 or 18 AWG CU insulated conductor ICEA withstands. See Table Below.

ICEA I2t Withstand Limit CU Conductor Thermoplastic Insulation (75°C)		UL 248 I²t Let-Thru Limits for 30A Class CC, J, Fuses
CU Wire Size	Short-Circuit I²t Withstand	
16 AWG	7,344 A²s	7000A²s (value for 50kA, 100kA, and 200kA)
18 AWG	18,657 A²s	
Conclusion: All commercially available fuses of 30A or less of these fuse types will provide short-circuit protection for 16 and 18 AWG CU insulated conductors		

Note to Table: all commercially available UL Class CC, J, and T 30A or less fuses can protect these conductors from short-circuit currents. However, the actual maximum ampere rating permitted for a given application is restricted by the applicable NEC® requirements.

As important, the study confirmed that many other overcurrent protective devices do not provide the necessary level of protection. Therefore, fuses, other than Class CC, J, or T fuses, and circuit breakers are required to be marked "for use with 16AWG" or "for use with 18AWG". In essence, this means other fuses and all circuit breakers are required to be tested under a specific criteria for small wire and if pass, then listed and marked as such. UL issued a Special Service Investigation, An Investigation of the use of 16 and 18 AWG Conductors for Power Branch Circuits in Industrial Machinery Applications, file number E4273 to verify the test results. The analysis, test program and results can also be viewed in an IEEE paper presented at the 2002 IEEE Industrial and Commercial Power Systems Technical Conference titled, An Investigation of the Use of 16 and 18 AWG Conductors for Branch-Circuits in Industrial Machinery Built to NFPA 79 2002. The report and paper can be found on www.cooper-bussmann.com.

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- Toll-free fax: 800-544-2570
- E-mail: busscustsat@cooperbussmann.com

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- Monday – Friday, 8:00 a.m. – 4:30 p.m.
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