# 2005 National Electrical Code Changes Could Significantly Affect the Design and Installations of Emergency Distribution Systems


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The new 2005 National Electrical Code (NEC) is out and in circulation. Based on conversations with local code officials in the Seattle area, it is my understanding that the 2002 NEC will no longer be utilized and the 2005 NEC will take effect around September of this year. There are some potentially significant changes brewing in the 2005 NEC that could significantly transform the way emergency distribution systems are designed and built in the near future. To understand the full potential impacts of these changes to the 2005 National Electrical Code, I think it important to quote the new definition of selective coordination and the new codes in sections 100, section 517, section 700 and section 701.

**NEC 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 and settings.

**NEC 700.27: Coordination -** Emergency system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.

**NEC 701.18: Coordination -** Legally Required Standby system(s) overcurrent devices shall be selectively coordinated with all supply side over current protective devices.

**NEC 517.26: Application of Other Articles -** The essential electrical system shall meet the requirements of Article 700, except as amended by Article.

For clarity it is important to include the NEC definition (Section 100) of overcurrent and the fine print notes defining Emergency Systems and Legally Required Standby Loads in section 700 and section 701 below:

***Overcurrent:*** *Any current in excess of the rated current of the equipment or ampacity of the conductor. It may result from overload, short circuit or ground fault.*

It is significant to note that a "short circuit" is noted as one of the items that can cause an overcurrent. The typical molded case circuit breaker combination with the upstream breaker somewhat larger than the downstream breaker does not have a problem coordinating in the overload area of the time current curve, but a high level of current in the short circuit area of the time current curve can represent significant problems to selective coordination.

**NEC Section 700.1 FPN no. 3:** *Emergency systems are generally installed in places of assembly where artificial illumination is required for safe exit and panic control ... Emergency systems may also provide power for such functions as ventilation..., fire detection and alarm systems, elevators, fire pumps, public safety communication and industrial processes...*

**NEC Section 701.2 FPN:** *Legally Required Standby systems are typically installed to serve loads, such as heating and refrigeration systems, communication systems, sewage disposal , lighting systems and industrial processes, that, when stopped during any interruption of normal electrical supply, could create hazard or hamper rescue or fire fighter operations.*

Elevators are noted in section 700.1 as an emergency system load. Some jurisdictions in our area also consider elevators to be a legally required standby load. In either case, the National Electrical code has required elevators in certain situations to be selectively coordinated for some time. This selective coordination has been required per (NEC 620-62).

**NEC 620.62 ®: Selective Coordination-** *Where more than one driving machine disconnecting means is supplied by a single feeder, the over current protective device in each disconnecting means shall be selectively coordinated with any other supply side over current protective devices.*

The coordination of the over current protective device protecting a feeder serving a multi position elevator control panel can be achieved with an upstream breaker feeding down stream fuses. Figure 1 shows an example of an overcurrent protection coordination study illustrating the feeder breaker over current protection, the elevator fuse overcurrent protection and the elevator motor start up curves:

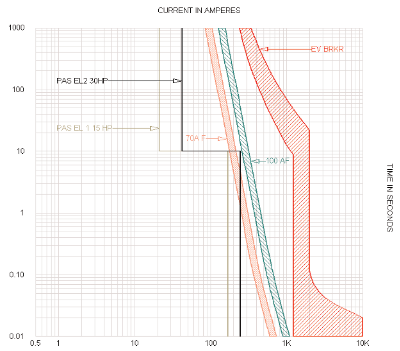


**Figure 1 -** *The graph indicates a 200 amp breaker in the main distribution gear feeding an elevator control panel with a 100 ampere dual element RK5 fuse and a 70 ampere dual element RK5 fuse. The protective coordination study must ensure that the two fuses will trip in a fault condition in any one of the separate elevator feeders and will not trip the 200 ampere main breaker. A fault in one of the elevator feeders that took out the main breaker would essentially take out both elevators from the electrical distribution system. As elevators can play a critical function during some emergencies and can be considered an emergency load, it is essential to ensure functionality.*

As you can see from the diagram, there is no overlap between the fuses and the breaker. This is true for both the overload and instantaneous (high current or short circuit) region of the time current curves. This selective coordination can be achieved because the breaker is upstream of the fuses, the blob on the lower right corner of the breaker curve represents a mechanical device opening to clear the fault. The bottom part of the "blob" is the time the contacts on the breaker unlatches, arcing will occur and the current will continue to flow in the breaker until there is physical separation of the contacts and the arc is extinguished. This coordination is not so simple if the breaker is on the left (downstream side) of the fuses or if the system utilizes all thermal magnetic breakers for the over current protective devices.

To illustrate the difficulty in selectively coordinating thermal magnetic breakers, I have provided the example below of two breakers, a 100 ampere and a 400 ampere molded case circuit breaker (Figure #2).

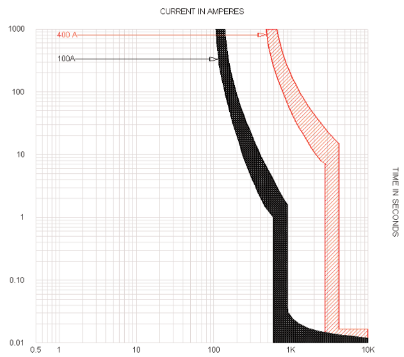


**Figure - 2 -** *Breaker Manufacturer (400 ampere Main & 100 ampere Sub breaker) - Both trip at 3,000 A to 4,000 A. No matter if the breakers are Series or fully rated*

These two breakers are coordinated in the overload region but would not be considered to be selectively coordinated in the short circuit region as per the definition of over load in the 2005 NEC. The typical emergency distribution system utilizes breakers downstream of breakers. In the example noted above if the available fault current was above 3,000 amperes to 4,000 amperes downstream of the 100 ampere breaker the electrical distribution system would not satisfy the wording of the revisions to the 2005 NEC. A 3,000 to 4,000 ampere fault current would probably unlatch the 100 ampere breaker before the 400 ampere breaker, but before the 100 ampere breaker extinguishes the arc and completely opens the circuit, the 400 ampere breaker would start to unlatch. Thus, in this situation, taking out both breakers in the emergency electrical distribution system.

In addition, for complete selective coordination, series rating would no longer be allowed. Series rating requires that both the downstream and upstream breaker trip to reduce the available fault current rating at the downstream device to lower levels. The combination of overcurrent protective devices must be tested together to verify performance based on UL 489. The rating of the combination cannot exceed the rating of the upstream over current protective device.

On the other hand, fuses can be completely coordinated. The melting time of a fuse is significantly faster than the mechanical operation of a breaker and will allow the downstream device to clear the fault without causing the upstream device to open, thereby exposing the smallest amount of the electrical distribution system to an outage as possible. See diagram Figure #3, showing a 400 ampere dual element fuse and a 100 ampere dual element fuse.

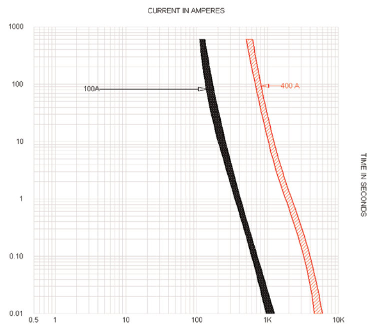


**Figure 3 -** *A 100 ampere dual element Fuse and a 400 ampere dual element Fuse - This system is completely Selective Coordinated*

Furthermore, larger, more expensive electronic power breakers can be programmed to remove the instantaneous portion of the breaker curve. This can allow the two breakers to be fully selectively coordinate. See diagram below (Figure #4):

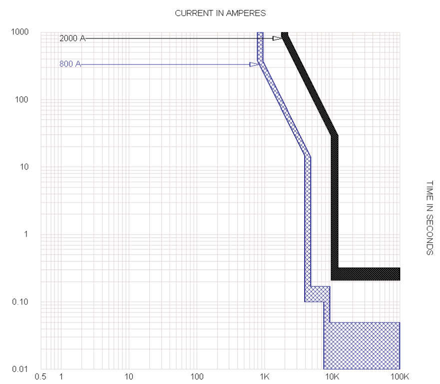


Figure #4 - *The graph above illustrates a 2,000 ampere main breaker and an 800 ampere sub breaker. The instantaneous portion of the 2,000 ampere main breaker has been turned off to allow for complete selective coordination between the two breakers. The 800 ampere breaker should trip any fault downstream without tripping the 2,000 ampere main breaker. If a breaker without the instantaneous setting is utilized, the engineer must ensure that the equipment is rated for the potential high fault current that can last for several cycles. In this case, the 2,000 ampere breaker will not trip for approximately 0.2 to 0.3 seconds or about 12 cycles to 18 cycles. In this case, switchgear construction would have to be utilized. Switchboard construction is only rated to handle its rated fault current for three cycles. Switchgear construction can handle the rated fault current for 30 cycles.*

It must be understood that the short time delay from not having an instantaneous trip can allow fault currents to flow for several cycles (typically up to 30 cycles), which can subject the electrical system to high mechanical and thermal stresses. The system equipment must also be coordinate to ensure it can withstand this tripping time delay. Switchboard construction will handle its rated fault current for only three cycles. Switchgear construction can handle its rated fault current for 30 cycles. There is a manufacturer that makes a hybrid type of switchboard that will handle the rated fault current for 30 cycles, but in general, if the engineer chooses to go the route of providing breakers with no instantaneous function, the system must use more expensive switchgear construction. Furthermore, this type of construction will require rear access which will typically increase the size of electrical rooms and decrease leasable space.

In addition, the instantaneous portion of the time current curve can only be turned off on ANSI rated power breakers. Typically, if the system utilizes molded case or insulted case breakers, the breakers utilize an instantaneous override function for high fault current levels. In this situation, selective coordination can be lost if the available fault current is above the preset override current level. For these reasons, as well as the fact that many small breakers do not have the option of no instantaneous trip setting, breakers without instantaneous tripping are more suited for larger systems. Smaller emergency and standby systems are not well suited for this type of selective coordination between breakers. If you have a short circuit on a 20 ampere thermal magnetic branch circuit that is protected on the supply side by a thermal magnetic 100 ampere panel main breaker, there is typically no way to verify for sure which breaker will trip first. Either or both breakers may trip which would indicate that the electrical distribution system is not selective coordination.

With zone interlocking, selective coordination can be achieved without removing the instantaneous trip setting. Zone interlocking is a protective function that will minimize the extent of an outage. The interlock function can be utilized for a ground fault or a phase fault. During a fault condition with a pre programmed and predetermined current level at the load side of a downstream breaker, the downstream breaker can be set to trip instantly. This breaker can be programmed to send a restraining signal to the upstream breaker no tot trip. The restraining signal can be coordinated between multiple levels of over current protection devices. This system would require additional electronic relays, control wiring between the relays and engineering and analysis to determine the correct settings to ensure full selective coordination and to avoid nuisance tripping. This type of system would certainly add significant cost and complexity to the electrical distribution system and would not be suitable or cost effective for a majority of medium and small emergency electrical distribution systems with multiple 20 ampere single pole breakers.

On the other hand, I do not believe the best solution would be to utilize fused switches and fused panel boards throughout emergency and legally required standby electrical distribution systems that are served by standby generators. Although I am aware of one fuse manufacturer that is in the process of developing a 200 ampere main lug only fused lighting panel that will be 20 inches wide by 5 ¾ inches deep, most fused systems can take up considerably more space than a typical panel board or switchboard. Additionally, many maintenance personnel currently enjoy the ease of resetting a breaker instead of ensuring that spare fuses are available and replacing spent fuses in the event of a short circuit or an overload. A lack of good maintenance protocols may actually reduce site availability and uptime if spare fuses are not available after an overload trip or short circuit.

Due to the critical nature of the emergency and legally required standby electrical distribution systems, selective coordination has been mandated as a revised code for these systems in the 2005 National Electrical Code. I do agree that emergency distribution systems should require a high degree of site availability and uptime and should strive towards full over current protection and selectability between protective devices. This selectability can be accomplished with both fuses and circuit breakers when they are selected appropriately and when over current protective device settings have been coordinated. Selective coordination of emergency and legally required standby systems over current protective devices with the supply side over current protective devices will provide for a more reliable electrical distribution system, but I think local code authorities should think long and hard about the potential far reaching ramifications of the full implementation of this code change. There may be some middle ground.

For example, the main breakers only, in the main emergency or standby distribution panels feeding the emergency and standby sub distribution panels could have the instantaneous portion of the breaker turned off. The remainder of the downstream breakers could then be the normal type of thermal magnetic breaker. In this situation, under worst case scenario of a fault current at the downstream side of a 20 ampere breaker exceeding the instantaneous setting of the up stream sub distribution breaker, only the specific emergency or legally required standby branch distribution panel and branch breakers would be subject to a complete outage. The main emergency and standby electrical distribution system could remain functional to feed the other emergency and standby branches. In this situation, only the main gear would be subject to the expense of the ANSI power breaker, switchgear construction and the extra space required for the larger gear.

The one line diagram and the graph below (Figure 5 and Figure 6) represents an 800 ampere ANSI power breaker with the instantaneous setting turned off from either the generator** or the normal power feeding into an 800 ampere automatic transfer switch. The automatic transfer switch feeds an 800 ampere main lug only panel with several 225 ampere molded case circuit breakers that feed 225 ampere main lug only emergency distribution panels. The emergency distribution panels are filled with 20 ampere molded case circuit breakers that feed emergency lighting at 277 volt single phase. Both the 225 ampere and the 20 ampere breakers are set to instantly trip at 10 times their rated current. A fault downstream of one of the 20 ampere breakers less than 2,250 ampere would only take out the 20 ampere breaker. A fault downstream of the 20 ampere breaker larger than 2,250 amperes could take out both the 20 ampere and the 225 ampere breaker. In no case will a fault on the secondary side of a 20 ampere breaker or on the secondary side of the 225 ampere breaker take out the 800 ampere main breaker. A fault would limit the outage to one branch panel under worst case scenario. Depending on the available fault current in the system, the location of the fault on the 20 ampere circuit and the nature of the fault (bolted or arcing), a fault downstream of the 20 ampere breaker could very likely only take that 20 ampere breaker in this configuration.

** The generator main breaker may not have to be an ANSI power breaker with the instantaneous portion turned off if the generator cannot provide 8,000 amperes of fault current. The amount of fault current that can be provided by the generator will be based on the reactance of the alternator in the generator. If the fault current at the generator main breaker is less than 8,000 amperes then a standard breaker with the instantaneous setting of 10 times the continuous current can be utilized.

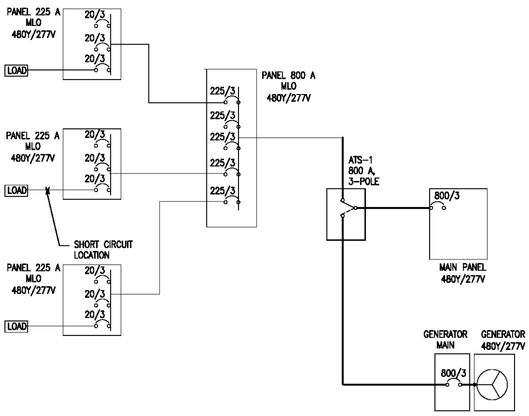


**Figure 5 -** *This one line diagram above represents an 800 ampere power breaker at both the generator service and the main service. The 800 ampere power breaker feeds an 800 ampere automatic transfer switch that then feeds an 800 ampere main lug only (MLO) panel filled with 225 ampere breakers. These 225 ampere breakers feed 225 ampere MLO panels filled with 20 ampere breakers that feed 20 ampere, 277 volt emergency lighting circuits.*

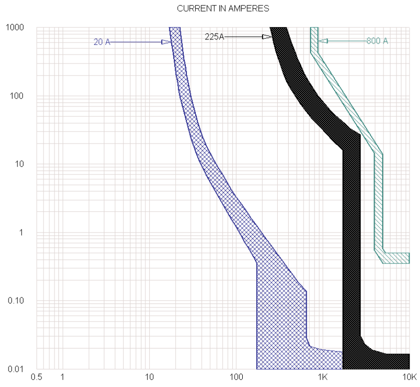


**Figure 6 -** *The graph above illustrates an 800 ampere ANSI power breaker with no instantaneous setting and a 225 ampere and a 20 ampere breaker with instantaneous settings at 10 times the constant current. A fault on the downstream side of the 20 ampere breaker of less than 2,250 amperes will only take out the 20 ampere breaker. A fault of greater than 2,250 amperes could take out both the 20 ampere and the 225 ampere breaker. A fault on the downstream side of the 20 ampere breaker should at no time take out the 800 ampere breaker.*

Additionally, a coordination study could be mandated to tweak the system settings of the breakers to ensure that the maximum available fault current is coordinated with the instantaneous settings of the breakers. For example, in figure #2 above, if the calculated maximum available fault current at the 100 ampere breaker was only 7,000 amperes, and the overlap of the breakers occurred between 3,000 amperes and 4,000 amperes, then only the most severe fault currents would take out both breakers. A fault with any amount of impedance, other than a bolted short, in this case would probably not rise to the level of the instantaneous portion of the 400 ampere breaker. Fault current calculations are based on a worst case scenario of a bolted short, the reality is that most fault currents are based on an arcing short. In a bolted short, no additional impedance is introduced into the system, the level of fault current will be based only on the impedance in the electrical distribution system to the point of the fault. These impedances include components like conductors and transformers. An arcing fault introduces additional impedance into the distribution system that will lower the actual fault current flowing through the short. Based on a publication from one breaker manufacturer, 80% of faults are what would be considered low to very low arcing faults that would produce about 10% of the fault current seen from a bolted short. The publication also indicated that about another 15% of faults would be considered low to medium faults that would produce about 30% of the fault current seen from a bolted short. This indicates that a vast majority of faults are no where near the worst case scenario from a fault current calculation simulating a bolted short circuit.

If the breakers in the main emergency or main standby distribution panels were switched from the standard thermal magnetic breakers with or without the ability to adjust the instantaneous trip to breakers with ampere plugs and long time trip settings, the instantaneous setting of the upstream breaker could be increased. The first example below (Figure #7) is of a 225 ampere and a 20 ampere breaker. Neither breaker has an instantaneous trip setting. Both breakers have a default of about 10 times their continuous current ratings for the instantaneous trip. The 225 ampere breaker will trip at about 2,250 amperes.

Figure 7 represents a 225 ampere breaker with no adjustment for the instantaneous portion of the time current curve and a 20 ampere breaker with no adjustment for the instantaneous portion of the time current curve. Both breakers have the default instantaneous settings set for about 10 times their continuous current rating.

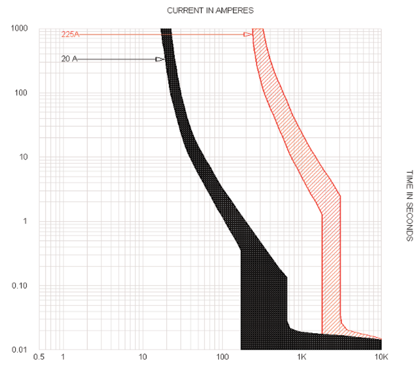


**Figure 7**

The next example below (Figure 8) is of a 225 ampere and a 20 ampere breaker. The 225 ampere breaker has an adjustable instantaneous trip setting. The setting is set for 10 times the constant current rating of the breaker. The 225 ampere breaker will trip at about 2,250 amperes.

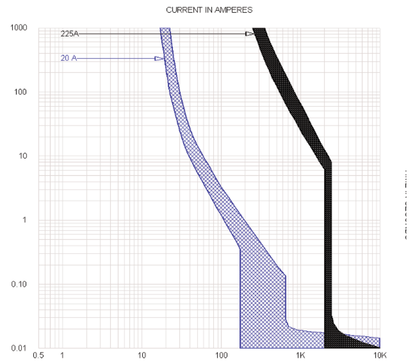


**Figure 8 -** *The above figure represents a 225 ampere breaker with an adjustment for the instantaneous portion of the time current curve and a 20 ampere breaker with no adjustment for the instantaneous portion of the time current curve. The 225 ampere breaker is set for 10 times the continuous current rating. The 20 ampere breaker has the default instantaneous settings that is set for about 10 times the continuous current rating.*

In the situation below (Figure 9), we have utilized a 600 ampere breaker with a 600 ampere sensor and a 450 ampere plug with a 50% long time pick up (LTPU) setting. This breaker could be located in the main emergency or standby distribution panel feeding a main lug only (MLO) 480 / 277 volt panel with multiple 20 ampere breakers feeding emergency lighting circuits. The instantaneous setting has been set at 10 times the constant current rating of the plug (450 amperes). The long time pick up is set for 50% and reduces the 450 ampere plug setting to 225 amperes. As long as the breaker settings are locked off so they cannot be easily changed, this configuration can protect a 225 ampere feeder and feed a 225 ampere main lug only (MLO) panel (See quotation from the National Electrical Code below, Section 240.6 (C)). The 10 times setting for the instantaneous trip will be based on the 450 ampere plug setting and would be increased to 4,500 amperes. In the above examples (Figure #5 and Figure #6), the 225 ampere breaker was set at an instantaneous setting of 2,250 amperes. The instantaneous trip setting has been increased by 100 %. The larger instantaneous setting would certainly reduce the potential of a fault current taking down the upstream breaker. This solution is not perfect, but would probably represent significantly less cost and physical space than utilizing ANSI power breakers and switchgear construction required when utilizing breakers with the instantaneous portion of the time current curve removed. In this situation, fault currents above 4,500 amperes could still trip both breakers. In addition, there would be additional expense involved in breakers with sensors and plugs.

**National Electrical Code ®, Section 240.6 (C) - 2005**

*(C) Restricted Access Adjustable Trip Circuit Breakers.*

*A circuit breaker(s) that has restricted access to the adjusting means shall be permitted to have an ampere rating(s) that is equal to the adjusted current setting (long time pick up setting). Restricted access shall be defined as located behind one of the following:*

*1. Removable and sealable covers over the adjusting means.*

*2. Bolted equipment enclosure doors.*

*3. Locked doors accessible only to qualified personnel.*

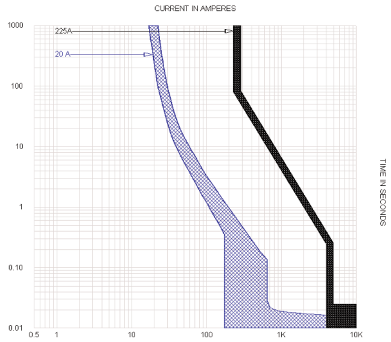


**Figure #9 -** *The above figure represents a 600 ampere breaker and 600 ampere sensor with a 450 ampere plug and a 50% (LTPU) long time per unit setting. The instantaneous setting is set at 10 times the 450 ampere plug setting. The second breaker is a 20 ampere breaker with no adjustment for the instantaneous portion of the time current curve. The 20 ampere breaker has the default instantaneous setting of about 10 times the constant current rating.*

In conclusion, I believe a broad sweeping change to the National Electrical Code as indicated in this article should be evaluated and reconsidered before adoption. The effects of this change can be quite dramatic. The engineering and over current protection manufacturing community should find some middle ground that would best serve building owners and tenants. Coordination of the over current protective devices within the electrical distribution systems is important in order to isolate short circuits on the emergency and legally required standby distribution to the smallest portion of the electrical distribution system as possible. But requiring fused distribution, expensive ANSI rated electronic power breakers with the instantaneous portion of the time current curve turned off and switchgear construction or the use of zone interlocking for all system with emergency or legally required standby distribution could add a lot of expense, especially to smaller, less critical electrical distribution systems. Fused distribution can enlarge electrical room requirements and reduce total leaseable space. Fuses could also mandate stricter maintenance protocols and necessitate the availability of spares and could actually lengthen outages once they occur. Perhaps the answer to this situation may be to require over current protective device coordination studies and analysis from a qualified licensed electrical engineer to improve coordination between over current protection devices, but not to require complete selective coordination under the worst case scenario of a bolted short. This type of analysis could be required to manipulate instantaneous settings of breakers in reference to the available fault current in the electrical distribution system. If done correctly, an over current protective device coordination study and analysis could go a long way to enhance the electrical distribution system's reliability and reduce the extent of possible outages without causing undo expense to the client. Clearer heads should prevail.

**References:**

(1) National Electrical Code 2005

(2) Cuttler Hammer White Paper on the Differences Between Breakers and Fuses.