Application Considerations for Selective Coordination of LV Distribution Systems

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Abstract

Selective Coordination has been applied at the discretion of design professionals as a system performance standard in critical applications such as data centers and healthcare facilities for many years. NFPA 110 – Standard for Emergency and Standby Power Systems 2005 Edition Chapter 6, Section 6.5 Protection, General 6.5.1 states: "The overcurrent devices in the EPSS (Emergency Power Supply System) shall be coordinated to optimize selective tripping of the circuit overcurrent protective devices when a short circuit appears." NFPA 110, Annex A – Explanatory Material A.6.5.1 states: "It is important that the various overcurrent devices be coordinated, as far as practicable, to isolate faulted circuits and to protect against cascading operation on short circuit faults. In many systems, however, full coordination is not practicable without using equipment that could be prohibitively costly or undesirable for other reasons. Primary consideration also should be given to prevent overloading of equipment by limiting the possibilities of large current inrushes due to instanteous reestablishment of connections to heavy loads." The 2005 version of the NEC transferred the requirements from a system performance requirement to the NEC as a minimum public safety requirement requiring selective coordination on "legally required" life safety and standby essential systems. NEC Article 700 – Emergency Systems, Section 700.27 Coordination states: "Emergency system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices." This requirement addresses life safety systems. NEC Article 701 – Legally Required Standby Systems, Section 701.18 Coordination states: "Emergency system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices." Per NEC 2005, Article 700.27 & 701.18, FPN: "This requirement, new in the 2005 NEC, requires that all emergency system overcurrent devices be selectively coordinated with the overcurrent devices installed on their supply side. The term coordination (selective), as defined in Article 100, indicates that a selectively coordinated system is one where the operation of the overcurrent protective scheme localizes an overcurrent condition to the circuit conductors or equipment in which an overload or fault (short-circuit or ground fault) has occurred. Because the purpose of an emergency system is to provide power to essential life safety systems in a building or facility, a selectively coordinated overcurrent protection scheme that localizes and minimizes the extent of an interruption of power due to the opening of a protective device is a critical safety element. Continuity of illumination for occupant evacuation

or maintaining continuity of operation of essential safety equipment such as smoke evacuation systems is necessary for occupant safety during a fire or other emergency. Simply put, an overcurrent event (overload, short-circuit, or ground-fault) in a 20 ampere branch circuit cannot cause the feeder protective device supplying the branch circuit panelboard to open. This coordination must be carried through each level of distribution that supplies power to the emergency system." These requirements have been expanded in the 2008 version of the NEC to include: ARTICLE 708 Critical Operations Power Systems (COPS), Section 708.54 states: "Critical operations power system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices." Article 100 of the 2005 NEC defines Selective Coordination as: "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. NEC 2005 Article 100 Selective Coordination definition includes the following fine print notes (FPN): "This definition is no longer limited to Article 240. For the 2005 Code, selective coordination requirements have been expanded to include emergency and legally required systems of 700.27 and 701.18. The past Code requirements regarding selective coordination remain for elevator feeders in 620.62. The main goal of selective coordination is to isolate the faulted portion of the electrical circuit quickly while at the same time maintaining power to the remainder of the electrical system. The electrical system overcurrent protection must guard against short circuits and ground faults to ensure that the resulting damage is minimized while other parts of the system not directly involved with the fault are kept on until other protective devices clear the fault. Overcurrent protective devices, such as fuses and circuit breakers, have time/current characteristics that determine the time it takes to clear the fault for a given value of fault current. Design and subsequent verification of electrical system coordination can be achieved only through a coordination study that entails detailed knowledge of electrical supply system fault current characteristics and a design that integrates overcurrent protective devices that react to overcurrent and interact with each other in such a manner that the objective of minimizing outages by localizing the overcurrent problem and isolating that part of the emergency system can be achieved. It is important to note that modifications to the electrical system subsequent to the initial design and installation can significantly impact the original implementation of the coordinated system."

Article 240.12 of the 2005 NEC states: "Where an orderly shutdown is required to minimize the hazard(s) to personnel & equipment, a system of coordination based on the following two conditions shall be permitted:

(1) Coordinated short-circuit protection. With coordinated overcurrent protection, the faulted or overloaded circuit is isolated by the selective operation of only the overcurrent protective device closest to the overcurrent condition. This prevents power loss to unaffected loads.

(2) Overload indication based on monitoring systems or devices."

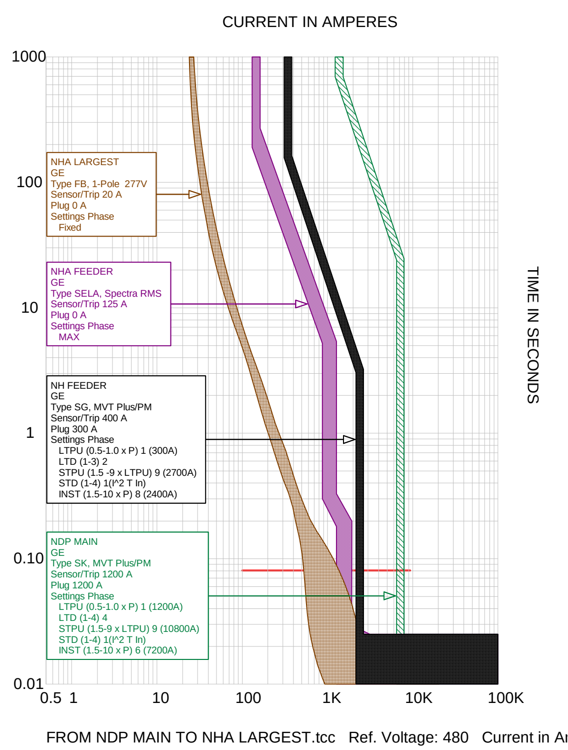
Implementation of these code sections is difficult at best. Specific interpretation regarding inclusion of instantaneous OCPD time bands and whether the normal feeders and their respective ground fault circuits were to be included resulted in confusion amongst the local AHJ and spirited discussions with competitive equipment manufacturers. As the plan review and inspection (IAEI) communities became more familiar with the requirements several states began to adopt "modifications" to the state codes to alleviate some of the confusion. Eventually two very different interpretations of the selective coordination codes began to surface. Interpretation one is defined as "instanteous selective coordination". It is being enforced in several states including North Carolina and Washington State. Interpretation two is based on the enforcement of selective coordination to the 0.1-second minimum time band and ignores the instantaneous time band for OCPD. This has been the standard for the healthcare industry (AHCA) in Florida for over 20 years. This method of selective coordination is named the AHCA, or non-instantaneous method of selective coordination. The AHCA method has been officially adopted by several states as a minimum standard, including Oregon and Massachusetts. The purpose of this document is to provide insight into applying selective coordination for the AHCA method of NEC 2005 mandated selective coordination. Instantaneous selective coordination will be discussed in more detail in a follow up article.

Best practices for AHCA or non-instantaneous selective coordination.

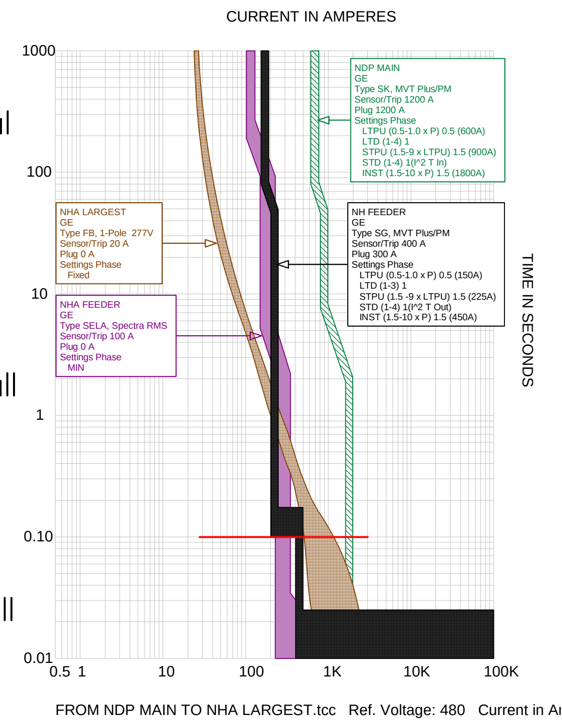
1. Series Ratings should be avoided in circuits that require selective coordination. Series ratings depend on the upstream OCPD to be "current limiting". Upstream devices open before fault currents to the downstream device reaches catastrophic failure levels for the downstream device. This is diametrically opposite of the principles of selective coordination.

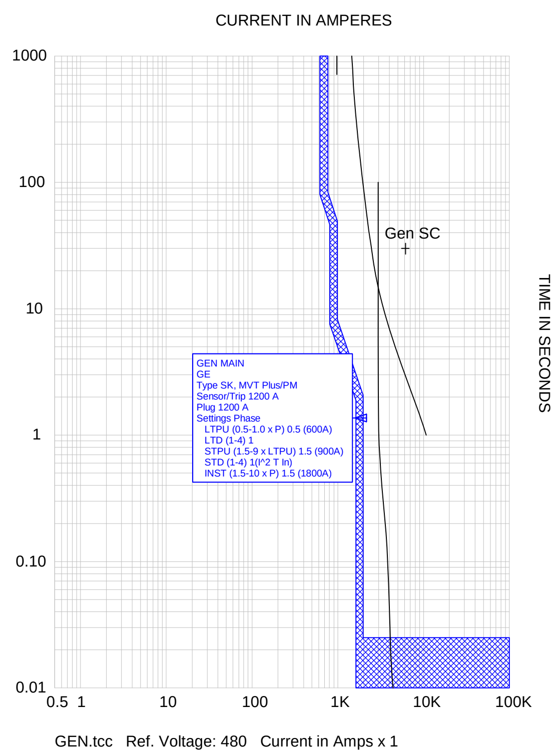
Reader Note: Curves can be enlarged by dragging a corner

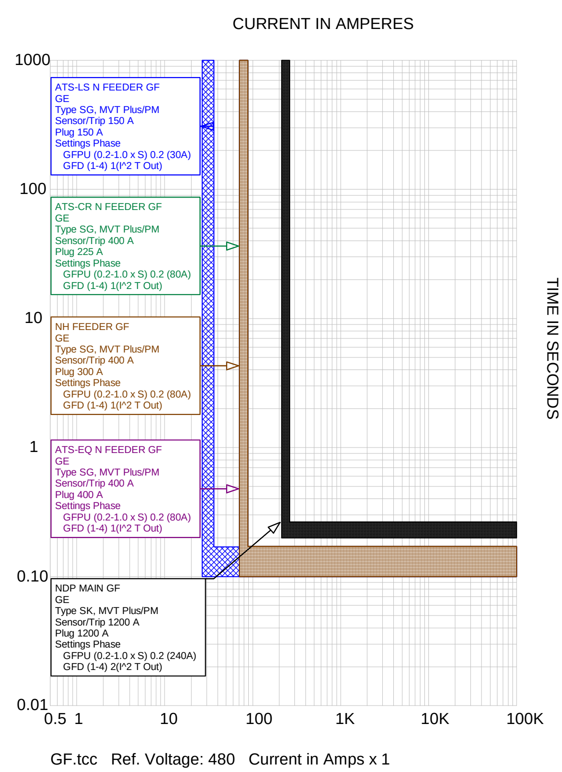
2. Bottoms up! Typically the smallest branch circuits are non-adjustable thermal magnetic OCPD. Coordination of branch circuits normally is the most difficult. Any adjustments to downstream OCPD (branch panel mains) affect the settings of upstream devices. In this example if NHA feeder should be evaluated with branch breaker NHA largest before NH feeder or NDP main are evaluated. Another important concept here is that the largest ampere rating of each frame must be evaluated relative to the upstream device, as each frame type will exhibit different characteristics.



3. Electronic trip OCPD field adjustment. While not mandated in the NEC for non-essential, ground fault or optional essential power distribution circuits, evaluation of settings for electronic trip OCPD will avoid embarrassing calls from irate clients complaining of nuisance trips. Please notice that the OCPD are mounted in equipment and shipped from the manufacturer with minimum settings for all electronic trip OCPD. Conversely the owner's personnel could take it upon themselves to adjust the OCPD's settings (typically to maximums). While this may cure the nuisance tripping problem the arc flash incident energy will increase as all settings are maximized increasing the OCPD's response time.

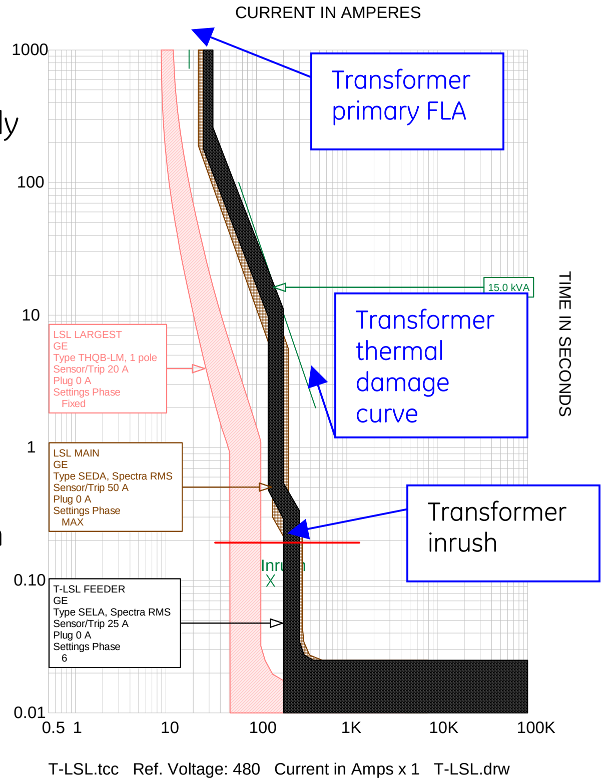




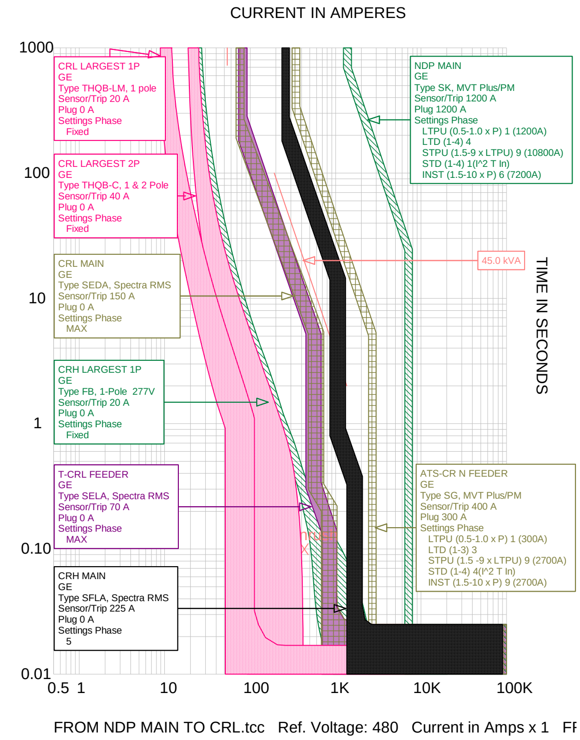


The examples above demonstrate factory default ground fault and a generator main at factory default settings. An invitation for the phone to ring with an angry client!

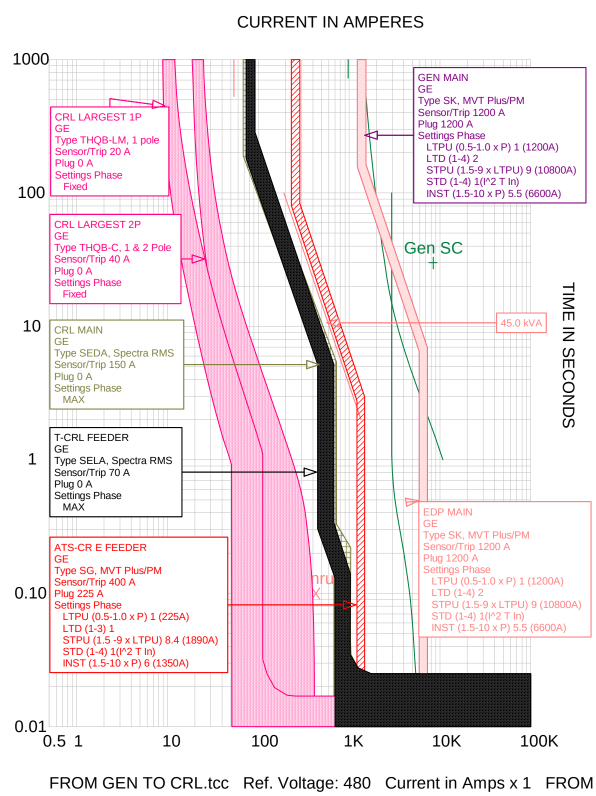
4. Selective coordination for dry type transformers. Smaller dry type transformers are a challenge to selectively coordinate. Some data regarding the transformer must be verified during the coordination process. Of particular interest is the transformer's inrush characteristic. Software programs designed to assist in the selective coordination evaluation process typically overstate the subject transformer's inrush characteristics. This results in an artificially high setting of the instantaneous trip of the transformer's feeder breaker in this case T-LSL. Inrush factor is normally stated in per unit (PU) of the transformer's primary FLA. In this case the software default was 12x. Data acquired from a transformer manufacturer was less than 8x! The transformer's long time or thermal setting should be greater than the primary FLA of the transformer. The transformer primary OCPD's instanteous setting (in this case T-LSL Feeder) should be greater than the transformer inrush data point. The transformer's secondary OCPD (LSL Main in this example) should trip before reaching the transformers thermal damage curve. Utopia would be for the primary OCPD to trip before the thermal damage curve. Very difficult in 15kVA and smaller dry types. Notice also that the primary and secondary OCPD do not coordinate and in fact are aligned almost perfectly. These OCPD are in series and are not required to coordinate. Finally, the transformers secondary OCPD or secondary panel main (in this example LSL) must coordinate with downstream branches (in this example LSL Largest).



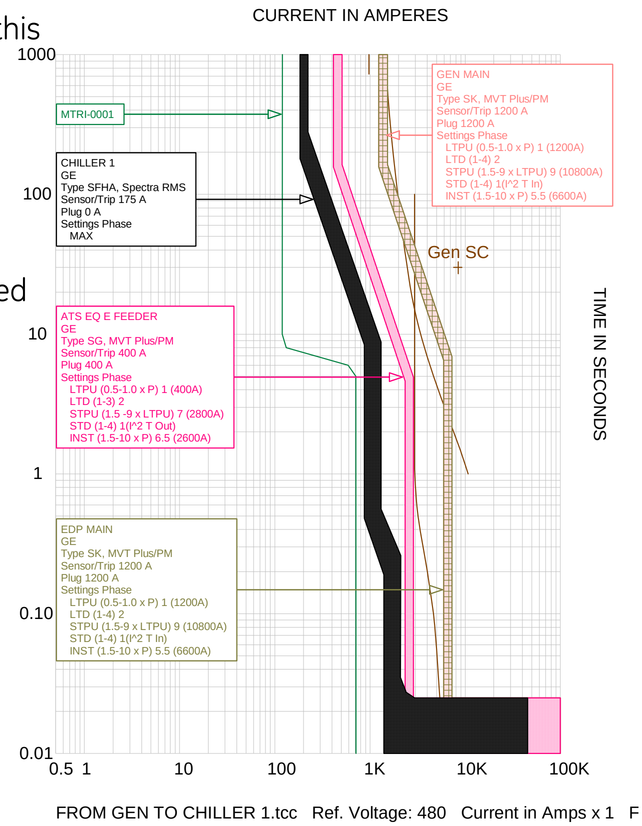
5. Coordinate each path from branch to main. If application requires selective coordination on essential and non-essential branches show TCC plot from largest branch of each type to generator and to normal main. Typically GF plots are separate. In this example of coordination for a critical branch panel (CRL) to the normal main NDP main. Notice there is a 480 VAC panel (CRH) and a 208Vac panel (CRL). Both on same plot.



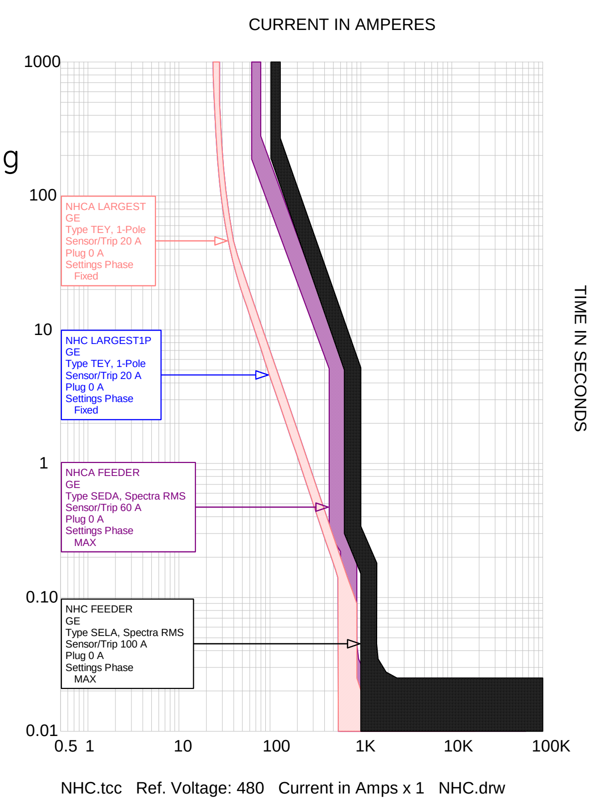
6. Same plot except to Generator.



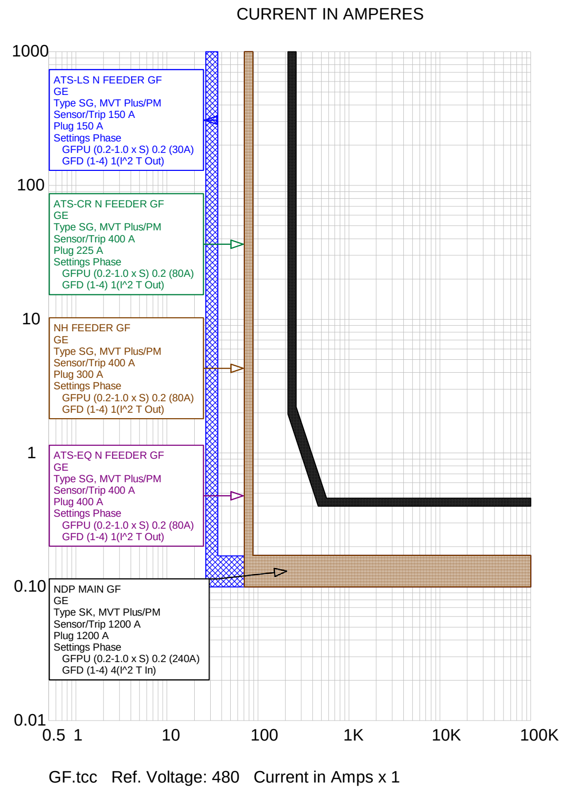
7. Selective coordination with motors. In this example we have a 100HP (Chiller 1) FVNR motor. LRA should be verified, as the software default is 5.9x FLA. VFD with bypass are FVNR in bypass mode and should be evaluated as such. Non-bypassed VFD are not FVNR and LRA is typically 1.15x FLA. VFD generated harmonic content should be separately modeled.



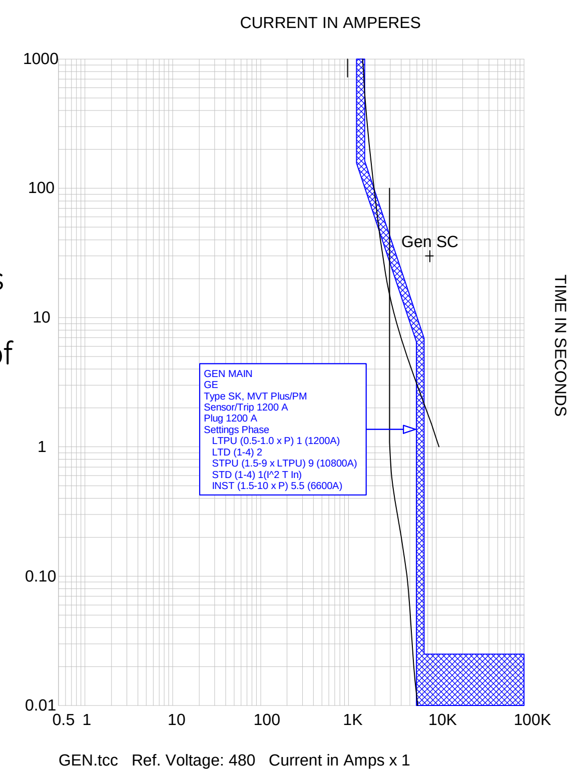
8. Layers are not our friend. In this example a 60A OCPD is sub-feeding a second panel. This scenario is very difficult to coordinate. Alternative feeding methods will need to be considered. Subfeed lugs with a non-fused disconnect or molded case switch is an excellent alternative if the AIC is below 10kA.



9. GF on separate plots



10. Generator modeling



Coordination to the emergency side of the system is the point where one should start. The use of smaller sized breaker's or loads is most often used and makes selectivity the most challenging. In today's market, many of the generator manufacturers provide self-protecting relays for the generators themselves, which allows the designer to concentrate on fewer over current devices. This could also eliminate the use of the Gen Breaker or Main breaker in the emergency distribution panel. In this example, (GEN-Chiller TCC) the GEN MAIN protects the generator from damage and allows the generator to come up to speed while protecting the cable and main bus. The second breaker from the left is the feeder breaker for the Equipment ATS switch and the Equipment Branch. Finally the Load/Chiller breaker both protects the equipment and allows the Chiller to come up to full load without nuisance tripping. In providing selectivity of the emergency loads we almost always start with the largest feeder breaker within the emergency panel and work downward. Once the largest breaker of that panel is coordinated, the others then settle in nicely and are set to protect downstream equipment while minimizing arc flash.

In summary, the primary advantage of appropriately applied selective coordination is fault localization. This results in increased system performance. However; poorly selected OCPD settings can result in increased system downtime, frustrated building occupants and unhappy property owners.