Coordinated Protection for Critical Environments

Expensive overcurrent protection for electrical distribution systems might not be worth the expense without a device coordination study.

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There's no doubt that a sudden power failure can have a dramatic effect on business, especially in a facility with critical operations. Isolating a fault condition to the smallest area possible is essential in providing the most reliable electrical system with maximum uptime for the facility. But expensive electronic distribution protection equipment might not be worth the extra cost unless a proper protective device coordination study is provided by an experienced engineer.

A properly coordinated system will limit a fault to the nearest upstream protective device. The key is a one-line diagram of an electrical system. Once this diagram is completed and the brands and models of the protective devices have been selected, then a protective coordination study can be undertaken.

There are several parameters that can be selected for each protective device. For example, the total number, type and sensitivity of the settings for each type of device will depend on the specific device. Adjustment of these parameters allows for what is referred to as *curve shaping.*

Curve shaping allows better coordination between upstream and downstream overcurrent protection devices. At right is a list of common possible parameters.

But, as previously mentioned, before beginning a coordination

Common Device Parameters

- **Overload region.** (Long Time per Unit). This is the long-time trip setting of the overcurrent protective device. This parameter, also know as *continuous amperes*, is a percentage of the breakers nominal rating and can typically be set at 20% to 100%. This setting is usually achieved with a thermal overload in a molded-case circuit breaker.

- **Long-time delay.** This setting allows for inrush from motors to pass without tripping the breaker. The setting affects the position of the "I squared T" slope just below the continuous current setting.

- **Short-time pick up.** This is typically provided with an adjustment of 5 to 10 times. This setting allows downstream overcurrent protection devices to clear faults without tripping upstream devices and can also be adjusted to allow for transformer inrush current.

- **Short-time delay and instantaneous override.** This setting postpones the short-time pickup, and can be done on a fixed setting or an I squared T ramp setting. This allows for better coordination between upstream and downstream devices. An instantaneous override can be set at high current to override this function and protect electrical equipment. The I squared T function of the short time delay can provide better coordination when coordinating a breaker with a fuse.

- **Instantaneous.** This setting will trip the overcurrent protective device with no intentional delay.

- **Ground-fault setting.** (Ground Fault per Unit). This is the percentage of the rating of the breaker for the ground fault setting. Per the *National Electrical Code*, ground fault cannot exceed 1,200 amps, regardless of the size of the breaker.

- **Ground-fault delay.** This setting allows for a time delay before ground-fault pickup. This allows for better selective coordination between multiple levels of ground-fault protection. In addition, the time delay cannot exceed one second (60 cycles) for ground-fault currents of 3,000 amps or more.

study, the engineer might need to design a one-line diagram—if one doesn't exist already—of the building electrical systems, and coordinate with the electrical contractor, equipment provider, or both, to determine the actual equipment to be installed. The following is required for an accurate protective coordination study:

1. Description, make and catalogue numbers of protective devices.
2. Full load current at the protective device.
3. Transformer kVA rating, impedance and inrush data.
4. Available fault current at the protective device.
5. Conductor cable information including current carrying capacity and insulation type.
6. Protective device design requirements from the serving utility.

These days, it's common to perform complicated electrical protection coordination studies with the help of advanced computer software. These software platforms will typically contain libraries that include required settings for most of the common overcurrent protective devices.

And as noted above, with the review of protective coordination study basics, the reliability of an electrical system and its equipment can only be assured if proper coordination is implemented among all the various protective devices.

THE NEC MANDATE

There are instances where the *National Electrical Code* (NEC) requires a protective coordination study. There are also times when K-rated transformers employed to deal with electronics and non-linear loads can reduce reliability if not properly coordinated.

On a typical transformer, the current and associated magnetic field is 90 degrees out of phase with the voltage. When you close a breaker and turn on a transformer, the instantaneous magnetic field can be twice as high as normal. In the "ideal" transformer, the current required to supply this magnetic field would also be twice as high. However, in a real transformer the core is saturated and the actual current required to create the field can be 12 times as high as normal. Factors such as the size of the core of the transformers and the time the voltage is applied play roles in determining the amount of inrush current.

The actual inrush current mentioned above would be different based on the actual transformer manufacturer. It is critical for the consulting engineer to contact the specific manufacturer of the

Figure 1

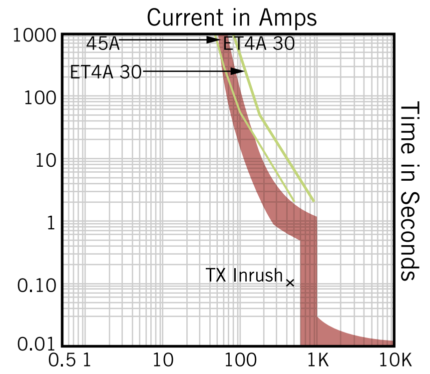


Figure 2

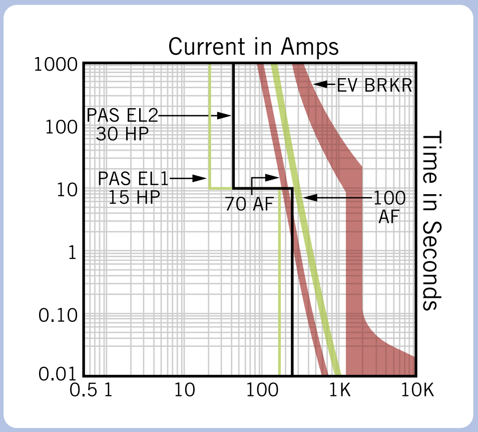
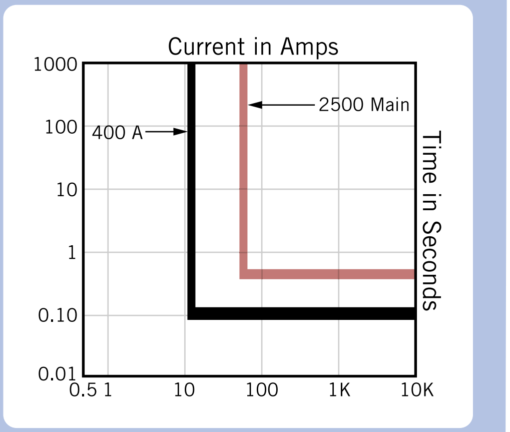


Figure 3



transformer supplied in the field. If actual transformer inrush data is not known, common industry standard is to assume the inrush is 12 times for 0.1 seconds and 25 times for 0.01 seconds. Figure 1 (p. 30) illustrates the transformer inrush at 12 times for 0.1 seconds.

Engineers were running into trouble some years back when the K13-rated transformer was becoming more prolific in regular office environments. A K13-rated transformer is oftentimes just a larger transformer with a smaller rating to compensate for harmonics. The same 110-amp breaker typically on the primary side of a regular 75-kVA transformer may trip when protecting a 75-kVA, K13 transformer. For sizing of the primary side, overcurrent protective device for K13 or higher transformers, I recommend multiplying the input full load amps of a transformer by 125% and going to the next common size up. In addition, a breaker with the instantaneous setting is often required to allow for the transformer current inrush. As a final step, I recommend a coordination study to ensure the system will work before it is too late, after construction is complete and the engineer is stuck with an angry owner.

Selective coordination is required when more than one elevator is supplied by a common feeder, per NEC 620-62. Figure 2 (above) is an example of a coordination study illustrating feeder breaker overcurrent protection, elevator fuse overcurrent protection and elevator motor start-up curves.

NEC 517-17 requires that if ground-fault protection is provided for the service disconnecting means, then an additional step of ground-fault protection shall be provided in the next level of feeder disconnecting means downstream toward the load. Figure 3 (above) is a good example of what a properly coordinated ground fault study should look like.

NEC 230-95 indicates that all 480-volt 3-phase services 1,000 amps and above must be installed with a ground-fault relay. The setting of the ground-fault relay cannot exceed 1,200 amps, regardless of the size of the overcurrent protection device. In addition, the time delay cannot exceed one second (60 cycles) for ground-fault currents of 3,000 amps or more. There shall be a minimum of six cycles (0.1 second) ground-fault delay between ground-fault devices in health-care facilities.

Ground-fault settings for main breakers serving downstream motors that are set too low or too fast may trip a main overcurrent protection device before tripping the local thermal magnetic overcurrent protection device during motor starting ground faults. On the other hand, ground-fault settings that are too high can cause undue damage before a ground fault is interrupted. It is important to provide the ground-fault setting that will not permit nuisance tripping, but will protect the electrical equipment from excessive damage during an event.

In my experience, sometimes perfect coordination between a set of devices cannot be obtained. Certain settings may be required on a breaker that could affect the settings of many breakers. In some cases, there may be many levels of breakers that may cause overlap of the breaker curves within the tolerance of the curves. It is at these times that experience will allow the engineer to make judgment calls as to certain compromises in coordination between devices. The engineering behind protective coordination studies is not an exact science, by any means.

On many occasions, I have seen completed projects with no protective device study. In such cases the breaker manufacturer will ship the breakers with all settings set to the most sensitive. This will ensure the most protection, but will increase false trips and is typically not good for the reliability and uptime of the systems.

As soon as the owner complains of a false trip, the facility personnel will probably set all of the dials to least sensitive. This reduces the likelihood of false trips, but might not adequately protect the electrical system and reduces selective coordination of the system.

In short, a coordination study is typically required to ensure that the most reliable electrical system has been installed. In addition, there are instances where the NEC requires that a study be performed. In either case, the cost of a coordination study is cheap insurance for most any facility that would be adversely affected by an extensive power outage.

The important point to remember is that protection equipment can be an expensive investment, and it's well worth the cost of investing in a coordination study by an experienced electrical engineer. ⒺⓃⒹ

What's in a Coordination Study?

In addition to understanding the basics of coordination studies, other key issues involved include:

- **Proper sizing of the transformer primary breaker based on transformer saturation and the proliferation of K-rated transformer.**
- **Elevator protection coordination as required per the NEC.**
- **National Electrical Code article 517 and ground fault coordination studies.**