



Property Risk Consulting Guidelines

XL Risk Consulting

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PRC.5.0.4

ELECTRICAL COORDINATION - SYSTEM STUDIES

INTRODUCTION

In the broad context, designing an electrical system so its components work together is electrical coordination. The process is a series of engineering studies of the electrical system to evaluate its reliability. These studies include fault current analysis, insulation coordination analysis, load flow studies, system coordination analysis and design reliability studies. These studies/analyses are updated as changes take place.

Once problems uncovered by the electrical coordination, system studies process are resolved, the electrical system is presumed to be safe, appropriately protected and able to perform as required, barring catastrophic disturbances. Immediate actions on revealed deficiencies minimize the number of electrical failures, the extent of damage when failures do occur, and the number and extent of production interruptions and injuries caused by failures.

These coordination studies may be accomplished by a qualified electrical engineer in the facility engineering department, or by an electrical engineering consultant specializing in this work. Documents resulting from these studies are important tools for electrical maintenance activities.

A fault current analysis is also called a short circuit study. Its purpose is to determine short circuit current values in an electrical circuit. It calculates the maximum current flows resulting from all possible electrical faults. The information developed is needed to complete insulation coordination studies.

An insulation coordination analysis examines ratings of components in the circuit and compares them to overcurrents and overvoltages. To accomplish this, it compares short circuit values with interrupting ratings of devices used for switching. It correlates the insulation strength of electrical equipment with expected overvoltages and with the characteristics of surge protective devices in the system.

Electrical load flow studies are used when designing or extending an electrical system. Load flow studies determine nominal or normal current flows in the system. These studies examine both short-time characteristics and steady-state conditions. Electrical load flow studies are needed for insulation and system coordination analyses.

System coordination is alternately called overcurrent coordination, protective coordination, selective coordination, or simply, coordination. It examines the effects of overcurrent on protective devices that are arranged in series, electrically. The intent of system coordination is to have the protective device electrically closest to a fault or overload react to isolate the load from the power source. If the electrically nearby protective device fails to open, the next closest protective device in the series should open. System coordination compares response times of the various protective devices in the

circuit to evaluate the resulting sequence of operations. Where necessary to improve selectivity, protective devices may be adjusted or replaced.

Design reliability studies deal with failure mode analysis and alternative system designs. A discussion of these studies is beyond the scope of this Property Risk Consulting Guideline. See NFPA 70B for more information.

Taken together, these analyses can show whether or not changes are needed for the power supplies, loads, conductors and system components to work together effectively and safely. They are used to prevent and limit electrically-caused losses and to protect property and production profits.

POSITION

At least yearly upon discussion with the electric utility supplier, determine the maximum available short circuit current at the utility connection.

Perform or update the appropriate electrical studies and analyses whenever:

- The available short-circuit current from the power supply (utility) increases.
- A new electrical system is being designed or an existing system is being expanded.
- Changes to the electrical system are planned.
- New equipment is to be added to a circuit.
- Existing equipment is to be replaced with equipment designed to other-than-identical electrical performance characteristics. Verify designs by reviewing specifications and consulting with manufacturers.
- A fault or overload causes a wider power interruption than it should, thus suggesting failure of system coordination.

Maintain a copy of the up-to-date electrical coordination analyses in the department responsible for electrical maintenance. Include equipment specifications and relay settings in the documentation.

At least yearly, verify that data in the electrical coordination analysis is up-to-date, and that it documents the latest electrical system configuration, equipment and settings.

As part of electrical coordination analyses, perform the following:

- Load flow studies — determine normal electrical load characteristics, voltages and currents.
- Insulation coordination studies — analyze interrupting ratings; analyze overvoltages and surge protective devices. See PRC.5.2.2.
- Fault current studies — determine maximum fault current (short circuit) currents.
- System coordination studies — perform a time-current study of all protective devices from loads back to power supplies. Address the extent of circuit isolation upon faults and overloads. Coordinate protective device functioning to isolate the smallest circuit possible upon faults and other overcurrents to minimize the extent of property damage and power interruption.

When performing a system coordination analysis of a stationary battery circuit, determine and record the maximum available short-circuit current at the battery terminals at 77°F (25°C). Battery manufacturers can provide this information. The interrupting rating of the protective device should be sufficient to interrupt this current.

Give high priority to correcting deficiencies uncovered by these electrical system studies.

DISCUSSION

For the purposes of this Property Risk Consulting Guideline, fault current, insulation coordination and system coordination analyses are components of an “electrical coordination analysis.” The analysis typically starts with the preparation of a one-line electrical diagram showing all system components —

power sources, primary feeders, secondary feeders, substations, branches and loads. The diagram and the analysis begin at the load end of the circuit, and work back to the power source. Because overcurrent is commonly selected as the electrical characteristic on which protection is based, short-circuit and load-flow values are calculated and added to the diagram as the analysis progresses. Current values are updated as the analysis moves through the system, and from transformer secondaries to transformer primaries.

Included in the analysis is an examination of insulation withstand ratings of equipment. A withstand rating is the highest test voltage that can be applied to an electrical insulation system without causing flashover, puncture or other such electrical failure. System overvoltage scenarios are compared to withstand ratings.

Further, the analysis examines the sequence of operation or selectivity of protective devices. The purpose of selectivity is to limit the impact of an electrical fault or overload on business operations. Systems are commonly installed with protective devices electrically in series between the branch load and the power source or service entrance. Sometimes, backup devices are installed to increase the reliability of protection by providing a second chance for selectivity or limited power interruption. Ideally, operating a protective device close to a load will cut power to the smallest possible portion of the system. To fuse or trip a protective device at the service entrance because of a fault at a remote machine shows a lack of selectivity or poor system coordination.

Selectivity can be accomplished because manufacturers of overcurrent protective devices define the time-current performance characteristics of their products. Such information is usually available on a graph. The graph typically shows a “band” rather than a line to accommodate manufacturing variations or tolerances in the product. Sometimes, users select from a family of bands to obtain a specific performance range. Specifications and final settings of these devices establish their time-current performance in the circuit. During a coordination analysis, these characteristics are plotted on a time-current graph to document the sequence of operation of each protective device from the load or fault, back to the power source in the circuit.

In general, selectivity minimizes interruptions to unfaulted loads. With selectively coordinated protective devices, protection takes place quickly. Only the smallest possible portion of the system is interrupted upon the failure or abnormal condition. If the closest protective device fails to operate, then the next closest device can be expected to operate. Selectivity improves electrical protection by limiting the extent of an outage.

However, selectivity may occasionally have to be compromised, particularly with complex systems. Sometimes, no protective device with the desired time-current performance characteristic is available. Or, the characteristic curve of a required fuse might overlap with that of a required relay. In these situations, complete selectivity is impossible. Further, in other situations, special needs of system protection might outweigh the need for selective coordination.

In many loss control systems, specific electrical arrangements and coordination are vital to safety and protection. Fire pump circuits are one example. See PRC.14.2.1.

Electrical Code Coordination

Based on article 110.9 of the *National Electrical Code*[®] (NEC), a switch or other device intended to interrupt normal circuit current must have an interrupting rating sufficient for the maximum current that must be interrupted. Nominal circuit voltage is used in these calculations. Interrupting ratings are specified in amperes.

The article also requires the interrupting rating of a device intended to stop the flow of current from a fault (short circuit) to be sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment. This means the ampere rating must be equivalent to or higher than the highest possible fault current at the point of connection between the protective device and the circuit. Nominal circuit voltage is used in these calculations and the current is calculated for a direct short (zero-impedance, line-voltage, short-circuit) at the connection point.

Both requirements address insulation coordination and require a fault current analysis. Neither directly addresses selectivity.

Typical short circuit interrupting ratings are much higher than overload or overcurrent ratings to which fuses are designed or breakers are set. For example, for a circuit with conductors selected to safely carry a maximum of 20 A, the ampacity or ampere rating of a protective fuse would normally be 20 A. However, that same 20 A fuse could have an interrupting rating of 100,000 A.

When protective devices cannot safely interrupt fault currents, they might not only destroy themselves as they attempt to operate, they might also cause injury, expand damage and fail in their primary purpose of opening the electric circuit. If isolation is not successful, fault current will continue to flow through and across damaged circuit components even after the fuse has melted or the circuit breaker has opened.

While the NEC requires electrical circuits to be electrically coordinated, it uses the term in a limited sense, primarily to limit damage to property. Quoting from article 110.10:

The overcurrent protective devices, the total impedance, the equipment short-circuit current ratings, and other characteristics of the circuit to be protected shall be selected and coordinated to permit the circuit protective devices used to clear a fault to do so without extensive damage to the electrical components of the circuit.

Beyond Code

The NEC does not address the selectivity of protective devices. It is not the scope or purpose of the NEC to safeguard production output. Minimizing production interruptions is a production and loss control concern, and can require meeting more than the minimum of code-level protection. Concerns for profitability go beyond code safety and beyond actions focused on property loss control.

Electrical coordination is used when designing new electrical systems and when examining, updating and maintaining existing electrical systems. It determines whether electrical equipment is appropriate for its use. It examines the characteristics and arrangement of each protective device. It anticipates short circuits, determines available short circuit currents and investigates their effects on the system. It identifies protective equipment and trip settings necessary to selectively clear (isolate) overcurrents in the electrical system. It prevents some electrical losses and limits the extent of damage and power interruption on others.

A system is electrically coordinated when all of these analyses have been performed and all deficiencies have been corrected. These procedures should be repeated when any change affects the results and upon failures of selectivity. Detailed information on system coordination is presented in IEEE Std 242.