

The Locomotive

Short-Circuit and Protection Coordination Studies

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Introduction

How do you know if a circuit breaker will work when it is called upon to interrupt an electrical fault or short-circuit? If you haven't had a short-circuit/protection coordination study done on your electrical system recently, the answer is: you don't know for sure.

Even the best designed and maintained power systems occasionally suffer short-circuits that draw unusually high currents. If these currents exceed the capability of the protective devices in the power system, a short-circuit event will cause the devices to explode like a bomb.

The First Step

A short-circuit study is an analysis of an electrical system that determines the magnitude of the currents that flow during an electrical fault. Comparing these calculated values against the equipment ratings is the first step to answering the question above and ensuring that the power system is safely protected. Once the expected short-circuit currents are known, a protection coordination study is performed to determine the optimum characteristics, ratings, and settings of the power system protective devices.



Medium-voltage switchgear being tested under short-circuit conditions. This explosion was created under laboratory conditions to test equipment during arc faults. (courtesy Cutler-Hammer division of Eaton Corporation)



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All recommendations are general guidelines and are not intended to be exhaustive or complete, nor are they designed to replace information or instructions from the manufacturer of our equipment. Contact your equipment service representative or manufacturer with questions.

How is a Short-Circuit Study Done?

A short-circuit study is comprised of the following steps:

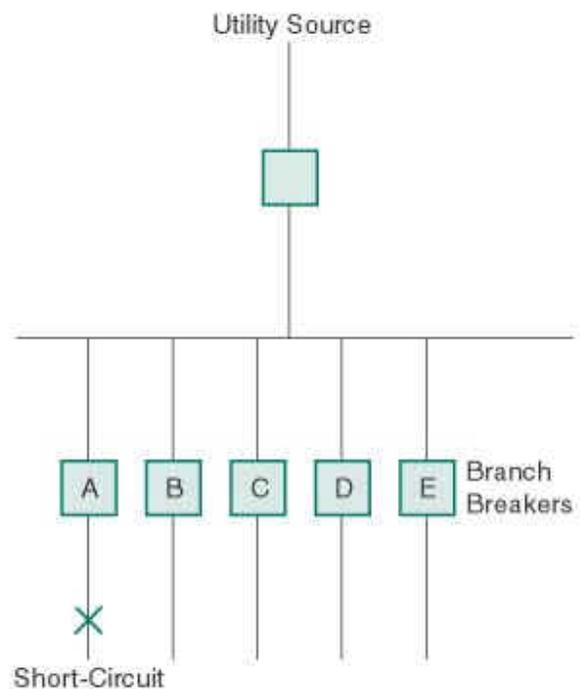
- **Data collection** — Information on all the components is obtained during a field visit and then tabulated. Additional data is obtained from the electric utility, manufacturers, or calculated from field data.
- **One-line diagram** — A power system diagram that shows how all components are electrically connected is created, or, if one already exists, updated. Additional data needed for the study, such as cable impedances, can be obtained with information from this diagram.
- **Computer analysis** — Using one of the many computer software programs available, the system data is input and the short-circuit currents at various points in the system are calculated.
- **Tabulate results** — The output of the computer program is typically put into a table for comparison with the ratings of equipment in the system. If the calculated short-circuit current at a given point exceeds the short-circuit rating of the equipment installed at that point, then that location is flagged as being inadequately protected.
- **Final report** — A detailed report that describes the scope of the study, all assumptions, the origin of the data, the methods used for calculating the currents, the tabulated results, and recommendations for corrective action is published at the conclusion of the study.

Protection-Coordination

An electrical power system is designed so that if a short-circuit occurs, a protective device (such as a fuse or circuit breaker) will operate to “open the circuit” and prevent the continued flow of electrical energy to the faulted area. To minimize interruption of electrical service to other areas of the power system, the system is also designed so that the protective device closest to the short-circuit operates first to “clear the fault.”

For example, if a short-circuit occurs on a downstream branch circuit cable as shown in Figure 1 (below), the branch circuit breaker feeding that cable (Circuit Breaker A) should open first to isolate the fault, rather than the Main Breaker in the panel which would interrupt service to all branch circuits.

Figure 1:



If Circuit Breaker A failed to operate after a given time, then the Main Breaker would operate to open or “trip” the circuit, thus providing back-up protection. This time-sequence of operation is called “coordination of protective devices.” A protection-coordination study is done to determine the trip settings of each protective device in the power system so that maximum protection with minimum interruption is provided for all faults that may happen in the system.

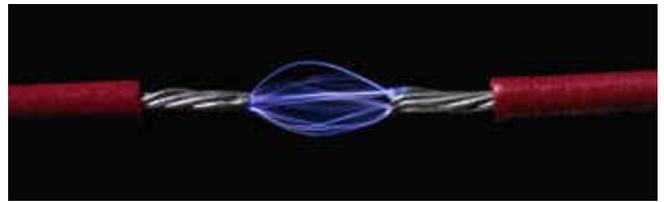
How is a Protection-Coordination Study Done?

A protection-coordination study is comprised of the following steps:

- Short-circuit study — As described above, an analysis of available fault currents in the power system is performed.
- Data collection — In addition to the data collected for the short-circuit study, additional information on the present settings and ratings of all protective devices is needed.
- Manufacturer's data — Each protective device has unique response characteristics, documented on manufacturer's "time-current curves" that are needed for the study.
- Computer analysis — While protection-coordination studies can be done by hand, it is much easier to use computer software available in the market. Many of the programs have a library of time-current curves for most devices found in power systems. Those not in the library can be input and stored for future use.

The computer program then allows the engineer to determine the optimum settings that will provide the best protection for the system. In some cases, coordination between two devices is not possible. Engineering judgment is then used to determine the most appropriate settings that will minimize equipment damage.

- Tabulate results — The settings and ratings of each protective device (circuit breakers, fuses, motor controllers, etc.) as determined by the analysis is put in a table for comparison with present field settings and ratings.
- Final report — A detailed report that describes the scope of the study, all assumptions, the origin of the data (including the time-current curves), the tabulated results, and recommendations for corrective action is published at the conclusion of the study.



How Often Should These Studies Be Done?

The initial short-circuit/protection coordination study should be done when a power system is first designed. However, for many systems, this is mistakenly the last time it is done. Over time, power systems usually undergo different changes that can impact the potential short-circuit currents or the coordination of protective devices.

The most common example is an increase in the energy available from the electric utility, the biggest source of current during a short-circuit. Since utility systems are continually growing and changing, the contribution of short-circuit current from the power company changes as well. For this reason alone, these studies should be done on a regular basis.

Expansion and growth of a facility will typically result in additional electrical equipment such as circuit breakers, motor control centers, transformers, and cables. New motor loads add to the available short-circuit current in a power system and must be considered to ensure that equipment ratings are not exceeded.

The frequency of performing short-circuit/protection coordination studies varies with each facility. If a change is constant, then regular analysis should be done in conjunction with planned modifications. For more static situations, the baseline studies should be re-evaluated every five to six years.

Summary

Preventive maintenance and testing alone will not ensure that an electric power system will operate reliably and safely when an abnormal condition occurs. Periodic engineering studies that calculate system short-circuit currents, evaluate protective equipment's suitability to handle those currents, and coordinate how those devices interact with each other are just as important, yet often overlooked. The combination of a comprehensive preventive maintenance program and sound engineering analysis is the answer.

About the Author

Matthew Glennon, assistant vice president with The Hartford Steam Boiler Inspection and Insurance Company's Loss Control unit, is a registered Professional Engineer in New Jersey with over 15 years of experience in electric power engineering and construction. He is a magna cum laude graduate of Manhattan College where he earned a Bachelor of Engineering degree in electrical engineering. In addition, he holds a Master of Engineering degree in electric power engineering from Rensselaer Polytechnic Institute (RPI) in Troy, N.Y., and an MBA in Finance from Rutgers University. He is an AEE Certified Power Quality Professional and a member of the Institute of Electrical and Electronics Engineers (IEEE), the National Fire Protection Association (NFPA) and the National Society of Professional Engineers (NSPE), as well as a Correspondent to the National Academy of Forensic Engineers (NAFE).