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HOW TO **PERFORM** an **ARC FLASH STUDY** in 12 STEPS

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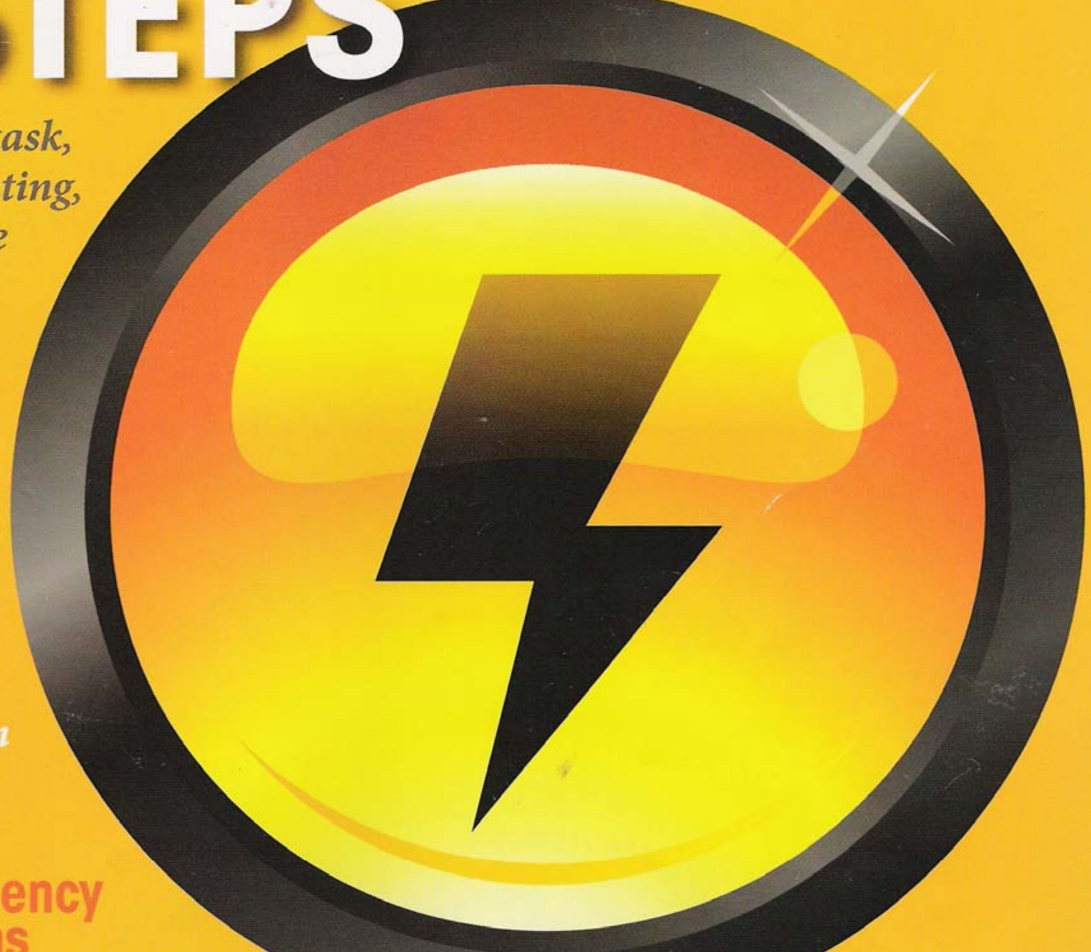

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How to Perform an **Arc-Flash Study** in **12 Steps**

BY JIM PHILLIPS, P.E.

YOU HAVE JUST BEEN ASSIGNED your first detailed arc flash study. After years of basing arc flash protection on the tables in NFPA 70E, *Standard for Electrical Safety in the Workplace*, you are about to take it to a whole new level. As you learn what's involved, you realize this is no small task. In fact, it could take weeks or months to complete, and the more you discover about these studies, the worse it seems to get.

Most detailed arc flash studies are based on IEEE 1584a-2004, *IEEE Guide for Performing Arc-Flash Hazard Calculations*, where you find new terms such as "gap distance," "X distance factor," "100% vs. 85% of arcing current," "arc in a box or air," and more. Your head begins to spin and panic sets in. Now what do you do?

Sound familiar? I have heard this story over and over again from people in my arc flash training class as they get ready to undertake their first arc flash study. As with any new task, it can be intimidating, but it doesn't have to be as difficult or confusing as it sounds.

In this issue, we begin a three-part series on how to conduct an arc flash study in twelve steps. Parts Two and Three will follow in successive issues.

The Detailed Arc Flash Study

NFPA 70E Section 130.3(B) requires that an arc flash hazard analysis "shall determine, and the employer shall document, the incident energy exposure of the worker (in calories per square centimeter). The incident energy exposure level shall be based on the working distance of the employee's face and chest areas from a prospective arc source for the specific task to be performed." It further states that "…flame-resistant (FR) clothing and personal protective equipment (PPE) shall be used by the employee based on the incident energy exposure associated with the specific task."

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THE FIRST STEP OF AN ARC FLASH STUDY IS TO OBTAIN DATA ABOUT THE ELECTRICAL SYSTEM. DEPENDING ON THE SYSTEM'S SIZE, AGE, AND COMPLEXITY, AS WELL AS WHAT DATA ARE AVAILABLE FROM PREVIOUS STUDIES, THIS STEP COULD REQUIRE A SIGNIFICANT AMOUNT OF MANPOWER. BEGIN BY REVIEWING EXISTING DATA, SUCH AS DRAWINGS, DOCUMENTS, AND SHORT CIRCUIT AND COORDINATION STUDIES.

Table 1: 12 Steps for Detailed Arc Flash Study

Step	Description
1	Data Collection Process
2	Develop Single Line Diagram
3	System Modeling
4	Arcing Short Circuit Calculations
5	Time-Current Curve Evaluation
6	Incident Energy Calculations
7	Flash Protection Boundary Calculations
8	Determine Personal Protective Equipment Requirements
9	Arc Flash Warning Labels
10	Develop the Report and Recommendations
11	Integrate the Study into the Electrical Safety Program
12	Training

NFPA 70E also requires determining the flash protection boundary, which is the distance from a potential arc source where the incident energy falls to a value of 1.2 cal/cm^2. This value is considered to be the point at which the onset of a second-degree burn occurs. Live work performed outside of the flash protection boundary does not require PPE, although the risk of some injury still exists.

The concept of these requirements is simple. At each location, the arc flash study is used to determine:

- The incident energy exposure for a worker's chest and face if an arc flash occurs.
- The level of PPE a worker must wear based on the possible incident energy exposure.
- The flash protection boundary.

Although NFPA 70E provides more generalized hazard risk tables as a simplified alternative for PPE selection, a detailed arc flash study requires performing calculations to estimate the magnitude of incident energy exposure. These calculations are based on specific details of the equipment, including its location, available short circuit current, device clearing time, grounding, arc gap distance, equipment type, and many other factors. The results are used to determine the flash protection boundary and required level of PPE.

This information, as well as data regarding electric shock protection and approach limits, is included on the detailed arc flash warning label placed on the equipment under study (see Figure 1). Before conducting live work, a qualified worker can refer to the label and obtain all the data necessary for the shock hazard and flash hazard analysis NFPA 70E requires.

Although an arc flash study can appear to be an overwhelming project, it can be more easily managed when broken down into the 12 basic steps (see Table 1).

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

2' - 0"	Flash Hazard Boundary
2.3	cal/cm^2 Flash Hazard at 18 Inches
#1	PPE Level
	FR shirt and FR pants or FR coverall
0.48	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
1' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 1"	Prohibited Approach - Class 00 Voltage Gloves

Equipment Name: PNL-3 (Fed by: BL-2)

Figure 1. Detailed arc flash label.

Step 1: Data Collection

The first step of an arc flash study is to obtain data about the electrical system. Depending on the system's size, age, and complexity, as well as what data are available from previous studies, this step could require a significant amount of manpower.

Begin by reviewing existing data, such as drawings, documents, and short circuit and coordination studies. After you've reviewed the data, you need to conduct a field survey to validate it and document any changes that have occurred and to obtain missing data.

Data requirements can be broken down into the following categories:

- Source/utility company
- Impedance data
- Overcurrent device data
- Arc flash study parameters

Since the incident energy depends on the magnitude of short circuit current, you must obtain the electric utility company available short circuit current (see Table 2). Many utilities provide the maximum worst-case short circuit current, which can be significantly higher than actual conditions, so caution should be used when requesting this information.

Normally, the largest short circuit current is considered the worst case, but lower short circuit cur-

Table 2: Source/Utility Company Data

Short Circuit Current
- Available Short Circuit Current - Normal
- Contingency Conditions
  - Minimum Short Circuit Current
  - Line / Transformer Out of Service
  - Maximum Short Circuit Current
- Voltage
- X/R Ratio

Protective Device Data
- Fuses
  - Manufacturer
  - Type
  - Size / Rating
  - Speed - Standard or Slow
- Relays
  - Type
  - Manufacturer
  - Settings
  - Current Transformer Ratios
  - Circuit Breaker Opening Time

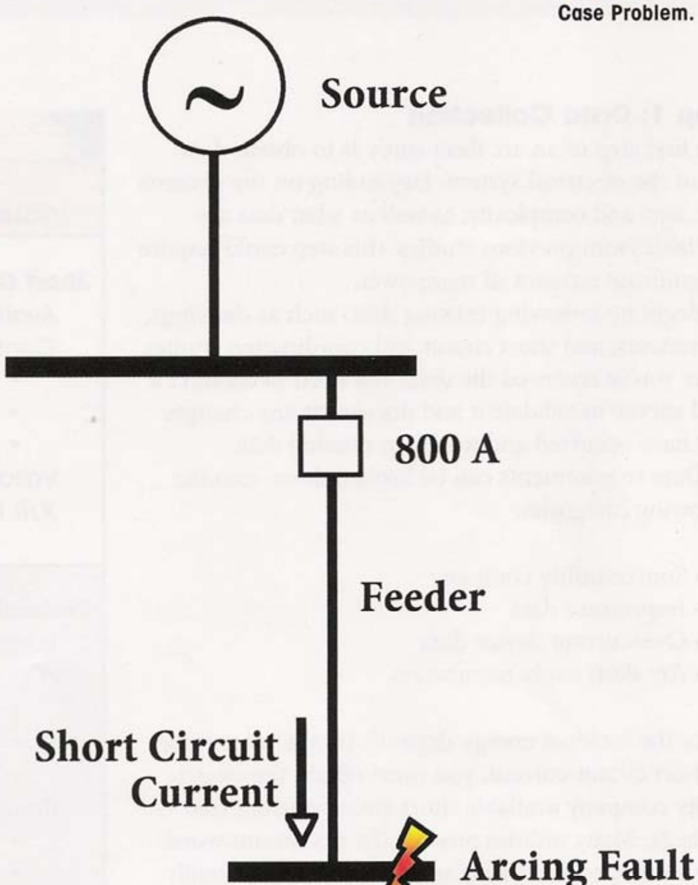
Table 3: Impedance Data

Transformer Data
- Nominal kVA Rating
- Primary and Seconary Voltage
- Percent Impedance
- Grounding Configuration
  - Solidly Grounded
  - Impedance Grounded
  - Ungrounded

Conductor Data
- Conductor Size—kCM /AWG
- Conductor Type
  - Copper
  - Aluminum
- Duct / Conduit Material
  - Steel, Aluminum, PVC, etc.
- Number of Conductors per Phase
- Length of Conductor Run
- Insulation Type
  - THHN, XHHW, etc.

Motor Data
- Horsepower Rating
- Voltage Rating
- Locked Rotor Code Letter (if available)

Figure 2. Case Problem.



rents can result in a higher incident energy exposure. This is because, although larger short circuit currents produce higher incident energy per cycle, they are typically of limited duration since overcurrent devices will probably operate in the instantaneous region. Lower-magnitude short circuit currents produce less incident energy per cycle, but the overcurrent device could take longer to operate, allowing a greater total incident energy exposure.

When requesting data from the utility company, it is important to emphasize that it will be used for an arc flash study. In addition to normal and worst-case maximum conditions, the utility should provide data based on minimum short circuit current conditions, as when a substation transformer or transmission line is taken out of service. During scheduled maintenance, the utility often will remove a major substation transformer or transmission line from service by opening circuit breakers and switches. This "reconfiguration" can greatly reduce the amount of short circuit current that could flow to a given area and affect the operating time of overcurrent devices.

Impedance Data

Transformer and conductor impedance also affects the available short circuit current at each location. Motor data can be critical, since running motors can produce additional short circuit current. Table 3 lists the typical data required to determine circuit impedances. Most commercially available arc flash computer programs contain large databases of impedances that help simplify the calculation process.

Overcurrent Device Data

The duration of an arc flash depends on the clearing time of the upstream overcurrent device. Time-current curves are used to determine the clearing time based on the overcurrent device's specific trip characteristics and settings. They can be obtained from the overcurrent device manufacturer or from the libraries of curves that most arc flash computer programs contain. You must acquire the overcurrent device data listed in Table 4 to obtain a device's correct time-current curve.

Arc Flash Data

You'll need additional information about the type of equipment under study, as well as the system grounding configuration. The magnitude of the incident energy depends on the equipment type: Is it a panel, motor control center, or switchgear? The grounding configuration—that is, effectively grounded or not effectively grounded—also affects the magnitude of incident energy (see Table 5).

Because it is often difficult or impossible to obtain all the data required, assumptions are frequently made, and "what if" calculations are developed to determine whether the missing data significantly affects the results. If you cannot obtain a conductor length for a particular circuit, for example, you can perform calculations based on several lengths to evaluate their impact on the study results. If each case produces similar results, you should use the worst-case assumption, and further efforts to obtain this data are probably not necessary. If one of the assumed lengths produces results that are quite different than the others, however, further evaluation is required.

Will Older Equipment Still Work?

Testing overcurrent devices is not technically part of the arc flash study, but it is a very good idea. Time-current curves indicate how long a device takes to operate and clear the fault, assuming it is in good working condition. If older equipment with questionable reliability or unknown tripping characteristics is part of the study, a conservative approach is to ignore its operation completely and rely on the clearing time of the next overcurrent device upstream. Using the next device is likely to yield a greater incident energy, leading to safer conclusions.

Step 2: Develop Single-Line Diagram

An arc flash study requires a good single-line diagram to document and organize the data and to evaluate different operating scenarios. The diagram should contain details such as protective device data, conductor sizes, and transformer data. Figure 2 illustrates a small single-line diagram used for a case problem that we will analyze later.

Step 3: System Modeling

Most arc flash studies are conducted with the help of elaborate commercially available computer programs that perform calculations based on methods defined in IEEE 1584a and integrate the single-line development, short circuit calculation impedances, time-current curves, and arc flash calculations. The results are then printed on detailed warning labels.

Table 4: Overcurrent Device Data

Low Voltage Circuit Breakers
Manufacturer / Model
Trip / Sensor Rating
Available Settings
Exisitng Settings
Fuses
Manufacturer / Model
Current Rating
Overcurrent Relays
Manufacturer / Model
Available Settings
Existing Settings
Current Transformer Ratio
Circuit Breaker Opening Time

Table 5: Arc Flash Data

Grounding Configuration
Grounded / Ungrounded
Equipment Type
Switchboard
Switchgear
Motor Control Center
Panel
Other

Since power systems can have various operating modes in addition to the normal base case condition, "what if" scenarios should also be created to determine whether special conditions exist that might produce results worse than the base case. Modifying alternative scenarios is relatively easy with most programs and usually requires only minor data adjustments to the original base case.

It is good to run as many "what if" scenarios as you can think of to uncover trouble spots. If the "what if" scenarios do not produce results worse than the base case, no further study is required. If an alternate scenario produces worse results, however, an additional evaluation is required to determine if that scenario is realistic.

Typical "what if" scenarios include different system configurations such as transformers removed from service, generators operating in parallel with the utility or operating separately, emergency operating conditions, maintenance conditions, ties opened or closed, and motor loads or large motors on or off.

In our next issue, we'll tackle Part Two of our three-part series on performing an arc flash study.

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