Best Practice #66
Performance of Arc Flash Calculations and Labeling

Facility: DOE Complex

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Brief Description of Best Practice: These best practices were developed from a working session of subject matter experts within the DOE and DOE contractors.

Why the best practice was used: The DOE/EFCOG Electrical Safety Subgroup developed four distinct project areas for improving electrical safety at its 2008 Electrical Safety Workshop in Denver Colorado. The task team for Workshop #1 “Arc Flash Calculations,” committed to submit a recommended best practice to the EFCOG Integrated Safety Management Working Group for posting on the EFCOG Best Practices website addressing improvements in arc flash calculations and labeling methodology to ensure more consistent implementation throughout the DOE complex.

What are the benefits of the best practice: Consistent and accurate calculations of arc flash energy and PPE requirements to ensure worker safety when exposed to energized electrical conductors.

What problems/issues were associated with the best practice: The DOE/EFCOG Electrical Safety Subgroup identified a need for a more consistent approach to developing arc flash calculations and labeling strategies for arc flash.

How the success of the Best Practice was measured: The subject Best Practice has been reviewed by the EFCOG Electrical Safety Working Group and several sites are in the process of integrating its principles into their work processes for evaluation.

Description of process experience using the Best Practice: There is no operating experience with the subject Best Practice at this time.

BEST PRACTICES FOR PERFORMANCE OF ARC FLASH HAZARD ANALYSIS, CALCULATIONS AND FIELD LABELING

1 INTRODUCTION

The most effective means to protect workers from an arc flash hazard is to de-energize the circuit in accordance with the requirements in NFPA 70E before attempting to work on or near exposed conductors. However, there are some tasks where work must be performed on energized circuits, such as when troubleshooting and testing circuits. NFPA 70E recognizes this exception and requires that an electrical hazard analysis be conducted if work is to be performed on or near energized conductors. The electrical hazard analysis includes a shock hazard analysis to determine the voltages to which personnel will be exposed and an arc flash hazard analysis to determine the arc flash boundary and personal protective equipment that workers inside this boundary shall use.

The arc flash hazard analysis must predict incident energy levels to which a worker could be exposed during an arc flash event so that clothing and protective equipment can be selected for the task. This arc flash analysis is not a simple task and may require an extensive understanding of electrical systems and engineering calculation methodologies. This paper discusses some of the current methods and best practices for conducting this analysis in an attempt to better quantify the hazard and protect the worker. This information was developed jointly in a working meeting of contractor and Department of Energy personnel at the 2008 EFCOG/DOE Electrical Safety Workshop in Golden Colorado.

2.0 SELECTING A METHOD FOR CONDUCTING AN ARC FLASH ANALYSIS

2.1 NFPA 70E, 130.3, states that a flash hazard analysis shall be done in order to protect personnel from injury. This analysis must provide the arc flash protection boundary and provide a basis for the PPE that workers inside the boundary will use in order to protect them.

Four methods are provided in NFPA 70E for conducting this analysis:

1. **Detailed flash hazard analysis using the Lee equations,**
2. **Detailed analysis using the IEEE 1584 equations,**
3. **Hazard risk category/PPE matrix table approach, and the**
4. **Simplified two category approach**

Studies that compare the four methods indicate that the results of each can vary widely and consequently the selection of PPE can be different depending on the method used. Each site should carefully study and understand the basis for each method to ensure that PPE selection is adequate for the hazard.

2.2 **The Table approach** is used as an alternative to the detailed flash hazard analysis as stated in NFPA 70E. The Table approach must be used with caution and only within the bounds of the assumptions for “normal” short circuit current and protective device clearing times. NFPA 70E states that the table method can be used only if the conditions, including the specific task to be accomplished, are within the assumed values for short circuit capacity and fault clearing times.

The Table approach is generally a conservative, simple, and relatively inexpensive analysis but can often result in “overprotection”. When a worker is overly encumbered with PPE, productivity and morale can be impacted. Too much PPE may also result in other hazards to workers such as heat stress conditions, limited worker mobility and dexterity, and vision. Likewise, using the Table approach without assessing applicability of footnotes may result in "underprotection" of the worker that could result in an injury if an electrical arc occurred.

2.3 **The simplified two-category approach** is similar to the Table approach above and is intended to be used in facilities with large and diverse electrical systems. This method is also used as an alternative to the detailed flash hazard analysis. The clothing systems listed in the two category approach must be used with other PPE appropriate for the hazard and risk associated with the task.

2.4 **The detailed flash hazard analysis** is the most precise method since it allows the analyst and worker to customize PPE based on specific conditions.. This method uses equations to accurately calculate the arc flash protection boundary and the incident energy level exposure to the worker. In order to use this methodology, a short circuit study and protective device coordination study must be completed to provide the information for these equations. Since the two detailed flash hazard analysis methods described in Annex D of NFPA 70E have proven to be effective in providing protection from arc flash injury, EFCOG recommends using either to determine the Arc Flash Protection Boundary and incident energy at the working distance from an arc flash source.

The available bolted fault current at the work location is required when using the NFPA 70E detailed flash hazard method. Two calculations should be made when using this method, one using the maximum "bolted fault" current and a second one using the lowest fault level at which the arc is self sustaining. For 480 volt systems, the industry accepted level for a self sustaining fault is 38 percent of the available bolted fault current. The upstream protective device clearing time should also be determined for the maximum short circuit current and the minimum fault level. The appropriate formula to select from NFPA 70E should be selected based on either "open air" or "enclosed in a box".

The detailed flash hazard analysis using IEEE 1584 is based on equations developed with statistical data from actual arc flash testing performed in laboratories. Many of the commercially available power analysis software packages use the IEEE 1584 model to calculate the arc flash boundary and incident energy levels. This method is generally accepted by industry throughout as the most precise for conducting an electrical flash hazard analysis and is the most widely used among industry. The inclusion of many variables of this method make it the preferred choice for Arc-Flash evaluations, but at the same time requires either a complex spreadsheet or computer program to be used efficiently.

Actual data must be collected for the applicable portions of the electrical distribution system where work is expected to be performed. Safety of personnel is directly related to the precision of the data collection. Inaccuracies or non-conservative assumptions using this method could result in selecting PPE that is underrated for the potential arc flash energy levels. Gathering the data for this analysis is the most critical part of the study.

2.5 The IEEE 1584 arc flash calculation includes nine steps:

Step 1: Collect the system and installation data

Step 2: Determine the system modes of operation

Step 3: Determine the bolted fault currents

Step 4: Determine the arc fault currents

Step 5: Find the protective device characteristics and the duration of the arcs

Step 6: Document system voltages and classes of equipment

Step 7: Select the working distances

Step 8: Determine the incident energy for all equipment

Step 9: Determine the flash-protection boundary for all equipment.

Commercially available software programs typically use this nine-step procedure. However, without proper training, incorrect assumptions for data collection can be made. Incorrect data in the software program could yield inaccurate results. Some considerations for data collection for a detailed arc flash analysis are provided later in this paper.

Some facilities and companies have decided to reduce the overall effort when conducting a detailed arc flash hazard analysis by making accurate generalizations. Using a generalization method, the analysis can be performed without the need to model every location. Using a generalization method, a detailed analysis can be performed for major equipment, generally down to the MCC level and then the analysis is extended to locations fed from the MCC by using spreadsheets to specify maximum cable lengths that will cause the arc flash category to increase at the end of the feeder. One such generalization method that has been used is described in an IEEE paper titled “Arc Flash Hazard Calculations: Myths, Facts, and Solutions”.

Limited guidance is currently provided in NFPA 70E and IEEE 1584 regarding arc flash energy levels and calculation methodology for DC and single phase voltage systems. IEEE 1584 paragraph 1.2 states that "Single-phase ac systems and dc systems are not included in this guide”. Until the IEEE / NFPA Collaboration on Arc Flash Phenomena Research Project has completed testing and provided guidance on DC and single phase systems, guidance in the pending revision (Chapter 10) to the DOE Electrical Safety Handbook should be used.

3.0 DATA COLLECTION FOR A DETAILED ARC FLASH HAZARD ANALYSIS CALCULATION

3.1 In order to provide accurate calculations for incident energy, the system data should be as accurate as possible. Single line diagrams, coordination curves, maintenance procedures and engineering databases should be reviewed to collect input data for the calculation. System cables should be modeled with accurate lengths. For existing equipment, this distance cannot be measured, but must be estimated. The more accurately this distance is estimated, the more accurately the equipment can be labeled to protect facility personnel. Transformer impedances should be modeled according to actual nameplate impedance values. While design impedances may differ only slightly, the smallest variation of available fault current may significantly affect the magnitude of the incident energy calculated for a given location. Contributions from utility substations may fluctuate during various switching scenarios or maintenance procedures. A range of possible contributions should be obtained and evaluated to facilitate the determination of the worst case scenario.

3.2 Perform field walk-downs to validate drawings and assess equipment condition. Drawings may not always be available or may not reflect actual field conditions if equipment is not maintained under a configuration management system. Fuse sizes, motor loads, breaker settings found in the field may be different than that shown on drawings and will affect arc flash incident energy levels. When differences are found, engineering should be contacted to resolve and drawings should be updated as appropriate. It is very important to maintain as-built drawings for configuration management.

3.3 Use PPE during field walk-downs when opening doors and covers to electrical enclosures that cannot be de-energized. PPE selection for arc flash may be based guidelines in an IEEE paper “Learnings from Arc Flash Hazard Assessments” when a site’s electrical system is first being assessed.

3.3 Take photos of switchgear, MCC’s, etc. during field walk-downs. Take photos of fuse sizes, breaker settings, equipment, and transformer nameplate data to facilitate and expedite field survey and limit equipment downtime.

3.4 Request and obtain accurate utility data for both maximum and minimum fault contributions from the utility. Be prepared to explain why the minimum and maximum values are needed. If the utility is uncooperative, use engineering judgment to determine the minimum and maximum values. These two values will form the basis of at least two scenarios for the calculations. Contributions from utility substations may fluctuate during various switching scenarios or maintenance procedures. A range of possible contributions (maximum and minimum value) should be obtained and evaluated carefully to determine a worst case operating scenario.

3.5 The foundation for a proper arc-flash study includes having access to accurate information from the utility. The actual available short circuit current and the parameters or settings for the final utility over-current protective device should be provided by the utility. It should be noted that a conservative fault current value (which historically has been provided by utilities) may not provide the "worst case" arc-flash condition. In many cases, calculations of arc flash hazard based on conservatively high available fault current values can underestimate the actual flash hazard at circuit locations. Therefore, having the actual available fault current is necessary in order to ensure appropriate PPE. Accurate over-current protective device parameters are also necessary to establish accurate arc-flash calculations to ensure appropriate PPE.

3.6 Determine normal electrical system operating configurations. The worst case for arc flash energy may not be the current operating configuration. All reasonable configurations should be evaluated during the analysis. Some examples are large motor loads (both running and off), on-site generation used in sole-source and parallel with the utility configurations, and tie circuit breakers in every allowable condition. The number of scenarios required increases rapidly with the system’s greater complexity.

3.7 Determine if the electrical system is grounded. System grounding can cause incident energy calculation differences when using the IEEE 1584 methodology. Ensure grounding is addressed if using a software model. Errors in the grounding entry can cause a transition from one hazard risk category to another.

4.0 CALCULATION METHODS AND BEST PRACTICES

4.1 Procure and use a software model to facilitate calculation of the arc flash energies and boundaries. Many commercial software models are available that provide accurate calculation of arc flash energy and boundaries such as SKM Power, ETAP, ArcPro, Bussman, and EasyPower. The software model will allow the user to examine all operating scenarios as well as proposed changes to the system that may result in an optimum design. Also, once the model is built, it is easy to update as equipment is added or removed from service.

Arc flash calculation programs and calculators are readily available to the public on some web sites. However, use of these sites should be discouraged unless the user can verify and validate the accuracy and pedigree of the calculator.

4.2 Modeling, however, requires a substantial amount of manpower to gather data, input to program, and to evaluate the model. This process can improve overall configuration control through this extensive review and revision of baseline technical documents. Manpower and expense are also associated with the maintenance of the model and the software license agreements.

4.3 Ensure the latest revision of the software model is used. Validate the software model through hand calculations or other approved methodologies. Note that some commercially available models, such as ETAP, can be purchased with a commercial license that provides verified and validated libraries and ISO 9001 certification. A license is also available with verification and validation certification for nuclear facilities. Purchase maintenance agreement otherwise it will be costly if you do not maintain with current revision.

4.4 Be sure that the software package selects the correct clearing time for incident energy when electrical system mis-coordination is present. In some cases, the fault clearing device may not be the first protective device up stream from the fault if system not coordinated. It can be several buses remote from the faulted bus.

4.5 Do not assume that the higher bolted fault currents will result in the worst case arc flash energy levels. It can be confusing when someone trained to determine available bolted fault currents becomes responsible for determining arc flash hazard levels. If the person is trained only to calculate the available fault currents to determine interrupting rating requirements, rounding up the available fault currents can be misconstrued as a conservative procedure. If the arc flash hazard calculations are only performed with the highest possible available fault current, the resulting hazard calculations could be too low. Therefore, a conservative assumption for an interrupting rating calculation could be a dangerous assumption for an arc flash hazard analysis.

4.6 Select and use the IEEE 1584 methodology when using a software model. The IEEE 1584 standard was developed using test data compiled from several laboratories. The equations were developed from a statistical analysis of data points and represent the most comprehensive set of equations to date for calculating incident energy and flash protection boundaries. Future testing and analysis may result in revisions to the present 1584 method, but at present, it is the most state-of-art method for arc flash hazard analysis and should be used.

4.7 Perform IEEE 1584 calculations at both 100% and 85% arcing fault current values as recommended in this standard. Most software models perform this function automatically to determine the arc flash energy levels. At voltages below 1000V, this standard recommends that the incident energy be calculated at both these values since under some conditions, the clearing device at 100% of the arcing fault may be a different device than the one that opens at 85%. In short, at least four calculations are required. The first two involve the highest available fault current and the lowest available fault current. These are called scenarios. The second two calculations are then performed with 0.85 times the bolted fault current of each scenario. The most hazardous values are used for future steps, ensuring that such conditions are identified.

4.8 Document all assumptions in the arc flash hazard analysis report. Some typical assumptions may include the following if accurate information from drawings and field walk-downs are not achievable: No motor load, cable sizes, types of conductor (Copper or Aluminum), breaker trip settings, fuse sizes and type, etc.

4.9 Use tolerances in model where accurate data is not known. Tolerances should be considered for the following type variables where accurate field data may not be available:

a. Cable size and length- At a minimum use typical cable sizes and look at layout drawings to get estimated lengths. When energy is near a change in clothing requirement, it can be valuable to get more accurate information.

b. Transformer impedance- Use actual nameplate values if possible. Typical impedance values from software can vary significant from nameplate value.

c. Trip time- If trip times for installed breakers or fuses cannot be determined, a 2 second maximum arcing time should be used.

4.10 Use realistic motor loads contributions in model. IEEE recommends that the study model include all motor loads that contribute energy to short circuits. Most accurate model includes all motors, and motor loads < 250 Hp can be lumped together to reduce effort. Some software packages provide the fault current used in the calculation for the entire duration of the fault. Others provide for removal of motor contribution after a fixed time (# cycles). The duration of the motor contribution can significantly affect the estimated incident energy. Generators are similar to a motor as a source of fault energy and programs can overestimate the duration of a fault current contributed by a generator. Decay depends on parameters of the generator. The manufacturer should be contacted.

4.11 Device trip settings may have a significant impact on arc flash hazard levels. Overcurrent protective device coordination studies should be done in conjunction with arc flash analysis studies to attempt to reduce and optimize energy levels. Many of the more advanced software packages integrate both protective device coordination and arc flash energy calculation so the impacts of different device settings can be studied for optimization. However, remember that coordination of power system circuit protection devices for selectivity does not necessarily reduce arc flash hazards.

4.12 Use realistic working distances when calculating energy levels. In some cases, the default working distances in IEEE 1584 or other standards may not be correct for the specific application or work task. Identify working distance on arc flash label so worker can re-assess hazard if he will be working at a closer distance than calculated.

4.13 The secondary of transformers in load centers can present arc flash hazards too dangerous to allow energized work under any circumstances, (i.e. exceeding Hazard Risk Category 4). These locations may require careful engineering and selection of components to reduce potential incident energy to a manageable level.

4.14 Formalize ownership of model and maintain and control for future changes to electrical system. A single responsible facility engineer should be assigned to control the model and any changes to it. Only one master copy of the model should be used. Additional copies could be made for engineering design studies for new designs or modifications. The final changes to the master, however, should be controlled via an engineering change process.

4.15 Ensure that changes in protective device settings to achieve selective coordination do not impact arc flash hazard levels. If protective device settings must be changed or corrected as a result of blackouts or loss of coordination, the engineer should remember to review the impact of the new settings on arc flash energy levels.

5.0 IMPLEMENTATION OF ARC FLASH HAZARD RESULTS

5.1 Establish a uniform field labeling methodology. Standardize label information and labeling strategy for the site or facility. Provide specific guidance on what equipment and how equipment should be labeled. Use color coding for labels to distinguish levels of hazards. Consider a red colored label to indicate "Arc Flash Exceeds 40 Calories- Do not work energized" when the arc flash energy exceeds 40 calories. ANSI Z535.4-1998, Product Safety Signs, and Labels, FPN No. 2. provides guidelines for the design of safety signs and labels for application to products. (See Attachment 1 for some typical arc flash labels used in industry.)

5.2 Many of the commercial software packages will automatically generate equipment and system specific arc flash labels and associated Energized Work Permits. This feature can result in a time savings and enhance accuracy of labeling information since the possibility of a transcription error is minimized.

5.3 Train personnel including operators and subcontractors to use the label to select PPE. Operators may not understand label terminology since they may not have an electrical background. Subcontractors need to be trained to understand the specific label for your facility since a label standard does not exist for industry.

5.4 Provide calculation results to work control to use when developing work packages. Also ensure that work control is on distribution for calculation revisions so latest results are always used.

5.5 Perform pre-job briefings to cover arc flash PPE requirements and arc flash boundaries. Emphasize that boundaries must be controlled during work to ensure that unqualified or unprotected personnel do not enter.

6.0 PERSONNEL QUALIFICATIONS FOR PERFORMING ARC FLASH HAZARD ANAYSIS

6.1 Arc flash calculations should be performed by qualified personnel under engineering supervision. An engineering background with an emphasis on electrical power systems is recommended for personnel when developing hand calculations or software models since the model may require manipulation of protective device settings to lower arc flash energy levels.

6.2 Require peer reviews of calculations by qualified personnel to verify data input. The verifier assures the technical accuracy of the document by performing administrative and mathematical checks as appropriate. The verifier should consider reviewing items such as, but not limited to the following:

a. Are inputs correctly selected and identified?

b. Are the assumptions made in the performance of the model adequately described and reasonable?

c. Is the design output reasonable compared to the inputs?

d. Was a review conducted to confirm that there are no interferences with other ongoing or planned modifications?

e. Have engineering judgments been identified, technically justified, and supported?

f. Have design optimization strategies been considered?

6.3 Provide formalized arc flash training on the specific software model being used by the facility for performing calculations. Many of the software programs require a steep learning curve and demand a significant amount of time to learn how to create the model and how to optimize through the data input fields. All of the major software companies offer arc flash training and application training on their packages.

Manage and control the model under a configuration control system

a. Designate a single point of contact to control the software model. This person may be the electrical system design authority engineer for the facility.

b. Ensure a process exists to ensure that future utility and system modifications are incorporated into model and field labeling changes as appropriate.

c. Ensure software updates are incorporated into model.

7.0 TECHNOLOGIES AND DESIGN FOR REDUCING THE ARC FLASH HAZARD

7.1 Consider the following as a means for reducing and optimizing arc flash energy levels:

7.2 Specify and use arc resistant switchgear

Many new designs are emerging from manufacturers. Arc resistant switchgear is tested to withstand an internal arcing fault and ensure that a person operating the switch or breaker is not exposed to the arc hazard.

7.3 Use Ground Fault Detection

Ground fault detection trips the circuit breaker during the early stages of fault development and prior to "bolted fault" conditions.

7.4 Specify Finger-Safe Components

Use finger-safe electrical components in panels and control cabinets. Finger-safe components may reduce the chance that an arcing fault will occur by preventing accidental contact with tools or other conductive materials.

7.5 Require an Insulated Bus

Use of insulated bus for equipment such as motor control centers, switchboards, switchgear, etc. This will reduce the chance that an arc fault may occur. In addition, it increases the probability that an arc fault will self-extinguish.

7.6 Size Protective Devices Low as Possible

Size the current-limiting branch circuit overcurrent protective devices as low as possible. Typically, the lower the ampere rating, the greater the degree of current-limitation provided by the device.

7.8 Reduce Pickup Settings

In some cases, the arcing fault current magnitude may not be large enough to operate the overcurrent protective device in its short delay or instantaneous trip time. If possible, the short delay or instantaneous pickup should be reduced to allow for more sensitive sensing of the calculated arcing current that flows through the protective device.

7.9 Reduce Time Delay Settings

If a protective device operates in its long time region, the time curve is normally an inverse type that has increased time delay as fault current decreases.

7.10 Enable Instantaneous Functions on Overcurrent Devices

This design change may be easy and low cost; however there is a loss of coordination with any downstream overcurrent protective device for faults above the pickup setting of the adjusted device.

7.11 Implement a Zone Interlocking Protection Scheme

This feature provides fast trip time for faults between the main and feeder circuit breakers. In some cases this feature may already exist in the switchgear but may not be implemented. Two or more breakers connected in series are interconnected with a twisted pair of communication wires between their trip units.

7.12 Change to a Faster Fuse Curve Shape

There is usually a range of current where the clearing time of an expulsion fuse is faster than the current limiting fuse when comparing the same fuse rating in amps. When the calculated arcing current appears in this range, changing from a current limiting fuse to an expulsion fuse will reduce the incident energy.

7.13 Reduce the Fault Current

Reduce the amount of energy available during a fault by controlling or limiting the amount of fault current by introducing impedance between the source and equipment. Two common means of limiting current are current limiting reactors and high resistance grounding. Using the smallest possible transformer or using multiple transformer circuits rather than a single large size may also contribute to fault current reduction.

7.14 Reduce the Fuse Ampere Rating

There are cases where the fuse is oversized for the circuit loading and a reduction in fuse ampere rating will result in faster fault clearing time.

7.15 Change to a Current Limiting Fuse

Current limiting fuses will generally reduce arc flash incident energy levels at downstream locations. However, ensure that when using current limiting fuses that the arcing fault current is great enough to cause operation in the current limiting range of the fuse.

7.16 Add a Current Limiting Fuse

Adding a fuse to an existing power system can decrease fault clearing time. Existing non-fused primary disconnect switches for transformers are locations where this retrofit may apply. Each application needs to be studied to determine the cost and benefit of the retrofit.

8.0 WORK METHODS FOR REDUCING THE ARC FLASH HAZARD

The following work methods should be considered as part of arc flash hazard analysis as a means for reducing arc flash energy levels:

8.1 Use of a Temporary “Faster” Trip Time When Work Is Being Performed

A procedure can include the reduction of protective device tripping time. The reduced time settings must be returned to the normal time settings after the work is completed. This can be easily accomplished with relays that have “group settings” where one of the groups is not currently used. A lockable switch could be used to enable the faster setting. For applications where the existing relay does not have a group setting available, it is possible to retrofit to a lockable switch that controls a relay with a faster trip setting. A separate contact in the lockable switch could be used to monitor the switch condition and alarm if the switch is not returned to normal after the work task is completed. A modified label or two labels may be required to indicate the two operating modes using the temporary “faster” trip time.

8.2 Change Work Location

In many cases, the incident energy on the primary side of a transformer is much lower than the incident energy on the secondary side. This occurs for two reasons: An arcing fault on the low-voltage side of a transformer is generally a higher magnitude than an arcing fault on the high-voltage side. The high-voltage protective device usually is a fuse or a relay with an instantaneous trip that clears a primary side fault in a few cycles. For example, the application of temporary grounds on primary side of transformer instead of load side can take advantage of the lower arc-flash hazard level that typically occurs on the primary side.

8.3 Work at a Greater Distance

Racking and switching of a circuit breaker may be the highest exposure to an arc flash that will occur in industrial facilities. In some cases, working distance can be increased with the use of live line tools or motorized devices. The worker can remotely control a motorized racking or switching unit so he/she does not have to stand directly in front of the electrical equipment. Racking tools can be extended in length to increase working distance. In other cases, the working distance may be greater because of the task. For example, the depth of a circuit breaker can be added to the worker distance during the task of racking the breaker in or out of a cell.

8.4 Eliminating Switching Conditions that may increase exposure

Arc flash exposure may be reduced through the sequence in switching. During job planning, the sequence of switching should be reviewed to minimize the number of personnel exposures.

8.5 Use Infrared Viewing Ports

The installation of infrared viewing ports can eliminate the need for removing equipment covers to scan equipment and minimize the risk of electrocution during the actual scanning process after the electrical conductors have been exposed.

8.6 Use Voltage Indicating Lights

Use LED lights to indicate presence of voltage for cubicles or enclosures. The lights are powered from line voltage of the equipment. The voltage indicating lights provide a pre-verification of electrical isolation.

9.0 REFERENCES

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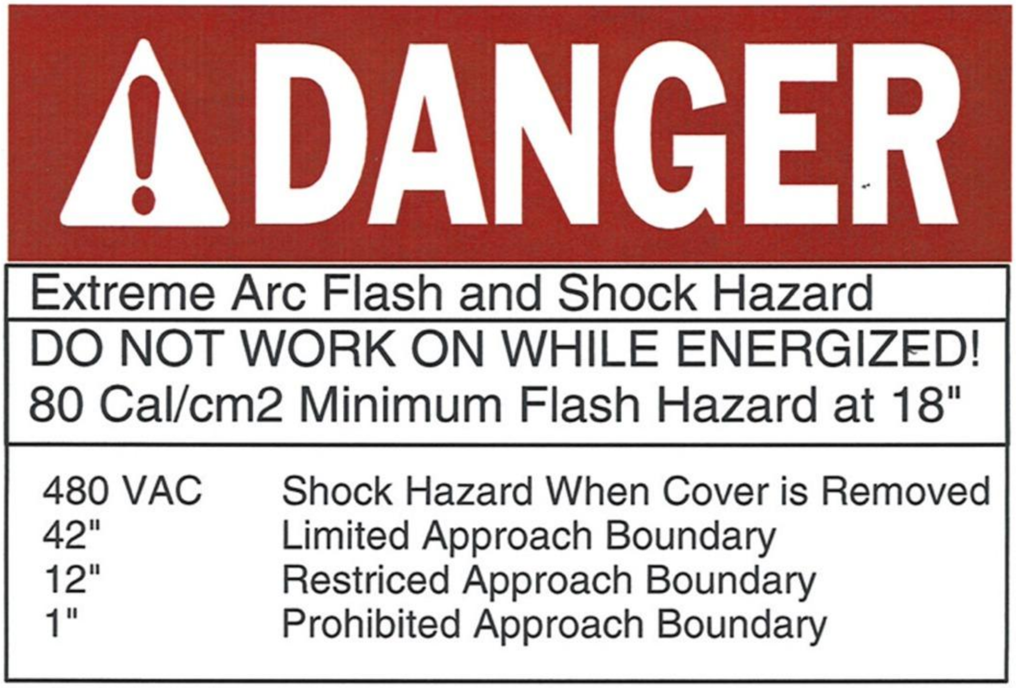
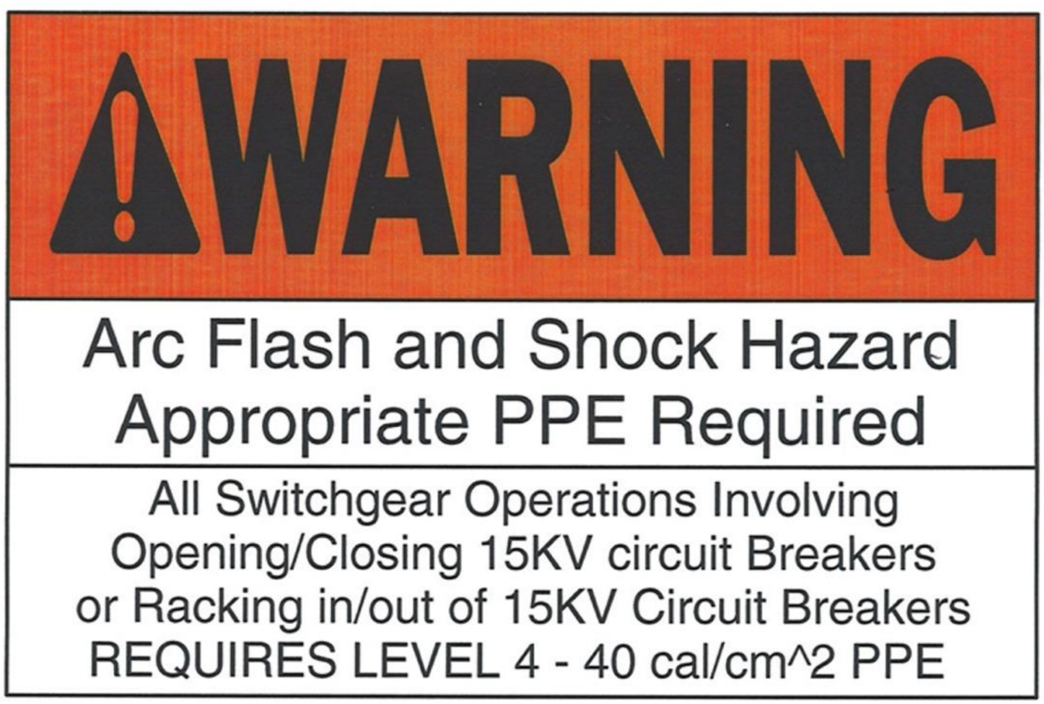
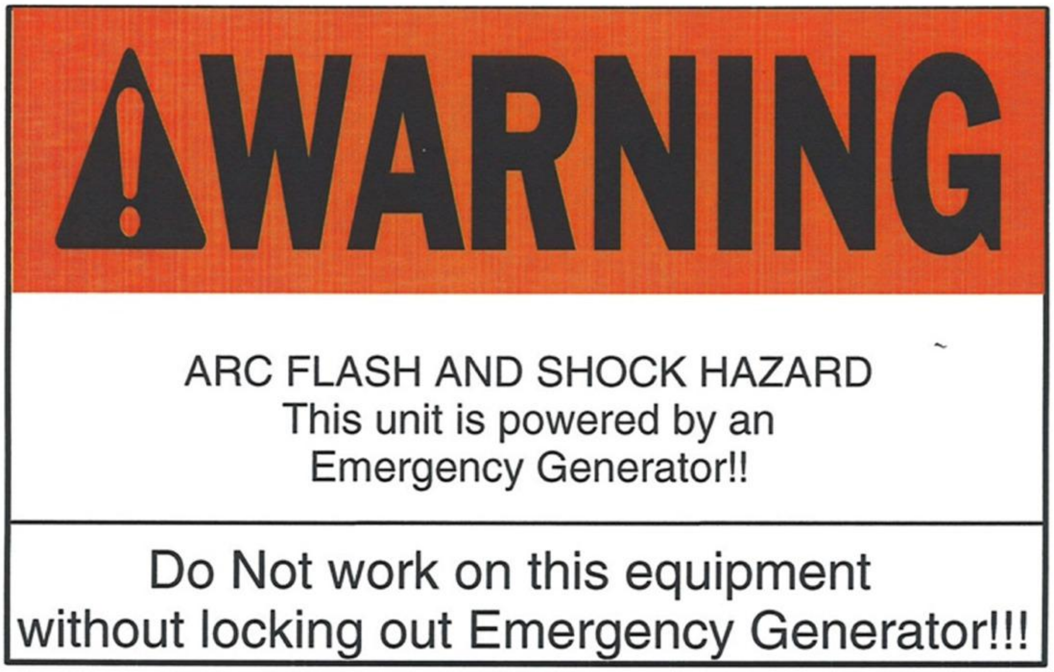
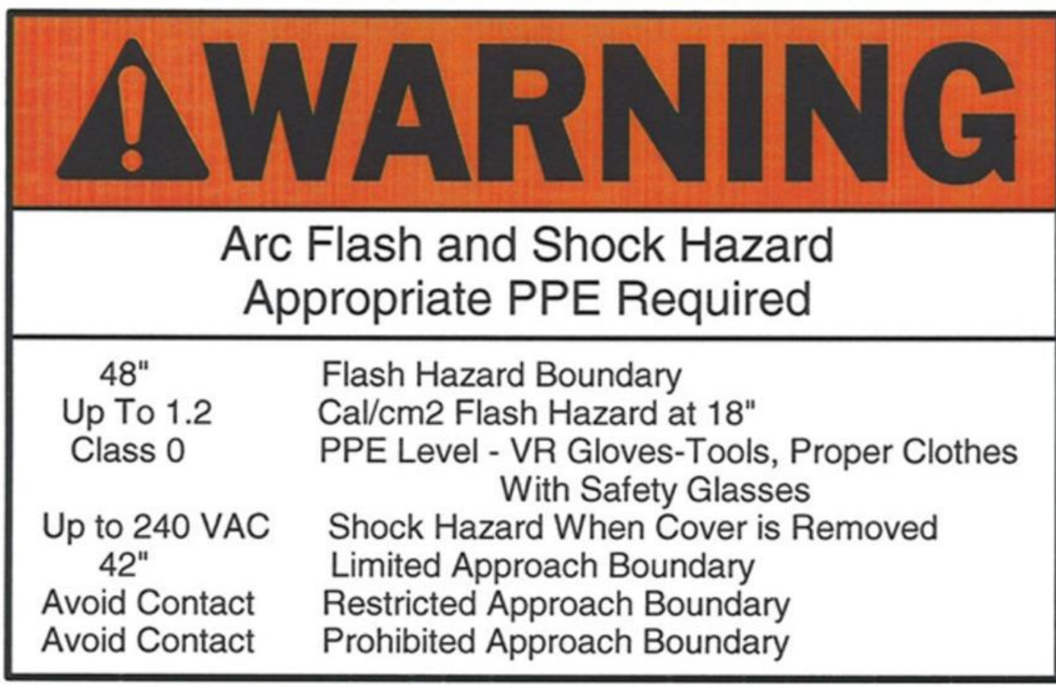
9.3 Wallace Tinsley, Michael Hodder and Aidan Graham, “Beyond the Calculations: Life After Arc Flash Analysis”, IEEE Paper No. 1-4244-1192
9.4 Slides, EFCOG Summer Meeting 2008, Golden Colorado, EFCOG webpage
9.5 J. J. Whipple and D. S. Ferguson, “White Paper, Pilot Modeling Project at MFC”, 6/15/2006
9.6 Michael Hodder, William Vilcheck, “Practical Arc Flash Reduction”, IEEE Industry Applications Magazine, May 2006


DANGER
Extreme Arc Flash and Shock Hazard
DO NOT WORK ON WHILE ENERGIZED!
80 Cal/cm2 Minimum Flash Hazard at 18"
480 VAC Shock Hazard When Cover is Removed
42" Limited Approach Boundary
12" Restriced Approach Boundary
1" Prohibited Approach Boundary


WARNING
Arc Flash and Shock Hazard
Appropriate PPE Required
All Switchgear Operations Involving
Opening/Closing 15KV circuit Breakers
or Racking in/out of 15KV Circuit Breakers
REQUIRES LEVEL 4 - 40 cal/cm^2 PPE


WARNING
ARC FLASH AND SHOCK HAZARD
This unit is powered by an
Emergency Generator!!
Do Not work on this equipment
without locking out Emergency Generator!!!


WARNING
Arc Flash and Shock Hazard
Appropriate PPE Required
48" Flash Hazard Boundary
Up To 1.2 Cal/cm2 Flash Hazard at 18"
Class 0 PPE Level - VR Gloves-Tools, Proper Clothes
With Safety Glasses
Up to 240 VAC Shock Hazard When Cover is Removed
42" Limited Approach Boundary
Avoid Contact Restricted Approach Boundary
Avoid Contact Prohibited Approach Boundary