EFCOG Best Practice #173

Best Practice Title: Compensatory Arc Flash Controls

Facility: DOE Complex

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Brief Description of Best Practice: Improper or inadequate maintenance can result in increased opening time of the over current protection device (OCPD), thus increasing the incident energy to which the worker is exposed. In cases where maintenance has not been performed in accordance with manufacturers' instructions or industry consensus standards, compensatory arc flash control measures may be deployed.

Why the best practice was used: Arc flash analysis can be impacted by conditions of maintenance.

What are the benefits of the best practice: This Best Practice provides compensatory arc flash controls for conditions of maintenance.

What problems/issues were associated with the best practice: No consistent guidance applied to complex.

How the success of the Best Practice was measured: Success will be measured by the use of this Best Practice into complex site operating procedures.

Description of process experience using the Best Practice: N/A

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Compensatory Arc Flash Controls

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It is assumed these controls are necessary until the inadequate condition is corrected (OCPD has been maintained, refurbished or replaced).

Compensatory Controls

Compensatory actions are based on reducing the incident energy by increasing the working distance from energized circuit parts and/or increasing the level of personal protective equipment (PPE). Selection of the specific control is based on feasibility. A combination of controls may be necessary.

1) Increase Working Distance

a. Use remote actuation device to actuate the OCPD

b. Operate OCPD that has been maintained upstream of the device to be controlled

c. Reduce available fault current (i.e., eliminate parallel system, etc.)

d. Use hot stick or other means to increase distance and thereby reduce incident energy exposure level.

Note: The incident energy from a potential arc flash source varies by the inverse square of the distance. For example if the working distance is 18 inches, increasing the distance to 36 inches reduces the incident energy to approximately ¼ of the former value. See Best Practice #163 for further information.

The aforementioned controls are not intended to be all inclusive or preclude alternate measures from being used if available.

2) Increase the level of PPE and/or add barriers/shielding

a. Escalate arc analysis - incorporate a 2 second maximum clearing time, as applicable, into the arc analysis. Based on escalation, prescribe arc rated clothing and PPE, OR

b. Use arc rated clothing and PPE using the alternative approach

c. Install barriers- i.e. shielding, blankets, etc., as appropriate.

Use of the 2 second maximum clearing time is based on the following statement from IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*:

"If the time is longer than two seconds, consider how long a person is likely to remain in the location of the arc flash. It is likely that a person exposed to an arc flash will move away quickly if it is physically possible and two seconds is a reasonable maximum time for calculations."

Sound engineering judgment should be used in applying the 2 second maximum clearing time, because there could be circumstances where an employee's egress is inhibited. For example, a person in a bucket truck or a person who has crawled into equipment will need more time to move away.

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NOTE 1: If the aforementioned administrative controls are not feasible and incident energy exceeds 40 cal/cm2 contact NFPA 70E AHJ.

NOTE 2: NFPA 70E Table 130.7 (C)(15)(a) should not be used where conditions of maintenance are inadequate since criteria for use of the table is based on an assumption of a clearing time of 1 second or less maximum clearing time.

If the 2 second rule is used to run out the arc analysis, keep in mind 2 seconds is a reasonable maximum clearing time. Since the condition of the equipment is unknown the 2 second rule is used. Two seconds is well founded by the IEEE-1584 standard which establishes the basis for arc analysis.

If an arc-flash analysis is performed using the 2 second rule and the resulting incident energy is less than 40 cal/cm^2, the worker only needs to wear PPE that is rated to the calculated incident energy.

Upstream device incident energy analysis

For energized electrical work at a point in a distribution system protected by a breaker that has not been maintained, the incident energy calculated at an upstream breaker that has been maintained may be used for work on or downstream of the non-maintained breaker(s) if :

a) There are no transformers between the upstream maintained breaker and the downstream point of work and,
b) The increase in impedance due to wire length and wire size between the maintained device and the point of work does not limit the fault current so low that the upstream maintained breaker will not trip in the instantaneous region. There is a point in any power system where the fault current will decrease to a point that is below the instantaneous setting of the upstream over current device causing an increase in clearing time and available incident energy. There is also a point in the system where, despite the increase in clearing time, the fault current is so low that the incident energy will not be higher than that of the upstream device. The engineer performing the analysis will need to exercise judgment for these conditions. Some evaluation may be required but it is not intended that a detailed evaluation be performed for every point in the system.

NOTE: Compensatory measures do not apply to fused disconnect switches, however, the switch mechanism, spring clips, etc. are required to be maintained.

As an alternative to arc analysis and application of the 2 second rule, the following approach may be applied if it is known the original arc flash incident energy (i.e., arc flash analysis prior to application of the 2 second rule) is less than 40 cal cm2:

For low risk tasks such as thermography and other non-contact inspections HRC 1 PPE for <1KV rated equipment and HRC 3 PPE for ≥1KV is required. Thermal imaging and photography are noncontact activities that do not involve interaction with the equipment and therefore have a decreased risk of initiation of an arc event. The criterion for non-contact activities is based in part on NFPA-70E-2012 task tables for performing infrared thermography and other non-contact inspections outside the restricted approach boundary. If the fault current is greater than that allowed by the notes to Table 130.7C(15)(a) for the particular class of equipment, additional PPE **is not** required for inspection, due to the low risk of initiating an arc-flash.

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For operation of overcurrent devices that have not been maintained, the compensatory measures require:

- No arc flash PPE for systems up to an including 240 VAC,
- PPE rated 4 cal/cm2 is for voltages greater than 240 VAC up to 1 KV and,
- PPE rated for 25 cal/cm2 for voltages 1 KV and above.

For work on energized circuit parts greater than 240 VAC on equipment that has not been maintained, the compensatory measures are:

PPE rated for 40 cal/cm2 for work on energized parts, trouble shooting, zero energy verifications and opening hinged and bolted covers to expose bare circuit conductors and circuit parts without performing an arc-flash analysis, if it is known that the original arc-flash analysis incident energy (i.e, arc-flash analysis prior to application of the two second rule) is less than 40 cal/cm^2. The option to use a 40 cal/cm^2 clothing ensemble is an appropriate compensatory measure considering that incident energy is expected to be greater due to inadequate conditions of maintenance.

When using the alternative approach, the flash protection boundary (FPB) should be established and controlled at a default distance of 12 feet. The default distance is based on engineering data indicating serious injuries are unlikely if PPE is worn while working within the default distance in proximity to energized circuit parts.

NFPA 70E applies risk based hazard analysis based on the task to be performed. Note for 600 Volt switchgear, operation of a breaker is a HRC category 0 while other activities such as voltage testing is HRC 2* or higher even though the potential energy is unchanged for 600 V class switchgear. What is different is the probability of injury. The option to default to a HRC 4 clothing ensemble as an appropriate compensatory measure is based on relative risk. NFPA 70E Annex D.8 states *"An IEEE working group produced the data from tests it performed to produce models of incident energy. Based on the selection of standard personal protective equipment (PPE) levels (1.2, 8, 25, and 40 cal/cm2), it is estimated that the PPE is adequate or more than adequate to protect employees from second-degree burns in 95 percent of the cases."*

NFPA emphasizes the need to deenergize when incident energy exceeds 40 cal/cm2. NFPA 70E 2004 states: *"When incident energy exceeds 40 cal/cm2 at the working distance, greater emphasis than normal should be placed on de-energizing before working on or near the exposed electrical conductors or circuit parts."* It is recommended work be limited to de-energizing systems as much as possible.

Compensatory arc flash control measures are not needed for low energy electrical distribution systems, ≤ 240 VAC, supplied by a single transformer rated less than 125 KVA.

The above measures are to be used to compensate for the lack of or limited maintenance of OCPDs that are relied upon to operate in the event of equipment failure. It should be noted that de-energization of electrical systems is the preferred option.