INTRODUCTION

This EOP contains required work methods and procedures to mitigate arc flash hazards to ensure employee safety and regulatory compliance.

PURPOSE

The purpose of this procedure is to provide approved PPE requirements and mitigating work practices for all Overhead and Underground Workers to reduce worker exposure in the event of an electric arc flash.

ACCOUNTABILITY

1. Electric Systems Engineering, T&D Work Methods
   A. Update procedure as necessary
   B. Provide guidance to Operations personnel when requested
2. Electric Asset Management
   A. Conduct a system study for the arc flash assessment to calculate the incident heat energy tables
   B. Update and revise as required
3. Learning and Development
   A. Provide training on safe work practices to mitigate arc flash
4. Safety
   A. Provide regulation oversight and compliance
5. Operations
   A. Ensure employees are trained
   B. Provide PPE/FR Clothing
   C. Understand and comply with the procedure

REFERENCES

OSHA 29CFR 1910.269
OSHA 29CFR 1926 Subpart V, Appendix E
National Electric Safety Code (NESC)
ASTM F1506 – Performance Specifications for Wearing Apparel to Electric Arc and Related Thermal Hazards
IEEE References
National Grid Safety Procedure H-807 Arc Flash Analysis and Mitigation (Rev 08/13/2016)
National Grid Employee Safety Handbook
National Grid NG-EOP D017– Protective Cover-up for Energized Line Work
NG-EOP UG011- Underground Electric
NG-EOP UG022 – Network Transformer & Protector
NG-EOP Definitions

DOCUMENT CONTENTS

Table of Contents

1.0 GENERAL INFORMATION

In April, 2014, OSHA revised 29 CFR Parts 1910.269 Electric Power Generation, Transmission, and Distribution and 1926 Subpart V, Electrical Protective Equipment.

Under the new standard, employers are required to conduct an arc flash assessment of their systems to determine incident heat energy exposure and proper procedures/PPE for employees. In order to conduct the assessment, OSHA permits the employer to make broad estimates that cover multiple system areas provided that:

1.1 The employer uses reasonable assumptions about the energy exposure throughout the system.

1.2 The estimates represent the maximum exposure for those areas.

In order to conduct the study, a Job Task Assessment was done for work in an energized area which exposes the worker to an arc flash hazard. The list of tasks focused on core tasks. Not every task performed by the worker was listed. This approach is permitted by the assessment criteria established by OSHA.

The assessment was separated into 2 parts:

1.3 Overhead work tasks

- 1.3.1 Rubber glove and live line hot stick methods
- 1.3.2 Single phase to ground arc in open air
- 1.3.3 Energy can radiate outward in all directions

1.4 Pad mounted equipment/underground work tasks

- 1.4.1 Live line hot stick work tasks
- 1.4.2 Phase to phase arc in an enclosure
- 1.4.3 Energy reflected back toward the worker
- 1.4.4 Also known as “Arc in the Box”

2.0 MITIGATION STRATEGY

Work Methods in conjunction with Engineering approached arc flash mitigation by using engineering controls and work practices to keep the arc flash incident heat levels low to have the least impact on the work force. The goal was to avoid as far as practical increased FR Clothing levels, additional PPE items and changes to well establish work practices. Unfortunately, exceptions do exist and it is critical that the worker has a general understanding of the arc flash assessment, components of the study and mitigation methods specifically selecting and maintaining the correct working distance. This will be further explained in the procedure below.

3.0 HEAT ENERGY EXPOSURE

The following parameters were used to estimate worker exposure to the heat energy from an electric arc and determine required FR Clothing arc-rating, Supplemental PPE, and Boundary Distance.

3.1 Calculations include:

- 3.1.1 Fault current, calculated by Engineering
- 3.1.2 Clearing time, calculated by Engineering
- 3.1.3 Length of electric arc and arc gap
  - a. Reasonable estimate made by Engineering
  - b. Arc gap estimate is 1 inch per 10kV
- 3.1.4 Working distance - electric arc to worker
  - a. Determined by Job Task Assessment
  - b. Overhead working distance is 15 inches
  - c. Underground working distance is 18 inches
  - d. Live line tools is minimum approach distance (MAD)

4.0 HEAT ENERGY CALCULATIONS

Two types of heat energy calculations were used in the system study to determine the maximum heat energy on the system. Minimum working distances and mitigating work practices are an important part of these calculations and must be adhered to in order to protect the worker from the heat energy of an electric arc flash.

4.1 Overhead systems

Overhead Line is treated as a "conductor in air" suspended which allows an electric arc flash to dissipate its energy in all directions

4.1.1 Conductor in Air

- a. Electric arc is single phase open air, phase to ground
  1. Requirements
     - I. Rubber glove work practices shall be used
     - II. Other phase(s) within MAD of the worker shall be covered
     - III. Ground potentials within the worker or below the work location shall be covered
- b. Workers qualified to perform rubber glove work methods
  1. Shall strictly follow NG-EOP D017 – Protective Cover-up for Energized Line Work
     - I. Proper installation and removal of protective cover up
     - II. 15kV and below

4.2 Pad Mount & Underground Equipment

Energized cable or parts on equipment which are enclosed on any side shall be treated as an "Arc in the Box" which requires increased head and face protection at lower incident energy levels than conductor in open air levels.

4.2.1 Arc is phase to phase

1. Exposed live parts enclosed on any side
2. Supplemental head and face protection required
   - I. Face shield
   - II. Hood

4.2.2 Arc in the Box rules apply:

- a. When live parts are not insulated or shielded and are contained in any enclosure, cabinet, handhole, meter channel, pull box, manhole or vault
- b. Any location where there is not a clear sphere for the heat energy to dissipate
- c. Equipment such as:
  1. Pad-mounted transformers
  2. Pad-mounted switchgear
     - I. Owned by the company or customer

3. Contained in vaults or manholes not insulated and shielded with any door open

4.3 The Arc Flash Assessment does not apply to manholes / vaults where all the cables are fully insulated and shielded or dead and grounded.

4.4 Upon entry into a manhole with energized cables the worker shall inspect all cables and equipment for any 'abnormality'

4.4.1 If any abnormality is found

a. The worker shall exit the manhole / vault

b. Issues shall be corrected or the affected equipment is de-energized, dead and grounded

c. Refer to NG-EOP UG011, Section 3.1.1

5.0 WORKING DISTANCE

An overall working distance was determined from the Job Task Assessment for both overhead and underground work and shall be adhered to by the worker. The working distance is measured from the workers torso to arc source. Working distance is defined below.

5.1 **Rubber glove– Work up to 15kV**

5.1.1 15 inches - working on single conductors in open air

5.1.2 18 inches – working on underground or pad mount equipment

a. Per OSHA 1910.269, Appendix E, Table 4

b. The Company Job Task Assessment findings are consistent with the national consensus standard working distances

1. See Appendix A, Table 4 of this document

5.2 **Live Line Work**

5.2.1 The **Minimum Approach Distance (MAD)** was revised by OSHA and shall be used for work with live line tools for all voltages above 15kV

a. Refer to Appendix A, Table 5 for Minimum Approach Distances

5.2.2 **Boundary Distance**–A calculated working distance in inches that identifies the level of FRC and any supplemental PPE required to work on or near energized lines, this is greater than MAD which reduces heat energy exposure

a. Heat energy does not exceed Standard 8 cal/cm^2 FR Clothing protection

b. 5 calorie boundary distance also given for pad mounted equipment

1. Removes the need for a face shield

c. When a boundary Distance is used for protection, it shall be strictly adhered to

1. *Refer to Arc Flash PPE Requirements Tables, Section 5.4.3 for proper working distance and PPE requirements*

5.3 Minimum Approach Distances (MAD) established by a Labor Agreement

5.3.1 Shall be followed if greater than OSHA MAD

5.3.2 If a Labor Agreement MAD is less than Boundary Distance for a circuit, line, or equipment, the Boundary Distance shall be followed with required PPE.

6.0 PERSONAL PROTECTIVE EQUIPMENT FOR VOLTAGES 1000 VOLTS AND GREATER

6.1 Company approved Flame Resistant (FR) clothing shall be worn when

6.1.1 Control, operate or work on or near energized equipment or circuits

6.1.2 Distance and position will expose the employee to electric arc hazards

6.1.3 It is the Employee's responsibility to ensure the base layer or clothing worn against skin shall be made from natural fibers or be FR rated.

a. Garments made from synthetic materials such as acetate, nylon, rayon, polyester, polypropylene, and spandex are prohibited.

1. These materials will burn and melt onto skin when exposed to high heat energy

6.1.4 Natural fiber non-melting, flammable materials

a. Are not arc rated

1. Such as untreated cotton, wool, silk, or blends of these materials
2. Are permitted to be worn but do not contribute to the arc rating of the required FR clothing

6.1.5 Approved FR Clothing provided in the Company managed FR Clothing Program

a. FR Clothing meets or exceeds arc rating of 8 calories/cm^2 or HRC level 2

1. Per NFPA/NESC guidelines
2. Garments worn as outer layers over FR clothing, such as jackets or rainwear, shall also be made from FR material.

Note: For employees required wear8 cal/cm², these garments may be rated less than 8 cal/cm² as long as an 8 cal/cm² garment is worn underneath

6.1.6 Exposed conductive articles shall not be worn when work is performed within reaching distance of live parts

a. Such as key chains or watch chains, rings, or wrist watches or bands

6.2 Other **Standard PPE** which shall be worn when exposed to electric arc hazards includes

6.2.1 Hard hat

6.2.2 Safety glasses

6.2.3 Rubber insulated gloves/protectors

6.2.4 Rubber insulated sleeves

6.2.5 Protective footwear

6.3 Refer to Safety Procedure H-807 Arc Flash Analysis and Mitigation

6.4 Supplemental personal protective equipment (PPE) is required when

6.4.1 Exposed to live parts of electrical circuits and equipment identified as having an arc flash heat energy

a. Above the Standard 8 calories cm^2on overhead equipment
b. Above 5 calories cm^2 on pad mounted / underground equipment

6.4.2 Refer to the ARC FLASH PPE REQUIREMENT tables
a. For PPE requirements on
1. All distribution circuits, 15kV and less
2. Sub-transmission and transmission lines
I. Requiring PPE / Supplemental PPE exceeding the normal requirements
b. For required Boundary Distance to avoid the need for supplemental PPE

6.4.3 These tables can be accessed on the Work Methods Infonet site or by the link below:

http://us3infonet/sites/eng_delivery_svcs/Pages/ArcFlashMitigation.aspx

6.5 If a circuit or line is not listed
6.5.1 Supervisors should contact
a. The Regional Engineer
b. Work Methods Lead Coordinator
6.5.2 Except Sub-Transmission pad mounted equipment
a. Only Sub-Transmission circuits with pad mounted equipment are listed
6.5.3 If a Sub-Transmission pad mounted equipment is encountered on a circuit not listed in the Arc Flash PPE Requirements Tables
a. See 6.5.1 above

6.6 It is recommended that all Supervisors
6.6.1 Filter the table by their area
6.6.2 Print and distribute the ARC FLASH PPE REQUIREMENT tables to their assigned crew members
6.6.3 Printed tables are uncontrolled and may not be the most current version, refer to the Work Methods web site for the most updated tables

7.0 PPE REQUIREMENTS FOR SECONDARY VOLTAGE (50v - 600v)

7.1 Secondary 50 – 600 Volts
7.1.1 Overhead (conductor in air)
a. No supplemental PPE required
7.1.2 Underground / Enclosed Equipment
a. 50 – 250 volt systems
1. No supplemental PPE required
b. 277/480 volt systems
1. Supplemental PPE required
I. Minimum of 12 cal/cm² Face Shield

c. 600 volt conventional manhole and duct systems (NE Only)
1. Shall be de-energized

7.2 Secondary 50 – 600 Volts (network system)
7.2.1 120/208 volt network protectors
a. No supplemental PPE required
7.2.2 277/480 volt and higher systems
a. Supplemental PPE required
1. Minimum of 12 cal/cm² Face shield
7.2.3 Refer to NG-EOP UG022 for additional requirements

7.3 These requirements are based on NESC Table 410-1. See Appendix A of this document

8.0 MITIGATING WORK PRACTICES

Approved work methods available to protect workers from an electric arc flash include:

8.1 MAINTAIN MINIMUM APPROACH DISTANCE or BOUNDARY DISTANCE
8.1.1 Reduces exposure to heat energy with
a. Increase in distance
1. Requires the use of Live Line tools
8.1.2 Minimum approach distance
a. Required distance to energized parts when using live line tools
b. Workers shall strictly adhere to MAD
1. Except when there is a greater Boundary Distance
I. Then Boundary Distance shall be maintained
c. Refer to Appendix A, Table 5 for Minimum Approach Distances
d. Required to maintain MAD per OSHA 1910.269
8.1.3 Boundary Distances
a. Greater than MAD
b. Workers shall strictly adhere to Boundary Distance
1. When Boundary Distance is used for protection
c. Refer to Arc Flash PPE Requirements Tables
8.1.4 Live-line tools
a. Hand guards recommended
1. Adjusted to MAD or Boundary Distance

8.2 INSULATE AND ISOLATE Practices for Energized Line Work
8.2.1 Overhead rubber glove or line work
a. Work shall be limited to only a single phase
b. Other phase(s) within MAD of the worker or equipment and material (i.e. pole) shall be covered or isolated to avoid incidental contact.

c. Ground potentials within the work zone or below shall be covered

d. To prevent phase to phase exposure

I. Cover on the way in and uncover on the way out

II. Maintain proper work position to reduce exposure

e. Reference the NG-EOP D017 – Protective Cover-up for Energized Line Work for proper work methods

1. To access use document link

http://us3infonet/sites/eng_delivery_svcs/Pages/EOPNG.aspx

8.3 FACE PROTECTION (FACE SHIELD)

8.3.1 Minimum of 12 cal/cm² Face Shields serve to reduce the extent and severity of a high heat energy exposure

a. Required for secondary voltage (277/480V) Underground / Enclosed Equipment

b. Refer to Arc Flash PPE Requirements Tables for overhead

c. Requirements based on OSHA 1926, Subpart V, Appendix E. See Appendix A, Table 6 of this document

8.4 PROTECTIVE DEVICES

8.4.1 Non-Reclose Assurance (NRA)

a. Station breaker or field recloser

b. Provides a single trip to lock out

c. Could lower heat energy by reducing clearing time

8.5 SWITCHING

8.5.1 De-energize a circuit, a portion of a circuit or equipment prior to performing work

a. Switch out load to alternate feeders

b. Avoid customer outage as far as practical

9.0 REVISION HISTORY

Version	Date	Description of Revision
1.0	08/17/15	This is a new document.
2.0	12/15/16	Supersedes document dated 08/17/15; Adjusted verbiage to match safety document H-807 ; add reference to NG-EOP D017 – Protective Cover-up for Energized Line Work for proper work methods and the EOP Definitions due to the SHE Corporate Audit 1992 Arc Flash Regulation.

APPENDIX A

Table 410-1—Clothing and clothing systems (cal/cm^2) for voltages 50 V to 1000 V (ac) ①

(See Rule 410A3.)

Equipment type	Nominal voltage range and cal/cm^2		
	50 V to 250 V	251 V to 600 V⑭	601 V to 1000 V
Self-contained meters / cabinets	4 ②	20 ④	30 ⑧
Pad-mounted transformers	4 ⑨	4 ⑨	6 ⑧
CT meters and control wiring	4 ②	4 ⑤	6 ⑧
Metal-clad switchgear / motor control centers	8 ③	40 ⑥	60 ⑧
Pedestals / pull boxes / hand holes	4 ②	8 ⑦	12 ⑧
Open air (includes lines)	4 ②	4 ⑦	6 ⑧
Equipment type	**Nominal voltage range and cal/cm^2**		
	50 V to 250 V	**251 V to 600 V⑭**	**601 V to 1000 V**
Network protectors	4⑩	⑪	⑪
Panel boards—single phase (all) / three phase (≤100 A)	4②	8⑫	12⑧
Panel boards—three phase (>100 A)	4②	⑬	⑬

①This table was developed from fault testing based on equipment type and is independent of fault current unless otherwise noted.

Calculations and test data are based on a 46 cm (18 in) separation distance from the arc to the employee. See IEEE Std 1584-2002.

Other methods are available to estimate arc exposure values and may yield slightly different but equally acceptable results.

The use of the table in the selection of clothing is intended to reduce the amount or degree of injury but may not prevent all burns.

②Industry testing on this equipment by two separate major utilities and a research institute has demonstrated that voltages 50 V to 250 V will not sustain arcs for more than 2 cycles, thereby limiting exposure to less than 4 cal/cm^2. (See *208-V Arc Flash Testing* [B1].)

③Value based on IEEE 1584 formula for Motor Control Centers. [Gap = 2.54 cm (1 in)] (Xd = 1.641) [46 cm (18 in) distance] 51 kA (Based on a 208 V, 1000 kVA, 5.3% Z, served from a 500 MVA system) Maximum duration without circuit protective device operation from industry testing (see *208-V Arc Flash Testing* [B1]) is 10 cycles: 46.5 cal/s/cm^2 x 0.167 s = 7.8 cal/cm^2.

④Industry testing on 480 V equipment indicates exposures for self-contained meters do not exceed 20 cal/cm^2.

⑤Industry testing on 480 V equipment indicates exposures for CT meters and control wiring does not exceed 4 cal/cm^2.

⑥Value based on IEEE 1584 formula for Motor Control Centers. [Gap = 2.54 cm (1 in)] (Xd = 1.641) [46 cm (18 in) distance] 12.7 kA at 480 V (worst-case energy value from testing). (See Eblen and Short [B31].) Maximum duration without circuit protective device operation from tests is 85 cycles: 26.2 cal/s/cm^2 x 1.42 s = 37 cal/cm^2.

⑦Incident analysis on this equipment indicates exposures do not exceed the values in the table.

⑧Engineering analysis indicates that applying a 150% multiplier to the 480 V exposure values provides a conservative value for equipment and open air lines operating at 601 V to 1000 V.

⑨Industry testing on 480 V equipment indicates exposures on pad-mounted transformers do not exceed 4 cal/cm^2. (See Eblen and Short [B31].)

⑩Industry testing on 208 V network protectors indicates exposures do not exceed 4 cal/cm^2. (See *208-V Arc Flash Testing* [B1].)

⑪Industry testing on 480 V network protectors indicates arcs will not self-extinguish and heat flux rates will exceed 60 cal/cm^2/s at 24 in working distance. Perform arc hazard analysis. (See Eblen and Short [B31].)

⑫Industry testing on 480 V panels with non-edge mounted bus bars indicates exposures do not exceed 8 cal/cm^2. (See Eblen and Short [B31].)

⑬Industry testing on panelboards with edge-mounted, parallel bus bars indicate arcs will not self-extinguish and heat flux rates will exceed 60 cal/cm^2/s at 46 cm (18 in) working distance. Perform arc hazard analysis. (See Eblen and Short [B31].)

⑭IEEE 1584 original test data indicates there is no significant difference between heat flux rates for 400 V class equipment verses 600 V class equipment.

Table 4

Selecting a Reasonable Distance from the Employee to the Electric Arc

TABLE 4 SELECTING A REASONABLE DISTANCE FROM THE EMPLOYEE TO THE ELECTRIC ARC		
Class of equipment	**Single-phase arc mm (inches)**	**Three-phase arc mm (inches)**
Cable	NA*	455 (18)
Low voltage MCCs and panelboards	NA	455 (18)
Low-voltage switchgear	NA	610 (24)
5kV switchgear	NA	910 (36)
15kV switchgear	NA	910 (36)
Single conductors in air (up to 46 kilovolts), work with rubber insulating gloves	380 (15)	NA
Single conductors in air, work with live-line tools and live-line barehand work	MAD - (2 × kV × 2.54) (MAD - (2 × kV /10)) †	NA

Source – Appendix E to Subpart V of 1926 – Protection from Flames and Electric Arcs

* NA = not applicable.

† The terms in this equation are:

MAD = The applicable minimum approach distance, and

kV = The system voltage in kilovolts.

Table 5

Minimum Approach Distance (MAD)

Voltage Range	Fault Condition
50V to 300V	Avoid Contact
301V to 750V	12” P-G 12” P-P
751V to 1kV	24” P-G 24” P-P
1kV to 15kV	26” P-G 27” P-P
15.1kV to 36kV	30.5” P-G 35” P-P
36.1kV to 46kV	33” P-G 38.5” P-P
46.1kV to 72.5kV	39.5” P-G 47” P-P
72.6kV to 121kV	39” P-G 52” P-P
230kV to 242kV	63” P-G 90” P-P
345kV to 362kV	102” P-G 150” P-P

Notes:

To avoid confusion and for consistency, all heat energy calculations were calculated at OSHA MAD, as listed in Table 5.
The MAD for Upstate NY Local 97 is defined as MAD plus 'Reaching Distance' which is greater than OSHA MAD thus the heat energy will be lower when adhered to.
The MAD above 72.5kV may increase after the review of IEEE 516 is completed per agreement with OSHA, expected February 2016.

Table 6

OSHA 1926 Subpart V Appendix E – Minimum Head and Face Protection for Single Phase, open air and Three Phase Exposure.

Exposure	Minimum Head and Face Protection		
	None*	Arc-Rated Faceshield with a Minimum Rating of 8 cal/cm^2*	Arc-Rated Hood or Faceshield with Balaclava
Single-phase, open air	2 – 8 cal/cm^2	9 – 12 cal/cm^2	13 cal/cm^2 or higher†
Three-phase	2 – 4 cal/cm^2	5 – 8 cal/cm^2	9 cal/cm^2 or higher‡

*These ranges assume that employees are wearing hardhats meeting the specifications in §1910.135 or §1926.100(b)(2), as applicable.

† The arc rating must be a minimum of 4 cal/cm2 less than the estimated incident energy. Note that § 1926.960(g)(5)(v) permits this type of head and face protection, with a minimum arc rating of 4 cal/cm2 less than the estimated incident energy, at any incident energy level.

‡ Note that § 1926.960(g) (5) permits this type of head and face protection at any incident energy level.