VILLAGE OF PAW PAW

SYSTEM ARC-FLASH STUDY

FINAL REPORT
April 7, 2017

Village of Paw Paw
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EXECUTIVE SUMMARY

GRP Engineering, Inc. was contracted by Wightman and Associates, Inc. to complete an arc-flash assessment on the Village of Paw Paw's electrical system, including distribution circuits and their associated equipment. This electric system arc-flash assessment was completed as part of an overall electrical system study and to keep employees safe from arc-flash hazards. The Village of Paw Paw's electrical system was analyzed for the available incident energy in an arc caused from a bolted fault. The results of the analysis were utilized to determine the appropriate personal protective equipment (PPE) to meet or exceed the requirements set forth in the 2017 NESC and OSHA's 2014 final ruling.

The NESC and OSHA require electrical utilities to complete an assessment to determine the potential exposure to an arc at all points of their electrical system or utilize standardized tables. Use of NESC Table 410-1 for equipment operating below 1000V is a practical method for the Village of Paw Paw due to utility size and the number of locations operating in this voltage class. An 8 Cal/cm^2 PPE system is acceptable with the exception of 277/480V self-contained meter bases, cabinets, switchgear and MCC's.

NESC Table 410-2 is not practical for the 7.2/12.47kV distribution system since it does not cover phase-to-phase fault conditions or faults in pad-mount equipment. Calculations show that a 4 Cal/cm^2 PPE system is acceptable for all work being completed on the 7.2/12.47kV distribution system. The amount of energy contained in an arcing event at this voltage level was minimal due to the low level of fault current and the fast operating times of the relcosers. In the future if the settings on the recloser controllers are changed, a review of this arc flash study should take place.

The attached tables provide the required PPE, the minimum distance that an employee can be while not wearing the required PPE of the corresponding hazard level, the arc-energy, and the hazard risk category. PPE requirements are provided based on the the rated voltage, and job duty/equipment type. Results are NOT provided for the secondary (<1000V) side of transformers, due to the excessive number of points to analyze. The NESC Table 410-1 covers all equipment under 1000V and shall be followed.

Arc energy calculations and PPE requirements have been based on information provided by American Electric Power (AEP) and the Village of Paw Paw to develop the system model from which the arc energy values were determined. Changes in equipment settings or system configuration may invalidate the calculations, values and PPE requirements. A periodic review of the data required for these calculations should be completed by the Village of Paw Paw to ensure the proper clothing system is being provided to employees.

VILLAGE OF PAW PAW
SYSTEM ARC-FLASH ASSESSMENT
BACKGROUND

Introduction

GRP Engineering, Inc. was contracted by Wightman and Associates to complete an arc-flash assessment on the Village of Paw Paw's electrical system, including distribution circuits and their associated equipment. This electric system arc-flash assessment was completed as part of an overall electrical system study and to keep employees safe from arc-flash hazards. The Village of Paw Paw electrical system was analyzed for the available incident energy in an arc caused from a bolted fault. The results of the analysis were utilized to determine the appropriate personal protective equipment (PPE) to meet or exceed the requirements set forth in the 2017 NESC and OSHA's 2014 final ruling.

Background

This study utilized a combination of the available fault currents calculated in the computerized system model, the working voltages, working distances, plus an examination of the NESC tables, NFPA tables, and revised OSHA standards to determine the required PPE and the arc flash boundary. The arc flash boundary is the distance from an electrical arc that an individual without any PPE must remain outside of to incur no greater than a curable second degree burn. The system model in Milsoft's WindMil Engineering Analysis software includes three 12.47kV American Electric Power (AEP) owned distribution sources, line reclosers, fuses, plus 7.2/12.47kV primary distribution lines and equipment.

A Windmil model was created from the ESRI GIS mapping software geodatabase. Due to the fuse sizes being unknown, they were assumed to be 100K on the 7.2/12.47kV system. By using 100K fuses in the analysis, a concervative approach to the arc-flash energy calculations was taken. This is because a 100k fuse gives the longest clearing time and thus the largest energy contained in an arcing event.

All line recloser controllers were modeled based on their existing settings. All recloser controllers utilize both fast and slow curves. During routine maintenance, the recloser controllers should be placed into "Non-Reclosing". This setting will force the controller to operate the recloser on its fastest curve and disable reclosing, causing the controller to lockout the recloser after its first opening sequence. This arc flash analysis was completed with the assumption that recloser controllers would be placed into non-reclose while work on energized equipment is completed.

Labeling all points on the Village of Paw Paws' electrical system as to the minimum PPE required and the arc-flash boundary at that particular location would be impractical. Therefore, categorizing locations into voltage classes, and work tasks or equipment being worked on and relating them to the required PPE provides a simple approach to determining the required PPE and educating employees. Tables listing the minimum PPE requirements were completed based on the analysis described in this document and are attached to the end of this report. The arc-flash analysis and final recommendations were categorized into the following four (4) voltage levels on the Village of Paw Paw's system.

- 7.2kV/12.47kV
- 277V/480V
- 120V/240V
- 120V/208V

While not all points on the Village of Paw Paw's system will be labeled for the minimum PPE, all points in the system model were analyzed for the maximum arc-flash incident energy based on the available fault current, nominal voltage, duration of the arc in cycles, gap between conductors (energized equipment and a tool or person), and the distance from the arc to the employee(s) completing the assigned work.

System Background

The Village of Paw Paw's electrical distribution system is comprised of three (3) 12.47kV sources and four (4) 12.47kV distribution circuits. Distribution circuits are protected by line reclosers with Cooper controllers with fuses installed at tap points on each distribution circuit to provide additional sectionalizing. The system protection scheme utilizes a fuse-saving philosophy. A fuse-saving scheme allows the recloser to operate prior to a fuse operating. This means that for any fault, the line recloser will first operate causing an interruption to the system prior to allowing a fuse to operate. This philosophy trades having fewer permanent outages by temporarily interrupting all customers on the circuit.

NESC Requirements

The 2012 edition of the National Electric Safety Code (NESC) revised the original 2007 requirements for flame retardant clothing while working on or near energized lines, parts, or electrical equipment. A minimum PPE rating of 4 Cal/cm^2 was acceptable under the 2007 NESC for working on equipment below 1000V. The 2017 NESC requires a detailed arc-flash study be completed or the use of NESC Table 410-1 (<1000V), 410-2 (1001V-46kV), and 410-3 (46kV-800kV) can be followed to determine the proper PPE required for live work.

Rule 410A3 of the NESC requires the following from employers for their employees while working on energized systems 50V – 800,000V.

1. Perform a detailed arc hazard analysis, or use NESC Tables 410-1, 410-2, 410-3 to determine the effective arc rating of clothing to be worn by employees working on or near energized lines, parts, or equipment at voltages 50V to 800,000V.

   The arc hazard analysis shall include a calculation of the estimated arc energy based on the available fault current, the duration of the arc (cycles), and the distance from the arc to the employee.

2. Require employees to cover the entire body with arc rated clothing and equipment having an effective arc rating not less than the anticipated level of arc energy.

OSHA Requirements

On April 11, 2014 OSHA announced that the final rule to improve workplace safety and health for workers performing electric power generation, transmission and distribution work had been published in the Federal Register. The final rule revises the 40 year old construction standard for electric power line work to make it more consistent with the general industry. The standard makes revisions to the Construction and General Industry requirements including a revised minimum approach-distance requirement (Table R-6) and new requirements to protect workers from electric arcs. OSHA standards 1910.269 and 1926 subpart V became effective on October 31, 2014 and electric utility's must provide FR clothing rated for the findings of the analysis by April 1, 2015.

Table 3 in the OSHA Standard gives four recommended, but not required, methods for calculating heat energy from an electric arc.

1. NFPA 70E-2012
2. "Predicting Incident Energy to Better Manage the Electric Arc Hazard on 600V Power Systems" IEEE conference paper
3. IEEE Std 1584-2002, 1584a-2004, and 1584b-2004
4. ArcPro a commercially available software program

The four suggested methods for calculating the arc-flash incident energy analyzed to determine the appropriate method for the study, the following was found. NFPA 70E-2012 is not acceptable for faults that occur inside of an enclosure, the IEEE conference paper is not acceptable for voltages above 600V, and ArcPro is not acceptable for three phase faults between 600V-15kV.

The use of the methods presented in IEEE Std 1584 has been deemed acceptable by OSHA for single phase and three phase faults in both open air and in enclosures for voltages 208V-15kV. This method was determined to be the most appropriate for the fault cases in this study. The Arc Flash Analysis routine in WindMil utilizes IEEE Std 1584 in its calculations and is therefore an acceptable method for completing an arc flash study and will be utilized for voltages between 1kV and 15kV.

OSHA has also published two tables in their final rule that detail the value of parameters to be used when calculating incident energy for an electrical arc. Table 4 details the selecting of a reasonable distance from the employee to the electrical arc and Table 5 details the selection of a reasonable arc gap between the conductors. The parameters in IEEE 1584 meet or exceed the values in the OSHA tables 4 and 5.

Standard PPE Levels

NFPA 70E-2004, Standard for Electrical Safety in the Workplace, which is the standard followed by non-utility employees, provides tables relating required PPE to the incident energy contained in a bolted fault. This table provides the Hazard-Risk Categories (HRC), clothing system descriptions, and the incident energy they offer protection for. This table is intended for non-utility workers, however the Protective Clothing and Personal Protection Equipment table in NFPA-70E does provide a good reference for relating specific PPE to their effective arc rating. Considering OSHA requires the clothing is treated to withstand the conditions that may be encountered and

suppliers of flame retardant clothing relate their products to this table, it is prudent to follow. According to the NFPA PPE table, HRC 1 and 2 require the use of face shields or arc rated hoods. However, OSHA is only requiring the use of face protection when the incident energy is above 8 cal/cm^2 in open air and above 4 cal/cm^2 when the arc is on underground equipment. Underground equipment is defined as pad-mount transformers, pad-mount switchgear, transclosures, primary metering cabinets, and sectionalizing cabinets.

PERSONAL PROTECTIVE EQUIPMENT (PPE)
NON-UTILIY PERSONEL

Hazard Risk Category (HRC)	**Clothing Description[1]**	**Required Minimum Arc Rating of PPE**	
		(cal/cm^2)	**(J/cm^2)**
0	Protective Clothing, Nonmelting or Untreated Natural Fiber (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials) with a Fabric Weight of at least 4.5 oz/yd^2. Shirt (long sleeve), Pants (long), Safety glasses or safety goggles (SR), Hearing Protection (ear canal inserts) Heavy duty leather gloves (AN)	N/A	N/A
1	Arc-rated long-sleeve shirt and pants or arc-rated coverall. Arc-rated face shield or arc flash suit hood. Arc-rated jacket, parka, rainwear, or hard hat liner (AN). Hard hat, safety glasses or safety goggles (SR), hearing protection (ear canal inserts), heavy duty leather gloves, leather work shoes (AN).	4	16.7
2	Arc-rated long-sleeve shirt and pants or arc-rated coverall. Arc-rated face shield or arc flash suit hood. Arc-rated jacket, parka, rainwear, or hard hat liner (AN). Hard hat, safety glasses or safety goggles (SR), hearing protection (ear canal inserts), heavy duty leather gloves, leather work shoes (AN).	8	33.5
3	Arc-rated long-sleeve shirt (AR), arc-rated pants (AR), arc-rated coverall (AR), arc-rated arc flash suit (AR), arc rated arc flash suit pants (AR), arc-rated arc flash suit hood, arc-rated gloves, Arc-rated jacket, parka, rainwear, or hard hat liner (AN). Hard hat, safety glasses or safety goggles (SR), hearing protection (ear canal inserts), leather work shoes (AN).	25	104.6
4	Same requirements as category 3, but clothing is to be rated for 40 cal.	40	167.4

[1] AN: as needed (optional). AR: as required. SR: selection required.
[2] 4.184 Joules = 1 calorie

VILLAGE OF PAW PAW
SYSTEM ARC-FLASH ASSESSMENT
ANALYSIS

Analysis Criteria

The following sections state the criteria and assumptions that were utilized in this study to calculate the incident energy created from a fault. This includes, where applicable, the available fault current, nominal voltage, protective device clearing time, the gap between conductors, and the distance between the utility worker and the arc. The incident energy is the critical component in determining the level of PPE and can vary greatly depending on the variables noted above.

The amount of energy contained in an arc created by a fault is directly proportional to the exponential inverse of the distance of the employee from the arc. The exponential component of the arc energy calculation differs depending on the equipment type, i.e. open air vs. switchgear. Thus the further a worker is away from the arc, the less arc energy the individual will be exposed to and the required PPE will have a lower Cal/cm^2 rating. The exponential component is also less for enclosed equipment than for open air equipment. Therefore the incident energy in an enclosed arc will be greater than one in open air. A study produced under grant number SH-16614-07 from the Occupational Safety and Health Administration (OSHA) found that test results have shown the incident energy for a three-phase arc in a box can increase from 1.5 to 3 times depending on the arc parameters and box dimensions when compared to an open air arc with the same system voltage and available fault current.

120/208V, 120/240V, and 277/480V

As noted above, the 2017 NESC requires completion of an arc-flash study or utilization of Table 410-1 for locations below 1000V. NESC Table 410-1 provides a good alternative to performing an arc hazard analysis for secondary systems operating between 50V and 1000V. The PPE guidelines set forth in Table 410-1 are acceptable in lieu of performing an arc hazard analysis per Rule 410A3 of the NESC. Furthermore, the use of IEEE standard 1584 is not valid on voltages below 208V or faults less than 700A, using table 410-1 does not have these restrictions.

Table 410-1 provides clothing and clothing system ratings for working on equipment operating at voltages from 50V to 1000V (AC) based on the equipment type and range of voltage. This table was developed from fault testing on equipment located at a distance of 18 inches from employee to an arc, typical gaps from IEEE 1584b-2012, and are independent of the amount of fault current. Due to the extent of the electrical system at this voltage range, evaluating the arc energy is not practical and can change based on a number of factors including but not limited to, distributed generation, protective device operating times (main ac panel breakers or fuses), or available fault current. The guidelines established in NESC Table 410-1 were reviewed and shall be followed.

Using table 410-1 to protect employees from the hazards of an electrical arc will satisfy the requirements of the new OSHA Standard. It satisfies the requirement because it was developed by fault testing on electrical equipment. The calculations and data are based off of IEEE 1584, which meets or exceeds the arc energy parameters set in the new OSHA standard.

7.2/12.47kV

The NESC provides generalized Table 410-2 relating flame retardant clothing and clothing systems to voltage class, fault current and clearing time of the closest upstream protective device for voltages ranging from 1.1kV to 46kV. This table is based on specific separation distances from the arc to the employee, arc-gaps, and arc clearing times. Furthermore, Table 410-2 only applies to phase-to-ground faults and is also only valid for arcs on equipment in open air and not those contained in a box. This table is not applicable for three-phase faults or equipment in an enclosed box such as pad-mount transformers, outdoor switchgear, or transclosers. Therefore, NESC table 410-2 was not the primary method utilized in completing the arc hazard analysis on the 4.16kV and 12.47kV distribution system, and calculations were first performed using the IEEE Standard 1584 methods.

For faults below 700 amps, the methods in IEEE Standard 1584 are not valid. In cases where the fault current is below 700 amps, the equations and methods in the Lee Method will be used. The Lee Method may produce results greater than data points from open air arc tests depending on the system voltage and grounding. The results from the Lee Method are a worst case scenario and based on maximum power transfer. If the results from the Lee Method are unrealistic and the arc is in open air, an evaluation of NESC table 410-2 will be conducted.

IEEE Standard 1584, Guide for Performing Arc-Flash Calculations, provides an empirical equation to calculate the "incident energy" in an electric arc. This calculation takes into account the system voltage, distance to the arc, type of equipment, bolted fault current, gap between conductors, system grounding, and the duration of the arc. Determination of values for these variables is outlined below.

To analyze the 12.47kV distribution system, a nominal phase-to-phase voltage of 12.47kV was utilized. Fault currents were derived from the 12.47kV grounded wye WindMil system model. The duration of the arc was calculated from the recloser control settings (time dial and pickup), their associated TCC curves, and standard equipment operating times. Where there were fuses of unknown size, a 100K fuse was used. 100K fuses on the 12.47kV system were selected because they are the largest fuses that will coordinate with the line reclosers. These fuses also have the longest clearing times for any magnitude of fault current. Selecting the largest fuse that coordinates back to the line reclosers will usually yield a worst case result in the analysis.

The distance between the utility worker and the arc was selected to be 18" for work completed on all types of equipment. This includes work on distribution circuits (open-wire, spacer cable, and underground cable), polemount transformers, work inside of a transclosure, distribution switchgear, pad-mount transformers, air-break switches, and fused cutouts. A gap of 13-153mm between energized equipment and a conductor such as a tool or a human appendage was used. The gap was determined by using an IEEE Standard 1584 table that related the gap to the type of equipment. The values used when calculating the incident energy of the electrical arc meet or exceed what is set in the OHSA standard. This includes the distance from employee to the arc, the gap between the arcing conductors, and minimum approach.

The arc flash boundary at 12.47kV was calculated to determine the minimum distance an individual could be to equipment operating at this voltage level and not wearing the required PPE. The boundary was calculated by setting the incident arc energy from the IEEE equation to 1.2

Cal/cm^2 and solving for the distance. This was done for all the different types of equipment on the 12.47kV distribution system.

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SYSTEM ARC-FLASH ASSESSMENT
RESULTS AND RECOMMENDATIONS

Results and Recommended PPE

120/208V and 120/240V

When working on energized equipment with an operating voltage less than 250V, PPE clothing with a rating of 4 Cal/cm^2 will be acceptable for meter bases, metering cabinets, pad-mounted transformers, CT meters and control wiring, pedestals, pullboxes, handholes, or in open air. While working on energized metal-clad switchgear or motor control centers, PPE clothing with a rating of 8 Cal/cm^2 shall be required. Typically metal-clad switchgear or motor control centers will be on the load side of the meter, past the utility's point of demarcation, and would be customer owned. NESC Table 410-1 is duplicated on the following page to clearly list these requirements.

The OSHA Arc-Flash Study SH-16614-07 states "The pressure of an arc blast is caused by the expansion of the metal as it vaporizes and the heating of the air by the arc energy. This accounts for the expulsion of molten metal up to ten (10) feet away." IEEE 1584 states "The radiant energy and molten material that is released by an electric arc is capable of serious energy or killing a human at distances of up to twenty (20) feet away." Therefore all individuals not in the appropriate PPE shall remain a minimum of twenty (20) feet away from energized equipment, lines, or parts at this voltage while work is be conducted. Should work be completed in an area accessible by the public and within the arc flash boundary, such as over a sidewalk, signage and detours should be set up to route the public away from the work zone.

277/480V

When working on energized equipment with an operating voltage greater than 250V and less than 600V, PPE clothing with a rating of 4 cal/cm^2 will be acceptable for pad-mounted transformers, CT meters and control wiring, or in open air. While working on pedestals, pullboxes, or handholes, PPE clothing with a rating of 8 cal/cm^2 shall be required and a face shield shall be used. While working on meter bases or metering cabinets, PPE clothing with a rating of 20 cal/cm^2 shall be required and a hood is to be included as part of the PPE. While working on energized metal-clad switchgear or motor control centers, PPE clothing with a rating of 40 cal/cm^2 shall be required and a hood is to be included as part of the PPE. Typically metal-clad switchgear or motor control centers will be on the load side of the meter, past the utility's point of demarcation and would be customer owned.

Due to the nature of faults on low-voltage systems and the large incident energy contained in them, all individuals not in the appropriate PPE shall remain a minimum of twenty (20) feet away from energized equipment, lines, or parts at this voltage while work is be conducted. Should work be completed in an area accessible by the public and within the arc flash boundary, such as over a sidewalk, signage and detours should be set up to route the public away from the work zone.

The NESC Table 410-1 has been included in this study and is shown below to be used for a reference when selecting the proper PPE for the equipment type and the nominal voltage range. Not all equipment listed in the table may be encountered by utility personnel while performing their normal duties.

NESC Table 410-1

Equipment Type	Nominal Voltage Range and cal/cm^2		
	50V to 250V	**251V to 600V**	**601V to 1000V**
Self-contained meters/cabinets	4	20	30
Pad-mounted transformers	4	4	6
CT meters and control wiring	4	4	6
Metal-clad switchgear or motor control centers	8	40	60
Pedestals, pullboxes, or hand holes	4	8	12
Open air (includes lines)	4	4	6
Equipment Type	**Nominal Voltage Range and cal/cm^2**		
	50V to 250V	**251V to 600V**	**601V to 1000V**
Network protectors	4	Exceeds 60 cal/cm^2 perform arc hazard analysis	Exceeds 60 cal/cm^2 perform arc hazard analysis
Panel boards – single phase (all)/three phase(<100A)	4	8	12
Panel boards – three phase (>100 A)	4	Exceeds 60 cal/cm^2 perform arc hazard analysis	Exceeds 60 cal/cm^2 perform arc hazard analysis

Red notes the use of a face shield is required

7.2/12.47kV

Using the IEEE Standard 1584 equation and the arc flash utility in the WindMil system model, the incident energy for the entire 12.47kV distribution system was calculated. This was completed for AEP generation at maximum. Completing the study under a maximum generation case produces the greatest fault currents and typically results in the largest arc-flash incident energy. This allows for employees and the public to be protected regardless of how much generation is online at the time of an arc-flash incident. Each circuit was evaluated and the greatest calculated arc energy was recorded for each type of equipment on the associated circuit. The tables below show the calculated results of the arc-flash study at the 12.47kV voltage level.

Almena Circuit Arc-Flash Findings

Type of Equipment	Arc-Energy (J/cm^2)	Arc-Energy (cal/cm^2)	Hazard Risk Category
Line Recloser	1.18	0.28	HRC1
Overhead Wire	0.92	0.22	HRC1
Underground Cable	1.16	0.28	HRC1
Pole-Mount Transformer	0.90	0.22	HRC1
Pad-Mount Transformer	1.16	0.28	HRC1
Switchgear/Primary Cabinets	1.16	0.28	HRC1
Overhead Fuse	0.91	0.22	HRC1
Overhead Switch	1.24	0.30	HRC1

Red notes the use of a face shield is required

North Circuit Arc-Flash Findings

Type of Equipment	Arc-Energy (J/cm^2)	Arc-Energy (cal/cm^2)	Hazard Risk Category
Line Recloser	1.74	0.42	HRC1
Overhead Wire	1.36	0.32	HRC1
Underground Cable	1.65	0.39	HRC1
Pole-Mount Transformer	1.36	0.32	HRC1
Pad-Mount Transformer	1.61	0.38	HRC1
Switchgear/Primary Cabinets	1.61	0.38	HRC1
Overhead Fuse	1.29	0.31	HRC1
Overhead Switch	1.24	0.30	HRC1

Red notes the use of a face shield is required

South Circuit Arc-Flash Findings

Type of Equipment	Arc-Energy (J/cm^2)	Arc-Energy (cal/cm^2)	Hazard Risk Category
Line Recloser	1.74	0.42	HRC1
Overhead Wire	1.35	0.32	HRC1
Underground Cable	1.49	0.36	HRC1
Pole-Mount Transformer	1.35	0.32	HRC1
Pad-Mount Transformer	1.49	0.36	HRC1
Switchgear/Primary Cabinets	1.49	0.36	HRC1
Overhead Fuse	1.24	0.30	HRC1
Overhead Switch	1.34	0.32	HRC1

Red notes the use of a face shield is required

Walmart Circuit Arc-Flash Findings

Type of Equipment	Arc-Energy (J/cm^2)	Arc-Energy (cal/cm^2)	Hazard Risk Category
Line Recloser	1.16	0.28	HRC1
Overhead Wire	0.90	0.21	HRC1
Underground Cable	1.07	0.26	HRC1
Pole-Mount Transformer	0.90	0.21	HRC1
Pad-Mount Transformer	1.03	0.25	HRC1
Switchgear/Primary Cabinets	1.01	0.24	HRC1
Overhead Fuse	0.83	0.20	HRC1
Overhead Switch	0.90	0.21	HRC1

Red notes the use of a face shield is required

The maximum arc flash boundary at the above voltage level was calculated and determined to be 1'-6". This is less than the 2'-7" minimum approach distance. Therefore, all individuals not in the appropriate PPE shall remain a minimum of five (5) feet away from energized equipment, lines, or parts at this voltage while work is being conducted. Five (5) feet adds an additional safety factor to the calculated arc flash boundary distance. Non-utility personnel or unqualified persons shall remain twenty (20) feet away while live work is being completed.

Conclusion

The NESC and OSHA require electrical utilities to complete an assessment to determine the potential exposure to an arc at all points of their electrical system or utilize standardized tables. Use of NESC Table 410-1 for equipment operating below 1000V is a practical method for the Village of Paw Paw due to utility size and the number of locations operating in this voltage class. An 8 Cal/cm^2 PPE system is acceptable with the exception of 277/480V self-contained meter bases, cabinets, switchgear and MCC's.

NESC Table 410-2 is not practical for the 7.2/12.47kV distribution system since it does not cover phase-to-phase fault conditions or faults in pad-mount equipment (contained in a box). Calculations show that a 4 Cal/cm^2 PPE system is acceptable for all work being completed on the 7.2/12.47kV distribution system. The amount of energy contained in an arcing event at this voltage level was minimal due to the low level of fault current and the fast operating times of the relcosers. In the future if the settings on the recloser controllers is changed, a review of this arc flash study should take place.

The attached tables provide the required PPE, the minimum distance that an employee can be while not wearing the required PPE of the corresponding hazard level, the arc-energy, and the hazard risk category. PPE requirements are provided based on the the rated voltage, and job duty/equipment type. Results are NOT provided for the secondary (<1000V) side of transformers, due to the excessive number of points to analyze. The NESC Table 410-1 covers all equipment under 1000V and shall be followed.

Arc energy calculations and PPE requirements have been based on information provided by American Electric Power and the Village of Paw Paw to develop the system model from which the arc energy values were determined. Changes in equipment settings or system configuration

may invalidate the calculations, values and PPE requirements. A periodic review of the data required for these calculations should be completed by the Village of Paw Paw to ensure the proper clothing system is being provided to employees.

Village of Paw Paw
Under 1000Vac
Required PPE / Arc-Flash Table

NESC Table 410-1

Equipment Type	Nominal Voltage Range and cal/cm^2		
	50V to 250V	**251V to 600V**	**601V to 1000V**
Self-contained meters/cabinets	4	20	30
Pad-mounted transformers	4	4	6
CT meters and control wiring	4	4	6
Metal-clad switchgear or motor control centers	8	40	60
Pedestals, pullboxes, or hand holes	4	8	12
Open air (includes lines)	4	4	6
Panel boards – single phase (all)/three phase(<100A)	4	8	12
Panel boards – three phase (>100 A)	4	Exceeds 60 cal/cm^2 perform arc hazard analysis	Exceeds 60 cal/cm^2 perform arc hazard analysis

Red notes the use of face shield is required

Village of Paw Paw
12.47kV System Equipment
Required PPE / Arc-Flash Table

Job Duty/Equipment Type	Voltage	Arc-Energy (J/cm^2)[2]	Cal-System (cal/cm^2)	Hazard Risk Category (HRC)	Arc Flash Boundry (ft-in)[1]
Engineering Tasks	All	N/A	N/A	0	N/A
Control House Front Panel Operations	N/A	N/A	N/A	0	N/A
Wiring Tasks	≤240V	<16.74	4	1	20'-0"
Operating Air-Break Switches[3]	12.47kV	1.34	4	1	5'-0"
Line Recloser[3]	12.47kV	1.74	4	1	5'-0"
OH Conductors[3]	12.47kV	1.36	4	1	5'-0"
UG Conductors[3]	12.47kV	1.65	4	1	5'-0"
Polemount Transformers[3]	12.47kV	1.36	4	1	5'-0"
Fuses in Open Air[3]	12.47kV	1.29	4	1	5'-0"
Sectionalizing Cabinets & Padmount Switchgear[3]	12.47kV	1.61	4	1	5'-0"
Padmount Transformers[3]	12.47kV	1.61	4	1	5'-0"

Notes:

1. Distance personnel must observe if not wearing required PPE, molten metal up to 20' on equipment less than 240V per OSHA study.
2. Calculated using the maximum fault at the nominal system voltage
3. Based on a working distance of 18".

Hazard Risk Category 1

Protective Clothing, Nonmelting or Untreated Natural Fiber (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials) with a Fabric Weight of at least 4.5 oz/yd2. Shirt (long sleeve), Pants (long), Safety glasses or safety goggles (SR), Hearing Protection (ear canal inserts) Heavy duty leather gloves (AN)

Hazard Risk Category 2

Arc-rated long-sleeve shirt and pants or arc-rated coverall. Arc-rated face shield or arc flash suit hood for underground equipment. Arc-rated jacket, parka, rainwear, or hard hat liner (AN). Hard hat, safety glasses or safety goggles (SR), hearing protection (ear canal inserts), heavy duty leather gloves, leather work shoes (AN).

Hazard Risk Category 3

Arc-rated long-sleeve shirt (AR), arc-rated pants (AR), arc-rated coverall (AR), arc-rated arc flash suit (AR), arc rated arc flash suit pants (AR), arc-rated arc flash suit hood, arc-rated gloves, Arc-rated jacket, parka, rainwear, or hard hat liner (AN). Hard hat, safety glasses or safety goggles (SR), hearing protection (ear canal inserts), leather work shoes (AN).

AN: as needed (optional). AR: as required. SR: selection required.