ENERGY INDUSTRY

ELECTRICAL ENGINEERING ASSOCIATES

RECOMMENDED PRACTICES FOR APPLICATION OF IEEE 1584-2018 IN THE PETRO-CHEMICAL INDUSTRY

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Disclaimer

This document is a collection of recommended best practices for application of IEEE 1584-2018 *IEEE Guide for Performing Arc-Flash Hazard Calculations.* This document was assembled by a group of volunteers from the Energy Industry Electrical Engineering Association (EIEEA).

This document is not intended to replace knowledge of IEEE 1584 and its proper application. Users of this document shall be knowledgeable about the latest edition of IEEE 1584 and IEEE 1584.1 for its proper application. Users of this document must apply it and IEEE 1584 using sound engineering judgment.

Although the EIEEA believes this document provides suitable approaches for the practical and accurate application of IEEE 1584-2018, the EIEEA does not guarantee the approaches described will result in "worst case" incident energy calculations. The EIEEA does not guarantee this document covers all types of energized work tasks nor ensures safety or protection from the hazards of energized electrical work. The approaches described are expected to be a suitable approach for most real-life situations.

Users of this document must ensure that the approaches recommended herein are validated and appropriate for their specific real-world electrical systems. The authors are not liable for any misapplication nor is any guarantee implied that the approaches described are suitable for all electrical systems.

It should be noted that the methodology contained in this document considers energized work only at typical energized work locations. For example, it is expected that energized work such as troubleshooting would be performed in starter buckets in low voltage MCCs. However, it is not expected that energized work would be conducted on the bus bars of these low voltage MCCs. For this and other reasons, the user must consider whether the recommended practices in this document are suitable for their use.

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1.0 Introduction

This document provides a practical methodology for applying IEEE 1584-2018 *IEEE Guide for Performing Arc-Flash Hazard Calculations.* The identified approaches will generally provide results that are moderately conservative without requiring analysis of every possible combination of enclosure sizes, gaps, electrode configurations, etc.

Electrical equipment type and configuration could result in different incident energy levels calculated within the total assembly. Factors affecting these calculations include:

- Available bolted fault current
- Voltage
- Electrode configuration
- Gap between conductors
- Enclosure size (when applicable)
- Arcing Duration
- Working Distance

In a specific piece of electrical equipment, available bolted fault current and open circuit voltage will remain essentially the same throughout the electrical equipment (e.g. throughout a MCC). However, the other factors listed may change depending on the specific location being studied within the electrical equipment.

It may be impractical to calculate incident energy for all locations in each piece of electrical equipment, for example in a low voltage MCC. Many types of electrical equipment will have varying enclosure sizes, gaps and electrode configurations depending on the specific location. This could result in a large number of configurations to study. The recommendations in this document will help to ensure an approach that yields moderately conservative and accurate results based on sound engineering judgment and good engineering practices.

This document also provides guidance on low capacity systems (≤ 240 V, < 125 kVA) to help the user reduce the locations where calculations are required. See Sections 10.0 and 11.0 for more details.

Many types of facilities incorporate electrical systems with voltages above 15 kV, DC systems and single-phase systems. IEEE 1584-2018 does not apply to any of these electrical systems.

2.0 Purpose

The purpose of this document is to provide a practical methodology for applying IEEE 1584-2018 *IEEE Guide for Performing Arc-Flash Hazard Calculations.* The identified approaches are expected to produce incident energy calculation results that are moderately conservative without requiring analysis of every possible combination of enclosure sizes, gaps, electrode configurations, etc.

3.0 Scope

This document applies to incident energy analysis of three-phase, 208 V to 15 kV, AC, electrical systems in onshore oil and gas facilities. Some guidance is also provided for analysis of single-phase and DC electrical systems.

- For electrical systems above 15 kV, the user should investigate the method that their modelling software uses and determine its suitability. A simple 69-25 kV system was modelled using three common electrical modelling software packages (ETAP, SKM and EasyPower). It was found that the results were relatively consistent across all three and for several different optional methods within each software package. In general, it is believed that all three software packages will yield valid, conservative results when used with their default selections.
- DC electrical systems (if deemed required): the Doan “Maximum Power” method described in “Arc Flash Calculations for Exposures to DC Systems” (IEEE *Transactions on Industry Applications,* Vol. 46., No. 6) may be used but may result in overly conservative results. See also “DC arc models and incident energy calculations” by Ammerman et al (IEEE *Transactions on Industry Applications*, Vol. 46, No. 5) for more guidance to select the appropriate method for the specific situation.

4.0 Model Input Data and Software Settings

It is highly recommended that the user follows IEEE 1584-2018 section 6.2 and IEEE 1584.1-2013 for guidance on the equipment parameters required, the specific requirements for completing the incident energy analysis study and the recommended content for the report issued. The following guidelines are minimums. Models should be as detailed as practical for the given electrical system size and complexity.

- Calculations shall be based on IEEE 1584-2018. Check that this is selected in the arc flash calculation method selection screen.
- Ensure electrode configuration, gap and enclosure size are all properly specified.
- Arc duration shall be limited to a maximum of two seconds unless there is valid reason to deviate (e.g. egress from the area is impeded)
- Ensure selected working distances are appropriate for each piece of equipment based on the equipment type and the tasks performed at the equipment.

- Cable lengths shall be included. Typical R and X values may be used. Lengths to be as close as practical using cable schedules, field measurements, or scaled plot plans.
- Transformer Z% and X/R value.
- For systems supplied by transformers rated up to 1 MVA, motors less than 50 hp may be grouped, and motors rated 50hp and larger shall be modeled individually. For electrical systems supplied by transformers greater than 1 MVA, motors less than 100 hp can be grouped. For electrical systems supplied by transformers greater than 2 MVA, motors less than 200 hp can be grouped.
- Utility contribution to be obtained from or confirmed by the utility company.
- Generators to be modeled.
- All appropriate scenarios shall be modelled including expected normal and abnormal operations. Scenarios to be considered may include, but are not limited to:
    - Normal operating load, zero load, emergency load
    - Bus ties closed/open, standby/parallel generators running or not running
    - Utility feeds connected or running in islanded mode.
    - Large synchronous motors may also justify a scenario based on magnitude of back feed.
- For relays with multiple setting groups or other arc-reduction protective devices, all incident energy levels (including but not limited to normal and arc-reduction protection setting) shall be calculated. (i.e. with the arc reduction mode enabled and disabled)
- The installation being studied must be within the stated range for IEEE 1584-2018 for all parameters, including but not limited to: voltage, gap, bolted fault current, working distance and enclosure dimensions.
- IEEE 1584-2018 and this document assume that all equipment is installed, operated, and maintained as required by applicable codes, standards, and manufacturers' instructions, and applied in accordance with the equipment's ratings. Any deviation from these assumptions will invalidate the incident energy calculations.

5.0 Electrode Configuration

Recommendation

Use Table 1 to determine the electrode configuration that is suitable for each piece of equipment. For equipment that is not covered in Table 1, refer to guidance provided in IEEE 1584-2018 (including but not limited to section 6.6 and Annexes C, F, and G) to determine the appropriate electrode configuration.

Background

Electrical equipment electrode configuration has a very significant effect on the incident energy levels produced during an arc flash incident. The location of the arc whether it is in an enclosure or in open air is also very significant. IEEE 1584-2018 requires the user to select the appropriate electrode configuration from the following list:

VCB – vertical conductors/electrodes inside a metal box/enclosure

VCBB – vertical conductors/electrodes terminated in an insulating barrier inside a metal box/enclosure

HCB – horizontal conductors/electrodes inside a metal box/enclosure

VOA – vertical conductors/electrodes in open air

HOA – horizontal conductors/electrodes in open air

Note that the designations of vertical and horizontal were determined based on the test set-up used in developing IEEE 1584-2018. In general, if the arcing electrodes point at the worker, a horizontal configuration should be used for the incident energy calculation. Examples of electrodes pointing at a worker include the stabs for rack-in circuit breakers or the enclosed terminals of an oil-filled transformer. A less obvious example of where a horizontal configuration should be used for the incident energy calculation is if a worker was underneath bus bars that run vertically; in that case the conductors point at the worker and the plasma jets would be directed towards the worker.

Determining open air vs enclosure is easy and quickly narrows down the choices. Selecting the correct electrical equipment electrode configuration for an assembly can become more complicated. Based on the content in IEEE 1584-2018, the consensus best practice from the EIEEA 1584 Working Group for selecting electrode configuration was developed and is provided in Table 1.

It is worth noting that within electrical equipment enclosures, selection of HCB results in the highest calculated incident energy levels, then usually VCBB, followed by VCB*. However, HCB is the correct electrode configuration in only a small number of real-world applications and it results in much higher calculated incident energy than other electrode configurations. It is therefore not prudent to simply select HCB for all cases as this could result in a requirement for workers to wear much higher ATPV rated PPE than is required for the actual work being performed.

* - In some cases, VCB will result in a higher incident energy calculation than VCBB due to differences in arcing currents and the time-current curve of the specific protective device that must

clear. It is therefore recommended to calculate both VCB and VCBB instead of just VCBB where there are vertical electrode configurations.

It is recommended that for equipment such as low voltage MCCs where HCB is not studied, warning signs are placed on end panels advising that the end panel should not be removed while the equipment is energized. The incident energy at these locations would be based on horizontal electrode configurations and would result in much higher incident energy levels than anywhere else in the equipment.

6.0 Gap

Recommendation

Use actual gap measurements, where it is practical to obtain these. Where there are multiple gap measurements for a single piece of equipment, use the largest gap measurement. Where it is impractical to obtain actual gap measurements, use the values in Table 1.

Background

After studying the impact of gap on the results of the IEEE 1584-2018 incident energy calculations, it was determined that larger gaps result in increased energy (with all other factors remaining equal). Furthermore, larger gaps result in lower arcing currents. This information is very useful as the fault clearing time for a longer gap will be the same or a longer duration than for a shorter gap. Increasing the gap therefore always results in increased incident energy (within the stated range of IEEE 1584-2018).

Actual gap measurements should be used where practical. However, for electrical equipment where the gap varies or is not known, the suggested values for Gap in Table 1 should yield moderately conservative results. Table 1 indicates consensus best practice when the gap varies within a piece of electrical equipment.

Table 1 – Typical Selections for Electrode Configuration and Gap

Electrical Equipment Type (and location where appropriate)	Typical Electrode Configuration	Gap (Note 1)	Comments
Lighting/Distribution Panels and Panelboards (<250 V)	VCB and VCBB	25 mm	
Lighting/Distribution Panels and Panelboards (250-600 V)	VCB and VCBB	25 mm	
Low Voltage MCC (< 1000 V) All locations except end panels	VCB and VCBB	25 mm	
Transformer terminations (enclosed)	HCB	Use actual gap	Note 3
Transformer terminations (vertical bushings, free air)	VOA	Use actual gap	
Low Voltage Switchgear (< 1000 V)	HCB	32 mm	Notes 2, 4
Medium Voltage MCC (up to 5 kV)	Study Engineer to Determine	104 mm	Note 2
Medium Voltage Switchgear (up to 5 kV)	HCB	104 mm	Notes 2, 4
Medium Voltage MCC (5-15 kV)	Study Engineer to Determine	152 mm	Note 2
Medium Voltage Switchgear (5-15 kV)	HCB	152 mm	Note 2

Notes

1. The gap used in the calculations should be the actual gap whenever possible. When the gap is not known or varies throughout the electrical equipment, the gap in this Table can be used and will typically yield accurate or moderately conservative results.
2. HCB typically applies only when accessing main bus bars that run horizontally and are run towards the worker. Examples: accessing bus stabs through shutters with circuit breaker removed, using a testing truck, or sections of switchgear close-coupled to MCC.
3. HOA for CAN/CSA C227.4 (liquid-filled padmount) transformers with horizontal bushings behind a clamshell cover.
4. For breaker racking, the electrode configuration may be better represented by VCBB. Consideration should be given to including this configuration in the study results and equipment labelling. Actual working distance should also be considered if calculating incident energy specifically for racking operations.

7.0 Electrical Equipment Enclosure Size (when applicable)

Recommendation

For incident energy calculations in enclosures (i.e. not in open air), use actual enclosure measurements whenever possible. For equipment that has multiple enclosure sizes, use the smallest enclosure size to a minimum of 508 mm (H) x (508 mm (W) x 203 mm (D) (20” (H) x 20” (W) x 8” (D)).

Discussion

Where possible, actual enclosure measurements should be used. Actual dimensions can be obtained from direct measurements or electrical equipment drawings. However, it is recommended that enclosure measurements are not taken where this requires exposure to energized conductors or circuit parts. It is also noted that approximations within +/- 10% are acceptable as results of the incident energy calculations will be a within a few percent.

IEEE 1584-2018 denotes two types of enclosures: “Typical” and “Shallow”. Shallow enclosures are for enclosures with depth less than 203 mm (8”), height and width less than 508 mm (20”), and voltages less than or equal to 600 V. For Shallow enclosures, incident energy calculation results increase as the size of the enclosure increases (until the height or width reaches 508 mm at which point the enclosure becomes “Typical”). For Typical enclosures, the IEEE 1584-2018 calculation method results in increased incident energy for smaller enclosures. The limits to this relationship are at an enclosure size of 508 mm x 508 mm (20” x 20”). Enclosures that are smaller than this size do not result in higher incident energy levels.

For electrical equipment such as MCC’s that have multiple enclosure sizes, it is recommended that the smallest enclosure size, to a minimum of 508 mm (H) x 508 mm (W) x 203 mm (D), be studied and reflected on the equipment labelling. Below 508 mm (H) x 508 mm (W), the incident energy calculation either holds steady (for “Typical” enclosure depths) or decreases (for “Shallow” enclosure depths).

Enclosure sizes should be modeled for both the line side and the load side of the equipment’s integral main protective device (e.g. the main circuit breaker in a low voltage motor control center). The line side should be modeled with actual dimensions (or close approximations). The dimensions used for the load side should be modeled as the smallest enclosure size, without going below 508 mm x 508 mm x 203 mm.

8.0 Arc Duration

The fault clearing time used in the arcing fault calculations should be the expected fault clearing time of the upstream protective device. The fault clearing time used in the calculation should be limited to a maximum of two seconds except where egress is hampered (e.g. confined spaces, locations requiring ladders, bucket trucks for access, egress path is through the arcing location, abnormal body positioning).

9.0 Working Distance

Use the working distances in IEEE 1584-2018 Table 10 (copied here for convenience) unless there is valid reason to deviate.

Equipment class	Working distance	
	mm	in
15 kV switchgear	914.4	36
15 kV MCC	914.4	36
5 kV switchgear	914.4	36
5 kV MCC	914.4	36
Low-voltage switchgear	609.6	24
Shallow low-voltage MCCs and panelboards	457.2	18
Deep low-voltage MCCs and panelboards	457.2	18
Cable junction box	457.2	18

10.0 Low Capacity 208 V Panels Fed from a Transformer

Recommendations

I. Per IEEE 1584-2018, sustainable arcs are possible but less likely in three-phase systems operating 240 V nominal or less with an available short-circuit current less than 2000 A. For systems in this category, there is no need to calculate the incident energy if workers wear minimum ATPV 8 cal/cm^2 arc flash PPE when performing an energized work task. Alternatively, users may want to determine for themselves if the guidance from IEEE 1584-2018 means that there is no arc flash hazard for these systems in which case the user could determine there is no need for arc flash PPE. The wording in IEEE 1584-2018 is not definitive; however, it is expected that 240 V and lower systems with available short circuit currents less than 2000 A will not sustain an arc and therefore arc flash PPE is not required for these very low capacity systems.

II. Calculations of arc flash incident energy for 120/208 V panels fed from transformers rated 30 kVA or less are not required if workers wear minimum ATPV 8 cal/cm^2 arc flash PPE when performing a work task that could result in an arc flash. Note also that some 30 kVA transformers with higher impedance will have less than 2000 A available short-circuit current on the secondary side (see above for further guidance on this).

III. Calculations of arc flash incident energy may be required for panels fed from a 45 kVA transformer. The user may find that their specific installations always result in incident energy calculation results below 8 cal/cm^2. Incident energy calculation results will be highly dependent on transformer and system impedances and the tripping characteristic of the upstream protection device.

IV. Calculations of arc flash incident energy are required for panels fed from a transformer rated more than 45 kVA.

V. For single phase electrical systems, follow the guidance provided in IEEE 1584-2018, clause 4.11:
"*Single-phase systems can be analyzed by using the single-phase bolted fault current to determine the single-phase arcing current (using the equations provided in 4.4 and 4.10). The voltage of the single-phase system (line-to-line, line-to-ground, center tap voltage, etc.) can be used to determine the arcing current. The arcing current can then be used to find the protective device opening time and incident energy by using the three-phase equations provided in this guide. The incident energy result is expected to be conservative*."

VI. For locations other than panels, it may be necessary to perform arc flash incident energy calculations if an energized work task is required to be completed on that electrical equipment.

Background

IEEE 1584-2018 contains a significant change with respect to systems below 240 V fed by a single transformer sized 125 kVA or less. The previous version of IEEE 1584 (1584-2002), stated that this electrical equipment need not be considered. IEEE 1584-2018 now states that low capacity 208 V electrical systems and electrical equipment need to be considered when available fault current exceeds 2000 A. This section provides guidance on how to handle arc flash incident energy calculations for these electrical systems.

It is recommended that minimum ATPV 8 cal/cm^2 arc flash PPE is worn when performing work tasks on energized 120/208 V systems. There are two methods to demonstrate that minimum ATPV 8 cal/cm^2 arc flash PPE is adequate for 120/208 V systems:

a. Ensure that the available bolted fault current is less than 2000 A
b. Determine the parameters that ensure that the maximum calculated incident energy will be less than 8 cal/cm^2

IEEE 1584-2018 states that "Sustainable arcs are possible but less likely in three-phase systems operating at 240 V nominal or less with an available short-circuit current less than 2000 A".

Note that this statement does not state it is impossible to sustain an arc on electrical equipment rated 240 V or less with available short-circuit current less than 2000 A; it only states that it is "less likely".

For 120/208 V systems fed by a transformer, the following systems will have bolted short circuit currents that are always less than 2000 A (even if an "infinite bus" is assumed on the supply side):

- 15 kVA transformers (where Z >= 2.1%)
- 30 kVA transformers (where Z >= 4.2%)

(Note that these could be applied conservatively to single phase (120/240V) system since comparable size single phase transformers have slightly higher typical impedances.)

For the systems above, it is not likely that arc flashes would sustain and therefore minimum ATPV 8 cal/cm^2 arc flash PPE would adequately protect the worker.

However, some 15 kVA and 30 kVA transformers will have impedances that are less than the values shown above.

Table 2 shows the worst-case incident energy calculations for a lighting/distribution panel fed by a 15/30/45/75/112.5 kVA transformer with the following parameters:

- 208 V (line-to-line)
- 508 mm (20”) x 508 mm (20”) x 203 mm (8”) enclosure (H x W x D)
- VCBB electrode configuration
- 2 second clearing time
- 25 mm (1”) gap
- 457 mm (18”) working distance
- “Infinite bus” supply

<u>Panels fed from 15 kVA Transformers</u>
For 15 kVA transformers with impedances from 1.5% and up, the incident energy will be below 8 cal/cm^2.

<u>Panels fed from 30 kVA Transformers</u>
For 30 kVA transformers with impedances from 2.5% and up, the incident energy will be below 8 cal/cm^2.

For 30 kVA transformers with an impedance of 2%, the incident energy is 8.6 cal/cm2. This value is very close to 8 cal/cm2 (the minimum PPE rating). This is deemed acceptable for personnel wearing minimum ATPV 8 cal/cm2 arc flash PPE as:

- an arcing duration of 2 seconds is extremely conservative
- actual system impedances will reduce the fault current and therefore the incident energy.

For a 30 kVA transformer with an impedance of 1.5%, the incident energy will be 12 cal/cm^2 if we assume a 2 second clearing time. However, for this transformer impedance, it is expected that the arcing current will be high enough to result in tripping times well below 1 second (likely in the instantaneous region of the protective device's protection curve). In that case, the incident energy will also be well below 8 cal/cm^2.

It is therefore not necessary to perform incident energy calculations for panels fed from transformers rated 30 kVA and below if workers will wear minimum ATPV 8 cal/cm^2 PPE when there is a risk of arc flash occurring.

<u>Panels fed from 45 kVA Transformers</u>
Incident energy calculations may be required for 45 kVA transformers. Some 45 kVA systems will have less than 8 cal/cm^2 of incident energy due to either quick interrupting times by the upstream protection breaker or due to high transformer and system impedances that limit the arcing current. The user will need to investigate their specific installations for their 45 kVA transformers.

<u>Panels Fed from >45 kVA Transformers</u>
For transformers rated greater than 45 kVA, incident energy calculations are required for each system.

Table 2 – Worst Case Incident Energy Calculations for 208 V Panels

Incident Energy Calculation Assumptions
Gap = 25 mm (typical gap)
Enclosure size = 20" x 20" x 8" (results in worst case)
Working Distance = 18" (typical working distance)
Voltage = 208 V
Electrode Configuration = VCBB (typical for panels)
Clearing time = 2 seconds
IEEE 1584-2018 calculations

15 kVA	480/120-208 or 600/120-208		
		FLA x 1.25	Protective Device
FLA @ 208 V	41.7		
FLA @ 480 V	18.1	22.6	30 A
FLA @ 600 V	14.5	18.1	20 A

Impedance	208 V Bolted Fault	Minimum Arcing Current	current @ 480 V	480 V CB Rating	multiples	current @ 600 V	600 V CB rating	multiples	Incident Energy (cal/cm2) I.E. at 2 seconds	Comments
1.50%	2779.0	1110	481.0	30	16.0	384.8	20	19.2	5.4	
2.00%	2084.3	830	359.7	30	12.0	287.7	20	14.4	3.8	
2.50%	1667.4	670	290.3	30	9.7	232.3	20	11.6	3	below 2000 A bolted fault
3.00%	1389.5	560	242.7	30	8.1	194.1	20	9.7	2.4	below 2000 A bolted fault
4.00%	1042.1	420	182.0	30	6.1	145.6	20	7.3	1.8	below 2000 A bolted fault
5.00%	833.7	340	147.3	30	4.9	117.9	20	5.9	1.4	below 2000 A bolted fault

30 kVA	480/120-208 or 600/120-208		
		FLA x 1.25	Protective Device
FLA @ 208 V	83.4		
FLA @ 480 V	36.1	45.2	50 A
FLA @ 600 V	28.9	36.1	40 A

Impedance	208 V Bolted Fault	Minimum Arcing Current	current @ 480 V	480 V CB Rating	multiples	current @ 600 V	600 V CB rating	multiples	Incident Energy (cal/cm2) I.E. at 2 seconds	Comments
1.50%	5558.0	2280	988.0	50	19.8	790.4	40	19.8	12.2	likely trips instantaneously
2.00%	4168.5	1690	732.3	50	14.6	585.9	40	14.6	8.6	
2.50%	3334.8	1340	580.7	50	11.6	464.5	40	11.6	6.6	
3.00%	2779.0	1110	481.0	50	9.6	384.8	40	9.6	5	
4.00%	2084.3	830	359.7	50	7.2	287.7	40	7.2	4	
5.00%	1667.4	670	290.3	50	5.8	232.3	40	5.8	3	below 2000 A bolted fault

45 kVA	480/120-208 or 600/120-208		
		FLA x 1.25	Protective Device
208 V FLA	125.1		
480 V FLA	54.2	67.7	70 A
600 V FLA	43.4	54.2	60 A

Impedance	208 V Bolted Fault	Minimum Arcing Current	current @ 480 V	480 V CB Rating	multiples	current @ 600 V	600 V CB rating	multiples	Incident Energy (cal/cm2) I.E. at 2 seconds	Comments
1.50%	8337	3530	1529.7	70	21.9	1223.7	60	20.4	20	likely trips instantaneously
2.00%	6253	2590	1122.3	70	16.0	897.9	60	15.0	14	
2.50%	5002	2040	884.0	70	12.6	707.2	60	11.8	10.7	
3.00%	4169	1690	732.3	70	10.5	585.9	60	9.8	8.6	
4.00%	3126	1250	541.7	70	7.7	433.3	60	7.2	6.2	
5.00%	2501	1000	433.3	70	6.2	346.7	60	5.8	4.7	

75 kVA	480/120-208 or 600/120-208		
		FLA x 1.25	Protective Device
208 V FLA	208.4		
480 V FLA	90.3	112.9	125 A
600 V FLA	72.3	90.3	100 A

Impedance	208 V Bolted Fault	Minimum Arcing Current	current @ 480 V	480 V CB Rating	multiples	current @ 600 V	600 V CB rating	multiples	Incident Energy (cal/cm2) I.E. at 2 seconds	Comments
1.50%	13895	6170	2673.7	125	21.4	2138.9	100	21.4	37.6	likely trips instantaneously
2.00%	10421	4500	1950.0	125	15.6	1560.0	100	15.6	26.3	
2.50%	8337	3530	1529.7	125	12.2	1223.7	100	12.2	19.9	
3.00%	6948	2900	1256.7	125	10.1	1005.3	100	10.1	15.9	
4.00%	5211	2130	923.0	125	7.4	738.4	100	7.4	11.2	
5.00%	4169	1690	732.3	125	5.9	585.9	100	5.9	8.6	

112.5 kVA	480/120-208 or 600/120-208		
		FLA x 1.25	Protective Device
208 V FLA	312.6		
480 V FLA	135.5	169.3	175 A
600 V FLA	108.4	135.5	150 A

Impedance	208 V Bolted Fault	Minimum Arcing Current	current @ 480 V	480 V CB Rating	multiples	current @ 600 V	600 V CB rating	multiples	Incident Energy (cal/cm2) I.E. at 2 seconds	Comments
1.50%	20843	9410	4077.7	175	23.3	3262.1	150	21.7	60.8	likely trips instantaneously
2.00%	15632	7000	3033.3	175	17.3	2426.7	150	16.2	43.4	
2.50%	12506	5500	2383.3	175	13.6	1906.7	150	12.7	33	
3.00%	10421	4500	1950.0	175	11.1	1560.0	150	10.4	26.3	
4.00%	7816	3290	1425.7	175	8.1	1140.5	150	7.6	18.4	
5.00%	6253	2590	1122.3	175	6.4	897.9	150	6.0	14	

11.0 Small Generators

Recommendations

Incident energy analysis is not required if workers wear minimum ATPV 8 cal/cm^2 arc flash PPE while working on low capacity generator-fed systems when the system is below the following limits:

- 208 V systems fed directly by a generator rated 60 kVA (48 kW) or less with 9% Xd”
- 480 V systems fed directly by a generator rated 35 kVA (28 kW) or less with 9% Xd”
- 600 V systems fed directly by a generator rated 45 kVA (36 kW) or less with 9% Xd”

Background

Similar to the discussion in Section 10.0, some small generators will also have available fault currents that are either below the applicability limits noted in IEEE 1584-2018 or, in the case of 208 V systems, may not be capable of sustaining an arc flash. In these cases, the arc flash incident energy will be low. However, IEEE 1584-2018 does not state that there is zero risk from arc flash incident energy in systems below these limits.

If workers wear minimum ATPV 8 cal/cm^2 arc flash PPE while working on these low capacity generator systems, there is no need to calculate the incident energy.

- For 208 V systems fed directly by a generator rated 60 kVA (48 kW) or less with 9% Xd”, the available fault current is less than 2000 A which indicates that it is not likely that an arc flash would be sustainable (in accordance with IEEE 1584-2018 guidance). The maximum incident energy at these limits would be 7.9 cal/cm^2 (assuming HCB, 51 mm gap, 208 V, 2000 A available bolted fault current, 2 second duration, in a 508 mm (H) x 508 mm (W) x 203 mm (D) enclosure). This calculation is conservative, as Xd” only applies for a small fraction of the 2 second duration and impedance would increase after that.
- For 480 V systems fed directly by a generator rated 35 kVA (28 kW) or less with 9% Xd”, the available fault current is less than 500 A which is below the limits of applicability for IEEE 1584-2018. The maximum incident energy at these limits would be 4 cal/cm^2 (assuming HCB, 76 mm gap, 480 V, 500 A available bolted fault current, in a 508 mm (H) x 508 mm (W) x 203 mm (D) enclosure). This calculation is conservative, as Xd” only applies for a small fraction of the 2 second duration and impedance would increase after that.
- For 600 V systems fed directly by a generator rated 45 kVA (36 kW) or less with 9% Xd”, the available fault current is less than 500 A which is below the limits of applicability for IEEE 1584-2018. The maximum incident energy at these limits would be 4.6 cal/cm^2 (assuming HCB, 76 mm gap, 600 V, 500 A available bolted fault current, 2 second duration, in a 508 mm (H) x 508 mm (W) x 203 mm (D) enclosure). This calculation is conservative, as Xd” only applies for a small fraction of the 2 second duration and impedance would increase after that.