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Estimating Arc Flash Incident Energy in Open Channel Solutions

ABSTRACT

Arc flash is a significant concern for data center owners, operators, and designers everywhere. With the increased deployment of open channel solutions due to the flexibility and scalability delivered, operators need to understand the best safety practices for mitigating arc flash events.

One of the main benefits of open channel solutions is that the tap off units can be live inserted with no load being applied. As such, a specific risk assessment should be completed to accurately define the associated risk to operators. This is achieved by referring to the IEEE 1584-2018 and NFPA 70E and should be conducted by the data center operators or design consultants during the initial design stages.

INTRODUCTION

This paper provides guidance on applying calculating methods for arc flash events per IEEE 1584-2018. An arc flash study must be completed by component engineers. The information within this paper is an interpretation of the IEEE standard.

WHAT IS AN ARC FLASH?

The IEEE 1584-2018 defines an arc flash as 'an electric arc event with thermal energy dissipated as radiant, convective, and conductive heat.'

The NFPA 70E defines an arc flash hazard as 'a dangerous condition associated with the possible release of energy caused by an electric arc.'

Both definitions identify that a large amount of energy is released in an arc flash event, but what are the causes of such events? These causes can vary, but the IEC 61641 highlights the following as typical causes:

- conducting materials inadvertently left in assemblies during manufacturing, installation, or maintenance
- faults in materials or workmanship
- entry of small animals
- use of incorrect assembly for the application, resulting in overheating and, subsequently as internal arc
- inappropriate operating conditions
- incorrect operation
- lack of maintenance

The most common cause is human error.

Track Busway systems can minimize human error, while alternative power distribution systems typically have higher arc flash risks due to their specific construction and topology.

For more on the differences between these systems, please refer to the previous whitepaper, 'How to Reduce the Risks of Arc Flash Incidents in the Data Center,' found on www.starlinepower.com.

MANUFACTURING MITIGATION

Starline conducts a comprehensive test of all materials and assembled components to mitigate the possible faults within raw materials and the manufacturing process. These tests consist of a ground bond and dielectric withstand test.

Ground bond testing is where all metal connections, such as screws and pop rivets, are injected with 30Amps @ 8 v AC. This is a pass-fail test where the calculated resistance between the tested points needs to be less than 30 milli Ohms.

For the dielectric withstand test, the assembled busway is tested at 4000v AC for 5 seconds dwell time and 0 sec ramp time, requiring a max leakage of 5 milli amps or at 3100v DC for 2 sec dwell, 5 sec ramp and a max leakage of 10mA. These tests confirm the component's construction and detect any faults within the raw materials and assembly process.

PREVIOUS ARC FLASH TESTING

Starline has carried out arc flash testing to the IEC 61641 standard. This standard tests how low-voltage switchgear assemblies perform under an arcing event due to internal faults. Reviewing this data helps assign the IEEE calculation methods. A 250A Starline Track Busway system was tested, which consisted of a standard end feed and one section of busway.

A series of tests were conducted in compliance with IEC 61641 section 8. As a current protection device was used, the ignition wire size was determined by referencing table 2 of the IEC 61641.

With the ignition wire located in the end feed termination point, busway straight, and within the tap off box, the following test were conducted:

- 436v 15kA rms
- 436v 25kA rms
- 436v 36kA rms

Three tests were carried out at each fault level and after each test, a withstand test or power frequency withstand at 654v 60Hz was done. This confirmed the system was safe and the arc event caused no damage.

Fig 1: IEC 61641 Test Setup

IEEE 1584-2018 – HOW TO ADAPT THE PROCESS FOR STARLINE BUSWAY

The IEEE 1584-2018 provides information and a detailed analysis of how arc flashes occur and what factors alter the energy levels. The main constraints are:

- Enclosure size
- Tripping time of the protective device
- Bolted fault current available
- Gap between the conductors

The IEEE 1584 has two models depending on the open circuit voltage of the system under analysis. Because Starline's open circuit voltage is under 600V, the model used is for 208 ≤ Voc ≤ 600v.

After identifying the correct model, determine the equipment electrode configuration from table 9 of IEEE 1585-2018. These options are:

- HOA – horizontal conductors in open air
- VOA – vertical conductors in open air
- HCB – horizontal conductors inside an enclosure
- VCB – vertical conductors inside an enclosure
- VCCB – vertical conductors terminated in an insulating barrier inside an enclosure

As the IEEE 1584 pertains to all switchgear, you must determine which configuration best suits the application. With the open channel busway having a horizontal conductor configuration, the HCB format would be considered. Referring to the 61641 test results and table 9 of the IEEE 1584-2018, the arc flash direction coincides with the VCB configuration for an enclosed end feed unit and confirms the HCB for the straight section. This is because the HCB format directs the arc flash toward the operator.

After the electrode configuration is confirmed, a correction factor is required. This is determined by the size of the enclosure under analysis. The IEEE 1584-2018 has two classifications for this factor: typical
or shallow.

For the typical classification, the standard for a low voltage switchgear enclosure is 20" x 20" x 20" (508mm x 508mm x 508mm). Depending on the amperage of the busway, the end feed enclosures differ in size, and therefore the correction factor differs. This is because of

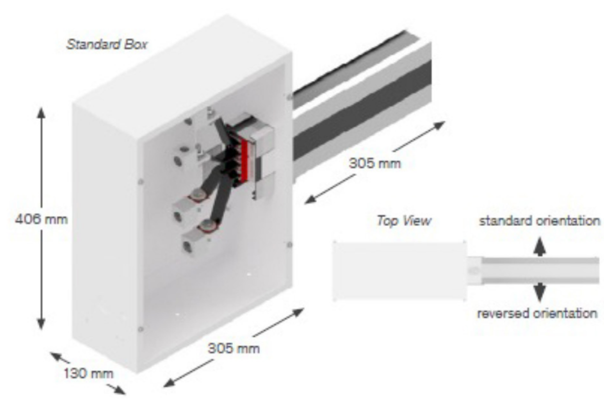

Fig 2: Standard T3 Enclosure

the difference in creepage and clearance requirements for each amperage rating. For example, if we take a standard Starline T3 160–225-amp enclosure, dimensions 305mm X 406mm x 130mm, it falls into the shallow classification and has a different correction factor equation.

The IEEE 1584 defines the difference between Shallow and Typical in section 4.8.2, which states:
The enclosure is 'shallow' when the following conditions are met:

A) The system voltage is less than 600V ac
B) Both the height and width are less than 508mm (20 in).
C) The enclosure depth is less than or equal to 203.2mm (8 in)

If any of these conditions are not met, the enclosure is considered typical.

As the T3 enclosure's nominal voltage is 400v and the dimensions are 406 x 305x 130mm, the enclosure falls within the specification detailed above. Each end feed enclosure must be assigned to either shallow or typical, as this affects the correction factor value.

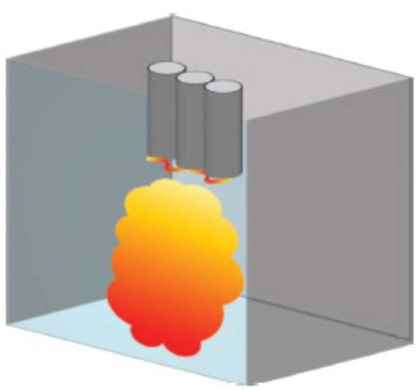

Fig 3: VCB Format Per IEEE1584-2018

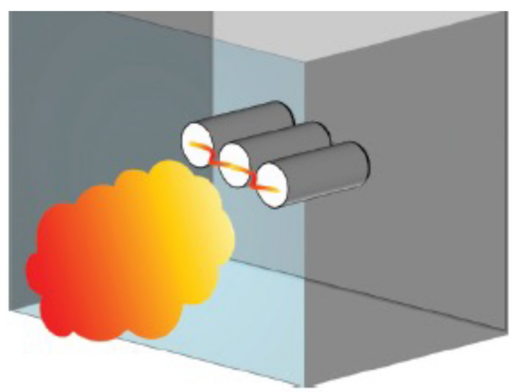

Fig 4: HCB Format Per IEEE1584-2018

The busway straights should be assessed separately. Fig 4, the HCB electrode configuration, shows the flash direction is directed to the operator. The enclosure is classified as shallow because of the busway straight dimensions and the data collected via the 61641 testing.

The busway straight section of any installation should be considered a single enclosure, taking the height and width per system amperage. We can generate a more accurate correction factor and energy calculation by limiting the open channel length to within the shallow classification of 508mm.

Using this approach, the energy and boundary can be provided at any point along the busway channel.

Taking all of these into account, the correction factor can be obtained using the formulas identified in the IEEE 1584-2018 section 4.8.

CORRECTION FACTORS

With any non-typical enclosure, a correction factor must be applied. The Starline range varies depending on the system amperage. A separate correction factor must be applied to the end feed and busway straight section, as the IEEE 1584 has a different equation for typical and shallow enclosures.

GAP MEASUREMENT

Measurement was taken from all four terminals to determine the gap in each configuration and amperage range; then, the longest distance was recorded in Table 1 for insertion into the IEEE 1584 formulas. This was completed for end feed units and busway straights because of the difference in dimensions. An analysis should be completed per the site-specific conditions.

Gap Per amperage (Max)		
SYSTEM	FEEDS	STRAIGHT
M160	33.51	35
M225	33.51	35
G/M250	50.02	91.4
G/M 400	50.02	92.4
G630/M630	48.087	92.4
M800	53.408	94
M1000	56.3	90.5
M1250	56.3	90.5

Table 1: Conductor Spacing

EXAMPLE CALCULATION

System Specification:

- Supply – 3000kVA 11kV / 400V 50Hz ISC 3Φ 51.55kA
- Busway – Metric 1250 Amps ISC 3Φ @ busway connection point 46.6576kA

Due to the transformer's proximity to the busway, this system had high fault currents throughout.

We require four main components to implement the IEEE 1584-2018 to this open channel busway section schematic. The short circuit current at the connection location is 46.6576kA, the system voltage at 0.4kV, and the tripping time of the upstream protective device. In this case, an ABB EMAX2 ACB – E1.2 Performance Level N 66kA Ekip Touch LSIG 1250A 3P was selected. This device gives an instantaneous trip time of 0.01 seconds or 10milli seconds.

Putting these values into the IEEE 1584-2018 low voltage formulas gives the results in Table 2. These have been calculated via an Excel document and Electrical OM software for comparison. These values are for the end feed cable termination unit, which would be a sealed unit under normal conditions.

End Feed M1250				
VALUES	EXCEL		ELECTRICAL OM	
	VCB	HCB	VCB	HCB
IARC_600 (kA)	31.7	30.81	NA	NA
IARC (kA)	24.5	23.6	24.16	23.21
E_600 (J/cm2)	3.2	6.658	3.14	6.655
BOUNDARY (mm)	345.3	525.4	341	525
IARC_MIN (kA)	21.4	20.9	21.08	19.88
E_MIN (J/cm2)	2.81	5.87	2.755	5.669
BOUNDARY (mm)	323.7	480	NA	NA

Table 2: Arc Flash Calculation Values End Feed

As the table shows, the HCB format is more conservative and provides larger values in incident energy and boundary. The difference between these two configurations is the PPE category that can be applied. VCB provides less than 4 J/cm2 compared to HCB, where values reach 6.65 J/cm2 resulting in a higher category for PPE. As detailed above, the end feed units are classified as VCB, but if a more conservative approach is required, HCB provides larger values.

If we compare these values collected from the end feed unit, where no-live work would be undertaken, to the busway sections, we see a small reduction in incident energy but an increase in arc flash boundary.

Busway M1250		
VALUES (HCB)	EXCEL	ELECTRICAL OnM
IARC_600 (kA)	30.08	N. A
IARC (kA)	22.87	22.19
E_600 (J/Cm2)	4.82	5.016
BOUNDARY (mm)	526	457
IARC_MIN (kA)	20.26	19.01
E_MIN (J/Cm2)	4.67	4.237
BOUNDARY (mm)	434	N. A
M1250	56.3	90.5

Table 3: Arc Flash Straight Values

As such, it is the best practice to model both enclosures and take the largest incident energy and arc flash boundary to determine the PPE category required for the installation. However, you should take into account normal operating conditions.

The max energy calculated from end feed and busway calculation is 6.658 J/cm2 / 5 = 1.33 Cal/cm2. This is considering the HCB format on the end feed enclosure. Considering that the end feed in normal operation consists of conductors inside an enclosure and are VCB configuration, the highest energy is from the busway at 4.67J/cm2, which is equal to 0.934 Cal/cm2.

Per the IEEE section 6.10 on analysis and determining the arc flash boundary: “The arc-flash boundary is the distance from a prospective arc flash where the incident energy is 5.0 J/cm2.” This is due to the assumption that 5 J/cm2 is the energy required to cause second-degree burns. The energy levels from this calculation fall below this level, but when referring to the NFPA 70E-15 annex H.3(a) table, a PPE list is provided for less than 1.2Cal cm2. This includes appropriately rated clothing, gloves, goggles, hard hat, hearing protection, and a face shield when required.

CONCLUSION

It is best practice to split the system when providing incident energy calculation in open channel systems. Because end feeds are generally larger than the busway channel, the energy and boundary results will differ. When considering the electrode configuration, this differs for the end feed unit and busway straight.

Under normal operation, end feeds are enclosed systems and therefore are categorized as VCB configuration; alternatively, HCB configuration is advised for all open channel calculations. As shown in the example calculation, the largest boundary was supplied by HCB format on the busway straights. For improved safety, take the largest energy and boundary calculation from the end feed and straight sections to determine the PPE category required.

Starline's open channel solutions combined with the rotating paddle reduce the risk to data center operators and users. Arc flash studies are essential in improving safety and mitigating risks to data center operators while working with open-channel solutions.

ABOUT STARLINE

Starline is a global leader in power distribution equipment. For more than 30 years, Starline Track Busway has provided data centers with the most flexible, reliable, and customizable overhead power distribution systems on the market today. Other Starline products include the Critical Power Monitor (CPM), which works with Starline Track Busway to improve energy efficiency, and Plug-In Raceway, the flexible, wall-mounted power distribution system.