ASSESSING LOW-VOLTAGE ARC HAZARDS

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An electrical protection program is an essential component of any power system. These programs reduce the risk of damage to equipment and processes, but more importantly, they minimize your staff's exposure to potentially-fatal arc flash hazards. One of the core components of such a program is the ability to identify and analyze high-risk arc flash areas in your electrical system.

When identifying arc flash hazards, there is one critical issue that must be considered: In many electrical facilities, protective device trip settings have been set only on bolted 3-phase short circuit criteria. Yet low-voltage arc faults less than 1.0kV may produce a current magnitude significantly smaller than the circuit's maximum 3-phase bolted short circuit current. While the released incident energy should be smaller at lower current magnitudes, overcurrent devices may take longer to trip, causing the release of incident energy up to several minutes.

Today, the process of identifying and analyzing high-risk arc flash areas typically falls under two calculation methods: NFPA 70E and IEEE 1584. Although both methods consider low-current magnitude, each has a different way of accounting for its effect in the calculation of incident energy.

Another significant factor to consider is the introduction of CSA-Z462, which has been developed by the Canadian Standards Association. Developed in parallel with the 2009 Edition of NFPA 70E, CSA-Z462 will be the primary calculation method used at Canadian facilities. Because the 2009 Edition of NFPA 70E is rooted in the 2004 edition, it is fundamentally important to understand NFPA 70E.

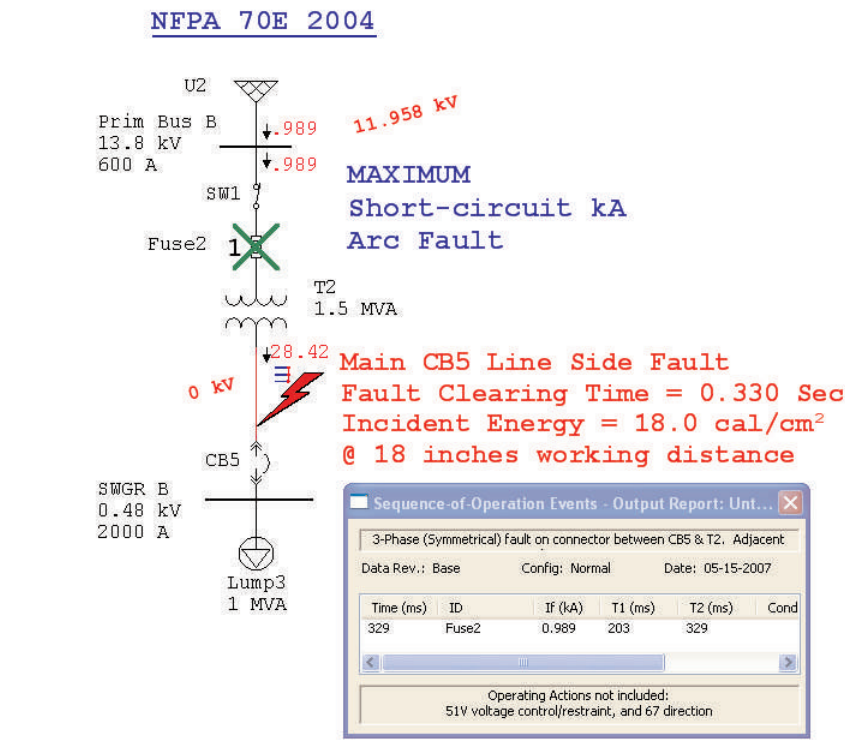

Figure 1: Arc Fault at line side of CB5 showing NFPA 70E results

METHOD A: NFPA 70E

Under the NFPA 70E 2004 method, it is recommended that incident energy for equipment 600V and below be determined from the "maximum" and "minimum" short-circuit currents. In fact, it recommends a 62% reduction of the maximum available short-circuit current to determine situations where the upstream overcurrent device could take seconds or minutes to operate (NFPA 70E 2004 Annex D.6).

The reduction percent corresponds to the industry accepted minimum current level for self sustaining arc faults. Equation [D.6.2 (a)] can then be used to calculate incident energy.

METHOD B: IEEE 1584

The other method to calculate incident energy for low-voltage equipment is IEEE 1584TM-2002 and 2004a "IEEE Guide for Performing Arc-Flash Hazard Calculations" (sections 5.1 to 5.5). The IEEE 1584 empirically-derived equations can predict very low arc fault current values. IEEE 1584 2002 equation 1 can be used to determine the magnitude of the actual arc fault current – unlike NFPA 70E that uses the available short circuit current.

In the simple electrical system described in this article, the calculated arcing current magnitude can be as low as 45% of the maximum available bolted 3-phase short-circuit current. The 45% value already accounts for the additional 15% reduction recommended by IEEE 1584 for systems with nominal voltages less than 1000V (section 5.2 of IEEE 1584a 2004).

DETERMINING THE HIGHEST INCIDENT ENERGY VALUE

One area of concern for arc flash analysis is the lower magnitude of low-voltage arc faults. Depending on which method is used to determine the incident energy results, the results can be very different. Yet no matter which method is used for arc flash analysis, it may be necessary to run several variations in the arc fault current magnitude. This will help determine with certainty the absolute highest incident energy value that can be released.

It is essential that you consider all the possible arc flash locations and the protective devices involved for protecting the circuit to properly identify low-voltage arc hazards. In addition, it may be

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necessary to run two sets of calculations – one for maximum currents and another for minimum currents.

In Figure 2, we use power system analysis software to perform arc flash analysis at two locations in the system to determine low-voltage arc hazards. This system has a typical arrangement for overcurrent and short-circuit protection. The 1.5MVA transformer is fed from a 177MVAsc utility connection and is protected for short-circuit with a 100-Amp, 15.5kV standard-speed fuse located on the 13.8kV primary voltage side. The transformer feeds a 480V switchgear with a main 2400-Amp power circuit breaker with a solid state trip device.

The power system analysis software is then used to simulate an arc fault on the switchgear bus bars at the “SWGR B” location. You can see the computer program results for a fault at this bus using the IEEE 1584 2004a method in Figure 2.

We also used the NFPA 70E method to evaluate the arc fault at the same location for both maximum and minimum expected short-circuit currents. The protective device expected to trip the arc fault is the main breaker CB5. The results of the four different arc fault analyses are listed in Table 1.

When using the maximum short-circuit current to determine the incident energy, the results reveal that because of the fast action of the instantaneous part of the solid state trip device in CB5, the incident energy released at the bus is 2.69 cal/cm_ with a hazard category of 1, based on NFPA 70E-2004, Table 130.7(C). However, if you use the minimum short-circuit current, the resulting incident energy can reach as high as 25 cal/cm_ (category 4). This is caused by the much longer clearing time of CB5.

IEEE 1584 predicts hazard category 3 results (12.5 to 14.51 cal/cm_) as the worst-case scenarios. The IEEE 1584 method provides the more accurate results in this case since it is using the actual arcing current (Ia) to determine the time it takes the CB5 breaker to operate.

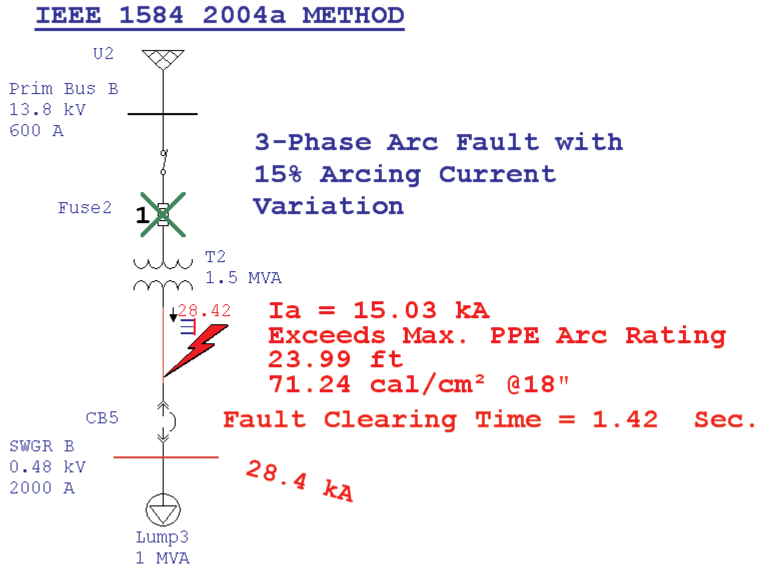

Figure 2: Arc Fault at Bus SWGR B showing IEEE 1584 results

Table 1: I.E. for a fault at Bus “SWGR B” @ 18.0 inch working distance e

Method	Ibf or Ia at Fault loc. (kA)[1]	Power Circuit Breaker Opening Time (sec.) for CB5	Incident Energy at Bus SWGR B (cal/cm_)	Hazard Cat
NFPA 70E Max kA	28.42 (Ibf)	0.05	2.69	1
NFPA 70E Min kA	10.84 (Ibf)	0.500	25.01	4
IEEE 1584 (100% Ia)	15.03 (Ia)	0.250	12.50	3
IEEE 1584 (85% Ia)	12.78 (Ia)	0.346	14.51	3

Table 2: I.E. for a fault at CB5 @ 18.0 inch working distance

Method	Ibf or Ia at Fault loc. (kA)[1]	Fuse Total Clearing Time (sec.) for Fuse[2]	Incident Energy at CB5 (cal/cm_)	Hazard Cat
NFPA 70E Max kA	28.42 (Ibf)	0.330	18.0	3
NFPA 70E Min kA	10.84 (Ibf)	4.139	>>40.0	N/A
IEEE 1584 (100% Ia)	15.03 (Ia)	1.42	>>40.0	N/A
IEEE 1584 (85% Ia)	12.78 (Ia)	0.346	>>40.0	N/A

Note 1: Ibf or Ia denotes whether the bolted 3-phase short-circuit (Ibf) or the arcing current (Ia) were used to determine the fault clearing time.
Note 2: The Fuse total clearing time was determined from the current at the 13.8 kV base. (see Figure 3)

ESTABLISHING WORST-CASE INCIDENT ENERGY

The preceding simulation may not be adequate to determine the worst-case incident energy for this low-voltage equipment. If you simulate an arc fault at the main breaker compartment, as shown in Figure 1, the incident energy released at this location can be much larger since the primary protective device would be Fuse2 with a longer clearing time.

In Table 2, the results indicate that the incident energy released for a fault located at the line (incoming) side of the circuit breaker CB5 is more threatening due to the longer operating time of the fuse. The Time Current Characteristic

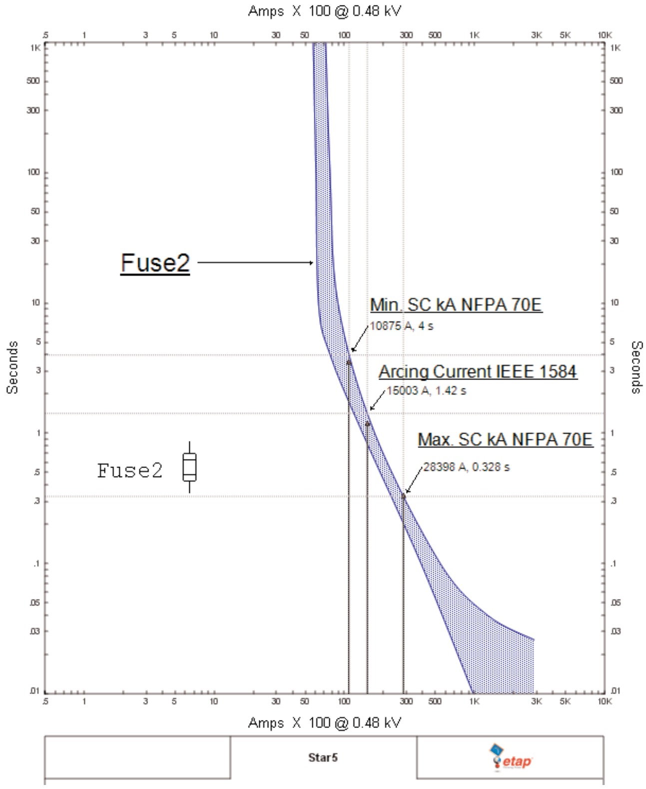

Figure 3: Fuse TCC showing long times at steep portions of the curve

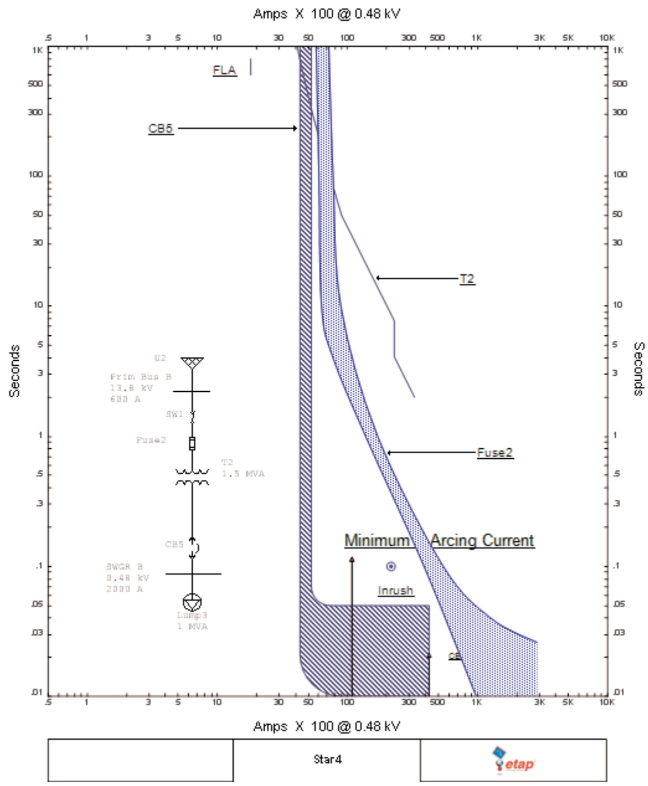

Figure 4: TCC showing Maintenance mode for CB5

(TCC) of Fuse2, along with the expected fault clearing times for the minimum, maximum and arcing fault values, can be seen in Figure 3.

It should be noted that a small reduction in the fault current leads to a much longer total clearing time. In fact, there have been several documented arc flash incidents in low-voltage equipment that have lasted for several seconds or even minutes due to slow response of upstream protective devices.

An effective method to minimize the hazard associated with low-current magnitude arc faults in low-voltage equipment is to change the settings of the protective devices to decrease the arc fault clearing time. In general, main power circuit breakers do not have their instantaneous response enabled because of coordination with devices downstream.

In the case of the arc faults at the bus, temporarily setting the instantaneous pickup of the main power circuit breaker to the left of the lowest expected arc fault current value should significantly reduce the fault clearing time. Some devices on the marketplace are available with "Maintenance" modes that automatically override normal protective device coordination settings and introduce an instantaneous pickup setting.

This instantaneous pickup setting is low enough to pick up the arc fault current magnitude. When the energized electrical work or maintenance is complete, the main protective device can be set back to normal operation settings. The maintenance mode settings and the fault arrow marked as "Minimum Arcing Current" shows the absolute lowest arcing current magnitude in Figure 4.

Although adding and reducing instantaneous pickup settings is one way to reduce the hazard associated with low-voltage arcs, you may also consider using light detecting relays or "Arc Flash Sensors". These devices detect light emitted by the arc fault. If there is an arc, the light sensors will send a trip signal to relay, which can take less than 2 cycles to trip the breaker. Arc sensors can also be used with overcurrent relays. The arc sensor relay would only send the tripping signal if both overcurrent and light sensors detect the presence of an arc fault. A set-up like this will also reduce nuisance trips caused by light sources not related to arc faults.

MINIMIZING RISK

On a final note, you should give serious consideration to not performing energized work in high-risk locations that depend on upstream overcurrent protective devices to trip the fault unless you minimize the hazard in some way. This approach for reducing incident energy is one more method to significantly reduce the risk of arc flash incidents and minimize your staff's exposure to potentially lethal arc flash occurrences.

In short, whichever analysis method is used (IEEE 1584 or NFPA 70E, or a combination of both) it is imperative that you consider extremely low magnitudes of the arc faults in low-voltage equipment. Both the maximum and minimum arc fault current levels must be analyzed to accurately assess the hazard of energized electrical work.