Reduce Arc Flash Energies by Reducing Fuse Ampere Rating

Tech Topics: Arc Flash Note 5, Issue 1

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Points of Interest:

- Current Limiting fuses limit incident energy to low values if the arcing fault current exceeds the fuse threshold current
- Fuses of the same UL fuse class but with lower ampere ratings will have lower threshold values.

Threshold Current and Incident Energy Calculations

Current-limiting fuses can limit arc flash incident energy to low values provided that the arcing fault current exceeds the fuse's threshold current. Threshold current is defined as the lowest prospective rms symmetrical current at which the fuse will clear in less than 1/2 electrical cycle. By clearing in less than 1/2 cycle, the fuse limits both the peak instantaneous current (I_p) and the rms current (I_{rms}) as seen in Figure 1. For a more in depth explanation of current limitation, refer to Mersen Arc Flash Note 2—Reducing Arc Energies with Current-Limiting Fuses.

As discussed in Arc Flash Note 2, the amount of incident energy generated by an arc flash event is determined to a large degree by the magnitude of the current (I_{rms}) and the duration (*t*) of the fault. A current-limiting fuse that reduces I_{rms} and t during an arcing event will significantly reduce incident energy. However, if the arcing fault current is less than the fuse's threshold current, the fuse will limit t but not Irms and the incident energy will be higher and depend on the clearing time of the fuse.

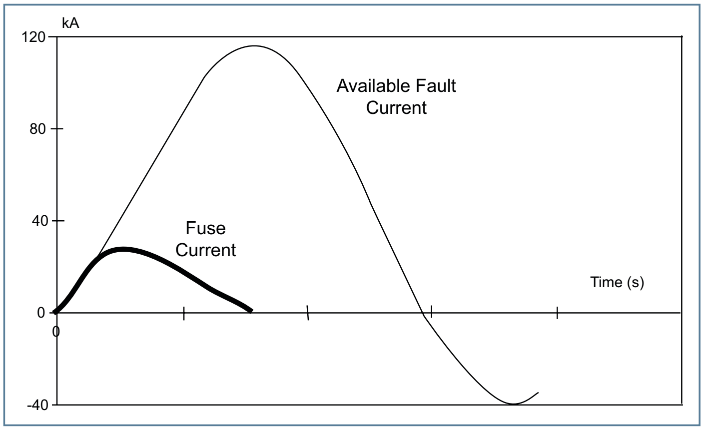

Figure 1. Fuse Current Limitation

Within the same fuse class, current-limiting fuses that have lower ampere ratings will have lower threshold currents. This wider range of current-limiting operation can be used to reduce arc flash energy in applications where available fault currents are low relative to the existing fuse's threshold value.

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Because of the variability of arcing fault currents and the difficulty in accurately calculating bolted fault currents, IEEE 1584™2002, Guide for Performing Arc Flash Hazard Calculations recommends that incident energy calculations be conducted using both the calculated arcing fault current from your study and 85% of that value. The lower fault current value can actually yield higher energies if it creates a situation in which the fuse is operating at less than its threshold current. In these cases, the higher incident energy calculation should be used in your arc flash hazard analysis.

For circuits of 600 volts and less, arcing fault current can be significantly lower than the bolted fault value. NFPA 70E states that at 480 volts, arcing fault current could be as little as 38% of the bolted fault value. To best represent incident energy levels for current-limiting fuses, fuse manufacturers have undertaken extensive arc fault testing with their fuses.

Fuse performance for arc flash is determined in accordance with IEEE 1584 guidelines for arc in a box testing with vertical electrodes. In these tests, the prospective bolted fault current is first determined with a calibration test conducted with a shorting bar across the phases in the test box. The arc fault is then created by replacing the shorting bar with a fine wire and initiating the test. The incident energy from the resultant arc fault is measured with calorimeters. Due to the added impedance of the arc and the current-limiting effects of the fuses the arcing fault current is less than the bolted fault value determined during circuit calibration. After a sufficient number of tests are performed to establish an acceptable confidence level for the results, the fuse manufacturer publishes its test results based upon the bolted fault values. See Figure 2 for a plot of incident energy versus bolted fault current for A4BQ Class L fuses.

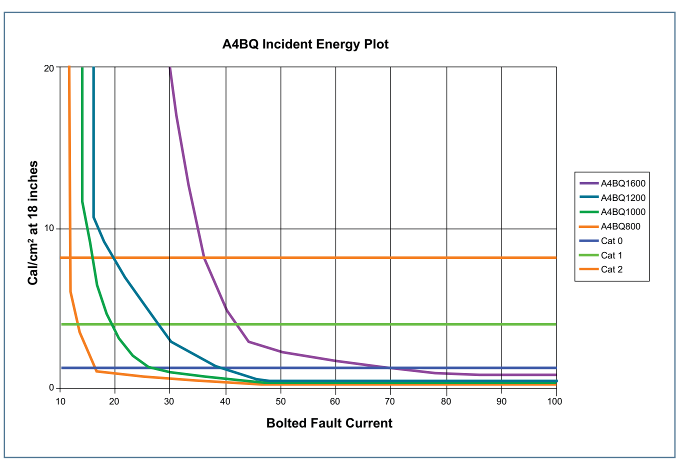

Figure 2: Incident energy chart for ABQ fuses. See Arc Flash Note 2 for proper use.

The following example illustrates a case in which a fuse of the same fuse class but with a lower current rating (and lower threshold) can significantly reduce arc flash incident energy.

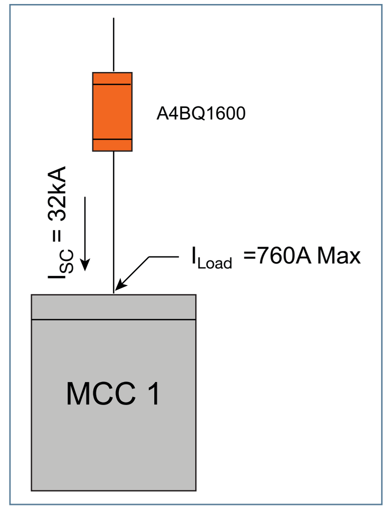

Figure 3: Single Line Diagram

Example

Situation. In the application depicted in Figure 3, the feed to MCC1 is protected by three A4BQ1600 Class L fuses. A load study indicates that the maximum load on MCC1 is 760 amperes, and the short circuit study predicts an available fault current of 32kA.

From our incident energy graph (Figure 2) we see that the projected incident energy for arc faults within the MCC would be approximately 14 cal/cm² for an 18 inch working distance. This requires PPE appropriate for NFPA 70E's Hazard/Risk Category 3. The company's electrical safety plan requires that Category 2 and higher hazards be evaluated for potential hazard reduction by engineering.

Solution. The plant electrical engineer reviews the load study and short circuit study values for MCC1 to verify their accuracy and concludes that he can replace the 1600 ampere fuses with A4BQ fuses of a lower ampere rating. After consulting with the fuse manufacturer, the engineer considers ampere ratings as low as 800A since Class L fuses are suitable for 100% operation.

The incident energy graph for A4BQ fuses (Figure 2) is then considered. With a bolted fault current of 32kA, the expected incident energy is 2.5 cal/cm² for the A4BQ1200 and 0.5 cal/cm² for the A4BQ800.

The engineer now has a decision to make. Although the 2.5 cal/cm² energy level for the 1200 ampere fuse may be acceptable, another calculation at 85% of the bolted fault current — 27kA — yields an expected incident energy for the A4BQ1200 of 4.0 cal/cm². It is clear that the 1200 ampere fuse would be operating near its threshold at these fault levels and that incident energies would be significantly higher if actual bolted fault levels are less than calculated.

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In contrast, the A4BQ800 fuse has a predicted incident energy of only 0.5 cal/cm² with a bolted fault current of 32kA, and 0.6 cal/cm² at the 85% value. The A4BQ800 provides expected incident energy of less than 1.2 cal/cm² for bolted fault current values as low as 16kA. Since the maximum load is 760 amperes and it is unlikely that all loads will be "On" at the same time in this application, the engineer selects the A4BQ800 fuses feeling that this is the safest way to mitigate the arc flash hazard. The PPE requirement for workers who must access this MCC in an energized state is reduced from Category 3 to Category 0. This dramatic incident energy reduction can minimize the possibility of worker injury. With the A4BQ Class L fuse's one-way interchangeable design (see photo above) the change is simple and requires no special hardware.

"Incident energy values from fuse tests are reported in terms of bolted fault currents but do take into account the difference between bolted fault currents and arcing fault currents"

Fusing Recommendations for Motor Control Centers with Consideration for Arc Flash Mitigation

Specifying a fused Motor Control Center (MCC) can yield the benefits of low incident energy, Type 2 "No Damage" protection of starters and selective coordination for overloads and short circuits. Consider the following to ensure optimal overcurrent protection.

- Consider available fault current when specifying the fusible mains. Select the ampere rating of main fuses so that the incident energy calculations on the bus and buckets yield an incident energy of less than 1.2 cal/cm². Use data such as that in Figure 2. For example, selection of an A4BQ800 would yield a calculation of 1.2 cal/cm² for bolted fault currents as low as 16kA.
- Select branch fuses per starter manufacturers Type 2 tables. For new MCC's, specify AJT (Class J) fuses for branch circuit protection. For NEMA- and IEC– style starters, these fuses provide "No Damage" protection against fault currents up to 100,000A. For existing MCC's, upgrade the branch circuit protection to A6D (Class RK1) fuses.
- Specify the ampere rating of the main fuses to be at least twice that of largest branch. With Amp-Trap 2000® products, full selective coordination will be achieved within the MCC for fault currents as high as 200,000A as long as the ampere rating of the main fuses is at least twice that of the largest branch circuit fuse.

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Fuses for Arc Flash Hazard Mitigation

Amp-Trap 2000® Fuses

When it comes to general purpose fuses, there is no better alternative than the Amp-Trap 2000 fuses for low current-limiting thresholds and low let-through energies. When applied so that the fuses will be current-limiting for arc fault currents, incident energy at working distances of 18” are typically less than 0.25 cal/cm². These fuses have been certified by starter manufacturers to provide Type 2 (No-Damage) short circuit protection for NEMA and IEC starters. The superior current limiting design also ensures the best degree of system coordination with upstream fuses and circuit breakers.

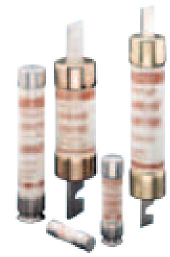
9F60HMH Medium Voltage Fuses

The inverse fuse curve discussed in this paper is available with E-Ratings up to 125E. As shown above, this time current characteristic can significantly lower incident energy calculations for transformer secondaries. As indicated above, extreme care must be taken to ensure the proper application of these fuses.

HSJ – High Speed Fuses

Often isolation transformers used for power electronics, results in very low arc fault currents. The resultant long clearing times of standard overcurrent protective devices yields very high incident energies. The low current-limiting thresholds and low let-through energies of the HSJ will provide superior protection of semiconductors and low incident energy calculations. Since the HSJ is listed as a Class J fuse it eliminates the need for additional branch circuit protection required of standard semiconductor fuses.

Non-Time Delay General Purpose Fuses



When faced with very low arc fault currents, analysts should consider our A4J Class J and A2K/A6K Class RK-1 Non-time Delay Fuses to obtain low incident energy calculations. Compared to the Amp-Trap 2000 fuses, these cannot carry the same motor start currents as the Amp-Trap 2000 nor coordinate as well as downstream fuses. Contact Technical Services for guidance on application of these fuses.

To learn about additional benefits download brochures from our website at: **us-ferrazshawmut.mersen.com**

Additional Resources - Tech Topics

- Arc Flash Note 1: Multiple Hazards of Arcing Faults (part no. TT-AFN1)
- Arc Flash Note 2: Reducing Arc Energies with Current-limiting Fuses (part no. TT-AFN2)
- Arc Flash Note 3: Arc Flash Hazard Analysis is Required (part no. TT-AFN3)
- Arc Flash Note 4: Reduce Arc Flash Energy by Upgrading to Class RK1 Fuses (part no. TT-AFN4)
- Arc Flash Note 5: Reduce Arc Flash Energy by Reducing Fuse Ampere Rating (part no. TT-AFN5)
- Standards & Code Note 2: Critical Changes to the NFPA 70E Standard 2009 Edition (part no. TT-SCN2)

Other Application Literature & Resources

- For more info on Medium Voltage fuses see Advisor 111 Catalog Section E.
- Amp-Trap 2000 Brochure (part no. BR-AT2000)
- Advisor: Selectivity Between Fuses (See the Application Section (Section P) of the Advisor 111 Catalog.)
- Arc Flash Info Center for more professional papers and articles www.us-ferrazshawmut.mersen.com/arcflash

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