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Fuse application for medium-voltage starters

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Medium-voltage starters utilize vacuum contactors for the control of medium-voltage motors. These vacuum contactors have limited interrupting ratings so main fuses are used in conjunction with the contactors to provide fault clearing capability when the system fault current exceeds the contactor rating. This paper discusses the application considerations for the medium-voltage fuses used in these starters.

Eaton manufactures a complete line of medium-voltage current-limiting motor starting fuses. They are designated as R-rated fuses and can interrupt high fault currents while limiting the peak current, reducing the mechanical and electrical stress to the starter, downstream loads, and other components. These fuses have been tested individually and as part of a complete Ampgard motor starter. The proper application of medium-voltage motor starting fuses includes consideration of voltage rating, maximum interrupting rating, minimum interrupting rating, continuous current rating, peak let-through, and coordination.

Medium-voltage R-rated fuses are typically available with voltage ratings 5.5 kV, 7.2 kV, and 15 kV. The fuse voltage rating should be between 105% and 150% of the system voltage. Fuses with ratings below their applied voltage may fail to interrupt the fault current. Because voltages often fluctuate, the 5% minimum safety margin is applied to cover system overvoltage conditions. Fuses with ratings greatly in excess of their applied voltage may over-voltage the system when they operate and clear a fault. Current-limiting fuses develop a voltage above their rated voltage when interrupting high fault currents. These high voltages can damage connected equipment. A typical rule of thumb is that the fuse voltage rating should not exceed the system rating by more than 150%. This limit does not restrict the use of higher rated fuses if the system can withstand the higher voltage produced by the fuse. Eaton CLS current-limiting fuses are designed so that the arc voltage peak at rated interrupting current is less than three times the voltage rating.

The fuse will have a maximum continuous current rating, at which the temperature rise of the fuse will not exceed UL® allowable limits. The fuse will have a minimum melt curve, which identifies the time and current where the fuse ribbons will begin to melt. The fuse will also have a total clearing time curve, which identifies the time and current where the fuse will fully clear a fault current.

To protect the fuse from fatigue and early failure, Eaton selects the fuse based on the rule of thumb that the motor locked rotor current is 6-times full load amperes and that the acceleration time is 10 seconds. A 25% safety factor is added to prevent fuse fatigue due to repeated starts. The formula FLA x 6 x 1.25 must be less than the 10 second current from the fuse minimum melt curve. **Figure 1** illustrates the described method of fuse selection based on the minimum melt curve. Fuse E is the correct fuse to use in the illustration. Motors that have a locked rotor current significantly more than 6 times full load, or that have acceleration times significantly in excess of 10 seconds may require a specific comparison of the start current and start time to ensure that the starting current doesn't damage the fuse. Evaluate the minimum melt curve to ensure that the locked rotor current x 1.25 at the motor starting time does not exceed the point on the minimum melt curve.

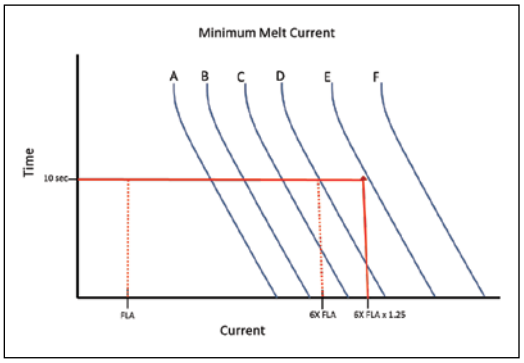

Figure 1. Fuse E selection based on minimum melt current

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Fuses have a maximum interrupting rating, typically 50 kA symmetrical for Eaton motor starting fuses. The 50 kA symmetrical rating is associated with an 80 kA asymmetrical rating and a 133 kA peak current. To ensure the fuse's ability to interrupt fault current, the power system to which the fuse and starter are applied should not exceed these ratings.

R-rated fuses also have a minimum interrupting rating as noted on the fuse nameplate. Extended duration currents above the fuse continuous current rating, but below the minimum interrupting rating can cause significant damage and will eventually result in a fuse failure. Starters utilizing R-rated fuses must always include an overload relay to ensure the main contactor opens if currents above the fuse continuous rating are present for more than 100 seconds.

As previously noted, medium-voltage starters utilize contactors with limited interrupting ratings to interrupt normal operating and overload currents and fuses to interrupt fault currents. Proper starter coordination ensures that the contactor interrupts these normal currents and the fuse interrupts fault currents. For example, the Eaton 400 A SL contactor can interrupt 8500 A. If a fault current of greater than 8500 A is flowing through the starter, the contactor must remain closed until the fuse has had time to clear the fault. Ampgard starters have been tested with Eaton motor starting fuses to ensure proper coordination between the contactor and the fuse. The use of a fuse with a different total clearing curve may not properly coordinate with the Eaton contactor.

Current-limiting fuses have maximum let-through current based in their current-limiting characteristics. Eaton medium-voltage starters have been tested to verify that all starter components can withstand the magnetic and thermal forces associated with this maximum let-through current. The use of a fuse with a higher let-through current may allow the other starter components to be damaged during a high fault condition.

Eaton starters have been designed and verified to carry rated current on a continuous basis. The highest heat generator in a starter is the power fuse. Eaton's motor fuses have a low resistance to ensure that the starter can pass all thermal requirements. The use of a fuse with higher resistance can result in temperatures exceeding the limits as noted in the equipment standards.

Fuses can be damaged when dropped or otherwise handled roughly. If one or more of the fuse ribbons becomes damaged, the fuse can run hot, and may eventually fail. Fuses should be inspected periodically. If signs of overheating exist, a micro-ohm reading of the fuse resistance can be made to determine if the fuse has a higher than normal resistance. Make micro-ohm readings of other fuses with the same ratings in another starter to determine the normal resistance for a particular size. It is recommended that fuses be replaced in sets of three because damage to one fuse may be an indicator that all three fuses experienced similar overcurrent conditions.

The application of medium-voltage starters with properly selected current-limiting fuses should provide many years of reliable service for your motor starting needs.

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