Motor Starter Protection

Motor controllers are highly susceptible to damage due to short circuits. Even for moderate or low-level faults, extensive damage may occur if the short circuit protective device is not carefully selected. The most vulnerable parts are the starter contacts and heater elements. Fault currents can weld the contacts and cause the heater elements to vaporize or be critically damaged. The metalized vapors from such damage then can initiate further starter destruction in the enclosure.

Often, after a fault, no apparent damage is visible (i.e., the contacts are not welded and the heater elements are not burnt up). However, the heat energy from the fault may have caused too high of a heat excursion for the heater elements or overload relay sensing element to withstand, with the result being a permanently altered and degraded level of overload protection.

The question is, what can be done to obtain the highest degree of short circuit protection for motor controllers? The solution is to use short circuit protective devices that are current-limiting and size them as close as practical. A current-limiting fuse can cut off the short-circuit current before it reaches damaging levels. Even for potentially high short-circuit currents, the quick clearing of the fuse can limit the current passed through the starter to safe levels. Dual-element Class RK5 and RK1 fuses are recommended since they can be sized at 125% of the motor full-load current, rather than 300% sizing for non-time-delay fuses.

The branch circuit protective device size cannot exceed the maximum rating shown on equipment labels or controller manufacturer's tables. 430.53 requires observance of the requirements of 430.52 plus, for circuits under 430.53(C) the motor running overload device and controller must be approved for group installation with a specified maximum rating protective device. Under 430.54 for multi-motor and combination-load equipment, the rating of the branch circuit protective device cannot exceed the rating marked on the equipment. Therefore, be sure to check labels, controller overload relay tables, equipment nameplates, etc. In no case can the manufacturer's specified rating be exceeded. This would constitute a violation of NEC® 110.3(B). When the label, table, etc. is marked with a “Maximum Fuse Amp Rating” rather than marked with a “Maximum Overcurrent Device” this then means only fuses can be used for the branch circuit protective device.

Achieving Short Circuit Protection

In order to properly select an overcurrent device for a motor starter, four areas require particular attention:

1. Withstand rating of the contactor.
2. Wire Damage.
3. Cross-over point of the fuse and relay curve.

Please refer to the following graph.

Contactor Withstand Rating

The first area of concern is the withstand rating of the contactor. In order to prevent damage to the contactor, the maximum peak let-through current (I_p) and maximum clearing energy (E2) (amps² seconds) of the fuse must be less than the equivalent ratings for the contactor. The clearing time and let-through characteristics of the fuse must be considered when verifying adequate protection of the contactor.

Wire Damage

Secondly, motor circuit conductors have a withstand rating that must not be exceeded. If the overcurrent protective device is not capable of limiting the short-circuit current to a value below the wire with-stand, the wire may be damaged, or destroyed.

Cross Over Point

Thirdly, the cross-over point (Ic) is the point where the fuse curve intersects the overload relay curve. For current levels less than the cross-over point the overload relay opens the circuit. For current values greater than the cross-over point the fuses open the circuit and prevent thermal damage to the overload relay, contacts, and the motor circuit. This point of intersection should be approximately 7-10 times Ie, where Ie is rated current. Ideally the fuse should allow the overload relay to function under overload conditions, and operate before the overcurrent reaches the contactor’s breaking capacity.

Motor Damage

Finally, all motors have an associated motor damage curve. Single phasing, overworking, and locked rotor conditions are just a few of the situations that cause excessive currents in motor circuits. Excessive currents cause motors to overheat, which in turn causes the motor winding insulation to deteriorate and ultimately fail. Overload relays and dual-element, time-delay fuses, are designed to open the motor circuit before current levels reach the motor damage curve.

IEC and UL Standards for Allowable Damage

IEC 947-4-1 and UL508E differentiate between two different types of coordination, or damage levels.

— Type “1” Considerable damage, requiring replacement. No external damage to the enclosure. Short circuit protective devices interrupt intermediate to high short-circuit currents which exceed the withstand rating of the motor starter. A non-current-limiting device will interrupt these high currents, but this type of damage will typically result.

— Type “2” “No Damage” is allowed to either the contactor or overload relay. Light contact welding is allowed, but must be easily separable. (Note: If access is not possible and the contacts cannot be separated, “Type 2” protection cannot be achieved.) This level of protection typically can only be provided by a current-limiting device, that is, one which limits the available short-circuit current to a significantly lower value.
Five Choices — 1 Solution

IEC Motor Starter Protection

Five methods of providing motor starter overcurrent protection are delineated in the five examples that follow. In noting the levels of protection provided by each method, it becomes apparent that the use of dual-element, time-delay fuses (Example 5) is the only one that gives protection at all levels whether it be “Type 2,” “Back-up Overload,” “Back-up Single-Phase,” etc.

These examples are based on a typical motor circuit consisting of an IEC Starter, and a 10 HP, 460V motor (Service factor = 1.15). These “Level of Protection” examples reflect the branch circuit protective device operating in combination with the IEC starter overload relays sized at approximately 115% of motor FLA and contactor Ie = 18 amps.