FEATURE

Protecting motor circuits

Type 2 protection helps maintain productivity and prevent downtime

By Steven R. Goble

MOTOR CIRCUITS form a substantial part of any commercial or industrial installation. With greater emphasis being placed on reduced down-time and increased productivity, proper application and selection of motor branch circuit protective devices is essential. Standard industry practice is to use components listed by Underwriters Laboratories, or certified by the Canadian Standard Association, and applied according to the National Electrical Code. However, U.L., CSA, and NEC testing and application procedures are largely oriented toward fire safety, with little, if any, concern about maintaining productivity or preventing downtime. Simply selecting the branch circuit protective device to comply with one of these codes or standards may not provide an acceptable level of protection.

Underwriters Laboratories has developed standards to verify that an electrical product will not cause fire or electrical shock hazards. UL 508 is the standard used to evaluate the short circuit protection of industrial control equipment. Section 58 of the Standard outlines the testing requirements and criteria used to determine if the test results are acceptable. Short circuit test values given in Table 58.2 of UL 508 are used to establish the short circuit rating for the contractor and overload relay of motor starters. The manufacturer must state whether this rating is restricted by a maximum fuse or circuit breaker size in order to pass the minimum short circuit test requirements.

Compliance to the standard allows deformation of the enclosure, but the door shall not be blown open and it shall be possible to open the door after the test. The contacts shall not disintegrate, but welding of the contacts is considered acceptable. When testing with fuses, damage to the overload relay is not allowed, and it must perform in accordance with the calibration requirements. Tests with circuit breakers allow the overload relay to be damaged with burnout of the current element completely acceptable. For short circuit ratings in excess of the levels listed in Table 58.2 of UL508, the damage allowed is even more severe.

Welding or complete disintegration of contacts is acceptable and complete burnout of the overload relay is allowed. Therefore, a user cannot be certain that the motor starter will not be damaged just because it has been U.L. Listed for use with a specific branch circuit protective device. U.L. tests are for safety and do not define the level of damage allowed.

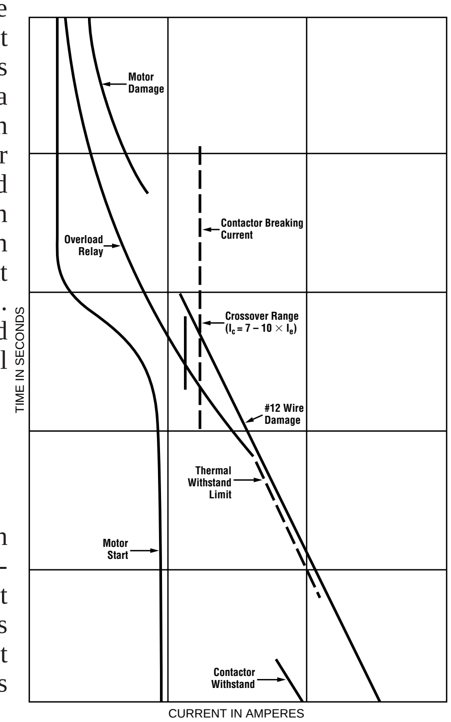

FIG. 1. Motor and Motor Circuit Damage Protection, 10H.P. @ 460V, 3 ph.

Selecting protective devices

In selecting the branch circuit protective device, the designer must be aware of the limits of the motor circuit components, as follows (see Fig. 1):

• Excessive currents from single phasing, overloading, and locked rotor conditions cause motors to overheat, leading to eventual failure. Overload relays and branch circuit protective devices should be selected to open the motor circuit before current levels reach the heating curve (motor damage) of the motor. The overload relay and branch circuit protective devices must also be able to withstand motor starting current or, “inrush current,” which typically lasts for up to 10 sec, without tripping prematurely (see Fig. 1).

• Wire damage can occur under two conditions. First, motor circuit conductors have a short circuit withstand rating that must not be exceeded. If the branch circuit protective device is not capable of limiting the short circuit current to a value below the wire withstand, the wire may be damaged, or destroyed. Secondly, overheating caused by overload conditions which exceed the conductor ampacity can lead to wire damage, and conceivably, a fire.

• Contractor and overload relay short circuit withstand ratings are generally not available from manufacturers. The withstand capacity of these devices varies as a function of physical size and construction. Withstand ratings are expressed in energy (given by the Joule integral I^2t) and peak current for various levels of fault current. NEMA designed products often have higher withstand capabilities than the newer IEC style motor starters. Regardless of the style of control device used, the characteristics of the branch circuit protective device must ensure that the let-through energy and peak current do not rise above the levels

430-52.
MOTOR BRANCH CIRCUIT PROTECTION

Maximum rating or setting of protective devices+

FUSE		CIRCUIT BREAKER*	
Non-time Delay	Dual-element Time-delay	Instantaneous Type Only	Inverse Time Type
300%	175%	700%	250%

+See Article 430, Section 430-52, exceptions “1 thru 3”.
*For latest information, check manufacturer’s data and/or Underwriters’ Laboratories U.L. Standard 508 for damage and warning label requirements.

that the contractor and overload relay can withstand.

• Breaking capacity (current) is also of significance. The branch circuit protective device must operate at all currents above the contactor breaking capacity. Sustained current exceeding the breaking capacity will cause destruction of the contactor which could lead to a more hazardous failure of the control equipment. Therefore, the intersection of the branch circuit protective device and overload relay characteristic should not exceed the breaking capacity of the contactor. This intersection is known as the **crossover point** (current). At currents immediately below the crossover point, the overload relay trips and the contactor is required to break the circuit. Consequently, the crossover point should not exceed the breaking capacity of the contactor. For currents immediately above the crossover point, the branch circuit protective device should be sufficiently fast enough to avoid thermal damage to the overload relay.

Selecting branch circuit protection

The branch circuit protective device may be either a fuse or circuit breaker. Section 430-52(a) (440-22a) of the NEC requires that the branch circuit protective device shall not exceed the values calculated in accordance with Table 430-152. These values have been established to insure applications are essentially free from hazard, but do not define the level of protection. The values given in Table 430-52 are maximum values and do not preclude the application of lower sizes.

When selecting the protective device, the following conditions must be satisfied to prevent damage to the motor circuit and minimize downtime in the event of an overcurrent condition:

• The time current characteristic must be able to withstand the motor inrush current. The branch circuit protective device should also be capable of providing "backup" motor overload protection for the overload relay. If contacts have welded or the overload relay has been miscalibrated, a second level of protection is provided for the motor and motor circuit conductors.

• The time-current characteristics must be such that currents above the contactor breaker capacity and the thermal withstand limit of the overload relay are cleared.

• The peak let-through current (Ip) and the let-through energy (I^2t) of the branch circuit protective device must be low enough to prevent damage to the contactor, overload relay, and conductors. The let-through characteristics must be sufficient to protect the circuit components for all levels of fault current. The maximum acceptable Ip and I^2t for fuses is limited by U.L. and CSA for each fuse class. The more current limiting the fuse, the lower these values will be.

U.L. does not specify maximum Ip or I^2t for circuit breakers. Circuit breakers that take 1/2 cycle or greater to clear a fault may not limit the Ip or I^2t values to levels below the withstand capabilities of the motor starter. To obtain this information the circuit breaker manufacturer must be contacted.

Preventing damage to starter

In order to properly select a branch circuit protective device that not only provides motor branch circuit protection, but also protects the circuit components from damage, the designer must look beyond mere safety standards. Coordination of the branch circuit protective device and the motor starter is necessary to insure that there will be no damage or danger to either the starter or the surrounding equipment. Unfortunately, the information needed to thoroughly evaluate the coordination of the branch circuit components is not readily available. There is, however, an IEC (International Electrotechnical Commission) Standard that offers guidance in evaluating the level of damage likely to occur during a short circuit with various branch circuit protective devices. IEC Publication 947, "Low Voltage Switchgear and Control, Part 4-1: Contactors and Motor Starters," addresses the coordination between the branch circuit protective device and the motor starter. It also provides a method to measure the performance of these devices should a short circuit occur. IEC defines two levels of protection (coordination) for the motor starter under short circuit conditions:

Type 1. Considerable damage to the contactor and overload relay is acceptable. Replacement of components or a completely new starter may be needed. There shall be no discharge of parts beyond the enclosure.

Type 2. No damage is allowed to either the contactor or overload relay. Light contact welding is allowed, but must be easily separable.

Comparing branch circuit protective devices

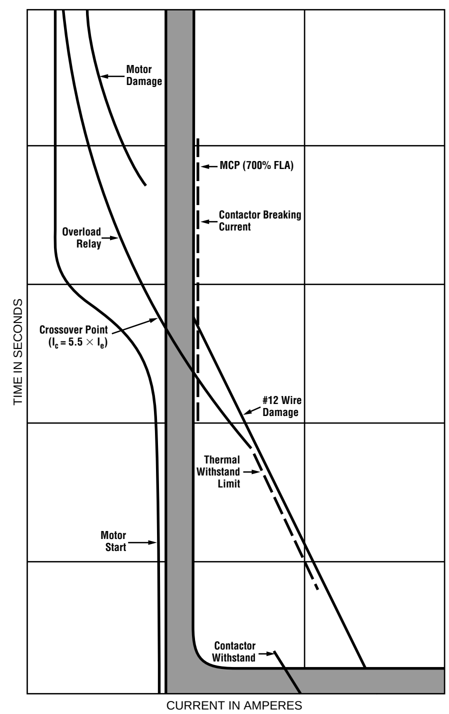

FIG. 2. Motor Circuit Protector Sized @ 700% FLA.

A comparison of the branch circuit devices commonly used will give an idea of the level of performance the user can expect.

A **motor circuit protector** (MCP) is a magnetic only (short circuit only) device that will operate under short circuit conditions in excess of its instantaneous trip setting. To allow a motor to start, and prevent nuisance tripping, typical trip settings are 700% to 1300% of motor full load current (FLA). This device typically takes 1/2 cycle of short circuit current to clear the circuit. Unless otherwise noted, these are not considered to be current

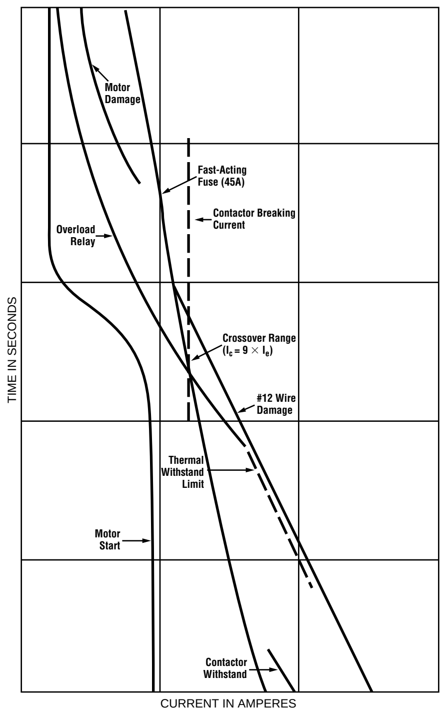

FIG. 3. Fast-Acting Fuse, IEC Type Sized @ 300% FLA.

limiting devices. An MCP affords Type 1 protection under short circuit conditions due to the 1/2 cycle or greater opening time (note the intersection of the contactor withstand curve with the MCP curve. Fig. 2). Replacement of the motor starter can be expected. MCPs provide no back-up overload protection for the motor circuit. If the relays are unable to operate in an overload or single-phase condition, the motor and other components can be subjected to excessive heating.

A **fast acting fuse** (Fig. 3) has characteristics that do not exhibit intentional, built-in time delay during harmless inductive surges (motor starting currents, transformer magnetizing current, etc.). Because of this lack of time delay, fast acting fuses are typically sized at 300% of motor FLA to prevent nuisance tripping on motor start-up. However, unlike the MCP, they can exhibit superior short circuit performance. When operating in their current limiting range, these fuses can reduce the damaging energies associated with short circuits. If the characteristics are fast enough, they can protect the motor circuit components, and the motor starter. In many cases, these fuses may provide Type 2 protection for the starter.

Let-through energy for fast acting fuses, although within Type 2 limits, will generally by higher than properly sized, lower rated time delay fuses of the same class. Fast acting fuses sized at these values offer no back-up overload protection for the motor circuit. If the relays are unable to operate during an overload or single-phase condition, the starter and other components may be subjected to excessive heating and damage.

A **dual-element time-delay fuse** (Fig. 4) is one whose characteristics have an intentional, built-in delay to withstand harmless inrush currents. Sizing dual-element time-delay Class J fuses at 125% of motor FLA, or next size larger if 125% does not correspond to a manufacturer's standard fuse size, affords several distinct protection advantages to the starter, motor circuit, and motor.

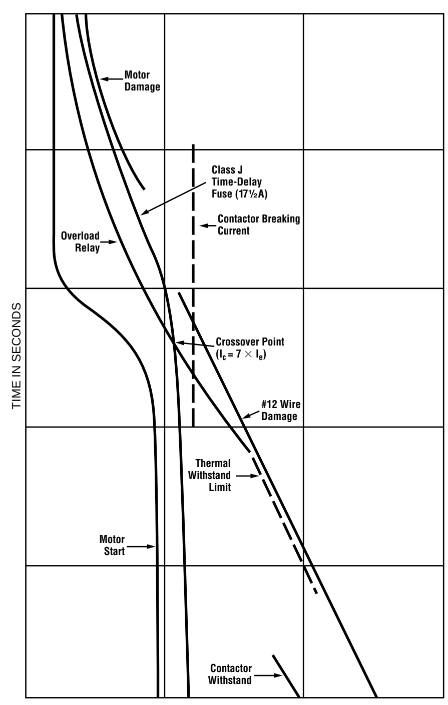

FIG. 4. Dual-Element, Time-Delay Class J Fuse Sized @ 125% FLA.

They provide Type 2 protection under short circuit conditions, due to their excellent short circuit let-through values. This type of protection does, by definition, require that the starter be reusable following fuse replacement. Note that relay calibration shall not be affected. They provide practical, inexpensive back-up overload protection for the motor circuit. If the relays are unable to operate in an overload or single-phase condition, properly sized fuses will open before the motor damage curve is reached. This sizing of fuses and relays is based on the actual running current of the motor, if the motor is not fully loaded, or the motor nameplate current–whichever is lower.

Several other benefits are established when utilizing 125% sizing:

• The dual-element time-delay design allows the motor to start even though 125% sizing is used.

• The motor circuit conductors ares protected from short circuit and overload damage.

• Contactor withstand and contactor heating curves are within the protection capabilities of the fuse (which relates directly to Type 2 protection).

• The crossover point (Ic) is between the optimum coordination limits of 7 to 10 times contactor ratings. For overloads up to this value, the relay should operate first. If the relays do not operate, for whatever reason, the backup dual-element time-delay Class J fuse will open before the motor damage curve is reached. For short circuits above this value, the fuse short circuit element will operate, protecting the motor starter and components from damage.

Summary

When selecting the proper branch circuit protective device there are several alternatives to choose from. The designer must evaluate what level of protection is required to provide maximum safety, productivity, and efficiency. Specifying components tested to safety standards is not enough and it's not enough to follow established application limits. The test methods outlined in IEC 947-4-1 for verification of coordination between the starter and branch circuit protective device can be used to determine the performance level of the selected components. ■

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