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Fuses and overload protection for motor starting with class E2 controllers

This issue of TechTopics is concerned with the selection and setting of overload protection, and the selection of fuses, for protection of motors.

There are several fundamentals that must be considered.

- The primary fuses in a class E2 fused-contactor combination are selected for short-circuit protection, not for overload protection. The fuse protects the contactor (and the load circuit) from short-circuit currents. The contactor, together with the overload relay, provides protection for all normal switching and overload switching.

- Therefore, the fuse must always interrupt currents that exceed the interrupting capability of the contactor without fuses.

- The overload/overcurrent protection relay must assure that the contactor is not commanded to interrupt currents above its capability.

The standard for medium-voltage motor controllers (UL 347) provides application information on coordination between the fuse and the overload protection. The standard defines the take-over current (also often called the cross-over current) as the point (on a time-current characteristic curve) where the overload-protection curve intersects the fuse curve. The curve of interest for the fuse is the minimum melting-characteristic curve, as the fuse-interruption process starts when the fuse melts and begins to introduce resistance into the circuit.

The process begins by selection of the main-power fuse size. The fuse selected must have a continuous-current capability that is higher than the highest normal running current of the motor.

The highest normal running current of the motor is equal to the nameplate full-load amperes (FLA) multiplied by the service factor of the motor (normally, 1.15), and by a factor to reflect the tripping tolerance of the protective relay. For electromechanical relays, this factor is usually 1.10, while for microprocessor relays, a factor of 1.05 is considered reasonable. For this discussion and example, consider a motor with a FLA of 140 Amperes (A) and service factor of 1.15, and a relay factor of 1.05, so the maximum normal running current is 140 x 1.15 x 1.05 = 169 A. A fuse size of 9R is selected, with a continuous current capability of 180 A (200 A at 104 °F (40 °C) ambient in open air, derated for capability in an enclosed application).

Next, the overload-current protection must be selected. The user often specifies the particular model of protective relay required. Modern microprocessor relays have a very broad range of protective settings and characteristic curves that may be selected to closely match the motor-thermal capacity, and this TechTopics issue will not address these details. Our example shows a representative overcurrent curve selection and characteristic for the purposes of this TechTopics issue. The pickup current of the protective relay should be no less than the highest normal running current calculated earlier, in this case, at least 169 A. The characteristic selected has a pickup setting of 170 A with a very inverse characteristic and a six second fixed delay for high currents. The example motor, with full-load current (FLA) of 140 A, has a locked rotor current of six times FLA, or 840 A, and an acceleration time of 4 seconds (s).

With this information, the composite curve of fuse minimum-melting time and overload current-protective characteristic can be constructed.

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Figure 1: Example of fuse selection and overload protection
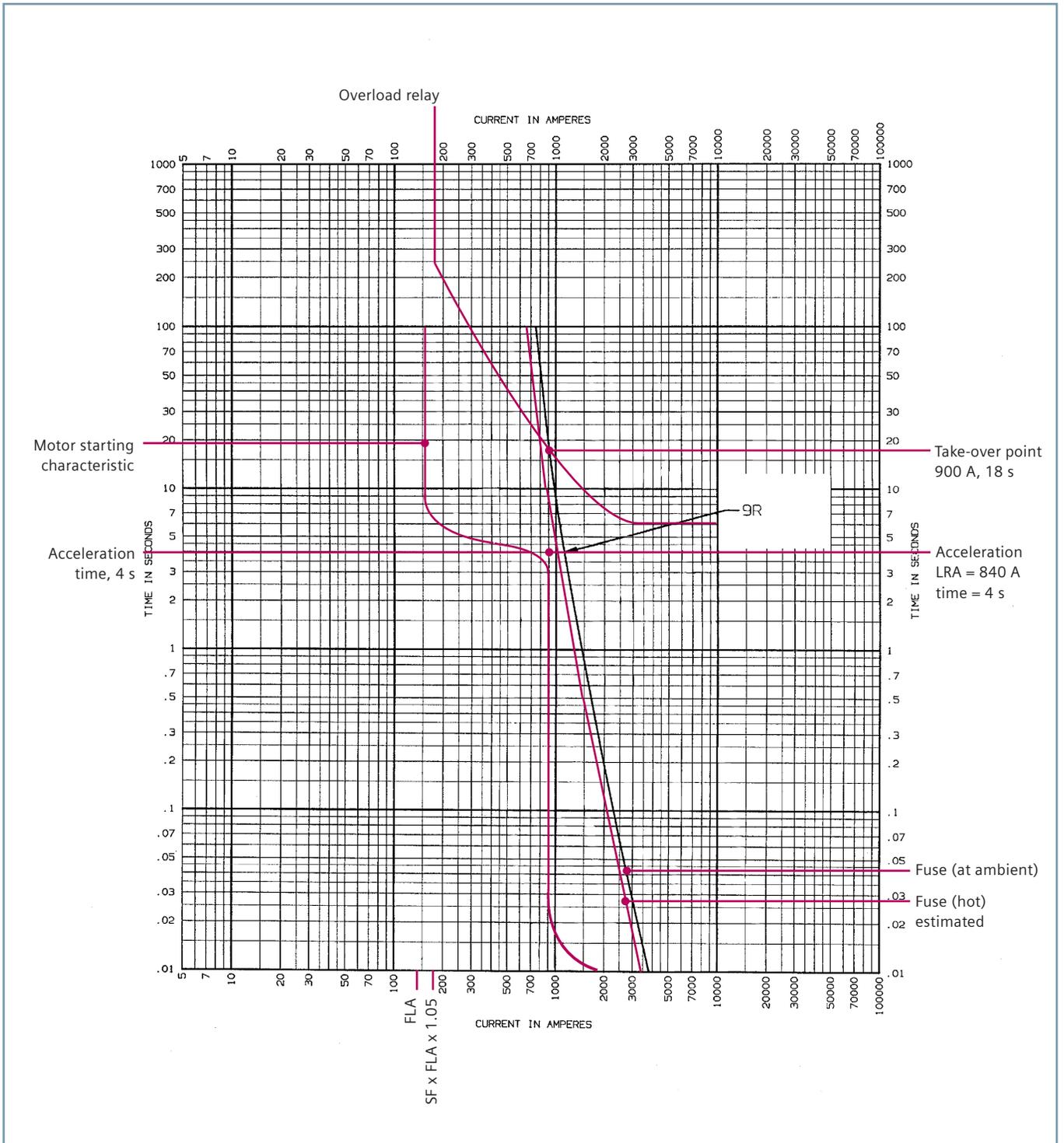
In the characteristic curve, the take-over point is approximately 900 A and 18 s. The acceleration time of the motor is given as 4 s, and the locked-rotor current (LRA) is 840 A. The point (840 A, 4 s) is shown to illustrate that the fuse does not operate during the starting time of the motor. The current at the take-over point should be no lower than the locked-rotor current of the motor.

One additional fundamental consideration is necessary. The standards for NEMA motors require that the motor be capable of:

■ Two starts in succession, coasting to rest between starts, with the motor initially at the ambient temperature, or

■ One start with the motor initially at operating temperature with rated load.

The more severe of these two conditions is normally that of two starts from cold condition. During the first start operation, the fuses heat up significantly due to the starting current which is six times FLA for most of the accelerating time. Since the fuse is already "hot", the effect of the second start is that the fuse characteristics are altered, as the time for fuse operation will be shortened as the fuse elements are already at somewhat elevated temperature. To compensate for this, the rule of thumb will be used that the melting time of the fuse at the locked-rotor current must be at least three times the motor-accelerating time to allow for the condition of two starts from ambient. Based on these considerations, Siemens has created the application charts for easy application of fuses that are contained in the instruction manuals for the controllers.

It must be cautioned that the application charts assume typical motor data for medium-duty motors, and special consideration is necessary when the motor data differs from the typical data assumed in preparation of the application charts.

In the example curve, the protective relay operating time at 840 A is about 18 s, so meets the rule of thumb requirement of at least 3 x 4 = 12 s. In the example, the operating time of the fuse at the LRA of 840 A is about 30 s, illustrating that the protective relay, rather than the fuse, will open the contactor in the event of a failed start, and avoid nuisance-fuse operation.

Also, the contactor-interrupting capacity must be considered. The take-over point should not exceed the contactor-interrupting capacity. Contactors are subjected to an overload test to UL 347, normally at ten times the continuous current of the contactor, for this example, 10 x 400 = 4,000 A. The take-over point on the characteristics is at approximately 900 A and 18 s, so is well within the interrupting capacity of the contactor without fuses.