Control and Protection of Premium Efficiency Motors

Ignoring the effects of increased inrush of premium efficiency motors could lead to nuisance tripping and lost production time.

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Introduction

The Energy Independence and Security Act of 2007 (EISA) passed by Congress and signed into law December 19, 2007 mandates efficiency standards for general-purpose, three-phase alternating current industrial motors from 1 to 500 HP NEMA Design A & B that are manufactured for sale in the United States after December 19, 2010. Premium efficiency motors consume less power by lowering the full load amperes (FLA) of the motor and are typically 2% - 8% more efficient than standard motors. A side effect of the premium efficiency design is to increase the motor inrush or locked rotor amperes (LRA) from the normal 6 times FLA to 9-14 times FLA. This shift in the motor market may impact the selection and the performance of industrial motor control and protection equipment.

The purpose of this article is to explore considerations in selecting branch short-circuit protection, selection for specific types of motor controllers and selection of overload protection when applied to premium efficiency motors.

Selection of MCCB Devices

Selection of branch-circuit short-circuit protection for energy efficient motors.

NEC 430-52 (C) (1) specifies the maximum values of fuses or circuit breakers which can be used to protect motor branch circuits. Refer to Figure 1 below.

There is no difference in selecting a non-time delay or dual-element (time delay) type of fuse and no difference in selecting an Inverse-time breaker (thermal-magnetic breaker UL489 MCCB) for premium efficiency motors. But when selecting an Instantaneous trip breaker (magnetic only or MCP) the maximum values increases from 800% (8 x FLA) to 1100% (11 x FLA). So, the effect of increased inrush may change the selection of the Instantaneous trip breaker (magnetic only or MCP) because of increased inrush. Note that Instantaneous trip breakers must be tested by UL with the specific contactor and overload relay to comply with NEC and UL and testing is also required to apply high fault current ratings (KAIC) to the assembled starter.

NEC 430-52 (C) (6) specifies:
"A listed self-protected combination controller shall be permitted in lieu of the devices specified in Table 430.52. Adjustable instantaneous-trip settings shall not exceed 1300 percent of full-load motor current for other than Design B energy-efficient motors and not more than 1700 percent of full-load motor current for Design B energy-efficient motors."

Sprecher + Schuh offers the KTA7 Type E self-protected combination controller, which has a magnetic trip value of 11-13 X FLA and is designed for the typical 6x FLA inrush motor. Alternatively, Sprecher + Schuh also offers the KTC7 Type E self-protected combination controller, which has a 17-20 X FLA magnetic trip value and is designed for the energy efficient motor with inrush greater the normal 6 x FLA inrush under discussion. Both KTA7 and KTC7 are UL tested and approved as branch short-circuit

Type of Motor	Non-time Delay Fuse	Dual Element (Time-Delay) Fuse	Instantaneous Trip Breaker	Inverse Time Breaker
Single-phase motors	300	175	800	250
AC polyphase motors other than wound-rotor	300	175	800	250
Squirrel cage - other than Design B energy-efficient	300	175	800	250
Design B energy-efficient	300	175	1100	250
Synchronous	300	175	800	250
Wound rotor	150	150	800	150
Direct Current (constant voltage)	150	150	250	150

Figure 1: Percentage of Full Load Current

protection, disconnect, manual controller and overload relay (manual combination starter). Further, the KTA7 or the KTC7 can be combined with a CA7 contactor and is UL short circuit current rated (SCCR) under a fault current up to 65 KAIC. So, the effect of the increased inrush of energy efficient motors may change the selection of the self-protected combination controller from the now typical KTA7 to the KTC7 for motors with an inrush of 11-14 x FLA but the solution is already in place and fully tested by UL.

If the inrush of premium efficiency motors greater than 12-13 X FLA is ignored and KTA7 is applied; then, it is likely that KTA7 will trip at 12-13 X FLA (depending on the FLA set point) as if a short circuit condition existed, which would be considered nuisance tripping. A short circuit causes the KT7 red flag to display and this is the way you can discern if the device tripped on simple overload versus short-circuit. Application of a KTC7 on premium efficiency motor with higher inrush is the simple solution.

Selection of Control Devices

Selection of magnetic controllers (contactors) to switch energy efficient motors.

The design and UL testing of contactors is based on motors designed for 6 x FLA inrush. In general, the decrease in FLA of premium efficiency motors will not change the selection of the proper contactor since contactors are HP rated by UL and CSA in North America. The typical motor starts and settles down to FLA in 3-5 seconds (see Figure 2). Unless the motor is re-started frequently the additional inrush current of energy efficient motors won’t significantly impact electrical life expectancy. For typical applications, we don’t see much change in strategy required to select a contactor based on HP.

Applications requiring frequent starts (more than once per minute) may experience excessive heating from the additional inrush current. The primary concern would be motors that are stopped during inrush which means the contactor must break the higher

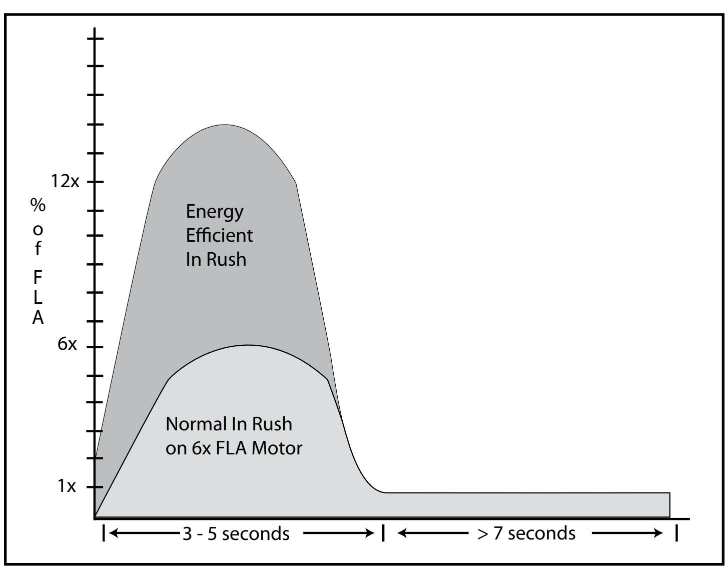


Figure 2: Typical Motor Inrush

inrush current (9-14 x FLA) of energy efficient motors. Since the x-axis of AC4 (jogging, inching, and plugging applications) life curves are based on rated operational current then the lower FLA and higher LRA requires some additional consideration. Although Sprecher + Schuh publishes AC-4 usage curves, we already recommend consulting with your Sprecher + Schuh Technical Support personnel whenever selecting a contactor for jogging, inching, and plugging applications. Now considering premium efficiency motor inrush; we highly recommend Technical Support be consulted with these applications.

Selection of Overload Devices

Selection of overload relays to protect energy efficient motors.

The design and UL testing of overload relays is based on motors designed for 6 x FLA motors. UL 508 and NEC defines three points of the time current curve for overload relays as follows:

- 1.25 x FLA (for 1.15 SF motors) will trip (time not specified)
- 1.15 x FLA (for 1.0 SF motors) will trip (time not specified)
- Reference NEC 430-32
- 2 x FLA trip in less than 8 minutes
- 6 x FLA (LRA) less than 20 seconds

High efficiency motors with less FLA and greater inrush (LRA) will cause an overload relay to trip faster under locked rotor based on the time current curve but typical applications should not cause a problem. (time current curves for CEP7 are published on page B15 of our SSNA9000 catalog, page B31 for CT7N, and page F29 for the KT7).

Typical T-frame motor applications have acceleration times of less than 5 seconds and are best protected by Class 10 overload relays (see Figure 2). Class 10 is defined as tripping in less than 10 seconds under locked rotor conditions (6 x FLA). A motor with long acceleration times (greater than 7 seconds) requires Class 15 or 20 and in rare cases Class 30 trip response curves (see Figure 3). Applications that involve long

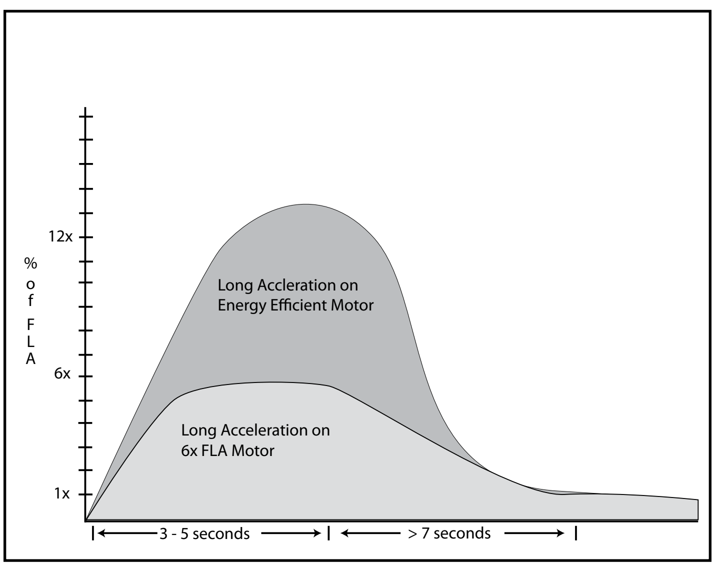
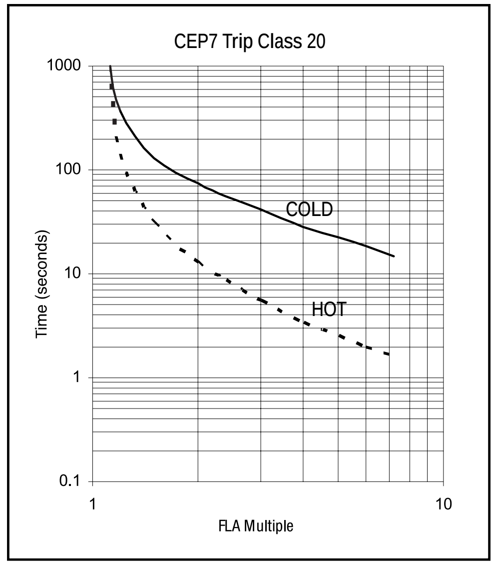


Figure 3: High Efficieny Motor Inrush



acceleration times include, but are not limited to centrifuges, punch presses, turbines, and large fans powered by small motors. Long acceleration times added to increased inrush values of premium efficiency motors will accelerate early tripping due to the nature of the overload relay time current curve. CEP7-EE__ overload relays have dip switches which are field adjustable to determine the trip class which best suits the application.

Multiple motor starter panels are commonly built with 2-component starters including KTA7 self-protected combination motor controllers plus CA7 contactors. KTA7 will be able to handle inrush currents 6 – 12 x FLA with no problem. We have discussed how KTC7 can be used with inrush current 13 x FLA or as high as 17 x FLA. The added complexity of long acceleration applications may require 3- component starters which use KTB7 magnetic only controllers plus CA7 contactors and CEP7-EE__ adjustable class overload relays.

The advantage of a KTB7 magnetic-only motor circuit controller is that it will NOT trip due to simple overload, as that would be the job of the CEP7-EE_ overload relay. The KTB7 Motor Circuit Controller is designed and tested to protect a motor circuit in case of a short circuit. The separate Sprecher + Schuh CEP7-EE_ overload relay with selectable trip class is used to protect the motor against overload. So, when selecting a KTB7 you need to be concerned with choosing a magnetic release (short-circuit trip) value *and* a rated operational current compensating for the increased heat from the inrush of the motor. In applications with motor starting times exceeding 10 seconds (heavy duty starting) the rated operational current (Ie) of the motor FLA must be multiplied by the following factors for selection of the KTB7 Motor Circuit Controller.

Trip classes according to UL 508 Section 52 and IEC 60947-4-1

Class	10	15	20	25	30
Factor	1.00	1.22	1.42	1.58	1.73

The maximum number of motor starts is 25 cycles/hour with a minimum OFF-time of 120 seconds between cycles. This additional calculation and selecting a larger frame size is necessary to compensate for (or dissipate) the increased heat resulting from long acceleration applications effecting the rated operational current of the KTB7.

KTB7 Application Example: Motor 480 VAC, 10 HP, Ie 14 FLA
Heavy duty starting application with start time of up to 18 seconds

Solution: Starting time up to 18 seconds requires dimensioning for CLASS 20.

- Selection of the Motor Circuit Controller for Short Circuit Protection:
  Multiply the rated operational current I_e with the factor for CLASS 20:
  $I_e(20) = 14\text{ A} \times 1.42 = 19.9\text{ A}$
- Select corresponding Sprecher + Schuh KTB7 from catalog using next higher current rating:
  KTB7-25H-25A

Field testing may be the right way to determine the best possible selection (when dealing with inrush current in the 12-14 X FLA range) of KTB7. The objective must be to choose the smallest current and trip value that will allow the motor to start and run under normal conditions without nuisance tripping during inrush and therefore provide the fastest reaction time in case of a real short-circuit.

Similar to contactors; applications requiring frequent starts may experience excessive heating from the additional inrush current of premium efficiency motors. Thermal overload relays and solid state overload relays have a built in “hot curve” that will be impacted from the additional inrush of premium efficiency motors. Further, motors that frequently experience locked rotor conditions (LRA) may become an issue in applications like rock crushers and sawmills. Added protection may be required in the form of jam protection (CEP7-EJM side mount module) to shut down the motor (for example at 3 x FLA set point) before the jam current reaches full magnitude of 9-14 x FLA. This will help prevent excessive heating of the motor and the delay of re-start due to the overload ‘hot curve’.

Summary

In conclusion, the use of premium efficiency motors represents an additional challenge when selecting industrial motor control and protection equipment. Ignoring the effects of increased inrush of premium efficiency motors could lead to nuisance tripping and lost production time. Consult with your local Sprecher + Schuh representative when challenged with motor control and protection applications to resolve the application issues.

References

The purpose of this article was to address the impact of high efficiency motors on selecting industrial controls. We didn’t address the specific of the Energy Independence and Security Act of 2007 or the change in motor design to meet the standards. The following are places on the internet you can research these issues in more depth:

http://www.nema.org/gov/energy/efficiency/premium/
http://motionsystemdesign.com/motors-drives/mark-calendar-december-19-2010-0909/#
http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/electricmotors_eisa_compliance_faqs.pdf

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Publication No: TECH-High Efficiency Motors_111 03/2011