ENHANCING SHORT CIRCUIT SAFETY WITH TYPE 2 COORDINATION FOR MOTOR STARTERS

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I. INTRODUCTION

As of April 26, 2006, suppliers of UL listed Industrial Control Panels (ICP) must clearly label the Short Circuit Current Rating (SCCR) of each panel so that users can properly apply them per National Electrical Code® (NEC) Section 110.10. The new NEC Article 409 requires SCCRs be clearly marked on all ICPs. With the increasing importance of short circuit protection, it is worthwhile to reconsider the advantages and rationale of specifying Type 2 Coordination for "No-Damage" Protection of motor starters.

It is not uncommon for specifiers to believe that they are achieving Type 2 protection if the components are UL Listed and applied per the NEC. In fact, UL 508 allows for a higher degree of damage in the High Fault Acceptance Criteria. To ensure that you are properly specifying the level of short circuit protection that you desire, this note provides:

- An overview of the types of damage short circuit currents can cause to starters.
- A review of current standards and their requirements for short circuit current ratings.
- Guidance on achieving Type 2 levels of short circuit protection.

II. SHORT CIRCUIT CURRENT DAMAGE OF MOTOR STARTERS

Short circuit currents can cause damage to electrical components by a combination of up to three ways: excessive electromagnetic forces, excessive heating and the extreme heat energies due to arcs.

In the case of a contactor, the repulsive force created between contact surfaces during a short circuit can cause the contacts to part and begin to break the fault current. The resultant arcing caused by this phenomena can lead to disintegration of the contacts and without proper precautions could lead to a serious arc flash event (see Arc Flash Note 1). Because this force is proportional to the "square of the current" ($F\alpha\ Ip^2$), the magnitude of the force can build rapidly in the first half cycle. Protection against these forces often requires that the instantaneous peak current be kept to a sufficiently low level by current limiting devices.

The next element to consider is heating. Heating of the contact's surfaces normally occurs because of the contact resistance. Since this resistance is very low, the heat generated during normal operation can easily be dissipated and operating temperatures kept within specified levels. However, under short circuit conditions the heat can build quickly to high levels due to the thermal energy delivered by the current (Heat $\alpha\ I^2t$).

Excessive heating can damage contacts and also burn open the current element of the overload relay which can potentially lead to an arc flash event if not properly protected. Protection against this heating often requires that the I^2t be kept to a sufficiently low level by current limiting devices.

III. UL STANDARDS AND TYPE 2 COORDINATION

Motor starters used today are typically UL listed and applied per the NEC. Under short circuit conditions, motor starters meeting the requirements of UL 508 and installed according to the NEC will not pose a fire hazard and will be safe for operators. But neither the NEC nor the UL 508 standard addresses "No Damage" levels of protection for motor circuits and their components.

The test levels for the standard short circuit test in UL 508 are shown in Table 1. The standard also provides starter manufacturers the requirements for listing their equipment at higher short circuit current ratings. This is increasingly important where starters rated less than 50 HP are being used in ICPs requiring a SCCR higher than 5,000A. For ratings in excess of the standard values shown in Table 1, the degree of damage allowed is greater than that for the standard tests.

Motor Controller HP Rating	**Test Short-Circuit Available**
1 HP or Less (300v or Less)	1,000A
<50 HP	5,000A
51 HP to 200 HP	10,000A
201 HP to 400 HP	18,000A
401A HP to 600 HP	30,000A
601 HP to 900 HP	42,000A
901 HP to 1600 HP	85,000A

Table 1. From industrial control equipment, UL 508

The following excerpts from UL 508 Table 53.1, Maximum Damage Criteria, are some of the levels of damage allowed when pursuing short-circuit ratings in excess of the values shown in Table 1.

> Discharge of parts or any risk of a fire shall not occur...
> ...The contacts of the motor control device are able to weld or completely disintegrate...
> When burnout of the current element of a mechanical overload relay occurs, the device shall be marked...
> The door or cover shall not be blown open, and it shall be possible to open the door or cover.
> When deformation of the enclosure occurs...
> There shall be no breakage or cracking of insulating bases to the extent that the integrity of the mounting of live parts is impaired.

Many starters, including NEMA-type and IEC-type, have been tested by their manufacturers with UL 508E—Outline of Investigation to meet IEC60947-4-1 which identifies two levels of coordination or protection against damage:

Type 1 Coordination ensures that the controller does not cause danger to persons or installation under short circuit conditions. However, the controller is not likely to be suitable for further services without repair and replacement of parts. Under test conditions defined in the standard, Type 1 damage may include vaporized heater elements and permanently welded contacts. Under actual conditions, Type 1 damage may require that a new starter be obtained and installed after repair to the control panel is completed. See Figure 2 for an example of Type 1 performance.

Figure 2. During test. Heater element were vaporized and contacts solidly welded. Type 1 performance.

Type 2 Coordination not only ensures that there is no danger, but that there is "No-Damage" to the controller for downstream faults. The following excerpt is from the UL 508E definition for Type 2 Coordination.

> "Under short circuit conditions, the controller shall not result in danger to persons or the installation, and after the short circuit test the controller shall be suitable for further use..."

The only allowable damage under Type 2 Coordination is light contact welding provided that the contacts are easily separable. See Figure 3 for an example of Type 2.

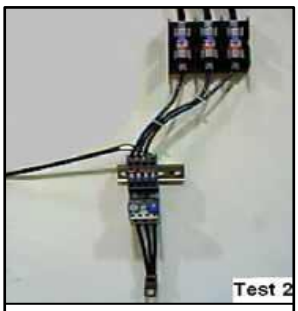

Figure 3. Test with AJT as overcurrent protection of IEC Starter for 22kA short circuit at 480V. Type 2 protection -NO DAMAGE.

To qualify for Type 2 Coordination (No-Damage Protection) the motor starter manufacturers must test all combinations of starters, contactors, overload relay and short circuit protective devices (SCPD). The tests include:

- A low-level short circuit test to confirm proper operation of the SCPD.
- A high-level short circuit test to check for No Damage protection of the contactor and overload relay.
- A Dielectric Voltage-Withstand Test to prove the adequacy of the insulation after both short circuit current tests have been performed.
- An Overload Relay Calibration Test to verify that the overload relay conforms to published tripping characteristics.
- A discrimination test to ensure proper coordination between the overload relay and the fuse.

Achieving "No-Damage" short circuit protection of a motor starter requires that the overcurrent protective device limit both the peak current and the I^2t let-through energy.

Type 2 coordination is typically obtained with tests at 100,000A with very current limiting devices. AJT (Class J) and A6D (Class RK1) fuses are ideally suited for this application. These current limiting fuses will clear a short circuit within their current limiting range in less than ½ cycle and prevent the fault current from reaching its first peak as shown in Figure 4.

Table 2 compares the I^2t let-through energy and Ip limits of Class J and Class RK-1 fuses with that of a 1 cycle fault current of 100,000A. For example, the 100A Class J highlighted in the table lets through 0.05% of the 1 cycle I^2t energy.

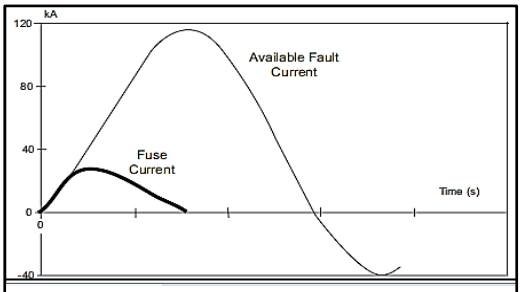

Figure 4. Fuse current limitation.

	I^2t (a^2s)			IP (Amps)		
Size	1 Cycle	RK-1	J	1 Cycle	RK-1	J
30A	166,666,667	10,000	7,000	230,000	10,000A	7,500
60A	166,666,667	40,000	30,000	230,000	12,000A	10,000
100A	166,666,667	100,000	80,000	230,000	16,000A	14,000
200A	166,666,667	400,000	300,000	230,000	22,000A	20,000
400A	166,666,667	1,200,000	1,100,000	230,000	35,000A	30,000
600A	166,666,667	3,000,000	2,500,000	230,000	50,000A	45,000

Table 2. Comparison of UL248 I2t and Ip limits for a test current of 100,000A

IV. FUSES FOR TYPE 2 COORDINATED PROTECTION OF MOTOR STARTERS

The fuses shown are UL Listed for branch circuit protection and have been proven in third party laboratory tests to meet the requirements of IEC 60947-4-1 by motor control manufacturers. To properly select these fuses for Type 2 protection of motor starters, refer to the selection tables in the Publication "How to Achieve Type 2 'No Damage' Protection of Motor Starters with Mersen (Amp-Trap

2000®) Current Limiting Fuses". The data in these tables has been obtained from the manufacturers or their web sites for your convenience. These tables are also available on our web site. Also, refer to the Application Section of the Advisor for more information on selecting fuses for motor circuits.

- **Amp-Trap 2000® AJT Class J Fuse**
  The ideal choice for new applications of 600 amps and less, AJT offers excellent current-limiting performance for short circuits and time delay for overloads. The unique Class J dimensions prevent improper substitutions. Lower current-limiting thresholds and let-thru energies provide the best degree of arc energy mitigation. The time delay for overloads ensures reliable operation in the presence of temporary overloads.

- **Amp-Trap 2000® A6D Class RK1 Fuse**
  When it comes to upgrading existing applications of 600 amps and less there is no better alternative than the A6D. The A6D's low current limiting thresholds and let-thru energies offer excellent arc energy mitigation. The time delay for overloads ensures reliable operation in the presence of temporary overloads. Its dimensions allow for simple upgrades of existing Class H, Class K and Class RK5 fuses.

- **Amp-Trap 2000® A6T Class T Fuse**
  The ideal choice for applications of 800 amps and less where space is limited, A6T offers excellent current-limiting performance for short circuit. The unique Class T dimensions prevent improper substitutions. Arc energy mitigation is comparable to the AJT Class J fuse.