DC Motor Protection

The purpose of DC motor protection is to extend a motor's lifespan by protecting it from conditions that can damage that the motor's windings—both electrically and mechanically. Motor winding damage can result from any of the following conditions (Ref. 1):

- Mechanical damage
- Excessive moisture
- High dielectric stress
- High temperature

While each of the above conditions can lead to winding damage, the *apparent* failure is "thermal degradation of the insulation or burnouts. Insulation life is reduced by about half for each 10° C increase in winding temperature" (Ref. 1). To avoid thermal degradation of the insulation, there are a number of methods, devices and circuits used to monitor potential motor hazards and fault conditions and to de-energize the motor when these conditions are met.

Potential Motor Hazards and Fault Conditions

A review of motor hazards and common fault conditions is useful in understanding the different approaches taken to protect motors. These fault conditions are divided into the following categories (Ref. 2):

- Motor-induced faults
- Load-induced faults
- Environment-induced faults
- Power source-induced faults
- Application-induced faults

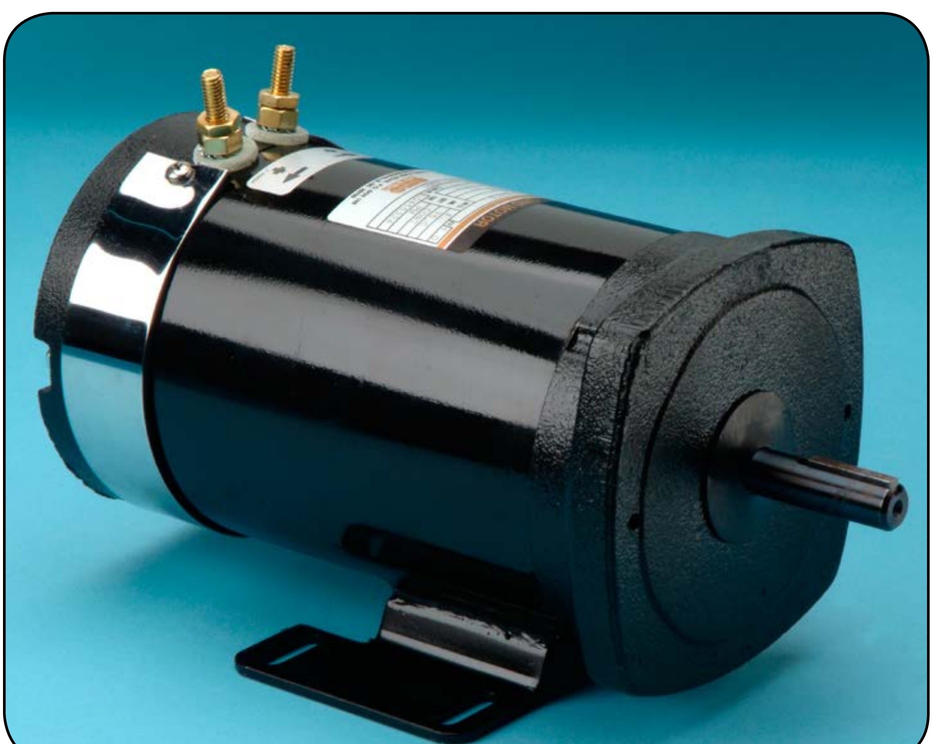
Motor-induced faults (Ref. 2) are directly related to the motor and its associated wiring. Common motor-induced faults include burnt out insulation, bad bearings, loss-of-field and other mechanical failures. Wiring problems, chafed or exposed wiring, cabling faults or abraded insulation can cause "short circuits between power phases or between a power phase and earth ground in the motor winding or its connections" (Ref. 3). (*Note: Even though wiring or cabling faults are related to power source-induced faults, they are categorized as motor-induced faults.*)

Load-induced faults (Ref. 2) are "the prolonged overloading as a result of the application of excessive mechanical load" (Ref. 3). Jamming (locked rotor) is a common load-induced fault that causes an apparent overload or high inertia (Wk^2d). In pump applications, for instance, oil that is cold or highly viscous may cause a fault; oil heaters are a possible solution to correct this fault condition.

Environment-induced faults (Ref. 2) include high ambient temperature, cold/damp environment, high contaminant level and blocked ventilation, among others. These conditions can increase the temperature of the windings by collecting moisture, degrading by corrosion or insulating the windings from contaminants. Loss of ventilation—especially at low speeds—also increases winding temperature.

Power source-induced faults (Ref. 2) typically will cause high motor currents that can thermally degrade the motor windings from I^2R heating. These fault conditions are numerous and include over-voltage; under-voltage; phase reversal; open phase failures (Ref. 3); unbalances; ground-faults; power transients; harmonics; and loss-of-field.

Application induced-faults (Ref. 2) are caused by operating conditions that typically cause overcurrent or overload conditions. These conditions include high duty cycle; jogging; rapid plugging (or plug reversing); over-speeding (Ref. 4); and synchronization problems.



Motor Protection Methods

Motor protection methods include devices and circuits that are used within the motor or used with the motor's control circuitry to monitor fault conditions. They include:

- Thermal overload relays

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- Transient voltage protectors
- Ground fault relays
- Distance relays
- Fuses, contactors and circuit breakers
- Under-voltage protection
- Locked rotor protection
- Loss-of-field relays
- Reversed-current protection
- Isolation transformers
- Harmonic filters
- Power conditioners

Thermal overload relays (Ref. 5) protect motors from overload conditions. There are two main types: inherent and external. Inherent thermal overloads (Ref. 6) are bi-metal devices embedded in the motor's windings. They are essentially thermostats with two dissimilar metals bound together that will bend to open (in some cases, close) a trip switch (Ref. 7) at a temperature set-point, which is proportional to motor current in an overloaded condition. The switch is connected to the motor's control circuitry to alarm and/or de-energize the motor. External thermal overload protection (Ref. 5) involves heaters that are connected in series with the motor's windings and mounted on the motor contactor or circuit breaker. There are two types of overloads: solder pot and bimetal strip. Solder pot overloads will melt when the heat generated by the motor current in an overload condition occurs; this action opens the motor control circuit and trips the motor off the power line. Bi-metal-strip (Ref. 5) thermal overloads operate similar to inherent overload protection. While thermal overload protection is most commonly used, electronic and magnetic overload protections are also used to combat overload (Ref. 8). Electronic overloads are current sensors. They sense actual motor current; when the motor current reaches a predetermined level, a relay will trip and open the motor control circuit. Magnetic overloads use electromagnetism to sense an overload. When an overload condition is sensed, a relay coil will pull in (close) and trip the motor off the power line.

Fuses and circuit protectors are not overload protectors; rather, they are overcurrent protectors designed to "protect the motor from a direct ground or short-circuit condition" in the motor or its associated wiring and cabling (Ref. 5). Short-circuit protection is incorporated into a motor contactor with "high-breaking-capacity fuses" or a circuit breaker with "instantaneous attracted armature-type relays." Ground fault relays or interrupters are another type of overcurrent protection. They monitor "unintentional current paths between a current-carrying conductor and a grounded surface" (Ref. 9). For motors, ground fault current paths are typically found through dust, water, or worn insulation. Ground faults pose worker safety hazards (Ref. 10). Reverse current relays are a protective feature used in motor-generator applications where a standby battery is being charged by the generator. The reverse current relay prevents the battery from discharging and motorizing the generator (Ref. 11).

For DC motors, the loss-of-field can potentially cause a dangerous, overspeed condition (Ref. 12). Hence, loss-of-field relays are used to monitor the motor's field. They are connected in parallel with the field and monitor the DC motor's field current. In the event that the field current decreases below a certain limit (Ref. 13), the loss-of-field relay will drop out and de-energize the motor's armature.

When a motor fails to start or accelerate after it's been energized, it is exhibiting a locked-rotor condition. In this condition the "motor is subject to extreme heating, much more so than in an overload condition since the heat has very little time to be dissipated in the conductors and other parts of the motor" (Ref. 14). Locked-rotor conditions can be protected by an overcurrent relay set for permissible I^2t times and currents. But for large DC motors, another solution is to build a zero-speed switch into the motor (Ref. 15). If the motor does not accelerate to open the zero-speed switch, the motor's power supply is de-energized. However, there's a disadvantage to the zero-speed switch; in situations where the motor starts but locks up at less than full speed, the zero-speed switch can close and de-energize the motor's power supply. Locked-rotor protection can also be accomplished by a distance relay (Ref. 16).

Power source-induced faults include under-voltage, overvoltage, open phasing, phase rotation and phase imbalances. (*Note: Generally speaking, phase imbalances, phase rotation faults and* *open phasing are associated with AC motors, and are not addressed in this article. But it should be noted that if a DC motor is powered by a DC converter, this controller protects the motor from these conditions*.) (Ref. 17) Under-voltage faults can cause either high motor currents or a failure to start. Hence, most under-voltage protection is part of the motor starter. However, for prolonged under-voltage conditions, an inverse-time-under-voltage-relay can be used to protect from this condition (Ref. 18).

Rather than using discrete components to protect a DC motor from over-voltages or surges, DC drives, isolation transformers (Ref. 19) and power-conditioning equipment (Ref. 20) are typically used to provide this type of protection. However, MOVs (Ref. 21), arrestors (Ref. 22), harmonic filters (Ref. 23) and power factor correction capacitors can also provide overvoltage protection (Ref. 23).

Interlocks: Indirect Motor Protection

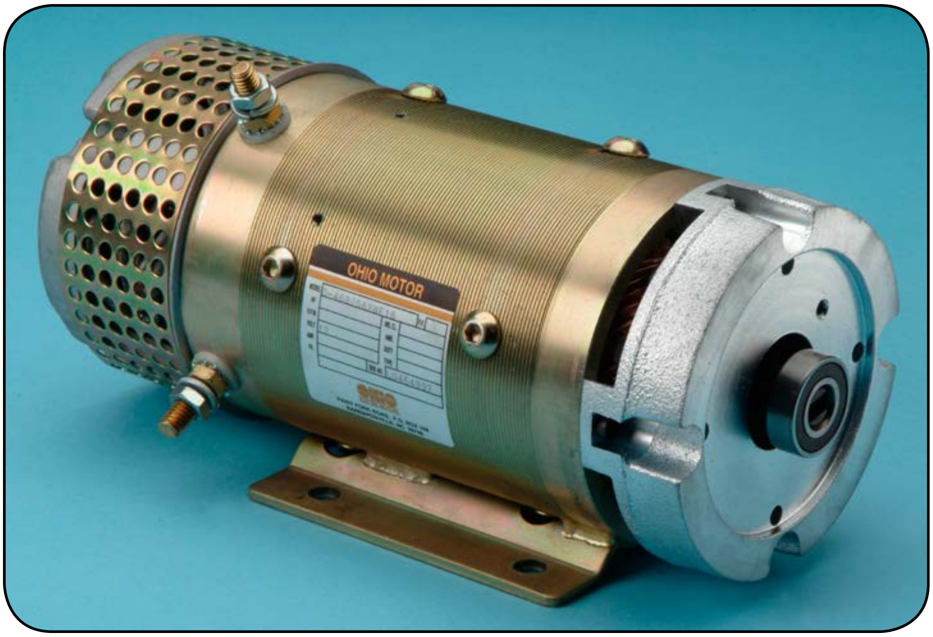
Interlocking is used to "prevent (motor) contactors from being energized simultaneously, or closing together and causing a short-circuit (Ref. 24)." In this respect, interlocking is an indirect type of motor protection and generally is used with motor starters for reversing and/or auxiliary control. There are three types of interlocks:

- Mechanical
- Electrical
- Auxiliary contact

Mechanical interlocks will physically prevent two motor contactors (forward and reverse) from closing simultaneously. "This interlock locks out one contactor at the beginning of the stroke of either contactor." On the other hand, electrical interlocks use a push-button control or auxiliary contact to electrically isolate one contactor while energizing the other contactor (Ref. 25). Auxiliary contact interlocking is a wiring modification of push-button interlocking. There are two types of auxiliary contacts: normally closed (NC) and normally open (NO). For interlocking protection in a reversing circuit, an NC auxiliary contact is wired in series with the opposing motor contactor coil. Thus, when a motor is running in the forward direction, the forward contact coil is energized through the NC auxiliary contact. When the reverse direction is selected, the NC contact will open and de-energize the forward contact coil while the reverse coil will energize through its NC auxiliary contact.

Environmental Protection

Environmental contamination can adversely affect normal motor operation. Dust, air particulates, explosive vapors, water, humidity and high ambient temperatures can all shorten the lifespan of a motor. To protect a motor from these environmental conditions, the National Electrical Manufacturers Association (NEMA) and the International Electro-Technical Commission (IEC) have classified motor enclosures based upon the level of protection they provide (Ref. 26). The two major classifications of motor enclosures are open and totally enclosed. Open motors are further classified as drip-proof, splash-proof, weather-protected, semi-guarded and guarded. Totally enclosed motors are classified as totally enclosed non-ventilated, fan-cooled, explosion-proof, dust ignition-proof, air-to-water cooled and air-to-air cooled. **PTE**



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