Littelfuse®

Expertise Applied | Answers Delivered

Motor Protection:

What's Your Relay Telling You?

Using Smart Relays to Protect Motors

White Paper

by Kip Larson,
Director of Product Technology,
Littelfuse, Inc.

Introduction

Motor protection relays protect against damage and downtime caused by problems such as overcurrent, phase loss, voltage unbalance and more. Unlike old-fashioned overload relays, modern relays are smart electronic devices that can tell the operator which condition triggered a shutdown. Smart relays display the information on a built-in screen or provide fault information via Bluetooth® or a local network. This white paper covers the types of alarm conditions commonly encountered and offers tips on corrective actions.

Jam

This message displays if motor current exceeds a set amount (less than starting current) while in Run mode. It directs operators to look for a problem with the load, rather than with the motor. The set point for this function (like all relay set points) is password-protected, preventing operators or others from changing it. With jam protection, the relay must be smart enough to know when the motor is in startup mode and temporarily disable the jam protection. Without this ability, one must specify a time delay after which one assumes the motor has started. Jam protection can detect a mechanical jam in the motor (imagine an industrial mixing machine stalling on a foreign object) or a severe overload that has stopped the motor and will dramatically reduce the time to trip, preventing extreme damage that can occur in a short period of time.

Thermal Overload

When a relay displays this message about high motor temperature and shuts off the motor, look for changes that may have increased the load, such as a torn conveyor belt, stuck raw material, or failed bearing. Thermal overloads detected by digital relays are not really a result of high temperature. The cause is the motor current exceeding the normal motor current and service factor settings, which is then tracked by the thermal model programmed into the relay. This model estimates the motor temperature based on the current. Some sophisticated relays use input from temperature sensors on the windings.

Too-frequent starts are another cause of overtemperature, and relays having dynamic thermal-overload capability will protect the motor. A motor built to NEMA standards is designed to provide two starts from cold without damage. To relate this to a thermal model, the motor uses approximately 50 percent of its available thermal capacity (I^2t) with one start. Therefore, if the motor is interrupted once or twice during a start, the motor will soon be in danger of damage and the relay should trip. "Thermal capacity" is based on motor specifications entered into the relay by the user and can be customized for fan-cooled motors that do not require the full 50 percent of the thermal capacity to complete a start.

Overcurrent and Undercurrent

Excess current through a motor, if it continues long enough, will cause overheating and dramatically shorten the motor's life. Small overcurrents just above the rated current — 5 or 10 percent, for example — will slowly overheat the windings and over time damage the insulation. While all motors must be protected by internal/external thermal overloads (bimetallic or eutectic), by the time these operate the motor may be dangerously hot; it is better to sense an overcurrent condition early, so the cause can be investigated and any necessary corrective measures can be taken. These older style overloads may also allow the motor to be restarted more quickly than would be possible if it were necessary for it to cool down to a safe temperature.

Overcurrent in a motor can be caused by a number of things. Overvoltage and undervoltage can cause it *(see Figure 2)*, but more common are mechanical problems. A binding shaft or bad bearings can directly increase the load on the motor, and should be corrected immediately. On a wastewater lift station pump, a rag caught in the impeller can cause excessive drag and increase current, or it can reduce flow and cause an undercurrent. Debris caught in the pump can cause a jam or locked rotor, which requires an immediate shutdown to prevent motor damage.

Because the power consumed by a centrifugal pump is an almost linear function of flow, anything that reduces flow will reduce motor power consumption. A loss of flow/undercurrent condition can damage the pump or motor if the fluid is used for cooling. This condition is true regardless of if the restriction is on the intake or discharge side of the pump.

Underload and Undercurrent

There are two ways to detect an underload: current and power. Equipment operating normally with a power factor greater than 0.7 will show a dramatic change in current if unloaded. When equipment is designed to operate normally lightly loaded (pf less than 0.4), the loss of load does not significantly change the current, but a modern relay will have enough resolution to see this change by measuring the power (phase angle, combined with the current). This type of monitoring is more complex, but more accurate for lightly loaded devices like magnetically coupled (mag-drive) pumps that need flow loss detection.

There are some problems unique to pumps that make it worthwhile to consider a protective relay designed specifically for this application *(see Figure 1).* These units have a variety of designations: pump protection relays, electronic overload relays, electronic motor protective relays and others, but in general they tend to have certain characteristics in common. One way in which units suitable for pump protection differ from those for general motor protection is the ability to sense underload.

Figure 1.
The Littelfuse MP8000 Bluetooth® Enabled Overload Relay is a smart universal relay that can communicate to a technician's smartphone or tablet via Bluetooth. They can safely monitor at a distance with no need to open the control panel.

How to set the response to an underload can vary with circumstances. Take, for example, a lift station pump that takes in a rag, causing a small overload or underload. It may be worthwhile to set the protective relay to shut down for several minutes, and then make one restart attempt, allowing the debris an opportunity to free itself. If the problem returns then the relay should shut off the motor, alarm, and require manual intervention.

In some submersible well-pumping applications it may be common for the well to run dry temporarily from time to time; in this case it makes sense to shut down the pump, and set a fairly long restart delay, allowing the well to refill and normal operation to resume.

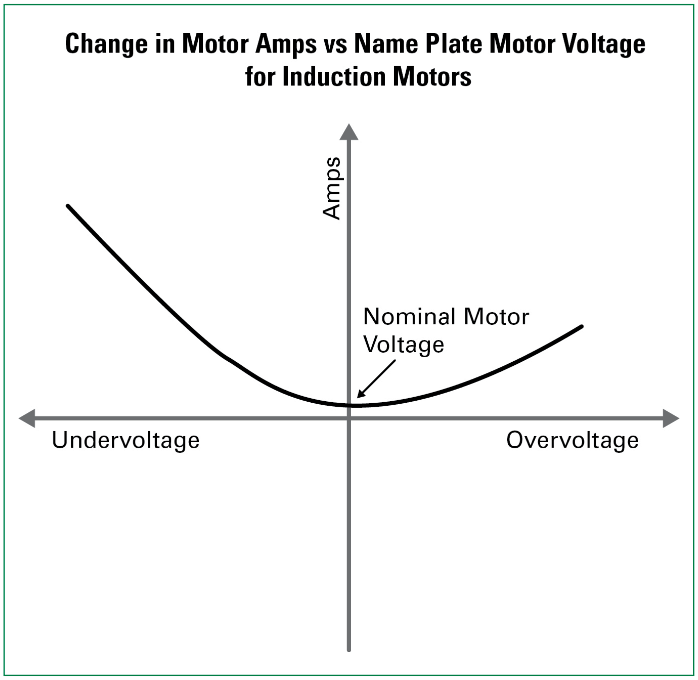
If the mechanical coupling between the motor and pump fails, then the result will be a free-spinning motor and a stopped pump. While this may not damage the motor, it wastes electricity without doing any useful work, and should be detected and corrected as soon as possible.

Overvoltage and Undervoltage

Overvoltage will increase the current through the motor, and result in increased motor heating and shortened life. If the power utility increases its line voltage to compensate for increased load and then the load decreases, an unsafe rise in current can occur.

Similarly, if the power utility allows the voltage to sag under heavy loads, then the motor can suffer a low voltage condition, which will also cause it to draw more current (*see Figure 2*).

Figure 2.
An increase in motor amperes may indicate either an undervoltage or an overvoltage condition.



Three Phase Voltage or Current Unbalance

Three phase motors are designed to have balanced power, so all three motor windings share the load equally. If one phase of the voltage is significantly different (high or low) from the others, then the result will be excessive current in one or more of motor windings, which can lead to overheating, insulation degradation and shortened motor life. Phase imbalance can be caused by the presence of single-phase loads that are not evenly distributed among the utility's phases. Air conditioners can be prime offenders, although there are many other possibilities, including air compressors, arc welders, and the list goes on.

The urgency of the situation will depend on the amount of unbalance. Protection relays can be set to ignore small unbalances and alert/shut down on larger ones; the appropriate setting for the relay will depend on how much unbalance the motor can tolerate, and how often an unbalanced condition occurs.

While it is possible for the utility to install a set of autotransformers to correct phase imbalance caused by single-phase loads, these solutions tend to be expensive. Many times the single-phase loads can be better distributed across the three phases, but detecting the problem is an important part of the solution.

Missing Phase

If the voltage balance on a three-phase system becomes severe, the result is a single-phase condition on the motor, which will quickly overheat it, and the motor must be shut down until the problem is corrected.

It is also possible to have a complete loss of one phase at the motor but not in the incoming electrical system because of a failed contact on a contactor, a loose or corroded connection, or a damaged wire between switchgear and motor. Some protective relays have the ability to detect, protect, and identify this problem.

Phase Reversal

Phase reversal, which can happen as the result of work on the power system, will cause the motor to run backwards. Some equipment, like scroll compressors, will be quickly damaged by this, while centrifugal pumps may be unharmed, but will do no useful work. Detecting the undesired phase sequence and preventing a motor from starting so the problem can be corrected is the best solution with this type of problem.

Ground Faults (low-level)

While a low-impedance ground fault (a short circuit to ground) is obvious, and will trip the primary circuit protection device, a low-level ground fault that draws only a small current can be more difficult to detect. Such a fault can be caused by minor insulation breakdown. If it is detected early it can often be repaired by cleaning and re-varnishing the motor (aka "dip and bake"). If allowed to continue, such a fault can do significant damage, degrading insulation and eventually causing so much damage that the motor must be completely rebuilt, or the motor may even be unrepairable.

It's also possible for dust and dirt to accumulate in junction boxes. If moisture is present, this may create a high-resistance path to ground. A protection relay can detect these small currents and alert the operator or shut down the motor before significant damage is done.

Depending on the cause, the cure can be as simple as a thorough cleaning of the electrical connections (with the power shut off, of course).

Summary

A smart motor protection relay can detect and protect against a wide variety of damaging conditions. Fully understanding how to program the device and interpret its readout can prevent many problems and help avoid unnecessary downtime.

Kip Larson *is Director of Product Technology, Industrial Business Unit, Protection Relays, Littelfuse, Inc. He has more than 30 years of industrial electronics product design and application experience. He received a B.S. in Electrical Engineering from South Dakota School of Mines and Technology.Larson may be reached at larson@littelfuse.com or 605-348-5580, ext 116.*

Please see page 5 for Common Causes of Relay Indications and Possible Corrections reference chart.

Common Causes of Relay Indications and Possible Corrections

Relay Indication	Likely Cause	Correction
Overcurrent	Overvoltage	Correct voltage problem at source
	Undervoltage	Check wiring; contact utility
	Excess flow	Review pump spec/application
	Bad bearings	Replace bearings
	Foreign material in pump	Clean out pump
	Jammed pump	
Undercurrent	Restricted flow	Correct flow restriction
	Lack of liquid to pump	Shut down until liquid is restored
	Broken shaft coupling or belt	Repair mechanical components
Current Unbalance	Bad wiring	Examine and correct
	Unbalanced power input	Reconnect single-phase loads to balance phases
Overvoltage	Bad regulation from utility	Correct voltage problem at source
Undervoltage	Bad regulation from utility	Correct voltage problem at source
	Wiring problem	Examine and correct
Single Phase	Broken wire	Repair wiring
	Bad contactor	Replace contactor
	Blown fuse/utility failure	Replace fuse/contact utility
Phase Reversal	Miswiring upstream in electrical system	Exchange two phases at input to pump power panel
Ground Fault	Small defect in insulation	Have motor tested and re-varnished if feasible
	Contamination in wiring or junction boxes	Clean out contamination
Contactor failure	Faulty contactor	Replace contactor/contacts
	Bad connections on load side	Repair connections
Overtemperature	Poor ventilation	Unblock air ventilation to motor cooling fins and general area. Clean motor of dust and debris.
	Unbalance condition	See "current imbalance" above
	Bearing friction	Lube or replace bearings
Jam	Load exceeds motor's capability	Inspect the load to determine if it has changed
	Mechanical jam	Check for mechanical jams, failed bearings, or other problem that would prevent the rotor from turning

For more information, visit
Littelfuse.com/MotorProtection

Additional technical information and application data for Littelfuse protection relays, generator and engine controls, fuses and other circuit protection and safety products can be found on **www.littelfuse.com**. For questions, contact our Technical Support Group **(800-832-3873)**. Specifications, descriptions and illustrative material in this literature are as accurate as known at the time of publication, but are subject to changes without notice. All data was compiled from public information available from manufacturers' manuals and datasheets.

FORM NO. PFD772
Rev: 1-B-091417