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Fundamentals of Electric Actuator Control

A VIEW OF THE ELECTRICAL FUNCTIONS OF A MOTOR ACTUATOR

FUNDAMENTALS OF ELECTRIC ACTUATOR CONTROL

ELECTRIC ACTUATORS HAVE BECOME A POPULAR WAY TO AUTOMATE ALL TYPES OF INDUSTRIAL VALVES. ONE OF THEIR PRIMARY ADVANTAGES IS THE INHERENT FLEXIBILITY OF THEIR CONTROLS BOTH BECAUSE OF WHERE THE CONTROLS CAN BE LOCATED AND BECAUSE OF THE WIDE RANGE OF CONTROL SYSTEM INTERFACES AVAILABLE.

BY RICHARD D. OAKS

Every motor requires controls, and the motor of an electric valve actuator is no different. The function of the electric actuator's controls is to start and stop the motor. Those controls typically consist of the motor switchgear, devices that control that switchgear and various interfaces with the plant control system.

A simple on-off switch or a switch and a motor starter can control a fan motor that operates in only one direction. However, a valve actuator motor must be controlled considering criteria such as:

- valve position
- torque or thrust output
- motor protection
- control system commands
- local control
- operation in both directions (since we want to open *and* close the valve).

Controlling the Motor

To control the motor, contacts large enough to handle the current required for starting and running the motor must be provided. Those contacts are engaged and disengaged by a magnetic coil. The contacts and coil make up a magnetic starter. That starter's contacts make and break the power to the motor as the starter coil is energized and de-energized.

Since an actuator must operate in both directions, we need a means to reverse the direction of the motor. For three-phase motors, this can be accomplished by reversing two of the three motor power leads or phases. We achieve phase reversal by using two motor starters, which work together to be what we commonly refer to as a reversing starter.

Figure 1 shows how a reversing starter reverses the direction of a motor. When Coil A is energized, Contacts A close, and the motor runs in the clockwise direction. When Coil B is energized, Contacts B close, and the motor runs in the counter-clockwise direction. Note that motor power leads L1 and L3 are reversed when Contacts B are energized as opposed to when

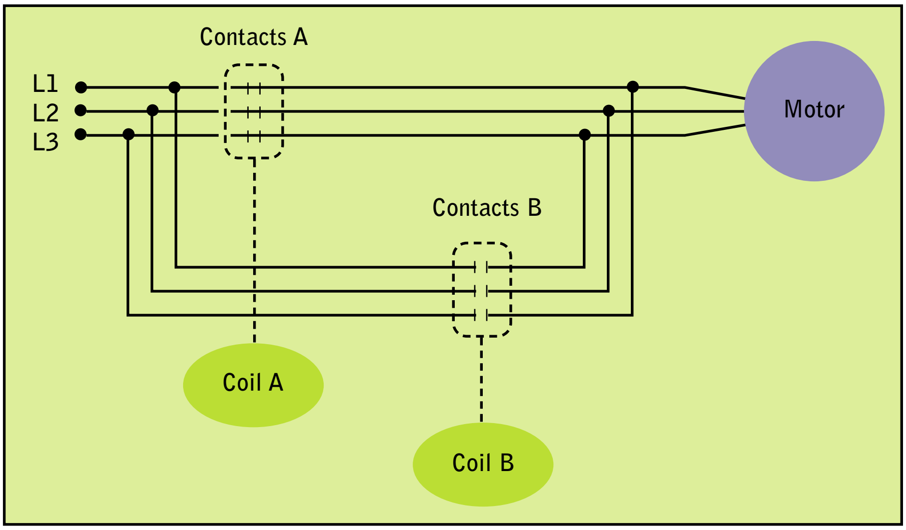

Figure 1—Reversing starter: Coil A pulls in Contacts A, resulting in clockwise motor rotation. Coil B pulls in Contacts B, resulting in counter-clockwise motor rotation.

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Contacts A are energized. Conversely, when the coils are de-energized, the contacts open and the motor will stop.

Most reversing starters are furnished and configured with mechanical and electrical interlocks. This is a redundant system whose purpose is to ensure both starters will not energize at the same time.

The motor power available in industrial facilities varies. Typically, three-phase motor power available in North America is 460 volts / 3 phase / 60 hz. The power available in many overseas facilities has a frequency of 50 hz. Voltage ranges from 208 to 600 volts.

In a similar manner, reversing the two power leads with reversing starters operates single-phase motors. Generally, single-phase actuator motors also are furnished with starting capacitors. In some cases, single-phase motors can be operated without reversing starters. For example, a switch can be used to reverse the power leads. In this case, all motor control contacts are subject to the current drawn by the motor, so we must assure the contacts both in the actuator and in the process control system are capable of accommodating the motor current.

In addition to magnetic reversing starters, solid-state starters are sometimes furnished with actuators. Solid-state starters do not have moving parts, and they switch the power to the motor electronically. Generally, these devices are used in rigorous modulating applications when the actuator is expected to start up to 1,200 times per hour.

Position Sensing

Position sensing is primarily needed to determine when the valve has reached the open or closed end of travel so the motor can be de-energized.

Various methods of position sensing are used. The most common is a mechanically operated switch referred to as a limit switch. The switch is physically tripped by a mechanism operated by and mechanically linked to the output of the actuator. The most effective method for tripping the switch is to use a counter gear device, but cams can also be used to mechanically trip switches.

Another method of position sensing is a proximity switch, which operates similar to the mechanically operated switch, but without the physical tripping mechanism.

In addition, an encoder can be used to sense position. The encoder senses mechanical motion or travel and translates that information into electronic data. The two types of encoders are absolute and incremental, and both are used in electric actuators. Incremental encoders have output signals that repeat over the full range of travel, so each position is not uniquely defined. When the incremental encoder is turned on, the position is unknown since the output signals are not unique to a specific position. Absolute encoders, on the other hand, have a unique value for each position. When an absolute encoder is turned on, the position is known. For both types of encoder, there are various methods to determine the position for the encoder, but with electric actuators, the methods are magnetic and optical. With all encoders, the information is gathered and stored electronically, so the end-of-travel positions can be programmed, enabling the actuator motor to de-energize at each end of travel.

A supplementary sensing method is continuous position feedback throughout the entire valve stroke. This indicates to an operator or process control system the current valve position at any point of valve travel. The operator is then able to view valve position as 0 to 100% open on a meter at a control console. The position feedback signal is usually 4 to 20 milliamps from a transmitter, but it also can be a resistance reference from a potentiometer.

Torque Sensing

Torque sensing is needed to limit the output torque of the actuator. The torque-sensing switch is commonly called a torque switch, and several methods of sensing are used. The most widely used method is to measure the actuator output torque by determining the axial movement of the actuator's sliding worm gear, which compresses springs. The axial movement is converted to a rotary movement, which trips a switch. That same rotary movement can also drive an encoder.

A second method of sensing is to measure the motor current. By correlating that current to output torque, a switch can be tripped at a specific value of current and, therefore, the torque at that value.

A third method involves measuring motor speed by rapidly sensing position changes. The motor speed is high without load and falls as the load or torque output rises. By compensating for voltage and temperature variations, a correlation can be established between motor speed and torque output. Torque limits can then be determined rela-

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tive to that speed.

Another method uses a load cell and switch in conjunction with the sliding worm gear.

In all cases, a switch is tripped or an electronic device signals when a certain level of output torque is reached, and the actuator motor is de-energized.

Motor Protection

Many motors in industry, such as those used to operate pumps and fans, are designed to operate continuously. Motors in electric motor actuators, however, are not designed to operate continuously—they are designed to generate high output torque instantaneously for the purpose of unseating a valve. Continuous running could result in the motor overheating, insulation breaking down and possible motor failure. As a result, the motor must be protected from the excessive accumulation of heat.

One method of protection is to install one or more thermal switches in the motor windings. These switches operate like thermostats—when a certain temperature is reached, the switch trips and de-energizes the motor. When the motor windings cool, the switch remakes, and the motor circuit is restored.

Another method of protection is to sense motor current. When the current reaches a specific level, a switch trips and the motor is de-energized. Typically, the switch then resets automatically.

Figure 2—Local controls: open-stop-close pushbuttons; open-fault-close indicating lights; local-off-remote selector switch

Control Power

The actuator motor often draws relatively high current, up to several hundred amps at a high voltage such as the 460 volts previously mentioned. The control circuit, however, is always low voltage—DC or single-phase AC with low current—usually less than one amp. As a result, a control transformer or power supply is provided with the motor controls. The power supply converts the motor power to control power. For example, 460 volts / 3-phase motor power might be converted to 24 volts DC or 120 volts AC. In some facilities, the plant control system provides 24 volts DC for the actuator control circuit.

Local Controls

Another element that affects motor control is use of local controls. These devices can directly operate the valve. Typical local controls are

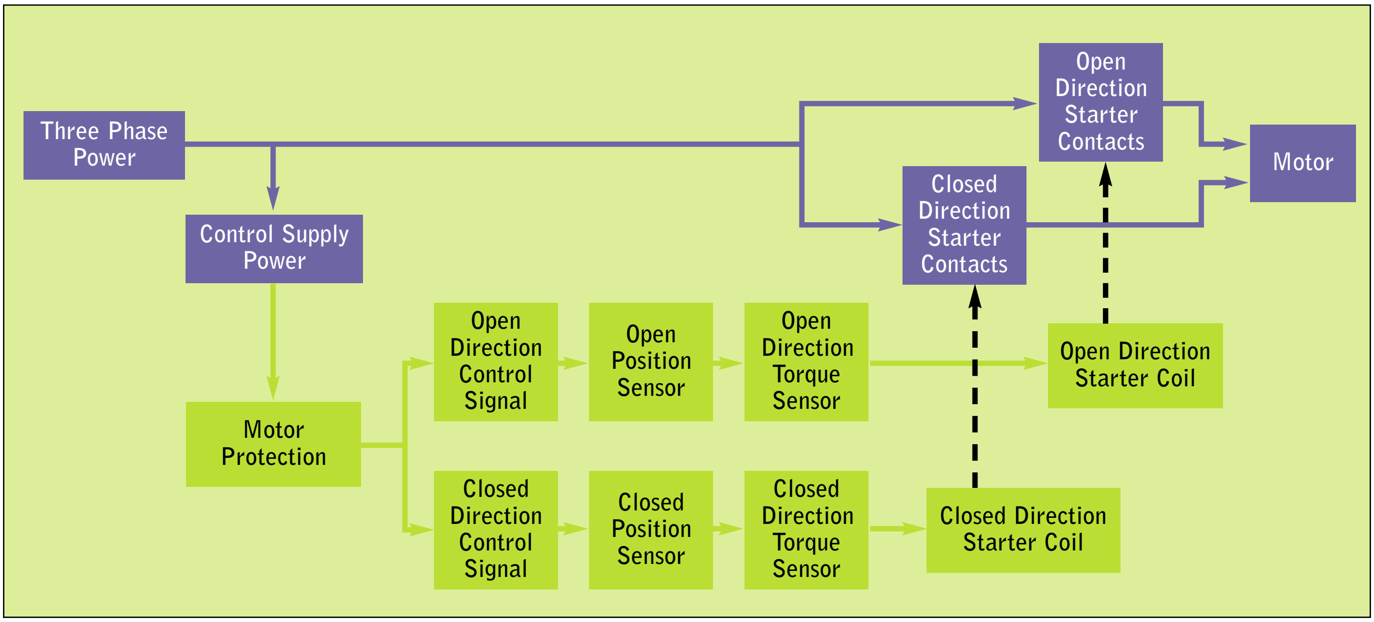

Figure 3—In this motor control logic block diagram, the power circuit is shown with blue lines and the control circuit with green lines.

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pushbuttons—for local open-stop-close control and selector switches—generally for local open-stop-close control or selection of local-off-remote modes of operation.

In addition to controls, indicating lights are used to designate various actuator status criteria such as when:

- open valve position is reached
- closed valve position is reached
- the monitor relay is tripped
- over-torque condition occurs or
- the selector switch is in the remote position.

Figure 2 shows a typical local control station with three pushbuttons (open-stop-close), a selector switch (local-off-remote) and three indicating lights (open-fault-close).

Motor Control Circuit

We now have several important devices that must be tied together to control the actuator motor. Each direction of travel has a control circuit in which the controlling devices work together logically to control the respective motor starter.

Figure 3 shows a block diagram of an actuator motor control circuit. The motor power components are connected with blue lines. Those components are the input of the control power supply, the open starter contacts, the closed starter contacts and the motor. The control components are connected with green lines. An open direction control signal, open position limit switch or sensor, and open direction torque switch or sensor are tied together in series with the open direction starter coil. When we get a signal to open the valve, the open direction starter coil will be energized as long as the open position has not been reached and the pre-set torque limit has not been exceeded. The starter coil will pull in the starter contacts, and the motor will run until the starter drops out, which will occur when the position is reached, the torque exceeds the pre-set limit, the control signal is removed, or the motor protection trips. The closed direction control signal, limit switch, torque switch and starter coil are similarly configured. The output of the control power supply and motor protection devices are usually common to both circuits.

In the past, these devices were all hard-wired into an electrical control circuit. Most actuators furnished today perform the same function electronically by connecting the devices with electronic-printed circuit boards. The availability of LEDs and dip switches on the circuit boards and interfaces with PCs gives actuator users the ability to easily change control circuit parameters, such as selecting position or torque seating for the clockwise direction or counter clockwise direction of actuator rotation.

Figure 4—An electric actuator with integral motor controls

Where Are Controls Located?

The location of the electric actuator controls varies. While the position sensing, torque sensing and motor thermal switch protection devices are always at the actuator, the rest of the controls (reversing starters, power supply, control logic and local controls) can be located either at the actuator or remotely.

When the motor controls are

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Figure 5—An electric actuator with remote motor controls

located at the actuator, they are described as integral controls. Figure 4 shows an actuator with such controls. Over the past 20 years, the trend has increasingly been toward furnishing integral controls with electric actuators. This configuration is preferred because of its high degree of reliability, since the entire control package is designed, assembled and tested by one responsible supplier—the actuator manufacturer.

When the motor controls are located in a remote location, they are called remote controls. Figure 5 shows an actuator with remote controls and cabling between the actuator and controls. Furnishing the controls remotely is common practice when the automated valve is inaccessible or located in an environmentally unfriendly spot such as places with high-ambient temperatures or that are frequently submerged.

Control Signals

Control of electric actuators is very flexible. Command control signals can originate from a device as simple as a local open-stop-close switch or pushbuttons. Contact closure or discrete open-and-close control signals can also originate from remote control stations or process control systems. With contact closure, a normally open contact closes, completing the control circuit and allowing the actuator motor to run until a limit is reached, the torque switch trips or the control contact is opened. When the control circuit is interrupted, the starter drops out and the motor stops.

A local-off-remote selector switch is frequently used to allow plant personnel to select between controlling with integral pushbuttons or remote open-and-close contacts. This switch is usually furnished with the local controls.

A 4-20 milliamp analog signal also can be used to position an automated valve at or between the fully open or fully closed positions. Generally, 4 milliamps is a close signal while 20 milliamps is an open signal, and any signal between 4 and 20 commands the valve to go to a position proportional to the signal—for example, 12 milliamps is a 50% open signal.

The device that accepts the analog signal is known as a positioner. It compares the command signal (usually 4-20 mA) and the present valve position commonly known as position feedback (usually 4-20 mA or 0 to 5000 ohms). The positioner determines the difference between the two values and energizes the open-or-close motor control circuits accordingly. For example, if 4 milliamps represents the closed position and the command signal is 8 milliamps while the feedback signal is 12 milliamps, the positioner will determine what is required for the valve to travel from the 12 milliamp position toward the 8 milliamp position, therefore driving the actuator in the closed direction.

The positioner is furnished with the motor controls. Analog signals

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are frequently used to control automated valves in process control applications requiring positioning or modulating service. As with the contact closure example, a local-off-remote switch is generally furnished with the positioner. In this case, we select between the integral pushbuttons in the local position and the positioner in the remote position.

Digital communication or fieldbus technology is also used to communicate control signals from a control system to individual valves. With a conventional control system, as many as 16 dedicated control wires can be running from the control station to each actuator. The cost of the wire, conduit and installation labor for a conventional control system is high. With a fieldbus system, the control station is wired to each actuator with a common bus or fiber optic cable. The cost of cabling material and installation is significantly lower when compared to a conventional system. In addition, other control instruments such as transmitters, or controlled devices such as pump or fan motor starters, can be added to the same control bus. Plus, more information can be transmitted from the actuator to the control system, including the number of valve operating cycles, motor thermal switch trip, limit switch trip or torque switch trip in mid travel and diagnostic data. This information can be a valuable tool to the plant owner, operating personnel and maintenance staff.

The means of communication is by one of many protocols such as Profibus, DeviceNet, Modbus or Foundation Fieldbus. When we use digital communications, the control station is a computer or programmable logic controller (PLC). This PC or PLC may be tied into a larger distributed control system, supervisory control and data acquisition system, or plant-wide network.

Summary

As this article shows, control of electric actuators is very flexible. Many types of control configurations and technologies can be used to control an actuator electrically. It is important for the purchaser or specifier to clearly indicate to the actuator supplier how the actuator is to be controlled as well as what controls they expect the supplier to furnish. **VM**

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ACTUATOR CONTROLS CHECKLIST

- ☐ Are the motor controls to be integral with the actuator?
- ☐ If the controls are going to be remotely mounted, is the actuator supplier expected to furnish them?
- ☐ What is the available motor power?
- ☐ How are the actuators going to be controlled (discrete signals [24 VDC or 120 VAC], analog signal [4-20 mA], fieldbus [PROFIBUS DP, DeviceNet, Modbus, Foundation Fieldbus], etc.)?
- ☐ Are there any other special control considerations (solid-state starters, special local controls, control power furnished by control system, etc.)?

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