



THE JOURNAL

From Rockwell Automation and Our PartnerNetwork™

2015 Special Report on Electrical Systems

Your electrical systems are vital to so many of your production operations and affect worker safety and costs. Learn how to minimize arc-flash hazards, choose motor-control technology, protect motors, and understand safety interlocking standard (EN) ISO 14119. Also discover how a forge press builder cut energy consumption using VFDs and visualization solutions; how EtherNet/IP-connected SCR power control modules can help cut costs; and how to synchronize controls configuration data.



BRING NEW LIFE INTO ELECTRIC CONTROL VALVE ACTUATION

Electric actuators based on servo-motor and roller-screw technologies can enable a responsive and accurate electric actuator solution that's well suited for valve control.

By Barb Boynton, [Curtiss-Wright/Exlar® Actuation Solutions](#).

➤➤ Electric actuators have long been used for general valve automation. However, when applied to control valves, limitations inherent with legacy electric technology can restrict its effective use for modulation control, especially when fast response is required. Servo motor control and roller screw technology, both used for years in the motion control industry, don't have these limitations. Therefore, they can offer a responsive, accurate electric solution, well suited for demanding valve-control applications.

Motor Technology

Legacy electric valve actuators use single- or three-phase induction motors to provide the necessary driving force. While they're suitable for on/off applications, induction motors suffer from heat-rise limitations and a high mechanical time constant that limits their ability to modulate on a continuous basis.

All motors produce torque through the interaction of two slightly offset magnetic fields, one on the stator (stationary, or housing portion of the motor), and one on the rotor (rotating, or shaft portion of the motor). In

an induction motor, electrical current flowing through wound copper wire in the stator generates a magnetic field. The stator magnetic field then induces a similar, but offset, magnetic field in the rotor, similar to how a generator generates electricity.

Unfortunately, building a magnetic field through induction requires a significant amount of electrical current, a by-product of which is heat generation caused by inefficiencies inherent in the design. Because the induced magnetic field must be built each time the motor starts or reverses direction, the more an induction motor must start and stop, the more current is consumed, and therefore heat is generated. This heat must be dissipated to prevent damaging the motor windings.

During steady-state operation, current consumption is at a minimum, and the small amount of heat generated is dissipated easily. With each start and stop, additional current is consumed and heat generated. Under extreme circumstances, such as continuously modulating a control valve, the induction motor won't be able to dissipate enough heat and must be powered down for a period of

All motors produce torque through the interaction of two slightly offset magnetic fields.



time to allow for cooling. High ambient temperatures can prolong the needed cooling time.

Induction motors also have inherently high rotor inertia. This is a benefit when trying to maintain a constant speed. However, high rotor inertia requires more torque, and therefore more current to accelerate and decelerate, leading to more heat generation as described previously. The high rotor inertia of an induction motor therefore severely limits the motor's ability to accelerate quickly and frequently, making it a poor choice for modulating applications.

Permanent magnet servo motors have significantly lower rotor inertia than induction motors, and therefore consume less current.

In contrast, permanent magnet servo motors use permanent magnets to supply the rotor's magnetic field. As the name implies, a permanent magnet continuously supplies a magnetic field without the need for additional current during field buildup.

Also, permanent magnet servo motors have significantly lower rotor inertia than induction motors, and therefore consume less current while offering significantly higher acceleration and deceleration capability. Additional benefits of permanent magnet servo motors include a smaller overall package size and significantly higher efficiency, making them an ideal choice for modulation.

Mechanical Powertrain

To minimize the inherently larger induction motor package size while still providing the desired output force, legacy electric actuators incorporate substantial gear reduction in the form of worm or spur gears. While accomplishing the goal of minimizing package size, the high reduction severely limits the available output speed of the actuator. Additional drawbacks of this type of mechanical transmission include a relatively short useful life and low energy efficiency.

Because of their limitations, application of traditional electric actuators has been limited to slow, low duty cycle applications, because they're not suitable for controlling rapidly and continuously changing process parameters such as pressure.

For linear applications, an additional lead screw or ball/roller screw assembly is needed to convert the motor's rotary torque to linear force. While they're economical, lead screws use a nut that rides directly on the screw, which can result in high sliding friction and low efficiency, limiting useful life and maximum speed. Using lead screws in continuous duty applications also can result in premature screw failure and a short life.

The limitations of legacy electric actuators significantly affect system life. The most common failure mode in a legacy system is exceeding the rated duty cycle, leading to premature motor failure. Wear in the mechanical transmission resulting in significant reduction in system stiffness, and therefore unacceptable system response, is another common failure mode.

The net result of limitations with legacy electric actuator technology is that even the "high end" solutions have a design life of about only 50,000 operations.

A study done by Exxon Mobile and presented in May 2012 at Coking.com included the following wear issues:



Major electric actuator wear areas include:

- Drive sleeve and worm shaft bearings.
- Sliding surfaces — drive sleeve splines, worm shaft splines, worm and worm gear teeth.
- Motor pinion and drive gear.

Failure areas include:

- Circuit boards damaged by heat and steam.
- Vibration-induced damage.
- Sticking of interlock relays.

Ball and Roller Screws

A better choice for converting rotary to linear motion are ball screws, which have been successfully employed in the industrial motion-control industry for years. Ball screws use ball bearings to provide rolling contact between the nut and screw, providing longer life and higher efficiency when compared to a lead screw.

A better choice for converting rotary to linear motion are ball screws.

Unfortunately, ball screws still don't offer adequate life for high duty cycle modulating applications, and their moderate force capacity results in a larger-than-necessary system package size. They're also difficult to maintain, particularly with lubrication.

The ultimate choice for converting rotary to linear motion in high-duty cycle, high-response applications is the roller screw. Instead of ball bearings to provide roll-

ing contact, roller screws use threaded rollers that gear the nut to the screw, similar to the relationship of planet gears to the sun and ring gears in a planetary gearbox. Unlike ball screws, which transmit loads through the ball bearings via point contact, roller screws transmit loads via line contact, thus distributing the loads over a greater surface area. This results in higher force capacity and five to 15 times the life expectancy compared to an equivalently sized ball screw.

Servo-motor technology coupled with planetary roller screws have been employed in the industrial motion-control industry in a variety of arduous applications, including military environments and high cycle/high speed loads. The technology offers no duty-cycle limitations, response and stroke times of milliseconds, and virtually no dead time.

This makes these actuators a perfect choice when electric actuation is needed for control-valve applications. In fact, the combination of servo motor and planetary roller screw offers the only true electric alternative to a hydraulic cylinder in terms of force density, life and overall durability.

Removing Limitations

Legacy electric actuator technology has drawbacks that limit its effectiveness for use on control valves. Electric actuators based on servo-motor and roller-screw technologies remove legacy limitations, allowing for a highly responsive and accurate electric actuator solution that's well suited for valve control. □

Curtiss-Wright/Exlar® Actuation Solutions, based in Chanhassen, Minnesota, is a participating [Encompass™ Product Partner](#) in the Rockwell Automation® [PartnerNetwork™](#). Exlar designs, manufactures and sells linear and rotary actuation products worldwide, serving industries including industrial automation, automotive, process and defense.