Omnivise iSER® Actuator

Intelligent Self-Contained Electrohydraulic Redundant Actuator

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Introduction

Many steam turbines are controlled by antiquated mechanical hydraulic control (MHC) systems resulting in control issues, unplanned outages due to failures and wear, and high maintenance costs. In addition, the experienced personnel required to operate and maintain these systems are rapidly disappearing and finding replacement parts is increasingly difficult. The main barrier to upgrading to a modern electrhydraulic control (EHC) system is the exceptionally large capital investment in the demolition of the old system, installation of the new system, and updates to the plant control system. The single largest expense when modernizing a control system is typically the installation of new welded high-pressure piping for the hydraulic system.

The Siemens Energy iSER Actuators solve these challenges at a significantly lower cost. Their self-contained design eliminates the main costs of piping installation while providing the precision control needed for operation and increasing the reliability, safety, and flexibility that turbine owners desire. In addition, Siemens Energy iSER actuators offer advantages over modern EHC systems, including eliminating virtually all leak points, greatly improved diagnostic capabilities, and enabling of predictive instead of reactive maintenance.

The Costs of Control

Many of the large steam turbines used for power generation are still controlled with mechanical hydraulic control (MHC) or early electrohydraulic control (EHC) systems. These aging, overly-complex systems can saddle their owners with significant – and avoidable – costs.

There are three common solutions that various owners have devised to surmount the shortcomings of older MHC and EHC systems:

- **Low-pressure retrofit** These include using current-to-pressure converters, trip system upgrades, or low-pressure actuator upgrades to partially digitize the control. These upgrades are the cheapest solution, but dirty oil and worn existing components remain significant issues.

  Higher tolerances on modern valves mean that dirty oil can quickly cause failures unless filtration or an oil cleanliness mitigation strategy is implemented Furthermore, due to the nature of the multiple amplification stages in these old systems, simply upgrading the first stage does not fix problems inherent or existing in the subsequent stages

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iSER® Benefits

- ✔ Eliminates pipe installation costs
- ✔ Increases overall reliability
- ✔ Provides precise control
- ✔ Boosts flexibility
- ✔ Eliminates most leak points
- ✔ Improves diagnostics
- ✔ Enables predictive maintenance

Figure 1 Siemens Energy iSER benefits section.

- **EHC retrofits** This involves the total removal of the MHC system and its associated control and protection functions. It has an exceedingly high installation cost due to the newer high-pressure piping that must be installed. Typically, an upgrade to part or all of the DCS or turbine control system is also required, in addition to upgrades of the protection functions that existed in the MHC system.

- **Hybrid retrofits** These are typically done to upgrade the primary control/governor valves to an EHC system while leaving the stop or safety valves and turbine protections in the MHC system. This solution also has a high installation cost due to the newer high-pressure piping that must be installed, in addition to upgrades to part or all of the DCS or turbine control system, which are often required as well. These costs are partially controlled by choosing only to upgrade control of the valves that have the highest return on investment.

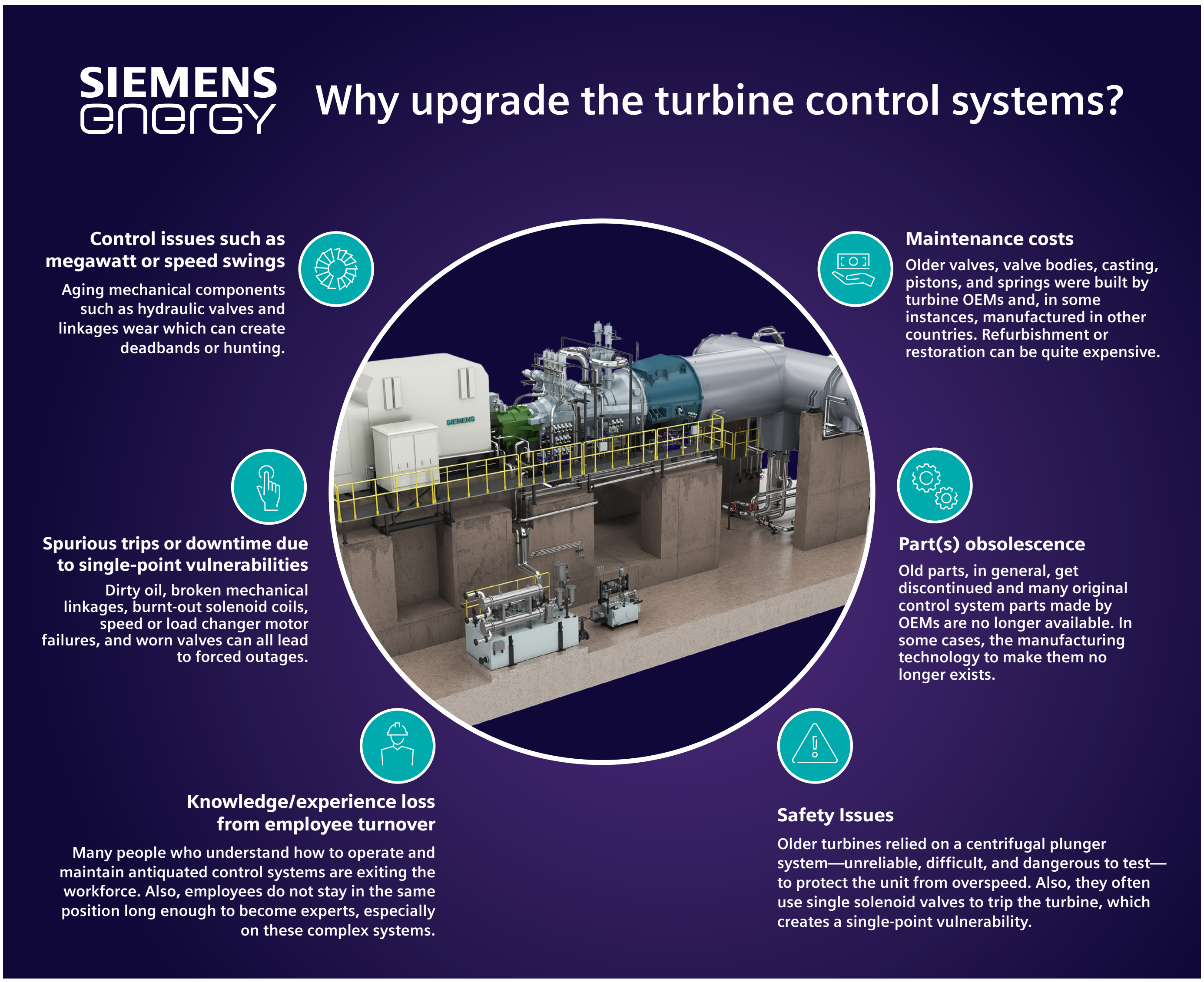

Figure 2 There are a multitude of reasons why turbine owners decide to upgrade their control systems.

Actuators: A brief history

For over 70 years, hydraulics have controlled the main turbine steam admission valves and, therefore, turbine speed and power output as well.

Hydraulic control started around the 1950s using the lubrication system oil and was known as mechanical hydraulic control (MHC). In addition to control and lubrication, the MHC system also served as a protection system thanks to its ability to rapidly shut the steam valves.

Protection systems detect undesirable or dangerous operating conditions of the turbine-generator and trip the turbine returning it to a safe state. Common protection functions would protect the turbine in the event of overspeed, low bearing oil pressure, high thrust bearing wear, and low condenser vacuum pressure.

The first hydraulic control systems were commonly 150 psi systems. Advancements in pumping technology allowed the system pressure to be upgraded, and the first 250–300 psi systems began appearing in the mid-1960s.

Due to issues related to contamination from wear debris from the lubricating functions, the control and lubrication systems started to be separated. This was the beginning of modern electrohydraulic control (EHC) systems in power and industrial plants.

These separate systems allowed different pumps and technology to be used, allowing the system pressure to increase to approximately 1600–2000 psi, where it has remained since the early 1970s.

As the turbine protection systems were still part of the lubricating system, the control and safety functions had to be linked by a physical connection between the lubricating and EHC systems. These hybrid systems were installed throughout the 1970s and 1980s.

From about the 1990s to the present day, the protection and safety systems have been updated to include either electronic or digital interfaces. The lubrication system is no longer used for protection, and the turbine controls are digital systems connected to an EHC system.

Much of the advancement in EHC systems over the last 50 years has been centered on improving the cleanliness and reliability of fire-resistant fluids and the introduction of electronic instrumentation and digital controls, but the fundamental design of the hydraulic portion has remained mostly unchanged.

It is important to note that one key feature of all modern power generation systems is redundancy, as the push for reliability has grown very strong. It is quite normal to find duplex or dual redundant systems, and triple redundant systems are not uncommon.

Even with modern hydraulic systems, there are still many problems. The most common issue with hydraulic systems is contamination. Modern EHC systems utilize servo valves, which are contamination-sensitive components requiring a high degree of fluid cleanliness. This entails the use of system filters and often point-of-use filters to protect the servo valve and guarantee reliable operation.

Another major issue is leaking oil, as these systems are in plants with extremely hot surfaces, such as steam piping. Therefore, industry standards and insurance companies typically require fire-resistant fluids to prevent potential fires. These fluids have special chemistries that require them to be maintained. This maintenance mostly involves keeping the fluid cool and treating it with chemicals or other means so that acids do not form. Improperly maintained fluids can result in system-wide issues and great expense.

Unfortunately, the problems encountered with modern EHC systems are many and cannot be linked to a specific device or device class. Failure to properly maintain the complete system usually translates into unexpected downtime.

Figure 3 A steam turbine upgraded with Siemens Energy iSER Actuators.

The Siemens Energy Solution

The patented Siemens Energy iSER (Intelligent Self-Contained Electrohydraulic Redundant Actuator) is a linear actuator providing precise position control of valves based on a 4-to-20 mA input current signal. The actuator was designed for the demanding application of steam turbine control and the pumping system was developed by Siemens Energy to provide optimal flow and precise motion control of the actuator, all while offering the redundancy needed for reliable and safe operation.

Siemens Energy iSER is a self-contained hydraulic system. This means that all the pumps, motors, valves, and other components necessary to operate the hydraulic cylinder are attached to the cylinder itself and there is no separate hydraulic power unit or associated piping. It is also a hydrostatic system, so when the actuator has reached the desired position, the motors turn off and the valve is held in position.

There has been great interest in self-contained hydraulic actuators because they can eliminate the need for expensive piping and installation. Until now, however, there were never any products on the market offering the force, rugged design, closing speeds, and redundancy required for reliable operation demanded by the power generation industry.

iSER Actuators compared to other self-contained actuators

The typical design of self-contained hydraulic systems on the market today relies on a servo motor with a reversible pump. By precisely controlling a motor that is rigidly connected to a pump, you can directly control the fluid delivery to and from either side of a hydraulic cylinder. This design has some inherent drawbacks, though.

The most significant limitations of other self-contained actuators are the lower pressures at which they operate and their lack of redundancy. By nature of their design, reversible pumps have limitations on the pressures at which they can operate. The iSER Actuator's multiple unidirectional miniature piston pumps allow for higher pressures, from 2250 psi to 3500 psi, and redundancy of the main actuator driving components.

Redundancy is one of the biggest challenges for any self-contained hydraulic system. Internally, the iSER Actuator has a 2oo2 (two-out-of-two) fluid pumping design, with two dedicated motors/pumps for forward stroke and 2oo2 motors/pumps for backward stroke of the actuator, ensuring fault-tolerant operation during its service. The actuator can continue to operate with the loss of one motor or pump in either forward or backward stroke or loss of a linear variable differential transformer (LVDT).

One somewhat surprising advantage is that the entire system has a smaller envelope than most self-contained actuators on the market. The iSER has a relatively compact build because it uses multiple miniature pumps mounted inside the manifold and small DC motors that drive the pumps.

Most existing actuator designs contain an unnecessary feedback loop for servo motor control. Instead of relying on the actual position of the valve, they require a specialized driver. In contrast, the iSER Actuator's permanent magnet DC motors allow for the use of pulse-width modulation (PWM) to control the speed and power of the motor (and therefore the pump), and only require a final valve position feedback loop.

Other than the motors and pumps, which are specially sized for the system and to each other, all the components are standard, and the valves and instruments use common cavities. Great care was used when designing the system to specifically allow for vendor diversity. This means that almost every moving part can be replaced with an off-the-shelf component and is manufactured by multiple companies, allowing owners to easily future-proof their investment.

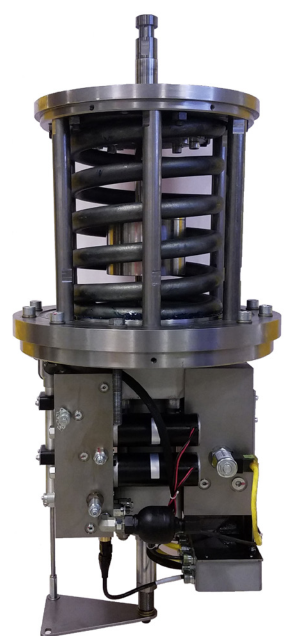

Figure 4 A photo of Siemens Energy iSER Actuator. Actual product may differ.

The iSER Actuator is controlled by a programmable logic controller (PLC), whose control algorithm helps in the precise positioning of the actuator based on the LVDT position feedback, responds quickly to changes in demand, and has logic built in that acts according to the plant scenario. There are several benefits to PLC control:

- **Greater operation flexibility** Configurable gain, motor settings, and deadband allow individual actuators to respond differently, as required for efficient plant operation.
- **Increased reliability** Faults or failures can be addressed online by allowing the easy switching between duplex to simplex operation of the motors/pumps or LVDTs.
- **Troubleshooting and diagnostic ability** With the added instrumentation and digitization of the operation and protection functions, more information is in the hands of the operators, I&C technicians, and maintenance personnel.
- **Predictive maintenance** Because the operation functions, such as how often and how long the motor and pumps run, are controlled directly by the PLC, their effective lifetimes can be calculated or determined by using historical performance and fed back to the PLC to provide alerts. This saves money compared to corrective or time-based preventative maintenance.
- **Digital communications** All data that is collected by the iSER Actuator can be digitally transmitted by an Ethernet-based protocol, thereby saving on the footprint and cost of hardwired signals. This allows for better trending and depth of data to understand issues before they become significant.

To protect the system under control from damage, a modular trip manifold is attached to each actuator, which acts rapidly in case of any problem to fail close the actuator within a fraction of a second and can also incorporate a partial stroke or valve freedom test solenoid. The trip system can be configured to meet customer requirements for redundancy and online testability.

Figure 5 iSER Actuator cabinet

The trip system is independent of the actuator control system and is controlled from the customer's external control system. In the event of an emergency, a trip from the external control system will de-energize solenoid valves, which rapidly close the actuator. In the tripped state, the actuator control is unable to move the actuator.

iSER Actuators offer advantages over all the other self-contained actuators on the market today, and they provide some significant benefits compared to modern EHC systems as well.

iSER Actuators compared to EHC systems

Fire-resistant fluids are commonly required in power plants as well as in many industrial plants due to the possibility of oil leaks, which can fall onto hot surfaces and ignite fires. In these situations, large EHC systems can convey large amounts of fuel to a fire. A great deal of expense can go into maintaining these fire-resistant fluids. In fact, a quick internet search reveals the existence of a whole sub-industry devoted to the maintenance, monitoring, flushing, and cleaning of fire-resistant fluids. A 650 MW turbine can be controlled with iSER valve actuators that use about half a gallon of oil per actuator by virtue of their high pressure, smaller size, and self-contained design. In contrast, an EHC system could quickly pour 250 gallons of oil onto a plant fire.

One of the challenges of any hydraulic system is oil cleanliness. Modern EHC systems utilize servo valves that are very precise and require extremely clean oil to operate continuously because of very tight tolerances within their components. Because servo valves are the most sensitive component in EHC systems, the fluid must be kept exceptionally clean for their reliable operation. Since no servo valves are used in iSER Actuators, the most sensitive components are the solenoid valves, which are more dirt tolerant by a factor of 4. Furthermore, all the pumps and motors can be changed for less than the cost of one servo valve.

One of the other more significant costs of upgrading to an EHC system is integration into the existing control system. Because of the numerous options and configurations of control systems on the market, the iSER Actuator was designed to be control system agnostic. In addition, the actuators were designed to only need a minimum of electrical inputs to run them:

- Power: 125 VDC/120 VAC or higher
- Trip System Power (from plant source)
- Position Demand Signal

Depending on the location of the iSER Actuator control PLC, this eliminates a significant amount of field wiring compared to an EHC system.

Another less obvious benefit is the elimination of multiple amplification stages. In an EHC system, the hydraulic pumps provide high-pressure fluid to the system; afterward, inside the servo valve, an electronically controlled torque motor pilots a spool valve and then the hydraulic cylinder. In iSER Actuators, the motors are in direct control of the pumps, which act directly on the hydraulic piston to move the valve, eliminating all stages. This issue is much more pronounced on MHC and early EHC systems with multiple amplification stages, such as follow-up pistons, amplifier pistons, and pilot valves.

Actuator limitations

It would not be fair to only discuss the benefits of self-contained actuators. Their use includes some limitations as well.

The first is larger wiring and cabling costs. Depending on the number of actuators and desired feedback, the wiring costs can be higher overall, but will still be vastly less expensive than the wiring, cabling, and piping costs of a modern EHC system.

Another limitation is that actuators have a non-centralized trip system, so there are more solenoid valves involved with tripping the unit. Therefore, a larger current draw is needed, as well as more components that could potentially have a fault. On the other hand, these additional components increase the fault tolerance of the safety system, making it more reliable overall.

Another possible obstacle is that their operation requires installation of one to several PLCs, and this can be a challenge for some utilities with cybersecurity and other requirements related to North American Electric Reliability Corporation – Critical Infrastructure Protection (NERC CIP) standards. The benefits, however, include greater operation flexibility, diagnostic ability, predictive maintenance, troubleshooting, and communication options, as described above.

The final limitation is actuator speed under control (not in a tripping condition). Because smaller pumps are used, there is a limit to how fast the actuator can move through its full stroke, but as mentioned above, because of higher pressures and therefore lower volumes smaller pumps are adequate for most steam turbine applications.

Conclusion

The Siemens Energy iSER Actuator is an innovative approach to steam turbine control that eliminates or greatly reduces virtually all the major barriers to upgrading antiquated MHC systems.

Its self-contained design eliminates the major costs associated with a remote hydraulic power unit and interconnecting high-pressure piping installation. The ability to control and tune individual actuators provides the flexibility to operate in the myriad of modes in which modern power plants are being required to run. The built-in redundancy of the major operational and safety components produces the reliability and safety that utilities and independent power producers have come to expect. Its higher pressures and compact design represent the next step in electrohydraulic control.

Most importantly, the iSER Actuator has been proven in the field and is currently in operation controlling large (> 600MW) steam turbines.

Figure 5 Steam turbine retrofitted with Siemens Energy iSER Actuators.

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