Intelligent diagnostics for pipeline valves

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Introduction

From its industry-leading position, Tyco Flow Control has researched and developed several devices to assure the operation of critical automated packages. The basic automated valve package currently installed on major plants and pipelines around the globe is based on what is generally considered tried and trusted technology, but this is no longer sufficient given that these devices are critical to the efficiency of the plants. If they do not operate to the required standard they can have a serious detrimental impact on the economic and environmental performance of the plant and on company performance overall. The same plants have additional demands placed on them from various international standards, to ensure that they conform to legislative conditions for health and safety, fugitive emissions and safe working practices, to name but a few. This paper is intended to show and understand technologies for intelligent diagnostics on automated valves packages.

1. The Pipeline Valve

The main concept for a pipeline valve from the point of view of energy is a device that in the close position take the 100% of the energy flow in the pipeline, in the open position it takes 0% of the energy, that means no turbulences no restrictions.
Environmentally is a device that has 0 (or near zero) fugitive emission. The ISO 14313 standard – former API 6D – rules the specification for pipeline valves.

1.1.0 Inline leakage test
A feature described at ISO14313 is the Double block and bleed. This function allows to test the valve inline under pressure.
If the both valve seats are OK, with the valve at close position, when the vent drain is open, after body cavity relief, the flow must stop. With the add of a pressure gauge, after the depressurization the measured pressure must not increase is both seals are ok.
Also if a leakage is detected thru the stem seals after the cavity relief, that means that not only the stem seal is damaged

1.2.0 Automatic Leakage detection

Electronic devices that detect changes on polymeric wires can be attached to the leakage test points together automatic command manifold subsystems in order to detect and report leakage in remote locations.

1.3.0 The valve torque

The valve torque has several components: rubbing, hydrostatic and hydrodynamic force.

The figure 5 shows the typical torque vs. position curve of a pipeline ball valve. There are continuous torque components due to mechanical rubbing, the break torque is calculated using the formula \( T = K_r + (K_p \times P) \), where

- \( K_r \) is the rubbing component
- \( K_p \) is the static pressure factor
- \( P \) is the static pressure

However, specially at big size and high flow speed the dynamic component can produce a torque overshoot higher than the break torque that appears between 10% ~ 30% position, in many cases this “overtorque” don’t carry troubles because is absorbed by the safety factor required during actuator selection (1.25 to 2 times).
2. The actuator

The actuator is a device that convert energy, in this case focused to convert the supply energy to mechanic torque to move different types of valves

2.1. Gas, Hydraulic, Electric actuator

According to the primary supply energy, actuators can be operated by instrument compressed air, pipeline gas (direct or over oil), electric power, electrohydraulic (powered by solar panels, thermoelectric generators, batteries), the preferred for pipeline are gas and electrohydraulic operated.

According to the requirement to convert the piston linear thrust to rotating torque, the actuators can be classified in rack and pinion and scotch yoke.

Remembering the ball valve torque curve, especially for higher diameter, the choice is the scotch yoke, that can transfer the energy following the valve needs.
3. Partial Stroke Test concept – PST

The new technology allows early detection of valve + actuator future failures during normal and emergency operations and partial stroke tests. The partial stroke test allows to reduce the MTI (Manual Test Interval) that has direct influence on the PFD (probability of Failure to danger – Failure on Demand) in order to reach high safety integrity level- SIL- with safety instrumented systems according IEC61511 standard.

3.1. Mechanic PST

The mechanic PST is a device fixed between the actuator and the valve, in the test mode a piece locks the movement when the valve arrives 10%-15% of travel. Device to provide remote test can be added.

Fig. 7

3.2. Actuator integral PST

The actuator integral PST is a device fixed by side of the actuator piston valve, in the test mode a piece locks the movement when the valve arrives 10%-15% of travel. Device to provide remote test can be added.

Fig. 8
3.3. Pneumatic control panel for PST

For fully automatic pneumatic control panel, pneumatic switches are added over the actuators that interlock the travel at desired position, venting the piston chamber and returning to the operating position, different circuit are required for normal operation and test operation, the control panel became very complex and maintenance is required.

3.4. Electronic PST

In the limit switch box, additional switches and solenoid are provided to do the PST. When the actuator arrives to the partial stroke position, the switch operates the solenoid that stop and return the actuator to the original position.

![Westlock Quantum777 PST](image)

Fig. 9

Intelligent devices use continuous position monitoring, the microprocessor calculates the position and drive the solenoid when the actuator arrives to the programmed position, also record and logging capabilities are added to these devices.

![Delta Force and Biffi IMVS](image)

Fig. 10

4. Diagnostics based on torque measurement

The piston actuators (linear or rotary, gas or hydraulic operated) require devices that measure and log: supply pressure, exhaust pressures, actuator chamber pressure, position and small time gaps between events in order to obtain data to do a device profile and to compare with the next operations, the inclusion of low consumption electronic devices doesn’t impact in remote standalone installations, that can be battery powered or solar powered. The main pipeline valves are operated few times in his lifetime, but with drastic results if the operation is not good, like human, environmental and properties damages of big proportions.
The first and elemental solution is to use double block and bleed valves or double array valves in order to check leakage during maintenance operation, closing 100% the valve, may be one at year.

The new technology allows early detection of valve + actuator future failures during normal and emergency operations and partial stroke tests.

4.1 Diagnostic on Electric intelligent actuators

The intelligent electric actuators have capabilities to calculate and storage torque curves of several strokes, through the strain gage sensors or current complex analysis. The torque information and events are recorded and stored in a non-volatile memory, that can be easily accessed by serial link or wireless or displayed in the actuator screen.

4.1.1 Direct Strain gage measurement

Using a strain gage over the output drive or intermediate position, the torque can be measured based on the material deformation, through compensated amplifiers the gage bridge output signal is driven to a microprocessor that calculate the torque.

4.1.2 Advanced Multivariable torque calculation

Measuring speed, voltage, temperature and motor current and using unique motor charts logged in a test bench the torque is calculated.

\[ T = f(\text{motor char, Vexp2, } ^\circ\text{C}) \]

\[ \text{RPM}(0\%) = (1-s)f^*60/2p \]

$$\begin{array}{|c|c|c|c|}
\hline
\text{RPM} & \text{RPM} & \text{RPM} & \text{RPM} \\
\text{(100\%)} & \text{(70\%}) & \text{(40\%}) & \text{(0\%}) \\
\hline
\end{array}$$

**Fig. 11**

4.1.3 Data and Event logging
Today’s electronic devices are able to store big amounts of information that can help to predictive maintenance. The actuator — see fig 12 — can register operations, alarm, warnings and other events.

Torque/Position graph and torque profile can help to detect possible malfunctions at early stages - see fig 13 - this information can be easily accessed by serial link or wireless and can be processed by human or heuristic software.

4.2 Diagnostic on Piston Actuators

The piston actuators (linear or rotary, gas or hydraulic operated) require devices that measure and log: supply pressure, exhaust pressures, actuator chamber pressure, position and small time gaps between events in order to obtain data to do a device profile and to compare with the next operations. The inclusion of low consumption electronic devices doesn’t impact in remote standalone installations, that can be battery powered or solar powered.

4.2.1 Piston Actuators: Torque calculation based on chamber pressure traces

The simplified output torque formula for an actuator is

\[ T = F \times r \]

Where

\[ F = P \times A \]
F is piston thrust
P is supply pressure
A is piston area
R is the lever radius, a constant in rack and pinion actuator, a function of the angle in scotch yoke actuators
Note: to simplify the rubbing influence was deleted

The key information to predict the valve + actuator operation are in the events or hits during the stroke, the levels and the graph shape. The increment of rubbing is translated in higher pressure to start the movement, delayed times and eventually saw tooth shape in the graph. As the torque is a direct function of the pressure chamber many devices show and perform analysis working only over the pressure records without conversion to torque units. The comparison between old records and recent records provide information about the evolution of the assembly, the intelligent devices capture the fingerprint of movement that is transformed in a baseline o torque/pressure profile

Fig. 14

Fig. 15
4.3.0 Pressure graph analysis

The automatic or human analysis of this information allows to determine the type of possible failures: actuator seal leakage, supply pressure availability during critical and combined operation, valve galling, exhaust blocked, solenoid delays, torque increasing, hydrodynamic torque effects during real operations and others. The Fig 16 shows the hits on a simplified pressure and position graph to understand what happens inside the actuator and solenoid system.

![Fig. 16](image)

Delta Force screens

![Fig. 17](image)

Fig 17 shows close and open stroke of an small ball valve with scotch yoke actuator.
The graph Fig. 18 show several hits to analyze:
1-How near is the supply pressure to chamber pressure in dynamic and static conditions
2-How many time is required to start the chamber pressurization since the solenoid received the signal ON
3-Overshoot in the actuator pressure – elastic deformation of components
4-Hysteresis during the start to travel
5-Smooth shape during the travel

Fig. 18

Fig 19 data logged shows the actuator pressure over a NPS 30" class #600 ball valve, without line pressure

Fig. 19
The Fig. 20 shows data logged for valves installed in a gas pipeline compression plant, TGN Argentina, this system uses a datalogger in the PLC room that collects the actuator pressure and position. This figure shows the pressure, calculated valve torque and position graph.

5 Conclusion

This technology was developed in order to ensure the “next operation of the system”, reducing and avoiding cyclical preventive disassembling-assembling operations.

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Literature

Visit www.tycovalves.com

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