

PREDICTING HEALTH OF FINAL CONTROL ELEMENT OF SAFETY INSTRUMENTED SYSTEM BY DIGITAL VALVE CONTROLLER

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ABSTRACT

Safety Instrumented System (SIS), commonly known as Emergency Shutdown (ESD) or Emergency Venting (ESV) or Safety Interlock Systems, are required by standards IEC61508/61511 / ISA S84.01 to be tested at a periodic interval based on HAZOP (Hazard Operation Analysis) design to achieve and meet required Safety Integrity Level (SIL). Traditionally Safety instrumented Systems are functionally tested during turnarounds on yearly or once in two year basis. Present economies and pressure to maximize production are forcing process industries to extend shutdown period to 3 or in some cases to 5 years. This puts onus on Final control element, which remains untested for longer time. Unfortunately Final Control Element represents significant failure contribution in SIS loop. If, offline testing is not possible then how do we test dormant valve that remains in one position (by the nature of application) without any mechanical movement.

This paper will discuss testing final control element of SIF loop, on-line, while plant is running, by using smart positioners to perform partial stroke test to detect dangerous failures, which would have remain undetected, if testing were not done.

Also smart positioners provides predictive diagnostics, which improves system availability. It generates safety audit documentation for validation, verification and future comparison.

Smart positioners or Digital Valve Controller, have capability to reduce spurious trips, during testing and also maintains safety availability, should a "Safety Demand" arise, during test.

INTRODUCTION

Major accidents worldwide have raised awareness in improved plant, personnel and properties safety, especially in the chemical, refinery, oil & gas industries, which involves inherent risk due to the leaking of dangerous chemicals, gases, and flammable wastes to the environment.

Growing concerns in the arena of safety instrumented systems (a layer of protection) and enforcement of governing industry standards is creating a significant demand for a device that can provide a method for testing safety valve operation without disturbing the process and providing diagnostic information about the final control element.

Safety Instrumented Systems (SIS) consists of Sensor, Final Control Element and Logic Solver. Final control element of SIS is not continually moving like typical control valves, but are normally expected to remain static in one position and then operate only when an emergency situation arises.

Previous industrial data indicates major failure contribution source of SIF loop is final control element. The typical failures being stuck in last position and may not operate when needed. This could result in a dangerous condition leading to an explosion, fire, and/or a leak of lethal chemicals and gases to the environment. To ensure the needed reliability and availability of these safety shutdown valves, they need to be tested frequently.

Unfortunately, the traditional method of testing these safety valves does not provide any internal valve diagnostics. It just allows mechanical movement but does not specifically provide inputs like if, the valve friction is increasing, process build up is occurring on bearing / shaft area, pressure is decaying, valve torque requirement is increasing etc. The purpose of this paper is to review how smart positioners diagnostic capabilities can be used to dramatically improve the reliability of these safety systems. At the same time significantly reducing, the risk of spurious trip, unscheduled maintenance, manual laborious test procedures, associated cost, as well as gaining a multitude of additional advantages.

COMMON CAUSES OF VALVE FAILURES AND CONCERNS

Safety Instrumented Systems are dormant or passive. Final control elements in these systems under normal circumstances are not moving. They remain in one position without mechanical movement and may never be called into action. Many potential failures of safety shutdown valve can remain covert or hidden, if valve is not exercised for a long time.

Typical Problems associated with SIS valves are:

- 1) Increased packing friction over time
- 2) Build up of process fluid material on shaft
- 3) Seize of shaft in bearing
- 4) Fracture valve shaft / stem
- 5) Corroded bearing

- 6) Broken spring of actuator
- 7) Permanent set of spring
- 8) Linkage breakaway friction
- 9) Slow air exhaust
- 10) Air exhaust path blocked
- 11) Spring return actuator dented not allowing valve travel
- 12) Increased valve break away friction
- 13) Actuator stem / shaft bent
- 14) Increased friction of closure element in seal

The main problem of shutdown valves, which represents significant failure contribution to SIS, is difficulties in testing to detect the valve health. Testing can be conducted Off Line or On Line. If, the valves need to be moved to its full 100% travel, it can only be done during annual turnaround. Now a day's turnaround being shifted from its normal course of time to higher time interval, due to economic reason, Safety shutdown valves remains as a biggest concern for plant safety management.

If, the test on shutdown valves can not be performed for longer interval then it affects its SIL (Safety Integrity Level) calculation of the loop, particularly valves that are significant contributors to Probability of failure on Demand (PFD). Increase in the test interval directly impacts the PFD value in a linear manner.

If, testing is to be performed on on-off shut down valves (Typically Solenoid operated) to find out health of valve, while plant is operation then only alternate left is to partial stroke the valve. But then potential hazard of spurious trip still remains. Also, if the test is in progress and demand arise, will the safety shut down valve will go to its fail-safe position. To address these major considerations smart positioners have been recently introduced in the SIS loop to find health of control element.

SMART POSITIONERS AS HEALTH DOCTOR FOR CRITICAL SAFETY SHUTDOWN VALVE

Digital Valve Controllers or “Smart” positioners” have proved as remedy to the cause in recent years to solve the diagnostic issues of Safety Shutdown valves. These smart positioners are communicating, microprocessor-based current-to-pneumatic instruments with internal logic capability. These smart positioners use HART® communications protocol to give easy access to information critical to process operation. The smart positioners have in built sensors for valve travel, pressure (supply and output pneumatic pressures) and pneumatic relay motion. All these data are processed in the microprocessor of smart positioner. This allows the smart positioner to diagnose not only itself, but also the valve and actuator to which it is mounted. It enables plant maintenance group to obtain information in advance for any possible deterioration in valve, before any dangerous condition can take place, thus improving safety reliability.

Partial-stroke testing through Smart Positioners confirms the valve is working without disturbing the process, while plant is running. It also allows more frequent on line testing since it is simple, less laborious and reliable. In past main concerns had been availability of safety valve during test to safety demand. With the use of Digital Valve Controller, on line testing has greatly relieved from worries of

non-availability during trip. Since the entire test procedure can be programmed into the microprocessor, partial-stroke testing can be performed automatically with no operator attention required. Companion software can be programmed to schedule test automatically. This allows the Test Interval to be as short as necessary (hourly, daily, weekly, etc.) to meet the target SIL values. The testing sequence is completely automatic, thereby eliminating any human errors and possible nuisance trips. However, for safety reasons, it is suggested that the operator initiate the test sequence locally or remotely with the simple push of a button.

While performing partial stroke test by smart positioner, it collects travel and pressure data during the test periods. The valve status and its response to mechanical movement can be monitored during the test. Valve performance trends are monitored and automatically analyzed after each partial-stroke test so that potentially failing valves can be identified long before they become unavailable. A cycle counter and travel accumulator will show the extent of valve movement.

The results of a signature test (See Fig. 1) can be used to easily determine packing problems (through friction data), leakage in the pressurized pneumatic path to the actuator, valve sticking, actuator spring rate, and bench set. The data points collected during partial stroke test will provide inferred information about initial inertia force, required pressure to actual movement of valve travel, sticking in shaft/bearing area, linkage dead motion etc. The smart positioner can save the results of this data for printout or later use. Overlaying the results of the current signature test with those of tests run in the past can indicate if valve response has degraded over time. Analyzed partial stroke test results can provide dynamic error band, dynamic linearity, torque (minimum / maximum) etc. This will enable an early detection of valve related problems. Knowing problem in advance and correcting it in time will increase valve availability, should a demand arise. It also reduces the amount of scheduled maintenance on the valve, because the tests can be used to predict when the valve needs maintenance.

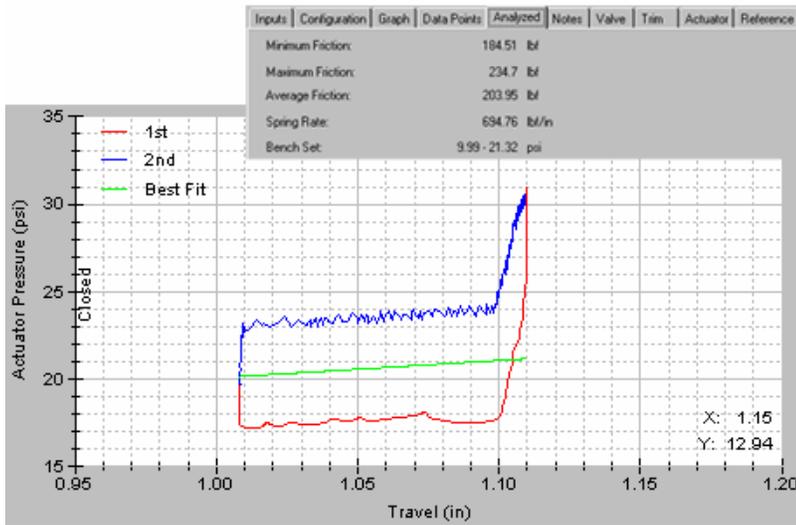


FIG. 1 – VALVE SIGNATURE TEST AND ANALYSIS ON AN SIS VALVE

Some smart positioners have the capability to alert the operator if a valve is stuck. It can notify key people for critical alerts via email or trigger a pager. This means key operational personnel can be continuously informed of alert status.

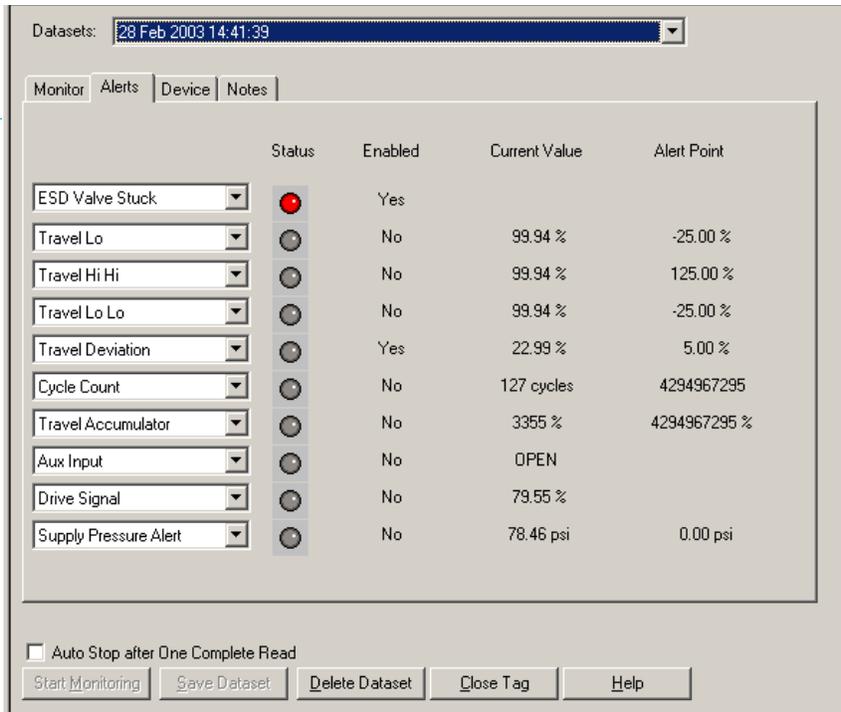


FIG. 2 – VALVE STUCK ALERT

As the positioner begins the partial stroke, it continually checks the valve travel to see if it is responding properly. If it is not, the positioner will abort the test and alert the operator that the valve is stuck. This will prevent the valve from slamming shut if the valve does eventually break loose. This will avoid spurious trip.

In short, a smart positioner can provide complete diagnostic health information on the final control element, including the positioner itself. If, valve is found stuck or having excessive friction or leaking air supply, an immediate alert notification will be provided. In addition, the smart positioner can provide complete documentation of any emergency event as well as documentation of all testing. Insurance companies will accept this Safety Audit Documentation for proof of testing. Best of all, this document can be completely automated so that expensive operator time is not required.

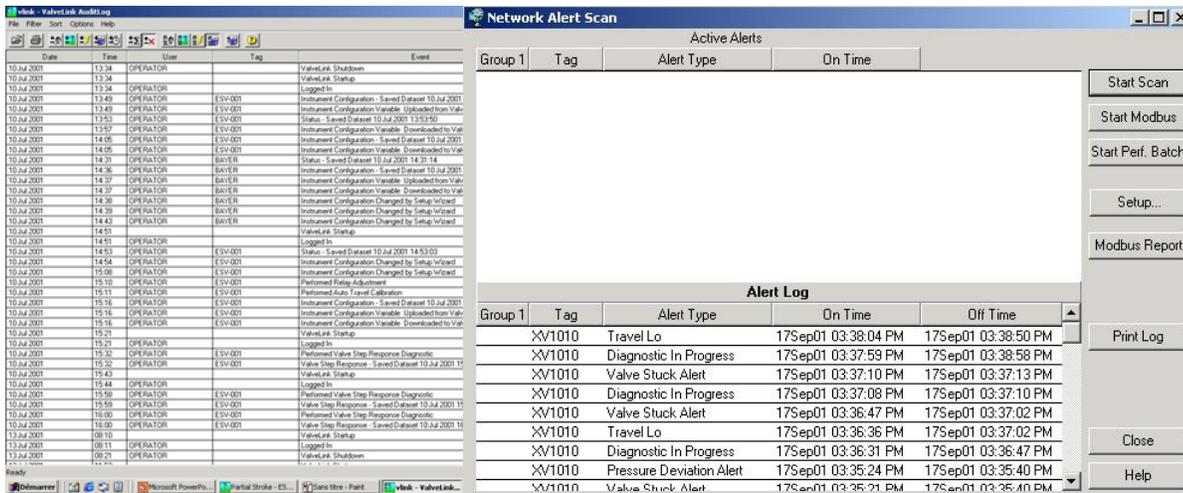


FIG. 3 – DOCUMENTATION FOR TEST AND ALRET RECORDS

Digital Valve Controller provides diagnostic as well as positioning information, the valve status and response time can be monitored continuously by its companion software (Fig – 4)

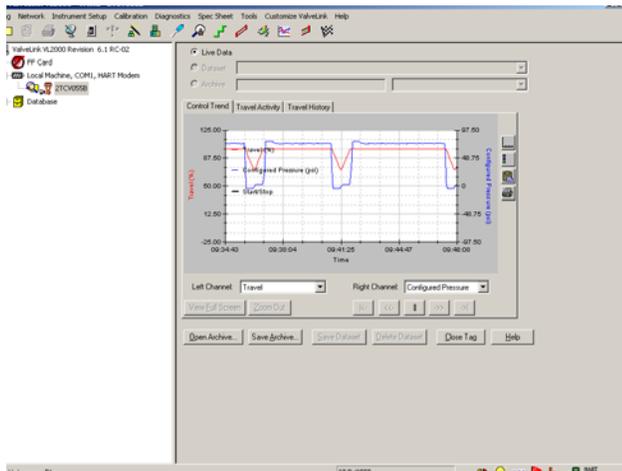


FIG. 4 – CONTINUOUS MONITORING OF VALVE HEALTH

Finally, should an emergency shutdown demand occur during testing, the smart positioner will override the test, driving the valve to its safe position. This increases availability of shut down valve to plant emergency demand.

CONCLUSION

Smart positioners are a great aid to predictive maintenance by providing a Valve Degradation Analysis, which is important for critical valves in safety related systems. This also reduces the amount of scheduled maintenance. While performing the partial-stroke test, if for any reason the valve is stuck, some smart positioners will not completely exhaust the actuator pressure. This assures that, if the valve become unstuck, it will not slam shut. These smart positioners will then abort the test and send an alert signal to the operator warning that the valve is stuck.

If, pressure deviation or travel deviation occurs, smart positioner will provide an alert notification accessible through either the HART communicator or associated software. This will be an indication of possible leak in packing area, change in friction, change in pressure etc, which may need either immediate attention or later planned maintenance of valve.

The smart positioner provides a time and date stamp on all tests and reports, which is very important for complying with the requirements of statutory authorities. It also provides the capability for comparing, storing and interpreting diagnostic data.

Smart positioners allow partial-stroke testing while the process is running with no threat of missing an emergency demand. This type of test applies a small ramp signal to the valve that is too small to disrupt the process, but is large enough to confirm that the valve is working properly.

While obvious diagnostics, performance and safety benefits can be gained through partial-stroke testing, many additional benefits can be obtained by using a smart positioner. Lower base equipment cost is achieved with considerable reduction in testing time and a reduced manpower requirement through the elimination of expensive pneumatic test panels and skilled personnel presently required for testing. In addition, remote-testing capability requires fewer maintenance trips to the field, as well as the establishment of an automated test routine that can produce great timesaving.