THE ADVANTAGE OF DIVERSITY IN SHUTDOWN SOLUTIONS

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discuss the benefits of instrumentation diversity for emergency shutdown solutions in the gas processing industry.

Personnel safety and asset reliability are top-of-mind concerns for gas processing operators. The ubiquity of complex processes, combustible gases, and high pressure applications in the gas processing industry demand an adequate level of emergency shutdown (ESD) safeguards in facilities. Creating safe operating environments, ensuring compliance to stringent safety standards, and optimising plant productivity are paramount objectives for every operator. Deploying a variety of instrumentation technologies on these ESD systems creates the necessary system redundancies to ensure that common-cause failure modes do not overlap.

Benefits of instrumentation diversity

Instrumentation diversity refers to the deployment of various technologies, brands, and types of instruments to achieve the same control, measurement, or emergency shutdown objective. Asset failures, such as pump malfunctions, can lead to hazardous situations, such as overpressure or overheating. By employing diverse instrumentation, the risk of a common mode failure is minimised. Common mode of failure is defined by the American Institute of Chemical Engineers (AIChE) as "Concurrent failures of different devices characterised by the same failure mode (i.e., identical faults)".[1]

While older assets are generally installed with mechanical ESD instrumentation, newer assets are installed with electronic instrumentation that provide the users with highly accurate process data for better decision-making. Each instrumentation technology has its own advantages and disadvantages. Significant operational, maintenance, and cost efficiencies for the facility can be achieved if the operator knows how to skillfully leverage the advantages of each instrumentation technology. The following section shows how these efficiencies are demonstrated.

Increased reliability and system redundancy

Relying on a single instrumentation technology can expose operators to significant risk, especially if the technology is susceptible to fail under similar application conditions. Diversification introduces redundancy and ensures continuous production even if one system encounters issues. Downtime can be minimised and operational disruptions prevented.

Improved data accuracy and faster control

While electronic instrumentation technologies can be more accurate and facilitate the capture of specific process data, mechanical-based instrumentation still offers unparalleled speed of response, which is critical in emergency shutdown applications. By integrating a diverse range of technologies, the operator can obtain data for precise process control while ensuring split-second emergency shutdown action, optimising the facility's performance, safely.

Greater flexibility and future-proofing

As industrial processes evolve, a diverse instrumentation portfolio allows the user to adapt quickly to new challenges and requirements. Facilities that rely on a single technology may face costly upgrades to stay current. Diversification allows for smoother integration of new technologies, alongside easier scalability and compliance with evolving industry standards without extensive system overhauls.

Types of instrumentation technology

There are several types of mechanical and electronic instrumentation technologies that are deployed for emergency shutdown.

Mechanical switch

These devices provide the fastest emergency shutdown response (~5 milliseconds) to a process change, because a control action (i.e. turn on or off) can be executed to the final element directly. Switches have been proven-in-use for decades and they are easy to install and operate. However, switches can be harder to maintain due to processes like manual calibration of switch settings. Mechanical switches do not require any power to operate and are often considered to be a final line of instrumentation defence in many gas processing plants, particularly during power outages.

Electronic switch

These are viewed as upgraded versions of the mechanical switch. While a little more costly than a mechanical switch, they offer expanded functionality such as programmable set points and deadbands across the entire range, and possess better repeatability compared to a mechanical switch (up to 4 times). They have very fast response times at <100 milliseconds and have the capability to provide a basic level of diagnostics about device health. Less time is required to maintain (i.e. uninstall, calibrate, set, reinstall) these electronic switches compared with traditional mechanical ones, thereby improving maintenance efficiency.

Transmitter

Transmitters are ubiquitous devices in industrial plants. They are able to transmit data from the field to the control system through standardised output signals like 4 - 20 mA, 0 - 10 V, or a digital signal. However, transmitters can only affect a shutdown via a programmable logic controller (PLC). This increases the shutdown response time (at ~250 milliseconds), making it slower compared to mechanical switches. Transmitters are costly but they are highly accurate and possess advanced device diagnostics.

Hybrid switch and transmitter

This proven-in-use novel technology represents a combination of the functions of a transmitter and a mechanical switch. There are very few instrumentation manufacturers who offer such hybrid technology in the market today. These devices are meant to provide a cost-effective solution for users that desire the advantages of a transmitter (availability of data) as well as the benefits of an electronic switch (ease of operation and maintenance). For instance, United Electric Controls' (UE) hybrid ONE Series switch and transmitter has a 4 - 20 mA output

Table 1. Comparison of instrumentation technologies

Characteristic	Mechanical switch	Electronic switch	Transmitter	Hybrid switch and transmitter
Set point and deadband adjustment	Manually through adjustment screw Limited adjustability range	Local keypad Full range adjustability	Through PLC or DCS	Local keypad Full range adjustability
Direct shutdown to final element	Yes	Yes	No	Yes
Display of process information	No	Yes	Yes	Yes
Accuracy	2.5%	0.5%	0.05%	0.5%
Diagnostic capability	No	Yes	Yes	Yes
Number of wires	Easy 2 wire connection	Easy 2 wire connection	2 or 3 wire connection	4 wire connection
Typical response time	Fastest (~5 ms)	Faster (~100 ms)	Fast (~400 ms)	Faster (~100 ms)
Calibration schedule	Every 3 - 6 months	Every 1 or 2 years	Every 1 or 2 years	Every 1 or 2 years
Maintenance efforts	High (up to 12h/ device/year)	Low (up to 0.5h/ device/year)	Moderate (up to 1h/ device/year)	Low (up to 0.5h/ device/year)
Installed unit cost	Lowest ($X)	Low ($1.5X)	High (up to $5X)	Low ($2X)

that can trend process data, but it also comes with a built-in relay that can be easily programmed to initiate a direct emergency shutdown at the final element.

Various instrumentation technologies can work on most applications, but the primary differentiators are speed of response, electrical ratings, and price.

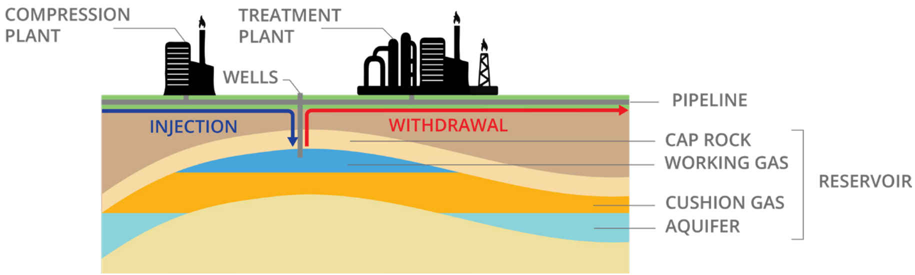

Figure 1. Natural gas storage system.

Case study 1: electronic switches to improve operational and maintenance efficiency

Natural gas storage is a process in which natural gas is injected into pre-existing depleted reservoirs and pumped out when there is a demand for it, as seen in Figure 1. Withdrawing the gas involves suction from the pipeline, discharging it, treating it in dehydration columns, and finally sending it to delivery collectors.

Mechanical pressure switches are typically deployed as ESD safeguards at each stage, for instance at the compressor's suction and discharge, the collector columns, the treatment columns, and the delivery collectors. One of Europe's largest natural gas storage companies was using mechanical switches for its ESD applications but was facing several instrumentation challenges:

- Mechanical switches have lower set point stability over wide-ranging temperatures. This resulted in numerous false trips.
- Mechanical switches do not display the process or switch status, making it difficult for maintenance workers to monitor the process and verify the settings.

The company decided to diversify its instrumentation technology by upgrading many of its mechanical switches to electronic ones. It arranged three electronic switches in a 2 out of 3 (2oo3) voting logic scheme to serve as emergency shutdown devices for the compressor station's gas delivery collector. This scheme ensured safety and minimised nuisance trips. The customer was able to realise the following benefits:

- Frequency of false trips was reduced, which increased operational uptime and efficiency. The electronic switches improved set point stability over wide-ranging temperatures.
- The digital display on the electronic switches made it easy for operators to verify process and switch status during maintenance rounds.
- With the electronic switches, operators could extract diagnostic information to quickly identify the root cause if a switch malfunctions, thereby improving maintenance efficiency.
- With a diversification of instrumentation technology, the operator reduced its risk of a common mode of instrumentation failure while improving operational uptime.

Case study 2: mechanical switches as a final line of defence

Design consideration

A global pump manufacturer, or original equipment manufacturer (OEM), supplies pumps to the hydrocarbon industry. Many of its systems already have electronic instrumentation like transmitters installed to accurately convey process data and turn off pumps via the PLC when needed. However, when it came to emergency shutdown of the pumps, where response time is critical, the OEM design team still relied on conventional pressure and temperature mechanical switches to perform a reliable emergency shutdown function for its dry screw pumps. The risk of an improper pump shutdown leading to pump failure could mean high repair costs, up to tens of thousands dollars per pump.

Implementation

The pump OEM evaluated several vendors on the end user's approved vendors list (AVL) and decided to install safety integrity level (SIL) certified temperature and pressure switches from UE. Temperature switches were installed on the water jackets as well as pump exhaust to prevent pump overheating. In addition, pressure switches were installed on the pump exhaust and set to 5 psi to prevent overpressure. SIL-certified mechanical switches were selected as they had proven-in-use reliability, minimising the possibility of instrumentation failure. The mechanical switches became a necessary complement to the overall pump instrumentation architecture by serving as a last line of defence to prevent pump damage. The combination of electronic transmitters and mechanical switches was an integral part of the instrumentation schematic for each pump system. Diversification of instrumentation technology was a critical design consideration to eliminate common mode of failure.

Conclusion

Every instrumentation technology has its advantages and disadvantages. The limitations of each instrumentation technology accentuates the importance of instrumentation diversity. Operators who know how and when to leverage these advantages for their instrumentation application, or even deploy multiple technologies to create layers of necessary redundancy, are able to build a robust, sustainable instrumentation architecture for plant safety. HE

Reference

1. 'Common Mode Failure', Center for Chemical Process Safety https://www.aiche.org/ccps/resources/glossary/process-safety-glossary/common-mode-failure