The value of safety valves

FLOW CONTROL

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Chemical and petroleum plants are paying ever-increasing attention to plant safety in order to reduce the risk of the emission of toxic materials, of having an uncontrollable fire or of an explosion.

Safety valves are the most important components in the safety loop (sensor, safety logic and final element), because most of the problems that occur are related to the functionality of the final element [1]. It is important to remember that these elements are moving mechanical devices, which operate in very difficult environmental conditions. This makes the need for regular valve testing and for testing while the process is running absolutely essential.

Safety valves are used to protect processes, personnel and the environment against process disruption. Such valves are operated only in trip situations. But when they are required to operate, it is essential that they ensure that the valve is switched to the safety position. However, because these shutdown valves are rarely cycled, there is always concern over whether they will operate when actually needed. In practice, unless these valves are periodically stroked, it is virtually certain that they will not work when called upon to do so.

Safety standards and measurement

Chemical and petroleum plants are paying ever-increasing attention to plant safety in order to reduce the risk of the emission of toxic materials, of having an uncontrollable fire or of an explosion, or any combination of the above in their plants. The guiding influence in these projects has been the IEC61511 safety standard, which requires companies to evaluate every area of their plant and assign a targeted Safety Integrity Level (SIL) to it. This applies when equipment meets the IEC61508 standard and is integrated into an overall system. So, basically, IEC61508 is the standard designed for device manufacturers and IEC61511 the standard for end users.

The statistical measure of availability in an emergency is called the Probability of Failure in Demand (PFD). For individual components, PFD can be measured using the following equation, which is well known and widely used in industry. However, there are many ways to calculate PFD and the equation shown is just one example. [2]

PFD calculations consist of two parts: on-line testing and off-line testing. When dealing with safety valves, the on-line diagnostics part relates to Partial Stroke Testing (PST) and the off-line part to periodic maintenance. With frequent on-line testing, better diagnostic coverage, shorter mean times for repair and good communication methods, it is possible to achieve lower PFD figures.

Conventional on-line testing

Partial stroke testing is the method most commonly used to test valve functionality while the process is running. Conventionally, this has been done using a mechanical stroke-limiting device or a pneumatic switch for each safety valve. With these devices attached, the movement of the safety valve is limited, allowing it to be partially stroked without interfering with the process. Once the movement of the safety valve is restricted, technicians send a signal from the control room to determine whether or not the valve will respond. Not only is the manual work associated with conventional testing methods expensive, it is also unreliable. Concern over the reliability of conventional safety-valve testing procedures stems from many causes including the lack of real-time data and the absence of trending data. Another significant drawback to conventional testing methods is that they render the valve unavailable during testing should a real safety issue be encountered.

Introduction of intelligent control for safety valves

Due to the reasons that conventional methods had a number of drawbacks, safer and more reliable methods of testing safety valve functionality were clearly needed. At the beginning of this century, PST implementation was considerably improved when the first intelligent safety valve controller, Neles ValvGuard, was released on the market. BP took the device into use almost immediately after its launch and reported significant improvements in plant safety and also in operating costs [3].

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Probability of Failure in Demand (PFD) equation

$$PFD = DC \cdot \lambda_d \cdot \left(MTTR + \frac{TI_A}{2}\right) + (1 - DC) \cdot \lambda_d \cdot \frac{TI_M}{2}$$

DC	Diagnostics Coverage Factor
λ_d	Dangerous Failure Rate = 1/MTBF (Mean Time Between Dangerous Failures)
TI_A	Testing interval for automatic tests (on-line)
TI_M	Testing interval for manual tests (off-line)

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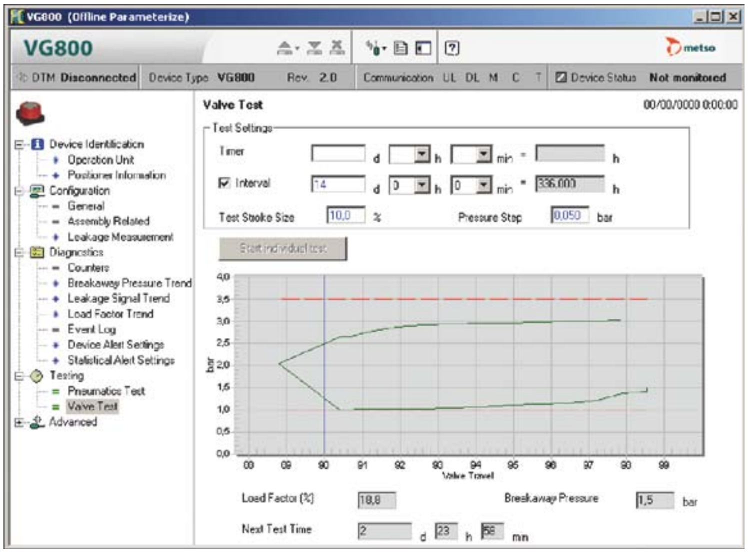

Figure 1. PST testing example: Actuator pressure measurement vs. valve position.

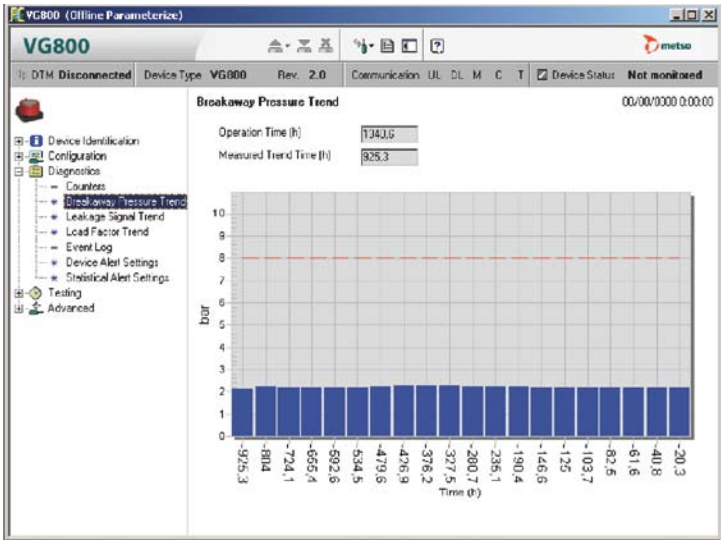

Figure 2. Breakaway pressure measurement comparison.

Partial stroke testing is technology whereby the emergency isolation valve is moved only slightly, so that it does not disturb the protected process, yet the movement is sufficient to detect the most critical problems with the emergency valve. When PST is carried out using an intelligent emergency valve controller, the test results can be analyzed automatically after test implementation.

Advantages of on-line PST

Partial stroke testing allows more frequent valve stroking without disturbing the process. In this way, the required SIL level for Safety Instrumented Functionality (SIF) can be maintained for longer periods. In particular, when an intelligent emergency valve controller is used to implement PST, it is possible to detect the build-up of most of the problems typically encountered with emergency valves, even though the valve stroke does not cover the whole valve travel range. PST is designed to detect random hardware failures related to the final element. Detection is based typically on the change in valve dynamics, which can be seen when the latest PST results are compared to historical data. For example, Neles ValvGuard measures the breakaway pressure and load factor from PST and Figure 1 shows one method of doing a historical comparison using a graph.

Breakaway pressure indicates the pressure measurement level at which the valve starts to move during a valve test. Breakaway-pressure trend information can be used to analyze valve load changes. The load factor is calculated from PST data, which indicates the friction changes of the valve. A high load-factor value means increased friction due to an undersized actuator. Load-factor historical values are shown in the same way as a breakaway pressure trend.

Typical valve problems that can be detected with partial stroke testing are: sticking, stem seal leakage, valve seat leakage, mechanical valve or actuator failure and failure in the controller itself.

Technologies used in safety valve controllers

Developments in emergency valve design have remained rather static in recent decades when compared with the developments that emergency valve controllers have undergone. New technologies have been continuously adopted to meet the required safety specifications, while at the same time ensuring the cost efficiency of installation and operational costs. During the past few years, these technologies have been used more and more as a part of SIF implementation. But what are the latest technologies and how can they help with PST implementation or

Partial stroke testing with diagnostics capabilities can detect valve problems before they influence plant safety.

Technology	Benefit
Automatic PST implementation	PST implementation is possible without human interaction (risk reduction), ensures test implementation and assures that required the SIL level is maintained.
Constant monitoring of critical measurements during PST	These measurements are valve position and actuator pressure. If position measurement fails, the low level of actuator pressure ensures that no spurious trip is caused by a PST failure. Actuator pressure is also a critical measurement when analyzing the PST results.
Automatic analysis of PST results	Analysis of PST results should not be left to the end-user, but analyzed automatically by the controller. Communication failure, temporary absence of the asset management tool or maintenance personnel's lack of time cannot be allowed to delay or prevent PST result analysis.
Automatic reporting of test results	Ensures that PST results are stored and are not lost if there are communication problems between the host system and the emergency valve controller.
Real-time reporting of PST results	Ensures that possible detected problems with the emergency isolation valve are reported immediately to maintenance personnel and MTTR time can be kept to a minimum.
Automatic testing of valve pneumatics	PST interval can be relatively long (months), but valve pneumatics need to be tested more frequently (days). OREDA data states that nearly 15% of all SIF failures are caused by solenoid failure.
Analysis of emergency action	If there is a spurious trip or a real emergency and the trip result can be analyzed, it can be considered as an off-line test of the final element.
Asset management support	Open communication technology support when PST analysis data is integrated within most common asset management systems.

Table 1. Technology development in intelligent safety controllers.

analysis of the results? Table 1 describes the main technology features in recent years.

Future trends

One clear future trend seems to be the use of fieldbuses. FOUNDATION fieldbus and Profibus organizations are the most active in this area and are enlarging their specifications to cover Safety Instrumented Functionality. The reasoning is clear: Fieldbuses are used more often and have proved the technology.

New upstream processes are making more use of Fieldbus technology mainly because it reduces hardware, wiring and engineering costs and improves the asset management integration of final elements into the host system. Traditionally, on installation all control valves have fully supported Fieldbus communication technology, but emergency valve controllers are integrated into the asset management systems through HART communication using separate communication hardware.

FOUNDATION-based emergency valve controllers would give much faster response times for the status information and easier integration of higher-tier diagnostic information into the host system, when compared with the parallel HART network. This would improve the cost efficiency of the project when additional communication hardware is not required. At the same time, operation of the device is much easier for the end-user.

Conclusions

The use of intelligent functions with safety valve controllers has created considerable interest in the recent past. Nowadays, automatic PST implementation is seen more often as a serious possibility, rather than as a possible source of spurious trips. Furthermore, the analysis results of PST implementation are being widely used as a part of the maintenance program. This trend raises the need for easier field-device integration up to control system level, and expectations now lie in the wider use of fieldbus technology. ■

References:

[1] Sintef; Offshore Reliability Data Handbook; OREDA; 2002.

[2] Laaksonen J.; Reducing the Window of Potential Failures for Emergency Shutdown and Venting Valves by Automatic Partial Stroke Testing Devices; 2005; TÜV Symposium Cleveland, OH, USA; 12 p.

[3] ARC White Paper; Neles ValvGuard Allows BP to Increase Safety While Reducing Costs; 2001; 12 p.

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