THE PRESSURE OF PROTECTION

Julian Yeo, United Electric Controls, USA, explores the idea of creating an independent protection layer at the wellhead with SIL certified integrated devices as an effcient instrumentation approach for well pump operations.

Wellsite accidents can be attributed to various causes such as overpressure conditions. A well-known international insurance company addresses the daunting subject of 'planning for an oil and gas well control emergency' this way: "Operators within the oil and gas industry typically manage numerous operational risks. Failure to adequately manage exposures, such as the threat of oil spills, the challenge of finding qualified contractors and the need to protect new workers on the job, could drastically affect an operator's production goals and bottom line. Though the severity of risk can differ among these exposures, no other threat has the potential to challenge an organisation more than a well control event." [1] This article explores the idea of creating an independent protection layer at the wellhead with a case study illustrating how a large petroleum company in South America adopted a new approach to pump overpressure protection in remote oilfields.

Risk reduction

Risk reduction experts in upstream oil and gas production are focused on exploring techniques for reducing risk and maximising uptime. The well control event such as the overpressurisation of flow lines is an area of strong interest, especially because of the significant impact on production and potential for environmental repercussions.

Risk and reliability experts, Henry Johnston and Genebelin Valbuena, prescribed several recommendations for safe wellsite operations in their 2015 white paper entitled 'An Integrated Approach to Design Hybrid Independent Protection Layers'.[2] Some recommendations include:

- Having reliable methods such as layer of protection analysis (LOPA) for assessing risk related to well control.
- Having a combination of mechanical and instrumented systems used as safeguards known as independent protection layers (IPLs).
- A guided way of integrating mechanical and instrumented subsystems into a single protection layer such that it provides sufficient risk reduction for the risk scenario.

The paper opens up a discussion of how innovative pressure instrumentation available in the industry today can contribute quantitatively and qualitatively to risk reduction.

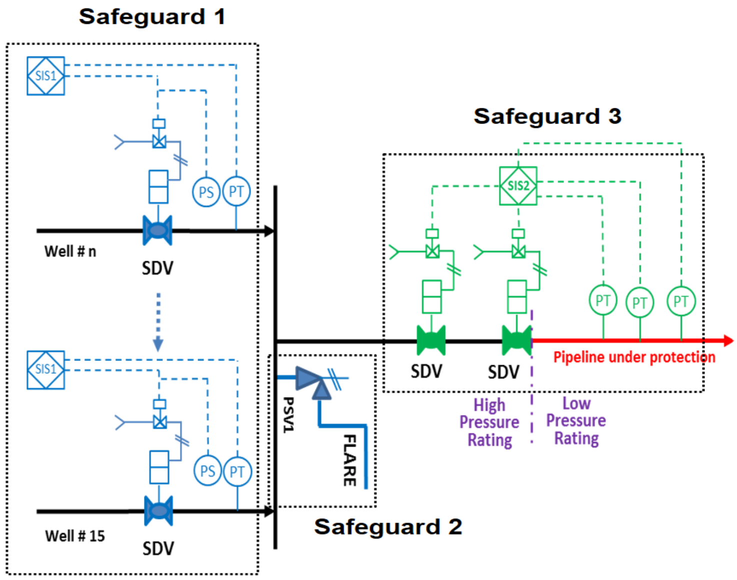

Figure 1. *Simplified process diagram of risk scenario at the wellsite. (Diagram courtesy of www.isa.org).*

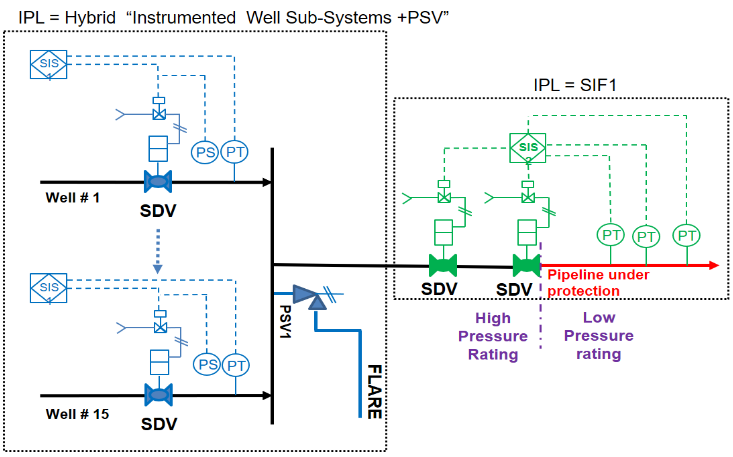

Figure 2. *Redrawing of IPL boundarie. (Diagram courtesy of www.isa.org).*

Figure 3. *SIL certified integrated instrumentation, combining functions of a transmitter, switch and gauge in a single device.*

Wellhead independent protection layers

According to the American Institute for Chemical Engineers Center for Chemical Process Safety (AIChE CCPS), an IPL is a combination of mechanical and instrumented safeguards that must be specific, independent, dependable, and auditable[3], and provide valid risk reduction. By definition, that risk reduction is limited to 10 on the risk reduction scale. An IPL is valuable because it can help prevent a scenario (e.g., overpressure condition) from escalating to the undesired consequence, without itself being adversely affected by the initiating event. It is also independent of other protection layers like a safety instrumented system (SIS).

Johnston and Valbuena outline a risk scenario involving the over-pressurising of flow lines from 15 well sources (Figure 1). Employing LOPA to model the risk scenario, they determine the right safeguards, including looking at initiating causes, their likelihoods, and what kind of IPLs might best be employed.

In Figure 1, the authors highlight a non-compliant legacy process that fails to meet the tolerable risk criteria of the operator. The LOPA team considered a combination of three safeguards in order to provide protection for the overpressure of the wells and protection of the low pressure export pipeline. Safeguard 1 defines the boundaries of an instrumented system at the wellhead – a safety instrumented function using a pressure transmitter (PT), pressure switch (PS), logic solver and an emergency shutdown valve (SDV). This combination is intended to automatically isolate any one of 15 wells flowing into the common manifold during an overpressure condition.

Unfortunately, the 15 out of 15 voting dilutes the risk reduction to a degree that Safeguard 1 no longer qualifies as an IPL (i.e. RRF<10). Safeguard 1 fails to meet the 'dependability/reliability' criteria of an IPL because the reduction of identified risk is unable to be quantified by a known and specified amount. Since this scenario can be a common concern in remote oilfields, the setup can be adjusted so that Safeguard 1 is qualified as an IPL, which would be a desirable goal.

Proposed solutions

One solution Johnston and Valbuena proposed is to integrate Safeguards 1 and 2 into a single IPL. Safeguard 2 is a mechanical system consisting of a pressure relief valve (PSV) and flare. Johnston-Valbuena observed that the combination of Safeguard 1 and 2 can be a valid IPL when the boundaries of the safeguards are re-drawn (Figure 2). When Safeguard 1 and 2 are integrated, the hybrid consisting of the instrumented well sub-system, pressure safety valve and flare achieves the target risk reduction.

The second solution outside the scope of the Johnston and Valbuena approach is to increase the reliability factor of the instruments (e.g. pressure transmitter, pressure switch) in Safeguard 1. By upgrading devices to safety integrity level (SIL) certified instrumentation, the risk reduction factor (RRF) of the system can be improved, such that the instruments can be deployed in the same conventional setup while qualifying Safeguard 1 as a valid IPL. SIL certified instrumentation can bring about quantitative and qualitative improvements to a wellsite, specifically pump operations.

SIL certified instrumentation for pump overpressure protection

While certified functional safety experts exercise complex quantitative risk assessment (QRA) and develop methodologies and innovative risk reduction approaches, instrument hardware manufacturers have been responding to industry's needs by designing SIL certified instrumentation (e.g., pressure controls) that make the deployment of an IPL or SIL 1 + Safety Instrumented System (SIS) much easier and more cost effective. Some of these pressure controls integrate the functions of a transmitter, switch and gauge in one device.

These 'hybrid' or 'integrated' devices are solid state subsystems in hazardous area enclosures that combine the functions of a pressure transmitter (PT), pressure switch (PS), and logic solver into a single standalone device. Integrated SIL certified instrumentation such as United Electric Control's ONE Series safety transmitter (Figure 3) can continuously monitor pump pressure at the wellhead through the 4 – 20 mA output and simultaneously control a final element directly, such as a solenoid valve (SOV) or (SDV), for immediate shutdown in the event of an overpressure condition. This shutdown is based on programmable thresholds and is executed through an embedded high capacity relay without the need for a logic solver.

Designing or upgrading an IPL or SIL 1+ SIS for protecting flowlines or rotating equipment (like a pump) could involve multiple devices such as pressure transmitters, trip modules, pressure switches, central or remote PLCs, wiring, conduit, stainless steel cabinets and sub-cabinets. Calculating failure rates and even a system's response time would be a highly complex task.

A SIL certified integrated device can help simplify the complexity as it combines multiple functions such as an analogue 4 – 20 mA output, microprocessor-based programmable solid state high capacity relay, hazardous area enclosure, additional soft digital output and complete diagnostics. Each output as a 'safety variable output' has failure rate data documented so that it can be utilised in a safety instrumented function (SIF). For designers looking for cost-effective solutions for valid risk reduction, such SIL certified integrated devices are certainly worth designing into the system.

Case study

A large petroleum company based in South America recently wanted to improve its production operations at the well site. One of its goals was to identify more efficient ways to protect their progressive cavity (PC) pumps from overpressure conditions that would result in pump damage and production disruption.

The current setup for pressure monitoring of the PC pumps had a few challenges. The operator had been using process transmitters containing an auxiliary digital contact for protection of their progressive cavity (PC) pumps. The transmitter's 4 – 20 mA signal was an input into the variable frequency drive (VFD) that controlled the PC pump. The operator also required a redundant shutdown of the PC pump in the event the VFD failed to act. The drawback of this conventional setup is that the auxiliary contact in the transmitter needed both an external power supply and relay housed in a separate enclosure in order to perform the redundant shutdown (Figure 4). In addition, the power supply or the relay were not certified for SIL 2 applications and were prone to failure, risking damage to the pump or causing spurious trips and costly maintenance expense.

The operator deployed United Electric Control's SIL 2 certified safety transmitter because it combined the 4-20 mA output that goes into the VFD with a safety relay that could directly shut down the PC pump. With the analogue signal connected to the VFD and the embedded logic solver and relay providing redundant safety shutdown of the PC pump, the external power supply, relay and added enclosure were eliminated. An additional digital signal could also be an input in to the VFD for alarm notification in the event the pump was shut down (Figure 5). The new control scheme provided simpler installation and programming at a significantly reduced cost. The improvement in device reliability and diagnostic output of the SIL 2 certified device meant that the customer could now calculate and achieve SIL 2 application protection.

The technological improvement offered by a SIL certified integrated pressure control eliminates two common failure points, namely the extra power source and the external relay. This increases system reliability, and decreasing installation times and costs. Quantitatively, higher risk reduction factors can be achieved, leading to the possibility of an IPL creation at the well head. Qualitatively, cost and operational efficiencies can be realised with a streamlined setup.

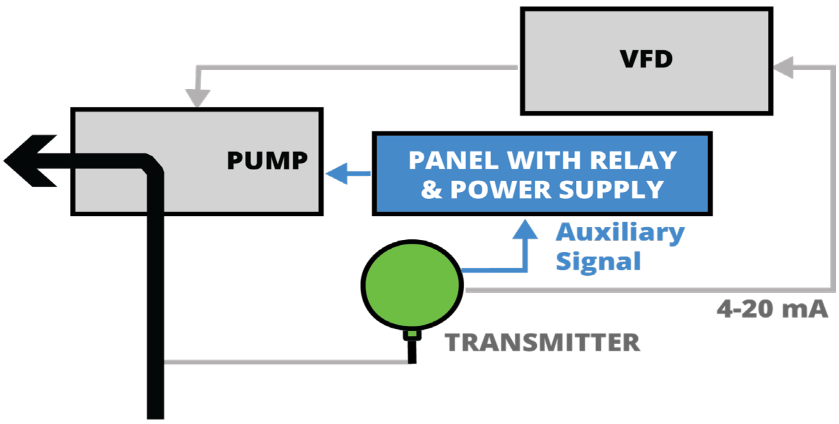

Figure 4. *Schematic of conventional setup with external relay.*

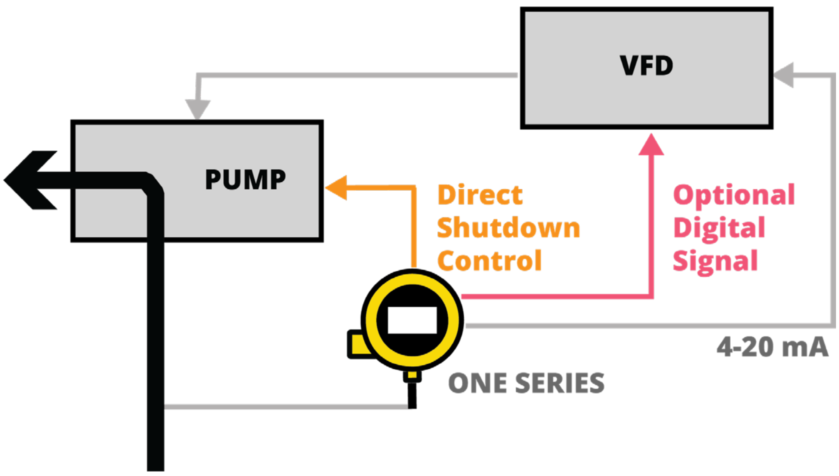

Figure 5. *Schematic of streamlined setup with a SIL certified integrated device.*

Conclusion

Wellsite accidents from overpressure conditions can have severe consequences. Remote oilfields that have been in operation for a long time should be assessed for asset integrity. Where necessary, the upgrading of instrumentation components such as SIL certified integrated pressure controls would be valuable in reducing risks on equipment such as progressive cavity pumps in the oilfields, creating safe, independent protection layers at a remote wellhead. This integrated instrumentation can eliminate failure points as well as auxiliary equipment (e.g. external relays), enhancing cost efficiencies, while ensuring a reliable safety shutdown of the pump during an overpressure condition.

References and notes

1. www.travelers.com/resources/business-industries/oil-gas/planning-for-a-well-control-emergency
2. "An Integrated Approach to Design Hybrid Independent Protection Layers" ISA 2015, Presented at ISA's 61st International Safety Symposium, Huntsville, AL http://www.isa.org.
3. Along with these four attributes, Center for Chemical Process Safety (CCPS) has more recently added Validated and Maintained; Access Security; and Management of Change.