LEAK DETECTION FOR LNG TANKS

Julian Yeo, United Electric Controls, USA, considers how it is possible to learn lessons from past incidents in the LNG sector to create a systematic approach towards leak detection.

Many years ago, oil and chemical operators began adopting a systematic approach to process safety and risk management, guided by two international functional safety standards: IEC 61508 'Functional safety of Electrical/Electronic/Programmable Electronic Safety-related Systems' and IEC 61511 'Functional safety - Safety Instrumented Systems for the Process Industry Sector.'

Both of these standards use a safety life cycle approach consisting of an 'analysis' phase where hazards are identified, including likelihood and consequences. This is then followed by a 'design and implementation' phase, where example calculations of performance and risk reduction that have been achieved are quantified. Finally, the process folds into an 'operation and maintenance' phase, where the performance of the plant-wide system is measured against predetermined safety integrity levels and reliability standards.

LNG facilities are adopting similar functional safety principles, especially in the area of leak detection. With demand for LNG growing, operators need a scalable way of safely processing and storing product, detecting a loss of containment, deploying fire and gas systems reliably where needed, and providing interlocking devices for de-energising equipment. In fact, operators require a whole gamut of preventative and mitigative measures for the protection of personnel, plants and the community.

Process safety experts have learned many lessons from analysing past accidents in the LNG sector. Two experts, whose work will be cited in this article, have studied no fewer than five events over a 50 year period between 1966 and 2016, recording key details and lessons that point to specific considerations, such as designing around safety instrumented systems (SIS).

Lessons learned

At the spring meeting of the American Institute of Chemical Engineers (AIChE) in April 2020 (16th Global Congress on Process Safety), a paper entitled 'Application of Safety Instrumented

Systems in Liquefied Natural Gas (LNG) Processes' was presented by two functional safety experts from exida – Denise Chastain-Knight and Patrick O'Brien.[1] They began their presentation by examining five incidents at LNG plants that resulted in multiple fatalities and enormous destruction.

Here are the key takeaways, quoting directly from the paper:

- Leaking LNG will create ice or hydrate as it vaporises. Final element valves must be specified to function in the presence of these solids.
- On loss of containment, LNG will vaporise, and has the potential to spread over a large area, where it can encounter an ignition source. The SIS must rapidly detect the leak and perform system isolation to reduce the size of the release.
- Process operations, such as filling, must have redundant systems that act to halt operations before loss of containment occurs. Processed conditions can change rapidly, so field elements must have a rapid response time.
- Once loss of containment occurs, it is desirable to stop equipment, such as compressors that add energy to the system. This equipment must be stopped quickly and reliably while minimising the potential for false trips.

Figure 1. An LNG facility during the winter season, with snow build-up.

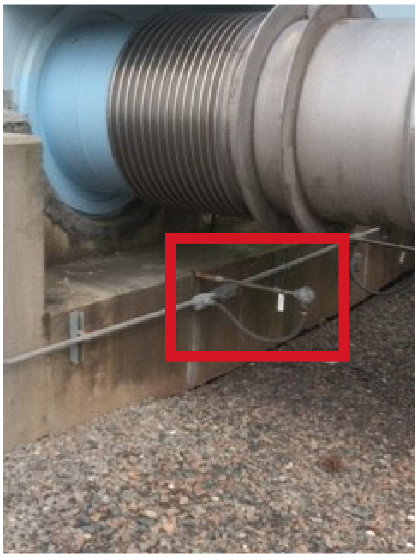

Figure 2. Temperature sensor to detect LNG leaks at the base of an LNG storage tank.

From observable lessons to the work of standards committees, a growing body of knowledge is available that informs functional safety approaches for LNG facilities including the identification and improvement of safety instrumented functions (SIFs), and the design of SISs to address those functions.

Alignment with normative standards

Prescriptive and other worldwide standards relating to LNG design, construction, equipment and processes support a systematic approach expressed in the IEC's functional safety standards. For example, EN 1473 – the European standard for 'Installation and Equipment for Liquefied Natural Gas - Design of Onshore Installations' references both IEC 61508 and IEC 6151 standards. Accordingly, these references constitute a requirement of the EN standard in whole or in part. The same linking paragraphs and references are stated in EN 50495 'Safety Devices Required for the Safe Functioning of Equipment with Respect to Explosion Risks.'

The US standard NFPA 59A 'Production, Storage, and Handling of Liquefied Natural Gas (LNG)' empowers alternative approaches to addressing the safety of processes and equipment, as long as these designs are approved by the authority that has jurisdiction. The standard includes an annex with explanatory material including risk criteria, hazard identification, risk assessment and risk management. This applies to the plant as a whole, and to individual systems, subsystems, and components.

Manufacturers of discrete equipment are contributing to the overall effort by designing certified products and safety systems in compliance with IEC 61508, often referred to as the umbrella standard from which derivative, sector-functional safety standards have emerged.

A systematic approach towards LNG leak detection

In their paper, Chastain-Knight and O'Brien touch on some key principles and considerations, including developing a functional safety management plan (FSMP). Many LNG projects have multiple vendors with different safety approaches and unique products. According to these experts, this can lead to an inconsistent risk profile for the facility. LNG operators must first align technology providers early in the design phase. Missing this step can lead to "costly redesign, start-up delays and unmitigated risk exposure."[1]

Secondly, it is recommended that the LNG operator methodically selects the appropriate sensors and final elements for the application and the environment, including meeting the defined safety integrity level (SIL) for a given function. Functional safety standards equate the SIL with how much risk reduction is expected and achieved. The user should build a safety case, calculating probability of failure (PFD) in an example SIF in order to establish SIL capability, and consider other limits including fault tolerance, architectural constraints, proof testing and system restoration requirements. Sensors and final elements are no longer an arbitrary selection, but systematically evaluated to fulfil the required SIL.

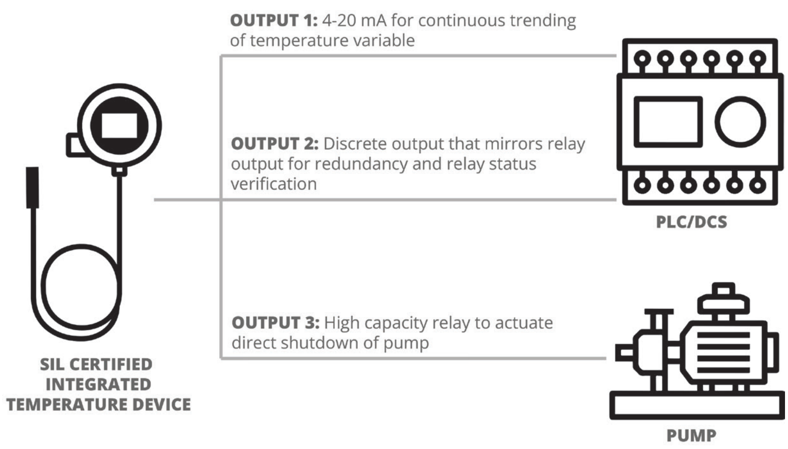

Figure 3. Three outputs of an SIL-certified integrated temperature device.

On the supply side, manufacturers of sensors, logic solvers and final elements used in LNG facilities should invest in product certification to bolster their reliability claims and help quantify the level of risk reduction achieved. Product certification is a clear way of proving that equipment satisfies the applicable functional safety standards, making it easier for the LNG operator to evaluate as part of the FSMP and equipment selection. An example of such a certification database is exida's Safety/Security Automation Equipment List (SAEL), a repository of certification documents, functional safety assessments (FSAs) and information on a range of certified automation products.[2] The certificates on this database include failure-in-time (FIT) data, which designers use to calculate PFD for both low demand and high demand safety functions.

Case study – leak detection using an SIL-certified integrated device

Challenge

LNG facilities are equipped with temperature sensors to detect leaks in wells and spillways within the dike containment area. A sudden drop in temperature detected by the temperature sensor indicates a loss of containment. This SIF is designed to initiate a plant-wide fire and gas (F&G) system to lay a blanket of foam in containment areas. In this hazard scenario, the SIF or SIFs would also de-energise equipment (e.g. compressors or pumps) so that no trace of LNG is pumped out of the containment area into neighbouring municipal septic tank systems, as well as to minimise the likelihood of a vapour cloud finding an ignition source.

Sometimes, during the colder winter months, these temperature sensors can become prone to failure due to snow and ice build-up (Figure 1). Often, these are standalone temperature sensors that require a wire run to a remote distributed control system (DCS) or programmable logic controller (PLC) (Figure 2). As part of a plant improvement effort, one particular LNG operator decided to adopt a systematic approach towards LNG tank safety by implementing safety loops and deploying SIL-certified integrated devices as an upgrade to many of its instruments, including temperature sensors.

Solution

By deploying an integrated SIL-certified sensor-transmitter-switch (e.g. United Electric Control's One Series Safety Transmitter, Figure 3), the LNG operator now has three safety variable outputs to detect an LNG leak and execute a safety action: a 4 – 20 mA signal, a programmable high-capacity solid state relay, and a discrete output. This type of standalone SIS is a cost-efficient upgrade compared to an individual temperature sensor, and offers more flexibility in terms of functions and data reporting, while minimising sensor failures.

If there is an LNG leak, the sensor-transmitter-switch detects the change in temperature and initiates a direct emergency shutdown of the sump pump while simultaneously signalling the DCS to fill the dike containment area with foam to prevent the ignition of fugitive natural gas. By acting directly to shut down pumps, the LNG operator achieves faster system response times and greater risk reduction. A voting mechanism of these safety devices could be employed to maximise availability.

Examples of these solutions can be found within the SAEL. In the first example, the discrete temperature sensor is a Type A (electromechanical) device with no logic or automatic self-diagnostics. In the example of the solution upgrade, the integrated device is considered a Type B (programmable electronic) product by virtue of its programmable electronic design and its self-diagnostics. Failure rate data is compiled and categorised differently for each of these Type A and B products.

Conclusion

The steady adoption of functional safety standards, beginning with the oil and gas industry, has influenced the process and energy sectors – including the growing LNG industry. Driving this adoption are lessons learned from prior incidents, together with expert analysis that informs a systematic approach to functional safety design for LNG facilities. Long-standing normative and prescriptive standards support this growing functional safety science aided by Certified Functional Safety Experts (CFSEs). Takeaways for LNG operators include having an FSMP for aligning safety philosophies across multiple vendors, and evaluating sensors and final elements based on factors such as its PFD. Equipment manufacturers should consider SIL certification to substantiate reliability claims. Public repositories such as exida's SAEL offer operators access to functional safety assessments and FIT data for certified equipment such as sensors, logic solvers and final elements. Leak detection for LNG facilities can now be approached systematically instead of arbitrarily. T&T

Note

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References

1. CHASTAIN-KNIGHT, D., and O'BRIEN, P., 'Application of Safety Instrumented Systems in Liquefied Natural Gas (LNG) Processes', exida, (April 2020), https://www.exida.com/Resources/Whitepapers/application-of-safety-instrumented-systems-in-liquified-natural-gas-lng-pro
2. 'The Safety/Security Automation Equipment List', exida, https://www.exida.com/sael