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Integrating fire and gas safety with process control systems: Why, what and how

If a fire, smoke or gas leak is detected in a hydrocarbon processing facility, prescriptive actions must be taken by the fire and gas (F&G) safety system, as well as by the process control system (PCS), to mitigate and control the hazard. Using a certified, documented F&G safety system that can communicate appropriate messages to the PCS during an event is vital to the safety of a facility and its occupants. However, specifying and integrating these two systems are not simple matters (**FIG. 1**).

According to the *Hydrocarbon Processing* Construction Boxscore Database, there are 261 active downstream projects in the US, with even more active downstream projects in the Middle East and Asia-Pacific regions (301 and 471, respectively).[1] Comprising both retrofits and new construction, these refining, petrochemical and gas processing/LNG projects represent investments of millions or even billions of dollars, and each of these projects will require an F&G safety system.

The complexities of hydrocarbon processing projects—and the potential hazards they contain—make it vital to understand why and how to integrate F&G safety with a production facility's PCS. Worker safety, plant output, code compliance and project implementation cost control all depend on using the right equipment and processes when integrating F&G safety with a facility's overall PCS (**FIG. 2**).

FIG. 1. A properly designed and certified F&G safety system provides information to the PCS to enable operations to consider both process and environmental conditions in a hydrocarbon processing facility.

Consider a chemical plant where flammable materials continue to be pumped into an area where fire has been detected. In these settings, an F&G safety system is the layer of protection responsible for mitigating the consequences of a hazardous event once it has occurred. In hazardous situations like this, it is imperative that an F&G

FIG. 2. Industrial processes, usually controlled by a PCS, must also be protected by an F&G safety system that can detect and provide a warning of hazardous conditions.

safety system communicate with the PCS. The performance requirements of both systems require validation that they can perform to the defined risk-reduction target. Methods to help define the performance requirements are available in standards, directives and recommended practices.

Integrated, independent or both?

In the US, National Fire Protection Association (NFPA) standard NFPA 72: National Fire Alarm and Signaling Code (2016) dictates that an F&G safety system cannot be dependent upon the PCS.[2] Alternately, the F&G system must be able to take immediate action to mitigate a detected risk and then report the action to the PCS regarding any process actions required. Independence between these systems is also recommended by two highly regarded international regulatory bodies: NORSOK, whose standards are supported by the Norwegian Oil and Gas Association and the Federation of Norwegian Industries; and the Health and Safety Executive (HSE), an independent regulatory body in the UK.

To fulfill the standards of both the Petroleum Safety Authority Norway (PSA) and the International Electrotechnical Commission's IEC 61508 and IEC 61511, NORSOK requires "… independencies between safety systems, i.e., a failure in one system shall not adversely affect the intended safety function of another, no interaction shall occur from the process control system to any safety system, from the process shutdown (PSD) system to the emergency shutdown (ESD) system, or from the PSD system to F&G."[3,4]

HSE's guide to the Control of Major Accident Hazards (COMAH) regulations refers to the Engineering Equipment and Materials Users Association (EEMUA) publication "EEMUA 191: Alarm systems: A guide to design, management and procurement," which states, in part, that "the alarm system should be designed in accordance with IEC 61508 to SIL 1 or SIL 2, with the designated reliability," and "the alarm system should be independent from the process control system and other alarms unless it has also been designated safety related."[5,6]

While standards and recommended practices state that the two systems—F&G safety and process control—must not interfere with each other, these documents do not prescribe methods for integrating the two systems. The result is several possible approaches for F&G safety system integration and PCS communications.

Process control encompasses the PCS and the process instrumentation. The overall safety system encompasses the PSD, the ESD and the F&G safety system, which includes subsystems for flame, gas and smoke detection, a safety system controller, and notification and suppression/activation equipment.

Why: The drivers for F&G safety systems.

While the overall role of an F&G safety system is to mitigate the results of hazardous events, the system's first role is to detect hazards, quickly and accurately. According to the literature, "the overall objective of F&G detection systems is to warn of possible impending events that may be threatening to life, property or continued business operations that are external to the process operation."[7]

The literature notes, "Process controls and instrumentation only provide feedback for conditions within the process system. They do not report or control conditions outside the assumed process integrity limits. F&G detection systems supplement process information systems with instrumentation that is located external to the process to warn of conditions that could be considered harmful if found outside the normal process environment. F&G detection systems may be used to confirm the reading of major process releases or to report conditions that process instrumentation may not adequately report or be unable to report (i.e., minor process releases)."[7]

Myriad regulations require F&G safety systems, and some have already been mentioned. Common regulatory and legislative bodies, standards and industry codes include UL, the Occupational Safety and Health Administration (OSHA), NFPA and the American Petroleum Institute (API). However, other global regulations are in place to ensure the safety of the industrial workplace, including regional- and industry-specific standards, such as NORSOK and the internationally recognized IECEx standards, which pertain to environments with explosive atmospheres.

Insurance companies such as Factory Mutual (FM) Global and Lloyd's of London provide guidelines for specific risks found within industrial processes.

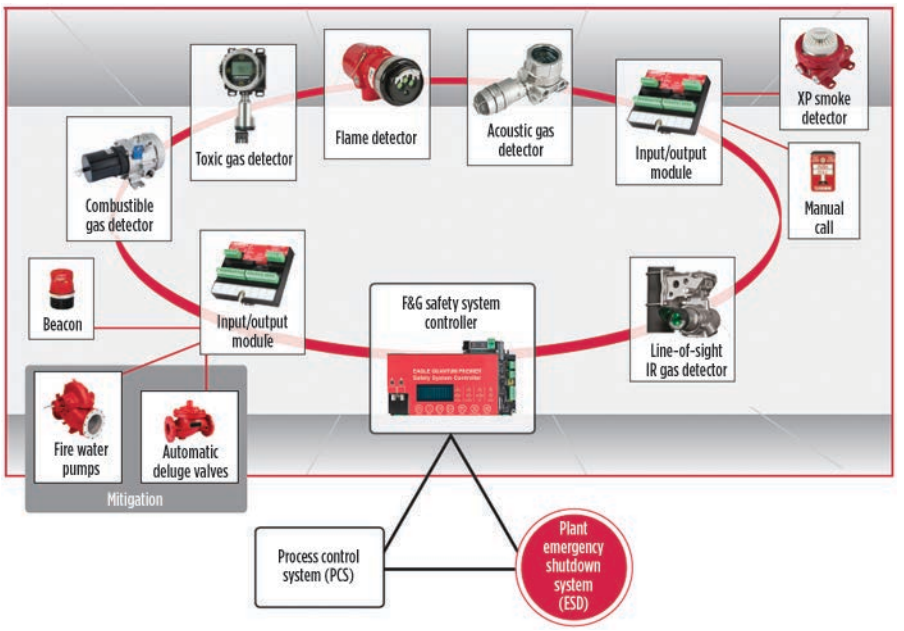

FIG. 3. An effective F&G safety system may include multiple types of detection devices plus an F&G safety system controller with inputs and outputs for notification and suppression-activation devices to contain or mitigate an event that may be threatening to personnel or process operations.

Manufacturing companies may also draft and enforce mandates related to safety, while local authorities having jurisdiction often enforce legislative and their own standards specific to the location involved.

What: The flame and gas system. An F&G safety system is comprised of several subsystems that can include, but are not limited to, flame, gas and smoke detection; a safety system controller; and notification and/or suppression-activation devices (**FIG. 3**).

Detection—the backbone. Following codes such as NFPA 72 and NFPA 70 and the National Electrical Code (NEC), flame and gas detectors must be performance-certified by product certifiers and capable for use in hazardous applications. Third-party product certification is critical, as it validates the expected performance of the F&G safety system. Organizations that certify product performance include FM, UL and other Nationally Recognized Testing Laboratories (NRTLs).

In addition to product performance certification, functional safety product certification is essential for validation of product reliability for high-hazard plant safety. Product certifiers must be accredited to assess and audit products, services and systems to ensure that they meet functional safety requirements. The following is an overview of the detector technologies often used in hazardous industrial applications.

Gas detection technologies. Gas leak detection is usually considered the first line of defense in mitigating risk and helping to prevent fire, explosions and process downtime in hazardous industrial settings. NFPA 72 (2016) defines a gas detector as "a device that detects the presence of a specified gas concentration." The gases detected may be combustible, toxic or both. Multiple detector types used for sensing gases exist, such as:

- Fixed-point detectors that employ electrochemical, catalytic or infrared technologies to detect the presence of a toxic or combustible gas. These detectors measure the gas concentration at their location and monitor for potential flammable or toxic gas leak conditions.
- Line-of-sight gas detectors that continuously monitor combustible gas levels between two points at ranges as far as 120 m (394 ft) apart. These detectors are often deployed in and around open areas and harsh environments that are typical of an industrial site, and are perfect for perimeter monitoring for gas clouds and for augmenting point detectors for optimal coverage in large open areas.
- Acoustic detectors that use ultrasonic sensors to detect leaks based on noise patterns. This technology is ideal for areas where risk exists for pressurized gas leaks. These are suitable for harsh outdoor applications, unmanned operations and extreme temperatures, and are unaffected by fog, rain and wind.

Each of these toxic and combustible gas detection approaches have benefits and limitations depending on environmental and application factors. Therefore, an optimal protection solution may involve using more than one type of technology and placing selected detector types in locations that maximize their effectiveness.

The goal of gas leak detection devices is to detect hazardous vapors before they accumulate to an explosive or lethal level. The information these devices send to the F&G safety system controller can be used in decision-making and communication with the process control/process shutdown systems to take actions, such as closing valves to limit the flow of gas to the endangered area or curtailing electric power near the leaking gas to reduce ignition potential.

Flame detection technologies. Rather than waiting to detect heat or smoke from a fire, hazardous locations often employ optical flame detectors tuned to specific fire emissions that can be sensed from a distance in a defined area of coverage. As described in NFPA 72, these radiant-energy-sensing detectors are line-of-sight devices that can employ several sensing technologies: ultraviolet (UV), infrared (IR), ultraviolet/infrared (UVIR) and multi-spectrum infrared (MIR).

In addition to providing rapid fire detection when response times are critical, these detectors are expected to be highly resistant to false alarms, which can be costly in terms of operation shutdowns and plant and equipment damage caused by fire-suppression materials.

Smoke detection technologies. F&G safety systems may also employ smoke detection to perform life safety functions for occupied spaces, as required by OSHA. Using a variety of technologies, these devices detect particles produced by combustion, including photoelectric, beam and video smoke. To be effective, smoke detectors should be located and spaced in anticipation of airflow from sources likely to present fire risks, but not to cause false alarms.

As NFPA 72 states, "The location of smoke detectors shall be based on an evaluation of potential ambient sources of smoke, moisture, dust or fumes, and electrical or mechanical influences, to minimize nuisance alarms." Smoke detectors in occupied areas can be connected to the overall F&G safety system, depending on the capabilities of the safety system controller.

When smoke alarms are connected to the safety controller, any local annunciation of the smoke detector would be represented in the F&G safety system so that personnel away from the incident are alerted. Adding a timestamp from the controller may also be valuable during incident reconstruction.

Smoke detectors installed in hazardous locations must be explosion-proof and—like all detectors used in high-risk locations—should have the necessary performance and hazardous-location approvals to ensure safe and effective operation, whether installed in defined areas or inside ductwork.

The F&G safety controller—the brain of the system. A complete F&G safety system is an integrated set of inputs and outputs consisting of flame, gas and smoke detectors; alarm signaling and notification; and extinguishing agent release and/or deluge operations designed to contain or mitigate an event that may be a threat to personnel or process operations.

Unlike the PCS, which only reports on conditions within the process system, the responsibility of the F&G safety system is to continually monitor and

analyze data collected by detectors in the process areas, make decisions to determine if/how to contain or mitigate the hazard, provide alarm notification and communicate the event to the PCS.

The brain of the F&G safety system is a certified safety controller, approved by product certifiers to be compliant to NFPA 72 for flame and gas detection and releasing, and integrated with (but independent from) the PCS.

This controller should do more than just handle inputs and outputs; it should also troubleshoot and provide real-time F&G safety system status and diagnostics. It should facilitate easy programming and configuration of flame and gas detectors and other field devices. The ideal F&G safety system should be certified SIL 2 capable, with the proper documentation that validates its performance capabilities and fault diagnostics.

An NFPA 72-compliant F&G safety controller for flame and gas detection and release will be able to:

- Detect specialized hazardous events, such as gases, vapors or fires
- Minimize responses to false events
- Provide automatic and/or manual mitigation of detected hazardous events
- Annunciate events to personnel
- Provide information on system readiness/health
- Provide historical information, including calibration, alarm and fault logs
- Communicate with third-party systems, such as the PCS and ESD system.

How: Information sharing between the F&G safety system and the PCS. Integrating complex alarm control and hazard mitigation is critical to life and plant preservation. In the past, F&G safety system controllers were limited to being hardwired together by using analog or contact closures in a conventional (e.g., point-to-point) design. Although still acceptable, this design provides limited diagnostics, is not inherently fault-tolerant and is less flexible to configure. While this configuration provides alarm and fault information, specific details of the event are not available to the controller because of the simple, binary nature of the communication path.

Conversely, an F&G safety system in an addressable loop has the F&G devices configured on a bidirectional, fault-tolerant loop topology, substantially increasing the amount of diagnostic information that can be shared with the F&G safety controller. This configuration is more reliable, as the controller is in constant communication with each device on the loop for alarm and diagnostic information.

As previously mentioned, an effective F&G safety system should include the capability to provide detection device status, in defined process areas, to the PCS. This enables the process owner to know exactly what, where and when events are occurring. However, since the F&G safety system and the PCS remain independent, a failure by the PCS will not affect the operation of the F&G safety system.

Takeaway. In hydrocarbon processing facilities around the world, F&G safety systems supplement PCSs by providing critical functions, such as warning and containing or mitigating a detected hazard. Although required to operate independently of the PCS, the F&G safety system can be integrated with the PCS to allow communication about an event that may threaten personnel or process operations.

Whether part of a plant retrofit or an all-new construction project, effective F&G safety systems must be properly certified and able to provide real-time safety system status and diagnostics. These systems should also be scalable and configurable, and have the ability to integrate with the PCS. It is important to consider all these features when selecting an F&G safety system to effectively and efficiently protect any downstream hydrocarbon processing project. HP

LITERATURE CITED

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