INDUSTRY UPDATE: SAFETY INSTRUMENTED FIRE & GAS SYSTEMS (SI-FGS)

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ABSTRACT

This paper will explore the current trends in the market place and industry in general with respect to Fire & Gas Detection Systems and their relationship to Safety Instrumented Systems. The concept of a Safety Instrumented Fire & Gas Detection System (SI-FGS) will be introduced and explained in detail. This will include a review of the following topics:

- Industry Update – ISA S84 Fire & Gas sub-committee
- Logic Solver Update - FM & UL 864 approved SI-FGS
- Product Update – FMEDA availability for Fire & Gas sensors and final control devices

In support of this paper, the authors conducted an informal survey of Fire & Gas System OEM’s, Engineering Firms and End Users, in an attempt to ascertain what are the driving factors towards the emergence and acceptance of Safety Instrumented Fire & Gas Detection Systems in the marketplace.

INTRODUCTION

The concept of a Safety Instrumented Fire & Gas Systems (SI-FGS) has emerged in the process industry. Its arrival is has generated both controversy and confusion. The term SI-
FGS represents the attempted application of performance based safety concepts to the design of Fire & Gas Detection Systems. ANSI / ISA S84.01 states that Fire & Gas Systems where operation action is required to initiate the system is not covered by the standard. Thus, those systems that automatically initiate an action could be addressed by the performance based Safety Instrumented System standards. However, the inherent differences between a Safety Instrumented System and a Fire & Gas System pose some challenges for an end user attempting to merge design techniques. This paper will discuss some of these differences and trends in industry.

**DIFFERENCES BETWEEN SIS AND FGS**

To better understand the concept of a Safety Instrumented Fire & Gas System, let us first explore the relationship and inherent differences between the functionality and design of these two very important systems.

A Safety Instrumented Fire & Gas System (SI-FGS) is a system comprised of initiating device sensors, logic solvers, final control elements, fire safety functions and / or notification appliances for the purpose of mitigating an event when predetermined conditions are violated.

![Figure 1 – Typical risk reduction methods found in process plants](image-url)
PREVENTION VERSUS MITIGATION

A Safety Instrumented System by definition is designed to bring the process to a safe state when demand is placed upon it. For instance consider a scenario, possible rupture of a vessel with subsequent release of a flammable / toxic material that could result in on-site injuries and / or fatalities due to the ensuing fire. A Safety Instrumented System could be designed that would close the feed valve if a high-high pressure condition was detected, thus eliminating the source of overpressure. If this action is taken, the process is returned to a safe state and the potential hazardous event has been completely prevented. A Fire & Gas Detection System may include some preventative functions as described above. However, it is typically comprised of mitigating functions. A mitigating function is described as an action that does not prevent the hazardous event from occurring but instead initiates actions that reduce the potential consequences of the event after it has occurred. For instance in the example described above, one could implement a Fire & Gas System to detect the fire and / or release of the flammable material at the ruptured vessel and initiate a suppression action (water mist, foam system, etc.) This system would be designed to contain the fire to a single unit operation, lessen the potential for injuries to personnel through area alarming, and protect capital investment of the facility by quickly containing / extinguishing the fire. The Fire & Gas Detection system acted after the primary event (vessel rupture) had occurred in an attempt to lessen the consequence of this condition. Even if the Fire & Gas System does not initiate a suppression related action, the act of sounding alarms / beacons is a common mitigating action. By removing personnel from the hazardous zone one is mitigating potential injury to those workers. Refer to Figure 2 below for a typical P&ID depiction of the relationship between the above described Safety Instrumented System and Fire & Gas Detection System.
Figure 2 – SIS & FGS Functions
ACTUATION STATE

Another inherent difference between Safety Instrumented Systems and Fire and Gas Detection Systems is the basic design principal regarding de-energize to trip and energize to trip functionality. Most Safety Instrumented Systems are designed to de-energize (i.e. remove power, instrument air, etc.) upon detection of a potentially dangerous condition. Most Fire and Gas Detection Systems, on the other hand, are typically designed to energize (turn on power, instrument air, etc.) upon detection of a potentially dangerous condition. One needs to recognize that most of the failure data used in Probability of Failure on Demand (PFD) equations presented in various Safety Instrumented System literature sources represent de-energize to trip systems. In this mode of operation, it is generally assumed that a dangerous detected failure is converted to a nuisance trip through initiation of a diagnostic generated shutdown. Another critical concept associated with energize-to-trip systems is the mandate for some sort of source of back-up power to be provided to bring the system to a safe state upon loss of power.

BACK-UP POWER REQUIREMENTS

Another inherent difference between Safety Instrumented Fire & Gas Detection Systems and typical commercial Fire and Gas Detection Systems is power consumption. A commercial Fire & Gas System, specifically designed to meet NFPA 72, includes design provisions to minimize quiescent power consumption during the time frame the system is operating on back-up power. A Safety PLC based system on the other hand has been designed to operate using a de-energize-to-trip concept and, as such, specific steps to minimize power consumption have not been implemented in these type systems. Thus, a commercial Fire & Gas Detection System is going to draw micro / milli-amps whereby a Safety Instrumented Fire & Gas Detection System is going to draw many amps. Therefore, one needs to recognize that commercially available battery systems to support the power consumption requirements of a Safety PLC, while still meeting all of the diagnostic and supervision related requirements of NFPA 72 with FM and / or UL Approvals already in place, may not readily exist at this time. At the time of this writing the authors are aware of a newly FM-Approved battery system that is capable of supporting a Safety PLC based Safety Instrumented Fire & Gas Detection System.

PRESCRIPTIVE VERSUS PERFORMANCE BASED SAFETY STANDARDS

For example, NFPA 72 (or EN-54) contains a large number of prescriptive requirements with respect to the design and installation of Fire & Gas Detection systems. This includes requirements on initiating device circuit supervision, notification appliance circuit supervision, fire safety function circuit supervision, suppression system designs, etc. The concept of a Safety Instrumented Fire & Gas System requires implementing both the
prescriptive requirements of a standard like NFPA 72 or EN-54 as well as the requirements of a performance based standard such as ANSI/ISA S84.00.01-2004 in an attempt to design a system that has the best of both worlds. Implementation of both prescriptive and performance based requirements is easier said than done as the performance based requirements as described below still pose some interesting issues for industry to address.

**FUNCTIONAL TESTING REQUIREMENTS**

NFPA 72 or EN-54 does not specifically mandate functional testing of Fire & Gas Detection Systems based upon the architecture of the system and desired availability. Safety Instrumented Systems, on the other hand, have underscored the importance of functional testing and it’s relationship to overall Probability of Failure on Demand calculations. This fundamental difference must be addressed for those intending to apply performance-based requirements to a Fire & Gas Detection / Mitigation System.

![Figure 3 – Graph of PFD and Functional Testing Relationship](image)

As can be seen in Figure 3, for a given SIS architecture, the probability of failure increases with time. By conducting a functional test of the system you are attempting to identify any potential covert failures in the system. This results in a resetting of the PFD “clock” back down to a minimal PFD.

**FIRE VERSUS GAS REQUIREMENTS**

NFPA 72 specifies requirements associated with fire detection and / or mitigation. Gas detection is typically considered an additional action that is labeled as “interference free”. Depending on the Authority Having Jurisdiction (i.e. Local Fire Marshall) one may not be allowed to mix Fire, Gas & shutdown functions within a single system unless the system has been specifically approved for this application. This issue should be carefully researched to
ensure the all goals of the project can be readily and easily achieved. For the Authority Having Jurisdiction inform a user during Acceptance Testing that, combining Fire & Gas logic within the Safety PLC, is unacceptable would have a major impact on the project. The author’s are aware of at least one NFPA 72 approved Safety Instrumented Fire & Gas Detection System that supports both Fire & Gas functionality.

RELIABILITY ENGINEERING ISSUES

The underlying principal behind Safety Instrumented System designs is based on reliability fundamentals regarding the failure modes of systems / devices and their impact on the ability of the system as a whole to perform it’s intended function. Probability of Failure on Demand for a simple 1oo1 (One out of one) system is defined as:

\[ PFD_{avg} = \frac{\lambda^{DU} \times TI}{2} \]

Where,

\[ PFD_{avg} \] – Probability of Failure on Demand Average
\[ \lambda^{DU} \] – Failure Rate Dangerous Undetected
\[ TI \] – Test Interval

When evaluating this simplified equation, it must be recognized that the inherent differences between a de-energize-to-trip and energize-to-trip system regarding the definition of \[ \lambda^{DU} \] for each system. Consider the system described in Figure 2 above.

Figure 4 – Fire & Gas Schematic

The following assumptions apply:

- BSH-201 closes a contact when fire is detected
- Logic Solver is a Programmable Electronic System
- UA-203 is a alarm horn / strobe that is normally de-energized
### Table 1– De-Energize-To-Trip Versus Energize-To-Trip Failure Modes

<table>
<thead>
<tr>
<th>#</th>
<th>Failure Mode</th>
<th>De-Energize-To-Trip</th>
<th>Energize-To-Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Open Circuit – Cut Wire associated with BSH-201 or UA-203</td>
<td>A cut wire will result in a safe detected trip when power is removed from the circuit (i.e. valve closes)</td>
<td>A cut wire will result in a dangerous undetected failure unless specific diagnostics have been included in the design to detect this condition.</td>
</tr>
<tr>
<td>2</td>
<td>Logic Solver Output stuck OFF</td>
<td>A stuck OFF output results in a safe detected trip when power is removed from the circuit (i.e. valve closes)</td>
<td>A stuck OFF output represents a dangerous undetected failure unless specific diagnostics have been included in the design to detect this condition.</td>
</tr>
<tr>
<td>3</td>
<td>Logic Solver Output stuck ON</td>
<td>A stuck ON output results in a dangerous undetected failure where power cannot be removed from the circuit (i.e. valve cannot be closed)</td>
<td>A stuck ON output results in a safe detected failure where power circuit is energized (i.e. alarm horn / strobe sounded when no fire present). Note that if this was a Halon System that fired, this failure might be classified as a dangerous detected failure.</td>
</tr>
</tbody>
</table>

Failure rate data and failure modes for a energize-to-trip design must be carefully evaluated to ensure PFD_{avg} calculations yield accurate results.

### FIELD DEVICE WIRING DIFFERENCES

Traditional Fire & Gas Systems utilize wiring schemes that allow many field devices to be daisy chained together on a single circuit. For instance, this type of circuit typically uses some sort of end of line device to monitor the contact state of multiple sensors or it can even use an addressable network / bus scheme. Safety Instrumented Systems, on the other hand, tend to have a single field device wired to a single I/O channel on the Safety PLC. This can result in increased costs for those attempting to migrate from a proprietary Fire & Gas System to a Safety PLC based Safety-Instrumented Fire & Gas Detection System. One should carefully review the wiring schemes required by the Safety Instrumented Fire & Gas Detection System to ensure the project’s scope and funding includes the cost to engineer and install new conduit / cable to all field devices. The author’s are aware of one NFPA 72 approved Safety Instrumented Fire & Gas Detection System that supports multiple field devices connected to a single I/O channel. Thus, all hope is not lost and, through careful research and due diligence, a user can, in fact, cost effectively migrate to a Safety Instrumented Fire & Gas System.

### PROPRIETRY VERSUS OPEN SYSTEMS
A major driving factor towards the emergence of a Safety-Instrumented Fire & Gas Detection System seems to be the desire for a facility to utilize a common logic solver hardware platform for both Fire & Gas systems. This choice offers the following benefits:

- Ability to use a common Human Machine Interface
- Reduction in spare parts
- Common maintenance training / practices
- Common engineering platform for reduction in training / support hardware
- Desire to eliminate of older legacy proprietary systems and consolidate to a common platform
- Potential cost reduction of life of system by using one platform in lieu of two to accomplish the same task

The same issues and economics that have virtually eliminated the proprietary Distributed Control System (DCS) are now forcing consolidation within the Fire & Gas and Safety Instrumented System marketplaces. In today’s competitive global economy companies need every cost advantage they can get to remain competitive.

**INDUSTRY UPDATE**

**ISA S84 FIRE & GAS DETECTION SUB-COMMITTEE FORMATION**

ISA has formed a new sub-committee to develop a technical report entitled Fire and Gas Systems (F&GS) Relationship to ANSI/ISA84.01-2004 (IEC 61511). The purpose of this technical report / guideline is to provide guidance for users and OEM vendors of industrial fire and gas systems to determine which, if any, safety instrumented functions of a F&GS should be implemented according to the requirements of ANSI/ISA 84.01-1996 and IEC 61511. The technical report / guideline will show examples of prescriptive functions that may be required by national fire codes, such as NFPA 72. This guideline, by reference to ANSI/ISA 84.01-1996 and IEC 61511, will demonstrate how to determine which functions are safety functions, and to determine the required SIL (Safety Integrity Level) for those safety functions. Also by reference to ANSI/ISA 84.01-1996, IEC 61508, and IEC 61511, the technical report / guideline will give some guidance as to how the safety functions can be implemented from a performance perspective to achieve the desired risk reduction. This sub-committee has generated a lot of interest from a variety of end users, OEM’s and consultants.

**LOGIC SOLVER UPDATE**

At the time of writing this article, the authors are aware of three (3) different Safety PLC offerings that have been submitted to UL or FM for an application-based approval for Fire & Gas Detection. Also, two (2) different Fire System OEM’s have developed Fire & Gas
Systems that have been TUV approved to meet a given Safety Integrity Level per IEC 61508. In addition, we are aware of a large number of recent projects where end users have been specifying the use of Safety PLC’s for Fire & Gas Detection Systems. These requests for quotation all included performance criteria associated with meeting a specific Safety Integrity Level with respect to the logic solver. Thus, whether the demand has been created by end users or through a marketing campaign developed by manufacturer’s of Safety PLC’s, the fact remains that Safety PLC’s are routinely being applied to Fire & Gas Detection designs with the requirement for meeting a specific Safety Integrity Level being imposed.

**SENSOR UPDATE**

A wide variety of fire and gas related sensors have had Failure Modes and Effects Diagnostics Analysis (FMEDA) performed. Refer to table below for a partial listing of some of these devices. As can be seen from the Table 2, several different OEM’s have recognized the need to provide data for use in a performance-based safety instrumented system design.

<table>
<thead>
<tr>
<th>#</th>
<th>Manufacturer</th>
<th>Model #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Detectomat GmbH</td>
<td>Optical-Thermal Loop Detector PL 3300 OT</td>
<td>Heat / Smoke - IR Detector</td>
</tr>
<tr>
<td>2</td>
<td>Det-Tronics</td>
<td>PIRECL Pointwatch Eclipse</td>
<td>Hydrocarbon Gas - Infrared</td>
</tr>
<tr>
<td>3</td>
<td>Det-Tronics</td>
<td>X3301 Multispectrum IR Flame Detector</td>
<td>IR Flame Detector</td>
</tr>
<tr>
<td>4</td>
<td>Draeger PLMS ltd.</td>
<td>Polytron Pulsar</td>
<td>Gas - Open Path (IR absorption)</td>
</tr>
<tr>
<td>5</td>
<td>Dräger Safety AG &amp; Co. KGaA</td>
<td>IR Gas Transmitter Polytron 2IR - Type 334</td>
<td>Gas - Infrared</td>
</tr>
<tr>
<td>6</td>
<td>Dräger Safety AG &amp; Co. KGaA</td>
<td>Polytron 7000</td>
<td>Gas - Electrochemical</td>
</tr>
<tr>
<td>7</td>
<td>Zellweger Analytics Limited</td>
<td>Searchpoint Optima Plus IR point</td>
<td>Gas - Infrared</td>
</tr>
</tbody>
</table>

It is significant that sensor OEM’s are beginning to provide data that could support the overall SI-FGS concept.

**CONCLUSION**

The concept of a performance-based Safety-Instrumented Fire & Gas Detection System (SI-FGS) is complex to say the least. Many issues need to be carefully considered when attempting to merge the prescriptive world of Fire & Gas Systems with the performance-
based world of Safety Instrumented Systems. However, end users and OEM’s both appear to be driving industry towards convergence of design criteria. Let’s review the facts:

- Numerous Fire & Gas Sensors have been submitted for FMEDA completion to support PFD calculations
- Several Safety PLC systems have been submitted for FM and / or UL Approval as Safety Instrumented Fire & Gas Detection Systems
- Several Fire Systems have been submitted to TUV for certification to IEC61508
- A FM Approved battery system capable of supporting a Safety PLC based FGS is now commercially available
- ISA has formed a sub-committee to develop a technical report on the relationship of Fire & Gas Systems and Safety Instrumented Systems

Thus, it appears that Safety-Instrumented Fire & Gas Detection Systems are gaining significant momentum and that can only benefit industry as a whole.

**DISCLAIMER**

Although it is believed that the information in this paper is factual, no warranty or representation, expressed or implied, is made with respect to any or all of the content thereof, and no legal responsibility is assumed therefore. The examples shown are simply for illustration, and, as such, do not necessarily represent any company’s guidelines. The reader should use data, methodology, formulas, and guidelines that are appropriate for their own particular situation.

**REFERENCES**


7. EN 54 *Fire Detection And Fire Alarm Systems, European Standards (Norme Europenne)*, 2001

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1oo1</td>
<td>1-out-of-1</td>
</tr>
<tr>
<td>1oo1D</td>
<td>1-out-of-1 D (D for extensive self-diagnostics)</td>
</tr>
<tr>
<td>1oo2</td>
<td>1-out-of-2</td>
</tr>
<tr>
<td>1oo2D</td>
<td>1-out-of-2 D (D for extensive self-diagnostics)</td>
</tr>
<tr>
<td>2oo3</td>
<td>2-out-of-3</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
</tr>
<tr>
<td>MTTFS</td>
<td>Mean Time To Fail Spurious</td>
</tr>
<tr>
<td>PFDavg</td>
<td>Average Probability of Failure on Demand</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
</tr>
<tr>
<td>RRF</td>
<td>Risk Reduction Factor</td>
</tr>
<tr>
<td>SI-FGS</td>
<td>Safety Instrumented Fire &amp; Gas Detection System</td>
</tr>
<tr>
<td>SIF</td>
<td>Safety Instrumented Function</td>
</tr>
<tr>
<td>SIL</td>
<td>Safety Integrity Level</td>
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<tr>
<td>SIS</td>
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