SAFIRE PROTECTION

FUNCTIONAL SAFETY IN FIRE PROTECTION SYSTEM E-BOOK

USEFUL TERMINOLOGY

BASIC PROCESS CONTROL SYSTEM (BPCS)
System which responds to input signals from the process, its associated equipment, other programmable systems and/or an operator and generates output signals causing the process and its associated equipment to operate in the desired manner but which does not perform any safety instrumented functions with a claimed SIL > 1.

COMMON CAUSE FAILURE
Failure, which is the result of one or more events, causing failures of two or more separate channels in a multiple channel system, leading to system failure.

COMMON MODE FAILURE
Failure of two or more channels in the same way, causing the same erroneous result.

DANGEROUS FAILURE
Failure which has the potential to put the safety instrumented system in a hazardous or fail-to-function state.

DETECTED
In relation to hardware failures and software faults, detected by the diagnostic tests or through normal operation.

FAILURE
Termination of the ability of a functional unit to perform a required function.

FAULT
Abnormal condition that may cause a reduction in, or loss of, the capability of a functional unit to perform a required function.

FAULT TOLERANCE
Ability of a functional unit to continue to perform a required function in the presence of faults or errors.

FINAL ELEMENT
Part of a safety instrumented system which implements the physical action necessary to achieve a safe state.

FUNCTIONAL SAFETY
Part of the overall safety relating to the process and the BPCS which depends on the correct functioning of the SIS and other protection layers.

HARM
Physical injury or damage to the health of people, either directly or indirectly, as a result of damage to property or to the environment.

HAZARD
Potential source of harm.

LOGIC FUNCTION
Function which performs the transformations between input information (provided by one or more input functions) and output information (used by one or more output functions); logic functions provide the transformation from one or more input functions to one or more output functions.

LOGIC SOLVER
That portion of either a BPCS or SIS that performs one or more logic function(s).

MITIGATION
Action that reduces the consequence(s) of a hazardous event.

MODE OF OPERATION
Way in which a safety-related system is intended to be used, with respect to the frequency of demands made upon it, which may be either:

- **low demand mode** – where the frequency of demands for operation made on a safety-related system is no greater than one per year and no greater than twice the proof test frequency;
- **high demand or continuous mode** – where the frequency of demands for operation made on a safety-related system is greater than one per year or greater than twice the proof check frequency.

PROOF TEST
Test performed to reveal undetected faults in a safety instrumented system so that, if necessary, the system can be restored to its designed functionality.

PROTECTION LAYER
Any independent mechanism that reduces risk by control, prevention or mitigation.

RANDOM HARDWARE FAILURE
Failure, occurring at a random time, which results from a variety of degradation mechanisms in the hardware.

REDUNDANCY
Use of multiple elements or systems to perform the same function; redundancy can be implemented by identical elements (identical redundancy) or by diverse elements (diverse redundancy).

RESIDUAL RISK
Risk remaining after protective measures have been taken.

RISK
Combination of the frequency of occurrence of harm and the severity of that harm.

SAFE FAILURE
Failure which does not have the potential to put the safety instrumented system in a hazardous or fail-to-function state.

SAFE FAILURE FRACTION
Fraction of the overall random hardware failure rate of a device that results in either a safe failure or a detected dangerous failure.

SAFETY
Freedom from unacceptable risk.

SAFETY FUNCTION
Function to be implemented by an SIS, other technology safety related system or external risk, reduction facilities, which is intended to achieve or maintain a safe state for the process, with respect to a specific hazardous event.

SAFETY INSTRUMENTED FUNCTION (SIF)
Safety function with a specified safety integrity level which is necessary to achieve functional safety and which can be either a safety instrumented protection function or a safety instrumented control function.

SAFETY INSTRUMENTED SYSTEM (SIS)
Instrumented system used to implement one or more safety instrumented functions. An SIS is composed of any combination of sensor (s), logic solver (s), and final elements(s).

SAFETY INTEGRITY
Average probability of a safety instrumented system satisfactorily performing the required safety instrumented functions under all the stated conditions within a stated period of time.

SAFETY INTEGRITY LEVEL (SIL)
Discrete level (one out of four) for specifying the safety integrity requirements of the safety instrumented functions to be allocated to the safety instrumented systems. Safety integrity level 4 has the highest level of safety integrity; safety integrity level 1 has the lowest.

SAFETY LIFE CYCLE
Necessary activities involved in the implementation of safety instrumented function(s) occurring during a period of time that starts at the concept phase of a project and finishes when all of the safety instrumented functions are no longer available for use.

SENSOR
Device or combination of devices, which measure the process condition (for example, transmitters, transducers, process switches, position switches).

SYSTEMATIC FAILURE
Failure related in a deterministic way to a certain cause, which can only be eliminated by a modification of the design or of the manufacturing process, operational procedures, documentation or other relevant factors.

TOLERABLE RISK
Risk which is accepted in a given context based on the current values of society.

UNDETECTED
In relation to hardware and software faults not found by the diagnostic tests or during normal operation.

VALIDATION
Activity of demonstrating that the safety instrumented function(s) and safety instrumented system(s) under consideration after installation meets in all respects the safety requirements specification.

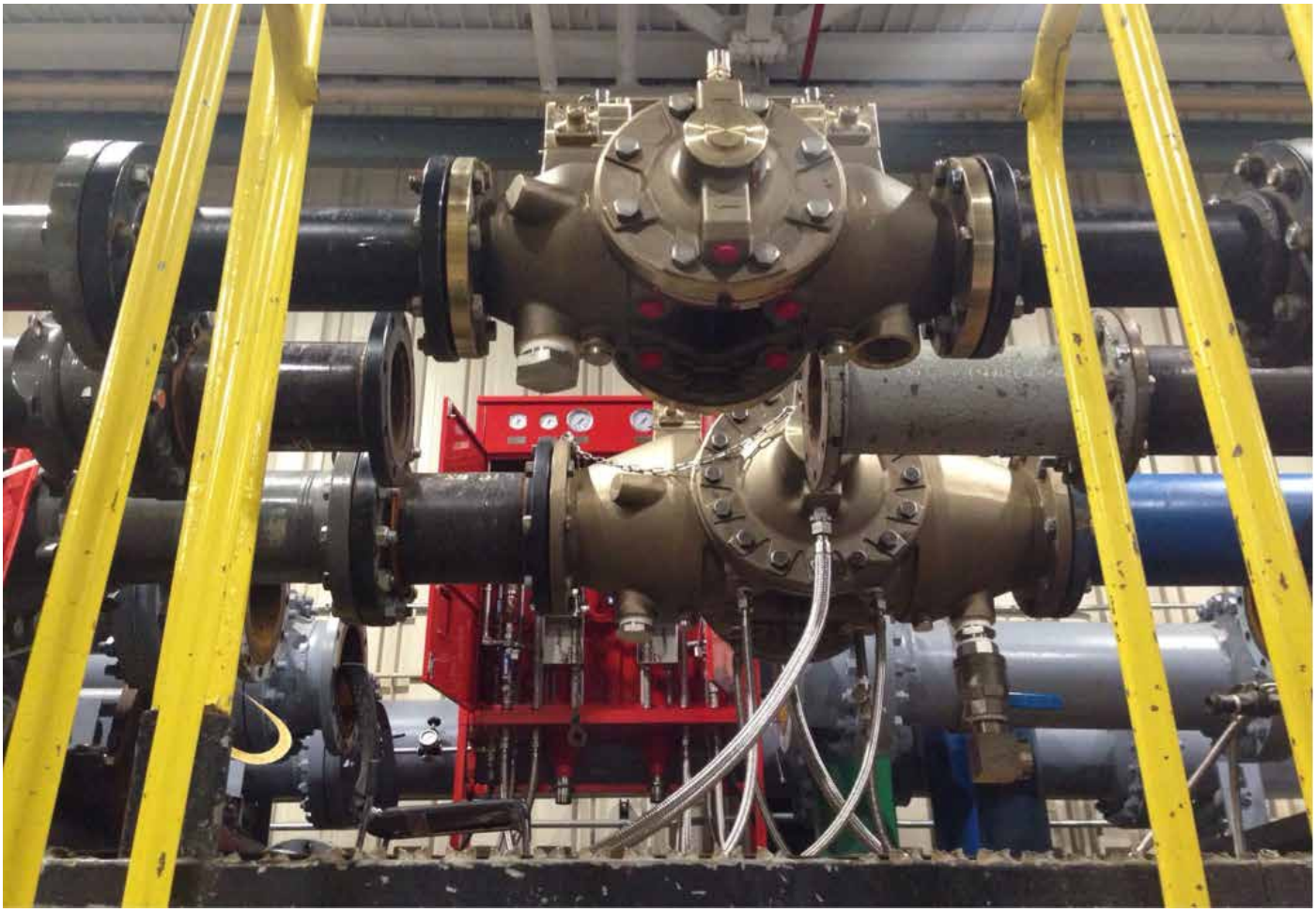
FUNCTIONAL SAFETY IN FIRE PROTECTION SYSTEMS

After the major accidents occurred in the Oil & Power industry in the last ten years, the technical community involved in the design of industrial processes has shown an increased and more intense interest in system reliability and availability. The attention is no longer limited to the core process but is also extending its boundaries to all those safety systems to which the monitoring and the mitigation effects are demanded.

If it is paramount that a process shall be designed with high reliability criteria, sometimes it is not fully understood that **the process reliability cannot rule out the risk of an accident taking place**. Engineering limitations also apply to a stressed safety oriented design approach and therefore, one way or another, systems are finalized and built accepting a certain level of residual risk.
If the risk of an accident cannot be lowered below a certain point, we should focus our attention on those systems designed to monitor the environment and provide mitigation effects. Those process sub-systems, such as Fire & Gas, deluge, monitors and gaseous based fire extinguishing systems, play a fundamental role in the safety of the plant and its occupants.

These systems are called into action when the residual risk of the hazard turns into an accident of major consequence, and their duty is to warn the occupants and the operators and mitigate the accident effects to the best of their capabilities. In this respect it is well known that a gas cloud detected and confined in time or a fire outbreak detected and extinguished by a deluge water spray system have the same objectives: saving lives, limiting the impact on the environment, reducing the production losses and safeguarding investments.

For the reasons above, functional safety is moving into Fire & Gas detection and suppression systems, with the objective of increasing the reliability and hence the performance of the safety functions used to monitor and mitigate the effects of a possible accident.



IEC 61508 AND IEC 61511

Safety is the acceptable reduction of an unacceptable risk of physical injury to people or damage to the properties. **Functional Safety is part of the overall safety that depends on a safety-related system** operating correctly in response to its input.
The significant hazards for the system have to be identified via a hazard analysis. If the hazard analysis shows that functional safety is necessary, appropriate systems are required to perform specific Safety Functions to reduce the risk. These systems are called Safety-Related Systems or Safety Instrumented Systems (SIS).

Two types of requirements are necessary to achieve Functional Safety:

· **Safety Function Requirements**: the scope of the safety function, derived from the hazard analysis.
· **Safety Integrity Requirements**: the probability that the safety function will be performed satisfactorily, derived from the risk assessment.

The Standard IEC 61508 "Functional Safety of electrical / electronic / programmable electronic (E/E/PE) safety-related systems" covers the safety lifecycle of the product, from the initial concept through hazard analysis and risk assessment, development of safety requirements, specification, design and implementation, operation and maintenance. IEC 61508 contains requirements for preventing failures and controlling failures, ensuring safety even when faults are present. It specifies the techniques and measures to achieve the required Safety Integrity.

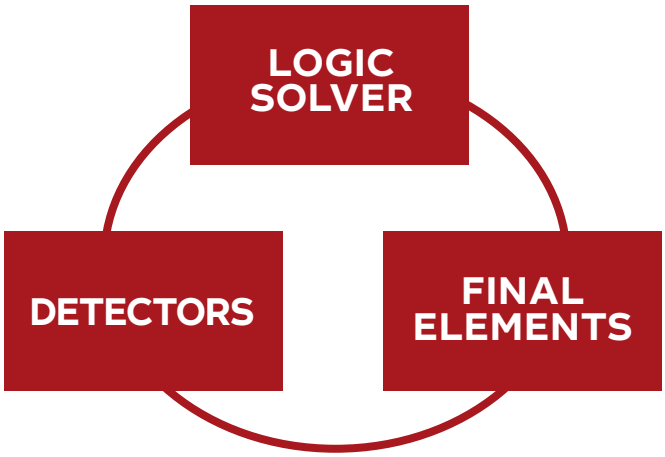
The Standard IEC 61511 "Functional Safety – Safety Instrumented Systems for the process industry sector" covers the safety lifecycle of the installation and contains the requirement for the correct selection of safety related equipment and the erection of Safety Instrumented Systems. IEC 61508 specifies alternative techniques to determine the Safety Integrity of the installation.

The Safety Integrity is the probability that the Safety Instrumented Systems will perform the required Safety Functions satisfactorily. **IEC 61508 specifies four levels of safety performance** for a safety function, **called Safety Integrity Level (SIL)**: SIL1 is the lowest level and SIL4 the highest level. **Each Safety Integrity Level is correlated with an increased Risk Reduction Factor (RRF).**
IEC 61508 details the requirements necessary to achieve each Safety Integrity Level.

SAFETY INTEGRITY LEVEL (SIL)	AVERAGE PROBABILITY OF FAILURE ON DEMAND (PFDAVG)	RISK REDUCTION FACTOR (RRF)
4	≥ 10-5 to < 10-4	10.000...100.000
3	≥ 10-4 to < 10-3	1000...10.000
2	≥ 10-3 to < 10-2	100...1000
1	≥ 10-2 to < 10-1	10...100
0	Basic Process Control Systems (BPCS)	

The table provides the target failure measures for a safety function allocated to a SIS operating in low demand mode. Low demand mode means that the frequency of demands for operation of the SIS is not greater than once per year, and not greater than twice the proof-test frequency.

FIRE & GAS SYSTEMS

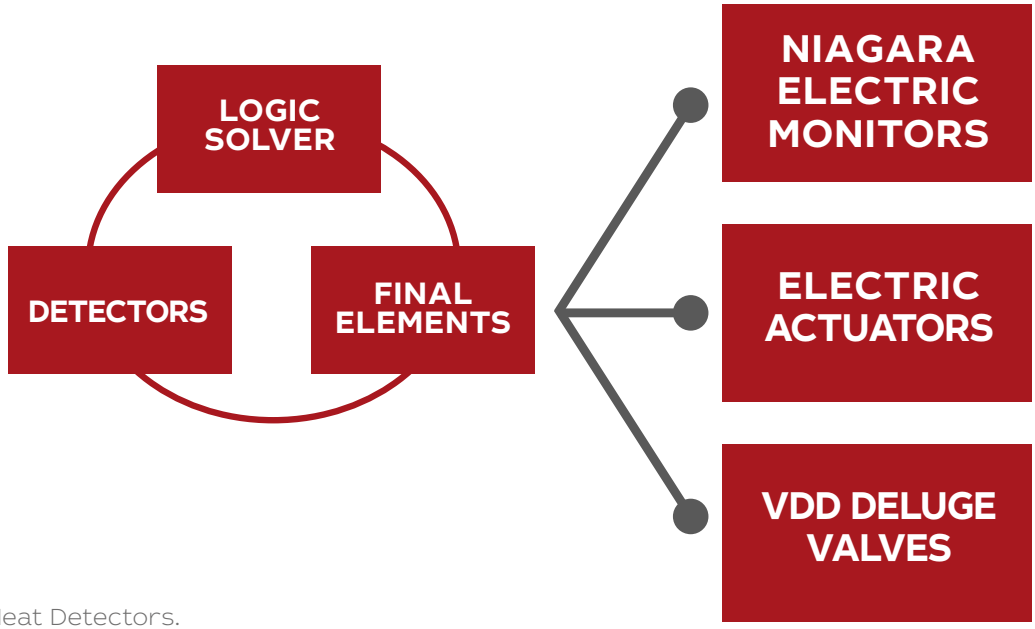


The tasks of a F&G system are to detect any hazardous fire or gas condition, to alert the personnel in the area and to activate the control and mitigation systems.

The F&G system effectiveness is the product of the following three factors:

- Detection Coverage: the fraction of the monitored area in which an eventual fire or gas hazardous condition would be detected.
- Mitigation Effectiveness: the probability that the activation of the Final Elements would reduce the consequences of a defined hazard.
- F&G Safety Availability, SA: it is connected to the Probability of Failure on Demand (PFDavg) by the following equation: 1-PFDavg. The PFDavg measures the Safety Integrity Level (SIL) of the system.

The Safety Availability of a F&G system can be evaluated through a Fault Tree Analysis (FTA) based on the PFDavg of each component. The main components of a F&G system are the following:



- Fire, Gas or Heat Detectors.
- Logic Solver.
- Final Elements (Deluge system, Shut Down system, etc.).

SIL SUITABLE FINAL ELEMENTS

So far the manufacturers' efforts to meet the functional safety criteria for F&G systems have focused mainly on electric and electronic devices, providing components suitable for increasing SIL level systems according to the desired level of functional safety.

However, the F&G system effectiveness is related to the Safety Availability of all its components: the overall performance of the system is affected by the weakest element of the chain of its components.
This is the reason that has led SA Fire Protection to focus its attention on the Final Elements, developing the following SIL suitable solutions according to IEC 61508 for the main types of fire protection systems (i.e. deluge water spray systems, monitors and gaseous based systems):

- The Double Chamber Deluge Valves Model VDD, suitable for SIL3 systems.
- The Double-Coil Electric Actuators for gaseous based systems, suitable for SIL2 systems.
- The Electric Monitors Niagara Series, suitable for SIL2 systems.

The SA SIL suitable Final Elements are validated by Bureau Veritas for integration within safety functions performing fire protection service in low demand mode.

DOUBLE CHAMBER DELUGE VALVES MODEL VDD

The deluge valve Model VDD is an innovative concept valve designed for fire protection systems according to NFPA 15, UL 260 and IEC 61508/61511. The VDD deluge valve combines all the functions available on the traditional deluge valves with a **fully redundant architecture**, designed to achieve higher reliability.

In fact, the VDD deluge valve has two priming chambers, each one provided with its own diaphragm and actuation trim, which offer two independent waterways to the water spray system. Each priming chamber provides the nominal design waterway for the fire protection system: in case of failure of one diaphragm, the opening of the other diaphragm allows the hydraulic waterway for the correct operation of the water spray system.

In practice this new concept translates into a **built-in emergency bypass line** that operates on both priming chambers in hot back-up.
Moreover, **a hydraulic bridge between the trims allows each trim to control both the diaphragms**, releasing the water trapped in the two priming chambers. If one trim should fail, the other trim can open both the priming chambers through the hydraulic bridge. Thus **the double chamber deluge valve can overcome a double failure trim + priming chamber**.

Advantages:

The advantage of using the VDD deluge valves can be measured in terms of increased reliability, lower response time and easier system operations.

1. Increased deluge system reliability and availability on demand (SIL 3 Validated by third party).
2. Response time to failure reduced to zero.
3. Continuous fire protection (no downtime for service or even repairs).
4. Deluge skid dimension & weight can be reduced accounting on the built-in by-pass in hot back-up.

Application:

Model VDD deluge valve is specifically designed for industrial harsh environments such as oil & gas onshore and offshore, chemical, conventional or nuclear power, military and those which require:

1. A low probability of failure on demand.
2. A safety instrumented system with a deluge system as final element capable of being integrated into SIL 3 systems.
3. Continuity of fire protection during maintenance or repair.
4. Reduction of weight, dimensions and cost of the skid..

Application typical include fire suppression or cooling of critical process equipment, toxic vapour mitigation and confinement.

DOUBLE-COIL ELECTRIC ACTUATORS

Gaseous based fire extinguishing systems include carbon dioxide, inert gases and halocarbons. All of them are kept pressurized into cylinders or containers ready to be discharged to the protected area. On a similar principle, water mist systems are made of a series of water cylinders propelled by a nitrogen reserve contained in a pilot cylinder. Normally these systems are composed of a series of sensors, a logic controller and a final element, which is often represented by a pilot cylinder.

When such systems are called for duty a missed activation of the pilot cylinder can lead to an unacceptable consequential scenario. SA pilot actuators have been developed for sensibly reducing the probability of such failures, increasing the Safety Availability of the fire extinguishing system. They have been validated by BV as suitable for safety instrumented systems with an expected SIL2 level. When used in combination to form external activation packages the actuator can contribute to form architectures that can be qualified to SIL 3.

Pilot Cabinet SIL 2 Offshore.

Water Mist Package Rolling Stock - SIL 2.

Advantages:

The **redundancy** of the double-coil electric actuator increases the reliability of the overall pilot cylinder. The actuator has two coils which receive two independent signals from the logic controller (F&G). If one coil fails, the other coil is able to open the cylinder valve. On the same principle these redundancy increase the overall system availability as the loss of one cable or the failure of the F&G discharge cards do not compromise the fire suppression system activation.
Such solution has been implemented to cover all those fire hazards which require an increased reliability for the fire extinguishing system and, therefore, a safety function with an expected **SIL2** level.

Applications:

The double-coil actuator is designed for those systems which require:

1. A low probability of failure on demand.
2. A safety instrumented system with a gaseous based fire protection system as final element, capable of being integrated into SIL2 systems.
3. The combination of a high safety integrity level with low dimensions and weight.

The double-coil electric actuator is specifically designed for the protection of gas turbines and their generators, critical IT server farms, electronic rooms governing industrial processes, and all general purpose installations on offshore platforms or FPSO, where generally a fire brigade is not easily available to compensate a possible fire-fighting system failure.

ELECTRIC MONITORS NIAGARA SERIES

The Niagara electric type remote controlled monitors are designed to deliver large amounts of water or water foam solution towards remote targets. They are commonly used to protect petrochemical jetty or within the process areas to cool structures, vessels or fight potential fires of a considerable magnitude.

From the safety availability point of view, the remote controlled monitor architecture comprises of a Logic Controller and one or more final elements (Monitor assembly). The logic controller is the heart of the system and distributes the commands to the monitor itself. In such system, or at least in the simplest version, the detector is not normally integrated and the system respond directly to human actions.

The Niagara monitors have been assessed and validated by BV as suitable for safety instrumented systems with an expected **SIL2** level.

The increased reliability performance of the Niagara series monitor is related to its particular design, which allows an **automatic self-diagnostic analysis** to be performed. At regular intervals the self-diagnostic system implemented in the Logic Controller checks the correct operation of the monitor actuators on given commands, allowing for constant monitoring of any possible failure of the monitor and the nozzle. In case of an anomalous condition, a warning signal is sent to the control station.

Advantages:

A possible failure of a traditional electric remote controlled monitor can be detected only when periodic maintenance and test are performed. The constant monitoring of the system status implemented in the Niagara series monitors, instead, allows a possible failure to be detected and repaired when the fire protection system is in "safe condition", sharply increasing the reliability of the overall fire system on demand. Such improvement reduces the probability that faults, taking places among regular maintenance intervals, will pass undetected.

Detecting a possible fault in a safety system in time, rather than in a fire condition, can make the difference on the emergency operation success.

Application:

The Niagara series monitors are specifically designed for petrochemical jetty and marine harbor protection, structure and vessel cooling, and those systems which require:

1. A low probability of failure on demand.
2. A safety instrumented system with monitors as final elements capable of being integrated into SIL2 systems.
3. A large amount of water towards remote targets.

Contact us for further information on how to achieve higher SIL levels for the complete fire detection and suppression system www.sasrl.it.

SA FIRE PROTECTION

+39 050 70 03 06

info@sasrl.it