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Theme

Modernization of the Fire and Gas System with Supervision in Train 1 of the BRN Site Using a Siemens S7-1500F Safety PLC

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Abstract

This final project focuses on the modernization of the fire and gas detection system of Train 1 at the BRN site operated by Sonatrach and ENI. The main objective is to replace the existing system with a more reliable solution that meets international safety standards, using an advanced safety controller. The project includes analysis of the current system, design of a new control architecture, integration of flame, gas, and smoke detectors, and development of a supervision interface for system monitoring. This modernization aims to improve detection speed, alarm response, and overall plant safety.

Résumé

Ce projet de fin d'études porte sur la modernisation du système de détection incendie et gaz du Train 1 du site BRN, exploité par Sonatrach et ENI. L'objectif principal est de remplacer le système existant par une solution plus fiable et conforme aux normes de sécurité internationales, en utilisant un automate de sécurité avancé. Le projet comprend l'analyse du système actuel, la conception d'une nouvelle architecture de contrôle, l'intégration des détecteurs de flamme, de gaz et de fumée, ainsi que le développement d'une interface de supervision pour le suivi du système. Cette modernisation vise à améliorer la rapidité de détection, la réactivité des alarmes et la sécurité globale des installations.

ملخص

يهدف هذا المشروع النهائي إلى تحديث نظام الكشف عن الحرائق والغازات الخاص بالقطار 1 في موقع بئر رباعة شمال الذي تديره سوناطراك وإيني. يتمثل الهدف الرئيسي في استبدال النظام الحالي بحل أكثر موثوقية ومتوافق مع المعايير الدولية للسلامة، باستخدام وحدة تحكم أمان متطورة. يشمل المشروع تحليل النظام الحالي، وتصميم بنية جديدة للتحكم، ودمج كواشف اللهب والغاز والدخان، وتطوير واجهة إشرافية لمراقبة النظام. تهدف عملية التحديث هذه إلى تحسين سرعة الكشف، واستجابة الإنذارات، وضمان سلامة المنشآت بشكل أفضل

Dedication

I wholeheartedly dedicate this work to my beloved parents, the unwavering pillars of my life. Your endless love, patience, and sacrifices have been the foundation of every achievement I've made. Your faith in me has been my compass, guiding me through every challenge and every triumph. This milestone is as much yours as it is mine.

To my two young sisters, whose innocence, smiles, and presence have been a constant source of joy and motivation throughout this journey you inspire me to be better every day.

To my colleague and true friend, Cherif Tarek, with whom I've shared not only this project but an entire journey of learning, perseverance, and growth. Your dedication, loyalty, and constant encouragement have made this experience deeply meaningful. Our collaboration was more than teamwork it was brotherhood.

To those closest to my heart, whose presence, encouragement, and unwavering belief in me have brought light and calm in moments of doubt this success is also yours.

This work is dedicated to all of you with love, respect, and heartfelt gratitude.

Bennaceur Nadir

First and foremost, I dedicate this thesis to my beloved parents, whose unconditional love, sacrifices, and guidance have shaped who I am today. Your support, both emotional and moral, has been my greatest strength throughout this journey.

To my two brothers, for always being by my side with encouragement, inspiration, and unwavering belief in me. Your presence has been a constant source of motivation, and I am proud to share this achievement with you.

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This work is dedicated to all of you, with sincere gratitude.

Cherif Tarek

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List of Abbreviations

- **BRN**: Bir Rebaa Nord
- **SH**: Sonatrach
- **ENI** : Ente Nazionale Idrocarburi (Italian National Hydrocarbons Authority)
- **AGIP**: Azienda Generale Italiana Petroli
- **HMD**: Hassi Messaoud
- **O&G**: Oil and Gas
- **OTC**: Oil Treatment Center
- **BBL**: Barrel
- **USD**: United States Dollar
- **EU**: European Union
- **ROM**: Rhourd Messaoud
- **ZEK**: Zemoul El Kbar
- **ZEA**: Zemlet Adreg
- **BSF**: Bir Sif Fatima
- **RDB**: Rhourd Debdaba
- **RERN**: Rhourd Er Rouni North
- **RAR**: Rhourd Attar
- **BRW**: BIR Rebaa West
- **BRSW**: Bir Rebaa Sud West
- **MLE**: Menzel Ledjmet
- **REC**: Rhourd Ech Chuli.
- **F&G**: Fire and Gas
- **ESD**: Emergency Shutdown
- **FD**: Flame Detector
- **SD**: Smoke Detecor
- **IR**: Infrared
- **3IR**: Triple Infrared
- **UV**: Ultravoilet
- **GD**: Gas Detector

- **MCP**: Manual Call Point
- **SIL**: Safety Integrity Level
- **PL**: Performance Level
- **LEL**: Lower Explosive Limit
- **PPM**: Parts Per Million
- **NO/NC**: Normally Open / Normally Closed
- **PLC**: Programmable Logic Controller
- **F-PLC**: Fail-Safe Programmable Logic Controller
- **HMI**: Human Machine Interface
- **SCADA**: Supervisory Control and Data Acquisition
- **DCS**: Distributed Control System
- **CPU**: Central Processing Unit
- **PS**: Power Supply
- **TIA**: Totally Integrated Automation
- **DC**: Direct Current
- **AC**: Alternating Current
- **mA**: Milliampere
- **VDC**: Volts Direct Current
- **I/O**: Input/Output
- **F-DI**: Fail-Safe Digital Input
- **F-DO**: Fail-Safe Digital Output
- **AI**: Analog Input
- **OB**: Organization Block
- **FB**: Function Block
- **FC**: Function (non-instance)
- **DB**: Data Block
- **HP**: High Pressure
- **MP**: Medium Pressure
- **LP**: Low Pressure

GENERAL INTRODUCTION

Algeria is widely recognized as one of the leading energy producers in Africa, endowed with vast reserves of oil and natural gas. Its hydrocarbon sector represents the engine of national economic development, contributing significantly to exports, national income, and energy supply for international markets. To sustain this strategic role and maintain uninterrupted production, it is essential to ensure the highest levels of operational safety and asset protection, especially in environments where the presence of flammable gases and volatile substances poses constant risks.

In such high-risk industrial settings, the Fire and Gas detection system represents a critical layer of protection. Its primary function is to continuously monitor for gas leaks, detect fire or heat anomalies, and trigger immediate alarms and shutdown actions to mitigate the consequences of hazardous events. The effectiveness of an F&G system is directly linked to its responsiveness, reliability, integration with other safety systems, and compliance with international safety standards.

At the BRN site, located in the heart of Algeria's oil-rich basin, Train 1 has been in continuous operation since 1995, utilizing a Fire and Gas system based on legacy technologies such as the Simplex 4100. While this system has provided fundamental protection over the years, it is now outdated and no longer meets the performance expectations of modern petrochemical safety environments. Its limited diagnostic capabilities, lack of integration with intelligent control platforms, and reduced adaptability to evolving risk profiles present major limitations.

Therefore, this project is dedicated to the comprehensive modernization of the Fire and Gas system in Train 1 of the BRN site, replacing obsolete instruments and architecture with advanced technologies that offer faster detection, smarter integration, and enhanced resilience. By doing so, we aim not only to align with best international practices but also to reinforce the site's safety culture, minimize operational risks, and ensure sustainable production continuity.

CHAPTER I: Presentation of the SH/ENI Grouping and OTC at Bir Rebaa Nord

I.1. Introduction

In this chapter, we present a general overview of the Sonatrach-Agip joint venture and the Sonatrach-Agip joint venture and the architecture of the Bir Rebaa Nord (BRN) oil processing centre (BRN), which is located to the south-east of HASSI MESSAOUD, and its main objectives. maintenance department in our work, we will describe the different sections and tasks of this department.

I.2. Presentation of The Sonatrach-Agip Joint Venture

I.2.1. Presentation

The SONATRACH-AGIP joint venture was created in 1993 by a partnership between the national company SONATRACH and the Italian company ENI. SONATRACH and the Italian company ENI. With the aim of exploiting all existing oil deposits existing oil fields in 5 blocks: 401, 402, 403a, b and c, for a period of 30 years. This is the first partnership between SONATRACH and a foreign company (AGIP). Construction work took 2 years, and the partnership went into production in 1995. The plant is ranked 2nd in Algeria in terms of treatment capacity.

I.2.2. Presentation Of Sonatrach

Sonatrach (founded in 1963) is the national company for the research, production, processing and marketing of hydrocarbons and their derivatives. Sonatrach's core business is the processing and marketing of hydrocarbons and their derivatives. Its mission is to develop the country's hydrocarbon resources and create wealth for economic development. Adopting a strategy of diversification strategy, this giant is expanding into other activities such as power generation, new and renewable energies, seawater production and renewable energies, seawater desalination, research and mining. Pursuing its internationalization strategy, Sonatrach operates in several regions of the world, in: Libya, Tunisia, Mauritania, Mozambique, Angola, Nigeria, Italy, Spain, Portugal, the UK, the Netherlands and Peru. It is ranked as the leading African company, with turnover exceeding 34 billion US dollars (2021). To accelerate its development programme in Exploration-Production, Sonatrach is strengthening its policy of cooperation with major foreign oil and gas operators. Partnerships have always been a key factor in Sonatrach's growth in Algeria and throughout the world. It is part of the company's overall effort to explore new territories and increase its hydrocarbon production. This growth strategy is all the more remarkable in natural gas: as Europe's third-largest gas supplier after Russia and Norway, Algeria plans to increase its gas production to more than 140 billion m3 by 2023.

I.2.3. Overview of Agip

Azienda Generale Italiana Petroli (Agip) was founded by the Italian state in 1926. At the time, it was responsible for building refineries to process crude oil imported from Iraq, and its role was to supply large quantities of liquid fuels to the navy and aviation. Today it is a brand of the Italian group ENI, one of the world's largest oil companies. [1]

I.2.4. Overview of Eni

ENI (Italian Ente Nazionale Idrocarburi, for Italian national hydrocarbons company), is a privately owned Italian hydrocarbons company founded in 1953. It is a global energy company, active across the entire value chain: from the exploration, development and extraction of oil and natural gas to the generation of electricity from cogeneration and renewable energies. By the end of 2020, Eni represented

- 68 countries
- Annual sales of 43.987 billion euros
- 64.99 billion m3 of natural gas sold
- More than 9.6 million residential and business customers in Europe. [1]

Figure I. 1 : Companies Logos **[2]**

I.3. Background

The GSA is an oil group governed by decree 93 08, of 25 April 1993, it is made up of two major companies:

_ SONATRACH (51%)

_ Agip-ENI ITALY (49%)

The association's activities date back to 15/12/1987, the date of signature of the first association contract between Sonatrach and the Italian company ENI for the exploration and exploitation of hydrocarbons on exploration blocks allocated to the SH-Eni association. Since then, GSA has managed five blocks (403, 403a, 403d, ROD and Gis SAT).

-**Block 403 contract**: contract to operate Block 403, which contains the following fields: BRN: Bir Rebaa Nord, BRW: BIR Rebaa West, BRSW: Bir Rebaa Sud West.

It was signed on 15/12/1987, and the financing of the exploitation of this block will be provided entirely by SH, with the exception of the foreign currency portion, which will be financed by Agip up to a limit of 50%.

-Block 403a contract: contract for the exploitation of the 403a block which contains the following deposits: ROM: Rhourd Messaoud, ZEK: Zemoul El Kbar, ZEA: Zemlet Adreg.

It was signed on 13/05/1995, the operating costs will be 100% financed by Agip except for ZEA which will be financed by 75% Agip and 25% SH.

-Block 403d contract: contract for the exploitation of the 403a which contains the deposits: ROM: Rhourd Messaoud Est, REC: Rhourd Ech Chuli.

The contract was signed on 30/05/1995 and Agip will finance 100% of the operating costs.

-ROD and Gis Sat block contract: contract signed on 10/04/2002 between GSA and BHP Billiton for the exploitation of the deposits: ROD: Rhourd Oled Djemaa, SFNE: Sif Fatima North Est.

-Satellite deposits: BSF: Bir Sif Fatima, RDB: Rhourd Debdaba , RERN: Rhourd Er Rouni North, RAR: Rhourd Attar .

These deposits extend over blocks 401a, 402a, 403a and 403d.

- **Financing is as follows:**

- blocks 401a and 402a (55% ENI and 45% BHP)

- block 403a 100% ENI

- block 403d 75% ENI and 25% SH [3]

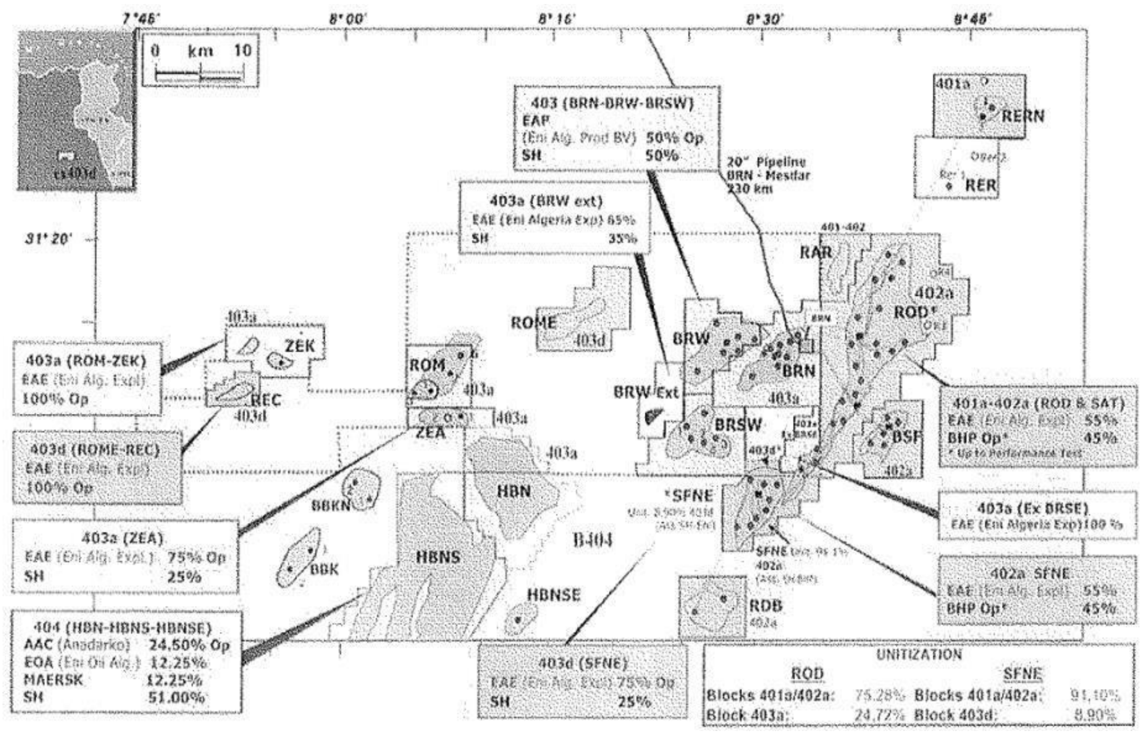


Figure I. 2 : Location of The Blocks **[3]**

I.4. Geographical Location of The OTC / BRN

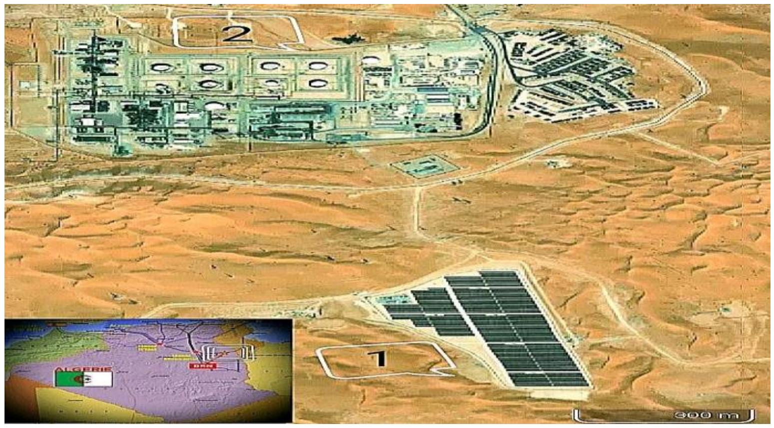


Figure I. 3 : Location of The BRN Field **[4]**

Bir Rebaa has a hot desert climate (Köppen BWh climate classification) with long, extremely hot summers and short hot winters. The climate is similar to that of Ouargla. Daytime temperatures soar during the summer months, hovering constantly around 45°C (113°F) between June and September.

This figure shows the geographical location of the BRN field, which is in the eastern part of Hassi Messaoud, approximately 315 km away, at latitude 31.14 north and longitude 8.34 east, with an average altitude of around 190 m.

The photovoltaic power plant, built in partnership between Sonatrach/Eni and which has been described as one of the largest in the country, occupies an area of 20 hectares containing 31,320 photovoltaic panels with a capacity of 10MW and aims to supply the Bir Rebaa field facilities with electrical energy, thereby recovering quantities of gas for export.

I.5. General Description of the OTC

The BRN (Bir Rebaa Nord) plant is located in the namesake area of the Sahara about 315 km east of HASSI MESSAOUD. The plant is designed to process crude oil from the BRN field and ship it via a 20-inch pipeline to the MESDAR terminal some 230 km away.

The original project was carried out with a single oil treatment train, while the second and third trains were built later.

The plant is dedicated to oil processing, but various complementary processing operations are also set up there, such as sending gas to Menzel Ledjmet and compressing it for reinjection into the fields, and treating and pumping water for injection into the fields. The plant has autonomy for all auxiliary services, such as

- Electricity generation by 3 turbogenerators for BRN only (ROD is supplied by Sonelgaz)
- Service and process fire-fighting water.
- Living and industrial base.
- Telecommunications.

A satellite oil center called ROM has been built to allow the exploitation of the homonymous deposit, with in addition other small deposits bordering ZEK and ZEA.

ROM production is collected from BRN's collection networks via a 32 km, 8 km pipeline.

The OTC is made up of 3 trains, each with a different processing capacity:

- The first train: 54,500 Bbl/D.

- The second train: 42,000 Bbl/D.

- The third train: 70,000 Bbl/D.

I.5.1. Process Units

- **Unit100** (producing wellheads and collection network): the purpose of this unit is to supply a sufficient quantity of hydrocarbon products to the successive treatment units.

- **Unit110** (reinjection wellheads and reinjection network): its role is to reinject the dehydrated gas into the appropriate wells.

- **Unit130** (inlet manifold): is a gathering point for production from producing wells in the field.

- **Unit200** (oil separators): the aim is to separate the associated gas and formation water from the crude oil at the inlet to the installation.

- **Unit210** (oil treatment): the aim is to stabilize the crude oil coming from the separation unit.

- **Unit250** (off-spec oil): its purpose is to temporarily treat the oil for operating problems caused by shutdowns of units 200 and 210.

- **Unit 310** (gas dehydration): the aim is to avoid the problems of water condensation in the presence of acid gases.

- **Unit360** (gas compression): the aim is to re-compress the gas coming from different points in the installation, at different pressure levels, so that it can be returned with the high-pressure gas to unit310 for dehydration.

- **Unit370/380/390** (re-injection of treated gas): the aim is to re-compress the gas coming from the dehydration unit to send it to the other networks.

- **Unit670** (corrosion inhibitor injection system): this unit comprises the installations needed to inject an anti-corrosion solution into the most important points of the process units at the Bir Rebaa Nord oil production center.

- **Unit 680** (methanol injection system): this unit contains the installations needed to inject methanol into the most important points of the process units at the Bir Rebaa Nord oil production center.

I.5.2. Auxiliary Units

- **Unit220** (oil storage and dispatch): the purpose is to store processed oil in tanks and dispatch it by pipeline.

- **Unit230** (flare system): its purpose is to ensure the safe operation of the facilities.

- **Unit420** (fuel gas system): the aim is to store gas from the process unit, produce it and distribute it to users at the Bir Rebaa Nord oil production center.

- **Unit430** (fuel oil system): the purpose of this unit is to store and distribute fuel oil in the Bir Rebaa Nord oil production center.

- **Unit450** (power station): the purpose of the power station is the production and distribution of electrical energy in the Bir Rebaa Nord production center.

- **Unit480** (emergency generator): is used to supply the users required to safely shut down the installations in the event of a total shutdown of the production of electrical energy and to restart the power station.

- **Unit490** (compressed air system): this unit contains the ancillary facilities needed to produce, store and distribute compressed air to users at the BirRebaa North oil production center.

- **Unit530** (service water system): this unit contains the equipment needed to store and distribute water to users at the Bir Rebaa Nord oil production center.

- **Unit 550** (purification and storage of lubricating oil): the purpose of this unit is to store new oil, purify and store used oil and send it to units 380/390.

- **Unit560** (oily water treatment): this unit contains the facilities needed to treat oily water from the process units and services at the oil production center.

- **Unit730** (fire-fighting water system): the purpose of this unit is to store water for use in the event of a fire.

- **Unit920** (power station): the purpose of the power station is to produce and distribute electrical energy in the Bir Rebaa Nord oil production center.

I.5.3. Explanation

The crude oil, which comes directly from an oil well at different pressures, passes through the inlet manifold and begins an almost identical circuit for the three trains, with the high-pressure arrivals sent to the HP separator and the low-pressure arrivals sent to the BP separators, where the 3 main products (oil, gas, water) are separated by gravity.

The oil is sent to the three-phase separator (210V01) via the 210EA01 heat exchanger to raise the temperature to 65-70X.

The oil leaving the three-phase separator is sent to the electrostatic desalter (210SD01) via the degassing tank (210V02) and by injecting a demulsifying product. The desalinated oil is sent to the stabilization column (210C01) via the heat exchanger (210EA02) for storage. The oil undergoes a TVR rectification operation using the reboiler.

The gas is sent to the dehydration unit (unit 310) using the compressors in unit360. The dehydrated gas is divided into two parts: fuel gas and re-injection gas. The fuel gas is used as fuel for the furnaces and turbines, while the re-injection gas is sent to the gas re-injection units (units 380 and 390).

The water is sent to the oily water treatment unit (unit 560), the purpose of which is to remove the traces of oil carried along with the purge water from the separators. The purified water is sent to the evaporator tank.

I.5.4. Storage And Shipping

The block diagram shows the different phases of the process, from the production wells to the gas reinjection wells and the shipment of the stabilized oil from the production center to the pipeline:

- Storage is in 3 floating roof tanks, each with a capacity of 14597 m3.
- Dispatch by centrifugal electric pumps (3 for 250 m3 each).
- 20' BRN - MESDAR pipelines, approx. 230 km long

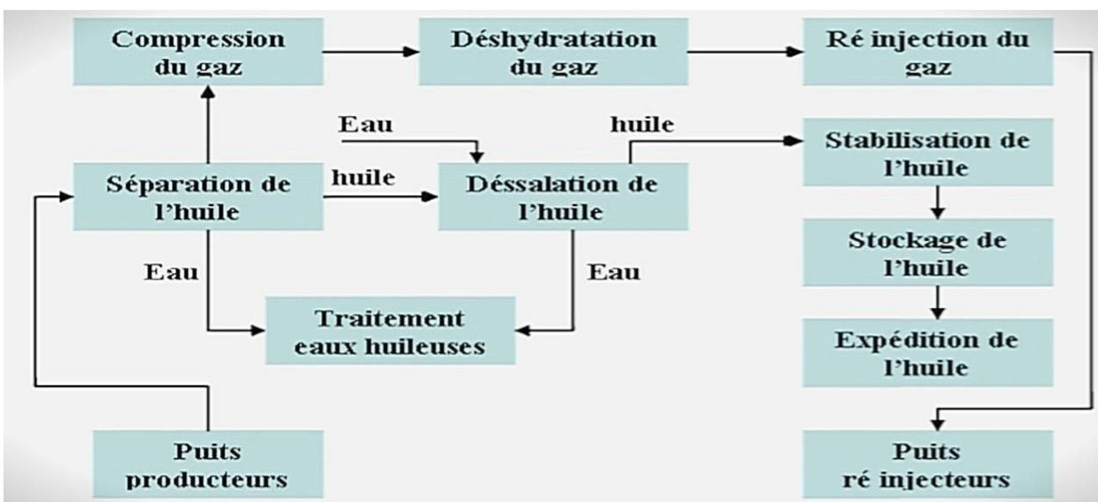


Figure I. 4 : Simplified Diagram of The Production Process **[4]**

I.6. SONATRACH-AGIP Group Organization Chart

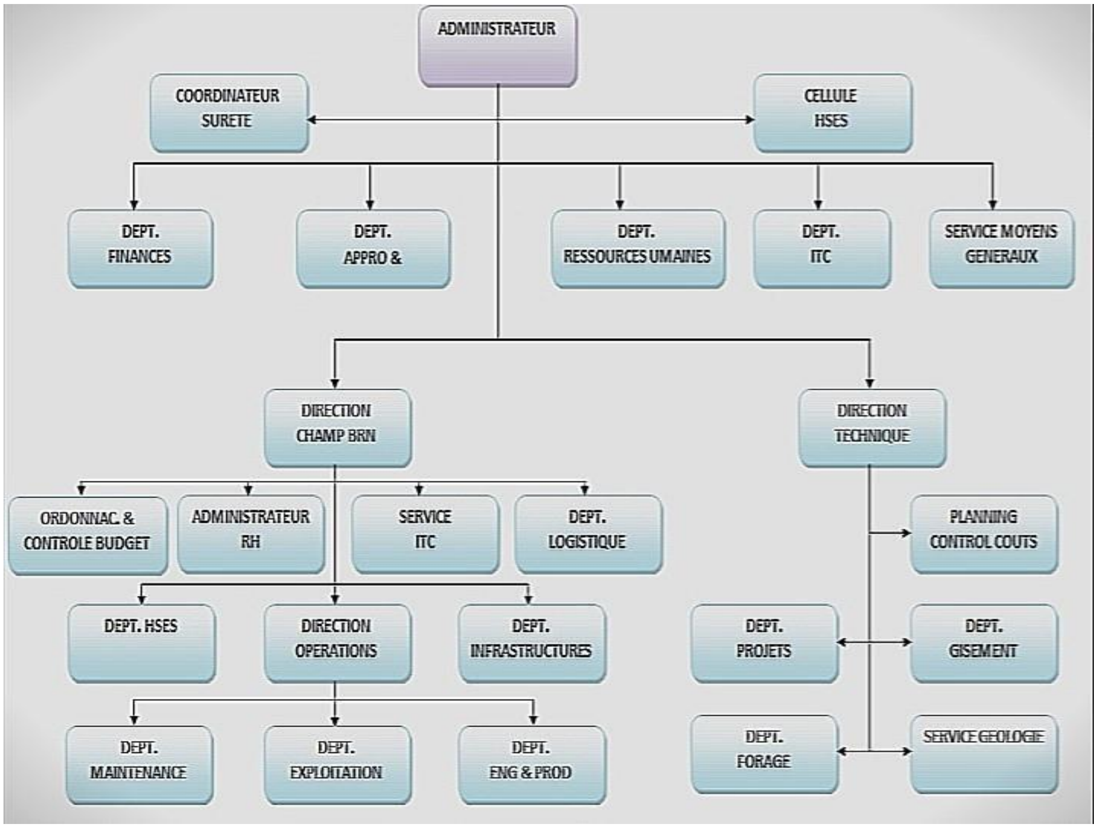


Figure I. 5 : SONATRACH-AGIP Group Organization Chart **[4]**

The maintenance department comprises two departments:

- Methods.
- Maintenance and servicing department.

I.6.1. Methods and Planning Department

The methods department is responsible for planning and scheduling work (both corrective and preventive), and is managed by a department manager to whom are attached three groups of engineers (instrumentalists, mechanics and electricians) in addition to an archivist and stock managers.

Equipment management is provided by a management unit called Computerized Maintenance Management System (CMMS), which manages maintenance using management software (Data Stream 7).

Work orders are triggered by the establishment of a WO by a structure requesting intervention for corrective WO and automatically for preventive WO.

I.6.2. Maintenance and Servicing Department

The role of this department is to intervene, in the field or at the plant, for preventive or curative missions; it is subdivided into 6 sections:

- Mechanical section
- Electrical section -
- Instrumentation section,
- Boiler making section
- Rotating machine inspection section -
- DCS section

I.6.3. Course of Operations

According to a need formulated by any department, any work request must be validated by the head of the maintenance department, then the CMMS unit controls a work order (WO) which will be issued for the intervention section concerned.

I.6.4. Maintenance Department Organization Chart

The maintenance department consists of two services, the methods service and the maintenance service, which contains sections as shown in the following figure:

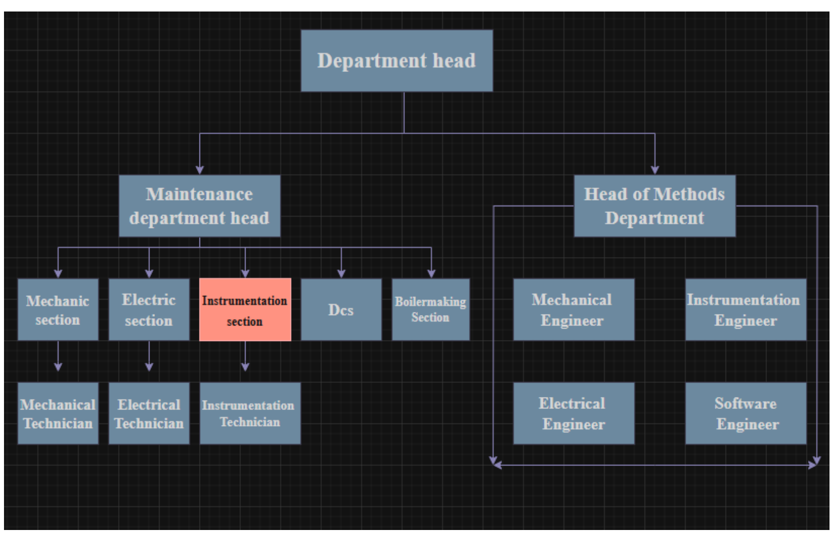


Figure I. 6 : Maintenance Department Organisation Chart **[4]**

I.7. Conclusion

The BRN (Bir Rebaa Nord) plant of the Sonatrach AGIP group is among the most important plants in the field of crude oil production and processing in Algeria due to its production capacity and processing quality, and to ensure the continuity of this production. AGIP built the M7 pumping station equipped with two Sulzer pumps, which play a role in ensuring the arrival of crude from the production wells to OTC

CHAPTER II: General Overview of Fire and Gas Detection Systems

II.1. Introduction to Fire and Gas System

Fire and Gas (F&G) detection systems are critical components of industrial safety infrastructure, particularly in high-risk environments such as oil and gas facilities, chemical plants, refineries, and petrochemical industries. These systems are designed to detect the presence of combustible gases, toxic gases, smoke, and flames, and to initiate appropriate safety actions to mitigate the consequences of potential fire and explosion events. The primary objective of a Fire and Gas system is to protect human life, safeguard assets, and minimize environmental impact by ensuring early detection of hazardous conditions. Once a potential threat is detected, the system generates alarms and may initiate automatic shutdown procedures or activate fire suppression systems, depending on the design and safety philosophy of the plant.

F&G systems operate continuously, monitoring specific zones or equipment areas where flammable or toxic substances may be present or where ignition sources exist. These systems are typically integrated into the overall safety instrumented system (SIS) of the facility and are governed by rigorous industry standards and guidelines to ensure reliability, accuracy, and rapid response.

Given the complexity and criticality of operations in the petrochemical sector, the deployment of a well-designed Fire and Gas system plays a vital role in achieving overall plant safety and regulatory compliance. In the following sections, the key components, technologies, design principles, and regulatory frameworks of F&G systems will be discussed in detail.

II.2. Components of a Fire and Gas System

A comprehensive Fire and Gas (F&G) detection system comprises several integrated components, each playing a specific role in identifying hazardous events and initiating safety responses. The effectiveness of the system depends on the proper selection, placement, and configuration of these components within the monitored facility.

II.2.1. Gas Detectors

Gas detectors are employed to identify the presence of combustible or toxic gases in the atmosphere. They can be based on various detection principles such as catalytic bead, infrared (IR), ultrasonic, or electrochemical technologies. Detectors may be designed to identify specific gases (e.g., methane, H_2S, CO) and are often installed in areas with high leakage potential such as compressor stations, manifolds, or gas treatment units.

II.2.1.1. Catalytic Bead (Pellistor) Detectors

Catalytic bead detectors, also known as pellistor detectors, are among the most widely used technologies for the detection of combustible gases and vapors in industrial environments. These sensors operate based on the principle of catalytic oxidation, where combustible gas is oxidized in the presence of a catalyst, releasing heat that is then measured. [5]

Figure II. 1 : Catalytic Bead Detector **[6]**

Operating Principle

The sensor consists of two small heated elements (beads) arranged in a Wheatstone bridge configuration. One bead is coated with a catalytic material (usually platinum or palladium) that promotes the oxidation of the target gas, while the second is inert and acts as a reference.

When a flammable gas (such as methane, propane, or butane) is present, it reacts with oxygen on the active bead’s surface, generating heat. This causes a temperature rise, increasing the electrical resistance of the bead. The reference bead, unaffected by the reaction, remains stable. The resulting imbalance in the Wheatstone bridge produces a voltage signal proportional to the gas concentration. [5]

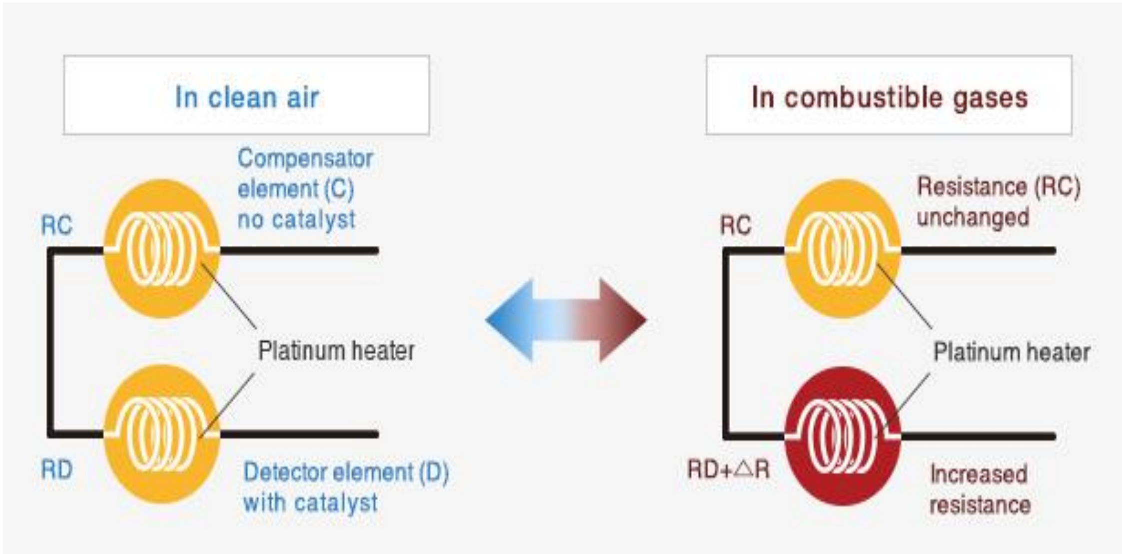


Figure II. 2 : Operating Principle of Catalytic Bead Detector **[7]**

Target Gases

- Methane (CH_4)
- Propane (C_3H_8)
- Butane (C_4H_{10})
- Hydrogen (H_2)

Advantages

- Cost-effective and widely available.
- Reliable and proven technology for detecting explosive gas concentrations.
- Good linearity in the 0–100% Lower Explosive Limit (LEL) range.
- Real-time detection with rapid response times.

Limitations

- Requires oxygen (typically >10%) for the catalytic reaction; ineffective in oxygen-deficient atmospheres.
- Susceptible to poisoning by substances such as silicones, lead, sulfur compounds, or halogens, which degrade the catalyst.

- Requires frequent calibration and maintenance to ensure accuracy.
- Not suitable for very high gas concentrations that may cause sensor saturation or damage.

Applications

- Compressor stations
- Gas processing units
- Pump rooms
- Storage tanks and pipelines
- Hazardous areas classified as Zone 1 or Zone 2

II.2.1.2. Infrared (IR) Gas Detectors

Infrared (IR) gas detectors are advanced detection devices designed to measure the concentration of combustible gases particularly hydrocarbons using the principle of infrared absorption spectroscopy. These detectors are widely employed in industrial safety applications due to their high reliability, fast response, and low maintenance requirements.

Figure II. 3 : Infrared (IR) Gas Detector **[8]**

Operating Principle

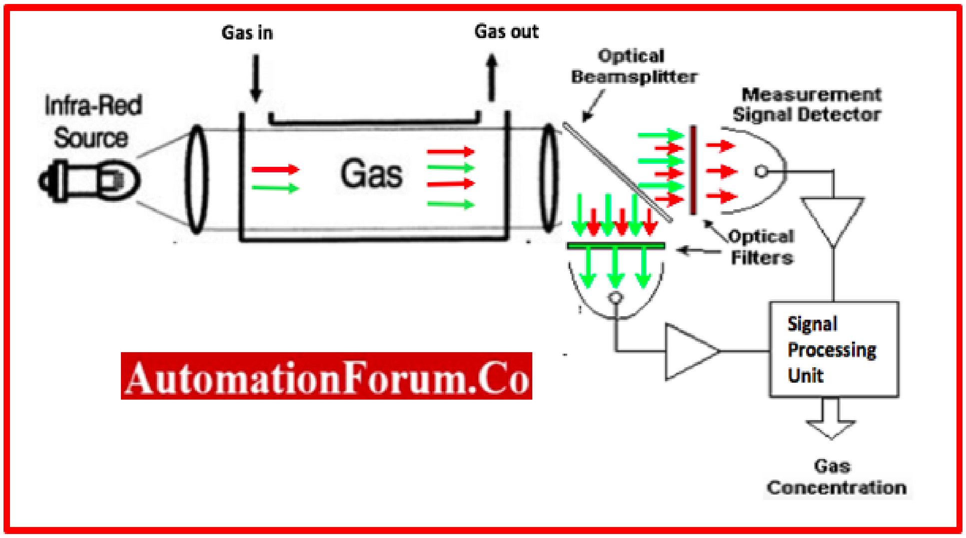


Figure II. 4 : IR Gas Detector Working Principle **[9]**

IR gas detectors operate based on the fact that hydrocarbon molecules absorb infrared radiation at specific wavelengths, typically in the 3.3 to 3.5 µm range. The detector consists of:

- An infrared light source that emits radiation through a sample path,
- A sensing element (photo-receiver) that measures the intensity of IR light after it passes through the gas sample,
- And often a reference channel to correct for environmental changes.

When hydrocarbon gas enters the optical path, it absorbs part of the IR radiation at its characteristic wavelength. The amount of absorbed energy is proportional to the gas concentration. The remaining IR signal reaches the detector and is compared with the reference, producing an output signal indicating the gas concentration.

There are two main configurations:

- Point IR detectors: Fixed detectors with short optical paths (a few cm to meters), ideal for local gas leak detection.
- Open-Path IR detectors: Use a beam of IR light over longer distances (5–150 meters) to detect gas clouds in open areas. [10]

Target Gases

- Methane (CH_4)
- Propane (C_3H_8)
- Butane (C_4H_{10})
- Ethylene (C_2H_4)
- Ethane (C_2H_6)
- Pentane, hexane, and heavier alkanes

Advantages

- No requirement for oxygen: Operates effectively in inert or oxygen-deficient environments.
- Immunity to poisoning: Unlike catalytic sensors, IR detectors are not affected by silicone, lead, or sulfur.
- Low maintenance and long operational life (typically 5–10 years).
- Fast response time and high sensitivity.
- Suitable for both point detection and wide-area open-path monitoring.
- Can operate reliably in harsh environments (dust, humidity, temperature variations).

Limitations

- Not suitable for hydrogen detection or gases that do not absorb IR light.
- Requires clear line of sight between the source and the detector (especially in open-path systems).
- May be affected by fog, heavy dust, or misalignment in open-path installations.
- Higher initial cost compared to catalytic detectors.

Applications

- Offshore platforms
- Gas turbine enclosures
- Compressor and pump skids
- Tank farms and loading terminals
- LNG plants and petrochemical facilities
- Areas requiring fail-safe operation and high Safety Integrity Level (SIL) compliance

II.2.1.3. Electrochemical Detectors

Electrochemical gas detectors are widely used for the detection of toxic gases and oxygen levels in industrial environments. These detectors operate based on redox (reduction-oxidation) reactions that occur at the surface of electrodes within a chemical sensing cell. The resulting electrical signal is directly proportional to the gas concentration, offering accurate and selective gas monitoring.

Figure II. 5 : Electrochemical Gas Detector **[11]**

Operating Principle

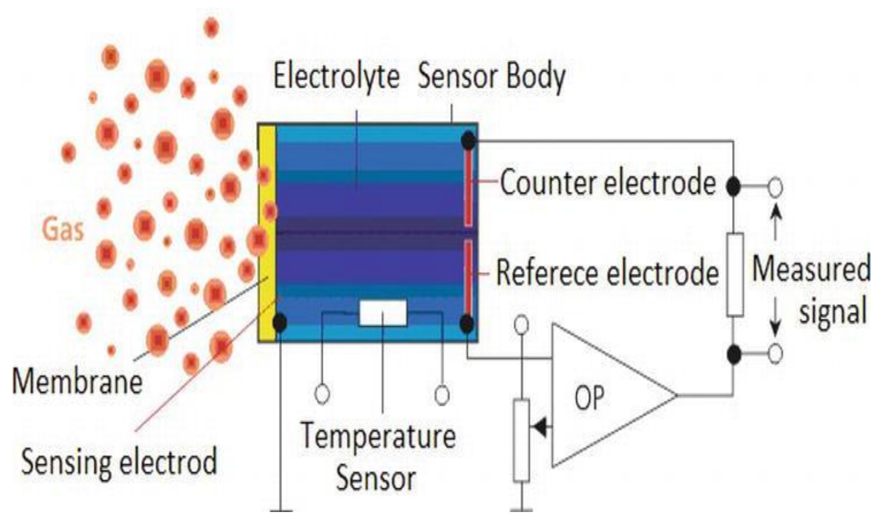


Figure II. 6 : Electrochemical Gas Detector Working Principle **[12]**

- Working electrode
- Counter electrode
- Reference electrode

These are immersed in an electrolyte solution (often acidic or alkaline). When the target gas diffuses through a porous membrane and reaches the working electrode, it undergoes an oxidation or reduction reaction depending on the gas type:

- For example, carbon monoxide (CO) is oxidized to carbon dioxide (CO_2).
- Hydrogen sulfide (H_2S) is oxidized to sulfur.

This reaction generates a small electric current between the working and counter electrodes. The current is measured and correlated to the gas concentration using a signal conditioning circuit. [12]

Target Gases

- Carbon monoxide (CO)
- Hydrogen sulfide (H_2S)
- Ammonia (NH_3)
- Nitrogen dioxide (NO_2)
- Chlorine (Cl_2)
- Oxygen (O_2) (for both enrichment and deficiency detection)
- Sulfur dioxide (SO_2)
- Other toxic industrial chemicals (TICs)

Advantages

- High selectivity: Designed to respond to specific gases with minimal cross-sensitivity.
- Accurate and sensitive detection, even at low parts-per-million (ppm) levels.
- Low power consumption, making them suitable for portable and battery-powered applications.
- Compact size and ease of integration into multi-gas detectors or personal gas monitors.
- Linear output over a wide concentration range.

Limitations

- Limited lifespan: Typically, between 1 to 3 years, depending on gas exposure and environmental conditions.
- Sensitive to temperature, humidity, and pressure fluctuations.
- Cross-sensitivity can still occur in complex gas mixtures without proper filtering.
- Requires calibration at regular intervals to maintain accuracy.
- May degrade when stored or operated outside recommended conditions (e.g., excessive dryness or exposure to solvents).

Applications

- Oil and gas plants (e.g., for H_2S detection in sour gas processing)
- Refineries and chemical plants
- Water treatment facilities (e.g., Cl_2 and NH_3 monitoring)
- Confined space entry (e.g., CO and O_2 sensors in portable gas monitors)
- Laboratories and industrial hygiene systems
- Gas utility service and leak detection [12]

II.2.1.3. Ultrasonic Gas Leak Detectors

Ultrasonic gas leak detectors represent a non-conventional approach to gas detection, based not on the measurement of gas concentration but on the detection of the ultrasonic acoustic emissions produced by high-pressure gas leaks. These detectors are particularly valuable in outdoor and well-ventilated environments where traditional point or open-path detectors may struggle to detect rapidly dispersing gases.

Operating Principle

When pressurized gas escapes through a leak (e.g., from a flange, valve, or ruptured pipe), it creates turbulent flow and generates broadband ultrasonic noise, typically in the range of 25–70 kHz—a frequency above the human hearing range.Ultrasonic detectors use acoustic sensors (microphones) to continuously monitor ambient ultrasonic noise. Advanced digital signal processing (DSP) is applied to differentiate the characteristic sound patterns of gas leaks from background industrial noise (e.g., mechanical vibrations or electrical interference). When the ultrasonic energy level exceeds a predefined threshold, an alarm is triggered. [13]

Figure II. 7 : Ultrasonic Gas Leak Detector **[14]**

Target Gases

- Natural gas (methane)
- Hydrogen (H_2)
- Nitrogen (N_2)
- Carbon dioxide (CO_2)
- Compressed air or steam

Advantages

- Immediate detection of pressurized gas leaks, often within milliseconds.
- Independent of wind direction, gas dispersion, or concentration levels.
- Operates in oxygen-depleted or inert atmospheres.
- Effective in harsh industrial conditions, including offshore platforms and compressor stations.
- Low maintenance and long operational life.
- Useful for early warning, minimizing gas buildup and reducing the risk of explosions.

Limitations

- Only effective for high-pressure leaks (typically >2 bar); may not detect small or low-pressure leaks.

- Does not provide gas concentration or identity — best used in combination with point or open-path detectors.
- May require tuning or filtering to avoid interference from non-leak-related ultrasonic sources (e.g., steam vents, mechanical noise).
- Requires proximity to the potential leak source, as acoustic energy diminishes with distance.

Applications

- Compressor and pump stations
- Gas turbines and high-pressure manifolds
- Offshore oil and gas platforms
- Environments with high airflows or open ventilation

II.2.2. Flame Detectors

Flame detectors are critical components of fire protection systems, especially in high-risk industrial environments such as oil and gas facilities, power generation units, and chemical plants. These detectors are designed to identify the presence of open flames by sensing the radiation emitted during combustion, specifically in the ultraviolet (UV), infrared (IR), or combined spectral bands. [15]

II.2.2.1. Ultraviolet (UV) Flame Detectors

Figure II. 8 : UV Flame Detector **[15]**

Operating Principle

Ultraviolet flame detectors operate by sensing UV radiation emitted in the range of 185 to 280 nanometers, which is released almost instantly during the ignition of a flame. The detector contains a UV-sensitive phototube or photodiode that reacts to this radiation.

When UV radiation is present:

- The sensor generates an electric current in response to ionized particles.
- The system interprets this signal as flame activity if it matches the expected intensity and duration.
- Fast response times (in milliseconds) make it ideal for detecting explosive fires or hydrogen flames, which are invisible to the human eye. [15]

Applications

- Hydrogen storage areas
- Enclosed cabinets or technical rooms
- Laboratories and indoor industrial installations

Limitations

- Sensitive to false alarms from arc welding, lightning
- Not suitable for smoky environments, as smoke can absorb UV radiation

II.2.2.2. Infrared (IR) Flame Detectors

Operating Principle:

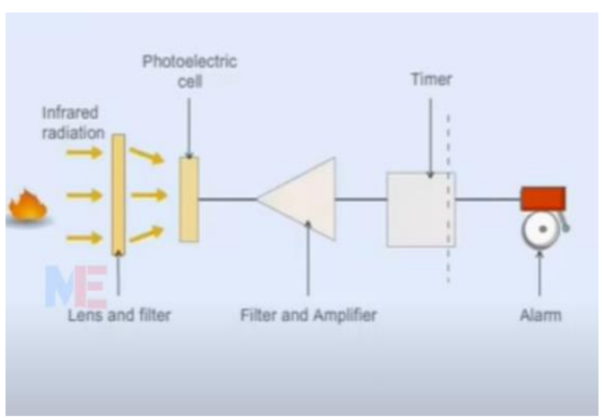


Figure II. 9 : Operating Principle of IR Flame Detector **[16]**

Infrared flame detectors operate by admitting only the flame's characteristic 4.3 µm CO_2 emission through a narrow-band optical filter into a pyroelectric sensor, where rapid fluctuations in incident IR intensity induce surface-charge variations that generate a minute alternating voltage; this voltage is then amplified, band-pass filtered around the typical flame flicker frequency (1–20 Hz), and evaluated—either by a precision comparator or embedded DSP—to confirm both amplitude and flicker patterns before producing a clean digital output to trigger alarms or safety interlocks. [17]

Advantages

- Fast response (typically <100 ms after flicker detection)
- High immunity to ordinary IR sources (sunlight, hot surfaces) when multi-band or DSP logic is used
- No consumables (no catalyst poisoning) and long service life

Limitations

- Inability to detect hydrogen or alcohol fires (they emit weak/no 4.3 µm IR)
- Line-of-sight required; performance degrades if the window is obscured by dirt or condensation
- Potential false alarms if hot machinery or welding in view produces flickering IR in the 1–20 Hz band (mitigated by multi-band or DSP logic)

II.2.2.3. Combined UV/IR Flame Detectors:

Figure II. 10 : UV/IR Flame Detector **[18]**

Operating Principle

These detectors combine UV and IR; they have fewer false alarms than the UV or IR detectors. They detect ultraviolet and infrared in the region's spectra emitted by a flame, it uses a photo tube sensitive to radiation ultraviolet in addition to an infrared sensor. When both types (UV and IR) of radiation are detected and the intensity measurement parameters determined by the algorithm of the microcomputer is satisfied, the device understands that it is in the presence of a fire alarms are triggered [18]

Applications:

- Offshore platforms
- Fuel depots
- Gas turbine enclosures
- Chemical units with risk of multiple fire types

Limitations:

- Higher cost
- Requires clear line-of-sight to the flame source
- Slightly slower response than UV-only detectors

II.2.3. Heat Detectors

Figure II. 11 : Heat Detector **[19]**

Heat detectors are fire detection devices that respond to changes in ambient temperature. Unlike flame or smoke detectors, which detect byproducts of combustion, heat detectors operate based on temperature thresholds or rate-of-rise patterns, making them suitable for harsh environments with high levels of dust, vapor, or smoke that might cause false alarms in other systems. [19]

II.2.3.1. Fixed Temperature Heat Detectors

Fixed temperature heat detectors are designed to initiate an alarm when the ambient temperature rises above a specific predetermined threshold. This threshold is typically set based on the environmental conditions of the installation site and ranges from 57 °C to 93 °C in most industrial applications.

These detectors rely on a thermally sensitive element—such as a bimetallic strip, fusible alloy, or semiconductor thermistor—that reacts once the ambient temperature reaches the set limit. When this threshold is exceeded:

- A mechanical detector may feature a fusible link that melts or a bimetal strip that deforms to close a set of contacts.
- An electronic detector (thermistor-based) senses the temperature electronically and triggers an alarm via signal conditioning and comparator circuitry.

Once the setpoint is reached, the detector either mechanically closes a circuit or sends a digital/electrical signal to the fire and gas control system, which may then initiate alarms, shutdown procedures, or activate fire suppression systems. [19]

Advantages

- Simplicity and reliability with minimal maintenance
- High immunity to false alarms from dust or vapors
- Compatible with hazardous area environments (available in explosion-proof enclosures)

Limitations

- Slower response compared to rate-of-rise or flame detectors
- Unsuitable for early detection of low-energy or smoldering fires

- Requires careful setpoint selection to avoid under- or over-sensitivity

II.2.3.2. Rate-of-Rise (ROR) heat detectors

Rate-of-Rise (ROR) heat detectors are thermal sensors that respond to a rapid increase in ambient temperature, typically around 6–8 °C per minute, regardless of whether the final temperature reaches the fixed alarm threshold. These detectors are engineered for early fire detection, especially in environments where a fast temperature rise may precede the onset of flames or smoke. [19]

Operating Principle

The detection mechanism is based on the comparison between ambient temperature variations over time. A typical ROR detector uses either:

- Dual thermistors (one exposed to the environment and the other insulated) to measure differential changes, or
- A pneumatic chamber that expands under heat; the rate of expansion triggers a mechanical switch when the temperature rises too quickly. [19]

Applications

- Ideal for mechanical rooms, MCC panels, electrical cabinets, and HVAC systems where temperature rise is the primary fire signature.
- Used in hazardous areas where flame or smoke detection is difficult due to environmental factors (dust, humidity, vapors).

Advantages

- Faster response to rapidly developing fires compared to fixed temperature detectors.
- Can detect fires even before reaching damaging temperature levels.
- Resettable after activation (in electronic models).

Limitations

- Less effective in slowly developing or smoldering fires.
- Susceptible to false alarms in high-heat environments without proper calibration.

II.2.4. Manual Call Points

Figure II. 12 : Manual Call Points **[20]**

Manual Call Points (MCPs), also known as Break Glass Units, are essential components of Fire and Gas (F&G) systems that allow personnel to manually trigger an alarm in the event of a fire, gas leak, or emergency condition. They serve as a redundant and human-activated safety interface, especially critical in areas where automatic detectors may not react immediately.

Operating Principle

The MCP is a normally closed (NC) contact device that, when activated, opens the electrical circuit and sends a discrete signal to the Fire and Gas controller. Most MCPs operate by pressing a plastic or glass element (designed to break or flex), which releases a microswitch or activates a pressure pad to change the circuit status. [20]

Types of MCPs

- Conventional MCPs: Wired in parallel to a fire loop, each sends a direct signal to the controller.
- Addressable MCPs: Each unit has a unique ID and communicates with the F&G panel via a digital protocol (e.g., MODBUS, PROFIBUS).

Advantages

- Provides a manual override in case of automatic system failure or delayed detection.
- Simple design ensures high reliability and low maintenance.
- Can be easily tested as part of routine safety checks.

II.2.5. Sirens (Audible Alarms)

Function

Sirens generate high-decibel audio signals (typically between 90 to 120 dB) that vary in tone and pattern to indicate the type and urgency of the alarm. The signal is activated by the Fire and Gas controller once a hazard is detected or an MCP is pressed.

Types

- Electronic Sounders – Generate tone digitally; allow multiple tones for different alarm types.
- Motor Sirens – Older type; produce sound mechanically via motor and rotor.

II.2.6. Alarm Beacons (Visual Alarms)

Figure II. 13 : Alarm Beacons **[21]**

- **Function**

Beacons provide a visual signal via high-intensity LED or Xenon strobe lights. They are crucial in noisy environments where audio alarms might not be heard, and also help to visually guide personnel during emergency evacuation. [21]

- **Types**

- Rotating Beacons: Mechanically rotate a lens or reflector to produce a sweeping light.
- Strobe Lights: Emit rapid, intense flashes (commonly Xenon or LED).
- Steady-State Beacons: Constant illumination, often in amber, red, or blue.

- **Color Codes**
  - Red: Fire or general emergency
  - Yellow: Gas leak

II.2.7. Extinguishing Agents

II.2.7.1. Carbon Dioxide (CO2)

Figure II. 14 : CO2 Fire Extinguisher **[22]**

CO_2 is a gas that extinguishes fires by displacing oxygen in the protected area. It is very effective for flammable liquid and electrical fires. CO_2 is mainly used in unoccupied spaces, like compressor rooms, because it can be dangerous for humans. Before discharge, alarms and delays are required to ensure the area is evacuated. [22]

II.2.7.2. Insert Gases (IG-541, IG-55, IG-100)

Inert gases are mixtures of nitrogen, argon, and carbon dioxide. They suppress fires by reducing the oxygen level to below the combustion threshold. These gases are safe for people for short periods and are used in control rooms, data centers, and technical spaces. Inert gases are clean and leave no residue. [23]

II.2.7.3. Clean Agents (FM-200, NOVEC 1230)

Clean agents are synthetic gases that stop fires by absorbing heat and interrupting the combustion process. They are safe for electronic equipment and people. FM-200 and NOVEC 1230 discharge very fast and leave no residue. NOVEC 1230 also has a low environmental impact and is often chosen for critical installations. [23]

II.2.7.4. Water Mist

Water mist systems spray fine droplets of water at high pressure. These small droplets absorb heat and block oxygen, cooling the fire very fast. Water mist is used in turbine halls, electrical rooms, and confined spaces. It causes much less water damage compared to traditional sprinklers. [24]

II.2.7.5. Dry Chemical Powders (ABC, BC)

Dry chemical systems release powder that interrupts the chemical reaction of fire. They are effective for flammable liquids, electrical fires, and general fires. However, the powder can leave a residue that may damage sensitive equipment. Dry chemicals are often used in kitchens, industrial areas, and storage spaces. [23]

II.3. System Architecture and Operation

The Fire and Gas (F&G) system architecture is designed to provide early detection, alarm notification, and automatic or manual mitigation actions during fire or gas emergencies.

It is a critical part of the overall plant safety design, ensuring the protection of personnel, equipment, and the environment.

II.3.1. Main Components of F&G System Architecture

The main components of a Fire and Gas (F&G) system architecture include field devices such as flame detectors, gas detectors (combustible and toxic), heat detectors, and manual call points, which serve as the primary sensors for hazard detection. These devices are wired to Input/Output (I/O) modules that collect detection signals and manage output commands. The heart of the system is the Fire and Gas Controller, typically a Safety PLC certified for SIL applications, which processes incoming signals based on programmed logic. Operator Interfaces, such as HMI or SCADA systems, provide real-time monitoring, alarm visualization, and system control capabilities. Communication within the system is established through industrial networks like PROFIBUS, PROFINET, or Modbus TCP, ensuring reliable and often redundant data exchange. Additionally, redundant power supplies and UPS systems are integrated to maintain continuous system operation during power failures, reinforcing the high availability and safety integrity of the F&G system. [25]

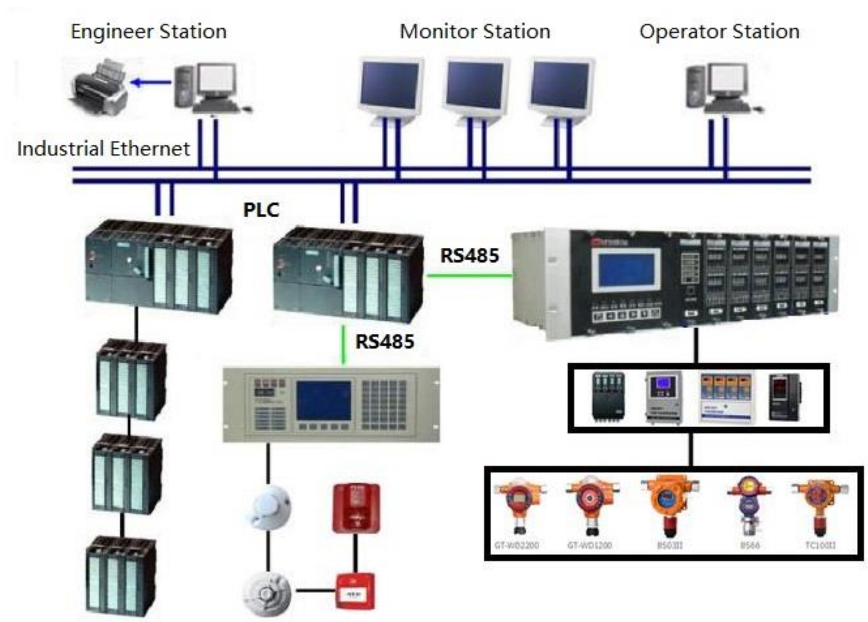


Figure II. 15 : Main Components of F&G System Architecture **[25]**

II.3.2. System Topology

The Fire and Gas (F&G) system typically adopts a distributed topology where field devices are grouped by specific plant areas and connected to local junction boxes or remote I/O panels. These panels communicate with the central Fire and Gas Controller through high-speed industrial networks, ensuring efficient signal transmission. To enhance system reliability, the architecture often employs redundancy at multiple levels, including dual controllers operating in hot standby mode, redundant communication networks (such as fiber optic rings), and duplicated I/O modules. This design philosophy eliminates single points of failure, guaranteeing continuous system operation even in the event of equipment faults or communication losses. The distributed and redundant structure of the F&G system is essential for achieving high safety integrity, fast response times, and robust protection of critical industrial assets. [25]

II.3.3. Operating Principle

The operating principle of the Fire and Gas (F&G) system is based on continuous monitoring of hazardous conditions using specialized field detectors that sense the presence of combustible gases, toxic gases, flames, or abnormal heat. When a detector senses a hazardous event, it sends an electrical signal to the Fire and Gas Controller, which processes the information according to a predefined Cause and Effect matrix. Depending on the severity and type of hazard detected, the controller initiates a sequence of automatic actions such as triggering audible and visual alarms, activating suppression systems (e.g., water spray, gas flooding), and sending emergency signals to higher-level safety systems like the Emergency Shutdown (ESD) system and the Distributed Control System (DCS). The F&G system is designed to operate in fail-safe mode, ensuring that any fault condition, such as a loss of power or communication, results in a safe and predictable system response to protect personnel, assets, and the environment. [25]

II.3.4. Safety and Reliability Features

The Fire and Gas (F&G) system incorporates multiple safety and reliability features to ensure maximum protection of personnel, assets, and the environment. These features include the use of Safety Integrity Level (SIL)-certified controllers and sensors, redundancy in critical components such as CPUs, communication networks, and power supplies, and the implementation of diagnostic functions that continuously monitor system health. Fail-safe design principles ensure that in the event of a device failure, communication loss, or power outage, the system defaults to a safe state by triggering alarms and safety shutdowns where necessary. Periodic proof testing, system self-checks, and automatic fault detection enhance the overall reliability and maintain the high availability of the system. In addition, the architecture is often designed with physical separation between redundant elements to protect against common-cause failures, ensuring continuous operation even under adverse conditions. [25]

II.4. Zoning and Coverage Strategies

Effective Fire & Gas zoning starts with a hazard and risk assessment to pinpoint likely fire and gas release scenarios and their severity. The plant is then partitioned into protection zones such as compressor enclosures, pump rooms, storage tanks, pipe racks, and control cabins each classified by ATEX gas zones (0, 1, 2) and by fire-risk level (high, medium, low) using HAZID/HAZOP studies and quantitative dispersion models to ensure detectors cover areas where gas clouds or flame sources are most probable.

II.4.1. Gas Detector Coverage

For combustible or toxic gas detection, the height and spacing of point detectors are determined by the gas's specific gravity, release rate, and ventilation. Lighter-than-air gases (e.g., methane, hydrogen) require detectors mounted near ceiling level, spaced typically 5–10 m apart in enclosed areas or guided by CFD (computational fluid dynamics) studies in complex layouts. Heavier gases (e.g., propane, chlorine) use floor-level detectors. Open-path detectors may span flanged connections or valve trains to cover long runs. Coverage is verified by ensuring each potential leak point lies within the detector's 90° conical detection zone at its LEL setpoint. [26]

II.4.2. Flame Detector Coverage

Flame detectors must "see" potential fire sources without obstruction. Each device's field of view (typically 90–120° horizontally, 60° vertically) and maximum range (e.g., 20–40 m for IR/UV detectors) dictate spacing and mounting height. Overlapping fields of view ensure no blind spots: detectors are placed such that their coverage cones intersect at key ignition points (valves, flanges). Reflective surfaces and sight-blockers are evaluated to prevent false negatives, and clearance zones are maintained to avoid obstruction by pipework or equipment. [27]

II.4.3. Heat Detector Coverage

Heat detectors are deployed in areas where optical detection is impractical (dusty, oily, or steam-laden environments). Fixed-temperature or rate-of-rise detectors are mounted on ceilings or high walls, typically with a grid spacing of 4–6 m in enclosures. Where rapid temperature gradients occur, rate-of-rise detectors provide earlier warning. In control rooms or technical cabins, photoelectric smoke detectors may supplement heat detectors, with coverage densities based on room volume per EN 54-7 guidelines. [27]

II.4.4. Overlap and Redundancy

High-risk zones (e.g., compressor seals, unloading stations) incorporate redundant detection by using two or more detectors of different types (e.g., gas + flame + heat) in the same zone. This multi-layered approach—often called "2oo3" or "voting logic"—

reduces the likelihood of missed alarms and false trips. Detectors in adjacent zones overlap at boundaries, allowing cross-verification and zonal fault diagnosis. [26]

II.4.5. Standards, Modeling, and Validation in Zoning

II.4.5.1. Industry Standards

International safety standards serve as the foundation for the design, installation, and operation of F&G systems. These standards are designed to guarantee system effectiveness, reliability, and safety. Some of the key standards include:

- NFPA 72 (National Fire Alarm and Signaling Code): This standard sets the requirements for fire alarm systems, including the proper placement of detectors, alarm systems, and response protocols. It emphasizes detection capabilities, alarm thresholds, and the response time of devices.
- IEC 61508 / IEC 61511: These are international standards for functional safety, which provide guidance for the design of safety systems, including Fire and Gas detection systems. The standards define the safety lifecycle of systems and equipment, including risk assessment, failure analysis, and safety integrity levels (SIL). These standards ensure that F&G systems are designed with the appropriate level of safety and redundancy to mitigate risks effectively.
- API 14C (Design and Installation of Fire and Gas Systems in Offshore Platforms): This standard, developed by the American Petroleum Institute (API), focuses specifically on the design and installation of fire and gas detection systems on offshore oil and gas platforms. It outlines guidelines for proper coverage, detector placement, and integration of F&G systems.
- EN 54 (Fire Detection and Fire Alarm Systems): EN 54 is a European standard that covers the performance and installation requirements for fire detection systems, including detectors for flame, gas, heat, and smoke. The standard provides specifications for the type, sensitivity, and positioning of detectors in various applications.
- IEC 60079-29-1: This standard deals with the design and use of gas detection systems for explosive atmospheres. It specifically addresses the layout, sensitivity, and

calibration of detectors to ensure that they can effectively detect hazardous gas releases. [27]

II.4.5.2. Modeling Techniques

To ensure the F&G system's effectiveness, modeling is critical to simulate potential hazards, gas dispersion, and fire behavior in complex industrial environments. Several methods are used to predict how gas will travel through the air or how a fire may spread:

- Computational Fluid Dynamics (CFD): CFD is a key modeling tool for simulating the movement of gases and heat in the environment. It helps predict how a gas leak will disperse in a specific area, taking into account airflow patterns, ventilation, and environmental conditions such as temperature and humidity. CFD modeling allows engineers to optimize the placement of detectors by visualizing where gas clouds are likely to accumulate and ensuring adequate coverage in high-risk areas.
- Gas Dispersion Modeling: This is a mathematical model used to predict the movement of gases after a release. Software like PHAST, FLACS, or Aloft is often used to simulate gas leaks, taking into account factors like wind speed, leak size, and gas properties. The results are then used to place gas detectors in locations where a gas cloud is most likely to form.
- Fire Modeling: Similar to gas modeling, fire modeling uses tools like Fire Dynamics Simulator (FDS) or PyroSim to simulate fire scenarios. These models consider various factors such as fuel source, ignition sources, and building layout to predict how a fire would spread in a facility. The data is then used to optimize the placement of flame detectors and heat sensors to provide early warning and effective response. [27]

II.4.5.3. Validation and Testing

After designing and modeling the Fire and Gas detection system, it is crucial to validate the system to ensure it will function as expected in real-world conditions. This validation process involves:

- Detector Placement Validation: Using the data from CFD or gas dispersion models, the layout and spacing of detectors are reviewed to confirm they will provide comprehensive coverage in the event of a gas leak, flame, or fire. Validation ensures that detectors are positioned to detect the hazard quickly and effectively.

- Cause-and-Effect Testing: After installation, the cause-and-effect logic programmed into the system must be tested to ensure that the system responds correctly to different scenarios. For example, if a flame detector detects a fire, the system should trigger the correct alarms and initiate the fire suppression system, and similarly, if a gas detector detects a leak, the correct safety measures should be implemented.
- Proof Testing: Regular proof testing of the detectors is performed to ensure they remain calibrated and functional over time. This involves simulating a hazardous event to check that the detector triggers the correct alarms and actions. Proof testing helps identify faulty or degraded sensors that may not respond appropriately in an emergency.
- System Commissioning: Before a system goes live, it undergoes commissioning procedures where the entire Fire and Gas system is tested in real-world conditions. This includes testing each individual detector, alarm, and suppression system to verify that they work together seamlessly. Commissioning is a final check to ensure all components are integrated properly, and the system performs as required. [27]

II.5. Signal Flow and Response

In a Fire and Gas (F&G) detection system, signal flow begins with the detection of an abnormal event, such as the presence of combustible gas, toxic gas, flame, or excessive heat. Upon detection, the field device (sensor or detector) generates an electrical signal proportional to the hazard's intensity. This signal is transmitted, either analog (4–20 mA) or digital (e.g., via Modbus, PROFIBUS, or FOUNDATION Fieldbus), to the Fire and Gas Control Panel or a Safety Instrumented System (SIS). The control logic processes the input signal, performs validation checks to avoid false positives, and then triggers pre-programmed actions based on the cause-and-effect matrix. Immediate system responses may include activating audible and visual alarms (sirens, beacons), initiating local shutdowns (e.g., closing isolation valves, stopping compressors), or executing facility-wide emergency shutdown (ESD) procedures. Critical actions are often designed with redundancy and are time-critical to ensure rapid mitigation of hazardous scenarios. Signal integrity, response times, and correct logical execution are validated during system commissioning and periodically proof-tested throughout the operational life of the installation. [27]

II.6. Integration with Safety Systems (ESD, DCS)

II.6.1. Purpose of Integration

The integration of the Fire and Gas (F&G) system with the Emergency Shutdown System (ESD) and Distributed Control System (DCS) is fundamental to achieving a rapid, safe, and coordinated response during fire or gas events. The F&G system provides early detection, while the ESD ensures automatic protective actions, and the DCS offers real-time monitoring and operator control. [25]

II.6.2. Emergency Shutdown System (ESD) Actions

- Upon receiving critical input from the F&G system, the ESD executes automatic actions such as:
- Isolation: Closing emergency shutdown valves (ESDVs) to isolate sections of the process.
- Depressurization: Opening blowdown valves to safely vent pressurized systems.
- Shutdown of Equipment: Stopping pumps, compressors, and critical rotating machinery.
- Utility Disconnection: Cutting off electrical supplies, fuel sources, or other utilities feeding the affected zone.

These actions are predefined in the cause-and-effect matrix and are executed independently of operator intervention, ensuring compliance with Safety Integrity Level (SIL) requirements. [25]

II.6.3. Distributed Control System (DCS) Role

- Alarm Visualization: Displaying alarms related to fire and gas events with specific detector information (zone, type, severity).
- Event Logging: Recording incidents for later analysis and auditing.
- Operator Intervention: Allowing trained personnel to manually initiate further actions or override systems when necessary.
- System Diagnostics: Monitoring the health and maintenance status of detectors and field devices. [25]

II.6.4. Communication and Redundancy

- Hardwired Inputs/Outputs: Used for high-priority shutdown signals to avoid communication delays.
- Redundant Networks: Dual-redundant communication paths (e.g., PROFIBUS or redundant Ethernet rings) ensure system availability even in case of single point failures.
- Failsafe Design: All safety-critical communications and logic are designed according to IEC 61508/IEC 61511 requirements, ensuring system response even during hardware or software faults. [25]

II.6.5. Benefits of Integration

- Higher Safety Integrity: Separation of control (DCS) and safety (ESD) functions preserves system independence and reliability.
- Enhanced Operator Awareness: Operators receive real-time situational data to manage the event more effectively.
- Regulatory Compliance: Adhering to safety standards (API, IEC, NFPA) ensures legal and operational conformance. [25]

II.7. Conclusion

The Fire and Gas (F&G) system plays a vital role in ensuring early detection of fire and gas hazards, enabling rapid protective actions to minimize risks. Through a combination of advanced detection technologies, strategic zoning, and integration with safety systems like ESD and DCS, the F&G system enhances industrial safety and operational reliability. Proper design, compliance with standards, and reliable communication paths ensure the system's effectiveness in safeguarding personnel, assets, and the environment.

CHAPTER III: Assessment of the Existing Fire and Gas Detection System in Train 1

III.1 Introduction

Train 1 of the BRN facility is a critical unit where the separation and initial treatment of crude oil, natural gas, and associated water take place. This section of the plant involves processes such as gas-oil separation, stabilization, and pressurization—operations that inherently present a high risk of fire and gas incidents due to the presence of flammable substances under pressure. To manage these risks, Train 1 is equipped with a Fire and Gas (F&G) detection system intended to monitor abnormal conditions and trigger early alarms in hazardous areas. The current system is centered around the Simplex 4100 fire alarm control panel, which acts as the main processing and signaling unit. The field instrumentation includes gas detectors, thermosensitive cables, manual call points, and alarm annunciation devices such as sirens and flashing beacons. These components are distributed across high-risk areas, including compressor rooms, separator units, and technical zones. Signal transmission is hardwired and primarily binary, with minimal logic or diagnostic capabilities. The system operates independently and is not fully integrated with the site's Distributed Control System (DCS) or Emergency Shutdown System (ESD). This chapter presents a comprehensive technical overview of the current Fire and Gas system deployed in Train 1, detailing its architecture, components, and operational behavior.

III.2 Overview and Functionality of the Simplex 4100 F&G Control Panel

III.2.1 Introduction

Simplex 4100 and 4100+ are fire alarm systems based on microprocessor. These fire alarm systems are U.L. Listed, limited to power, electrically supervised and protected against loss of primary AC power and the interference conditions. The basic 4100 systems contain eight device circuits initiation, two indicator device circuits, two auxiliary alarm relays and a board interface for local annunciators, a problem relay and a notification circuit of city configurable. The basic 4100 also includes a master controller board, a field cabling termination module, an 80-character alphanumeric display, a power supply and housing, LED annunciator displays and/ or dots Graphic advertisers can also be used. Depending on the options, the 4100 can control up to 512 points using software version 4.02 and up to 700 points using of software version 5.01 (or later).

The differences between 4100 and 4100+ are mostly invisible to an operator. Almost All functions of the 4100+ operator interface panel are exactly the same those of the 4100 system.

The most obvious difference between the two-systems hardware configuration. The 4100+ system uses a Master Controller board which is basically a redesign of the 4100 Master Controller Board. The 4100+ uses a faster microcontroller and more powerful. The CFIG EPROM has been replaced by a flash EPROM for site work easier. Battery backup RAM has been added to keep important historical data, even throughout the entire system. However, the eight monitor zones, the two signal circuits, the two auxiliary relay outputs and the LED switch/controller (for local annunciator) provided on master controller board 4100 are not provided on the 4100+ master controller board. If any of these features is necessary, they must be ordered separately as motherboards and daughter boards, as well as all the harnesses necessary for their installation.

The 4100+ system also uses switching power to provide up to 8amps of power at 24 VDC for charging devices and operation of the system, plus up to 4 amps for battery charging responsibilities. In addition, this power supply can communicate directly with the main controller via internal serial communications, signaling data such as system voltage and Current battery usage and charge information.

Because the 4100+ uses a faster and more powerful microcontroller, the 4100+ system can control up to 1000 points, depending on the system option. An alphanumeric display on the 4100/4100+ Operator Interface Panel indicates the system status. The alphanumeric displays various instructions and labels that guide the user through sequential operation for each abnormal state. Sound and visual indications are provided to indicate abnormal conditions, where they exist in the system. The 4100 and 4100+ systems are fully field programmable. Each can be custom programmed to meet a variety of customer/building applications and local code requirements. [28]

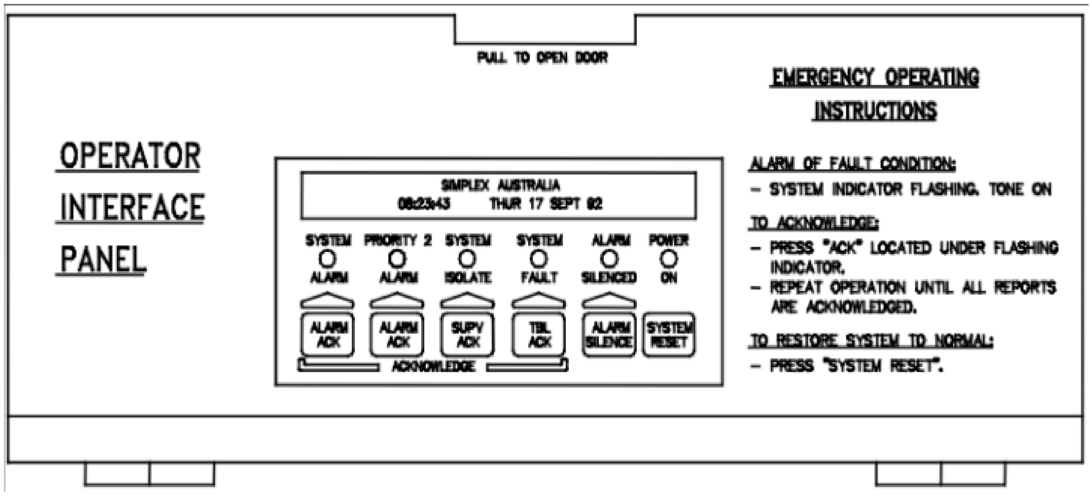


Figure III. 1 : Interface 4100 Operator Panel **[28]**

III.2.2 System Operational Description

The 4100-control panel, hereinafter referred to as the interface panel, shows the following

under normal conditions:

- Green "on" light is on (indicating that mains power is applied).
- All other indications of the OFF-interface panel.
- The alphanumeric display indicates that the system is normal, as shown below.

Abnormal conditions are indicated on the interface panel by flashing the LED alarm, monitoring or incident and signaling the audible alert. The alphanumeric provides information on the status of the point (alarm, monitoring and problem), type of alarm (smoke detector, traction station...), and number of abnormal conditions in the system and a custom label. The conditions for alarm, supervision and problem each have their respective confirmation key. By pressing the appropriate confirmation, the tone alert will be silent. However, the LED indicating the abnormal condition remains on until all primers are restored to normal. [28]

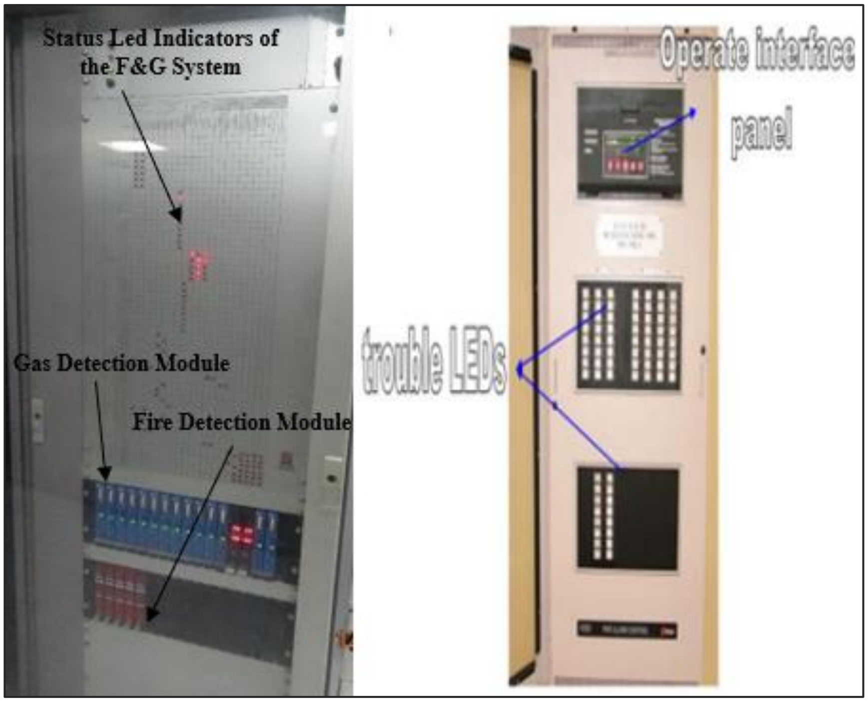


Figure III. 2 : General view of The Simplex 4100 **[28]**

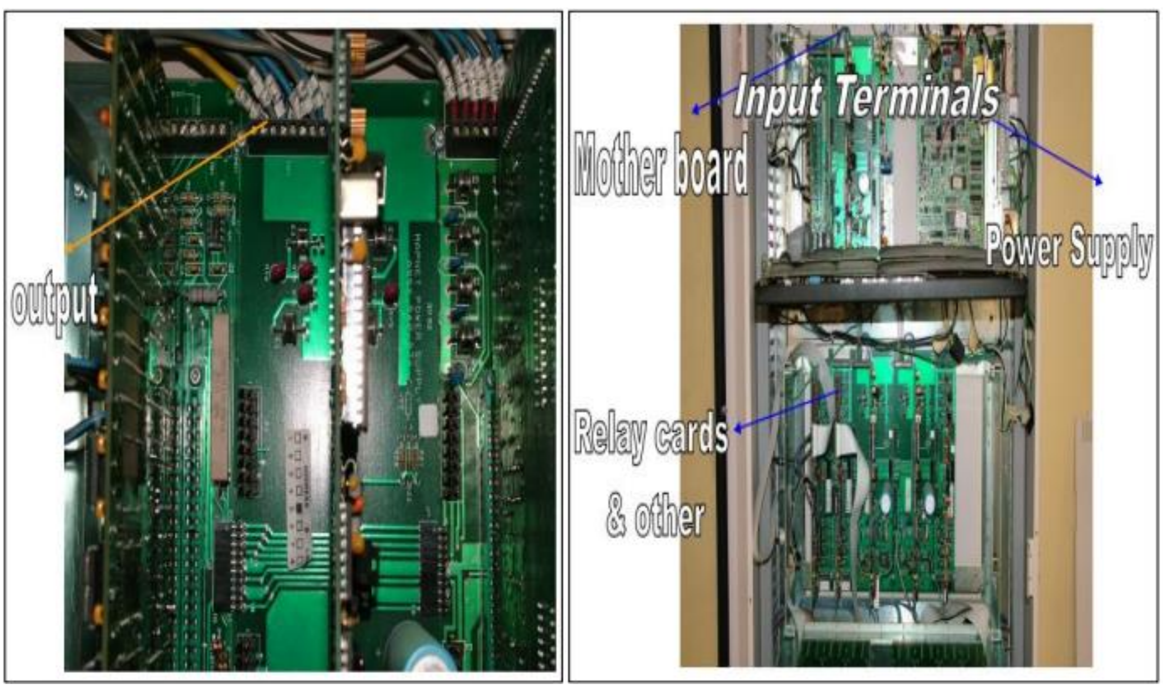


Figure III. 3 : The Simplex 4100 Modules **[28]**

III.2.3 Handling of Abnormal Conditions

If an abnormal condition occurs, at least one of the LEDs (alarm, isolation or default) will start flashing and sound alert. The panel will display the total number of abnormal conditions in the system. At a glance, the user knows which point the situation could be serious by reading the number of abnormal conditions displayed, such as the unique alarm shown below.

The simplex 4100 also creates a "List" when abnormal conditions exist. The list contains the number of abnormal conditions present in the system. The user pressing the <ACK> keys to display a list of abnormal conditions, examines each condition, alarms, displays the alarm list, restores affected devices and resets the panel if necessary. When an abnormal condition has been detected by the system, the appropriate LED will flash and the audible alert will sound for alarm conditions. The audible alert will be for isolation and fault conditions. By pressing the <ACK> key appropriate (under the flashing LED), will display the first recognized condition in the list appropriate. The <ACK> function can be protected by an access code. If the user does not have enough privileges to recognize the condition, a message will indicate the problem, but allows the user to see the points without recognizing them. If the user has a sufficient privilege to recognize the condition, a message is displayed to inform the user that the condition has been recognized.

The system is configured with Global Change Acknowledge to enable pressing an <ACK> key to globally acknowledge all abnormal points in the system. If all points have been acknowledged in this manner, an appropriate message is displayed. When the fault condition clears, the abnormal condition will automatically clear. Alarm conditions must be acknowledged [18]. After all points have been acknowledged, the LEDs will illuminate and the audible alert will be silenced. The total number of alarms, isolations, and fault conditions will be displayed on the alphanumeric display, with a prompt to press the <ACK> key for point evaluation. A subsequent press of the <ACK> key will scroll through the selected list in chronological order. After 30 seconds of keypad inactivity, the total number of abnormal conditions will be displayed again on the alphanumeric display. Pressing the <ACK> key will select a list.

The first point to be displayed will be either the first recognized point in the list, or the first point in the list if all are recognized.

The alarm, isolation, and fault lists are displayed in chronological order. A message indicates when the end of a list has been reached. The list message will contain the total number of abnormal conditions, such as the single alarm shown below. [28]

ALARM	Press ACK to review.	
ALARMS = 1	ISOLATED = 0	FAULT = 0

The <DISPLAY TIME> Key

The <DISPLAY TIME> key is used to show the time of day when the abnormal situation occurred. By looking at the time for each occurrence of abnormal state, the staff of the Fire brigade can determine the path and possible cause for each abnormal state. Note that the <DISPLAY TIME> key only displays the abnormal conditions time existing.

The red <DISPLAY TIME> button works for any point currently in an alarm, isolation or fault state. Date/time information is obtained at from the history log and are displayed on the alphanumeric display. In situations where multiple conditions are present, you can simply press a key to examine when each abnormal state occurred. An example of alarm condition is illustrated below.

TOWER BUILDING 3RD FLOOR	
SMOKE DETECTOR	ALARM

If the <DISPLAY TIME> key is pressed and held down, the screen displays alarm information, as shown below. This information is only displayed when the <DISPLAY TIME> key is held down.

```
TOWER BUILDING 3RD FLOOR
ALARM AT 19:56:32          MON 25 JAN 95
```

When the <DISPLAY TIME> key is released, the display returns to its original state.To display alarm information, follow these steps:

- Make sure that the point to check is displayed on the alphanumeric display in pressing the appropriate <ACK> key.
- Hold down the <DISPLAY TIME> key. Information about the abnormal state (alarm, isolation or fault) is displayed.
- Press the appropriate <ACK> key to display the next the state.
- Repeat steps 2 and 3 above, as needed. [28]

III.2.4 Alarm Conditions

When a System Alarm Condition is detected by the 4100. the condition is indicated by the following:

- Red "SYSTEM ALARM-LED is flashing
- Tone-alert is pulsing
- LEDs on annunciators may illuminate
- The alphanumeric display on the interface panel indicates an alarm condition, as shown below:

The interface panel has one red LED which is used to indicate an alarm condition. When an alarm occurs, the red LED flashes, the tone-alert pulses, and an alarm message is displayed on the alphanumeric display. When the key is pressed, the red LED stops flashing and begins to glow steadily, and the tone-alert is silenced. When the key is pressed, the system signals are silenced. When the alarm condition is cleared, the red LED turns off. [28]

III.2.4.1 Global Acknowledge Panel Operation During Alarm Conditions

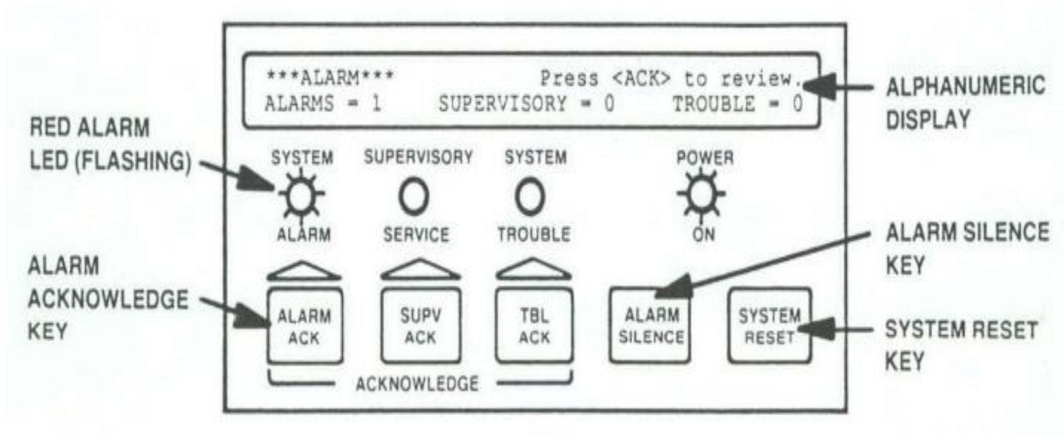
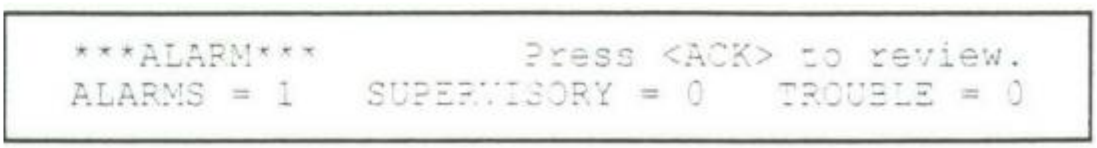


Figure III. 4 : Operator Interface Panel Showing Alarm Condition **[28]**

A GLOBAL ACKNOWLEDGE of a System Alarm Condition is accomplished in the following manner.

1. Unlock and open the enclosure door. Read the alphanumeric display on the interface panel. It reports the number of alarm conditions. as shown below:



2. Press the key under the flashing red LED. The following items should occur:

a. The tone-alert is silenced and the display will show pertinent report information, such as shown below:

b. The SYSTEM ALARM LED changes from flashing to steady ON, and all alarm conditions are acknowledged.

c. Pressing the key scrolls through all alarms in chronological order. [28]

III.2.4.2 Alarm Acknowledge key

The key is located directly under the SYSTEM ALARM LED. Pressing the key (twice for Individual Acknowledge or once for Global Acknowledge) causes the SYSTEM ALARM LED to change from flashing to steady ON and silences the tone-alert. Pressing the key does the following:

- Selects the next unacknowledged alarm point in the list for display (Individual Acknowledge)
- Acknowledges the displayed point or acknowledges all points on the list (Global Acknowledge)
- Scrolls the points chronologically after all points have been acknowledged.

If the key is passcode protected. you cannot use this key to acknowledge alarms unless you have the required access level. There are two types of acknowledges for the 4100 system: Global Acknowledge and Individual Acknowledge. Each acknowledge type operates with the System Alarm Condition in the following manner:

- Global Acknowledge — When Global Acknowledge. geis used on the 4100 system, a single key press of the key acknowledges all alarm status changes in the system. If status change information is required. you may review this data (after a 30 second delay) by pressing the key and reading the total number of alarm status changes on the alphanumeric display.
- Individual Acknowledge (For NFPA 72-1990 Requirements) — If an alarm condition has been acknowledged with the key and further unacknowledged conditions remain in the system. the tone-alert continues to sound and the next status change is shown on the alphanumeric display. This process repeats until all changes are acknowledged. When this occurs. the tone-alert is silenced. and the highest priority acknowledge change is indicated on the display. [28]

III.2.4.3 Alarm Silence Key

When an alarm condition exists, various signals. auxiliary relays. the city connection, and the tone-alert may activate, depending on the system configuration and the stage of the alarm condition. The key, when pressed, turns OFF all circuits programmed to follow the Alarm Silence key. The key press will:

- Turn OFF signal circuits
- Display a message, such as the one shown below:

```
ALARM SILENCE IN PROGRESS...
```

The following software functions affect ALARM SILENCE operation:

- If a Coded Input Device is activated. the key press may be ignored until this function has completed coding. Notification appliances cannot be silenced when a coded station is in alarm, however, the flashing LED will change from flashing ON to steady ON when the key is pushed. The notification appliances will be silenced automatically when coding is complete.
- If the Alarm Silence Inhibit Function is activated but not completed. the key press is ignored. The message. "ALARM SILENCE INHIBITED". is displayed for a short time to indicate the action was not taken. The message "ALARM SILENCE NO LONGER INHIBITED" is displayed when the inhibit function times out. If selected. the alarm silence inhibit may be programmed from 1 to 99 minutes. When selected. signals cannot be silenced until the programmed time has elapsed. [28]

III.2.5 Trouble Conditions

When a System Trouble Condition is detected by the 4100, the condition is indicated by the following:

- Yellow "SYSTEM TROUBLE" LED on the interface panel is flashing
- Tone-alert is ON steady • Annunciator LEDs may be illuminated
- Alphanumeric display on the interface panel shows the following message:

```
**TROUBLE**                 Press <ACK> to review.
ALARMS = 0     SUPERVISORY = 0     TROUBLE = 1
```

The interface panel has a yellow SYSTEM TROUBLE LED which lights whenever a trouble is present in the system. When a trouble occurs, the LED flashes, the tone-alert sounds steady, and a trouble message is displayed on the alphanumeric display. The trouble LED glows steady and the tone-alert is silenced when the key is pressed.

When Global Acknowledge is used, and the trouble clears, the system automatically clears without user intervention. After approximately 30 seconds, the system alphanumeric display should indicate a normal system, as shown below.

```
        SYSTEM IS NORMAL
    8:32:45    THU 17 SEP 92
```

When Individual Acknowledge is used, the tone-alert "re-sounds" when the condition clears. The key must be pressed twice (once to change from Alarm Summary to actual point, and once to acknowledge the condition). After a delay, the system alphanumeric display should indicate a normal system. [28]

III.2.5.1 Global Acknowledge Panel Operation During Trouble Conditions

A GLOBAL ACKNOWLEDGE of a System Trouble Condition is accomplished in the following manner:

-Unlock and open the enclosure door. The alphanumeric display on the interface panel shows the trouble condition:

```
**TROUBLE**                 Press <ACK> to review.
ALARMS = 0     SUPERVISORY = 0     TROUBLE = 1
```

```
FIRST FLOOR EAST WING      ROOM 24
FIRE MONITOR ZONE          OPEN CIRCUIT TROUBLE
```

-Press the key under the flashing yellow LED. The alphanumeric display shows the area and type of trouble. The tone alert is silenced and the yellow LED glows steady.

-Read the alphanumeric display. Then. investigate the problem to determine its cause:

a. Restore or replace the defective device (switch, wire, notification appliance, etc.) in accordance with device instructions or call Simplex to repair the system.

b. The trouble automatically clears when the problem has been corrected.

c. After a delay, the alphanumeric display should show the following message. [28]

```
SYSTEM IS NORMAL
8:36:24     THU 17 SEP 92
```

III.2.5.2 Individual Acknowledge Panel Operation During Trouble Conditions

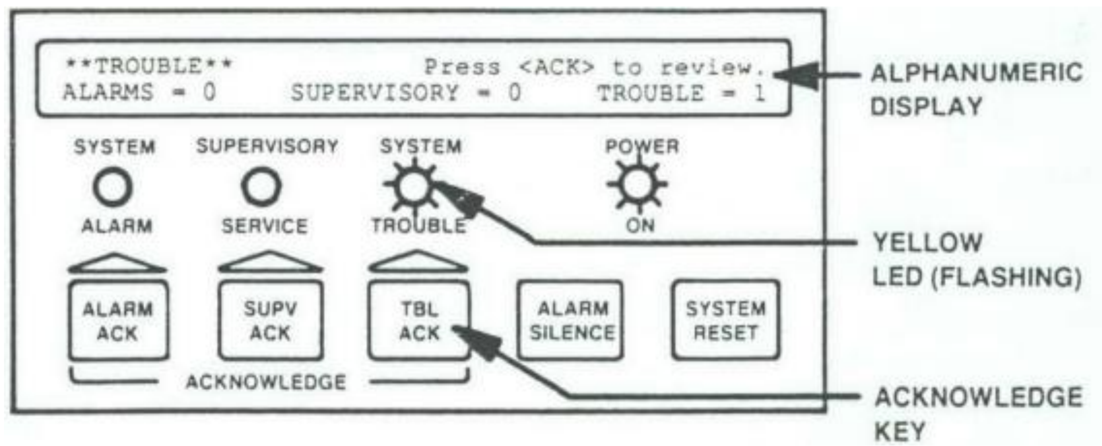


Figure III. 5 : Operator Interface Panel Showing Trouble Condition **[28]**

An INDIVIDUAL ACKNOWLEDGE of a System Trouble Condition is accomplished in the following manner:

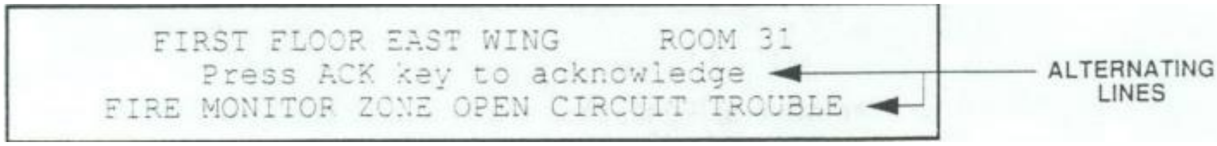
-Unlock and open the enclosure door. The alphanumeric display on the interface panel shows a trouble condition, such as shown below:

```
**TROUBLE**                 Press <ACK> to review.
ALARMS = 0     SUPERVISORY = 0     TROUBLE = 1
```

-Press the key. Repeat this step and read the reports.

a. The tone-alert is silenced and the LED glows steady.

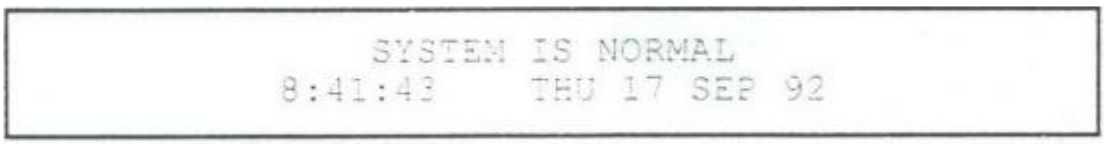
b. The alphanumeric display shows the area and type of problem, as shown below:



-Read the alphanumeric display. Then. investigate the trouble to determine its cause. Restore or replace the defec device (switch, wire, notification appliance, etc.) in accordance with device instructions. steady.

-Press the key under the flashing SYSTEM TROUBLE LED. The alphanumeric display shows the system status.

-Press the key under the yellow SYSTEM TROUBLE LED again. After a delay. the alphanumeric display should show the following message. [28]



III.3 Description of the Existing Detectors in Train 1

III.3.1 Model S4100C Combustible Gas Addressable Transmitter

Figure III. 6 : Model S4100C Combustible Gas Addressable Transmitter **[29]**

III.3.1.1 Description

The General Monitors Model S4100C hydrocarbon gas Addressable Transmitter is a highly reliable, self-contained, microprocessor-controlled monitor with integral 3digit readout. It is designed to measure and display concentrations of combustible gases in the range 0-100% LEL, but will continue to display concentrations up to 120% LEL. The sensing element may be incorporated in the transmitter housing or remotely mounted at distances in excess of 600m.

The S4100C will record the number of successful calibrations, compute the sensor output as a percentage of the new sensor reference output during calibration and store in non-volatile memory, along with calibration and set-up parameters. [29]

III.3.1.2 Specification

- Application: Combustible Gas Monitor Sensor Type: Continuous diffusion, low temperature catalytic bead
- Measuring Range: 0-100% LEL
- Measuring Resolution: 1% LEL
- Location: Hazardous area Overrange
- Indication: Display flashes for readings greater than 99% LEL, but continues to display gas concentration up to 120% LEL
- Calibration Level: * 25% - 90% LEL in 1% LEL increments
- Zero Drift: Less than 5% of full scale per year
- Accuracy (Linearity): ± 5% LEL
- Response Time (input step): T50 < 10 seconds [29]

III.3.1.3 Electrical Specification

- Supply voltage min/max: 10VDC/35VDC
- Electrical connection: Screened and armored cable
- Power Dissipation: 6 watts
- Supply current consumption, including sensor typ/max: 250mA/310mA @ 24 VDC, 500mA/620mA @ 12 VDC
- Current Range: 0 - 22mA

- Analogue output termination resistance min/max: (Including total cable resistance) 0-750 ohms
- Analogue output open-circuit detection current range min/max : 1mA - 22mA [29]

III.3.1.4 Environmental Specification

- Operating temperature range (continuous) min/max: -50°C to +70°C
- Storage temperature range min/max: -55°C to +85°C
- Relative humidity min/max: 5% to 100%, non-condensing [29]

III.3.1.5 Mechanical Specification

- Height excl. sensor: 150mm (6")
- Height incl. sensor: 200mm (8")
- Width: 150mm (6")
- Depth: 95mm (3.75")
- Weight incl. sensor: 2.5 kg (5.5lbs)
- Mounting holes: 4 x 7mm (0.28") Dia holes [29]

III.3.2 Thermosensitive Cable Heat Detection

Figure III. 7 : Thermosensitive Cable **[30]**

III.3.2.1 Descreption

ThermoCable digital linear heat detection (LHD) cable is a combination of advanced polymer and digital technologies that can detect heat anywhere along its entire length. ThermoCable is also compatible with any listed addressable or conventional panel. At the core of ThermoCable is a twisted pair of extremely low resistance (.05 ohm/ft. [.164 ohms/m] of twisted cable) tri-metallic conductors, sheathed in new advanced thermal polymers. These polymers are chemically engineered to break down at specific fixed temperatures allowing the twisted conductors to make contact and initiate an alarm at the control panel without any calibration for changes in the ambient temperature. The distance locating option allows the control panel to identify and display the location, in feet or meters from the panel, where the heat source interacted with the detection cable. [30]

III.3.2.2 Specifications

- Up to 10,000 ft. (3,048m) of ThermoCable per zone
- Approved for up to 35' (10.7m) spacing.
- 05 ohms/ft (164 ohms/m) resistance for twisted pair wire lower than any other type of linear heat detection wire
- Lower cost than other types of linear heat detection wire
- Compatible with ALL Fire Alarm Control / Releasing Panel Use with addressable modules Multiple alarm temperatures: (F°) 155°, 172°, 190°, 220°
- Distance locating available
- Can detect anywhere along the entire length of wire
- Multiple alarm temperatures combined on the same zone
- Total zone length replacement unnecessary after alarm
- Longer standard spool lengths mean less splicing [30]

III.3.3 Simplex 4089-9714 Smoke detector

Figure III. 8 : Simplex 4089-9714 Smoke Detector **[31]**

III.3.3.1 Description

The Simplex 4098-9714 is an analog and addressable, replacement, photoelectric smoke detector head. The Simplex 4098-9714 sensor head is designed to provide 360° smoke entry for optimum response to smoke from any direction. Due to its photoelectric operation, air velocity is not normally a factor, except for impact on area smoke flow for the Simplex 4098-9714. [31]

III.3.3.2 Specifications

- Communications and Sensor Supervisory Power: IDNet or MAPNET II communications, auto-selected, 1 address per base
- Communications Connections: Screw terminals for in/out wiring, 18 to 14 AWG (0.82 mm2 to 2.08 mm2)
- Remote LED Alarm Indicator Current: 1 mA typical, no impact to alarm current
- Remote LED Alarm Indicator and Relay Connections: Color coded wire leads, 18 AWG (0.82 mm2)
- UL Listed Operating Temperature Range: 32° to 100° F (0° to 38° C)
- Storage Temperature Range: 0° F to 140° F (-18° C to 60° C)
- Humidity Range: 10 to 95% RH
- 4098-9714 Smoke Sensor Air Velocity Rating: 0-4000 ft/min (0-1220 m/min) [31]

III.3.4 DB3 Range Atex Sounder

Figure III. 9 : DB3 Range Atex Sounder **[28]**

The ATEX DB3 sounder is an audible alarm designed specifically for hazardous environments. Producing up to 122dB at 1m, it ensures your alarms can be heard in explosive atmospheres.

This sounder is manufactured to a very high standard and boasts numerous certifications, as well as a high-power sounder function. Paired with a gas detection system, the DB3 offers a choice of 29 configurable tones and up to 4 tone stages with various control options for your alarm devices. This range has been specifically designed for standard use in the oil & gas, chemical and pharmaceutical industries. [28]

III.3.4.1 Specifications

- Certification : CENELEC EN50014, EExde IICT4/T5. Zones 1 and 2.
- Material: Body & horn in anti-static, UV stable, glass reinforced polyester. Swivel bracket in stainless steel. Captive cover screws in stainless steel.
- Finish: Body and horn, natural black or epoxy paint coated to client's color requirements.
- Sound Output: DB3 115dB(A) Typical.
- Voltage: Up to 48V dc. Up to 254V ac. [28]

III.4 Limitations of The Existing Simplex 4100 System

The Simplex 4100 Fire Alarm Control Panel (FACP), installed in Train 1 of the BRN site, has been in operation for several decades. Although it has provided basic fire detection functionality, it no longer meets the performance, flexibility, and integration standards expected of modern Fire and Gas (F&G) systems. The following sections detail its main limitations:

III.4.1 Obsolete and Non-Expandable Architecture

The Simplex 4100 is based on a conventional architecture that uses fixed hardwired loops and zone-based detection. This means that multiple devices share the same signaling path, and the panel cannot distinguish between individual device locations. Adding or relocating devices requires significant rewiring, making system expansion complex, time-consuming, and costly. [27]

III.4.2 Limited Detection Precision and Diagnostic Capabilities

Due to its zone-based nature, the system can only identify which area (zone) an event occurred in, not the exact detector or its condition. There is no built-in diagnostic system to detect sensor drift, contamination, or failure. As a result, false alarms and undetected faults are more likely, increasing the operational risk and maintenance workload. [27]

III.4.3 Incompatibility with Modern Smart Devices

The panel does not support addressable, intelligent detectors or digital communication protocols like Modbus, Profibus, or Ethernet/IP. It is unable to interface with modern smart flame or gas detectors that offer features like self-testing, fault reporting, or real-time concentration values. This makes the system incompatible with current-generation instrumentation and safety systems. [27]

III.4.4 Poor Integration with Safety Platforms (DCS, ESD)

The Simplex 4100 was not designed to integrate directly with Distributed Control Systems (DCS) or Emergency Shutdown Systems (ESD). There is no native support for process logic integration, remote command control, or advanced cause-and-effect functionalities. As a result, operators must rely on manual intervention or basic relay outputs for safety responses — which introduces delays and risks during emergencies. [26]

III.4.5 Maintenance and Spare Part Challenges

Given the age of the system, many components are now obsolete, including interface modules, display units, and relay boards. Spare parts are difficult to source and expensive, often requiring refurbished components or custom solutions. Maintenance staff are also constrained by a lack of diagnostic tools, as the interface is limited to basic LCD indicators and keypad controls. [27]

III.4.6 Non-Compliance with Modern Safety Standards

The system does not meet current IEC 61511 (Functional Safety for Process Industry) or IEC 60079 (Explosive Atmospheres) standards. It lacks the necessary Safety Integrity Level (SIL) certification and does not support redundancy, diversity, or fail-safe mechanisms. This compromises the reliability and traceability required in high-hazard oil and gas facilities like BRN.

III.5 Limitations of The Existing Fire and Gas Detection Instruments

Despite being operational, the current detection instruments installed in Train 1 are no longer adequate to meet the safety demands of a modern Fire and Gas (F&G) system. These legacy devices generally lack the advanced diagnostics, fast response times, detection accuracy, and seamless integration capabilities required in high-risk petrochemical environments. Furthermore, their limited compatibility with modern safety controllers, susceptibility to harsh environmental conditions, and inability to support predictive maintenance significantly undermine the overall effectiveness and reliability of the existing F&G system.

III.5.1 Model S4100C Combustible Gas Transmitter limitations

While the S4100C transmitter is an addressable device within the Simplex ecosystem, it suffers from several shortcomings:

- Limited Detection Range and Selectivity: The sensor typically works well with common hydrocarbons but lacks sensitivity for certain low-level gas concentrations or specific gases (e.g., H_2S or CO).

- Slow Response Time: The analog nature and lack of digital optimization result in a delay in detecting rapid leaks or dispersions.
- Calibration Drift: Over time, the sensor exhibits drift and requires frequent manual calibration, increasing maintenance demand.
- No Real-Time Diagnostics: The transmitter does not support modern diagnostic features like auto-zeroing, fault reporting, or sensor health monitoring.
- Limited Communication Protocol: It does not support modern fieldbus protocols, making integration with DCS/PLC systems complicated and limited to basic relay or 4–20 mA output. [27]

III.5.2 Thermosensitive Cable Heat Detection limitations

This detection method, based on a heat-sensitive polymer cable, also introduces several drawbacks:

- Delayed Activation: These cables only trigger alarms once a fixed high temperature is reached, meaning early-stage fires may go undetected.
- No Fault Monitoring: Cable degradation or open circuits may go unnoticed, as continuous self-diagnostics are absent.
- No Zonal Precision: A large length of cable may cover an entire area without indicating the exact location of heat buildup or fire origin.
- Poor Adaptability: Once installed, repositioning or replacing the cable is difficult and costly, making system updates challenging. [27]

III.5.3 Simplex 4089-9714 Smoke Detector limitations

This photoelectric smoke detector, though widely used, now shows several operational limitations:

- High False Alarm Rate: The detector is susceptible to dust, humidity, and process emissions common in oil and gas environments leading to nuisance alarms.
- No Addressability Outside Simplex Systems: It is not compatible with third-party systems or modern intelligent fire panels
- No Environmental Compensation: Unlike modern detectors, it lacks features like drift compensation, event logging, or dynamic sensitivity adjustment.

- Limited Maintenance Feedback: Maintenance personnel cannot assess the detector’s status remotely or in real-time, leading to inefficient servicing. [27]

III.6 Conclusion

The existing Fire and Gas system implemented in Train 1 of the BRN facility, while functional, reveals significant limitations in both architecture and instrumentation. The reliance on outdated components and legacy control systems, such as the Simplex 4100, restricts the system’s responsiveness, integration, and adaptability to current safety standards. These shortcomings highlight the urgent need for modernization to ensure a reliable, compliant, and high-performance safety infrastructure aligned with the critical demands of petrochemical operations.

Chapter IV: Modernizing the Fire and Gas System in Train 1

IV.1 Introduction

Train 1 of the BRN field, operational since 1995, continues to play a vital role in Algeria's oil and gas production infrastructure. However, the evolution of international safety standards, coupled with the emergence of modern automation technologies, necessitates a significant upgrade of its existing Fire and Gas (F&G) system. Aging detection instruments, limited diagnostics, and outdated control hardware no longer meet the reliability and responsiveness required in today's high-risk petrochemical environments.

This chapter presents a comprehensive modernization strategy aimed at enhancing the performance, flexibility, and safety of the F&G system in Train 1. The upgrade involves replacing the legacy Simplex control panel with a state-of-the-art Siemens S7-1500 Safety PLC, integrating advanced field instruments, and developing new logic programming using TIA Portal. A human-machine interface (HMI) will also be implemented to allow for real-time monitoring, intuitive alarm handling, and maintenance diagnostics.

Additionally, the new F&G system will be fully integrated with the plant's DCS, enabling seamless communication between safety and process control layers, thereby improving overall situational awareness and coordinated control.

IV.2 Upgraded Field Instruments

IV.2.1 FS24X Fire and Flame Detector

Figure IV. 1 : FS24X Fire and Flame Detector **[32]**

The FS24X is the latest generation high technology Multi-Spectrum Triple IR (IR/IR/IR/Visible) Fire and Flame Detector, which is part of FSX family of advanced technology Electro-Optical fire detectors. Using patented WideBand IR™, WideBand 4.3-micron IR™, and Visible detection technology, the FS24X is a quantum leap in flame and fire detection. Sophisticated software algorithms and dual microprocessors ensure that the FS24X has the highest fire detection performance combined with optimal false alarm rejection. The WideBand IR™ Infrared technology using high-speed solid-state Quantum sensors allows detection of all types of fires, hydrocarbon and non-hydrocarbon, in all weather conditions. If the detector's signal is blocked by ordinary window glass, the patented WideBand IR sensors will still alarm to the fire albeit at a reduced sensitivity and slower response time.

Dual microprocessors provide a high level of fail-safe operation combined with fast and reliable performance. The master microprocessor performs high-speed digital sampling and signal processing calculations, while the slave microprocessor handles various sensor data, performs communications, self-diagnostics and provides interface versatility and additional memory for storing Event Log and FirePic data. [32]

IV.2.1.1 General Specifications

Table IV. 1 : General Specification of The FS24X **[32]**

SENSITIVITY	Very high (60m), high (45m), medium (30m) and low (15m) - switch selectable
RESPONSE TIME	3-5 Seconds to 0.1 m2 (1 sq. ft.) n-Heptane fire at 30 m (100 ft.) 3-10 Seconds to 0.1 m2 (1 sq. ft.) n-Heptane fire at 60 m (200 ft.)
SPECTRAL SENSITIVITY	Visible: 400 – 700 nanometers Near Band IR: 0.7 – 1.1 microns Wide Band IR: 1.1 – 3.0 microns Wide Band IR: 3.0 – 5.0 microns
OPERATING VOLTAGE	24 Vdc nominal (18-32 Vdc) - regulated

POWER CONSUMPTION	Operating: 56 mA @ 24 Vdc nominal Alarm: 106 mA @ 24 Vdc nominal Heater: 155 mA – additional Note: Heater will turn on at -17ºC (0ºF)
OUTPUT RELAYS	Fire Alarm: SPDT (NO / NC) – De-energized/energized, latching/non-latching Fault: SPST (NO) – De-energized, latching/non-latching Auxiliary: SPDT (NO / NC) – De-energized/energized, latching/non-latching Contacts rating: 1 amp @ 24 Vdc
ANALOG OUTPUT	0 - 20 mA stepped - source or sink user selectable
LOOP RESISTANCE	50 - 400 Ohms
COMMUNICATION	One of the following – user selectable: • RS-485, ModBus Protocol • RS-485, FireBus II • RS-485 Special (optional) • HART, Optional plug-in module (not available on EN54-10 units)
VISUAL INDICATORS	Green LED: Power Red LED: Alarm Yellow LED: Fault
TEMPERATURE RANGE	Operating: 110° Field of View FS24X: -40ºC to +85ºC -(40ºF to +185ºF); 90° Field of View FS24X: -60°C to +85°C (-76°F to +185°F) Storage: -55ºC to +110ºC (-67ºF to +230ºF)
HUMIDITY RANGE	5 to 98% relative humidity, non-condensing
VIBRATION	Meets or exceeds MilSpec 810C Method 514.2, Curve AW12
WIRING	2.5 mm2 (14 AWG) to 0.326 mm2 (22 AWG); shielded cable recommended
CERTIFICATIONS	SIL Rating: FMEDA available on request

	EN54-10: FS20X certified 1175a/01 (LPCB); CPR 0832-CPR-F0515
SHIPPING WEIGHT	Aluminum: 1.6 kg (3.6 lbs.) Stainless Steel: 3.2 kg (7 lbs.)

IV.2.1.2 Principle of Operation

The FS24X flame and fire detectors operate on a 24VDC power supply, with both positive and negative lines connected in parallel across multiple units. Each detector provides dedicated relay outputs to indicate fault and alarm conditions. These outputs typically include a Normally Closed (N.C.) contact and a Common (COM) contact, allowing integration with safety systems such as PLCs or alarm panels. One of the detectors may also deliver a 4–20 mA analog output, configured in either sink or source mode, which provides a continuous signal representing the detection status or alarm level.

For optimal grounding and signal integrity, cable shields are interconnected and grounded at a single point—specifically at the power supply side—to avoid ground loops. The housings of each detector are grounded independently via external cables, and there is complete electrical isolation between the housings and the cable shields. This configuration helps ensure reliable signal transmission, electromagnetic compatibility, and intrinsic safety in hazardous environments. The system is designed for high responsiveness, delivering accurate and fast detection of flames while maintaining robust electrical performance in industrial settings. [32]

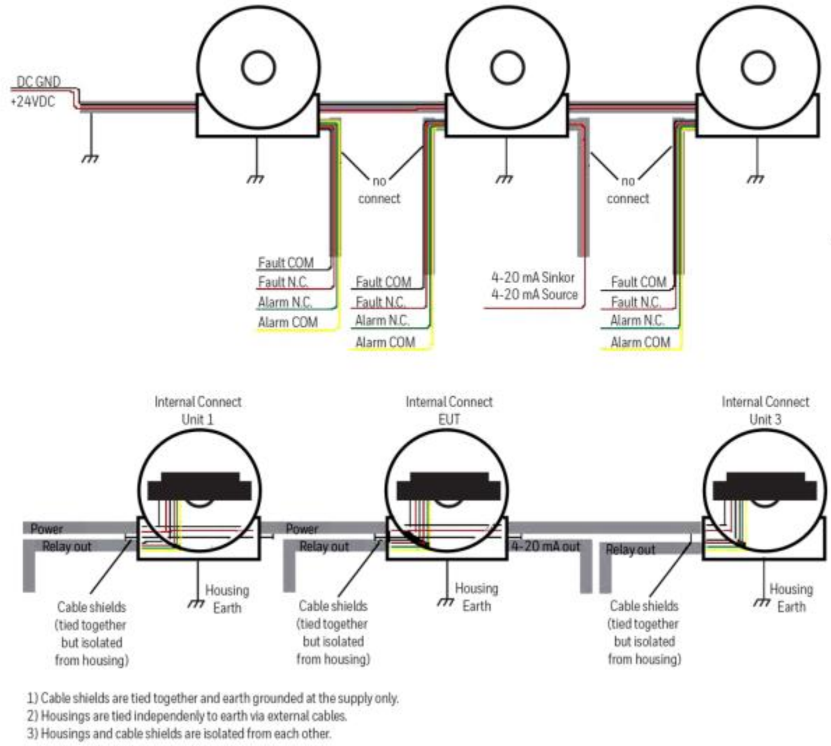


Figure IV. 2 : The FS24X Principal Operating **[32]**

IV.2.1.3 Features and Benefits

- **Features**
  - Triple IR Detection: Utilizes WideBand IR™, WideBand 4.3-micron IR™, and Visible detection technology to identify hydrocarbon and non-hydrocarbon fires in all weather conditions.
  - Long Detection Range: Detects a one square-foot Heptane fire at over 200 feet (Very High Sensitivity setting) with a wide cone of vision (110° full 100%, or 90° option available).
  - False Alarm Rejection: Sophisticated algorithms and dual microprocessors ensure optimal rejection of false alarms through Electronic Frequency Analysis™ and a Visible sensor.
  - FirePic™ Data Storage: Records pre-fire data in non-volatile flash memory for post-fire analysis, aiding in determining the fire's cause.
  - Real-Time Graphing (RTG™): Allows users to view live data the detector sees, enhancing diagnostics.

- Selectable Sensitivity: Offers four sensitivity levels (Very High, High, Medium, Low) to adapt to different environments.
- Versatile Outputs: Includes RS-485 Modbus communication, 4-20 mA analog output (sink or source), and Alarm, Fault, and Fire Verification relays.
- Rugged Design: Features a wide operating temperature range (-40°C to 85°C or -60°C to 85°C depending on the model) and is available in copper-free aluminum or 316 stainless steel enclosures with FM, ATEX, IECEx, and CE approvals.
- Self-Diagnostics: Automatic optical path and electronic self-test for reliable performance with minimal maintenance.
- Easy Installation: Plug-in terminations, two conduit entries (¾” NPT or 25mm), and a patented Electronics Module for straightforward field setup

- **Benefits**

  - Reliable Detection: Detects all fire types in challenging conditions (rain, fog, smoke), ensuring safety in diverse industrial settings like refineries, oil platforms, and chemical plants.
  - Reduced False Alarms: Advanced technology minimizes unnecessary alerts, improving operational efficiency.
  - Fewer Detectors Needed: Wide coverage area means fewer units are required compared to other detectors, lowering installation costs.
  - Enhanced Safety Analysis: FirePic™ and RTG™ provide critical data for post-event investigation, improving future safety measures.
  - Low Maintenance: Self-testing and durable design reduce upkeep, ensuring long-term, trouble-free operation.
  - Adaptability: Configurable settings and outputs make it suitable for a wide range of applications, from LNG facilities to aircraft hangars.
  - Compliance: Meets SIL 2 requirements and holds multiple certifications, ensuring it aligns with stringent safety standards. [32]

IV.2.2 Fixed Gas Detector Sensepoint XCD

Figure IV. 3 : Fixed Gas Detector Sensepoint XCD **[33]**

The Sensepoint XCD gas detector now features remote monitoring capabilities for toxic and oxygen sensors, offering enhanced flexibility in installation and application. This functionality is particularly valuable in hard-to-reach or hazardous areas, where it is preferable or necessary to separate the transmitter from the sensor. With a remote sensing range of up to 30 meters (100 feet) from the transmitter, this system provides an effective and robust monitoring solution, even in difficult or concealed locations, such as high ceilings, subfloors, or outside rooms under surveillance. One of the key advantages of the Sensepoint XCD is its user-friendly and efficient design. The sensor connects easily to the base of the transmitter, and the system automatically configures itself upon connection. Furthermore, configuration and maintenance are streamlined thanks to the LCD display and magnetic switches, which allow for non-intrusive, one-person operation. This greatly reduces maintenance time and costs, making it an ideal choice for modernized gas detection systems in industrial environments. [33]

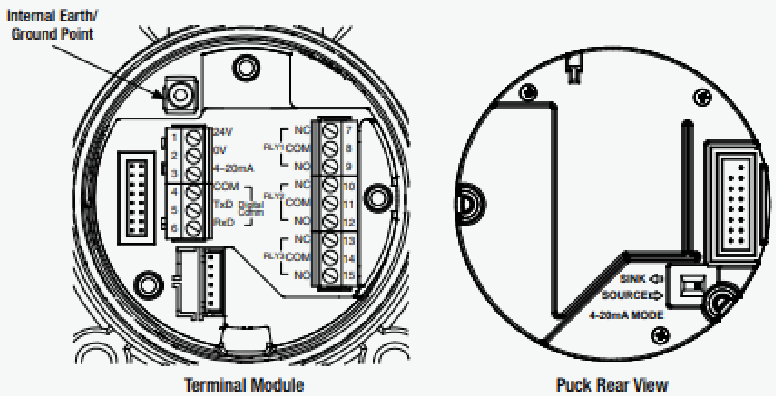
IV.2.2.1 General Specifications

Table IV. 2 : General Specifications of The Sensepoint XCD **[33]**

Use	3 wire, 4-20mA and RS485 MODBUS output fixed point detector with in-built alarm and fault relays for the protection of personnel and plant from flammable, toxic and Oxygen hazards. Incorporating a transmitter with local display and fully configurable via non-intrusive magnetic switch interface. Wide range of sensors available
Electrical	Input Voltage Range: 16 to 32VDC (24VDC nominal) for ATEX/IECEx/AP Versions 12 to 32VDC (24VDC nominal) for UL/CSA version
Material	Housing: Epoxy painted aluminum alloy LM25 or 316 stainless steels Sensor: 316 stainless steels Weather Protection: Plastic
Weight	Aluminium Alloy LM25: 2.0kg (4.4lbs) 316 Stainless Steel: 5.0kg (11lbs)
Mounting	Integral mounting plate with 4 x mounting holes suitable for M8 bolts Optional pipe mounting kit for horizontal or vertical pipe Ø1.5 to 3" (2" nominal)
Certified Temperature Range	-40ºC to +75ºC (-40ºF to +167ºF)
Operating Humidity	Continuous 20-90%RH (non-condensing), Intermittent 10-99%RH (non-condensing)
Operating Pressure	90-110kPa (EC Toxic Sensors), 80-12kPa (EC Oxygen, Catalytic Bead and Infrared Sensors)
Storage Conditions	-25°C to +65°C (-13°F to 131°F)

IV.2.2.2 Electrical and Wiring Schematics

Terminal Module Connections			
Terminal Number	**Marking**	**Connection**	**Description**
1	24V	+V Supply	Controller Connections
2	0V	-V Supply (0VDC)	
3	4~20mA	Current Output Signal	
4	COM	Drain	MODBUS RTU. RS485 (Optional)
5	TxD	MODBUS B (+)	
6	RxD	MODBUS A (-)	
7	RLY1/NC	Normally Closed	Programmable Relay 1 (Default A1)
8	RLY1/COM	Common	
9	RLY1/NO	Normally Open	
10	RLY2/NC	Normally Closed	Programmable Relay 2 (Default A2)
11	RLY2/COM	Common	
12	RLY2/NO	Normally Open	
13	RLY3/NC	Normally Closed	Programmable Relay 3 (Default Fault)
14	RLY3/COM	Common	
15	RLY3/NO	Normally Open	



Note: Terminal Blocks are plug/socket type and may be removed to ease wiring.

Figure IV. 4 : Electrical and wiring schematics **[33]**

Sensepoint XCD is designed for use in potentially explosive atmospheres. As such, installation should follow national guidelines using suitable mechanically protected cable and glands or conduit. Use 0.5mm2 (20AWG) to 2.5mm2 (~13AWG) cross sectional area cable as needed to ensure minimum operating voltage at the detector, depending on installed cable length. Cable diameter should be selected to maintain the minimum required voltage for the longest installed cable length under maximum power. The Sensepoint XCD transmitter may be wired in either Current Sink or Current Source configuration. These two options are offered to allow greater flexibility in the type of control system that it can be used with. Sink/Source is selectable via the switch located on the back side of the display module; accessible by removing the display module during installation/ commissioning. [33]

IV.2.2.3 Features and Benefits

- **Features**
  - Versatile Gas Detection: Monitors flammable gases (0-100% LEL), toxic gases (e.g., CO, H2S, NO2), and oxygen levels (0-25% v/v) using catalytic, infrared (IR), or electrochemical (EC) sensors.
  - Remote Monitoring: Supports remote sensor mounting up to 100 feet (30m) from the transmitter, ideal for hard-to-reach or high-temperature areas (up to 150°C/302°F).
  - Tri-Color Backlit LCD: Displays status with green (normal), yellow (fault), and red (alarm) colors, visible from a distance for quick assessment.
  - Non-Intrusive Operation: Adjustable via LCD and magnet switches without opening the unit, enabling one-person maintenance and reducing downtime.
  - Pre-Configured Outputs: Includes two programmable alarm relays, one fault relay, a 4-20mA output (sink or source selectable), and Modbus communication.
  - Robust Design: Available in stainless steel or aluminum explosion-proof housing, suitable for hazardous areas with ATEX/IECEx approvals.
  - Easy Installation: Plug-and-play sensor design with automatic configuration, integral mounting plate, and versatile wiring options (M20 or 3/4" NPT entries).
- **Benefits**
  - Enhanced Safety: Comprehensive monitoring reduces risks of gas leaks in explosive environments, protecting personnel and property.
  - Cost Efficiency: Minimizes maintenance costs with poison-resistant sensors, non-intrusive adjustments, and long service life.
  - Flexibility: Remote mounting and configurable settings adapt to various industrial applications, including confined or outdoor spaces.

- Reliability: Tri-color display and built-in diagnostics (e.g., Reflex Sensor health check) ensure consistent performance and early fault detection.
- Time Savings: Quick installation and maintenance without hot work permits streamline operations. [33]

IV.2.3 The FSP-951 Smoke Detector

The FSP-951 is a high-performance, addressable photoelectric smoke detector from System Sensor, designed to provide advanced fire detection for critical environments such as industrial plants, oil and gas facilities, and petrochemical installations. When integrated with a relay module, it becomes compatible with PLC-based systems, such as the Siemens S7-1200, enabling reliable signal communication between the detector and the automation system. The detector operates by using an optical sensing chamber to detect the presence of smoke particles, ensuring early warning of fire conditions while minimizing false alarms. The relay module provides dry contact outputs, allowing direct interface with PLC digital inputs for control and signaling logic. [34]

Figure IV. 5 : The FSP-951 Smoke Detector **[34]**

IV.2.3.1 Operating Principle of FSP-951 Smoke Detector

The FSP-951 photoelectric smoke detector, when paired with a relay base such as the B224RB, enables seamless integration with PLC-based safety systems. The detector operates on the principle of light scattering: when smoke particles enter the sensing chamber, they scatter a beam of infrared light, triggering the internal relay once a set concentration is reached. In our project setup, the output status of the detector is monitored by a Siemens PLC through a resistor-based detection logic. Specifically, the relay output is wired in such a way that each operating state (normal, alarm, or fault) corresponds to a distinct resistance value. Under normal conditions, the relay maintains a closed path with low resistance. When smoke is detected, the relay switches to a path that includes a higher resistance, which the PLC interprets as an alarm condition. In case of a fault—such as a wiring break, loss of power, or detector failure—the circuit presents infinite resistance or open-loop, allowing the PLC to detect the anomaly as a fault condition. This method ensures continuous monitoring and reliable status feedback using only analog inputs to read voltage variations across the resistor network, offering a cost-effective and fail-safe solution for industrial fire detection. [34]

IV.2.3.2 Features and Benefits

- **Features**
  - Photoelectric (optical) smoke detection for accurate and early detection of slow smoldering fires.
  - Intelligent addressable communication when used with compatible fire control panels.
  - Compatible with System Sensor relay bases to output a dry contact signal.
  - 360° visible LED for status indication (alarm, standby, trouble).
  - Advanced drift compensation and maintenance alert features to reduce false alarms and ensure optimal performance.
  - Low-profile design for compact installation.
  - Plug-in design with minimal intrusion into room space.
  - Compatible relay base (e.g., B224RB or B224BI) provides Form C contacts that can be read by PLCs.
- **Benefits**
  - PLC Integration: When paired with a relay base, the FSP-951 becomes suitable for direct interfacing with a Siemens S7-1200 PLC, enabling full control and automation via digital inputs.
  - Fast and Reliable Detection: The optical sensing method ensures early warning with low risk of false alarms — ideal for industrial environments.

- Maintenance-Friendly: Built-in drift compensation and sensitivity testing help reduce the frequency of manual maintenance and calibration.
- Modular and Scalable: Can be used in large systems with multiple detectors communicating with the central fire panel or independently through relays.
- Industrial Durability: Designed to function reliably in demanding environments like refineries, compressor stations, and control rooms.
- Visual Feedback: 360° LED ring gives real-time status information for easier field inspection and system monitoring. [34]

IV.3 Selection of The New Control System

IV.3.1 Overview of The Siemens S7-1500 F PLC

Figure IV. 6 : The Siemens S7-1500 F PLC **[35]**

The Siemens S7-1500 F Safety PLC is a high-performance, fail-safe programmable logic controller designed for applications requiring stringent functional safety, such as Fire & Gas (F&G) systems in industrial environments. It integrates standard and safety automation in a single platform, certified according to IEC 61508 up to SIL 3 and ISO 13849-1 up to PL e, ensuring robust protection in safety-critical processes. The S7-1500

F offers seamless integration with Siemens' TIA Portal engineering environment, allowing for unified development, diagnostics, and maintenance of both safety and standard logic. It supports a wide range of fail-safe I/O modules, including F-DI, F-DO, and F-AI, making it suitable for both discrete and analog safety signals. Equipped with advanced features such as integrated system diagnostics, deterministic real-time behavior, and PROFIsafe communication, the S7-1500 F ensures rapid response to faults, secure data handling, and modular scalability. Its robust design and powerful processing capabilities make it a reliable and efficient solution for modern industrial safety automation, particularly in hazardous environments like oil and gas facilities. [35]

IV.3.2 Safety Features and Functional Capabilities

The Siemens S7-1500 F Safety PLC is an advanced programmable logic controller specifically designed for use in applications requiring high levels of functional safety, such as Fire and Gas (F&G) detection systems, emergency shutdown systems (ESD), and burner management systems (BMS). It is fully compliant with IEC 61508 and ISO 13849-1 standards, enabling safety integrity levels up to SIL 3 and Performance Level e (PL e). The system integrates both standard and fail-safe automation within a single engineering environment, the TIA Portal, simplifying programming and maintenance tasks. The S7-1500 F supports fail-safe digital and analog I/O modules, including F-DI (Fail-safe Digital Input), F-DO (Fail-safe Digital Output), and F-AI (Fail-safe Analog Input) for monitoring and controlling a wide range of safety-relevant field devices, such as smoke detectors, gas sensors, flame detectors, emergency push buttons, and sirens.

One of its standout features is PROFIsafe communication over PROFINET, ensuring secure and deterministic data exchange between controllers and remote I/O stations in a safety network. The S7-1500 F has built-in redundancy mechanisms, such as monitoring of input signal plausibility, self-diagnostics, watchdog timers, and error-checking routines, all of which help detect and respond to potential faults in real time. This minimizes downtime and enhances system availability. Safety logic is processed using F-Blocks (pre-certified function blocks), ensuring correct implementation of safety functions like Emergency Stop (E-Stop), two-hand control, and speed monitoring.

Security is reinforced with features like access control, code integrity checks, password-protected access levels, and integrated firewall options, providing a high degree of cybersecurity in addition to functional safety. The system also includes real-time diagnostics and integrated web server functionality for remote monitoring and maintenance, reducing commissioning time and simplifying troubleshooting. Thanks to its modularity, the S7-1500 F can be easily scaled and adapted to various plant sizes and configurations, making it a powerful, future-ready solution for safety-critical applications in the petrochemical, energy, and manufacturing sectors. [35]

IV.4 Presentation of TIA Portal V17

TIA Portal (Totally Integrated Automation Portal) V17 is Siemens' advanced engineering framework that unifies all automation tasks in a single, intuitive interface. It allows for the seamless integration and configuration of PLCs, HMIs, drives, and safety systems, drastically reducing engineering time and minimizing errors. TIA Portal V17 supports multiple programming languages including Ladder (LAD), Function Block Diagram (FBD), and Structured Text (STL), and features powerful diagnostic tools, real-time monitoring, and version management. The platform enhances productivity through reusable libraries, hardware simulation, and efficient project structuring. With the support of Siemens S7-1200 and S7-1500 series, including their fail-safe (F) variants, TIA Portal V17 becomes a central tool for developing both standard and safety-related automation applications.

In the context of safety-critical environments such as Fire & Gas (F&G) systems, TIA Portal V17 plays a pivotal role. It supports the configuration and programming of fail-safe logic using dedicated safety blocks (F-blocks), ensuring compliance with international safety standards such as IEC 61508 and SIL 2/3. Through the Safety Administration Editor, engineers can configure safety I/O modules (F-DI, F-DO), define safety functions, and enforce password-protected access to safety logic. For Fire & Gas systems, where reliable detection and rapid response to hazardous conditions are vital, TIA Portal V17 ensures accurate signal processing from flame, gas, and smoke detectors, efficient alarm management, and secure shutdown procedures. The ability to simulate, test, and validate safety logic before deployment significantly increases system reliability and operator safety in high-risk zones. [36]

Figure IV. 7 : TIA Portal V17 **[36]**

IV.4.1 Creation a New Project in TIA Portal V17

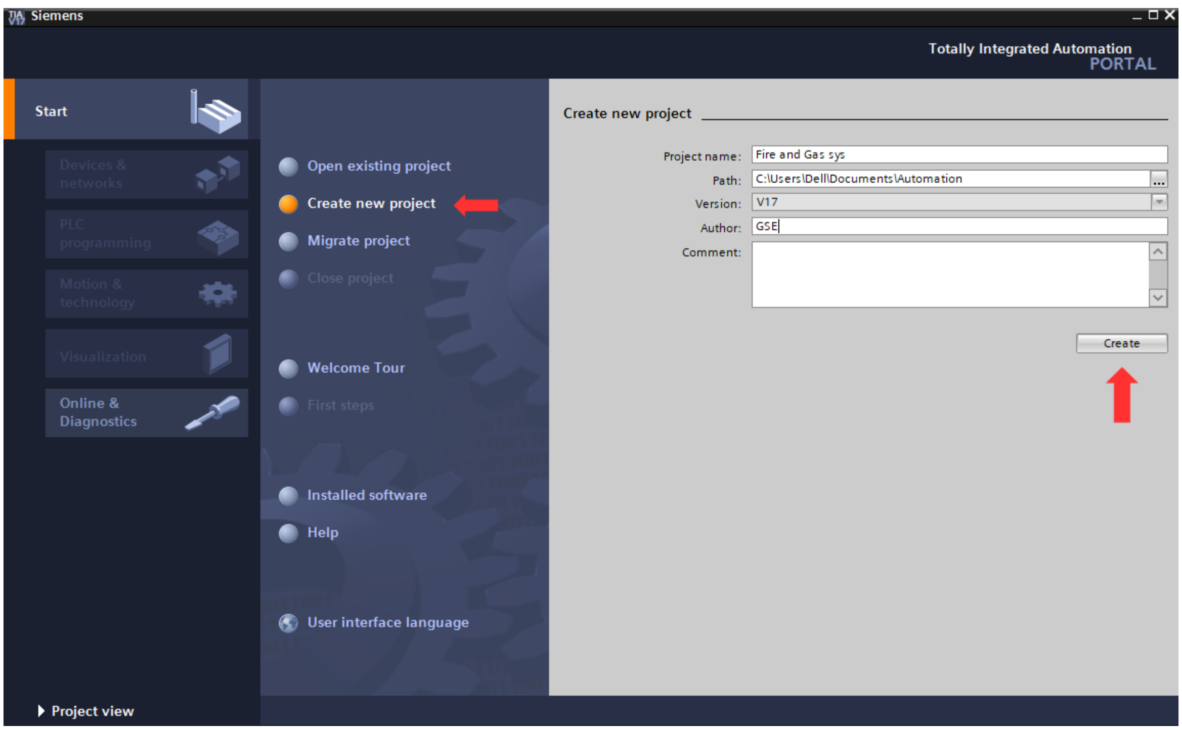


Figure IV. 8 : Create a new project in TIA portal V17 **[36]**

To create a new project in TIA Portal V17, the user begins by launching the software and selecting the "Create new project" option from the start screen. A project name, description, and storage location are specified before proceeding.

IV.4.2 Hardware Configuration

IV.4.2.1 The CPU 1516F-3 PN/DP

Figure IV. 9 : The CPU 1516F-3 PN/DP **[37]**

The Siemens CPU 1516F-3 PN/DP is a high-performance fail-safe CPU from the SIMATIC S7-1500 F family, specifically designed for safety-related applications requiring a high level of reliability, redundancy, and processing speed. This CPU supports both standard and safety programs in a single system and complies with IEC 61508 for use in SIL 3 / PL e safety applications. It features three integrated PROFINET ports and one PROFIBUS DP master/slave interface, enabling communication with up to 128 PROFINET I/O devices and a wide range of distributed and centralized configurations. The CPU offers 1.5 MB of user program memory and 5 MB of data memory, with an extremely fast bit performance of 1 ns per instruction, making it suitable for real-time fire and gas safety logic.

It integrates PROFIsafe protocol natively, allowing safe communication over standard Ethernet with fail-safe I/O modules. The CPU supports isochronous communication, integrated diagnostics, trace functions, and a web server for online monitoring and troubleshooting. It also includes configuration control (option handling) and motion control functions, although the latter is not needed for this project. Its modular, rack-mounted architecture ensures flexibility and scalability, while its built-in security mechanisms protect against unauthorized access and data manipulation. [37]

IV.4.2.2 Fail-Safe Digital Input Module F-DI 16x24V DC HF

Figure IV. 10 : Fail-Safe Digital Input Module F-DI 16x24V DC HF **[38]**

The F-DI 16x24V DC HF is a Fail-Safe Digital Input module from the SIMATIC S7-1500 series, engineered for use in safety-critical applications such as Fire & Gas (F&G) systems. It offers 16 fail-safe digital inputs operating at 24V DC, with built-in support for SIL 3 / PL e safety standards. This module supports advanced diagnostic functions and is designed to work within redundant architectures, allowing for dual-channel input configurations where necessary. Such redundancy ensures high system availability and fault tolerance, which are essential in applications where failure of a single input channel could compromise personnel or plant safety. The module is ideal for systems requiring robust input monitoring, especially in hazardous environments. [38]

- **Technical Overview**
  - Input Channels: 16 isolated fail-safe inputs
  - Part Number: 6ES7526-1BH00-0AB0
  - Rated Input Voltage: 24V DC
  - Input Delay: Configurable (default ~3.2 ms)
  - Input Type: Positive logic (sourcing)
  - Current per channel: approx. 6 mA
  - Isolation: Channel-to-channel and to backplane
  - Status LEDs: Channel diagnostics, group error
  - Diagnostics: Short-circuit, wire break, parameter errors
  - Safety Compliance: SIL 3 (IEC 61508) and PL e / Cat. 4 (ISO 13849-1)
  - Dimensions: 35 mm wide (standard S7-1500 form factor)
- **Features and Benefits**
  - High-frequency (HF) model with fast diagnostics and parameterization
  - Fully integrated with TIA Portal for simple configuration and testing
  - Supports both centralized (rack-mounted) and distributed (ET 200MP) configurations
  - Ideal for connecting safety sensors, such as flame detectors, gas detectors (via relay), emergency buttons, and manual call points
  - Advanced diagnostics for rapid fault localization and system availability
  - Enables creation of safety-related logic using F-Blocks in TIA Portal [38]

IV.4.2.3 Fail-Safe Digital output Module F-DO 8x24V DC/2A HF

The F-DO 8x24V DC/2A HF is a fail-safe digital output module from the Siemens S7-1500 F series, specifically engineered for safety-critical control tasks in applications rated up to SIL 3 (IEC 61508) and PL e (ISO 13849-1). It features 8 isolated fail-safe outputs, each capable of switching 24V DC at up to 2A, making it suitable for controlling alarms, sirens, beacons, shut-off valves, and other emergency systems within Fire & Gas (F&G) safety architectures. The module supports integration into redundant control systems, allowing for dual-channel output configurations where enhanced availability, reliability, and fault tolerance are required. This ensures continued safe operation even in the event of a fault, which is essential for maintaining high safety integrity in hazardous industrial environments. [39]

- **Technical Overview**
  - Type: Fail-Safe Digital Output Module (F-DO)
  - Channels: 8 outputs
  - Voltage: 24 V DC
  - Output current: 2 A per channel
  - Safety compliance: SIL 3 (IEC 61508) and PL e (ISO 13849-1)
  - Diagnostics: Channel-specific diagnostics, Open-load detection and Short-circuit protection
  - Switching type: Electronically controlled
  - Mounting: Centralized (for S7-1500 rack)
  - Width: 35 mm
  - Electrical isolation: Yes, between channels and system
- **Features and Benefits**
  - Supports high-reliability safety outputs for critical applications like Fire & Gas systems
  - Can drive actuators, sounders, alarms, and indicators
  - Short-circuit and open-circuit diagnostics improve system safety and maintenance
  - Compact design allows for efficient panel integration
  - Integrates with TIA Portal for seamless configuration and monitoring
  - Electrical isolation ensures safe signal separation [39]

IV.4.2.4 Analog Input Module AI 8xU/I/RTD/TC ST

This is a standard analog input module from the SIMATIC S7-1500 series (6ES7531-7KF00-0AB0), offering versatile signal acquisition capabilities. It supports a wide range of input signal types such as voltage, current. [40]

- **Technical Overview**
  - 8 analog inputs in a single module.
  - Supports : Voltage : ±10V, 0–10V, 1–5V and Current : 0–20 mA, 4–20 mA

- Resolution: Up to 16 bits for high accuracy.
- Diagnostic functions for broken wire or sensor failure.
- Standard module – not fail-safe, but usable for monitoring purposes in an F&G system (gas levels). [40]

Figure IV. 11 : Analog Input Module AI 8xU/I/RTD/TC ST **[40]**

IV.4.2.5 The Power Supply PS 60W 120/230V AC/DC

Figure IV. 12 : PS 60W 120/230V AC/DC **[41]**

The PS 60W 120/230V AC/DC (6ES7507-0RA00-0AA0) is a standard power supply module from the SIMATIC S7-1500 series, engineered to provide stable and regulated 24 V DC power to the CPU, I/O modules, and other essential components in a centralized rack-mounted control system. With an output capacity of 60 watts and 2.5 A, it is suitable for powering small to medium-scale automation architectures, including safety-critical applications such as Fire & Gas (F&G) systems. The module offers reliable power delivery with built-in protection against overloads and short circuits and mounts directly on the S7-1500 backplane for compact cabinet integration.

However, in high-availability safety systems, especially those governed by SIL 2 or SIL 3 requirements, a single power source presents a single point of failure. For this reason, the PS 60W module should be deployed in a redundant power configuration—typically by pairing two identical units with a redundancy module or diode isolation—to ensure continuous operation even in the event of a power module failure. This redundant setup is essential in F&G systems where uninterrupted power to the fail-safe PLC and field devices is critical for maintaining system integrity, alarm response, and emergency shutdown functionality during fault or hazard conditions. [41]

IV.4.2.6 PC System with WinCC Advanced

In addition to the safety PLC and field instrumentation, a PC station is configured as a centralized HMI system using WinCC Advanced. This PC system is connected to the same PROFINET network as the CPU 1516F-3 PN/DP and is responsible for visualizing the status of gas, smoke, and flame detectors, as well as providing real-time access to alarms, logs, and diagnostics.

The PC station allows operators to interact with the system through animated graphical pages, alarm pop-ups, and status indicators. Furthermore, it provides supervisory functionality for safety shutdown actions (ESD), zone isolation, and fault tracking, which are crucial in a Fire & Gas environment. [42]

- **Technical Overview**
  - PC Station: Industrial or engineering PC, with WinCC Advanced installed.
  - Communication: Connected via PROFINET to the S7-1500 F CPU.

- Role: HMI interface for F&G detector statusAlarm display and acknowledgment System diagnostics Maintenance interface
- TIA Portal Integration: The PC station and PLC project are developed in a unified environment, enabling synchronized tag management, alarms, and system testing.
- Redundancy Option (optional): For high-availability applications, the HMI PC can be duplicated or virtualized with backup failover. [42]

IV.4.3. Software Configuration

IV.4.3.1. User Program Blocks

In the Siemens S7-1500 F Safety PLC, program structure is modular and based on three main types of logic blocks: Organizational Blocks (OBs), Function Blocks (FBs), and Functions (FCs). These elements are fundamental in designing structured, reusable, and deterministic control logic, especially in safety-critical systems such as Fire & Gas (F&G) architectures.

- **Organizational Blocks (OB)**

Organizational Blocks serve as the entry points for the PLC execution cycle. The most commonly used OB in safety and standard applications is OB1, which acts as the main cyclic program block where all control logic is called. Additional OBs, such as OB35 (cyclic interrupt) or OB100 (startup), can be used for time-critical or startup-specific tasks. In safety systems, special F-OBs (like F-OB1) handle fail-safe routines and ensure that safety-relevant code is executed with the necessary reliability and diagnostics. [43]

- **Function Blocks (FB)**

Function Blocks are reusable code blocks that maintain their own memory using Instance Data Blocks (IDBs). They are ideal for programming modular and safety-critical components, such as gas detector processing, flame detector logic, or siren control. Each detector or actuator group can have its dedicated FB for encapsulating input evaluation, threshold comparisons, fault detection, and actuation logic, enhancing both modularity and maintainability. When safety logic is involved, F-FBs are used, which are certified to meet SIL 2 or SIL 3 standards. These are programmed using F-Logic inside the TIA Portal Safety Advanced environment. [43]

- **Functions (FC)**

Functions are similar to FBs but do not retain internal memory. They are useful for stateless operations, such as signal conversions, limit checking, or mathematical calculations. FCs are typically used within FBs or OBs for supporting utility tasks. [43]

IV.4.3.2. SCALE_X (Scale) and NORM_X (Normalize) Instructions

In the implementation of the Fire & Gas (F&G) system logic using the Siemens S7-1500 F (Fail-Safe) PLC, the standard Siemens function blocks NormX and ScaleX were employed for signal conditioning and analog value conversion. The NormX block was used to normalize raw analog input values (e.g., from 4–20 mA transmitters) into a 0.0 to 1.0 scale. This normalized signal was then passed to the ScaleX block to convert it into engineering units (such as °C, %LEL, or ppm), depending on the type of detector (e.g., gas sensor or temperature sensor). This two-step conversion process ensured that all analog values were accurately interpreted by the PLC program, regardless of the source sensor's range. This structure provided both clarity and modularity across different detection zones and alarm conditions, contributing to a robust and maintainable control architecture. [44]

Table IV. 3 : SCALE_X and NORM_X Instructions **[44]**

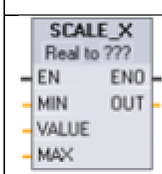
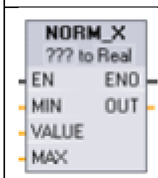
LAD	Description
	Scales the normalized real parameter VALUE where (0.0 <= VALUE <= 1.0) in the data type and value range specified by the MIN and MAX parameters: OUT = VALUE (MAX - MIN) + MIN
	Normalizes the parameter VALUE inside the value range specified by the MIN and MAX parameters: OUT = (VALUE - MIN) / (MAX - MIN), where (0.0 <= OUT <= 1.0)

Table IV. 4 : Data types for the parameters **[44]**

Parameter	Data Type	Description
MIN	SInt, Int, DInt, USInt, UInt, UDInt, Real, LReal	Input minimum value for range
VALUE	SCALE_X: Real, LReal NORM_X: SInt, Int, DInt, USInt, UInt, UDInt, Real, LReal	Input value to scale or normalize
MAX	SInt, Int, DInt, USInt, UInt, UDInt, Real, LReal	Input maximum value for range
OUT	SCALE_X: SInt, Int, DInt, USInt, UInt, UDInt, Real, LReal NORM_X: Real, LReal	Scaled or normalized output value

IV.5. Programming of the New F&G System

The programming of the Fire and Gas (F&G) system was carried out using Ladder Logic (LAD) within the TIA Portal environment. This graphical language was selected due to its simplicity, reliability, and suitability for safety-critical applications. The system covers two key areas: the compression zone, which includes gas and flame detection around critical equipment such as the Knock-Out (KO) drums, and the technical room, which is equipped with gas detection at the HVAC air intake as well as fire detection.

IV.5.1. Gas Detection Threshold Logic

The gas detectors installed in the system provide an analog signal represented in digital format, with a minimum raw value of 655 and a maximum value of 3672. These values are first normalized using a linear scaling function (NormX) in TIA Portal, converting the raw signal to a corresponding percentage value from 0% to 100%, representing the gas concentration. Based on this scaled value, the system applies defined thresholds to generate alarms. A value greater than or equal to 20% LEL triggers a High (H) alarm, while a value greater than or equal to 50% LEL triggers a High-High (HH) alarm, indicating a critical gas presence. In addition, a diagnostic fault is registered if the signal is less than or equal to 655 or greater than or equal to 3672, which may indicate a disconnected or faulty sensor. This logic ensures both accurate detection and reliable fault monitoring for safety-critical operations. This entire logic is implemented within a Function Block (FB) to ensure modular, reusable, and organized programming.

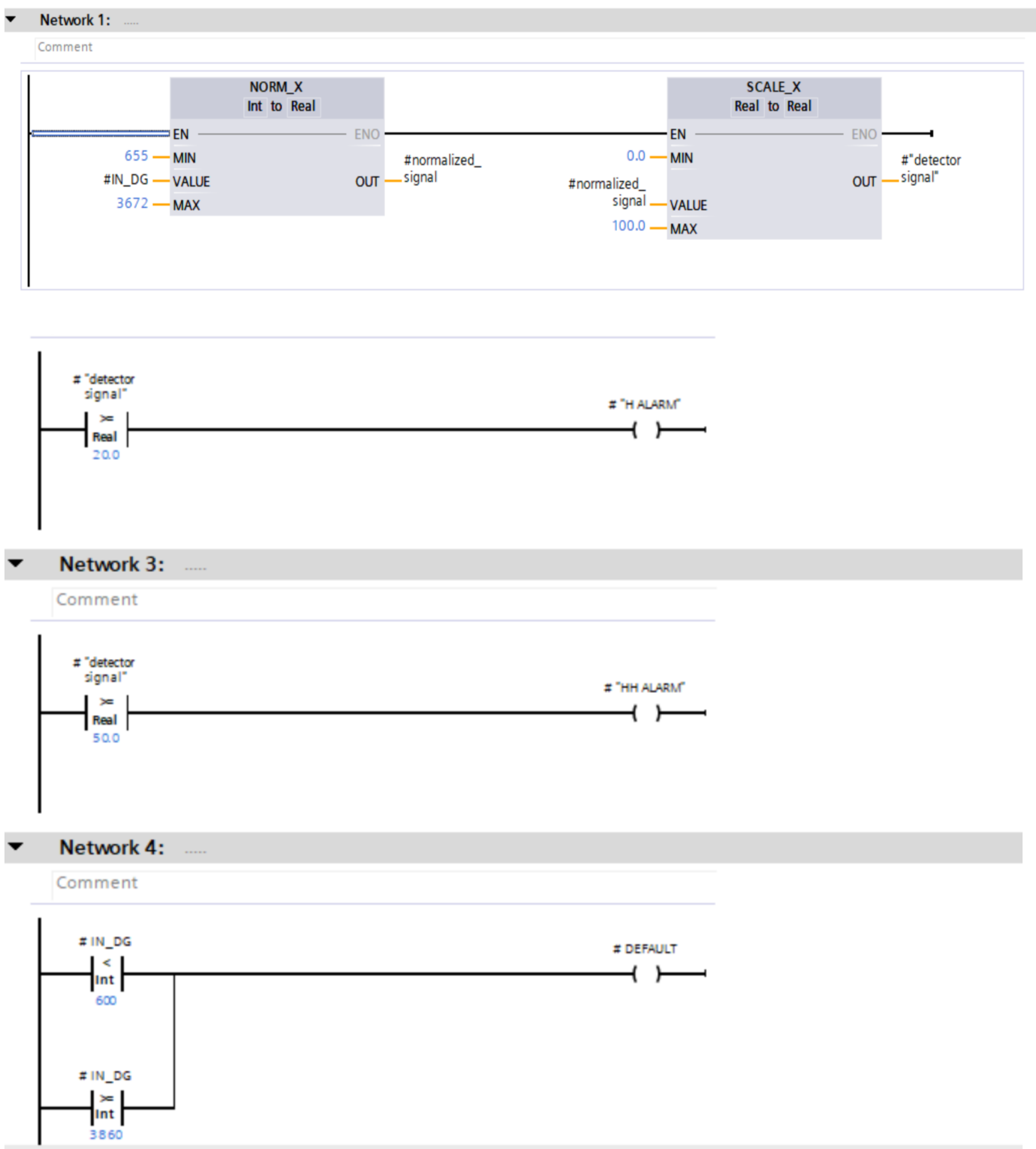


Figure IV. 13: Gas Detectors Threshold Logic

IV.5.1.1. Gas Detection in the Compression Zone 023

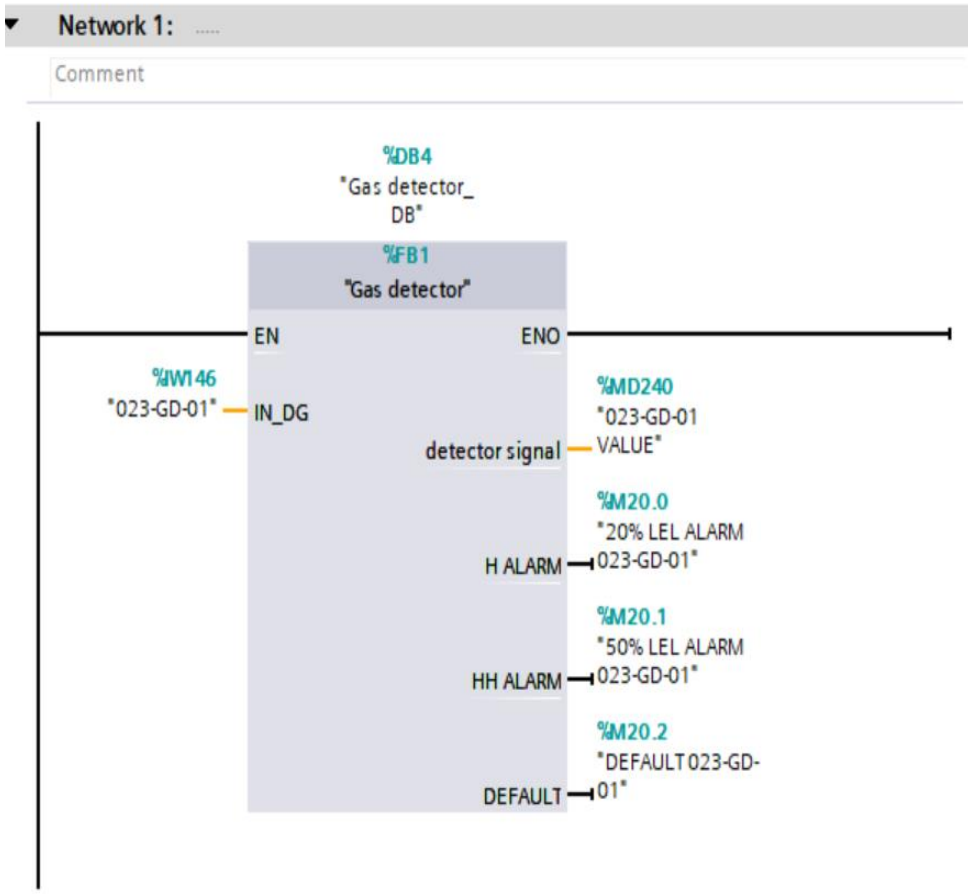


Figure IV. 14: Gas Detector Block in Compression Zone

- **Ko Drums 2oo3 Voting Block**

In the KO Drums area, gas detection is carried out using three independent gas detectors interfaced with the PLC. To enhance system reliability and safety, a 2-out-of-3 (2oo3) voting logic is implemented. This logic ensures that an alarm is only triggered when at least two detectors simultaneously detect a gas concentration that exceeds the predefined threshold. By requiring confirmation from multiple detectors, this approach minimizes the risk of false alarms caused by individual sensor malfunction or noise, while ensuring a high level of detection reliability in a critical zone such as the KO Drums.

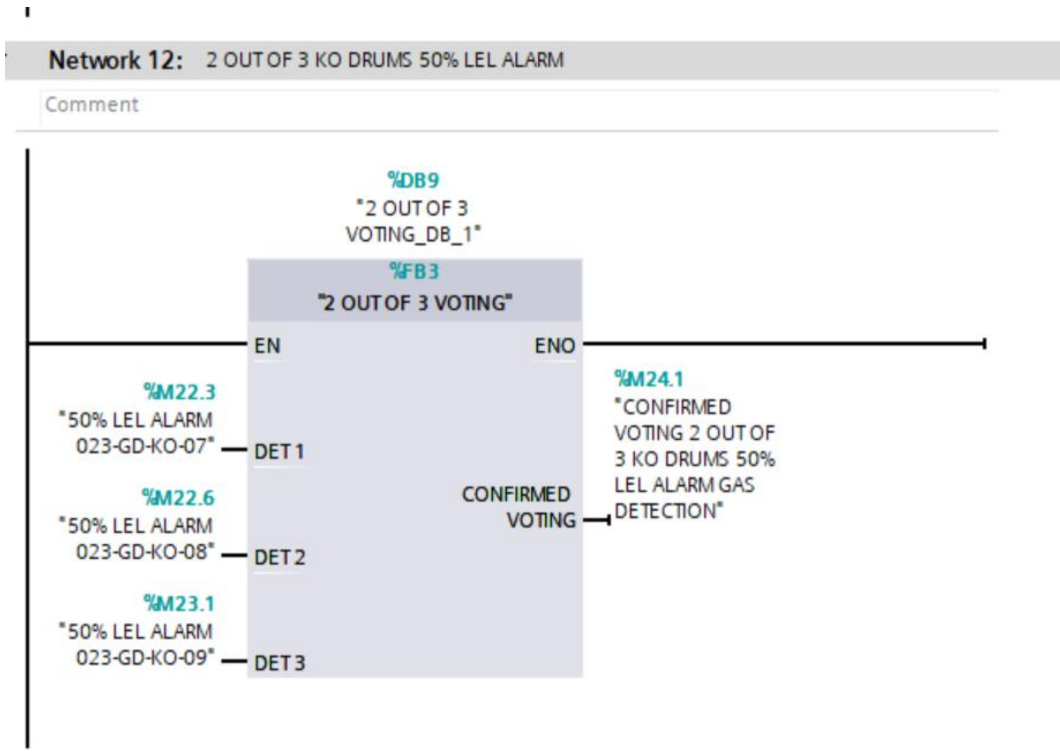


Figure IV. 15: 2oo3 Ko Drums Detectors Voting Block

- **Compressors 2oo6 Voting Block**

In the compressors area which contains three compressors (LP, MP, HP), gas detection is ensured through six strategically placed gas detectors connected to the PLC. To maintain a high level of fault tolerance and avoid false positives, a 2-out-of-6 (2oo6) voting logic is implemented. This configuration requires that at least two detectors simultaneously detect a gas concentration above the defined threshold in order to trigger an alarm. The use of 2oo6 logic increases the reliability of the detection system by confirming the presence of gas through multiple independent sources, reducing the likelihood of triggering alarms due to a single sensor anomaly.

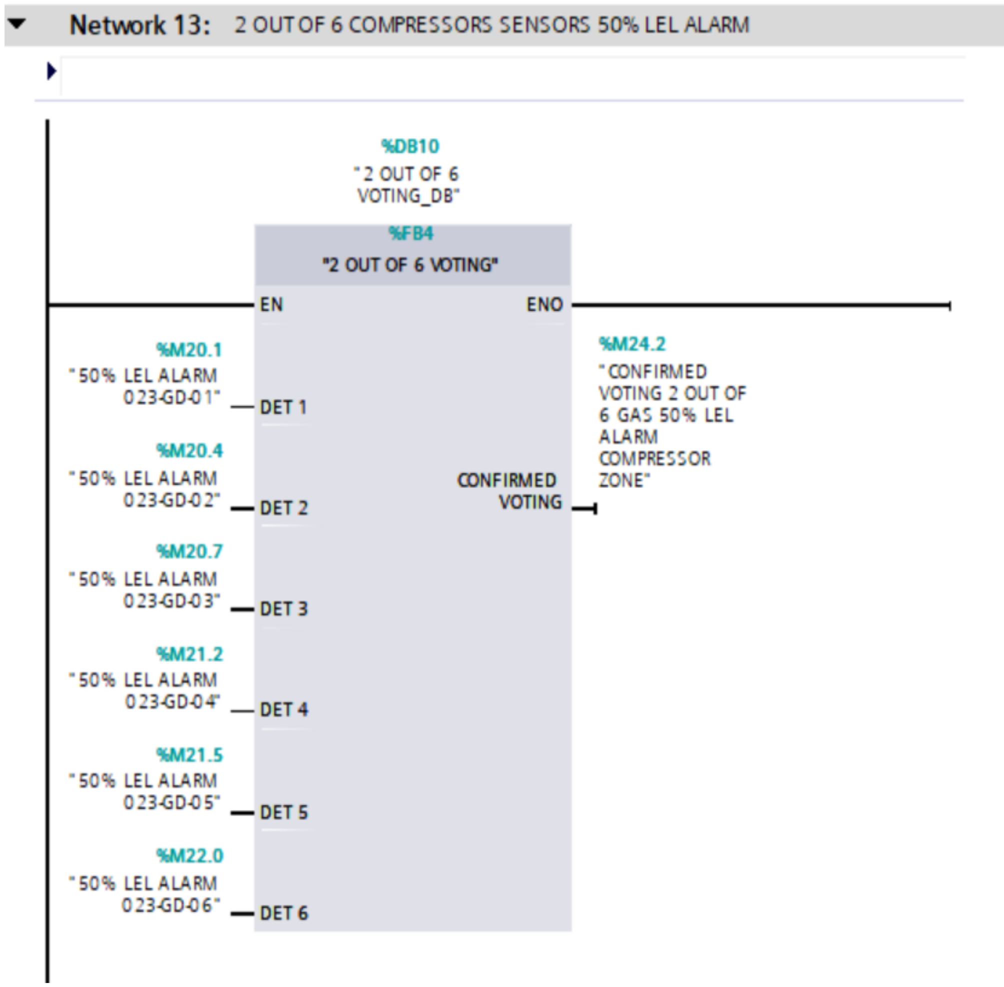


Figure IV. 16: Compressors 2oo6 Voting Block

IV.5.1.2. Gas Detection in the Technical Room 022

- **HVAC Intake 2oo3 Voting Block**

In the technical room, gas detection is implemented at the HVAC air intake to prevent the entry of flammable or toxic gases into the ventilation system. The setup includes three gas detectors, and a 2-out-of-3 (2oo3) voting logic is applied to enhance reliability and reduce false alarms. An alarm is triggered only when at least two detectors simultaneously detect the presence of gas. In addition, the system monitors for diagnostic faults, which are registered when the detector signals fall outside of the valid operating range. This entire logic is implemented in a Function Block (FB) to ensure clarity, modularity, and efficient reuse in the overall PLC program.

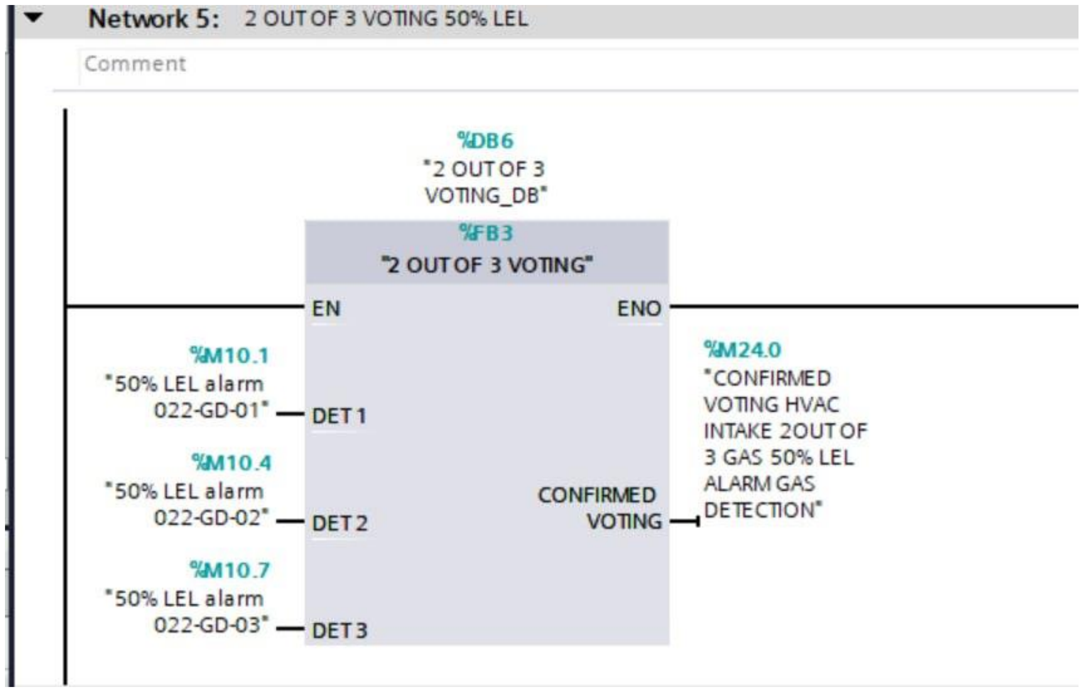
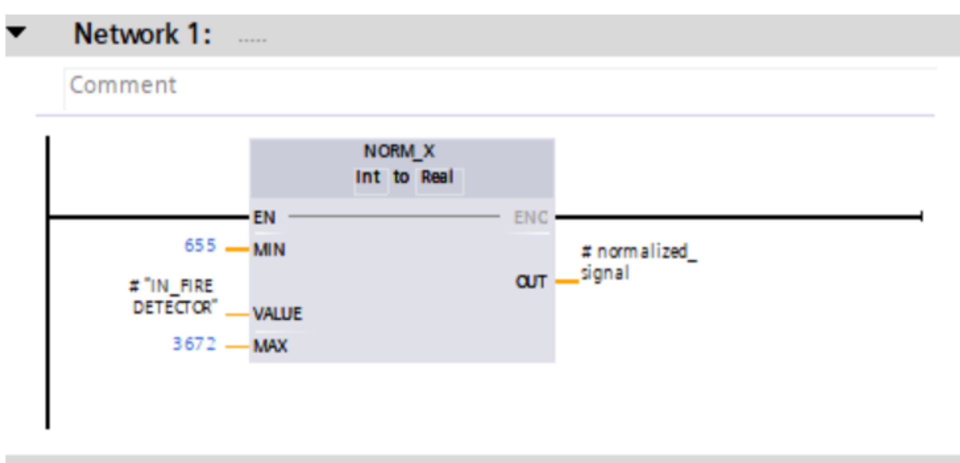


Figure IV. 17: HVAC Intake 2oo3 Voting Block

IV.5.2. Fire detection Threshold Logic

The raw analog signals from the detectors range between 655 and 3672, and are normalized using the NormX function in TIA Portal. A fire alarm is triggered when the normalized signal exceeds 1000, while a diagnostic fault is registered if the raw signal is less than or equal to 655 or greater than or equal to 3672, indicating a potential sensor failure. This logic is implemented within a Function Block (FB) to maintain modularity, scalability, and structured programming.



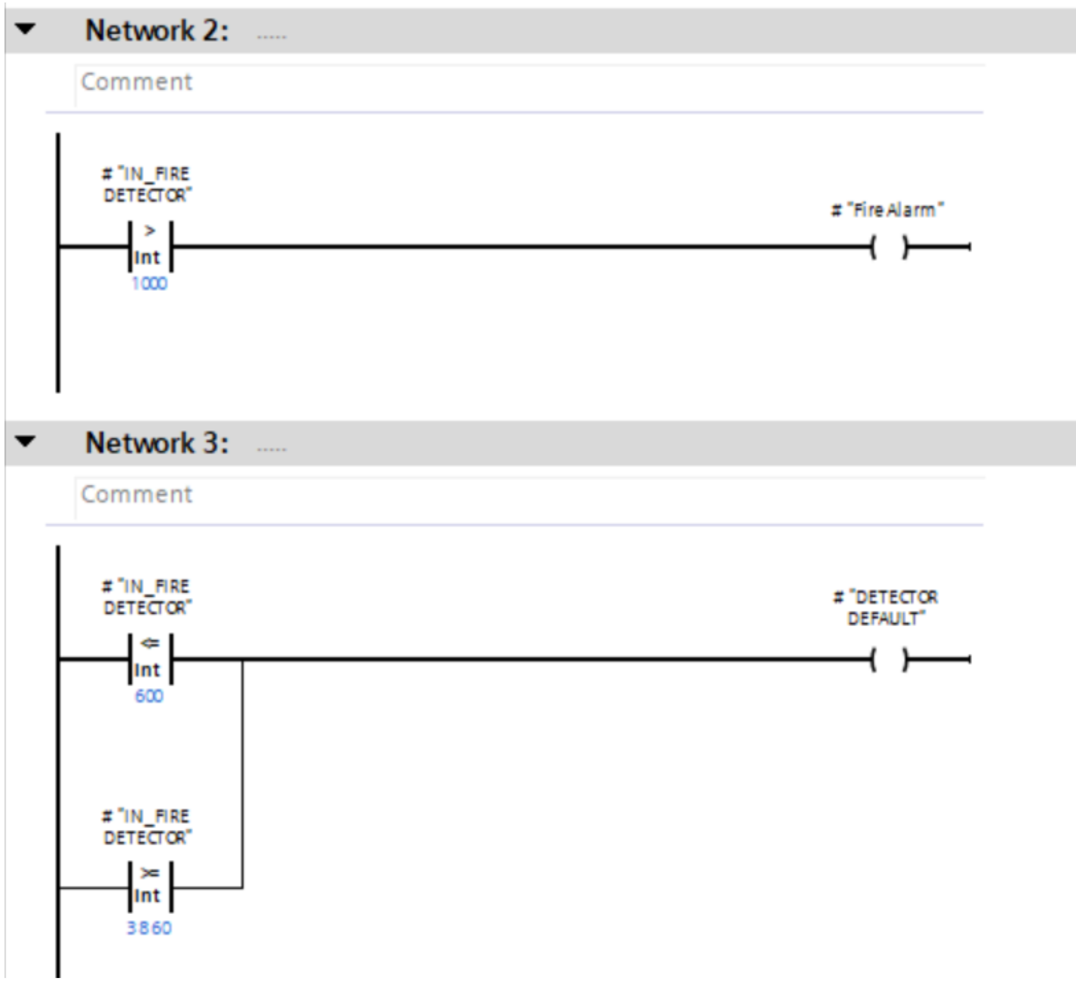


Figure IV. 18: Fire Detectors Threshold Logic

IV.5.2.1 Fire Detection in the Compression Zone 023

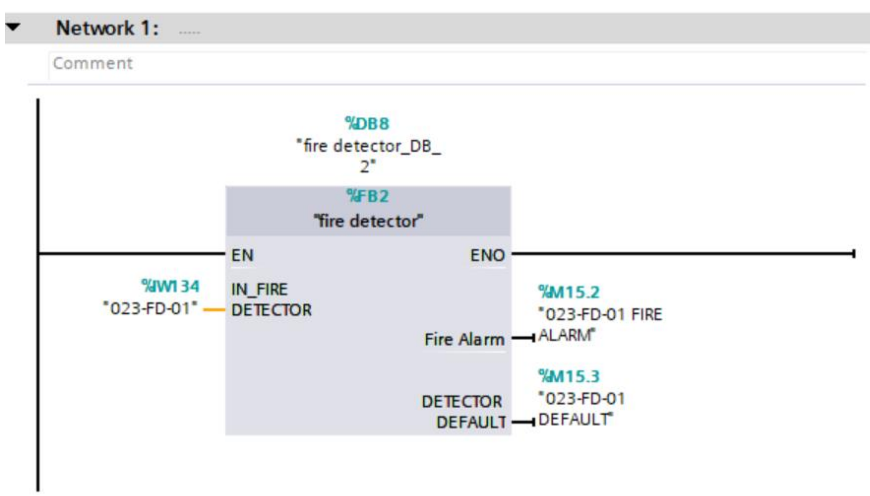


Figure IV. 19: Fire Detector Block in Compression Zone

IV.5.2.2 Fire Detection in the Technical Room 022

- **Smoke Detection Threshold Logic**

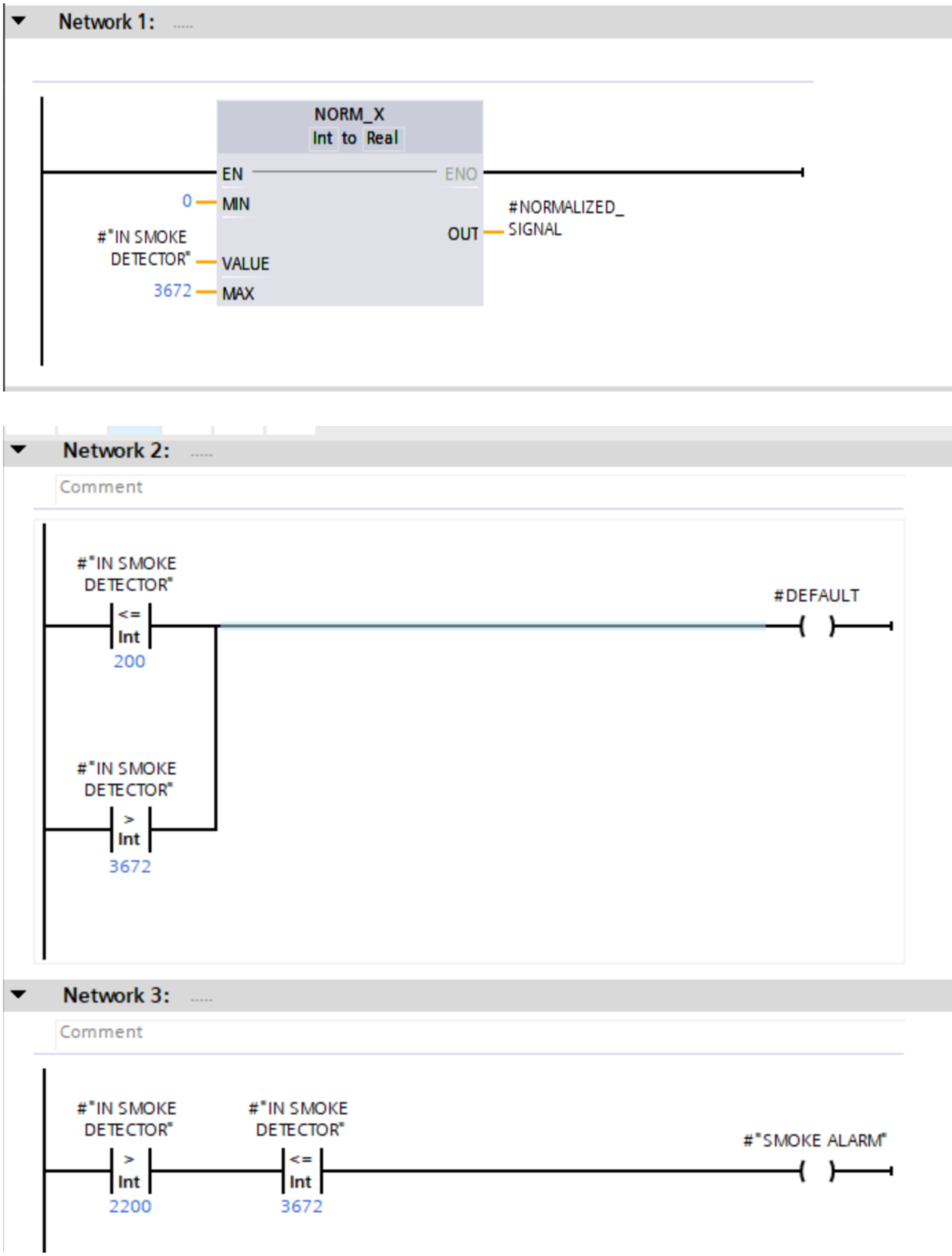


Figure IV. 20: Smoke Detection Threshold Logic

- **Smoke Detector Block**

In the technical room, fire detection is ensured by eight smoke detectors (SD) arranged into two independent circuits. Each circuit contains four detectors: two installed on the ceiling level and two on the floor void (underground). These detectors operate with OR logic, meaning the activation of any single detector within a circuit is sufficient to trigger a fire alarm for that circuit. This configuration provides reliable coverage for both above-ground and below-ground areas within the room.

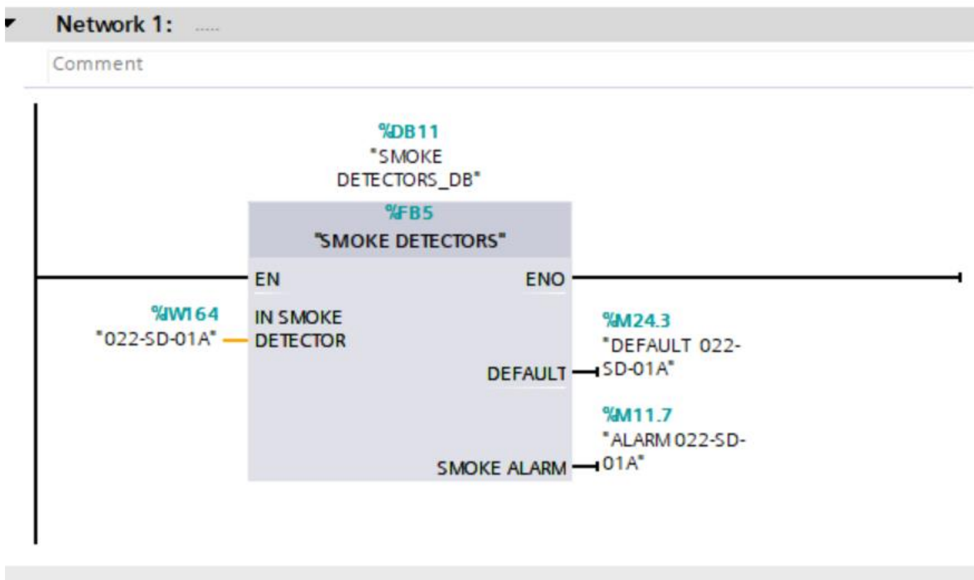


Figure IV. 21: Smoke Detector Block

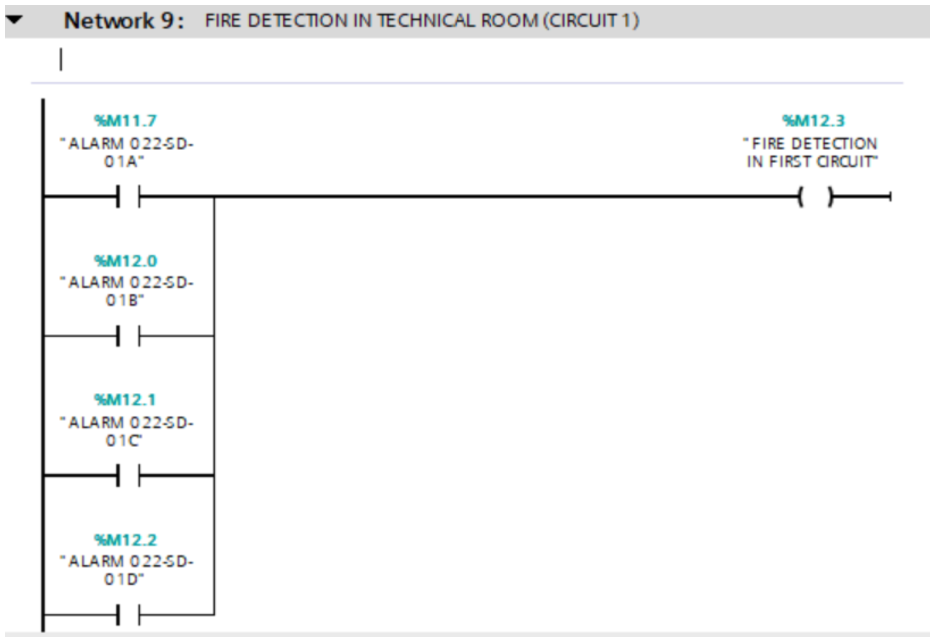


Figure IV. 22: Logic of Fire Detection (First Circuit)

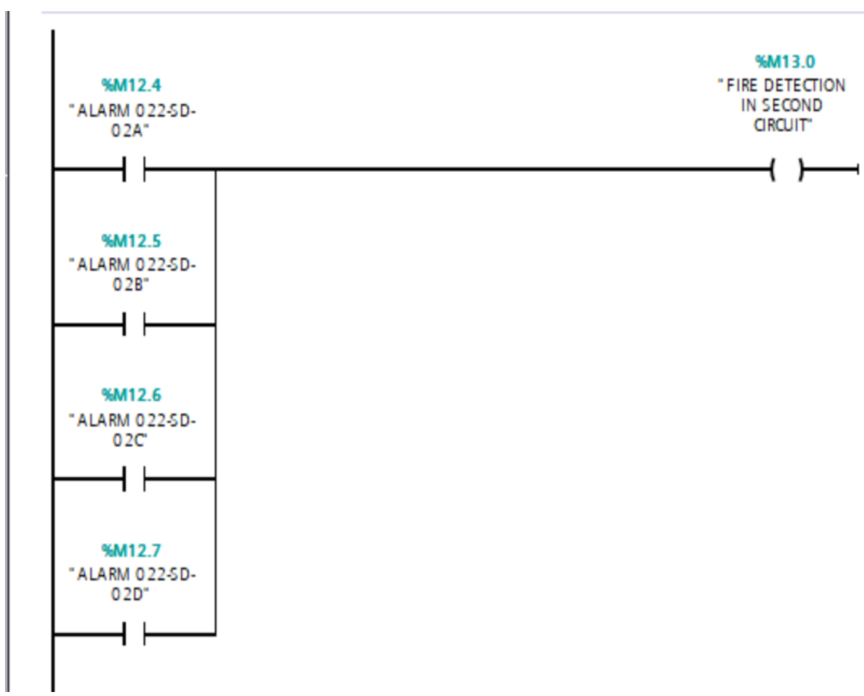


Figure IV. 23: Logic of Fire Detection (Second Circuit)

IV.5.3. Manual Call Point Alarm Block

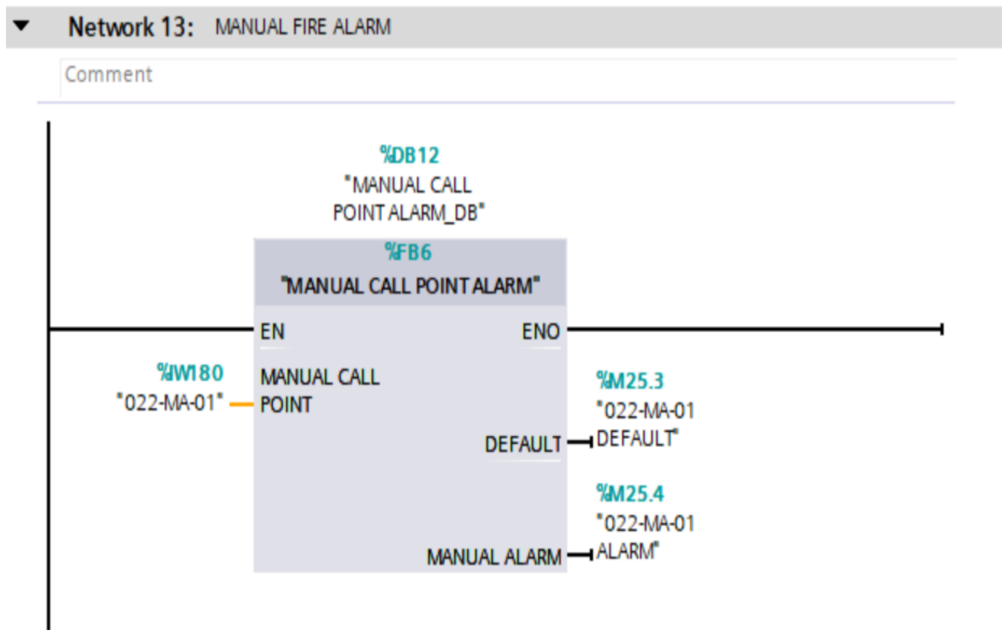


Figure IV. 24: Manual Call Point Alarm Block

IV.6. Supervision and HMI Interface Development

IV.6.1. HMI of Compression Zone

The HMI screen for Zone 023 – Compressors Area is designed to provide a clear and real-time overview of the Fire & Gas (F&G) detection system surrounding the three main compressors: Low Pressure (LP), Medium Pressure (MP), and High Pressure (HP). Each compressor is equipped with two flame detectors (FD) and two gas detectors (GD) strategically positioned to monitor for fire and gas leaks. Additional gas detectors are placed near the knockout drums (KO) to ensure full coverage of critical points. The gas detectors continuously measure the concentration of flammable gases, with the display showing values such as +1.492% LEL, which indicates the percentage of the gas relative to its explosive limit. The system also includes MA for emergency alarms. On the HMI, the color codes help operators quickly assess status: grey means normal, red means alarm, and yellow indicates a fault.

IV.6.1.1. Normal Status

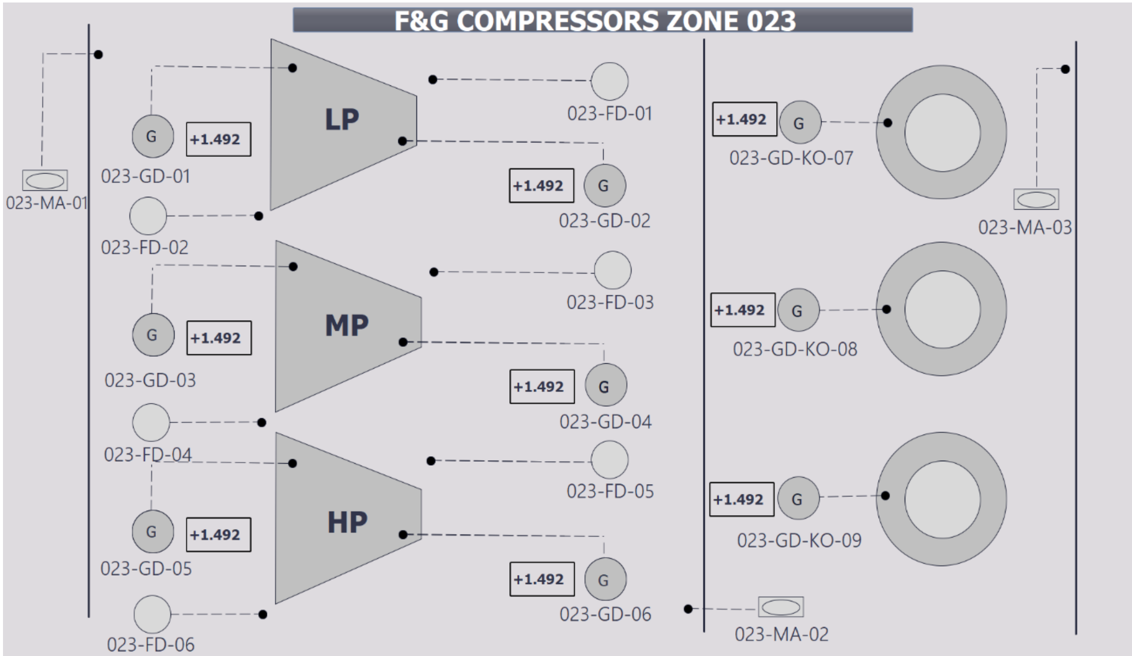


Figure IV. 25: HMI of Compression Zone in Normal Status

IV.6.1.2. Gas Detection Status

On the HMI screen of the compression zone, six gas detectors are placed around the compressors. The system uses a 2oo6 voting logic: if two detectors detect gas above 50% LEL, a general gas alarm is triggered. This activates a siren, the gas beacon, and sends a trip command to shut down the compressors. The triggered detectors turn red, indicating alarm status.

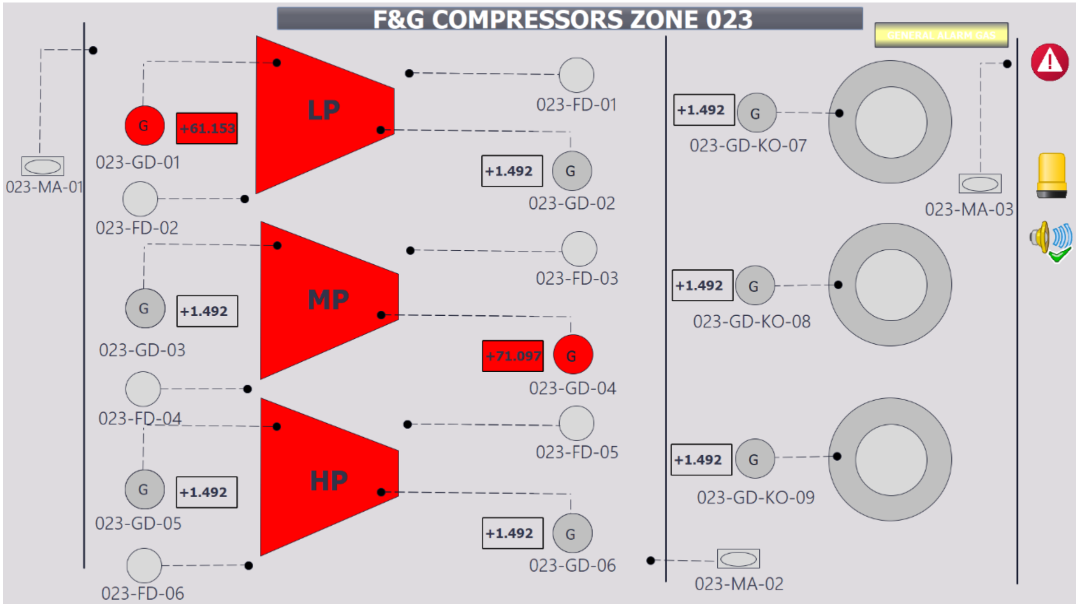


Figure IV. 26: HMI of Compression Zone in Gas Detection Status

IV.6.1.3. Fire Detection Status

On the HMI screen of the compression zone, there are six fire detectors, with two assigned to each compressor. A fire is confirmed when both detectors of a single compressor detect flames simultaneously. In that case, the system triggers the siren, the fire beacon, and sends a trip signal to shut down all three compressors. The detectors involved turn red, indicating a fire condition.

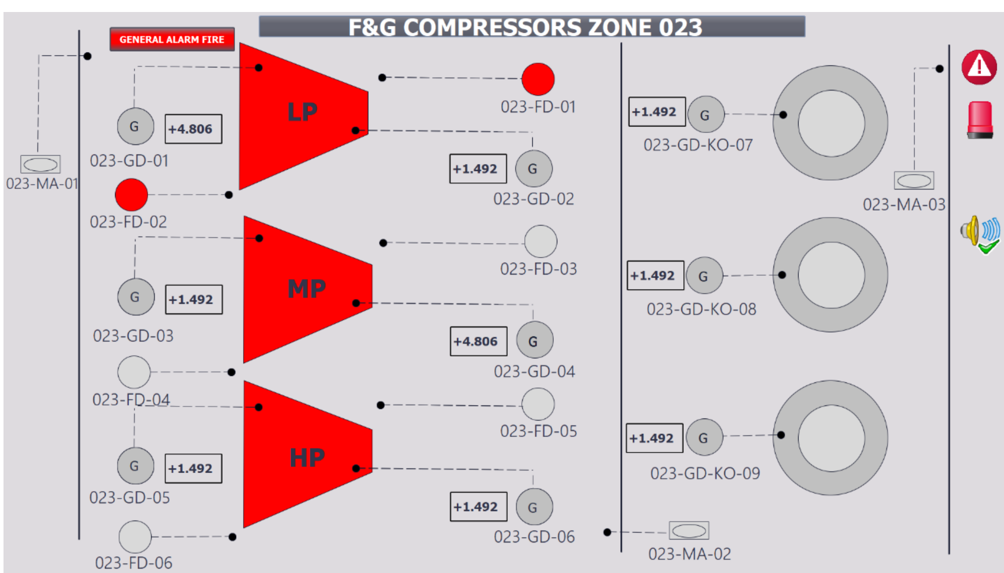


Figure IV. 27: HMI of Compression Zone in Fire Detection

IV.6.1.4. Fault Status

On the HMI screen, if any gas or flame detector experiences a fault such as a loss of signal, wiring issue, or internal error its status turns yellow. This visual indicator allows operators to quickly identify malfunctioning devices and take corrective action, even if no gas or fire is present.

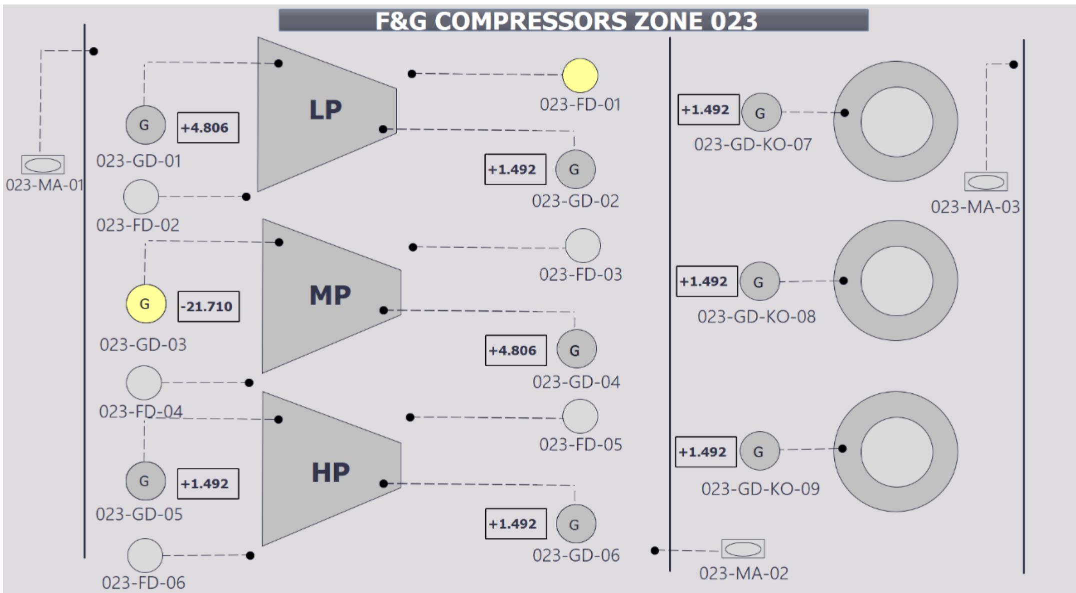


Figure IV. 28: HMI of Compression Zone in Fault Status

IV.6.2. HMI of Technical Room

The HMI screen for Zone 022 – Technical Room displays the layout of fire and gas protection inside the electrical cabinets area. The system includes three GD placed near the HVAC air intake and ventilation ducts to monitor gas presence. Additionally, the room is equipped with 8 SD above each row of control cabinets to detect early signs of fire. There are also two MCA for triggering the alarm in case of emergency. The color indicators on the HMI follow the standard: grey for normal, red for alarm, and yellow for fault, allowing operators to assess system status.

IV.6.2.1. Normal Status

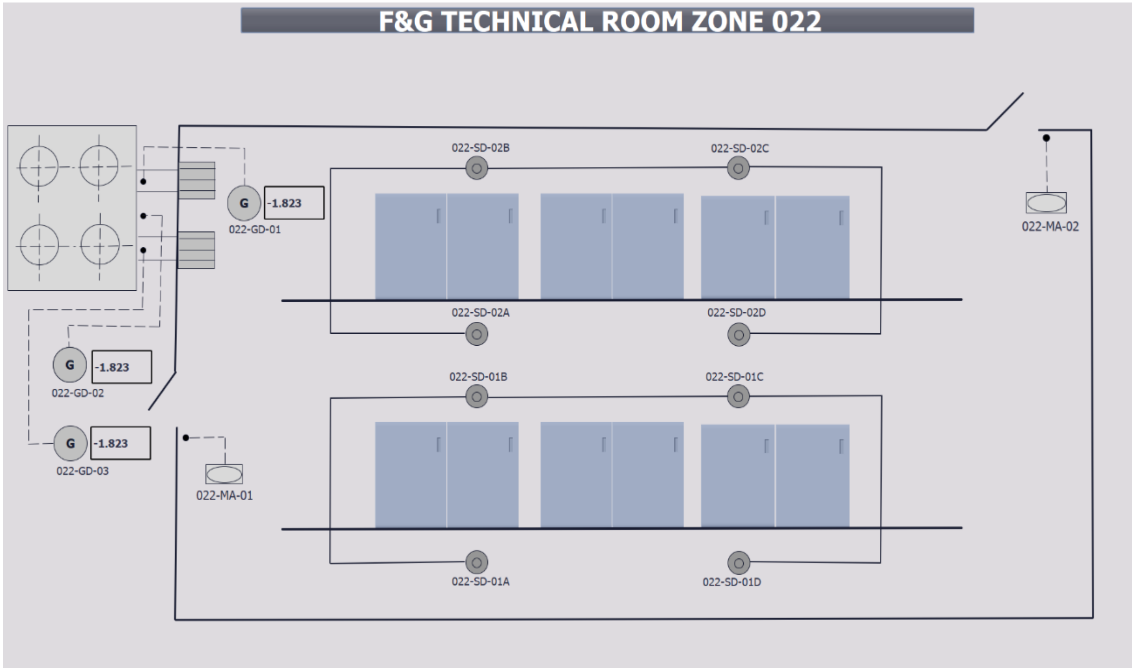


Figure IV. 29: HMI of Technical Room in Normal Status

IV.6.2.2. Gas Detection Status

On the HMI screen of the technical room, three gas detectors are installed around the HVAC air intake. When two out of three detectors detect gas levels above 50% LEL, the system confirms a gas presence. This triggers the gas siren, gas beacon, and automatically closes the fresh air dampers, switching the HVAC system to cooling and recirculation mode to prevent gas from entering the area with total plant ESD.

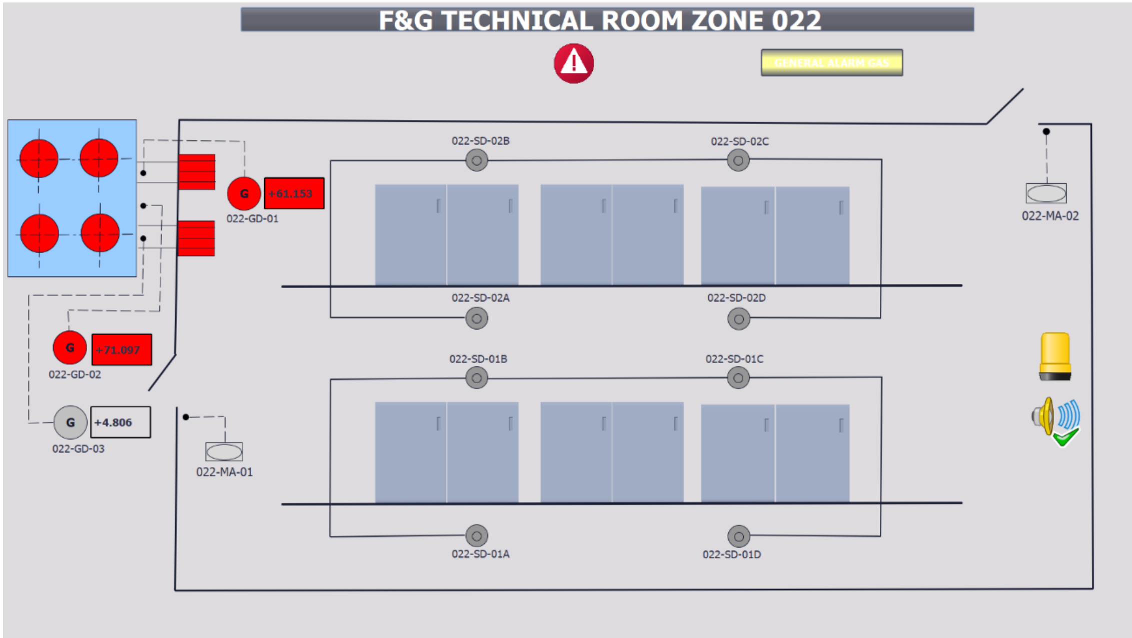


Figure IV. 30: HMI of Technical Room in Gas Detection

IV.6.2.3. Fire Detection Status

On the HMI screen of the technical room, the fire detection system is divided into two independent circuits. A fire is confirmed only when both circuits detect flames simultaneously. Once confirmed, the system closes the dampers, shuts down the HVAC system, and activates the fire siren and fire beacon.

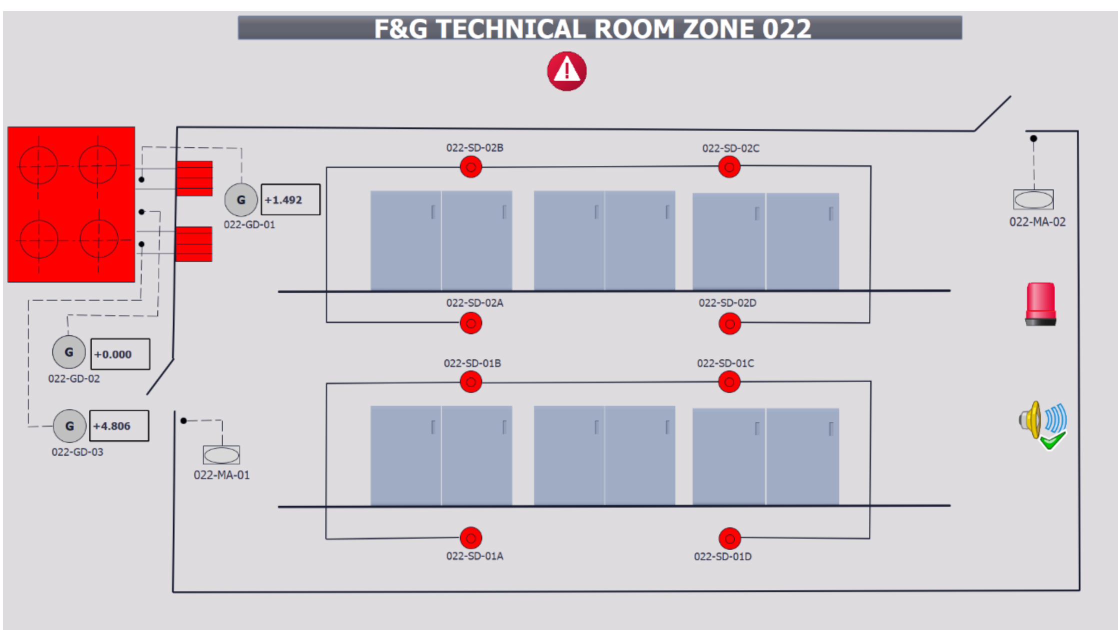


Figure IV. 31: HMI of Technical Room in Fire Detection

IV.6.2.4. Fault Status

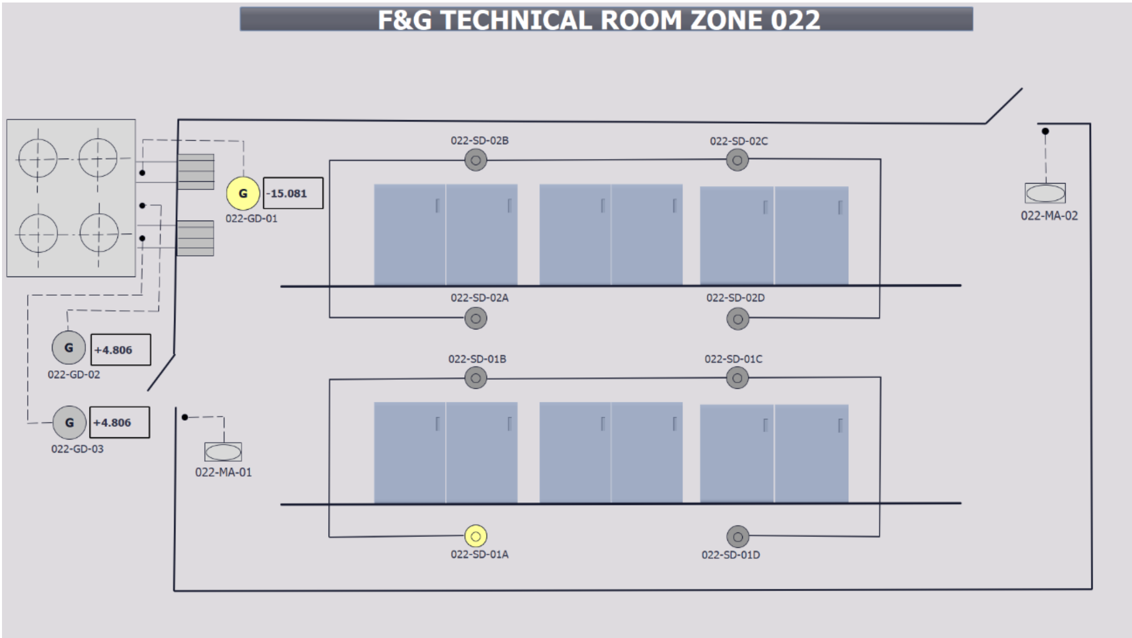


Figure IV. 32: HMI of Technical Room in Fault Status

IV.7 Implementation the PLC S7 1500 F with DCS and ESD

IV.7.1. Integration of the Siemens S7-1500 F PLC with DCS Honeywell EPKS

Figure IV. 33 : Honeywell EPKS Controllers

To ensure seamless communication between the Fire & Gas (F&G) system managed by the Siemens S7-1500 F PLC (CPU 1516F-3 PN/DP) and the centralized plant automation handled by the Honeywell Experion Process Knowledge System (EPKS) DCS, it is necessary to establish a robust and standardized data exchange mechanism. This integration allows the DCS to monitor F&G alarm statuses, detector values, and system health conditions, and optionally send reset or acknowledgment signals back to the PLC.

The integration can be achieved through industrial communication protocols, the most widely used being Modbus TCP/IP, depending on the system architecture and available licenses. [45]

- **Modbus TCP/IP Integration**

Modbus TCP/IP is a widely supported, vendor-neutral communication protocol used for integrating heterogeneous systems in industrial environments. In this architecture, the Siemens PLC acts as a Modbus TCP Server, exposing a range of internal variables (alarms, analog values, system flags) as Modbus registers. The Honeywell EPKS DCS acts as the Modbus TCP Client, continuously polling these registers to receive updated process data.

Each variable in the PLC is assigned a specific Modbus address (e.g., 40001 for a gas alarm), which the DCS maps to its internal points for visualization, historization, and control logic. This method is straightforward, reliable, and does not require extensive licensing beyond standard communication libraries. [46]

- **Functional Benefits of the Integration**
  - Real-time monitoring of critical F&G events such as gas concentrations, flame detection, or smoke alarms.
  - Centralized operator interface on the DCS HMI for visibility and alarm management.
  - Command feedback loop from the DCS to the PLC (e.g., remote reset of alarms or system bypass).
  - Improved reliability and coordination between safety and process control systems.

IV.7.2. Integration with Emergency Shutdown System (ESD)

The integration between the Siemens S7-1500 F PLC (CPU 1516F-3 PN/DP) and the Emergency Shutdown System (ESD) is a fundamental requirement for ensuring safe and coordinated response in hazardous situations. In this architecture, the Fire & Gas (F&G) PLC operates independently to detect flammable gas, smoke, and flame events, while the ESD system is responsible for executing shutdown actions across critical equipment, such as compressors, pumps, and valves. To ensure that safety-critical events detected by the PLC are acted upon immediately, a direct and reliable communication link is established between the two systems.

The most commonly applied method of integration is through hardwired fail-safe digital outputs. When the F&G logic identifies a critical event, it activates designated Fail-Safe Digital Output (F-DO) channels, which are wired directly to the digital inputs of the ESD PLC or shutdown logic relays. These signals typically include gas detection alarms, confirmed flame presence, smoke alarms, and manual emergency activations (MCPs). The wiring ensures deterministic, low-latency transmission of safety triggers, independent of network conditions. In high-integrity architectures, redundant signals or relay interlocking may also be used to increase reliability.

Additionally, the S7-1500 F can send status or heartbeat signals to the ESD system to confirm its operational state. In systems that support it, PROFIsafe over PROFINET or PROFIBUS may be used as an alternative to hardwired signals, allowing safe digital data exchange with SIL compliance. However, even in modern architectures, hardwired interfaces remain the preferred standard due to their simplicity, reliability, and compliance with safety design norms like IEC 61508 and IEC 61511. The result is a robust, fail-safe system in which fire or gas hazards are promptly escalated to plant-wide shutdown commands to protect personnel, equipment, and the environment. [47]

IV.8. Conclusion

The modernization of the Fire and Gas (F&G) system in Train 1 of the BRN site marks a significant step toward aligning safety infrastructure with modern industrial standards. This chapter detailed the selection and configuration of advanced field detectors, as well as the implementation of a robust control architecture based on the

Siemens S7-1500 F fail-safe PLC. By leveraging the capabilities of TIA Portal V17, the new system integrates powerful signal processing, real-time diagnostics, and an intuitive HMI interface, all designed to enhance reliability and operator responsiveness.

Moreover, the integration of the PLC with both the Honeywell EPKS DCS and the ESD ensures seamless coordination between process supervision and emergency response. This dual-layer architecture combining intelligent monitoring with fail-safe action provides a scalable, maintainable, and safety-compliant solution suited for high-risk petrochemical environments. Ultimately, this upgrade not only improves operational safety but also strengthens the long-term performance, flexibility, and maintainability of the plant's safety system

General Conclusion

This project has focused on the analysis, evaluation, and modernization of the Fire and Gas (F&G) detection system in Train 1 of the BRN oil treatment center, operated by the SONATRACH–ENI partnership. Given the aging nature of the existing infrastructure, which has been in operation since 1995, the need to upgrade the detection and control systems was both urgent and essential to meet current international safety standards.

A thorough assessment of the existing Simplex-based system revealed multiple limitations, including lack of diagnostic capabilities, weak integration with DCS and ESD platforms, and non-compliance with modern safety and functional requirements. In response, a complete upgrade strategy was developed, involving the replacement of obsolete detectors with high-performance devices. These field instruments offer faster response times, higher accuracy, and enhanced reliability.

At the core of the new system is the Siemens S7-1500 F Safety PLC selected for its robustness, SIL certification, and powerful integration capabilities. Configured using TIA Portal V17, the PLC handles detection logic, system diagnostics, and alarm management while communicating in real time with the Honeywell EPKS DCS via Modbus TCP/IP and interfacing with the ESD through fail-safe digital I/Os. This dual integration ensures full coordination between supervision and shutdown mechanisms.

Ultimately, the proposed modernization ensures a safer, smarter, and more maintainable F&G system, capable of protecting both personnel and infrastructure in a high-risk petrochemical environment. It reinforces operational continuity while providing a future-ready foundation that can be expanded and improved as new technologies emerge.

References

[1] O. Technology, "Oil and Gas Field Profile: Bir Rebaa Complex Conventional Oil Field, Algeria," GlobalData, 31 July , 2024. [Online]. Available: https://www.offshore-technology.com/data-insights/oil-gas-field-profile-bir-rebaa-complex-conventional-oil-field-algeria/.

[2] "Energy Magasin," 16 novembre 2022. [Online]. Available: https://www.energymagazinedz.com/2022/11/16/algerie-sonatrach-et-litalien-eni-annoncent-lentree-en-production-dun-nouveau-champ-petrolier/.

[3] B. Billiton, "Form 20-F Annual Report 2005," U.S. Securities and Exchange Commission (SEC), 2005.

[4] Sonatrach, "Sonatrach-Eni Joint Venture," 2006.

[5] S. S. (. Ltd, "Pellistor Application Note 1: Pellistor Sensor Technology & Applications," SGX Sensortech (IS) Ltd, 2014.

[6] "Karf Scoot," 2015. [Online]. Available: https://www.karfandscoot.com/sabit-gaz-dedektorleri-nasil-konumlandirilmali/.

[7] "Inst Tools," 2018. [Online]. Available: https://instrumentationtools.com/catalytic-type-gas-sensor-principle/.

[8] "Target Engineering," [Online]. Available: http://www.target-engineering.com/Lists/Details/Products/22/pointwatch-eclipser-pirecl-ir-gas-detector.

[9] "automation forum," 2017. [Online]. Available: https://automationforum.co/infrared-gas-detector-working-principle/2-1-9/.

[10] J. S. Fritz, Gas Detection for Safety and Environmental Monitoring, CRC Press, 2013.

[11] "SOLIADE," [Online]. Available: https://www.soliade.com/detection-flamme-et-gaz/.

[12] J. M. J. Wang, "Electrochemical Gas Sensors," J. Wang, J. Musameh, 2003.

[13] U. G. L. D. Technology, UE Systems, Inc., 2019.

[14] "MSA Safety," [Online]. Available: https://us.msasafety.com/Fixed-Gas-&-Flame-Detection/Gas-Detectors/Observer%C2%AE-i-Ultrasonic-Gas-Leak-Detector/p/000140006900001005.

[15] D.-T. (. E. Corporation), Flame Detection Handbook, Det-Tronics (Detector Electronics Corporation), 2018.

[16] "DG E LEARING ADU ACADEMY,Youtube," [Online]. Available: https://www.youtube.com/watch?v=L69vQN0SjIg.

[17] H. Analytics, "Infrared Flame Detectors: Principles and Applications," Honeywell Analytics, 2017.

[18] M. Safety, "Advantages of Combined UV/IR Flame Detection," MSA Safety, 2019.

[19] P. D. e. al., SFPE Handbook of Fire Protection Engineering (Chapter on Fire Detection), Society of Fire Protection Engineers (SFPE), 2016.

[20] Honeywell, "Honeywell Fire Safety – Manual Call Points Technical Overview," Honeywell, 2020.

[21] "RS," [Online]. Available: https://nz.rs-online.com/web/content/discovery/ideas-and-advice/beacon-lights-guide.

[22] "NFPA 12: Standard on Carbon Dioxide Extinguishing Systems," National Fire Protection Association (NFPA), 2018.

[23] "Data Sheet 8-9: Clean Agent Fire Suppression Systems," 2021.

[24] W. M. Association, "Water Mist Association – Water Mist Fire Suppression Systems," Water Mist Association, 2019.

[25] L. B. J. Smith, "Design and Implementation of Fire and Gas Detection Systems in Process Plants," *ISA Transactions,* 2018.

[26] ISA, "ISA-TR84.00.07: Fire and Gas Mapping," ISA, 2017.

[27] N. F. P. A. (NFPA), "NFPA 72: National Fire Alarm and Signaling Code," National Fire Protection Association (NFPA), 2022.

[28] S.-E. _. SpA, The Simplex 4100, Nuovo Pignone, 1993.

[29] "S4100C Combustible Gas Detector Product Data Sheet," MSA Safety Incorporated, 2019.

[30] ThermoCable, "ThermoCable Digital Linear Heat Detection Overview," ThermoCable, 2018.

[31] "Simplex TrueAlarm Analog Sensors and Bases (Model 4098-9714)," Tyco Safety Products, 2019.

[32] "FS24X Fire and Flame Detector Datasheet," Honeywell Analytics, 2017.

[33] "Sensepoint XCD Gas Detector Product Data Sheet," Honeywell Analytics, 2023.

[34] "SP-951 Addressable Photoelectric Smoke Detector Product Data Sheet," Honeywell International Inc., 2022.

[35] "SIMATIC S7-1200 / S7-1500 F-CPUs," Siemens AG, 2015.

[36] "TIA Portal V17 – Product Overview," Siemens AG, 2023.

[37] "SIMATIC S7-1500 Fail-Safe CPU 1516F-3 PN/DP Technical Data," Siemens AG, 2023.

[38] "SIMATIC S7-1500 Fail-Safe Digital Input Module F-DI 16x24V DC HF Data Sheet," Siemens AG, 2023.

[39] "DQ 8x24VDC/2A HF Digital Output Module (6ES7522-1BF00-0AB0) Manual," Siemens AG, 2023.

[40] "SIMATIC S7-1500 Analog Input Module 6ES7531-7KF00-0AB0 Datasheet," Siemens AG, 2020.

[41] "SIMATIC S7-1500 PS 60W Power Supply Module Technical Data," Siemens AG, 2023.

[42] "SIMATIC WinCC Advanced Overview," Siemens AG, 2023.

[43] S. A. (. Sector), SIMATIC S7-1500 Automation System System Manual, 2020: Siemens AG.

[44] S. AG, "SIMATIC S7-1200 Programmable Controller – SCALE_X (Scale) and NORM_X (Normalize) Instructions," Siemens Industry Online Support, Nuremberg, 2025.

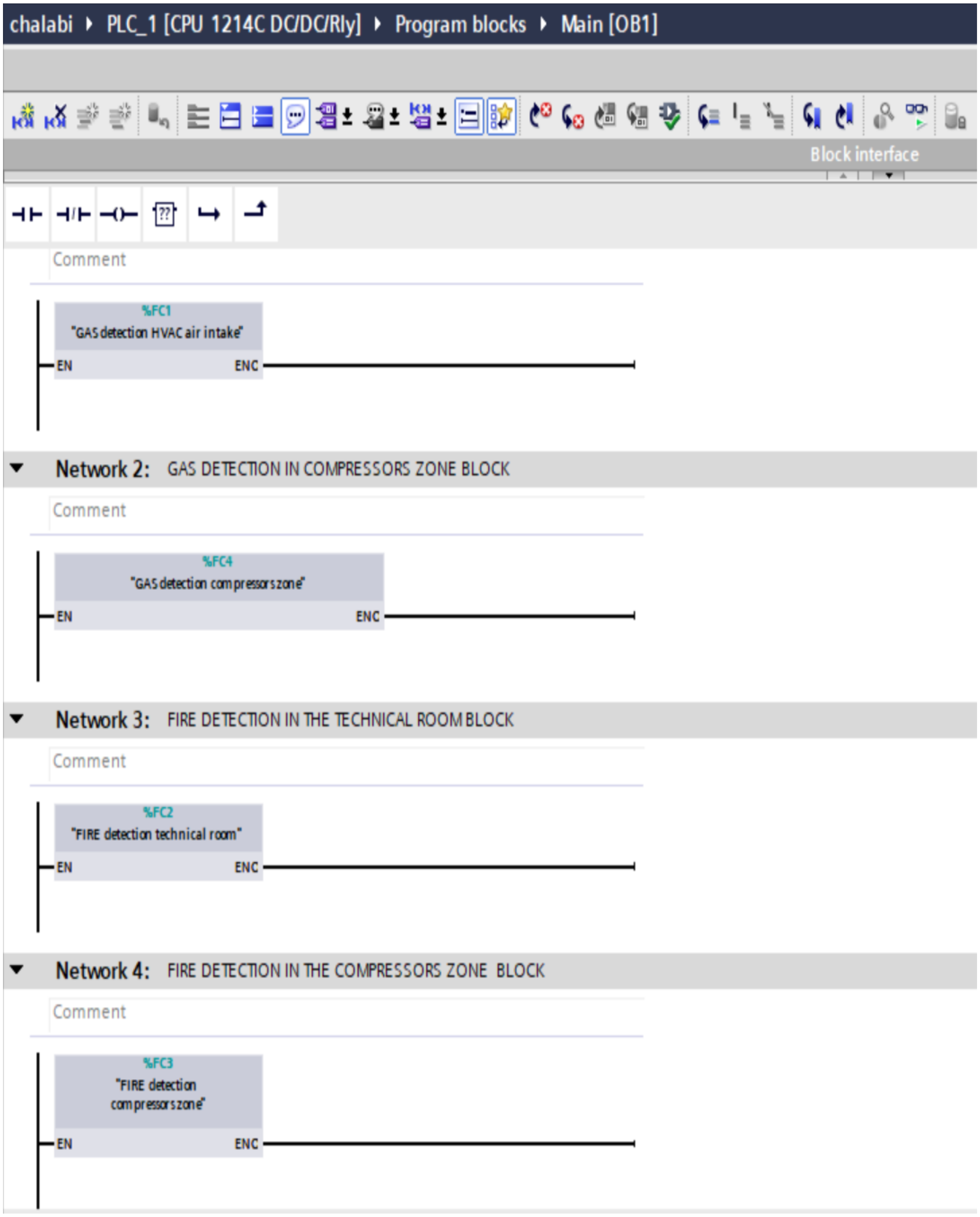
[45] H. I. Inc, "Experion PKS System Overview," Honeywell Process Solutions, 2017.

[46] S. AG, "Modbus TCP Communication via SIMATIC S7-1500 and TIA Portal.," Siemens Industry Online Support , 2022.

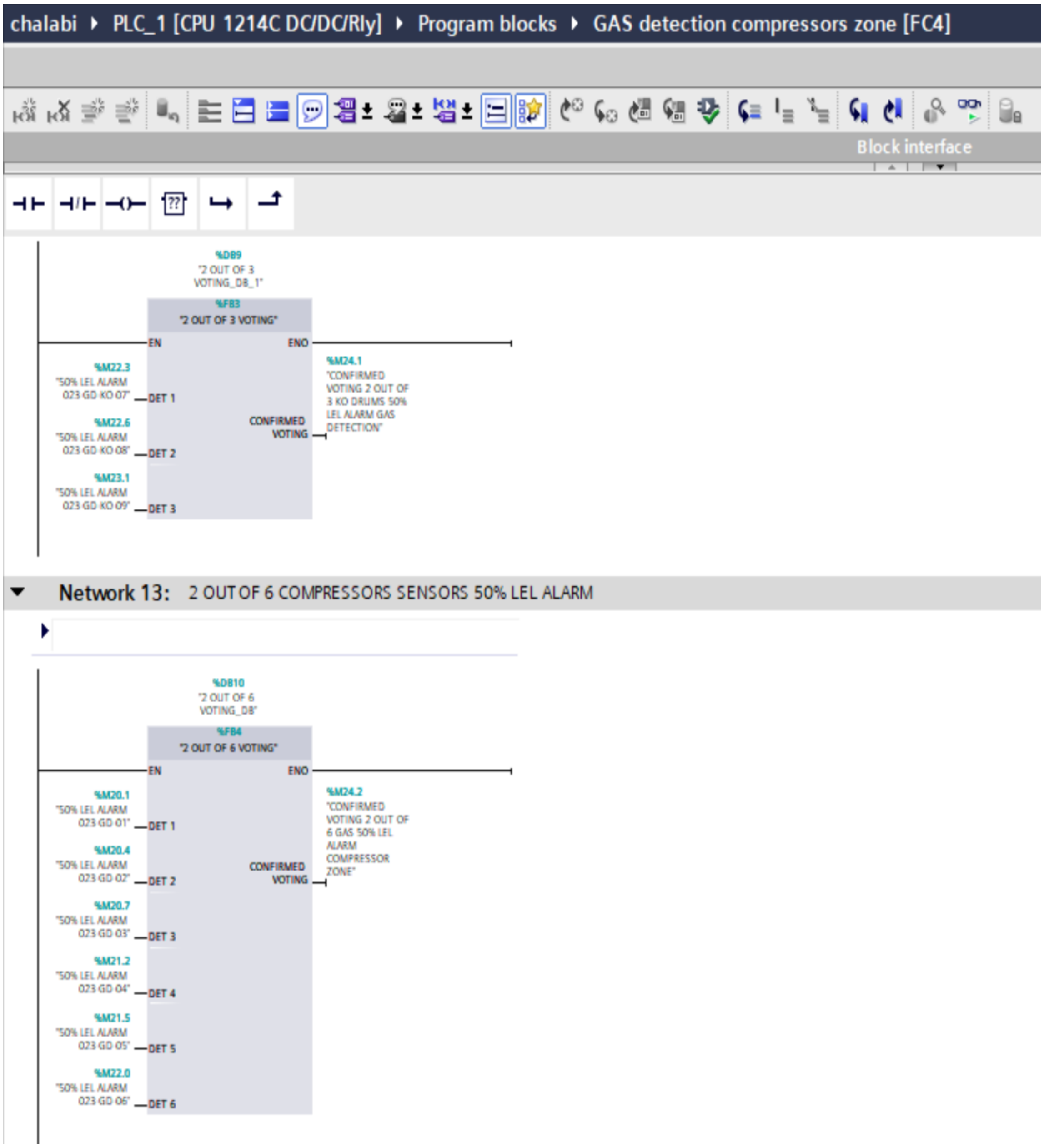
[47] S. AG, "SIMATIC S7-1500 Fail-Safe Systems – Safety Integrated Function Manual," Siemens Industry Online Support, 2021.

Annex

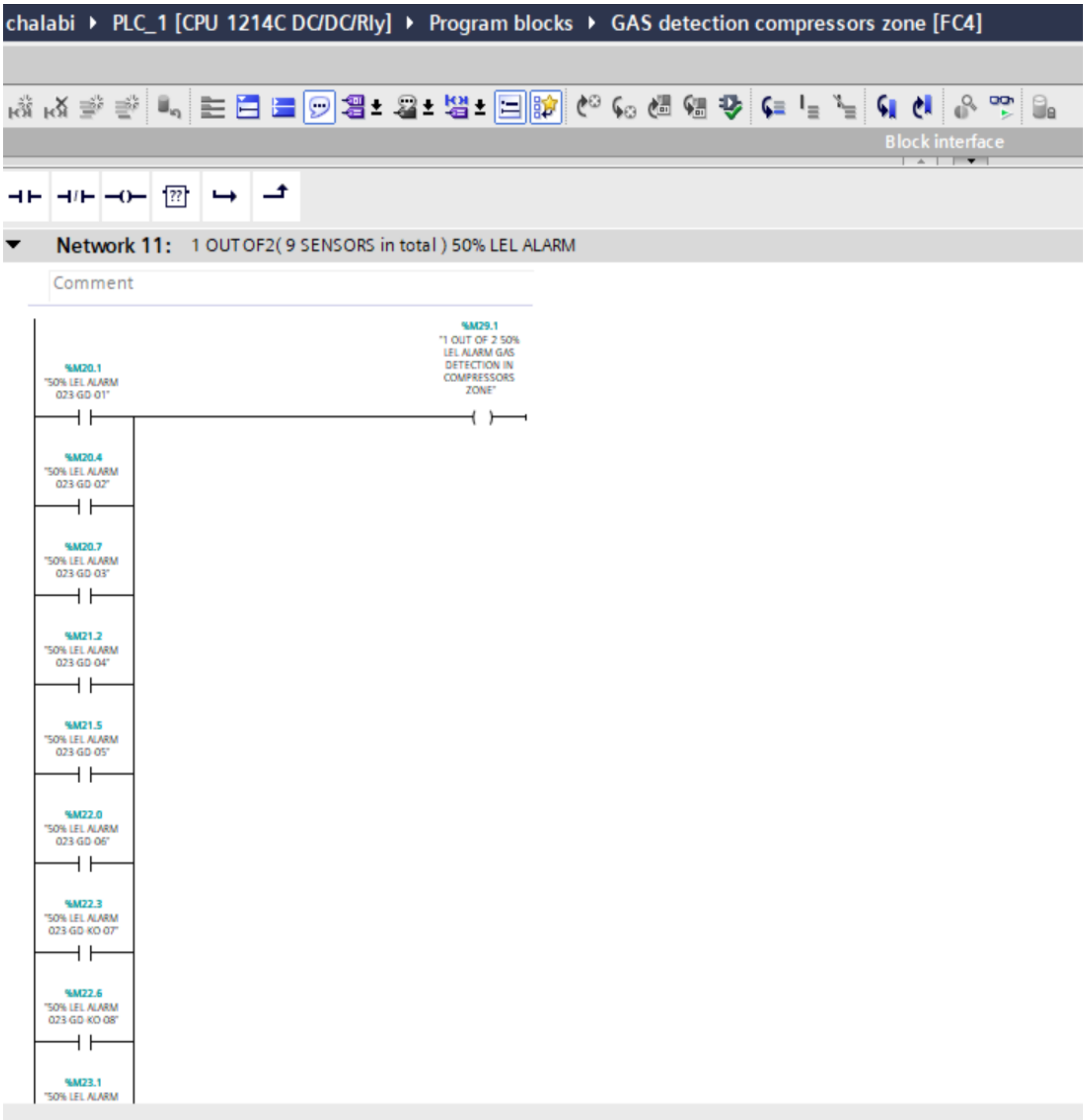
Annex 1



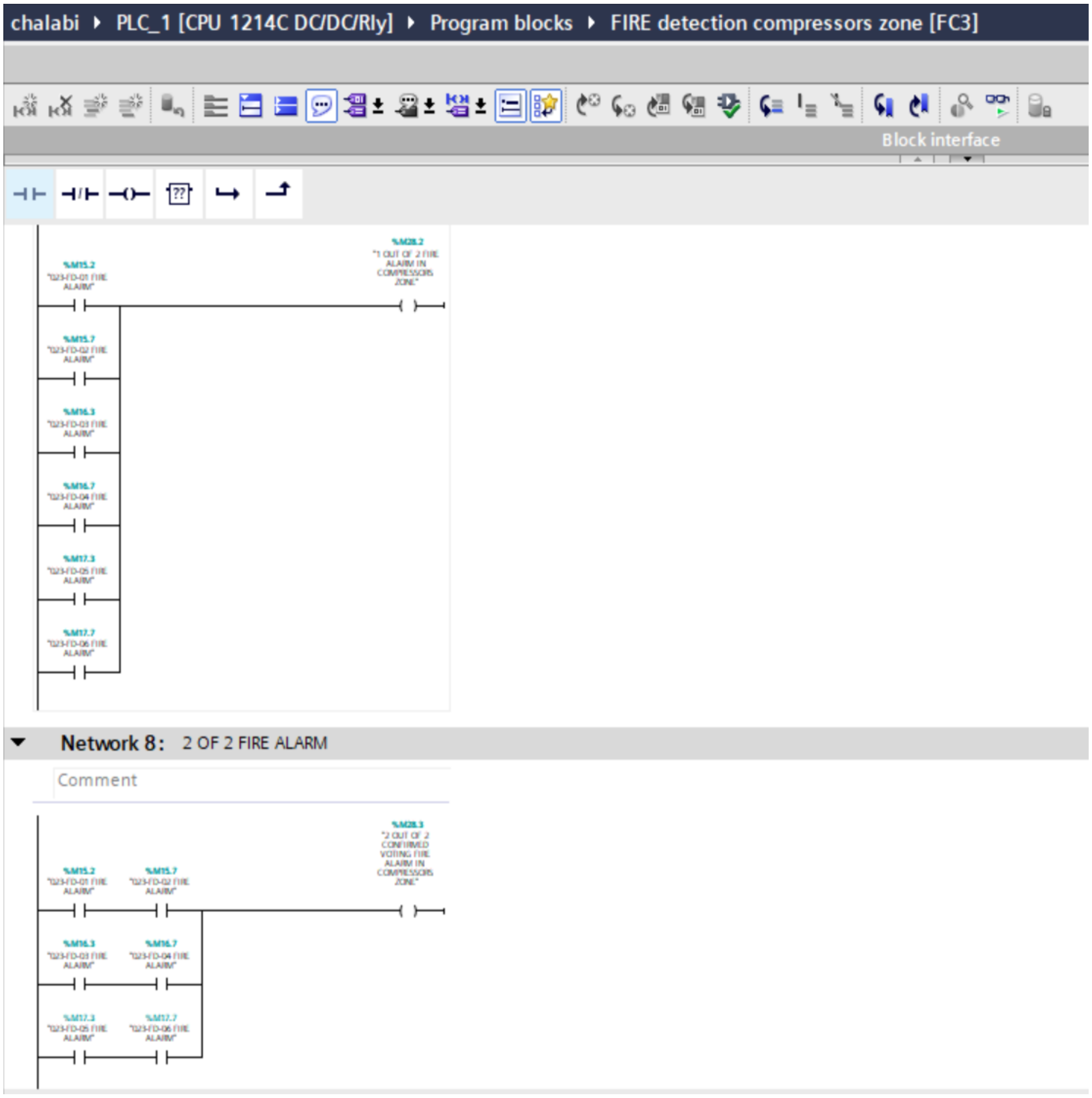
Annex 2


chalabi ▸ PLC_1 [CPU 1214C DC/DC/Rly] ▸ Program blocks ▸ GAS detection compressors zone [FC4]
Block interface
%DB9
"2 OUT OF 3 VOTING_DB_1"
%FB3
"2 OUT OF 3 VOTING"
EN
ENO
%M22.3
"50% LEL ALARM 023 GD KO 07"
DET 1
%M22.6
"50% LEL ALARM 023 GD KO 08"
DET 2
%M23.1
"50% LEL ALARM 023 GD KO 09"
DET 3
CONFIRMED VOTING
%M24.1
"CONFIRMED VOTING 2 OUT OF 3 KO DRUMS 50% LEL ALARM GAS DETECTION"
Network 13: 2 OUT OF 6 COMPRESSORS SENSORS 50% LEL ALARM
%DB10
"2 OUT OF 6 VOTING_DB"
%FB4
"2 OUT OF 6 VOTING"
EN
ENO
%M20.1
"50% LEL ALARM 023 GD 01"
DET 1
%M20.4
"50% LEL ALARM 023 GD 02"
DET 2
%M20.7
"50% LEL ALARM 023 GD 03"
DET 3
%M21.2
"50% LEL ALARM 023 GD 04"
DET 4
%M21.5
"50% LEL ALARM 023 GD 05"
DET 5
%M22.0
"50% LEL ALARM 023 GD 06"
DET 6
CONFIRMED VOTING
%M24.2
"CONFIRMED VOTING 2 OUT OF 6 GAS 50% LEL ALARM COMPRESSOR ZONE"

Annex 3

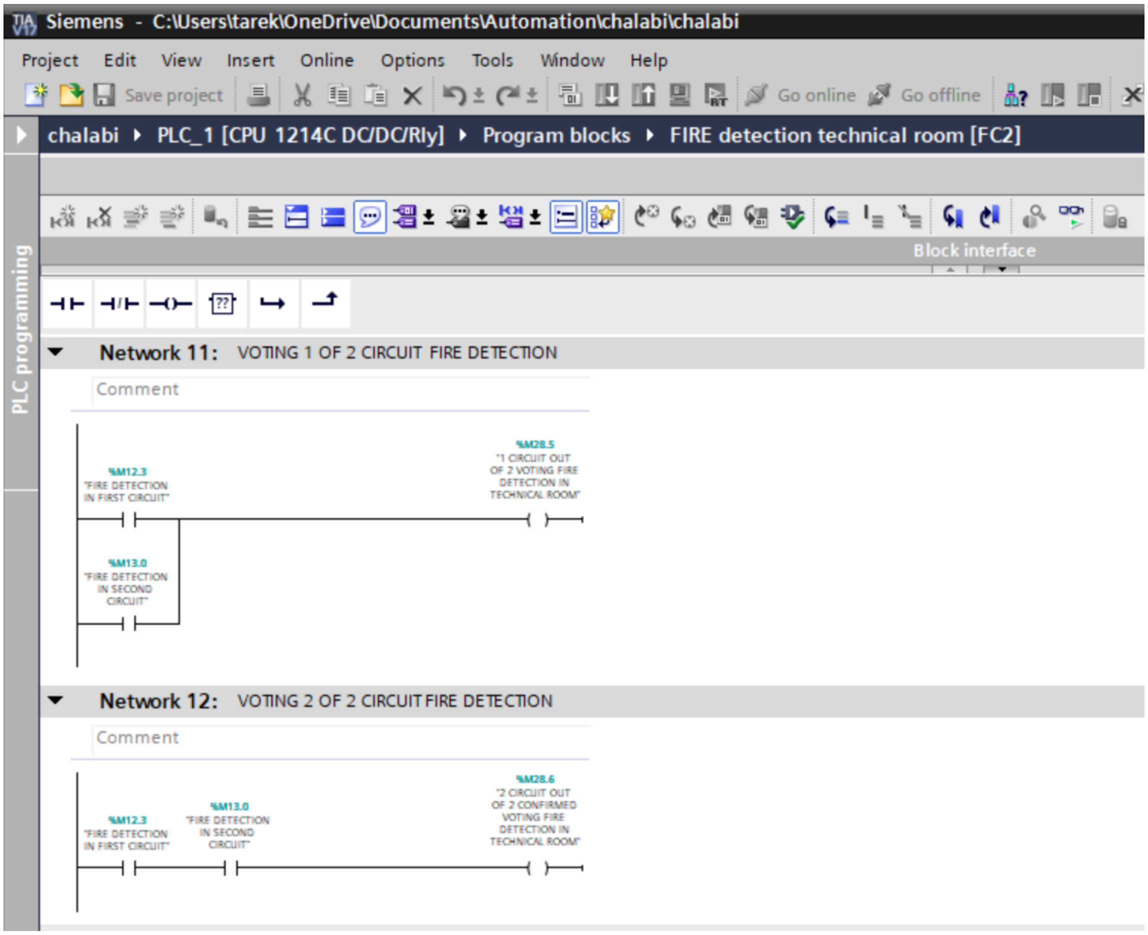

chalabi ▸ PLC_1 [CPU 1214C DC/DC/Rly] ▸ Program blocks ▸ GAS detection compressors zone [FC4]
Block interface
Network 11: 1 OUT OF2(9 SENSORS in total) 50% LEL ALARM
Comment
%M29.1
"1 OUT OF 2 50% LEL ALARM GAS DETECTION IN COMPRESSORS ZONE"
%M20.1
"50% LEL ALARM 023 GD 01"
%M20.4
"50% LEL ALARM 023 GD 02"
%M20.7
"50% LEL ALARM 023 GD 03"
%M21.2
"50% LEL ALARM 023 GD 04"
%M21.5
"50% LEL ALARM 023 GD 05"
%M22.0
"50% LEL ALARM 023 GD 06"
%M22.3
"50% LEL ALARM 023 GD KO 07"
%M22.6
"50% LEL ALARM 023 GD KO 08"
%M23.1
"50% LEL ALARM

Annex 4

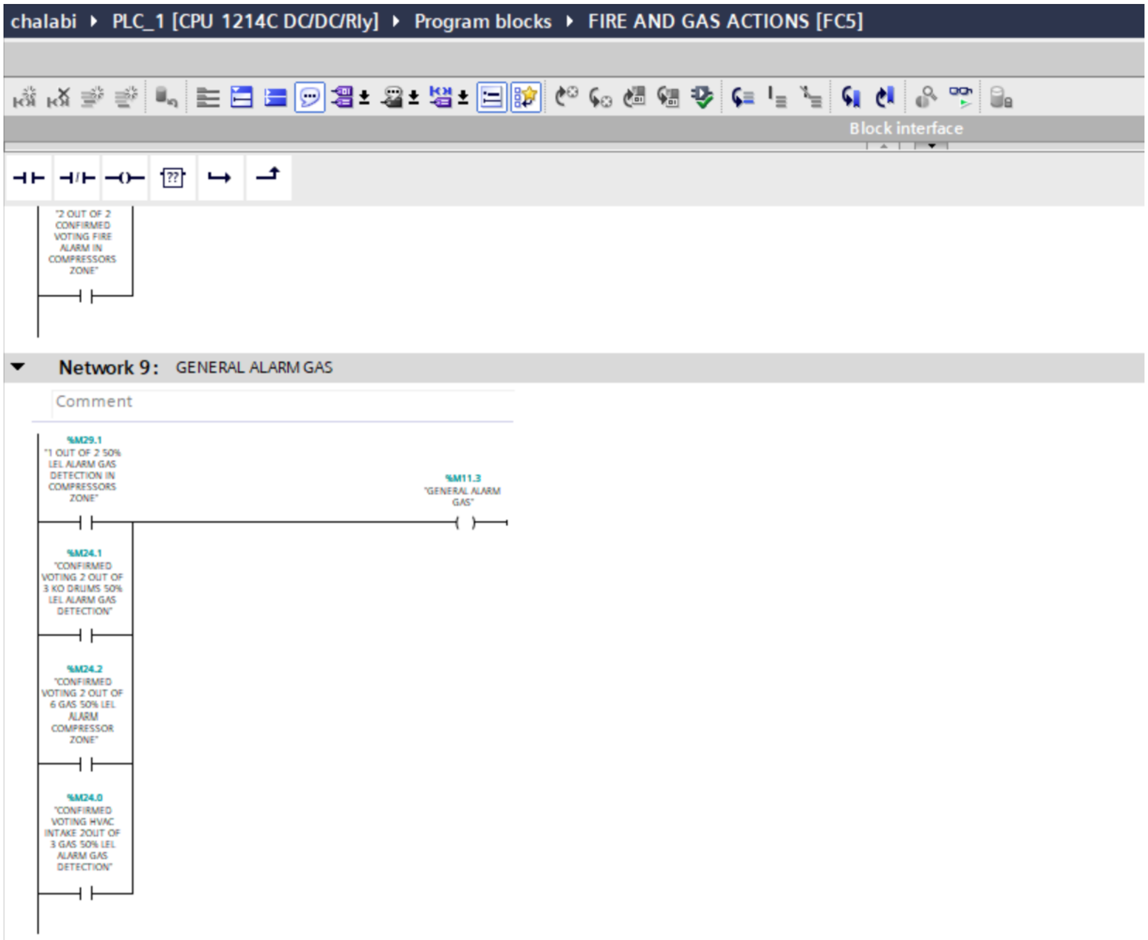


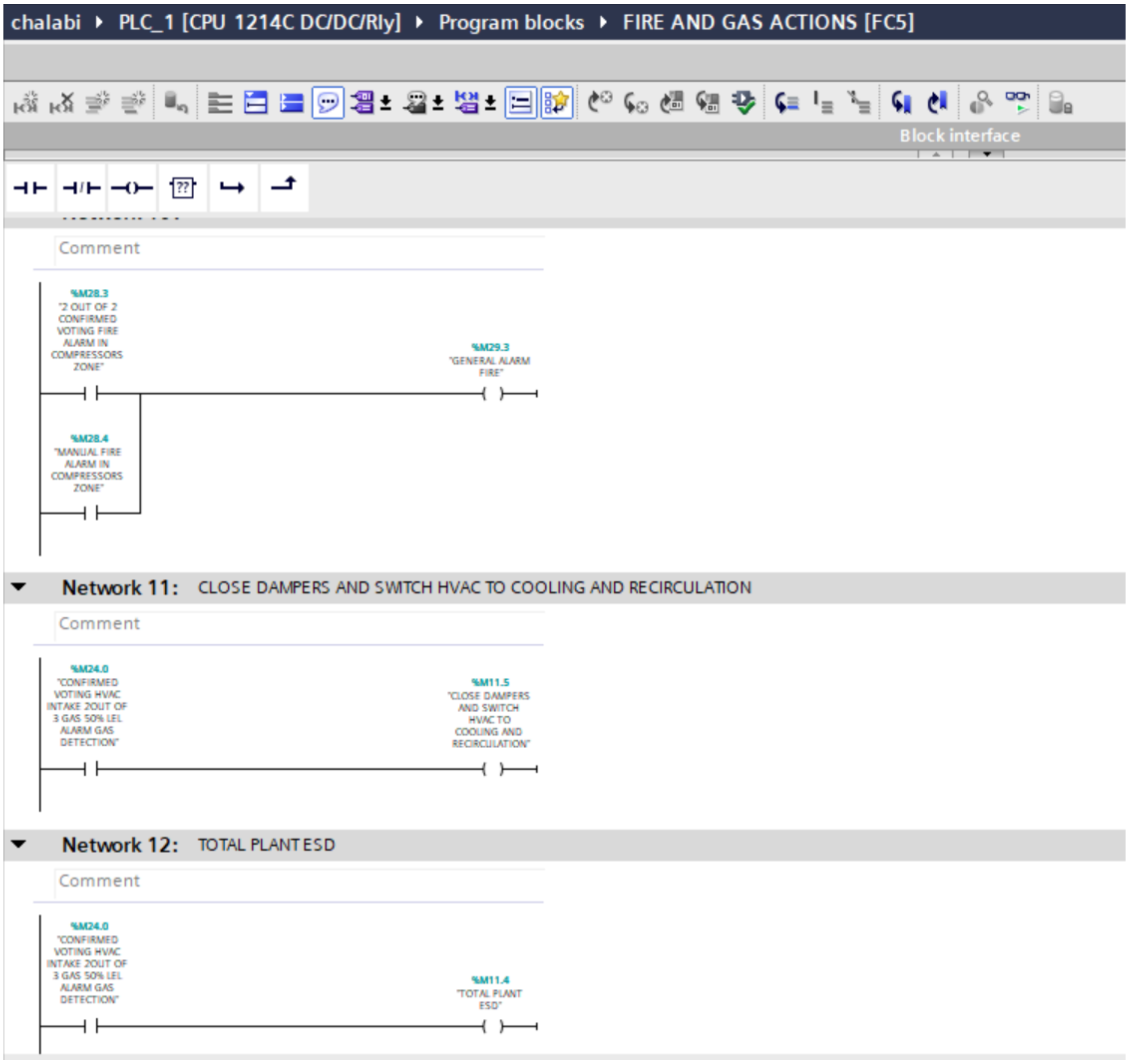
chalabi ▸ PLC_1 [CPU 1214C DC/DC/Rly] ▸ Program blocks ▸ FIRE detection compressors zone [FC3]
Block interface
%M15.2
"023-FD-01 FIRE ALARM"
%M15.7
"023-FD-02 FIRE ALARM"
%M16.3
"023-FD-03 FIRE ALARM"
%M16.7
"023-FD-04 FIRE ALARM"
%M17.3
"023-FD-05 FIRE ALARM"
%M17.7
"023-FD-06 FIRE ALARM"
%M28.2
"1 OUT OF 2 FIRE ALARM IN COMPRESSORS ZONE"
Network 8: 2 OF 2 FIRE ALARM
Comment
%M15.2
"023-FD-01 FIRE ALARM"
%M15.7
"023-FD-02 FIRE ALARM"
%M16.3
"023-FD-03 FIRE ALARM"
%M16.7
"023-FD-04 FIRE ALARM"
%M17.3
"023-FD-05 FIRE ALARM"
%M17.7
"023-FD-06 FIRE ALARM"
%M28.3
"2 OUT OF 2 CONFIRMED VOTING FIRE ALARM IN COMPRESSORS ZONE"

Annex 5

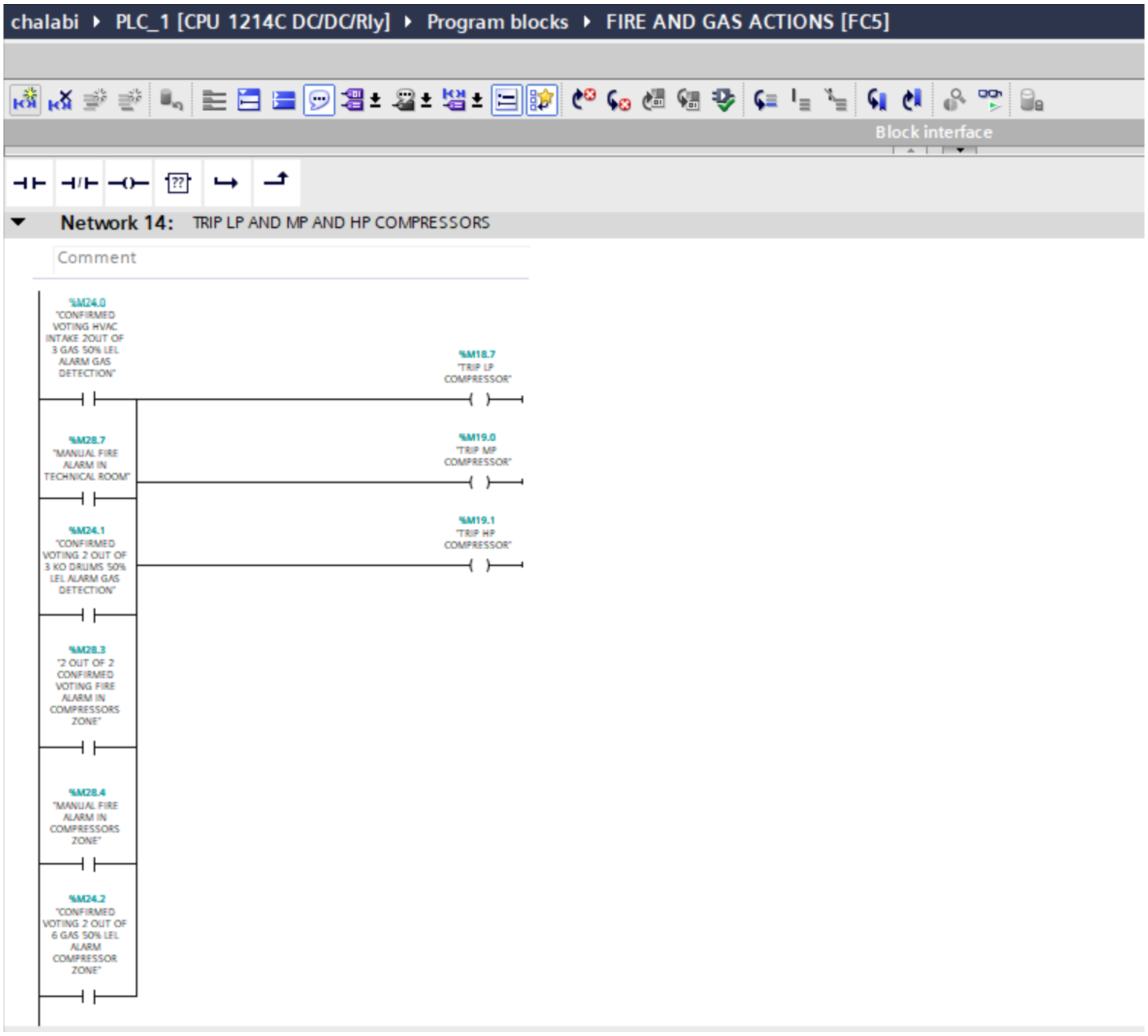

Siemens - C:\Users\tarek\OneDrive\Documents\Automation\chalabi\chalabi
Project Edit View Insert Online Options Tools Window Help
Save project
Go online
Go offline
chalabi ▸ PLC_1 [CPU 1214C DC/DC/Rly] ▸ Program blocks ▸ FIRE detection technical room [FC2]
Block interface
PLC programming
Network 11: VOTING 1 OF 2 CIRCUIT FIRE DETECTION
Comment
%M12.3
"FIRE DETECTION IN FIRST CIRCUIT"
%M13.0
"FIRE DETECTION IN SECOND CIRCUIT"
%M28.5
"1 CIRCUIT OUT OF 2 VOTING FIRE DETECTION IN TECHNICAL ROOM"
Network 12: VOTING 2 OF 2 CIRCUIT FIRE DETECTION
Comment
%M12.3
"FIRE DETECTION IN FIRST CIRCUIT"
%M13.0
"FIRE DETECTION IN SECOND CIRCUIT"
%M28.6
"2 CIRCUIT OUT OF 2 CONFIRMED VOTING FIRE DETECTION IN TECHNICAL ROOM"

Annex 6


chalabi ▸ PLC_1 [CPU 1214C DC/DC/Rly] ▸ Program blocks ▸ FIRE AND GAS ACTIONS [FC5]
Block interface
"2 OUT OF 2 CONFIRMED VOTING FIRE ALARM IN COMPRESSORS ZONE"
Network 9: GENERAL ALARM GAS
Comment
%M29.1
"1 OUT OF 2 50% LEL ALARM GAS DETECTION IN COMPRESSORS ZONE"
%M11.3
"GENERAL ALARM GAS"
%M24.1
"CONFIRMED VOTING 2 OUT OF 3 KO DRUMS 50% LEL ALARM GAS DETECTION"
%M24.2
"CONFIRMED VOTING 2 OUT OF 6 GAS 50% LEL ALARM COMPRESSOR ZONE"
%M24.0
"CONFIRMED VOTING HVAC INTAKE 2OUT OF 3 GAS 50% LEL ALARM GAS DETECTION"



chalabi ▸ PLC_1 [CPU 1214C DC/DC/Rly] ▸ Program blocks ▸ FIRE AND GAS ACTIONS [FC5]
Block interface
Comment
%M28.3
"2 OUT OF 2 CONFIRMED VOTING FIRE ALARM IN COMPRESSORS ZONE"
%M29.3
"GENERAL ALARM FIRE"
%M28.4
"MANUAL FIRE ALARM IN COMPRESSORS ZONE"
Network 11: CLOSE DAMPERS AND SWITCH HVAC TO COOLING AND RECIRCULATION
Comment
%M24.0
"CONFIRMED VOTING HVAC INTAKE 2OUT OF 3 GAS 50% LEL ALARM GAS DETECTION"
%M11.5
"CLOSE DAMPERS AND SWITCH HVAC TO COOLING AND RECIRCULATION"
Network 12: TOTAL PLANT ESD
Comment
%M24.0
"CONFIRMED VOTING HVAC INTAKE 2OUT OF 3 GAS 50% LEL ALARM GAS DETECTION"
%M11.4
"TOTAL PLANT ESD"


chalabi ▸ PLC_1 [CPU 1214C DC/DC/Rly] ▸ Program blocks ▸ FIRE AND GAS ACTIONS [FC5]
Block interface
Network 14: TRIP LP AND MP AND HP COMPRESSORS
Comment
%M24.0
"CONFIRMED VOTING HVAC INTAKE 2OUT OF 3 GAS 50% LEL ALARM GAS DETECTION"
%M18.7
"TRIP LP COMPRESSOR"
%M28.7
"MANUAL FIRE ALARM IN TECHNICAL ROOM"
%M19.0
"TRIP MP COMPRESSOR"
%M24.1
"CONFIRMED VOTING 2 OUT OF 3 KO DRUMS 50% LEL ALARM GAS DETECTION"
%M19.1
"TRIP HP COMPRESSOR"
%M28.3
"2 OUT OF 2 CONFIRMED VOTING FIRE ALARM IN COMPRESSORS ZONE"
%M28.4
"MANUAL FIRE ALARM IN COMPRESSORS ZONE"
%M24.2
"CONFIRMED VOTING 2 OUT OF 6 GAS 50% LEL ALARM COMPRESSOR ZONE"

GROUPEMENT
SONATRACH - AGIP

FIRE AND GAS CAUSE & EFFECT MATRIX

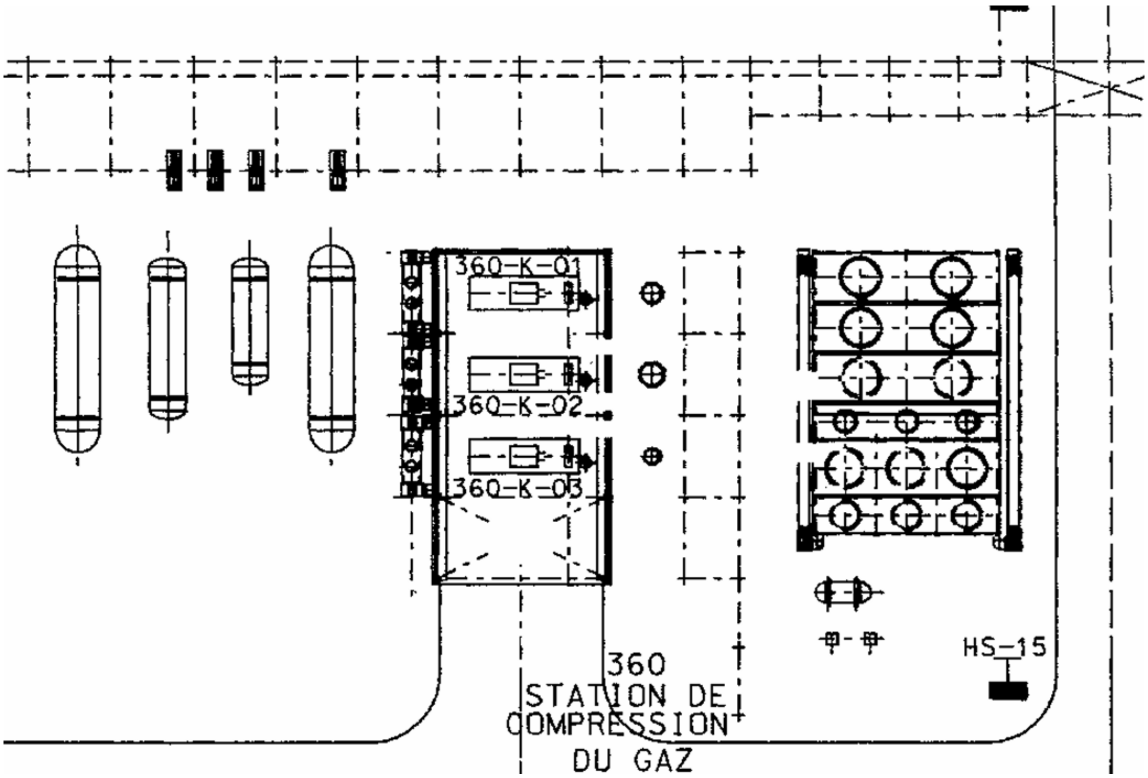
CHERIF TAREK
BENNACEUR NADIR
MAIIP 20

CAUSE

EFFECT — ALARMS / ACTIONS

service	THRESHOLD	VOTING	TAG NO	ALARM ON OPERATOR CONSOLE	INITIATE LOCAL ALARM HORN TECHNICAL ROOM	INITIATE LOCAL ALARM HORN COMPRESSORS ZONE	YELLOW LOCAL FLASHING TECHNICAL ROOM	YELLOW LOCAL FLASHING COMPRESSORS ZONE	RED LOCAL FLASHING TECHNICAL ROOM	RED LOCAL FLASHING COMPRESSORS ZONE	INITIATE GENERAL ALARM (GAS)	INITIATE GENERAL ALARM (FIRE)	CLOSE DAMPERS AND SWITCH HVAC TO COOLING AND RECI	CLOSE DAMPERS AND SHUTDOWN HVAC	HVAC FANS SHUTDOWN	TOTAL PLANT ESD	TRIP LP COMPRESSOR	TRIP MP COMPRESSOR	TRIP HP COMPRESSOR
TECHNICAL ROOM ZONE 022																			
Gas detection HVAC AIR INTAKE																			
Gas detection HVAC Air Intake	Single input 20% LEL	1 OUT OF	022-GD-01																
Gas detection HVAC Air Intake	Single input 50% LEL	1 OUT OF	022-GD-02	X	X		X												
Gas detection HVAC Air Intake	Confirmed input 50% L	2 OUT OF	022-GD-03	X	X		X						X		X	X	X	X	X
FIRE detection Instrument room and Floor Void																			
smoke det . HPO single I\P - Floor void			022-SD-01A																
smoke det . HPO single I\P - Ceilin	1OUT OF 2 CIRCUIT(single		022-SD-01B																
smoke det . HPO single I\P - Ceilin	INPUT) any one detector	1OUT OF 2	022-SD-01C	X															
smoke det . HPO single I\P - Floor	in either circuit		022-SD-01D																
smoke det . HPO single I\P - Floor void			022-SD-02A																
smoke det . HPO single I\P - Ceilin	2OUT OF 2 CIRCUIT(confirm		022-SD-02B																
smoke det . HPO single I\P - Ceilin	INPUT) at least one detec	2 OUT OF	022-SD-02C	X	X				X					X					
smoke det . HPO single I\P - Floor	in both circuit		022-SD-02D																
MANUAL FIRE ALARM IN THE TECHNICAL ROOM																			
Manual fire alarm	Confirmed INPUT	1 OUT OF	022-MA-01	X	X				X					X			X	X	X
			022-MA-02																
GAS COMPRESSION ZONE 023																			
LP Flash Gas Compressor Gas Detection																			
	Single input 20% LEL	1 OUT OF 2		X		X		X											
LP COMPRESSOR GAS DETECTI	Single input 50% LEL	1 OUT OF	023-GD-01	X		X		X			X								
	Confirmed input 50% L	2 OUT OF	023-GD-02	X		X		X			X				X		X	X	X
MP Flash Gas Compressor Gas Detection																			
	Single input 20% LEL	1 OUT OF 2		X		X		X											
MP COMPRESSOR GAS DETECT	Single input 50% LEL	1 OUT OF	023-GD-03	X		X		X			X								
	Confirmed input 50% L	2 OUT OF	023-GD-04	X		X		X			X				X		X	X	X
HP Flash Gas Compressor Gas Detection																			
	Single input 20% LEL	1 OUT OF 2		X		X		X											
HP COMPRESSOR GAS DETECT	Single input 50% LEL	1 OUT OF	023-GD-05	X		X		X			X								
	Confirmed input 50% L	2 OUT OF	023-GD-06	X		X		X			X				X		X	X	X
LP\MP\ HP KO Drums Gas Detection																			
	Single input 20% LEL	1 OUT OF	023-GD-KO-07	X		X		X											
GAS DETECTION at THE KO Drur	Single input 50% LEL	1 OUT OF	023-GD-KO-08	X		X		X			X								
	Confirmed input 50% L	2 OUT OF	023-GD-KO-09	X		X		X			X				X		X	X	X
LP Flash Gas Compression Shelter - Fire Detection																			
Flame Detector Single Input	Single Input	1 OUT OF	023-FD-01	X						X									
Flame Detector Confirmed Input	Confirmed Input	2 OUT OF	023-FD-02	X		X				X		X					X	X	X
MP Flash Gas Compression Shelter - Fire Detection																			
Flame Detector Single Input	Single Input	1 OUT OF	023-FD-03	X						X									
Flame Detector Confirmed Input	Confirmed Input	2 OUT OF	023-FD-04	X		X				X		X					X	X	X
HP Flash Gas Compression Shelter - Fire Detection																			
Flame Detector Single Input	Single Input	1 OUT OF	023-FD-05	X						X									
Flame Detector Confirmed Input	Confirmed Input	2 OUT OF	023-FD-06	X		X				X		X					X	X	X
MANUAL FIRE ALARM COMPRESSION ZONE																			
			023-MA-01																
MANUAL FIRE ALARM	Confirmed input	1 OUT OF	023-MA-02	X		X				X		X					X	X	X
			023-MA-03																

Annex 8


360-K-01
360-K-02
360-K-03
HS-15
360
STATION DE
COMPRESSION
DU GAZ