Order N°… ...... /FHC/UMBB/2024

PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA
MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH
UNIVERSITE M'HAMED BOUGARA-BOUMERDES

Faculty des Hydrocarbons and Chemistry

Final Year in Order to Obtain the Degree of
MASTER

Presented by

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Branch: Hydrocarbons
Major: Industrial Processes Automation: Automatic Control

Theme

Modification and Automation of Isolation Valves on the BOG COOPER Compressor

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Summery

To prevent surges in the centrifugal compressors of the BOG section at the GP2Z complex following trips or intentional shutdowns, the manufacturer included TOR-type isolation valves at the suction, discharge, and flare discharge points in the compressor design. However, since the BOG section was commissioned, these valves have not been procured. Consequently, the compressors have suffered from surge-related incidents, causing both process and mechanical failures in the section.

This project aims to install isolation valves at the suction, discharge, and vent points of a compressor in the BOG section and automate these valves using a Siemens S7-400 PLC. The objective is to provide crucial information on selecting and sizing the valves, as well as on the implementation and programming logic for these valves within the S7-400 PLC, thereby ensuring the safe and efficient operation of the COOPER compressor.

Key words: Siemens S7-400 PLC, GP2Z complex, BOG section, isolation valves.

Thanks

We thank ALLAH for giving us the courage, patience, willpower, and strength to face all the difficulties and obstacles that stood in our way throughout our years of study.

We would like to thank our parents who helped us, believed in us, and supported us throughout our lives. We would like to express our gratitude to our research supervisor, Mr. Beddak Karim. We would like to thank him for his supervision, guidance, and assistance throughout this process.

We would like to thank Mr. Mennaouar Fallahi, our project supervisor at GP2Z, for his trust, guidance, and presence that contributed greatly to the success of this work, especially for his help throughout the process. We would also like to thank the members of the jury for agreeing to evaluate our work. Without forgetting to thank everyone who helped us in any way in realizing this project.

Dedication

To my beloved parents, whose boundless love and unwavering support have shaped me into the person I am today, I am deeply grateful. Your care and warmth have always been my constant companions. May Allah protect you always.

To my siblings, family and dear ones, your constant presence and encouragement have meant the world to me. Thank you immensely.

To my friends, who have been like a second family throughout this journey, I appreciate everything you have done. Thank you for being there for me.

-Ouassim-

to my beloved parents, whose boundless love, unwavering support, and countless sacrifices have shaped me into the person I am today. Your endless encouragement and guidance have been my greatest source of strength.

To my family, whose constant support has fueled my perseverance.

To my friends, Badro, Alaa Eddine and others, who have been my second family and have supported me throughout this journey. Thank you all for your unwavering belief in me. I am profoundly grateful to each of you. May Allah protect and bless you always.

-Salah Eddine-

Table of contents

General Introduction 01

Chapter I: Description of the GP2Z complex

1.1 Introduction.. 02

1.2 Geographical location of the complex...02

1.3 Complex data sheet 03

1.4 History of GP2/Z complex.. 03

1.5 General organization 05

1.6 Gp2/Z Complex Flowchart 06

1.7 General description of the process...07

1.7.1 Buffer storage section 09

1.7.2 Dehydration section 10

1.7.3 Separation section 11

1.7.4 Refrigeration section 13

1.7.5 Boil off Gas section (BOG)..13

1.7.6 Storage section4 13

1.7.7 The utilities 14

1.8 Conclusion 14

Chapter II: Description of the GP2Z complex

2.1 Introduction…... 15

2.2 General information on compressors. 15

2.2.1 Types of Compressors…...15

2.2.2 Operating Principles…..16

2.2.3 Applications… 16

2.2.4 Efficiency and Control….. 16

2.2.5 Safety Considerations…...19

2.2.6 Compressors on oil and gas refinery… 19

2.3 BOG section (Boil off Gas)…..20
2.3.1 Propane recovery circuit...21
2.4 General information on the cooper compressor..21
2.4.1 Operating Principles…..21
2.4.2 Start-up procedure.. 23
2.4.3 Loading the compressor… 23
2.4.4 Shut-Down Procedure.. 24
2.4.5 COOPER Compressor characteristic…..24
2.4.6 Instrument list…..25
2.5 The problem posed….. 29
2.6 valves choice 30
2.6.1 System Requirements…...30
2.6.2 Recommended Electro valve...30
2.6.2.1 Specifications and Features of Solenoid Valves 31
2.7 Conclusion…...32

Chapter III: Cooper control logic and software improvement

3.1 Introduction…... 33
3.2 General information on PLC (Programmable logic controller)..33
3.2.1 Operating principle 33
3.2.2 PLC hardware 34
3.2.3 PLC key features... 35
3.3 Overview of PLC S7 400 35
3.3.1 Description of PLC S7-400…...36
3.4 Description of system Siemens S7-400 for COOPER compressor 38
3.4.1 Hardwar description... 38
3.4.2 Software description...39
3.4.2.1 Programming software (TIA Portal V14)..39
3.4.2.2 Control logic description 40
3.5 Simulation and result...56

3.6 Conclusion…..65

Chapter IV: COOPER SUPERVISION AND MONITORING

4.1 Introduction….. 65
4.2 General information on Human Machine Interface (HMI) 65
4.2.1 DEFINITION…... 65
4.2.2 Components of HMI 66
4.2.3 Importance of HMI..67
4.2.4 KP1200 COMFORT Tactile panel…..67
4.3 HMI for systeme cooper compressor...68
4.3.1 Screens description 68
4.3.2 System Alarms…...73
4.4 HMI simulation and results….. 74
4.5 Conclusion...76

General Conclusion... 78

List of tables

Chapter II

Table II.1: Measuring instrument…..25

Table II.2: Actuating device 29

List of figures

Chapter I

Figure 1.1: Location of the GP2Z complex in the Arzew industrial zone 02

Figure 1.2: Diagram of the GP2/Z complex 05

Figure 1.3: Gp2/Z Complex Flowchart 07

Figure 1.4: The process of the GP2Z complex...09

Figure 1.5: Storage spheres.. 10

Figure 1.6: Dehydration section 11

Figure 1.7: separation section 12

Chapter II

Figure 2.1: Reciprocating Compressor 15

Figure 2.2: Rotary Screw Compressor 16

Figure 2.3: Rotary Vane Compressor. 16

Figure 2.4: Centrifugal Compressor...17

Figure 2.5: Axial Compressors...17

Figure 2.6: cooper compressor P&ID diagram… 22

Figure 2.7: Solenoid valve 31

Chapter III

Figure 3.1: Programmable logic controller.. 33

Figure 3.2: PLC archetecture 34

Figure 3.3:Siemens PLC S7-400 35

Figure 3.4: S7-400 principal components.. 37

Figure 3.5: Programming tools of TIA portal. 40
Figure 3.6: The network of motor starter enable contact… 42
Figure 3.7: The network of motor stop contact...42
Figure 3.8: The network of machine run set…...43
Figure 3.9: The network of motor failed to start flag…..44
Figure 3.10: The network of flag reset button…..44
Figure 3.11: The network of oil pump start contact 46
Figure 3.12: The network of fan… 47
Figure 3.13: The network of trips… 48
Figure 3.14: The network of trips reset button… 49
Figure 3.15: The network of isolation inlet valve alarm… 49
Figure 3.16: The network of isolation discharge valve alarm…...50
Figure 3.17: The network of isolation inlet valve 51
Figure 3.18: The network of isolation discharge valve...52
Figure 3.19: The network of manual mode condition...52
Figure 3.20: The network of isolation torch valve...53
Figure 3.21: The network of pressure torch valve condition 53
Figure 3.22: The network of manual mode condition (torch valve)...54
Figure 3.23: The network of isolation torch valve alarme..54
Figure 3.24: Simulation of motor starter enable contact...55
Figure 3.25: Simulation of motor stop network..56
Figure 3.26: Simulation of machine run set..57
Figure 3.27: Simulation of motor flag..57
Figure 3.28: Simulation of reset button networks... 58
Figure 3.29: Simulation of oil pump network….. 59
Figure 3.30: Simulation of fan network….. 59
Figure 3.31: Simulation of the isolation inlet valve…..60
Figure 3.32: Simulation of the isolation discharge valve… 60

Figure 3.33: Simulation of torch valve pressure condition…... 61
Figure 3.34: Simulation of torch valve network..61
Figure 3.35: Simulation of inlet valve alarm… 62
Figure 3.36: Simulation of manual mode condition… 63
Figure 3.37: Simulation of manual mode condition (torch valve)…... 63

Chapter IV

Figure 4.1: Human machine interface... 66
Figure 4.2: KP1200 COMFORT Tactile panel... 68
Figure 4.3: Home screen...69
Figure 4.4: Compressor screen (COOPER)..70
Figure 4.5: Permissive screen 71
Figure 4.6: Isolation valves screen…...72
Figure 4.7: Alarms screen… 73
Figure 4.8: HMI Alarms 74
Figure 4.9: Simulation of compressor system...74
Figure 4.10: Simulation of permissive... 75
Figure 4.11: Simulation of isolation valves… 75

List of abbreviations

LPG: Liquefied Petroleum Gas.

GP2Z: Petroleum Gas of ARZEW (complex 2°)

LQS: liquefaction separation

DCS: Distributed Control System.

IHI: Ishikawajima-Harima Heavy Industries.

ISO: International Organization for Standardization.

BOG: Boil-Off Gas.

RTO: Regenerative Thermal Oxidizer.

PIC: Programmable Integrated Circuit.

FIC: Flow Indicating Controller.

TIC: Temperature Indicating Controller.

NGL: Natural Gas Liquids.

SRU: Sulfur Recovery Unit.

FCV: Flow Control Valve.

PCV: Pressure Control Valve.

PT: Pressure Transmitter.

FT: Flow Transmitter.

IBV: Inlet butterfly valve.

HV: Handle Valve.

TE: Temperature Element.

XV: On-Off Valve.

DC: Direct Current.

O/P: Output.

I/O: Input / Output.

MPI: Multi Point Interface.

LAD: Ladder.

FBD: Function Block Diagram.

ST: Structured Text (programming language for PLCs).

SCL: Statement List (programming language for PLCs).

DP: Differential Pressure.

PS: power supply

CP: communication processor

DI: Digital Input

DO: Digital output

RTD: Resistance Temperature Detector

OP: Operator interface

OB: organization block

FC: function

CCM: Central Control Module

ESD: Emergency Shut Down

GUI: Graphical User Interface

TFT: Thin-Film Transistor

SCADA: Supervisory Control and Data Acquisition.

HMI: Human Machine Interface.

TIA: Totally Integrated Automation.

CPU: Central processing unit.

AI: Entrée Analogique.

SIMATIC: Siemens Automatic

PLC: Programmable Logic Controller.

Profinet: Process Field Net

Profibus: Process Field Bus

General introduction

General Introduction

Automation is the scientific and technological field that performs the control of technical tasks using machines that operate without human intervention or with minimal intervention. Automation has become widespread in all production activities, both in industry and in service activities. Regardless of its application field and the techniques it employs, automation has continuously developed with the sole aim of reducing the difficulty of human labor and improving productivity and product quality.

The objective of this internship is to conduct a study on the Cooper compressor at the Boil-Off Gas (BOG) station of the GP2Z complex in Arzew. Specifically, the focus is on the isolation valves, which were previously operated manually. We have decided to transition these valves to automatic operation to ensure the efficient functioning of the programs and to facilitate the simplest possible method for isolating the compressor, thereby preventing potential issues.

Our report is organized into four chapters:

- Chapter I: This chapter provides an in-depth overview of the GP2Z complex, including a detailed description of its components, layout, and operating principles.
- Chapter II: This chapter delves into the intricacies of the Boil-Off Gas (BOG) section and the operating principles of the Cooper compressors used in the system.
- Chapter III: This chapter offers a comprehensive review of Programmable Logic Controllers (PLCs). It includes a detailed exploration of the Siemens S7-400 PLC, its features, and specific implementations of control logic for the Cooper compressors, demonstrating real-world applications of the Siemens S7-400.
- Chapter IV: This chapter presents the Human-Machine Interface (HMI) views for supervision and communication with the PLC.

Finally, our work will conclude with a general conclusion.

Chapter I

Description of the GP2Z complex

1.1 Introduction

LPG is considered to be a mixture of liquefied gases. It consists of propane and butane, in varying proportions depending on the nature of the oil deposits.

The general average composition of Algerian LPGs is around 60% propane and 40% butane (depending on the origin of the LPG), with traces of water. This is produced in the southern units, particularly in HASSI MESSAOUD and HASSI RMEL. This hydrocarbon is a source of energy, and it is transported by means of a pipeline of around 900 Km

1.2 Geographical location of the complex

The GP2Z complex is located in Arzew on a 29-hectare site on the plateau of the former "Les Ablettes" beach, between GL4-Z (formerly La Camel) to the north/west and FERTIAL (Ammonia) to the south/east. It is about 1 kilometer from the town of Arzew. **Figure 1.1.**

Figure 1.1. Location of the GP2Z complex in the Arzew industrial zone

1.3 Complex data sheet

- Location: ARZEW

- Area: 29 hectares

- Workforce: 436 agents

- Objective: 1.8 million t/year of LPG

- Product: Commercial propane and butane

- Process used: Pressure distillation

- Number of trains: 2 trains (semi-modulars)

- Production start date: 19/03/1973

- Source of supply: Gas from Hassi R'Mel and Hassi Messaoud oil and gas fields -

-Total production capacity: 1.400.000 tons per year

- Total storage capacity:

- A 70,000 m³ tank for refrigerated butane.
- A 70,000 m³ tank for refrigerated propane.
- Two spheres, each with a capacity of 1220 m³, for storing ambient butane.
- Two spheres of 1220 m³ each, for LPG [1].

1.4 History of GP2/Z complex

The GP2/Z complex has gone through several phases in order to adapt to the global market. The main mission of the complex is to separate LPG into propane and butane.

The National Company SONATRACH, in collaboration with the British company CJB, commissioned the GP2/Z complex on MARCH 17, 1973, which was later joined to the LQS branch.

1973: Start-up of the plant to process 4 million tons per year of LPG/condensate blends.

1984: Plant shutdown in July due to technical difficulties caused by the opening of the GP1-Z complex (JUMBO LPG) and the commissioning of condensate stabilization units at the southern fields.

1990: restarting of the plant with two trains in November for the treatment of LPG alone, after modification of the process, for a capacity of 0.6 million tons per year.

1993: GTP Company has launched renovation and development work on the complex's various equipment and facilities in order to increase production capacity and improve product quality, thereby increasing production capacity from 600,000T/year to 1,200,000T/year.

1996: increase in the plant's treatment capacity to 1.2 million T/year, this increase was made possible by the reconversion of two old LPG/condensate separation columns into LPG separation columns, the renovation of several pieces of production equipment and the replacement of the conventional process control system by the DCS.

1999: production capacity reached almost 1.8 million T/year.

2000: After the first phase of increasing capacity from 0.6 million T/year to 1.2 million T/year (target reached in October 1996), the complex underwent a second phase to reach a processing capacity of 1.8 million T/year. This target was reached in December 2000.

2003: Project to increase plant capacity to 2.5 million T/year, to enable the complex to be structured into two modular units, each of which will process 1.25 million T/year.

2005: Possible forecast of 3.5 million tons per year. The realization of projects in the south revealed a new load profile that was not in line with existing separation capacities in the north.

To be ready to receive these loads in 2005, the complex proposed a new expansion project that would increase its production to 3.5 million T/year. This project will involve the construction of 02 new storage tanks, each with a capacity of 70,000 m^3, and the rehabilitation of the old columns.

2007: the GP2/Z complex underwent some modifications following the renovation project carried out by IHI (a Japanese company), in order to secure the GP2/Z complex while maintaining production at 1.3 MT/year.

2008: the complex successfully completed a plant safety and reliability project carried out by the Japanese firm IHI.

2009: Certification ISO 9001/2008 and l'ISO 14001/2004 [1].

1.5 General organization

The layout of the site's various activities is as follows:

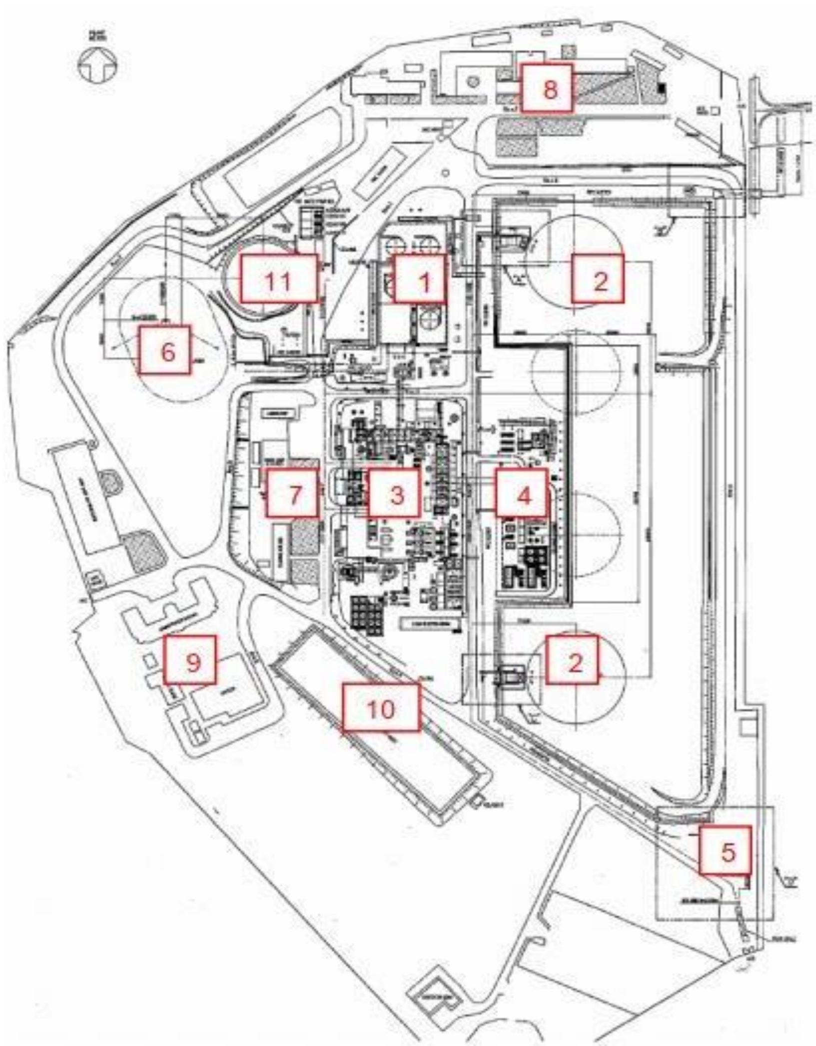


Figure 1.2. Diagram of the GP2/Z complex

Caption :

1 : pressurized LPG storage spheres, fillers and finished products

2 : refrigerated propane and butane storage tanks

3 : process zone (dehydration, separation, refrigeration)

4 : zone BOG

5 : truck loading area

6 : HP and BP torches

7 : control room

8 : technical rooms

9 : administrative offices and restaurant

10 : 35,000 m^3 fire water tank

11 : 54,000 m^3 fire water tank safety monitoring station

1.6 Gp2/Z Complex Flowchart

The GP2/Z complex is organized as follows:

- **Two sub-directorates:**
- **Personnel sub-directorate**: **D***

  It comprises four departments :

  - **R :** Human resources
  - **ADM/SOC :** Personnel administration and social affairs
  - **M :** General resources
  - **RT:** Work relations

- **Operations Sub-Directorate** : **D*E**
  - **A :** Sourcing.
  - **G :** Maintenance
  - **P :** Production

- **Four control departments:**
  - **I :** Safety
  - **F :** Finance
  - **T :** Technical
  - **W :** New work

Two other functions:

Attached to management :

- **ORG/INF :** Organization and IT Department
- **ASI :** Internal safety assistant.

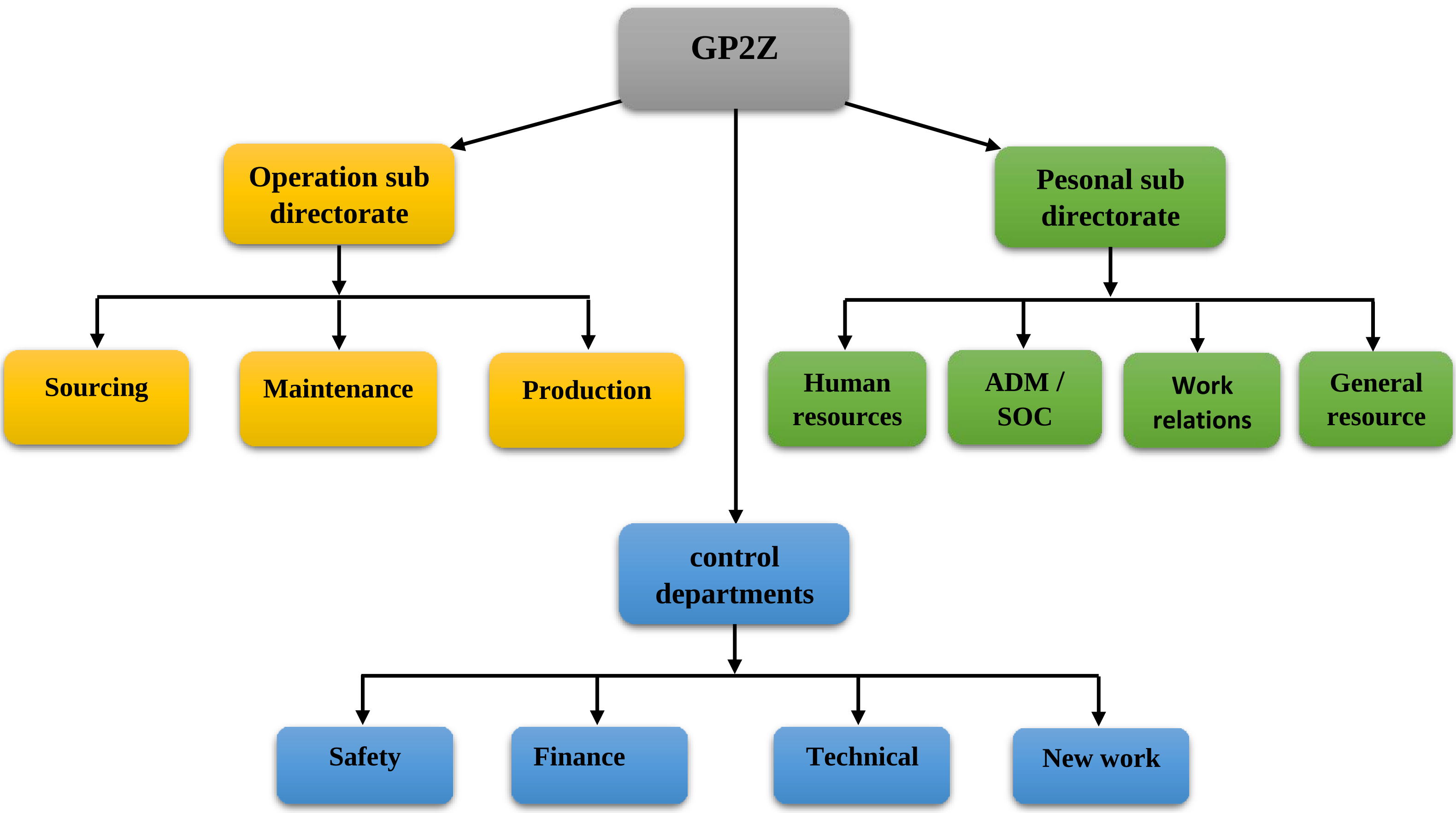


Figure 1.3. Gp2/Z Complex Flowchart

1.7 General description of the process

The LPG feedstock is composed of approximately 60% propane and 40% butane with traces of C_1, C_2 and C_5, CO_2 and H_2O. It comes from various oil fields in the south "Hassi R'mel, Hassi Messaoud etc.". The feedstock is sent through pumping stations and then transits through RTO, arriving at the GP2Z complex at a pressure of 20 bar and ambient temperature. The LPG feedstock passes through valve XV-6501, then enters two filters, as our LPG contains impurities (sand, dust, foreign matter).

The LPG charge leaving the filter in service enters a charge degasser tank to remove non-condensable gases such as lighter hydrocarbons and inert gases. The load is stored in 02 spheres (1220 m^3), to ensure safety operation in the event of problems at the pumping and conveying stations.

At the sphere outlet, the LPG is sent after the dehydration section to the two splitters for separation into butane and propane. The propane is recovered at the top of the column, while the butane is recovered at the bottom of the column, the latter passes through the reboiler to be heated by the TORADA (thermal oil) from the furnace. The vapor portion of the butane returns to the column to maintain heating at the bottom of the column. The liquid part of the butane is used to preheat the LPG charge, and is then sent to the refrigeration section, where it is cooled in two pressure stages (HP, MP). The propane obtained at the top of the column is used in part as reflux to the column. The rest is sent to the refrigeration section, where it is cooled in three stages (HP, MP, and BP).

Commercial C_3 propane and commercial C_4 butane are stored respectively in two tanks (70,000 m3). Ambient C4 butane is stored in two spheres (1220 m3). The general process is shown in **figure 1.4** [1].

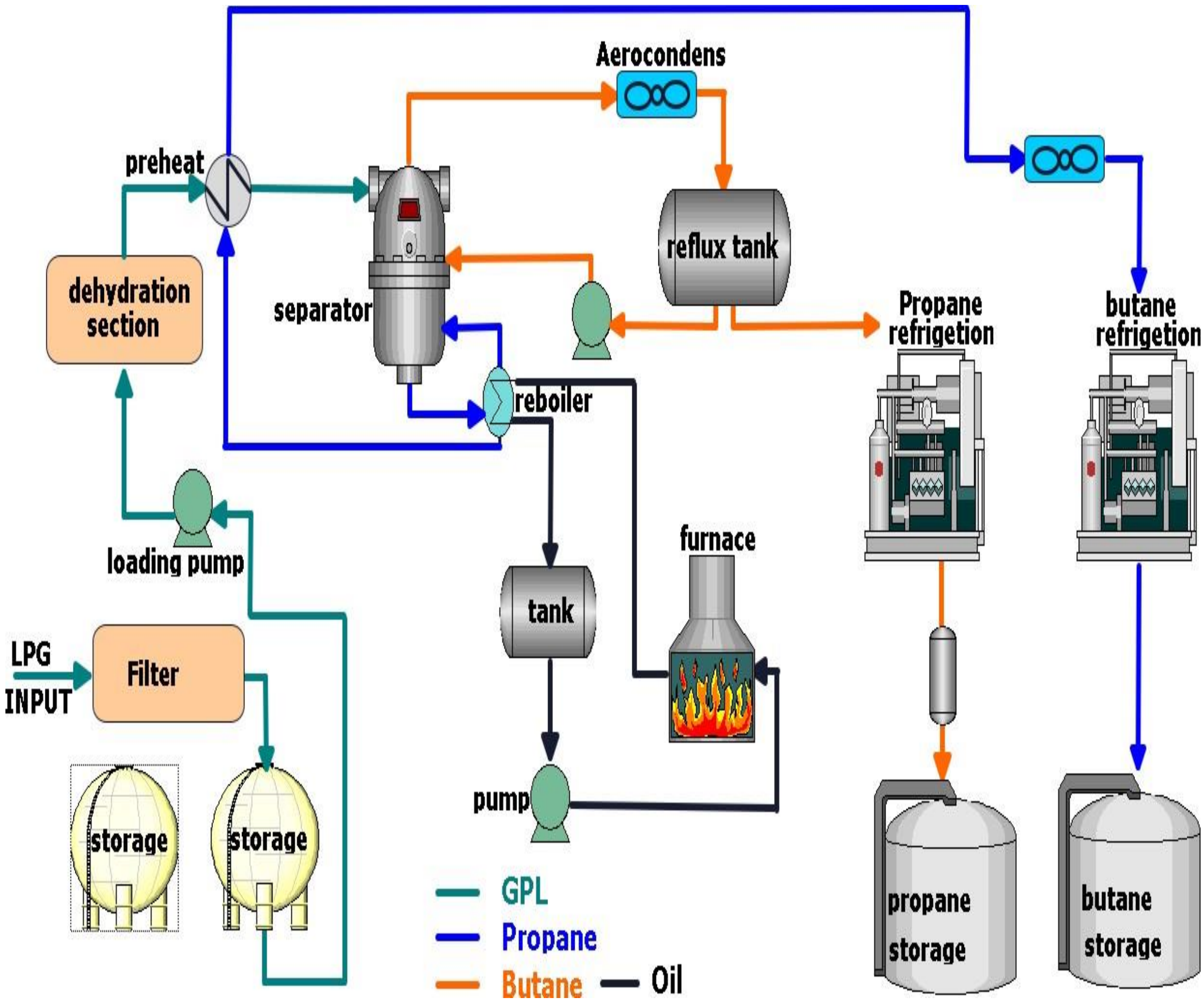


Figure 1.4. The process of the GP2Z complex

1.7.1 Buffer storage section

The gas and oil fields of Hassi R'mel and Hassi Messaoud are supplied by pipeline via the RTO terminal. The incoming LPG is expanded to 20 bars and then transferred to storage spheres, where it is stored at a pressure of 9 bars.

LPG is a mixture of components, to which fuel oil-gas is injected to make it more stable. The 09-bar pressure is maintained by a PIC controller, which allows the fuel oil to be admitted or discharged from the fuel oil-gas station.

The LPG mixture is pumped from the spheres to the dehydration unit to remove the water contained in the charge (the largest quantity) **Figure 1.5** [1].

Figure 1.5. Storage spheres

1.7.2 Dehydration section

The LPG liquid coming from the LPG storage spheres is saturated with water, its water content is estimated at around 320ppm including undissolved water. Consequently, the dehydration section of the feedstock is designed to lower the water content to 1ppm in the section following it. The water is adsorbed by the molecular sieves and vaporized by the hot gas during regeneration. The water vapor entrained by the fuel gas is condensed in the cooler and separated in the separator drum. This water is drained to atmosphere and the gas is fed into the fuel gas network. After the heating sequence, the adsorber is cooled by circulating cold gas through the heater, and when the cooling cycle is complete, the adsorber is filled with LPG and repressurized. It will then be put on hold until it is returned to adsorption for a new cycle [1] **Figure 1.6**.

Figure 1.6. Dehydration section

1.7.3 Separation section

The separation unit has been designed to separate the LPG feedstock mixture into commercial propane as the column overhead and commercial butane as the bottom product. It consists of 02 trains (02 splitters) 407/6201/A and B, each of which includes the following equipment:

- **TRAIN A: 407/6201/A:**
  - A separation column with 46 trays, (407/6201/A)
  - LPG charge preheater (405/6201/A)
  - A battery of air condensers (402/6202/A)
  - One reflux tank (410/6201/A)
  - Two reflux pumps (425/6202/A and B)
  - One reboiler (405/6224/A)

- **TRAIN B : 407/6201/B:**
  - A separation column with 46 trays, (407/6201/B)
  - LPG charge preheater (405/6201/B)
  - A battery of air condensers (402/6202/B)
  - One reflux tank (410/6201/B)

- Two reflux pumps (425/6202/C and D)
- One reboiler (405/6224/B)

The LPG feed at 23 bar pressure passes through the preheater, where it is preheated by butane from the bottom of the separation column. LPG inlet temperature is controlled by TIC 6213. LPG inlet flow is controlled by FIC 6203.

The LPG flow coming from the preheater enters at plate no. 24, the light hydrocarbons separate from the feed stream and rise to the top of the column against a continuous reflux of propane.

The commercial propane extracted as an overhead product is fully condensed in the condensers.

Propane from the reflux flask is drawn off by one of the A/B reflux pumps. A portion is reintroduced as reflux into the column. The reflux flow rate is controlled by the FIC 6205. The other part of the propane flows to the refrigeration unit via which maintains a liquid level in the reflux flask.

The liquid from the bottom of the column (butane) enters the reboiler where it is partially vaporized. The vaporized part returns to the column below the 46th plate as a vapor reflux, while the other part of the butane flows to the reboiler via which maintain a liquid level in the reboiler.

The heat required for reboiling is supplied by TORADA (Thermal Oil) from the furnace. The temperature of tray N°46, TIC 6258 controls the reboiling flow rate by acting directly on the TORADA flow valve **Figure 1.7** [1].

Figure 1.7. Separation section

1.7.4 Refrigeration section

The purpose of the refrigeration section is to cool propane and butane products at storage temperatures of -45°C for propane and -11°C for butane at atmospheric pressure.

The refrigeration system is a cascade system using pure propane as the refrigerant.

Cooling takes place in a closed loop at three temperature levels: 11.8°C, -16.9°C and -40.3°C, corresponding to high pressure HP (5 bar), medium pressure MP (1.5 bar) and low-pressure BP (0.05 bar) [1].

1.7.5 Boil off Gas section (BOG)

The Boil Off gas section recovers vapors of commercial propane and butane from their storage tanks.

The vapors are recovered from the tanks by compressors, condensed in condensers recovered in flask, then returned to their tanks [1].

1.7.6 Storage section

This section is used to store refrigerated commercial propane and butane. It includes two tanks, each with a capacity of 70,000 cubic meters. A propane storage tank (420/6204) and one for butane (420/6205).

- **1.7.6.1 Propane bac:**

This tank stores propane at slightly above atmospheric pressure and at a temperature of -45°C. The tank is fitted with three safety valves and contains four pumps (425/6104A-B-C-D) immersed in the tank to ensure propane shipment to the loading docks, the role of the pump (425/4104 D) is to cool the commercial propane shipping line from a cold temperature of -40°C to -47°C.

- **1.7.6.2 Butane bac:**

This capacity is designed to store butane at slightly above atmospheric pressure and at a temperature of -11°C. The tank is fitted with three safety valves, and four pumps (425/6101A-

B-C-D) are immersed in the tank to ensure butane to the loading docks, the role of the butane pump (425/6101 D) is to cool the commercial butane shipping line from a cold temperature of -11°C [1].

1.7.7 The utilities

They comprise the following networks:

- Fuel gas network:

It is designed to supply reboiler furnaces, turbines, flare pilots and the storage of LPG and butane.

- Electricity network:

For electrical power requirements, the complex has two sources of supply: SONELGAZ network and an internal generation system.

- Instrument air network:

A group of three compressors driven by electric motors supplies the air requirements.

- Inert gas network (nitrogen):

This network ensures equipment inerting operations prior to penetration and welding work.

- Methanol network:

The methanol network (methanol injection) is set up to de-ice commercial propane shipping lines.

- Fire water network:

It consists of a fire water reservoir with pumps and a fire water tank [1].

1.8 Conclusion

In this chapter, we provide a comprehensive overview of the processes within the GP2Z complex, detailing how LPG is separated into propane and butane. We trace each step of this separation process, from the initial phases to the final storage of these gases. Additionally, we explore the primary sections involved in this process and delve into the history of the complex, highlighting its development and significant.

Chapter II

General information on the cooper compressor

2.1 Introduction

Compressors are indispensable devices utilized across a multitude of industries, serving a fundamental role in transforming and manipulating gases and fluids. Operating on principles of thermodynamics and fluid mechanics, compressors are designed to increase the pressure of a gas or liquid, thereby reducing its volume and facilitating its movement through various systems. From powering industrial machinery to regulating air temperature in refrigeration and air conditioning units, compressors play a pivotal role in modern-day technology and infrastructure. By harnessing mechanical energy, compressors enable the compression, transportation, and processing of gases and fluids essential for numerous industrial processes, making them integral components of diverse applications worldwide.

2.2 General information on compressors

Compressors are devices used to reduce the volume of a gas or liquid by exerting pressure on it. They are widely used in various industries and applications, ranging from refrigeration and air conditioning to industrial processes and power generation. Here's some general information about compressors:

2.2.1 Types of Compressors

- **Positive Displacement Compressors:** These compressors work by trapping a volume of gas and then reducing its volume [2].

  - Reciprocating Compressors: Use pistons to compress gas.

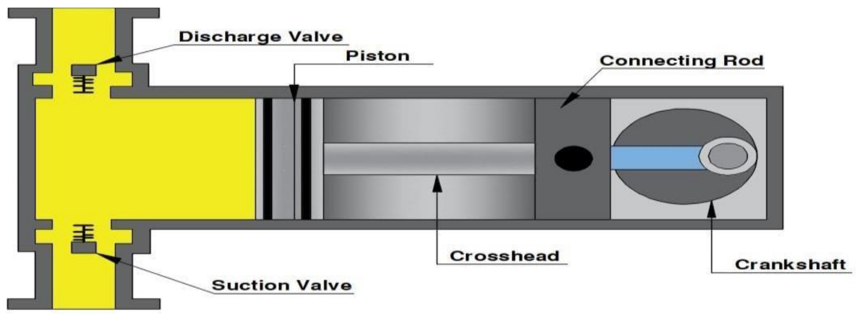


Figure 2.1. Reciprocating Compressor

- Rotary Screw Compressors: Use screws to compress gas.

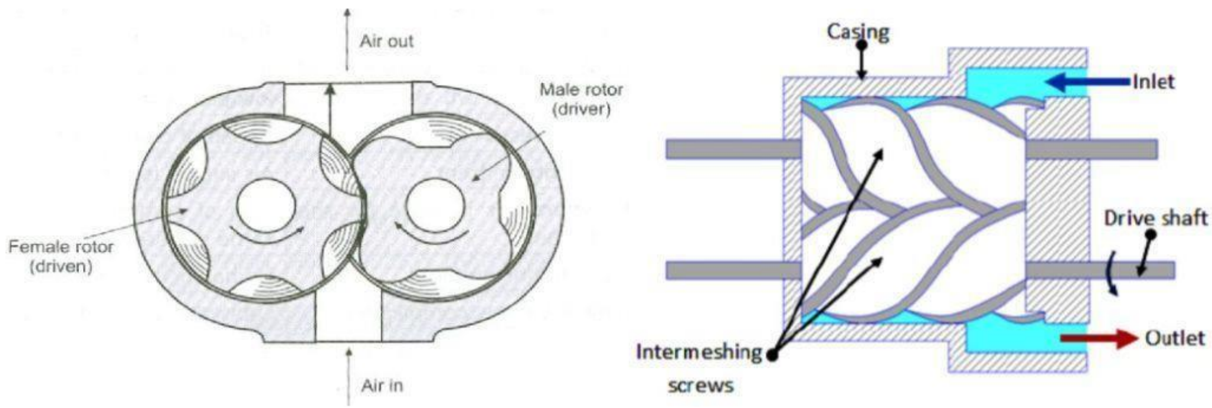


Figure 2.2. Rotary Screw Compressor

- Rotary Vane Compressors: Use vanes to compress gas.

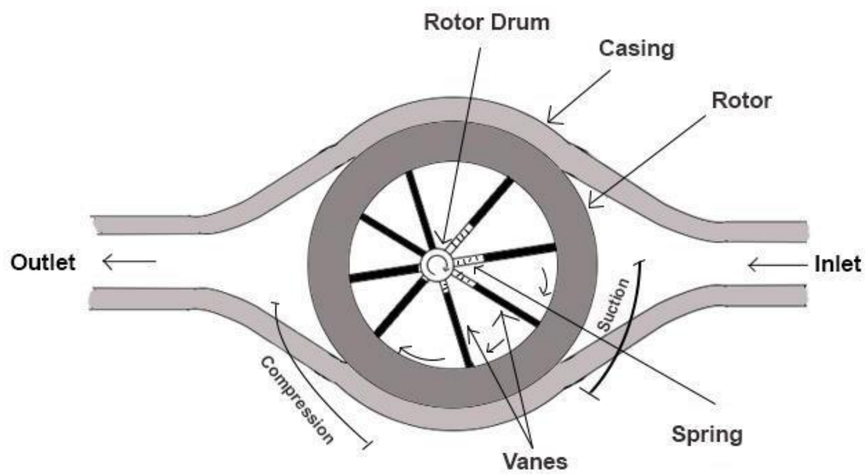


Figure 2.3. Rotary Vane Compressor

- **Dynamic Compressors:** These compressors use rotating impellers to increase the velocity of the gas, which is then converted to pressure [3].

  - Centrifugal Compressors: Use a rotating impeller to impart velocity to the gas.

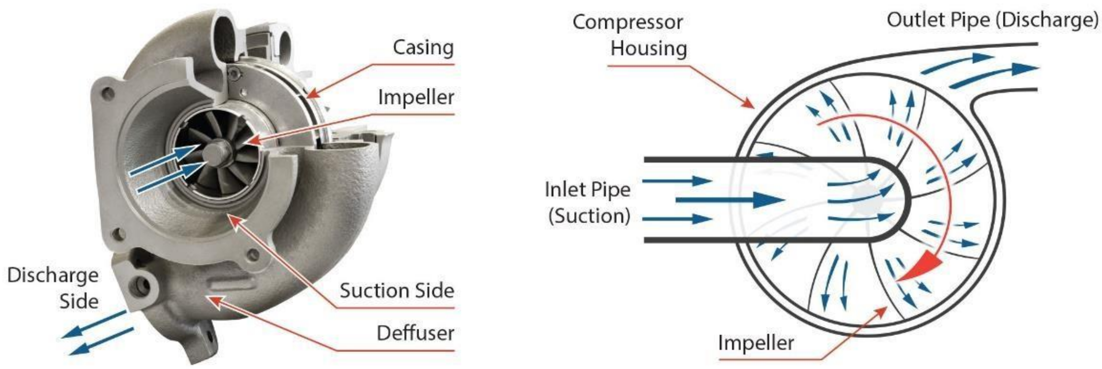


Figure 2.4. Centrifugal Compressor

  - Axial Compressors: Use rotating blades to compress gas in a straight-through flow path.

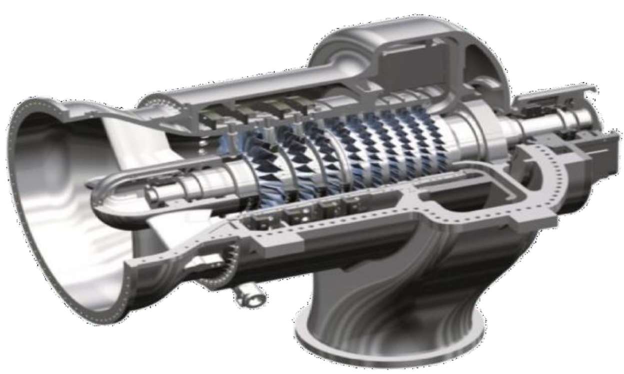


Figure 2.5. Axial Compressors

2.2.2 Operating Principles

Compressors work by increasing the pressure of a gas, which reduces its volume. This is achieved through the mechanical action of the compressor's components, whether it's pistons, screws, vanes, or impellers.

Positive displacement compressors operate by trapping gas in a chamber and then reducing the chamber's volume to compress the gas.

Dynamic compressors increase the velocity of the gas by imparting kinetic energy to it through rotating components. This kinetic energy is then converted into pressure [4].

2.2.3 Applications

- **Industrial Processes:** Compressors are used in various industrial processes such as gas processing, chemical manufacturing, and petroleum refining.
- **Refrigeration and Air Conditioning:** Compressors are essential components in refrigeration and air conditioning systems, where they compress refrigerants to transfer heat.
- **Power Generation:** Compressors are used in gas turbines and turbochargers for power generation and engine performance enhancement.
- **Oil & Gas Industry:** Compressors play a crucial role in natural gas processing, transmission, and storage operations.
- **Automotive:** Compressors are used in automotive applications, such as in the air conditioning systems of vehicles [5].

2.2.4 Efficiency and Control

Compressor efficiency is crucial for minimizing energy consumption and operational costs. Regular maintenance and proper operating conditions help maintain efficiency.

Control systems, such as variable speed drives and capacity control mechanisms, are often used to optimize compressor performance and match it with varying demand [6].

2.2.5 Safety Considerations:

Compressors handle high-pressure gases, so safety measures are essential to prevent accidents such as leaks or ruptures.

Proper ventilation, regular inspections, and adherence to safety protocols are necessary for safe compressor operation.

2.2.6 Compressors on oil and gas refinery:

In oil and gas refineries, compressors play a critical role in various processes, aiding in the refining, processing, and transportation of crude oil and its by-products.

- **Gas Processing:**

Natural gas extracted from oil wells or gas fields often contains impurities such as water vapor, carbon dioxide, and hydrogen sulfide. Compressors are used to pressurize the gas for transportation through pipelines to processing plants.

In gas processing plants, compressors are utilized to further compress the gas to higher pressures for purification processes such as dehydration, sweetening (removal of hydrogen sulfide), and separation of natural gas liquids (NGLs).

- **Hydrocracking and Catalytic Cracking:**

Compressors are employed in hydrocracking and catalytic cracking units, where heavy hydrocarbons are converted into lighter, more valuable products such as gasoline and diesel. They help circulate the catalyst and provide the necessary pressure for the chemical reactions to occur.

- **Reforming Units:**

Reforming units are used to convert low-octane naphtha into high-octane gasoline blending components. Compressors are used to maintain the required pressure and circulation of reactants in these units.

- **Hydrogen Production:**

Many refineries produce hydrogen through processes like steam methane reforming or catalytic reforming. Compressors are essential for compressing and circulating gases in these processes.

- **Sulfur Recovery Units (SRUs):**

SRUs are used to recover elemental sulfur from hydrogen sulfide-rich streams produced during crude oil refining. Compressors are used to compress the gas streams before they enter the sulfur recovery process.

- **Pipeline Transportation:**

Compressors are utilized along pipelines to maintain the pressure necessary for transporting crude oil, natural gas, and refined products over long distances. These compressors, often referred to as pipeline compressors or booster compressors, help overcome frictional losses and maintain flow rates.

- **Storage and Distribution:**

In storage facilities and distribution terminals, compressors are used to transfer refined products such as gasoline, diesel, and jet fuel from storage tanks to tanker trucks, railcars, or pipelines.

- **Flare Gas Recovery:**

Refineries often have flare systems to burn off excess or waste gases during upset conditions or maintenance activities. Compressors can be used to recover and compress these flare gases for reuse or sale rather than burning them off [7].

2.3 BOG section (Boil off Gas):

The BOIL-OFF gas section recovers commercial propane and butane vapors from their storage tanks.

The vapors are recovered from the tanks by compressors, condensed in air-condensers, collected in balloons then returned to their tanks.

This section contains six compressors, two vice compressors (Howden) 430/6102 C & D for loop, two centrifugal compressors (Cooper) 430/6101 E & D for propane, and two vice compressors 430/6102A/B for butane, controlled by Allen Bradley, Siemens S7 and Siemens S5 PLCs respectively [8].

2.3.1 Propane recovery circuit:

The cooper 430/6101/E/D compressors aspirate the propane vapors emitted by the 420/6104 tank and the vapors emitted by the flash flask (410/6206) at a pressure of 0.4 bar and a temperature of -45°C. The vapors are then discharged to the 405/6104 condensers, then to the 405/6102 schiller on the tube side, at a pressure of 8 bar and a temperature of 37°C, after which they are cooled to -23 by the refrigerant propane, then directed to the 410/6105 tank [8].

2.4 General information on the cooper compressor:

2.4.1 Operating Principles:

This is a multi-stage centrifugal compressor (3 stages) driven by an electric motor. The compressor will compress evaporated propane from a liquid propane storage tank. The compressed gas will be cooled by an air-to-gas intercooler. The intercooler fan also produces cooled air for oil cooling.

The compressed gas is then passed to an intercooler, which cools the gas so that it condenses back into a liquid, which is then returned to the tank.

The compressor's FCV170 inlet butterfly valve, PCV171 recirculation valve and associated intercooler are designed to deliver a constant gas pressure of 8.3 kg/cm^2 (PT 134) at the compressor outlet. Feed pressure to the compressor inlet will vary from 0.3kg/cm^2 to 0.9kg/cm^2 (PT131).

The compressor is equipped with 2 lubricating oil pumps. One is an auxiliary electric pump for starting and stopping the equipment, the other is driven by the motor shaft.

An anti-pumping system is used to protect the compressor. This system is based on flow measurement across FT 160, the inlet to the compressor's third stage, and on differential pressure measurement across the entire compressor.

This system uses a Siemens PLC with S7-400 processor to ensure the smooth operation and regulation of the 2 compressors.

This system uses a Siemens PLC with S7-400 processor to ensure correct operation and regulation of the 2 compressors.

The PLC is installed in the old control room, and each compressor has a local panel equipped with an OP console for visualization and access by instrument technicians [8].

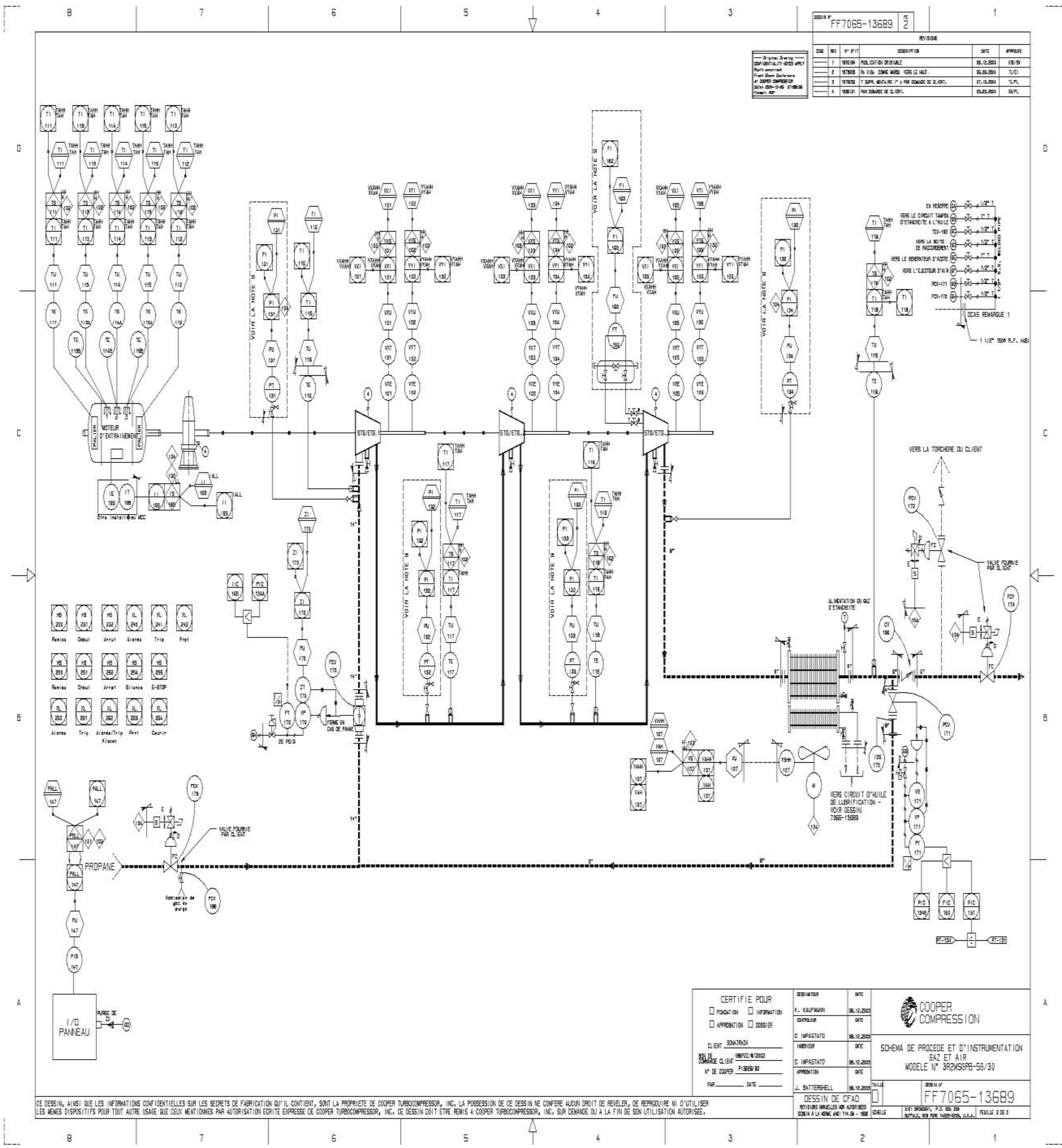


Figure 2.6. Cooper compressor P&ID diagram

2.4.2 Start-up procedure:

The following procedures must be followed before starting the compressor:

- Verify control panel purge system is active and that the control panel power is on.
- Immediately before start up, open each compressor housing manual drain valve and verify that there is no liquid in the compressor housing. Any liquid or gas exiting from the drain valve should be carried to a safe location to avoid personnel injury.
- Inlet Butterfly Valve, FCV-170, should be in the minimum closed position. The valve should not be fully closed but should be slightly cracked open at 5% to 10%.
- The compressor inlet pressure should not exceed the design inlet pressure.
- The recycle valve, PCV-171, should be 100% open.
- N2 buffer gas is on to seals.
- Buffered oil seal system is on and working.
- Auxiliary oil pump is running and oil pressure is above 1.12 kg/cm^2.
- All other permissive requirements of the compressor are satisfied [8].

2.4.3 Loading the compressor:

To load the compressor the Inlet Butterfly Valve FCV-170 needs to be opened and recycle valve PCV-171 needs to be closed. If the boil off flow rate is above the compressor turn down capability, then the recycle valve should be fully closed. When the recycle valve PCV-171 fully closes, the discharge pressure of the compressor increases because the system resistance also increases when all the flow goes into the process. This operation can continue until the compressor is fully loaded.

Compressor is considered fully loaded when the Inlet Butterfly Valve is fully open, the recycle valve is fully closed and motor amperage have reached the maximum amp limit. The maximum amperage could be reached due to max boil off gas flow, max inlet pressure, max discharge pressure, max inlet temperature or combinations of these.

To protect the motor from over loading due to extreme variation of the process conditions. This system works with the Inlet butterfly valve control system FCV170. For whatever reason, when the motor amperage exceeds the motor full load amp then either the Inlet butterfly valve or combination of IBV and recycle valve should modulate to reduce the motor amps below or at the full load amp set point. This means the IBV closes and/or the discharge pressure set point is lowered (which may open the recycle valve PCV-171) to reduce the motor amps to at or below the motor full load amp set point [8].

2.4.4 Shut-Down Procedure:

- The shutdown process should not allow the process gas flow to reverse itself while the compressor is coasting down. In addition to the discharge check valve CV-190, the operator will close the inlet isolation valve HV-173 and the discharge isolation valve HV-174 when the drive motor is de-energized.
- The compressor will first be unloaded before the drive motor is de-energized. Unloading the compressor is accomplished by first fully opening the bypass valve PCV-171(recycle valve) to reduce the discharge pressure and then by closing the inlet butterfly valve FCV-170 to reduce the motor amps. Once the compressor is fully unloaded, power to the main motor will be shut off.
- When the compressor is shut down, the operator will open HV-172 (torch valve) to reduce the pressure with the compressor piping. The pressure will be reduced to a pressure set point which is approximately 0.5 kg/cm^2. This depressurization step is intended to eliminate the settle out pressure while also maintaining a small positive pressure in the piping to prevent contamination. After reaching the pressure set point, the operator should close the valve HV-172.
- The cooler fan will continue to run for a short time after shut down to cool the oil system down and to reduce any thermal shocks on the cooler.
- If the compressor is not expected to restart within four or more hours, the seals must continue to be purged with process gas or clean dry N2 gas [8].

2.4.5 COOPER Compressor characteristic

- Treated gas: propane
- Aspiration pressure: 0.3 to 0.9 Kg/Cm^2

- Aspiration temperature: -44.5 ^{0}C
- Aspiration flow: 15 Ton/hour
- Discharge pressure: 8.3 Kg/Cm^{2}
- Discharge temperature: 60 ^{0}C
- Motor current: 122 Ampere

2.4.6 Instrument list:

- **Measuring instrument:**

TAG	Description	Measuring	Unite	Alarm threshold		Trip threshold	
				Low	High	Low	High
PT 131	Pressure transmitter	Aspiration pressure	Kg/cm^{2}	/	1.30	/	1.35
PT 132	Pressure transmitter	Aspiration pressure 2nd stage	Kg/cm^{2}	/	2	/	2.30
PT 133	Pressure transmitter	Aspiration pressure 3rd stage	Kg/cm^{2}	/	3.50	/	3.80
PT 134	Pressure transmitter	Discharge pressure	Kg/cm^{2}	/	9.50	/	9.75
FT 160	Flow transmitter	Differential pressure	Kg/cm^{2}	/	0.35	/	0.38
TE 116	Temperature sensor	Aspiration temperature 1st stage	^{0}C	/	40	/	70

TE 117	Temperature sensor	Aspiration temperature 2nd stage	^{0}C	/	45	/	85
TE 118	Temperature sensor	Aspiration temperature 3rd stage	^{0}C	/	60	/	90
VXT 101	Axial vibration transmitter	Axial vibration 1st stage	Micron	/	44.3	/	55.8
VYT 102	Radial vibration transmitter	Radial vibration 1st stage	Micron	/	44.3	/	55.8
VXT 103	Axial vibration transmitter	Axial vibration 2nd stage	Micron	/	44.3	/	55.8
VYT 104	Radial vibration transmitter	Radial vibration 2nd stage	Micron	/	44.3	/	55.8
VXT 105	Axial vibration transmitter	Axial vibration 3rd stage	Micron	/	44.3	/	55.8
VYT 106	Radial vibration transmitter	Radial vibration 3rd stage	Micron	/	44.3	/	55.8
PT 151	Pressure transmitter	Oil pressure before filter	Kg/cm^2	1.12	1.76	0.84	4.50

TE 120	Temperature sensor	Oil temperature	^{0}C	21	60	18	66
PT 151	Pressure transmitter	Oil pressure after filter	Kg/cm^2	/	2.75	/	/
TE 111	Temperature sensor	T^0 Motor bearing NDE	^{0}C	/	90	/	100
TE 112	Temperature sensor	T^0 Motor bearing DE	^{0}C	/	90	/	100
TE 113	Temperature sensor	T^0 stator U	^{0}C	/	140	/	145
TE 114	Temperature sensor	T^0 stator V	^{0}C	/	140	/	145
TE 115	Temperature sensor	T^0 stator W	^{0}C	/	140	/	145
PDT 135	Differential Pressure transmitter	ΔP sealing gas filter	Kg/cm^2	/	0.75	/	1.00
PT 136	Pressure transmitter	Sealing gas pressure 1st stage	Kg/cm^2	/	1.40	/	1.70
PT 137	Pressure transmitter	Sealing gas pressure 2nd stage	Kg/cm^2	/	1.40	/	1.70

PT 138	Pressure transmitter	Sealing gas pressure 3rd stage	Kg/cm^2	/	1.40	/	1.70
PT 148	Pressure transmitter	Supply pressure sealing gas	Kg/cm^2	6.00	/	4.50	/
FIT 211	Flow Indicator transmitter	Sealing gas flow 1st stage	Kg/h	7.60	/	4.50	/
FIT 212	Flow Indicator transmitter	Sealing gas flow 2nd stage	Kg/h	7.60	/	4.50	/
FIT 213	Flow Indicator transmitter	Sealing gas flow 3rd stage	Kg/h	10.10	/	6.10	/
FIT 214	Flow Indicator transmitter	Sealing gas flow (N2)	Kg/h	6.30	27.00	/	30
FIT 220	Flow Indicator transmitter	Sealing gas flow To torch	Kg/h	18.25	25.75	/	/

Table 2.1. Measuring instrument

- **Actuating device:**

The table below include all controlling valves in addition the valves that we add to our system (XV173, XV174, XV172).

TAG	Description	Function
FCV170	Flow control valve	Control the flow of inlet propane
PCV 171	Pressure control valve	Recycle valve to protect the compressor against pumping phenomena
HV 173	Handle valve	Inlet isolation valve
HV 174	Handle valve	Discharge isolation valve
HV172	Handle valve	Exhaust valve
CV 190	Check valve	Valve to ensure gas not returned

Table 2.2. Actuating device

2.5 The problem posed

In our current system, three manual valves HV-172, HV-173, and HV-174 are crucial for the reliability and safety of the operation. These valves serve essential functions: HV-172 is used for exhaust, HV-173 for inlet isolation, and HV-174 for discharge isolation. However, the manual operation of these valves poses a significant challenge to the system's overall reliability. Manual valves are prone to human error, inconsistent operation, and delayed response times, which can lead to operational inefficiencies and increased risk of system failure.

To address this issue, we propose replacing the manual valves HV172, HV173, and HV174 with automatic valves. Automatic valves will enhance the reliability of the system by ensuring consistent and precise operation, reducing the likelihood of human error, and enabling quicker response times to operational changes. This upgrade will significantly improve the system's safety and efficiency, contributing to the overall robustness and dependability of our operations.

2.6 valves choice

2.6.1 System Requirements

The propane gas compressor system requires valves that can handle:

- **Maximum Pressure:** 8.3 kg/cm² (approximately 117.96 psi)
- **Temperature:** -46°C to70°C
- **Material Compatibility:** The valves must be compatible with propane gas
- **Automation Capability:** The valves must integrate with our existing PLC system (Siemens S7-400 processor)

2.6.2 Recommended Electro valve

Solenoid valves are identified as the suitable replacement for the existing manual handle valves due to their robust design and automation capabilities, it consists of a solenoid coil and a valve body. The solenoid coil is an electromagnet that creates a magnetic field when an electric current passes through it. This magnetic field actuates a plunger or armature inside the valve body, which opens or closes the valve Key [9], considerations for selecting these valves include:

- **High Pressure and low Temperature Tolerance**: Solenoid valves are available in models designed to handle high pressures and temperatures, making them suitable for our system requirements.
- **Material Compatibility**: Solenoid valves can be manufactured from materials such as stainless steel or brass, which are compatible with propane gas.
- **Automation and Control**: These valves can be easily integrated with PLC systems for automated control. They equipped with open and close switches for precise monitoring and control of valve positions **Figure 2.7**.

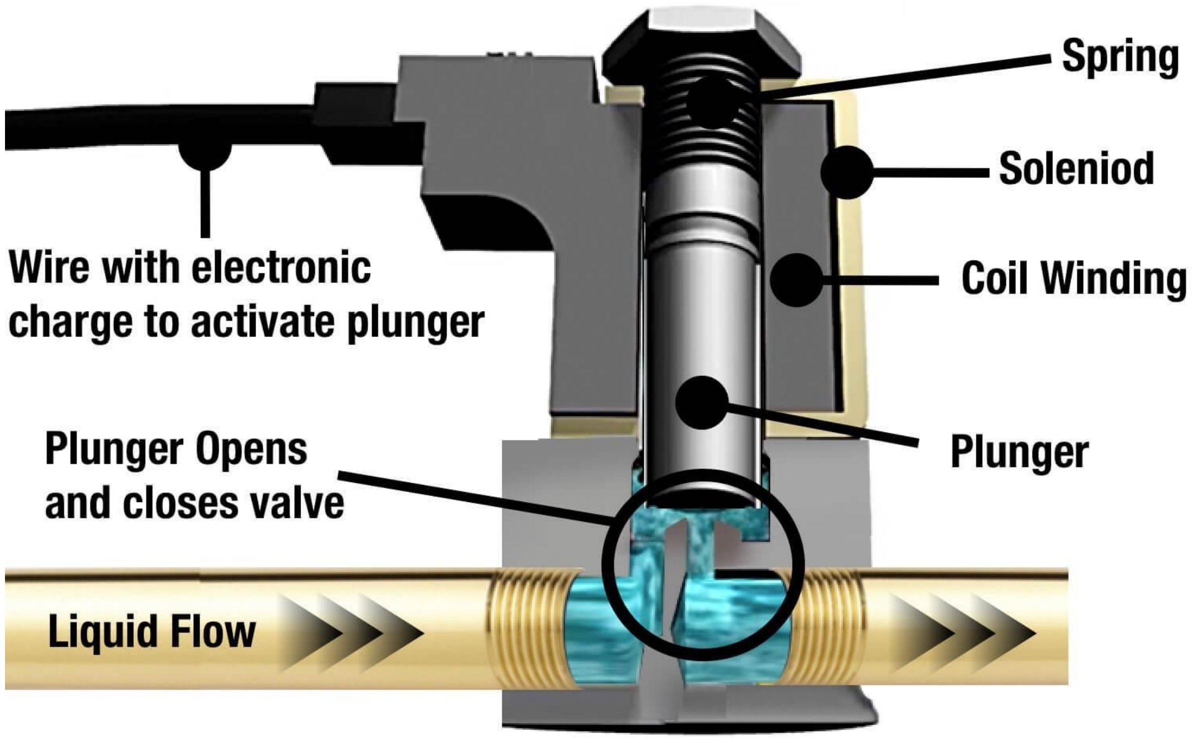


Figure 2.7. Solenoid valve

2.6.2.1 Specifications and Features of Solenoid Valves

To meet the specific needs of our propane gas compressor system, the solenoid valves should have the following features:

- **Valve Type:** Direct-acting
- **Material:** Stainless steel body with Teflon or Viton seals to ensure compatibility with propane and high temperature resistance
- **Pressure Rating:** At least 10 kg/cm² to ensure a safety margin above the maximum system pressure
- **Temperature Rating:** Rated for at least 100°C max temperature and -55°C for minimum to provide a margin above the maximum and minimum operating temperature
- **Electrical Compatibility:** Compatible with the control system voltage (110V AC)
- **Switches:** Equipped with open and close position switches for better control and monitoring

- **Dimension:**14" for inlet valve, 6" for outlet valve, 2" for exhaust valve
- **Security position:** close for both inlet and outlet valves, open for exhaust valve [10].

2.5 Conclusion

In Chapter 2, we explored the intricacies of the boil-off gas (BOG) section and the operational principles of the Cooper compressors used in the system. The BOG section is crucial for recovering commercial propane and butane vapors from storage tanks, ensuring efficient condensation and return to the respective tanks. This section utilizes advanced control systems, including Allen Bradley and Siemens PLCs, to manage the compressors effectively.

The chapter detailed the operational procedures for the Cooper compressors, including the start-up, loading, and shut-down processes. These compressors are multi-stage centrifugal machines that play a vital role in maintaining the required pressure and temperature conditions for propane recovery. The start-up procedure emphasizes safety and system checks to prevent damage and ensure smooth operation. During loading, the system carefully modulates the inlet butterfly valve and recycle valve to manage the compressor's load and protect the motor from overload.

The shut-down procedure ensures that the process gas does not reverse flow, protecting the compressor and associated piping from damage. The system also incorporates an anti-pumping mechanism and a sophisticated control system to maintain optimal performance and safety.

Overall, this chapter highlights the importance of precise control and monitoring in gas compression systems, ensuring the safe and efficient recovery of propane and butane vapors. The detailed procedures and control mechanisms discussed underscore the complexity and critical nature of these operations in industrial settings.

CHAPTER III

Cooper control logic and software improvement

3.1 Introduction

This chapter provides an overview of Programmable Logic Controllers (PLCs) with a focus on the Siemens S7-400 system and its application in controlling COOPER compressors. It begins with a general introduction to PLCs, covering their core components, and operational principles. The chapter then delves into an in-depth overview of the Siemens S7-400 PLC, highlighting its architecture, capabilities, and key features. Following this, it explores the specific implementation of the Siemens S7-400 system for COOPER compressors, detailing hardware configurations and software programming.

3.2 General information on PLC (Programmable logic controller)

A PLC (programmable logic controller) is a digital computer used for industrial automation to automate different electro-mechanical processes. It was introduced to eliminate issues such as high-power consumption that arose from the use of relays to control manufacturing processes. It consists of a programmed microprocessor whose program is written on a computer and later downloaded via a cable to the PLC. The program is stored in a non-volatile PLC memory **Figure 3.1** [11].

Figure 3.1. Programmable logic controller

3.2.1 Operating principle

The programmable logic controller receives information from connected input devices and sensors, processes the received data, and triggers required outputs as per its pre-programmed parameters. Based on its inputs and outputs, a PLC can easily monitor and record runtime data like operating temperature, machine productivity, generation of alarms when a machine fails, automatic start and stop processes and more. This means that PLCs are robust and flexible manufacturing process control solutions that are adaptable to most applications [12].

3.2.2 PLC hardware

PLC hardware components include:

- **CPU:** checks the PLC regularly to prevent errors and performs functions like arithmetic operations and logic operations.
- **Memory:** system ROM permanently stores fixed data used by the CPU while RAM stores the input and output device information, timer values, counters, and other internal devices.
- **O/P section:** this section gives output control over devices like pumps, solenoids, lights, and motors.
- **I/O section:** an input section that tracks on field devices like switches and sensors.
- **Power supply:** though most PLCs work at 24 VDC or 220VAC, some have isolated power supplies.
- 3**Programming device:** is used to feed the program into the processor's memory [13].

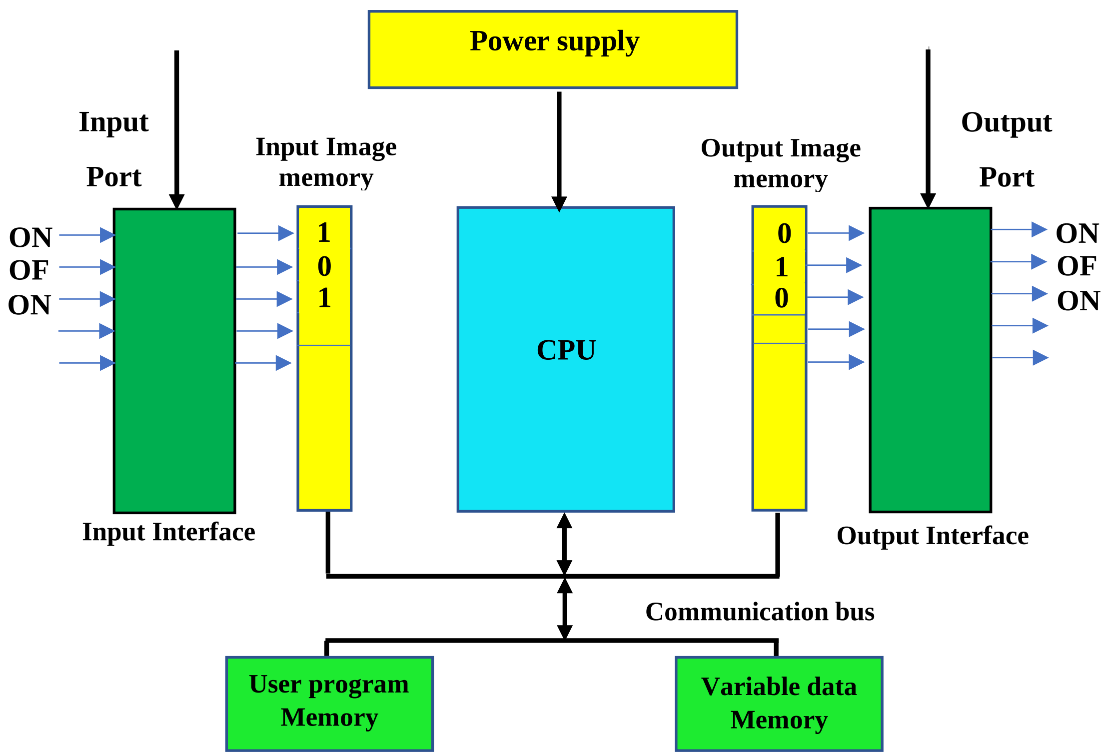


Figure 3.2. PLC archetecture

3.2.3 PLC key features

Key features of a programmable logic controller include:

- **I/O module:** The CPU retains and processes data while the input and output modules connect the PLC to the machinery. I/O modules provide the CPU with information and trigger specified results. I/O modules can be analog or digital. Note that I/O can be mix-matched to achieve the right configuration for an application.
- **Communications:** Apart from input and output devices, PLCs must connect with other system types. For instance, a user may need to export application data recorded by the PLC to a SCADA (supervisory control and data acquisition) system designed to monitor several connected devices. A PLC provides different communication protocols and ports to facilitate communication between the PLC and the other systems.
- **HMI:** Users require a HMI (human machine interface) to interact with a PLC. The operator interfaces can be large touchscreen panels or simple displays that allow users to input and review PLC information in real-time.

3.3 Overview of PLC S7 400

The Siemens S7-400 is a powerful and versatile programmable logic controller (PLC) developed by Siemens AG, a leading provider of industrial automation technology. It is part of the SIMATIC S7 family of PLCs, known for their reliability, scalability, and advanced features **Figure 3.3**.

Figure 3.3. Siemense PLC S7-400

3.3.1 Description of PLC S7-400

- **Scalability and Performance:** The S7-400 PLC is designed to meet the demands of complex industrial automation applications. It offers a high degree of scalability, allowing users to configure systems with varying numbers of input/output (I/O) modules, central processing units (CPUs), and communication interfaces. With powerful CPUs and fast processing speeds, the S7-400 can handle large volumes of data processing and execute complex control algorithms with precision and efficiency.

- **Modular Architecture:** The S7-400 PLC features a modular architecture, consisting of a rack-based system where different modules can be added or removed according to the application requirements. This modularity enables users to customize their PLC systems with the necessary I/O modules, CPUs, communication modules, and other accessories. The system can accommodate a wide range of digital and analog I/O modules, including inputs for sensors, switches, and transducers, as well as outputs for actuators, motors, and valves.

- **Communication Capabilities:** The S7-400 PLC supports various communication protocols, allowing seamless integration with other automation components, devices, and systems. It offers built-in interfaces for industrial Ethernet (PROFINET), PROFIBUS, DP, MPI (Multi Point Interface), and other fieldbus protocols. Communication modules can be added to extend connectivity options, enabling communication with devices such as Human Machine Interfaces (HMIs), Supervisory Control and Data Acquisition (SCADA) systems, remote I/O modules, and third-party controllers.

- **Programming and Engineering:** The S7-400 PLC is programmed using Siemens STEP7 or TIA PORTAL engineering software, which provides a comprehensive set of programming tools, libraries, and utilities for developing, testing, and maintaining PLC programs. Users can program the S7-400 in various programming languages, including ladder logic (LAD), function block diagram (FBD), structured text (ST), and statement list (SCL), allowing flexibility and versatility in application development.

- **Reliability and Redundancy:** Siemens S7-400 PLCs are known for their robustness, reliability, and built-in features for fault tolerance and system redundancy. They offer options for hot-swappable modules, redundant CPUs, and integrated diagnostics to minimize downtime and ensure continuous operation in critical applications. The system is designed to meet demanding industrial standards for reliability, safety, and performance, making it suitable for applications in industries such as manufacturing, process automation, energy, and infrastructure **Figure 3.4** [14].

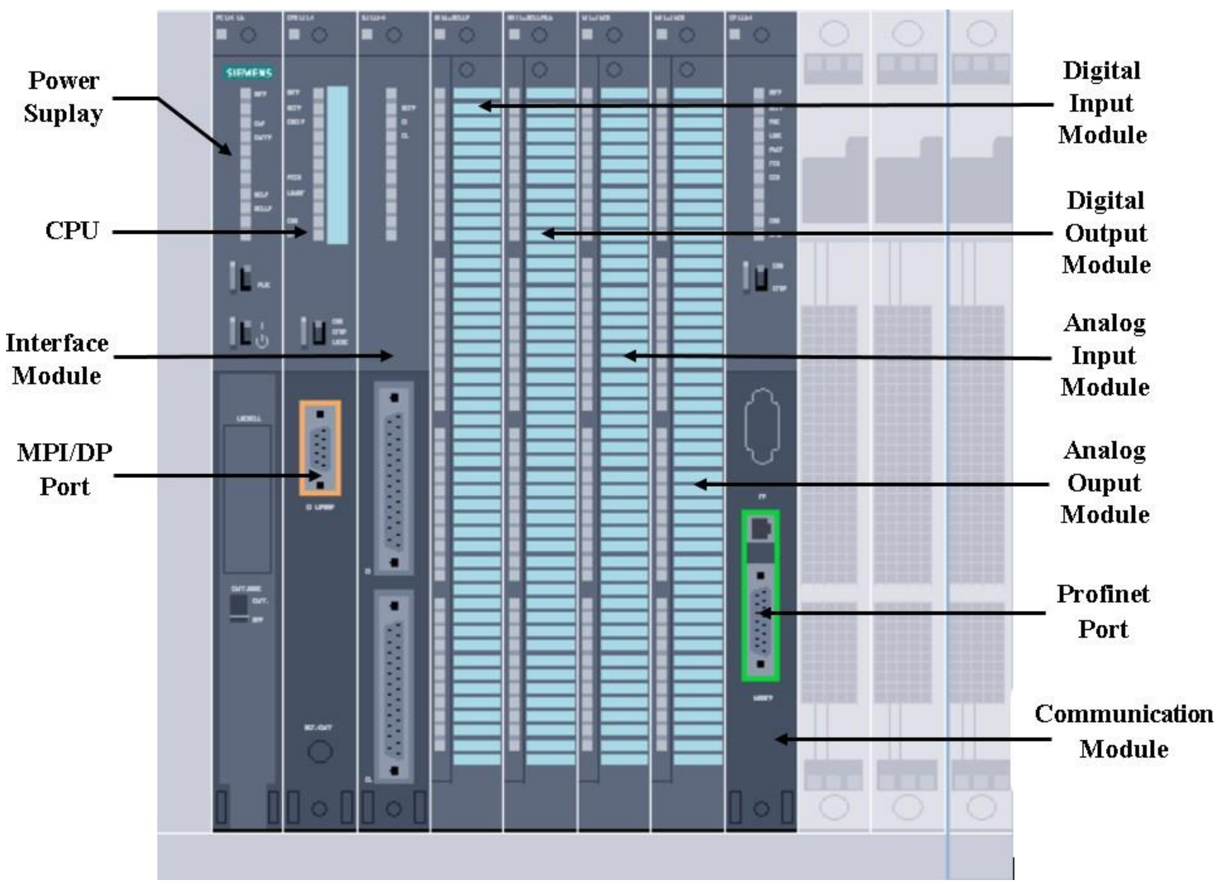


Figure 3.4. S7-400 principale components

3.4 Description of system Siemens S7-400 for COOPER compressor

3.4.1 Hardwar description

- **Main PLC "Control Room "**

A main PLC panel is located in the old control Room and consists of:

- Siemens CPU S7-400-2
- PS- 24V DC power supply
- Operator interface MP270
- CP 441-2
- Two sets of pushbuttons and pilot lights to operate each compressor independently
- 3 light bulbs for alarms of inlet, discharge and exhaust valves
- 7 Input/output modules:
    - 16 digital inputs (DI16) from I0.0 to I1.7 for compressor 2
    - 16 digital inputs (DI16) from I2.0 to I3.7 for compressor 1
    - 16 digital outputs (DO16) from Q0.0 to Q1.7 for compressor 1
    - 16 digital outputs (DO16) from Q2.0 to Q3.7 for compressor 2
    - 6 digital inputs (DI8) from I10.0 to I10.5 for new valves
    - 6 digital outputs (DO8) for new valves and alarm light
    - 8 analog inputs (AI8)
- Optical/Profibus communication modules with local compressor panels and CPU.

- **Local panel "site "**

A local panel is located next to the motor and contains the following items:

- Power supply PS307
- 9 Input/output modules
  - Digital input module (DI16) and 6 analog input modules (four AI8 and two RTD8)
  - Digital output module (DO16) and analog output module (AO8)
- Optical/Profibus communication modules with PLC panels
- Operator interface OP270

3.4.2 Software description

3.4.2.1 Programming software (TIA Portal V14)

The Totally Integrated Automation (TIA) Portal is Siemens' comprehensive software suite for programming and configuring automation systems. It integrates multiple tools into a single interface (step7, Wincc…), allowing engineers to program PLCs, design HMI screens, and configure motion control systems. Some key features of TIA Portal include:

- Support for programming Siemens S7-400, S7-1200 and S7-1500 PLCs using ladder logic, function block diagram (FBD), structured control language (SCL), and other languages.
- Ability to create HMI screens for supervisory control and data acquisition (SCADA) systems and operator panels.
- Configuration of Sinamics drives and other automation components.
- Structured programming using organization blocks (OBs), functions (FCs), function blocks (FBs), and data blocks (DBs).
- User-defined data types for organizing and replicating data structures.
- Multi-user collaboration features for simultaneous programming of different parts of a project **Figure 3.5** [14].

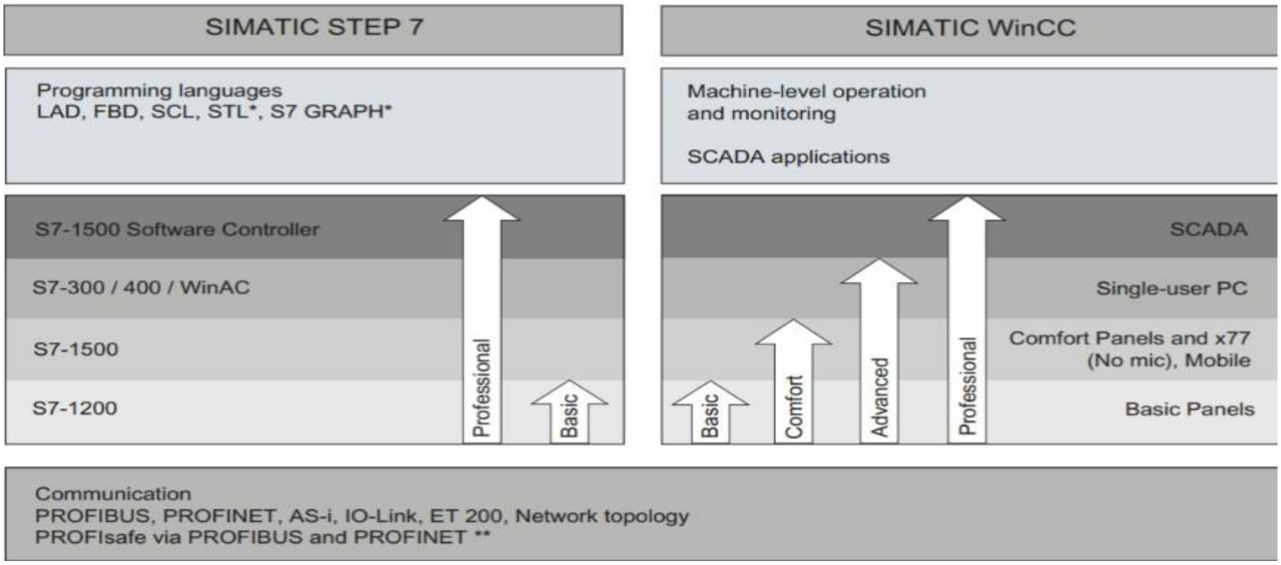


Figure 3.5. programming tools on TIA Portal

3.4.2.2 Control logic description

The PLC provides standard logic for compressor operation. This includes:

- Auxiliary oil pump control
- Drive motor control
- Local/remote logic
- Alarm and trip operations.

- **Motor control**

- Permissive Motor Start Output:

This output acts as an OFF contact on the Compressor Control Module (CCM). An OFF contact is a type of electrical switch that allows current to flow when it's open (activated) and interrupts the flow of current when it's closed (deactivated).

The CCM is permitted to run when the motor permissive output is activated. This means that the compressor control module is allowed to operate or start when the motor permissive output signal is active.

Motor Permissive Output:

This output is a signal indicating that certain conditions necessary for the motor to run are met. It's used as a control signal to allow or prevent the operation of the compressor control module.

The CCM stops when the motor permissive output is deactivated. So, when the conditions necessary for the motor to run are not met or are no longer met, the compressor control module stops operating.

Motor Run Output:

This output is activated when the compressor START push-button is pressed. It serves as a signal to start the motor.

The motor run output is activated by a 5-second rising edge, meaning it transitions from a low to a high state over a period of 5 seconds. This delay allows time for other necessary actions to occur before the motor starts.

Auxiliary Motor Contact:

An auxiliary motor contact is used to bypass the PLC run output. This contact provides an alternate path for the current to flow to the motor contactor, allowing the motor to start even if the PLC run output is not received. If this contact is not received at the PLC after the run command has been sent, indicating that the motor did not start properly, the controller will trip on a Motor Fault. This is a safety measure to detect and respond to faults in the motor starting process. Also, if the PLC does not receive a motor current reading after the load delay time, it will trip the motor with a Motor Fault **Figure 3.6.**

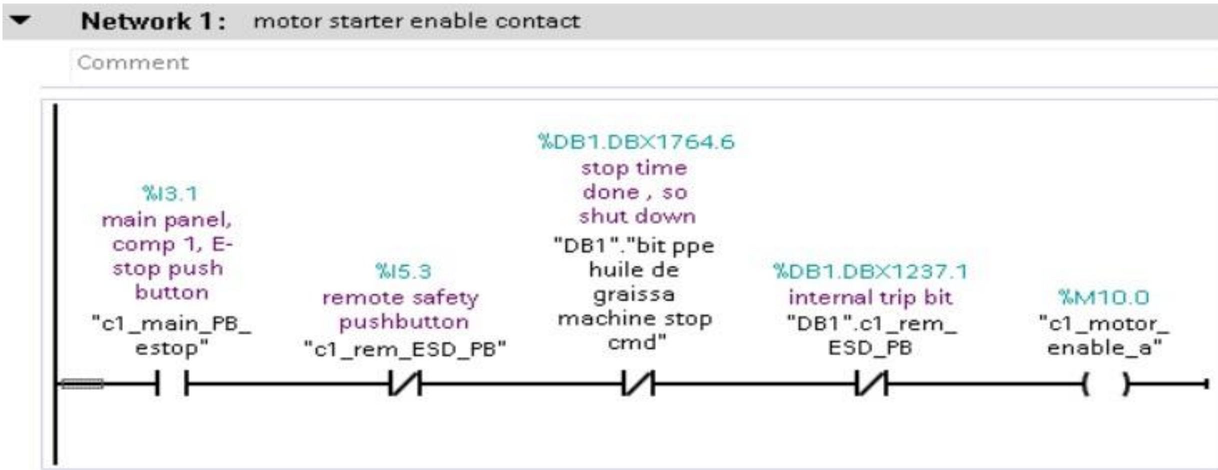
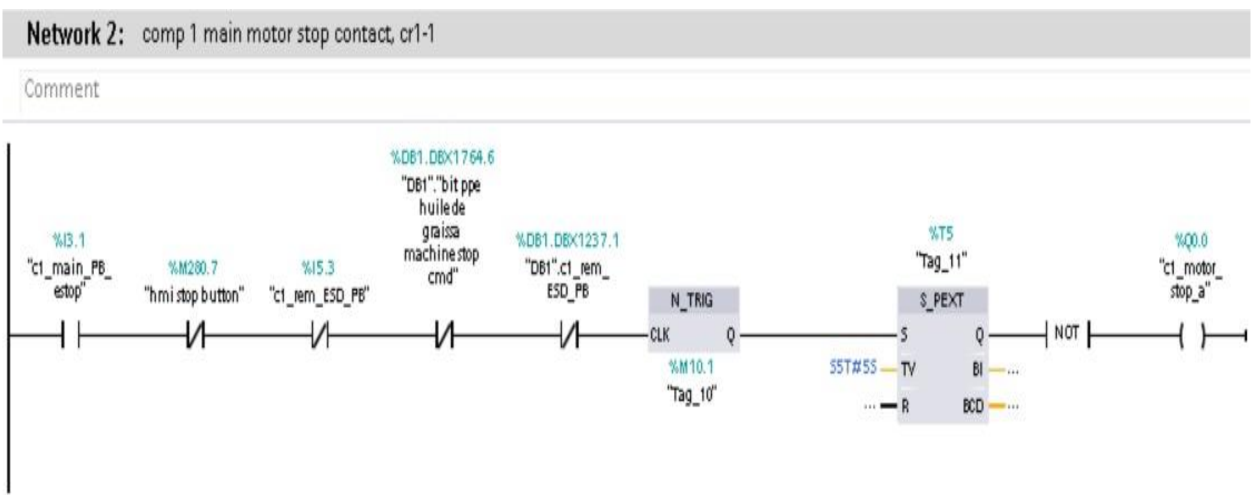


Figure 3.6. The network of motor starter enable contact

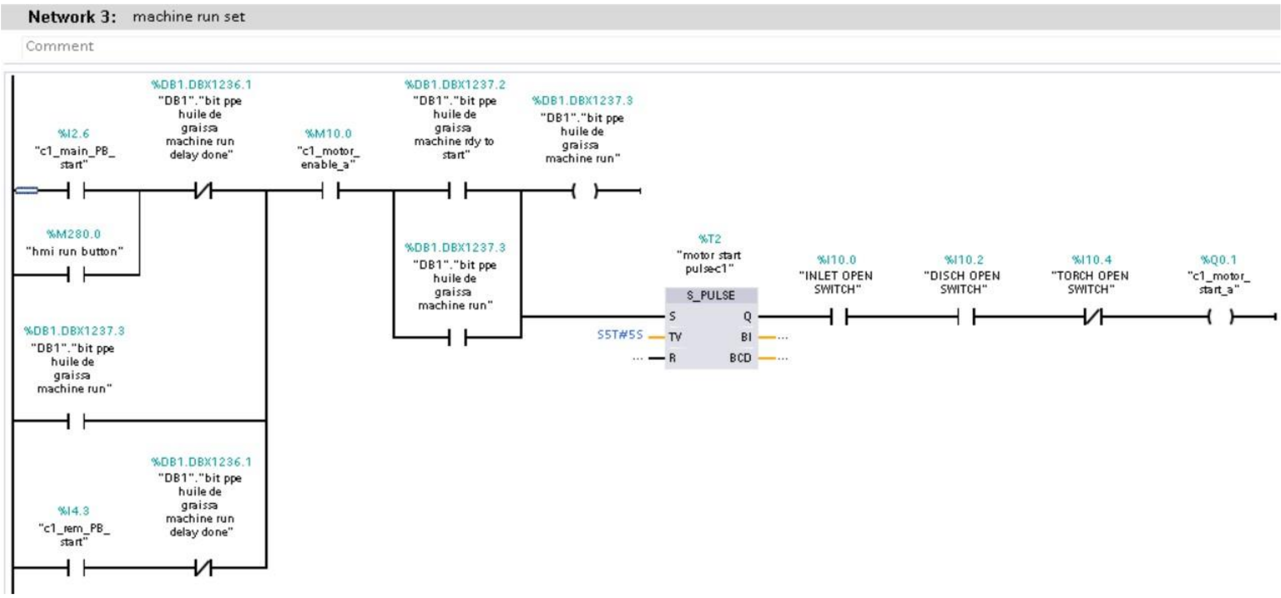
All Emergency Shutdown (ESD) pushbuttons must be in the normal state, there should be no localized shutdown, and the compressor must not have tripped. These conditions are stored in the M10.0 memory location **Figure 3.7.**



"c1_main_PB_estop"	%I3.1	main panel, comp 1, E-stop push button
"c1_motor_stop_a"	%Q0.0	comp 1 main motor stop contact, cr1-1
"c1_rem_ESD_PB"	%I5.3	remote safety pushbutton
"DB1"."bit ppe huile de graissa machine...	%DB1.DBX1764.6	stop time done , so shut down
"DB1".c1_rem_ESD_PB	%DB1.DBX1237.1	internal trip bit
"hmi stop button"	%M280.7	
"Tag_10"	%M10.1	
"Tag_11"	%T5	

Figure 3.7. The network of motor stop contact

When a change is detected on one of the contacts (stop push button, Emergency shutdown button, trips ….), a rising edge triggers a specified timer. The timer runs continuously until it reaches 5 seconds, after which it stops the motor via output Q0.0



"c1_main_PB_start"	%I2.6	main panel, comp 1, start push button
"c1_motor_enable_a"	%M10.0	
"c1_motor_start_a"	%Q0.1	comp1 main motor stop contact, cr11-2
"c1_rem_PB_start"	%I4.3	
"DB1"."bit ppe huile de graissa machine...	%DB1.DBX1237.2	run permisive bit 0-not ready , 1-ready to start
"DB1"."bit ppe huile de graissa machine...	%DB1.DBX1236.1	
"DB1"."bit ppe huile de graissa machine...	%DB1.DBX1237.3	machine run set
"DISCH OPEN SWITCH"	%I10.2	
"hmi run button"	%M280.0	
"INLET OPEN SWITCH"	%I10.0	
"motor start pulse-c1"	%T2	
"TORCH CLOSE SWITCH"	%I10.4	

Figure 3.8. The network of machine run set

If memo M10.0 is in a normal state and all protections and permissive are met, indicating the compressor is 'ready to start,' pressing the START pushbutton (either I4.3 or I2.6) initiates a compressor start sequence. This sequence begins only if the isolation valves are open and the exhaust valve is closed. A 5 second delay is allowed to start the motor via output Q0.1, enabling the motor contactor to engage **Figure 3.8.**

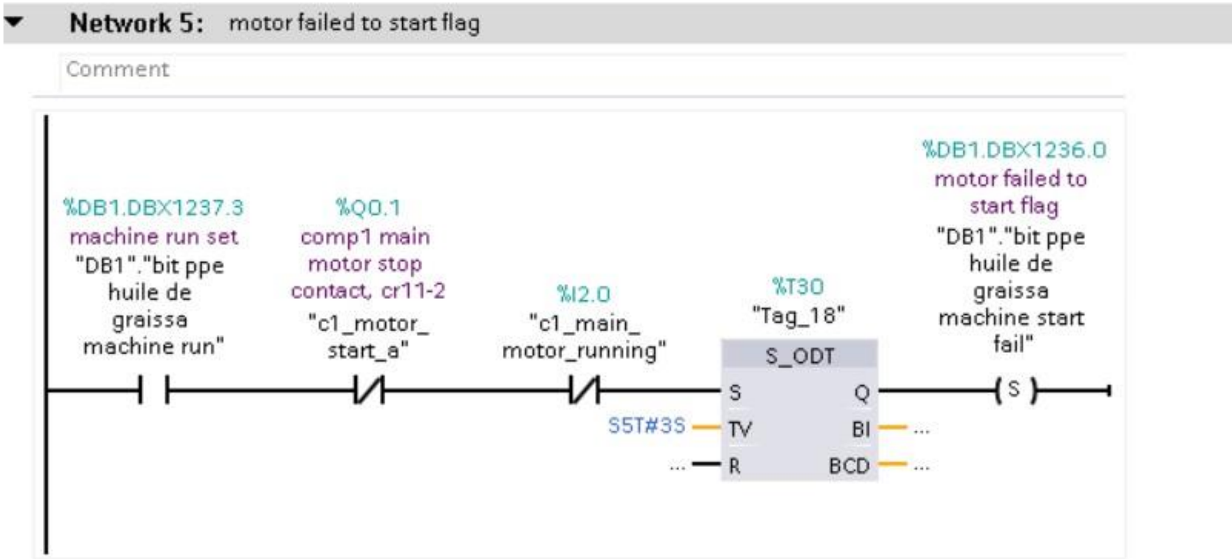


Figure 3.9. The network of motor failed to start flag

After the motor starts, the I2.0 motor in service signal indicates the motor's run status. A 3 second time window allows for motor feedback. If the feedback signal is received within this time and confirms that the motor is running, the system continues normal operation. However, if the feedback signal is not received by the PLC after the run command has been sent, indicating an issue with motor operation, the compressor will trip due to an electrical fault **Figure 3.9.**

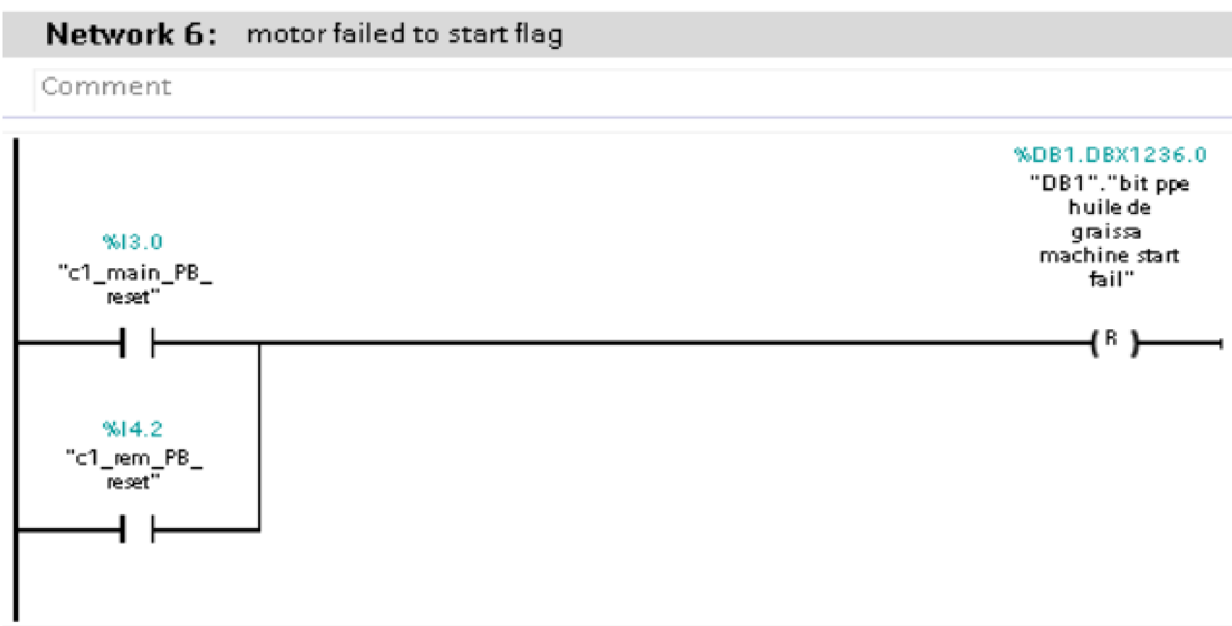


Figure 3.10. The network of flag reset button

The reset pushbutton, designated as I4.2 and I3.0, serves multiple functions within the compressor system. It is used to reset, acknowledge, and clear alarm and trip conditions. When pressed, it resets the system, acknowledges any active alarms or trips, and clears their associated conditions. This allows the compressor to be restarted safely and resume normal operation **Figure 3.10.**

- ## Oil pump control

Electric Auxiliary Oil Pump Control:

The electric auxiliary oil pump is controlled by PLC logic, meaning that its operation is determined by programmed instructions within the PLC (Programmable Logic Controller).

Fault Response:

In the event of a fault in the system, the auxiliary oil pump is designed to switch on automatically. This ensures that there is a continuous supply of lubricating oil in abnormal situations, helping to prevent damage to the machine or equipment.

Startup Procedure:

When the system is switched on, the auxiliary oil pump is started automatically. This ensures that lubricating oil is available from the beginning of the operation.

Shutdown Conditions:

The auxiliary oil pump will only be switched off under specific conditions:

- The machine is running.
- The charge delay time has elapsed (15 second).
- The oil pressure is above the lubricating oil pressure alarm setpoint.

Start Conditions:

The auxiliary oil pump starts under the following conditions:

- The system stop push-button is activated.
- The lubricating oil pressure drops below its alarm setpoint.

Reset Procedure:

The auxiliary oil pump will remain running until the RESET push-button is activated. If the low lubricating oil pressure condition persists, the controller will continue to generate an alarm, and the auxiliary oil pump will not stop. If the alarm condition is no longer present after the reset, the auxiliary oil pump will be stopped until its use is required again.

Oil Pump Starter Relay Contact:

The oil pump starter includes a relay contact that energizes to stop the pump. This relay contact is part of the control circuitry and is used to control the operation of the oil pump **Figure 3.11**.

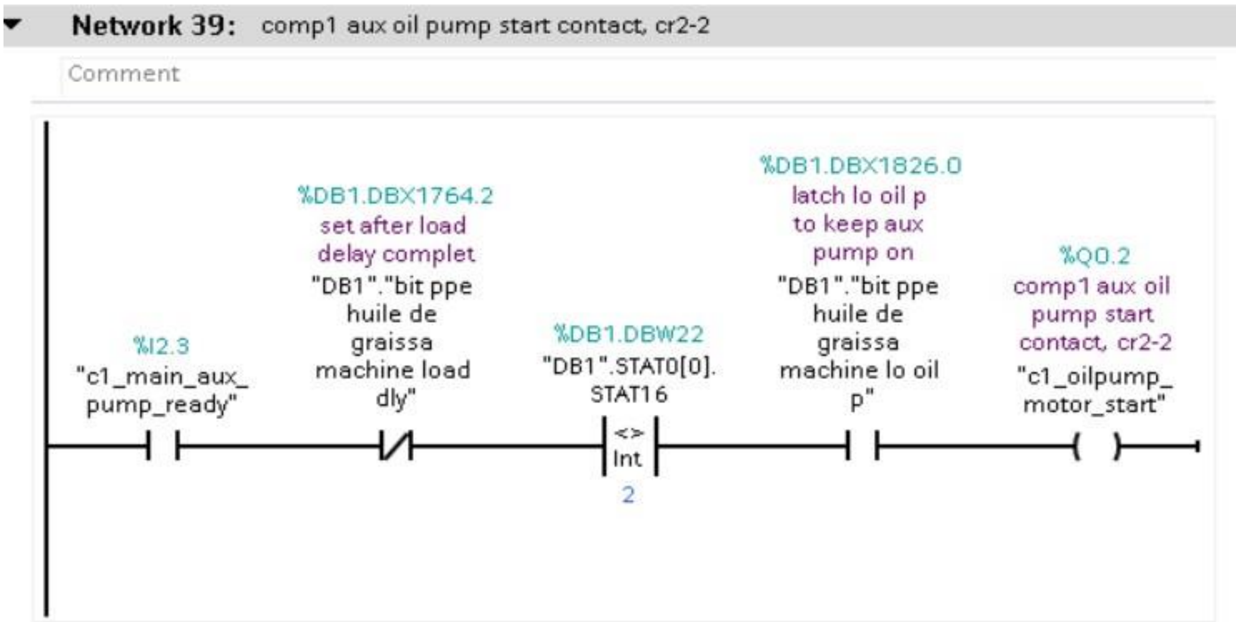


Figure 3.11. The network of oil pump starts contacts

Output Q0.2, labeled auxiliary pump start,' is activated under the following conditions:

- I2.3, a position feedback contact, indicates the pump is ready.
- The charge delay time has not expired
- The current intensity is different from Low.
- Oil pressure is low.

- ## Fan control

The cooling fan is started when the main motor is started. After the main motor has stopped, the fan remains on until the FAN OFF DELAY has expired **Figure 3.12.**

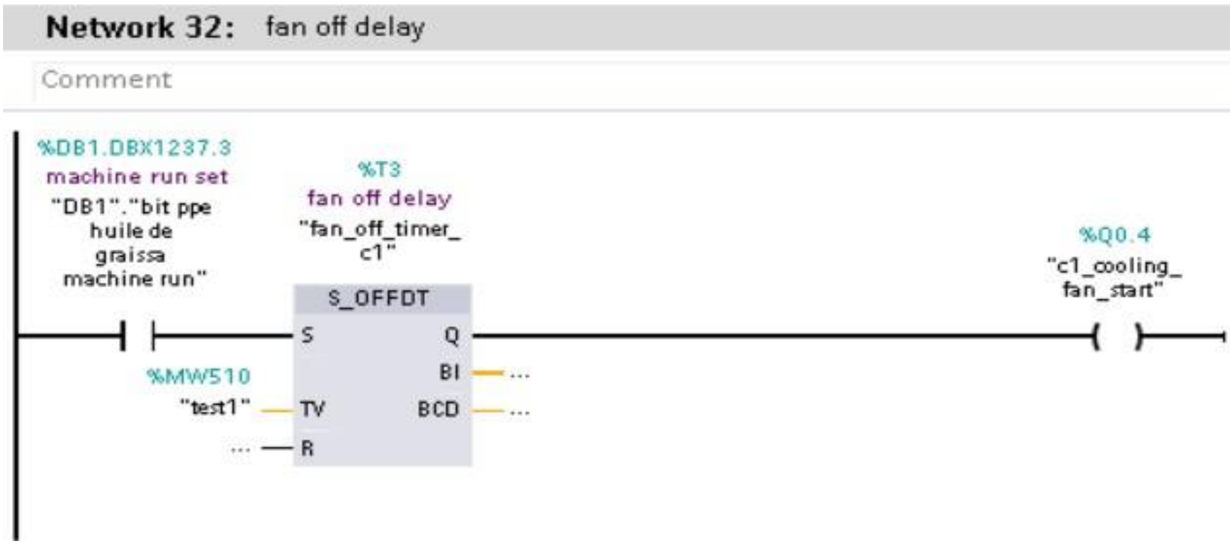


Figure 3.12. The network of fan

- ## Operation of alarms and trips

Monitoring Compressor Operation:

The PLC controller monitors the operation of the compressor using various analog inputs. These inputs measure parameters such as pressure, temperature, or flow rate.

Analog inputs can have associated alarm and trip levels based on machine specifications. These levels define thresholds for acceptable operation and trigger actions if exceeded.

Alarm Activation:

If an alarm level is exceeded, indicating a deviation from normal operation, the PLC controller recognizes the situation and activates an alarm. The alarm lamp is then activated to visually indicate the alarm condition. Pressing the RESET button on the panel silences the alarm temporarily.

Alarm Reactivation:

If the monitored point returns to a normal level after the alarm is silenced, the alarm is reactivated, and it must be acknowledged again by the operator. The "Activity list" screen provides a time/date stamp of alarms and certain events occurring on the compressor, allowing operators to track and review alarm history.

Trip Sequence:

Similarly, if an analog input exceeds the machine's trip level, indicating a critical condition, the PLC controller will initiate a tripping sequence to stop the compressor.

The tripping sequence includes steps such as starting the auxiliary oil pump, stopping the main motor, opening recirculation valves, closing inlet butterfly valves, and activating visual and auditory alarms **Figure 3.13.**

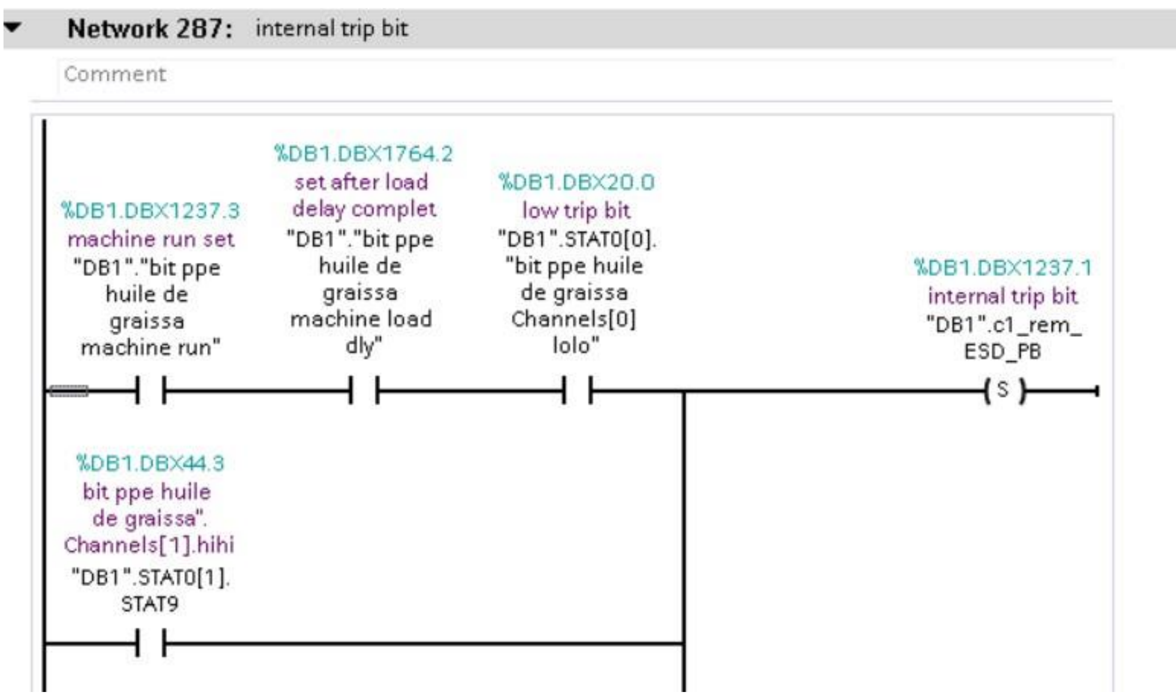


Figure 3.13. The network of trips

All the trips that required the shut (or not ready to start) of compressor are grouped in this network **Figure 3.14.**

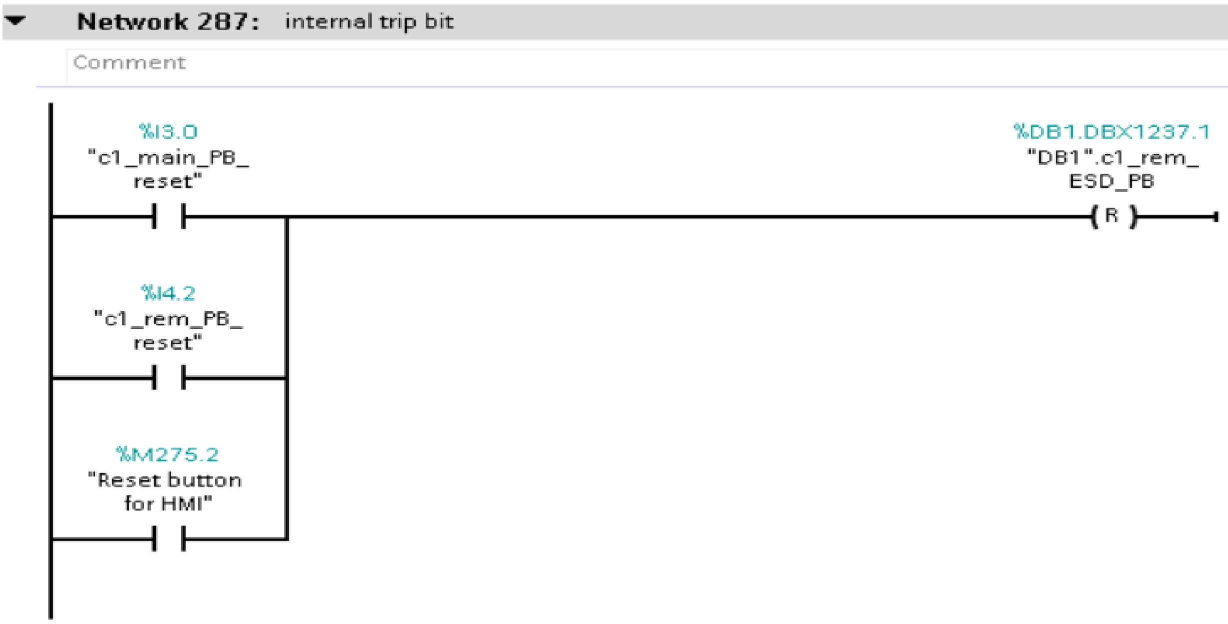


Figure 3.14. The network of trips reset button

After fixing the problem (the trip) you can't start the compressor again till you press on reset pushbutton I3.0 or I4.2 to clear alarm and trip conditions **Figure 3.14.**

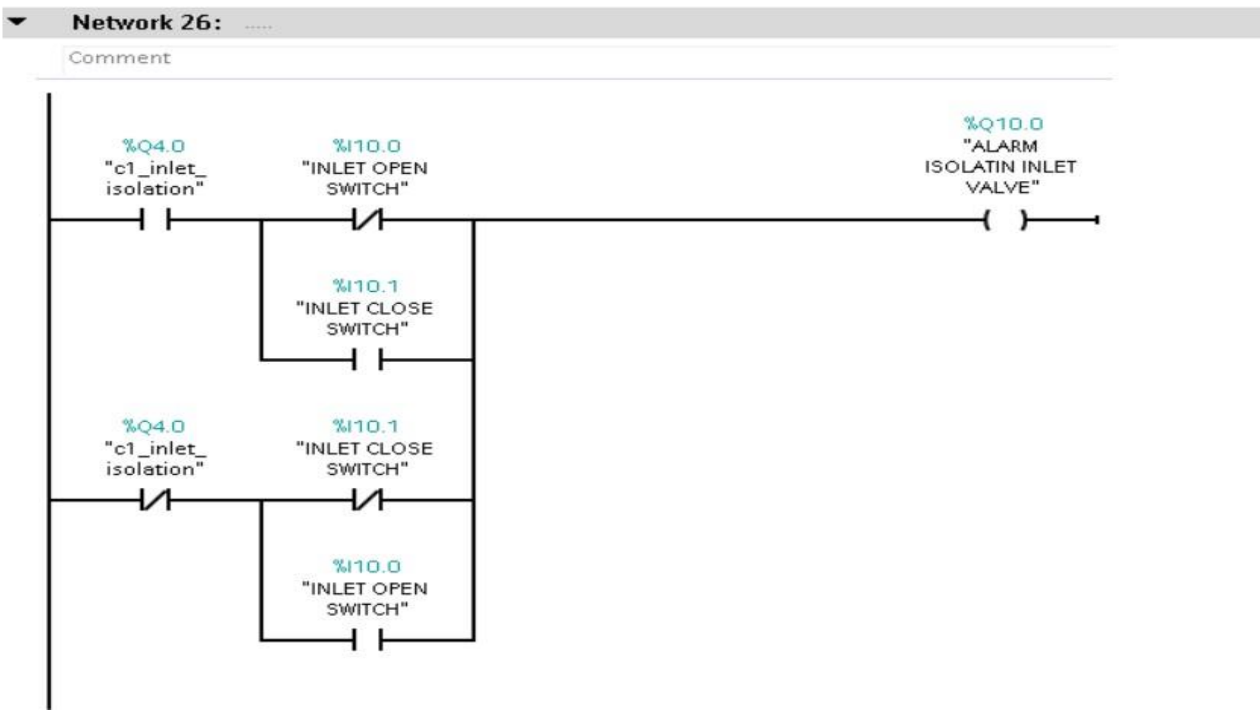


Figure 3.15. The network of isolation inlet valve alarm

This alarm pertains to issues with the operation of the inlet isolation valve, which involves both opening and closing actions. Two scenarios trigger this alarm:

When the valve is in the process of opening, if either the open or close switch fails to respond, which mean the valve doesn't open, the alarm will activate.

Similarly, when the valve is in the process of closing, encountering a similar failure with the open or close switch which mean the valve doesn't close will trigger the alarm **Figure 3.15.**

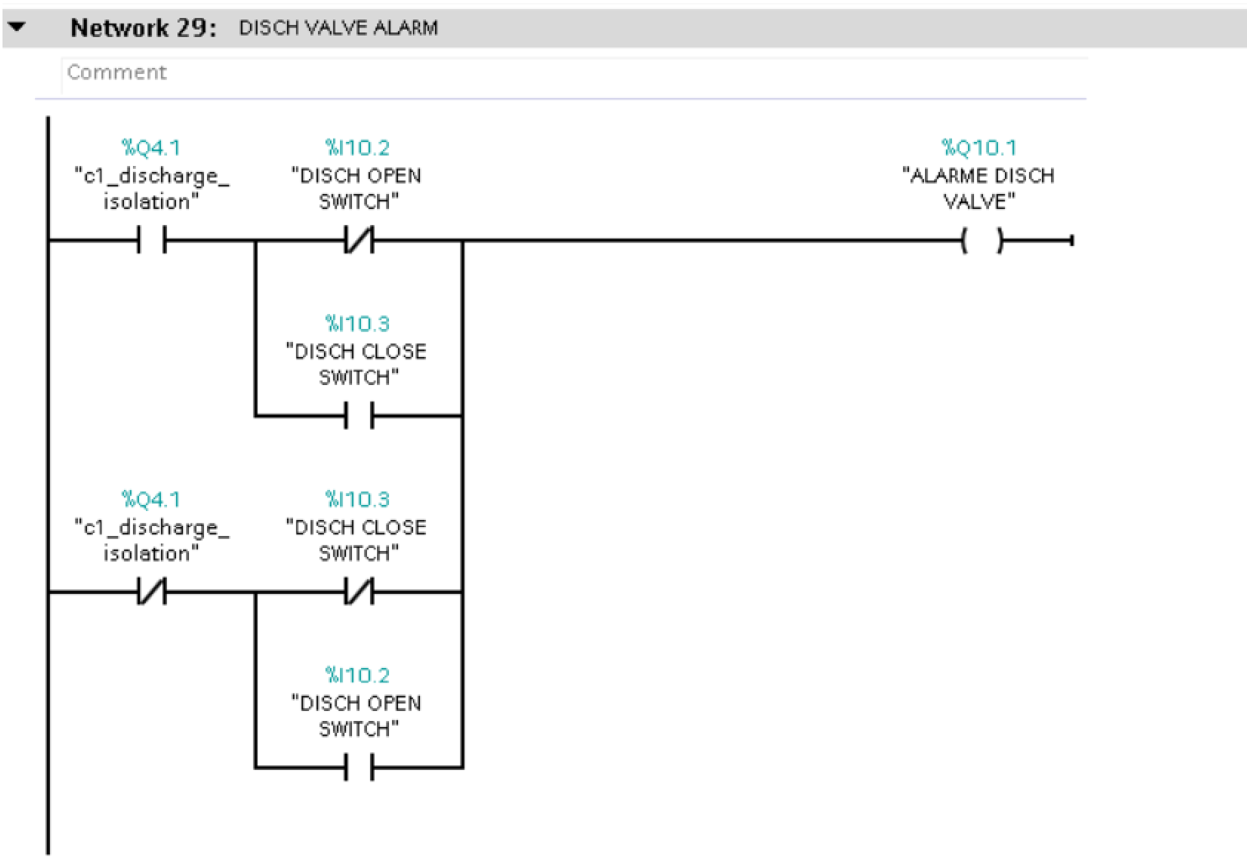


Figure 3.16. The network of isolation discharge valve alarm

This alarm is associated with the operation of the discharge isolation valve, encompassing both opening and closing actions. It is triggered by two scenarios:

If the valve fails to respond during the opening process due to a malfunction in valve (doesn't open) either the open or close switch, the alarm will activate.

Similarly, if a similar malfunction occurs during the closing process (valve doesn't close), the alarm will be triggered **Figure 3.16.**

- ## Isolation valves control

When the main motor of the compressor is started, the inlet and discharge isolation valves are activated. This means that they are opened to allow fluid to flow into and out of the compressor.

Activating these valves when the main motor starts ensures that the compressor is ready to receive and process fluid, enabling the system to operate efficiently **Figure 3.17.**

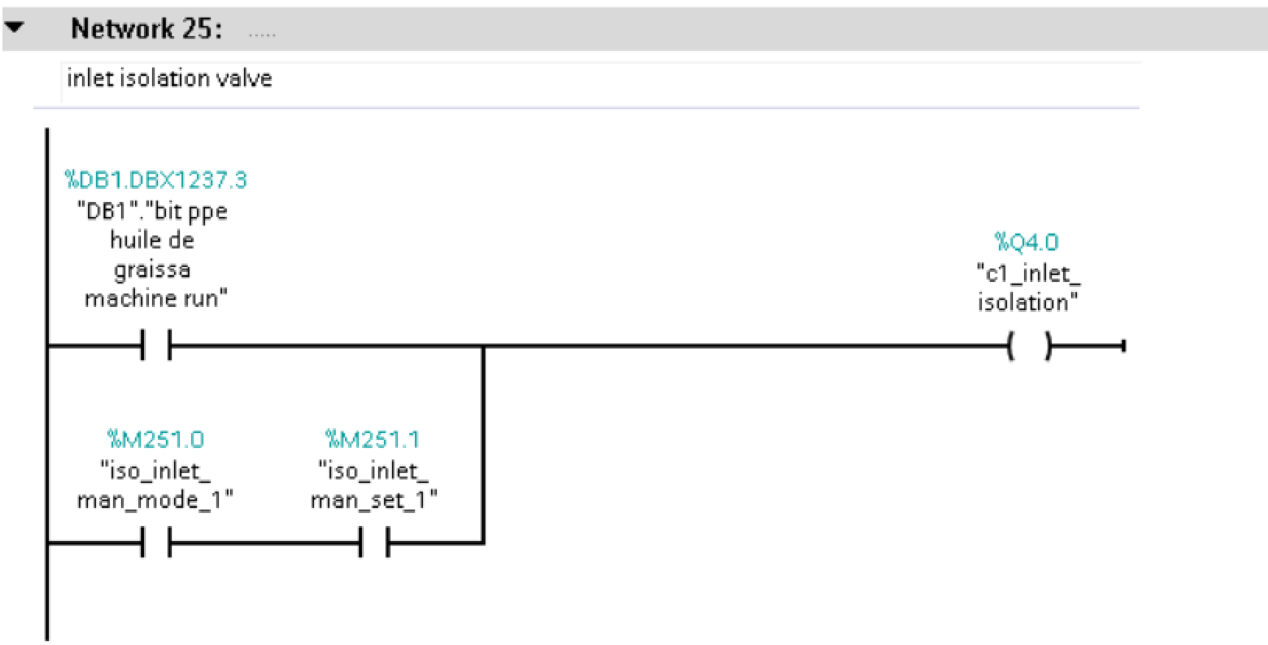


Figure 3.17. The network of isolation inlet valve

Output Q4.0, controlling the opening of inlet isolation valve XV173, is activated under the following conditions:

- If a motor status signal indicates the motor is in active mode, and the valve

OR

- If the valve XV173 is manually controlled via the manual switch (M251.0 is active), and we set M251.1 to ON using the Human-Machine Interface (HMI). If the compressor is in run state, we can't control the valves manually to avoid the risk of human negligence

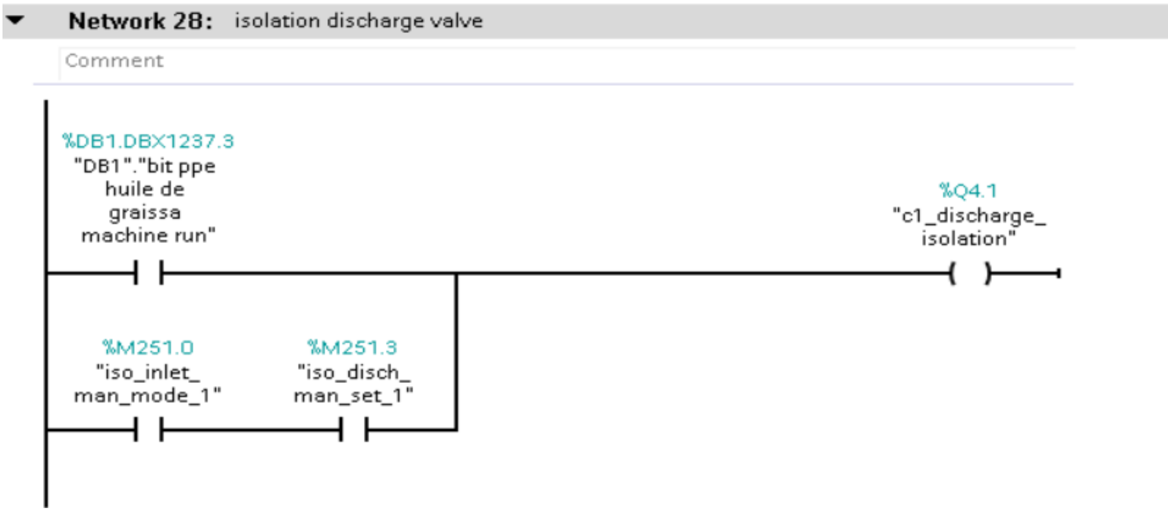


Figure 3.18. The network of isolation discharge valve

Same for isolation discharge valve **Figure 3.18.**

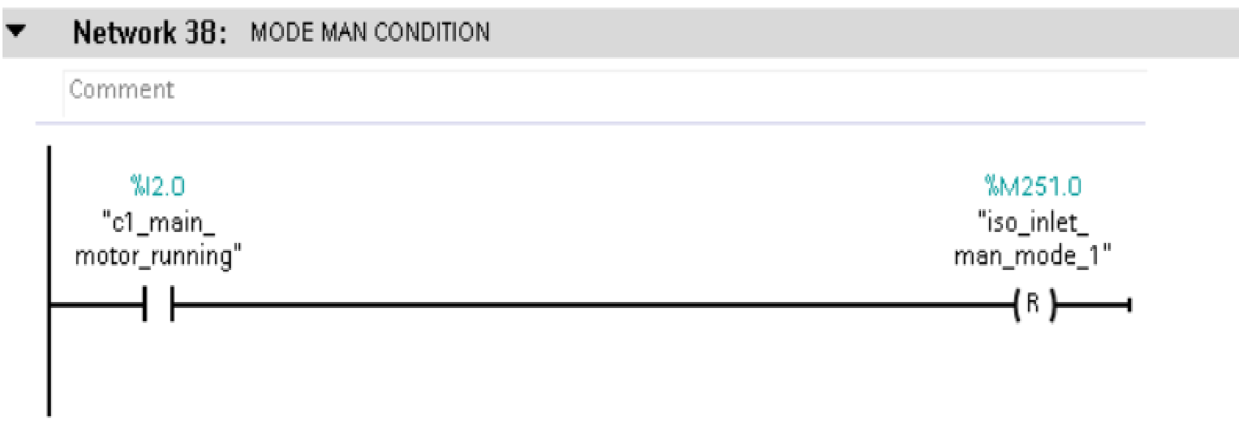


Figure 3.19. The network of manual mode condition

When the I2.0 contact, indicating the motor is running, is active, the manual mode switch becomes non-functional **Figure 3.19.**

- ## Exhaust valve control

The exhaust valve, XV172, is close while the compressor is running. When the main engine is stopped, the exhaust valve is open to allow the pressure dropping. It will remain open until the internal pressure falls below the adjustable residual pressure set point **Figure 3.20.**

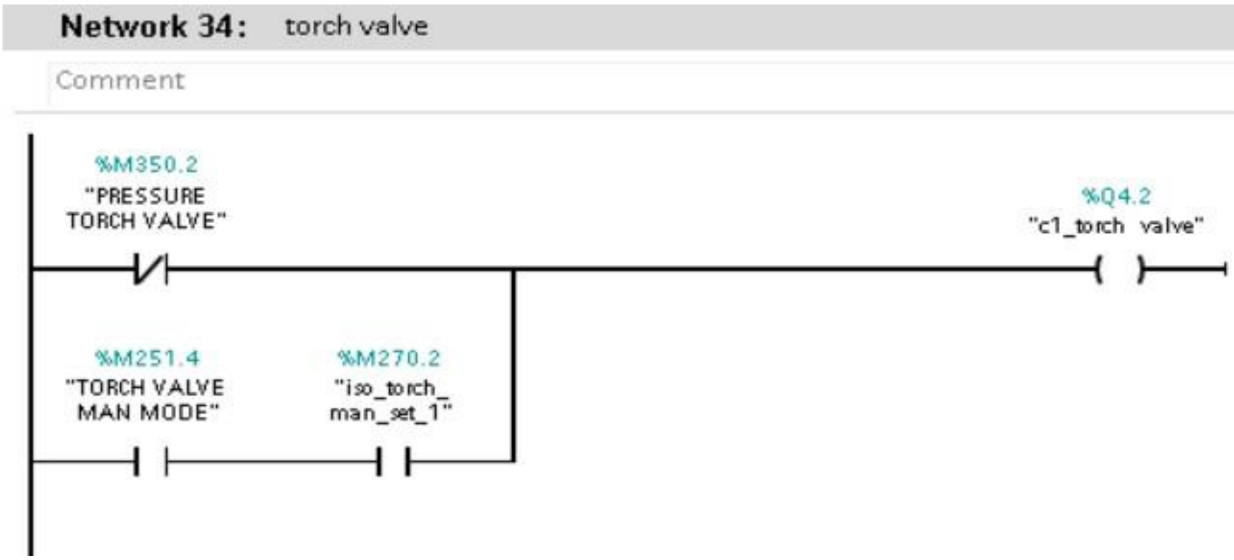


Figure 3.20. The network of isolation torch valve

The torch valve's operation is governed by conditions stored in M350.2 memory. When M350 is active, the valve is in initial state open (the valve is open in failure case); otherwise, it remains closed.

If the torch valve XV172 is manually controlled via the manual switch (M251.4 is active), and we set M270.2 to ON using the Human-Machine Interface (HMI) **Figure 3.21.**

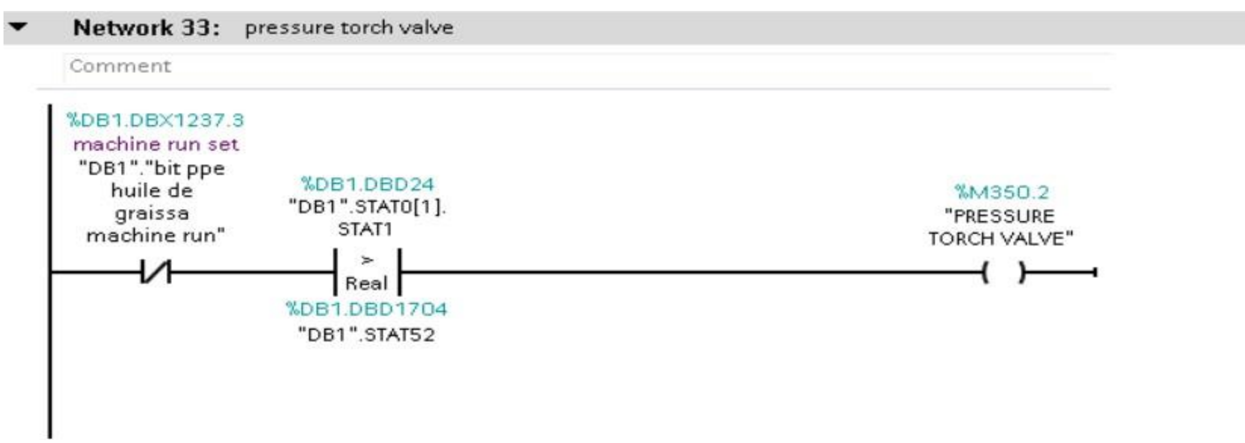


Figure 3.21. The network of pressure torch valve condition

Specifically, when the compressor is running (M350 inactive), the valve stays closed. However, when the compressor stops, the valve opens and remains so until the internal pressure drops below a set level.

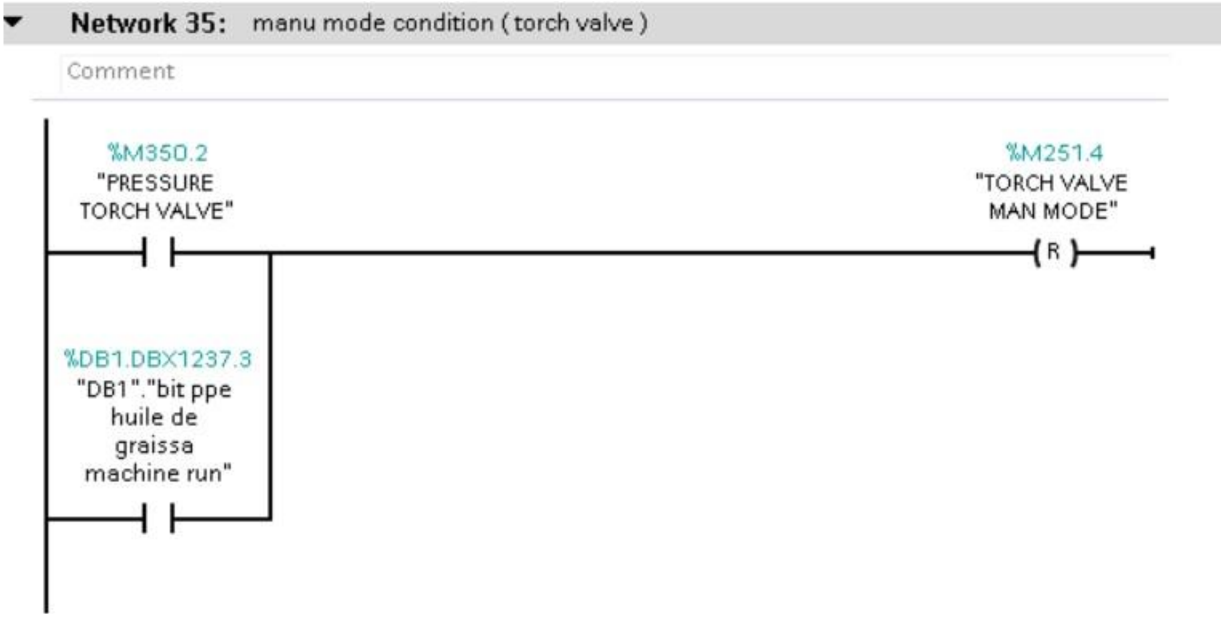


Figure 3.22. The network of manual mode condition (torch valve)

We can’t turn the control in manual mod when the compressor is running and if the internal pressure stays high **Figure 3.22.**

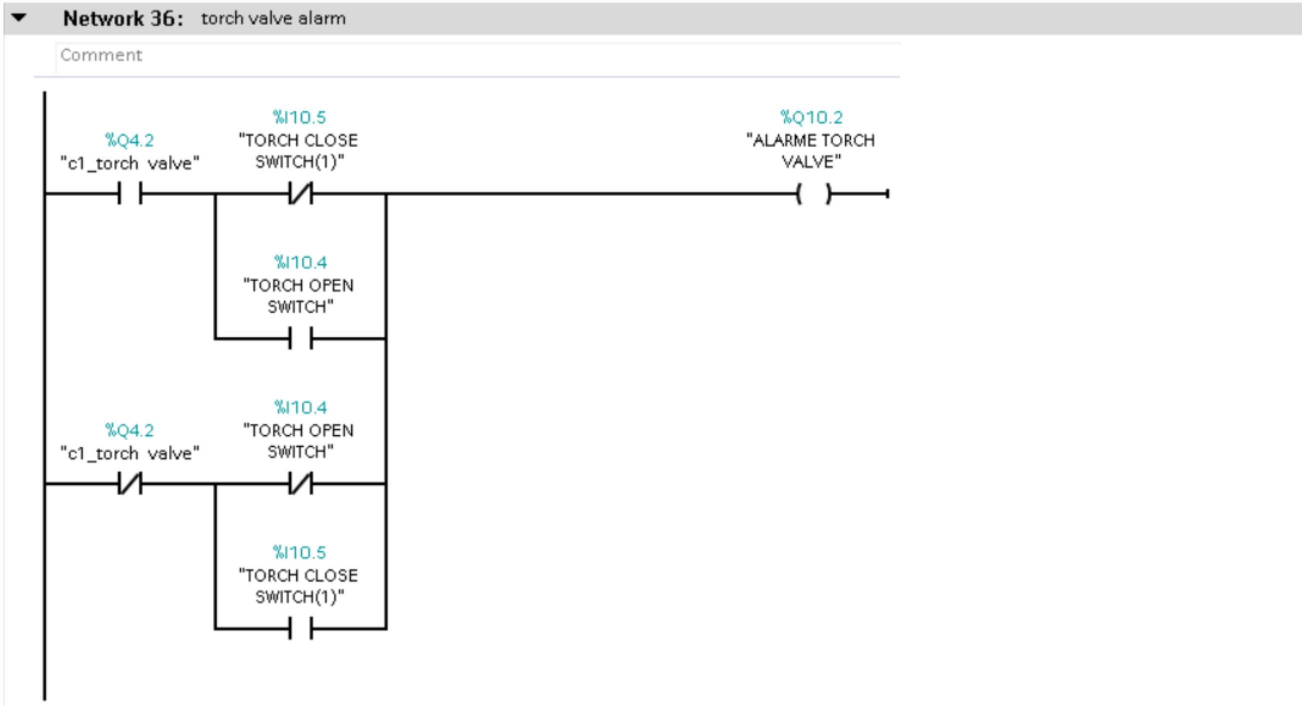


Figure 3.23. The network of isolation torch valve alarme

This alarm is linked to the functionality of the torch valve, covering both its opening and closing sequences. It is activated under two circumstances:

If the valve does not respond during the opening procedure due to a malfunction in either the open or close switch, the alarm will activate.

Likewise, if a similar malfunction occurs during the closing operation (valve fails to close), the alarm will be triggered **Figure 3.23.**

3.5 Simulation and results

- **Motor enable starter:**

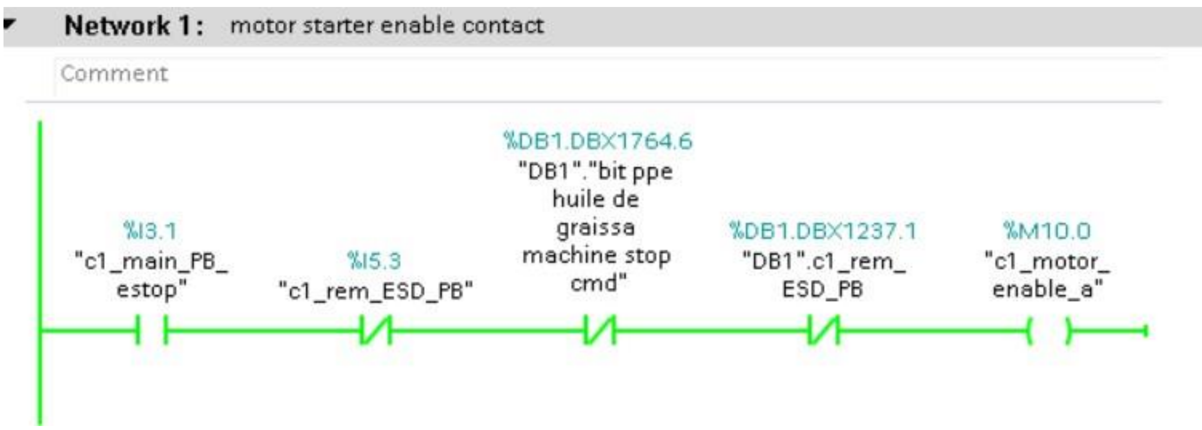


Figure 3.24. simulation of motor starter enable contact

When neither the main panel push button nor the remote push button is pressed, and there is no trip in our compressor system, the motor enable contact **(M10.0)** will be energized **Figure 3.24.**

- **Motor stop:**

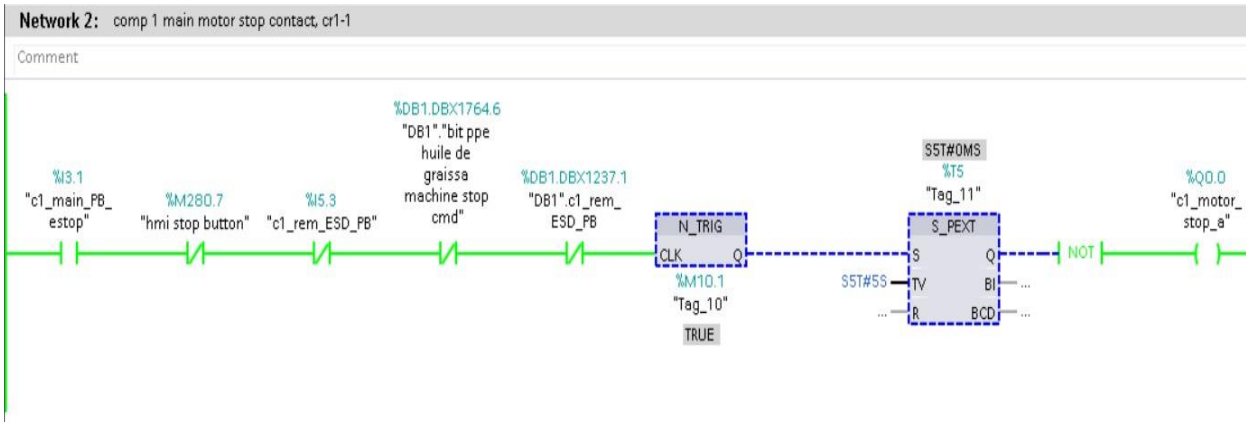


Figure 3.25. simulation of motor stop network

We can stop our motor by pressing either the main push button **(I3.1)** in control room or the remote push button (emergency push button) **(I5.3)**, as well as through the HMI **Figure 3.25.**

Motor start:

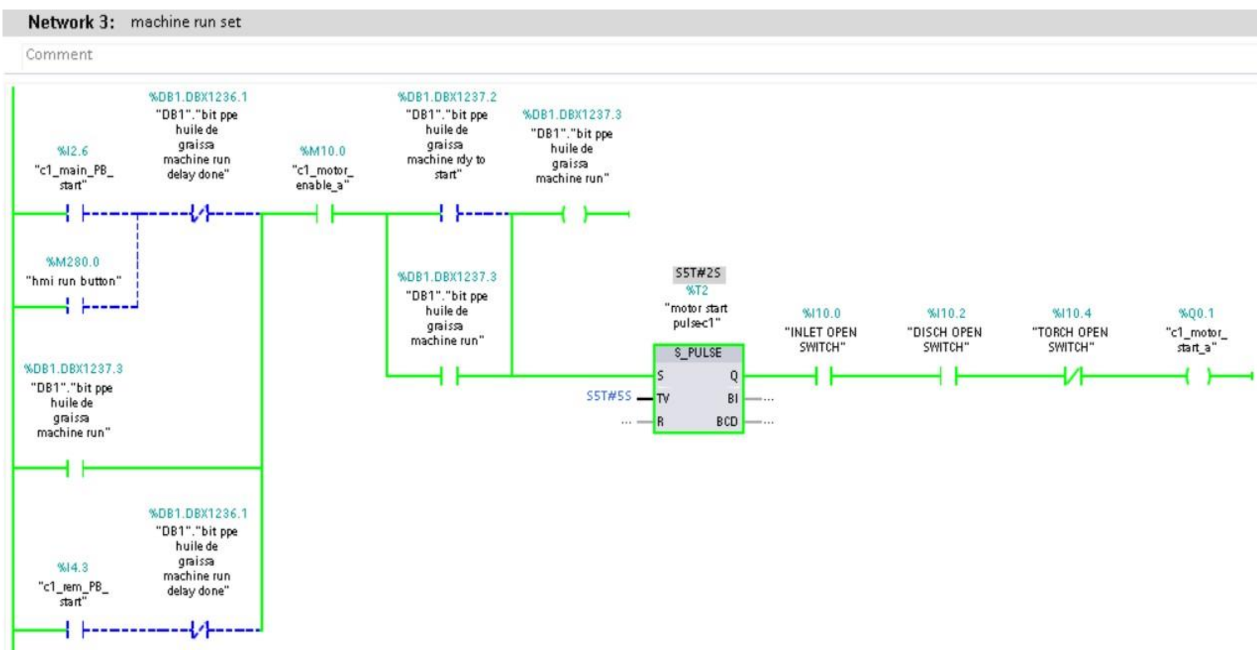


Figure 3.26. simulation of machine run set

"c1_main_PB_start"	%I2.6	main panel, comp 1, start push button
"c1_motor_enable_a"	%M10.0	
"c1_motor_start_a"	%Q0.1	comp1 main motor stop contact, cr11-2
"c1_rem_PB_start"	%I4.3	
"DB1"."bit ppe huile de graissa machine...	%DB1.DBX1237.2	run permisive bit 0-not ready , 1-ready to start
"DB1"."bit ppe huile de graissa machine...	%DB1.DBX1236.1	
"DB1"."bit ppe huile de graissa machine...	%DB1.DBX1237.3	machine run set
"DISCH OPEN SWITCH"	%I10.2	
"hmi run button"	%M280.0	
"INLET OPEN SWITCH"	%I10.0	
"motor start pulse-c1"	%T2	
"TORCH CLOSE SWITCH"	%I10.4	

Figure 3.26. simulation of machine run set

When all permissive are achieved and the motor enable is energized, we can start our motor using the main push button **(I2.6)**, the remote push button **(I4.3)**, or the HMI **Figure 3.26.**

- **Motor flag:**

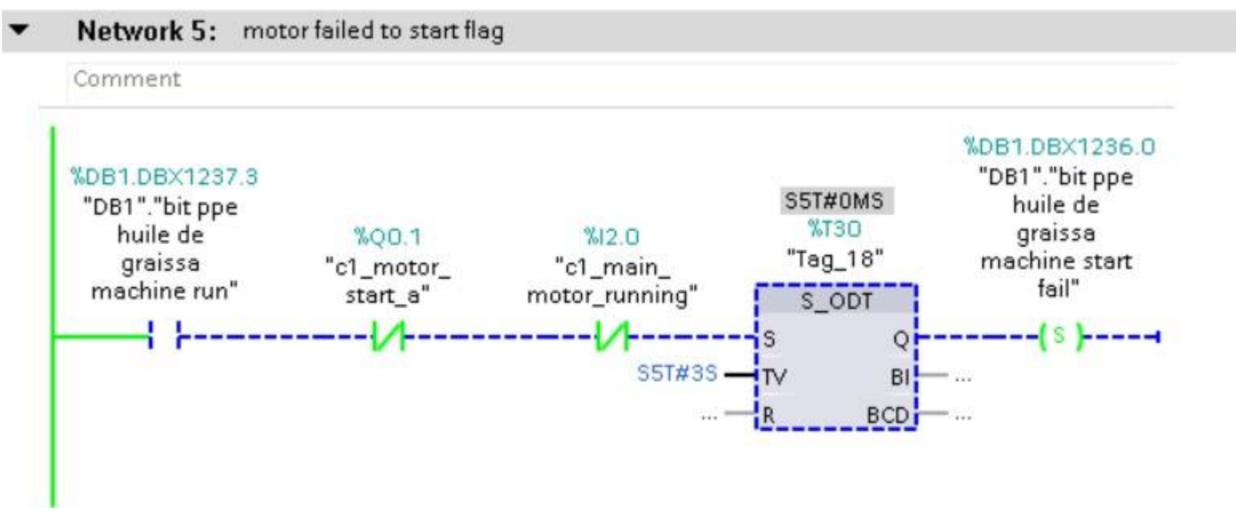


Figure 3.27. simulation of motor flag

Our motor is equipped with a sensor **(I2.0)** that detects the state of motor. If we start the motor and this sensor does not detect any activity, a flag will be triggered, indicating that the motor is not starting and there is a problem **Figure 3.27.**

- **Reset button:**

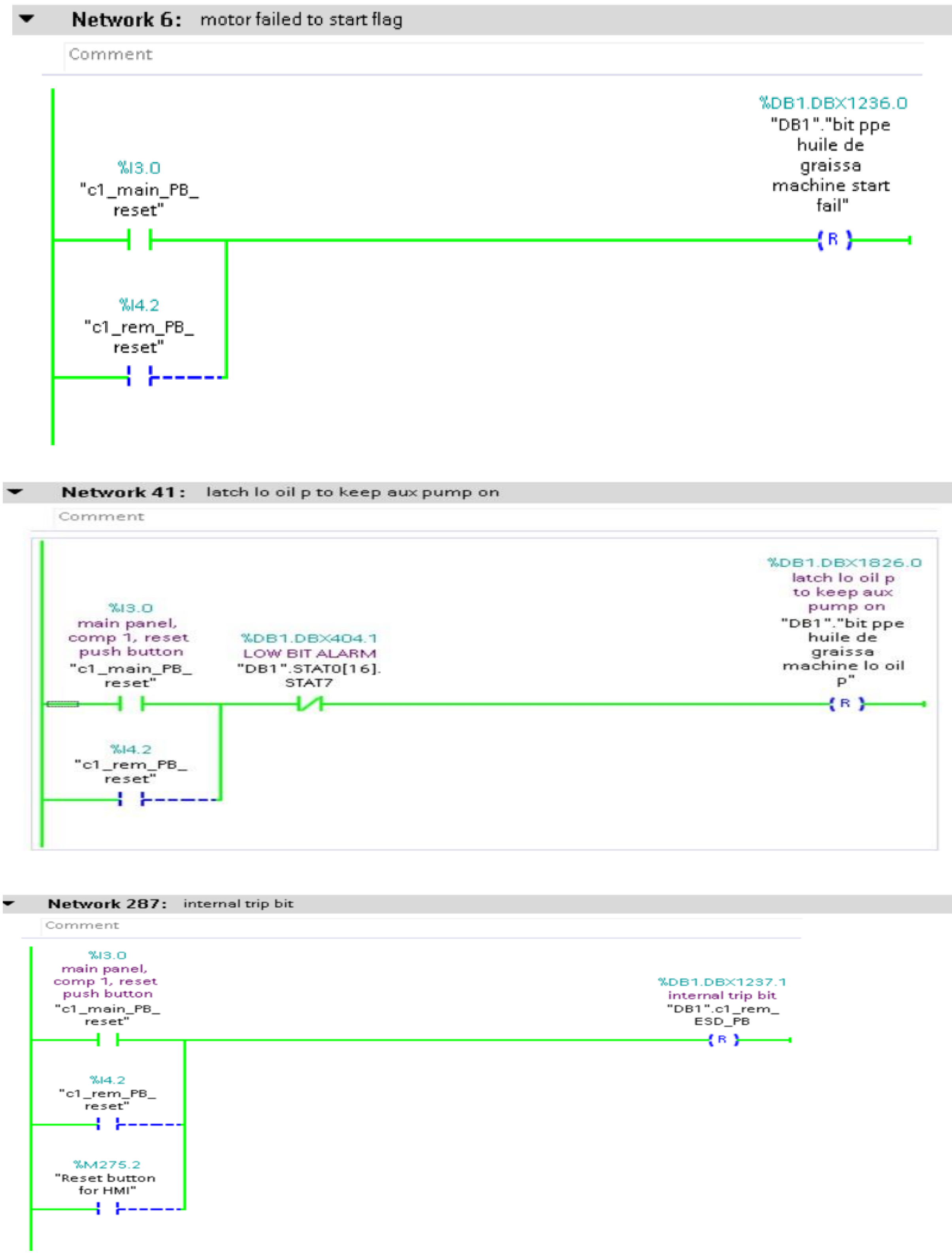


Figure 3.28. simulation of reset button networks

Our compressor is equipped with three reset buttons, these buttons can be found on the HMI, in the main panel and in the remote panel, their primary functions include resetting the motor flag signal, clearing the latch for the low oil pump signal, and resetting trips signal, these features are like in the networks above **Figure 3.28.**

- **Oil pump:**

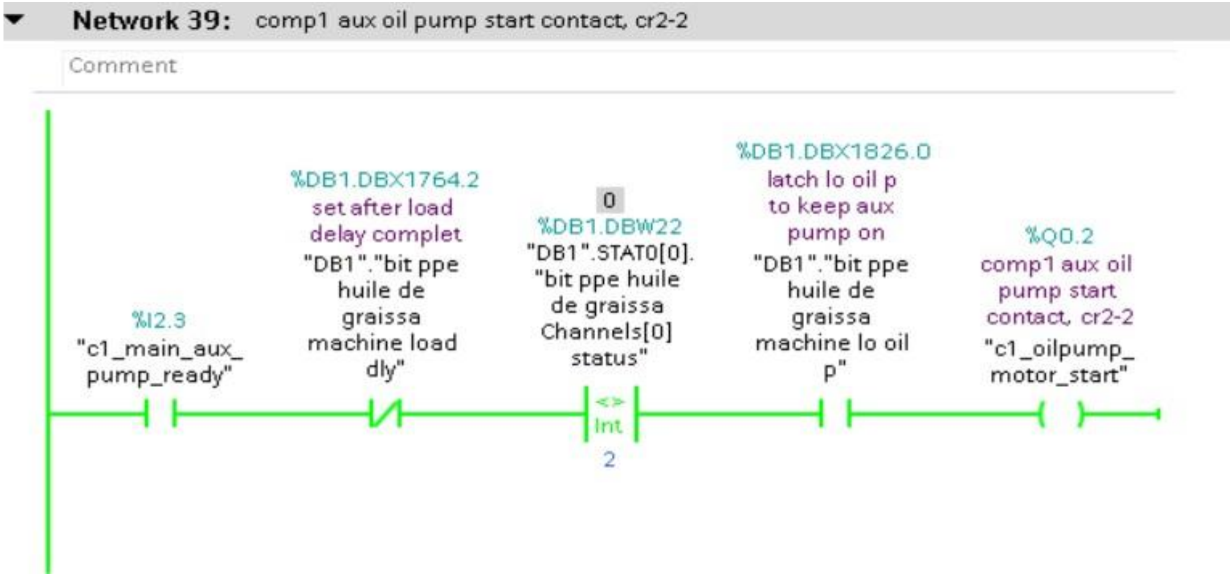


Figure 3.29. simulation of oil pump network

- **Cooling fan:**

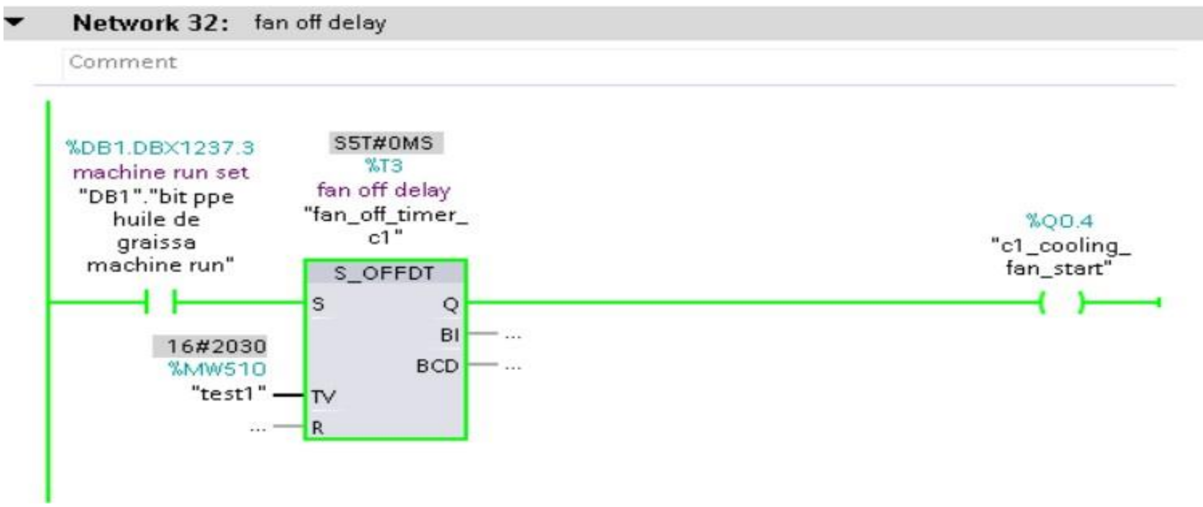


Figure 3.30. simulation of fan network

- **Isolation valves**

1-Inlet/Discharge valves:

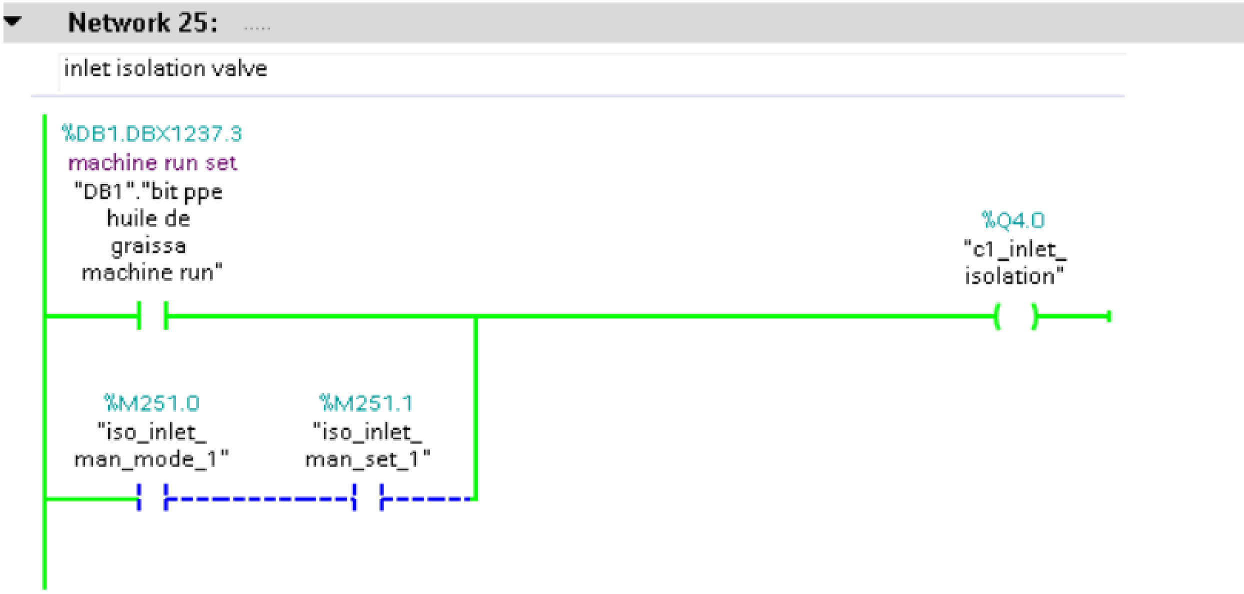


Figure 3.31. simulation of the isolation inlet valve

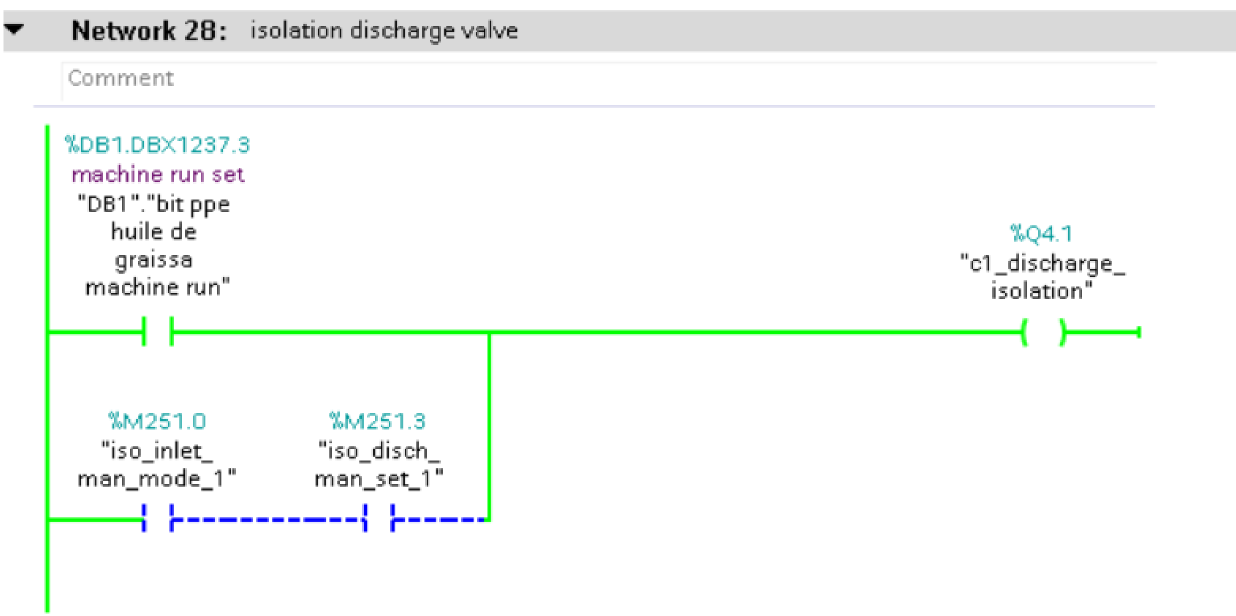


Figure 3.32. simulation of the isolation discharge valve

When the machine run set **(DB1.DBX1237.3)** energized, both the inlet and discharge valves open to allow the gas enter and exit from the compressor **Figure 3.31 and Figure 3.32.**

2-Torch valve:

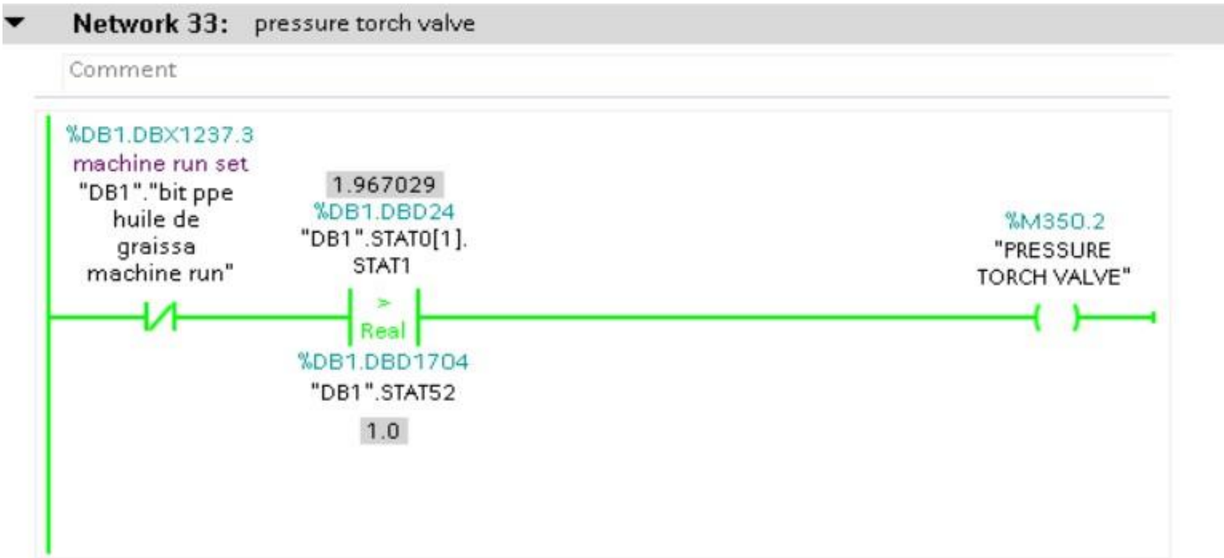


Figure 3.33. simulation of the torch valve pressure condition

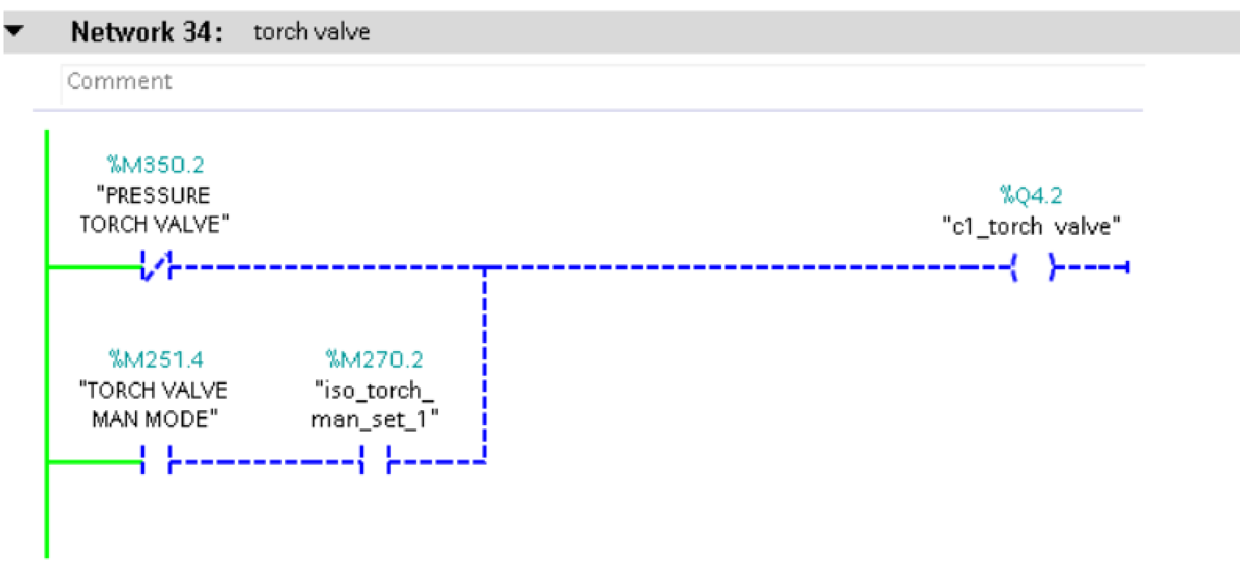


Figure 3.34. simulation of torch valve network

When the compressor is stop, the torch valve opens until the internal pressure being lower than the set point, the memory **(M350.2)** represent both the gas pressure if it is in the required range or not and the state of motor **Figure 3.33 and Figure 3.34.**

- **Isolation valves alarm:**

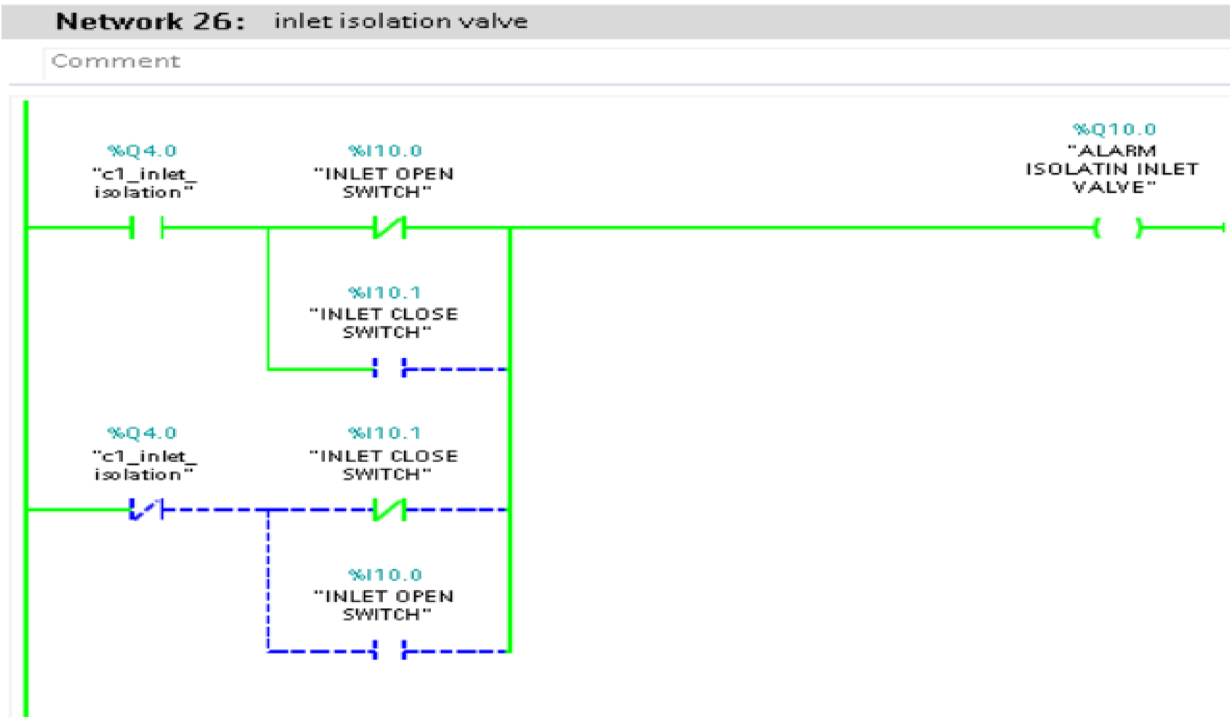


Figure 3.35. simulation of inlet valve alarm

The network diagram above explains the operation of the inlet isolation alarm. When the valve is opened, if the inlet open switch **(I10.0)** does not activate, an alarm signal is triggered. The same process occurs when the valve is closed. This principle applies to the alarms of the other valves as well, ensuring that any malfunction or failure in the valve operation is promptly indicated by an alarm, thus maintaining the integrity and safety of the system **Figure 3.35.**

- **Man mode condition (Isolation valves) :**

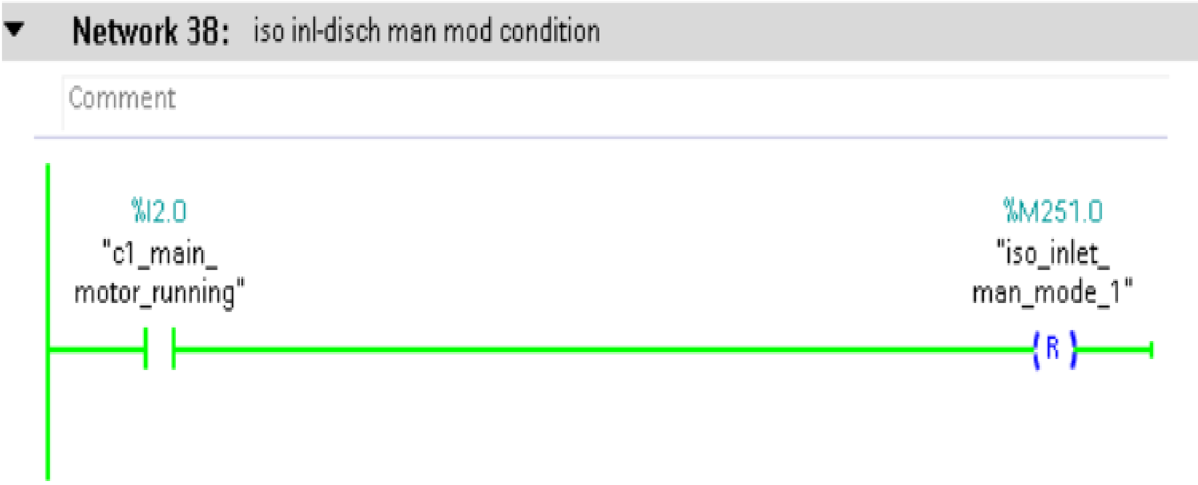


Figure 3.36. simulation of manual mode condition

The inlet and discharge valves man mode work in reverse with the motor, it means that if **(I2.0)** is energized, we can't move to the manual mode **Figure 3.36.**

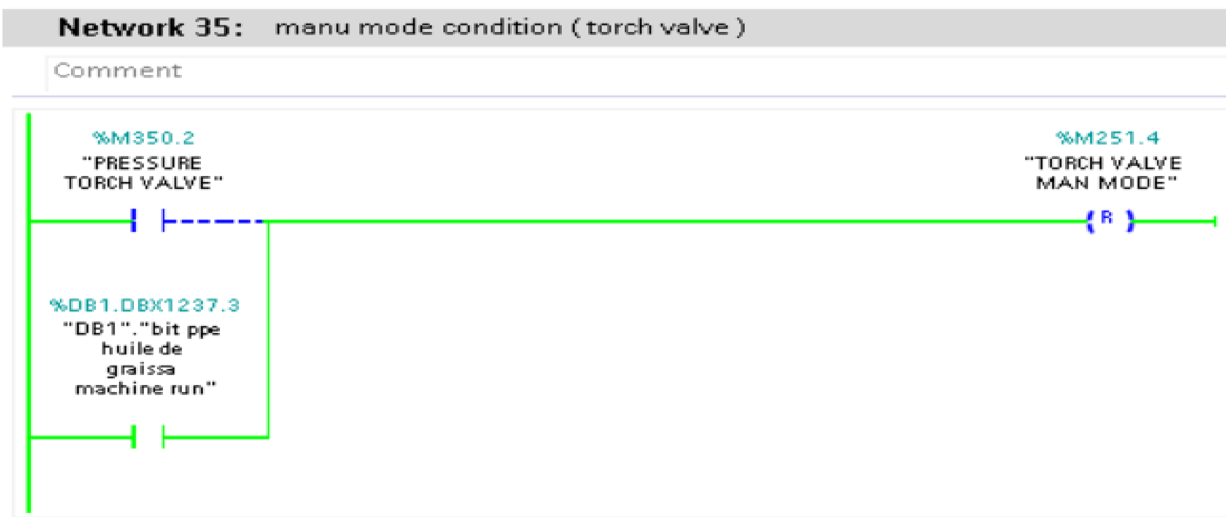


Figure 3.37. simulation of manual mode condition (torch valve)

The torch valve manual mode is also operational when our compressor is stopped, provided that the discharge pressure remains within the required range **Figure 3.37.**

3.6 conclusion

In conclusion, Chapter 3 provides a comprehensive examination of Programmable Logic Controllers (PLCs) with a specific focus on the Siemens S7-400 system and its application in controlling COOPER compressors. The chapter starts by laying a solid foundation with an introduction to the general principles, components, and operational features of PLCs, highlighting their importance in industrial automation.

The detailed exploration of the Siemens S7-400 PLC reveals its robust architecture, versatility, and advanced features that make it suitable for complex control tasks in industrial settings. Through the various sections, we see a meticulous breakdown of the hardware and software elements that contribute to the effective functioning of this PLC system.

Moreover, the chapter delves into specific control logic implementations for COOPER compressors, demonstrating how the Siemens S7-400 is applied in real-world scenarios. The discussions on motor control, isolation valve control, exhaust valve control, and alarm/trip mechanisms illustrate the intricate programming and logical sequences necessary for maintaining optimal compressor performance and safety.

By outlining the various operational strategies and control mechanisms, this chapter underscores the critical role of PLCs in enhancing the efficiency, reliability, and safety of industrial automation processes. The insights provided into the practical applications of the Siemens S7-400 PLC not only enhance our understanding of its capabilities but also emphasize the continuous improvements and innovations in control software necessary to meet evolving industrial demands.

Chapter IV

Cooper Supervision and Monitoring

4.1 Introduction

In this chapter, we delve into the intricate world of Human Machine Interfaces (HMIs), focusing on their critical role in industrial automation and process control. HMIs serve as the bridge between human operators and industrial machines, facilitating intuitive and efficient communication through integrated hardware and software solutions. The chapter begins by defining HMIs and highlighting their significance in optimizing productivity, enhancing safety, and enabling seamless interaction within manufacturing environments. As we explore the components and functionalities of HMIs, including the Simatic HMI KP1200 Comfort Panel, we will gain insight into how these interfaces contribute to the effective operation and monitoring of complex systems, such as the COOPER compressors.

4.2 General information on Human Machine Interface (HMI)

4.2.1 DEFINITION

HMI refers to the integrated hardware and software interface technology that enables intuitive and efficient communication between humans and industrial machines or systems. It encompasses graphical user interfaces, touchscreens, input/output devices, and communication protocols, facilitating real-time monitoring, control, and visualization of industrial processes. HMI plays a critical role in optimizing productivity, enhancing safety, and enabling seamless interaction within manufacturing, process control, and automation environments.

The advanced capabilities of today’s HMIs enable managers and supervisors to do much more than control processes. Using historical and trending data they offer vast new opportunities to improve product quality and make systems more efficient. For all these reasons, HMIs play a key role in the smooth and effective running of factories and manufacturing operations [15].

Figure 4.1. Human machine interface

4.2.2 Components of HMI

- **Hardware:** This includes physical components such as touchscreens, keypads, buttons, switches, sensors, and other input/output devices.
- **Software:** HMI software provides the interface through which users interact with the machine or system. It includes graphical user interfaces (GUIs), control software, programming environments, and data visualization tools.
- **Communication Protocols:** HMI systems often rely on communication protocols to exchange data with the controlled devices. Common protocols include Modbus, Profibus, Ethernet/IP, OPC UA, and others.
- **Integration with Control Systems:** In industrial settings, HMIs are often integrated with control systems such as Programmable Logic Controllers (PLCs) or Distributed Control Systems (DCS) to monitor and control processes [16].

4.2.3 Importance of HMI

- **Enhanced User Interaction:** HMI improves user experience by providing intuitive interfaces that allow users to interact efficiently with machines or systems.
- **Increased Productivity:** Well-designed HMIs streamline workflows and operations, leading to increased productivity in industrial, commercial, and even consumer settings.
- **Reduced Errors:** Clear and user-friendly HMIs minimize the potential for errors by guiding users through processes and providing real-time feedback.
- **Remote Monitoring and Control:** HMIs enable remote monitoring and control of machines or systems, allowing operators to oversee operations from a distance and intervene when necessary.
- **Data Visualization:** HMIs visualize complex data in a comprehensible format, enabling operators to make informed decisions quickly.
- **Safety:** In safety-critical environments, HMIs play a vital role in providing warnings, alarms, and emergency shutdown functionalities to protect operators and assets [17].

4.2.4 KP1200 COMFORT Tactile panel

The Simatic HMI KP1200 Comfort Panel is a versatile interface solution designed for efficient control and monitoring tasks. Featuring a keyboard command interface, it facilitates user interaction for seamless operation. The panel boasts a vibrant TFT widescreen display spanning 12 inches, capable of rendering images with impressive clarity and depth, thanks to its support for 16 million colors. Equipped with PROFINET and MPI/PROFIBUS DP interfaces, it ensures seamless integration into industrial networks for enhanced connectivity and communication. With a configuration memory of 12 MB, it offers ample space for storing configurations and data. Powered by Windows CE 6.0, it provides a robust and familiar operating environment **Figure 4.2** [18].

Figure 4.2. KP1200 COMFORT Tactile panel

4.3 HMI for systeme cooper compressor

4.3.1 Screens description

- **Home Screen:**

The initial interface prominently features identifier "Cooper" along with its corresponding logo, juxtaposed with the name of the manufacturing entity, presented in a smaller font on the right-hand side. Positioned atop is a timestamp denoting the current date and time, complemented by the prominent display of the compressor name. Adjacent to this arrangement, the Sonatrach logo is situated on the left, ensuring consistent visibility across all screens. Directly beneath the principal logo are four distinct buttons, designated for navigation to specific screens, each labeled accordingly: "VALVES," "PERMISSIVE," "ALARMS," and "COOPER." The background color of the interface is a soothing teal blue, selected for its aesthetic appeal and avoidance of darker hues, thereby enhancing user comfort and readability **Figure 4.3**.

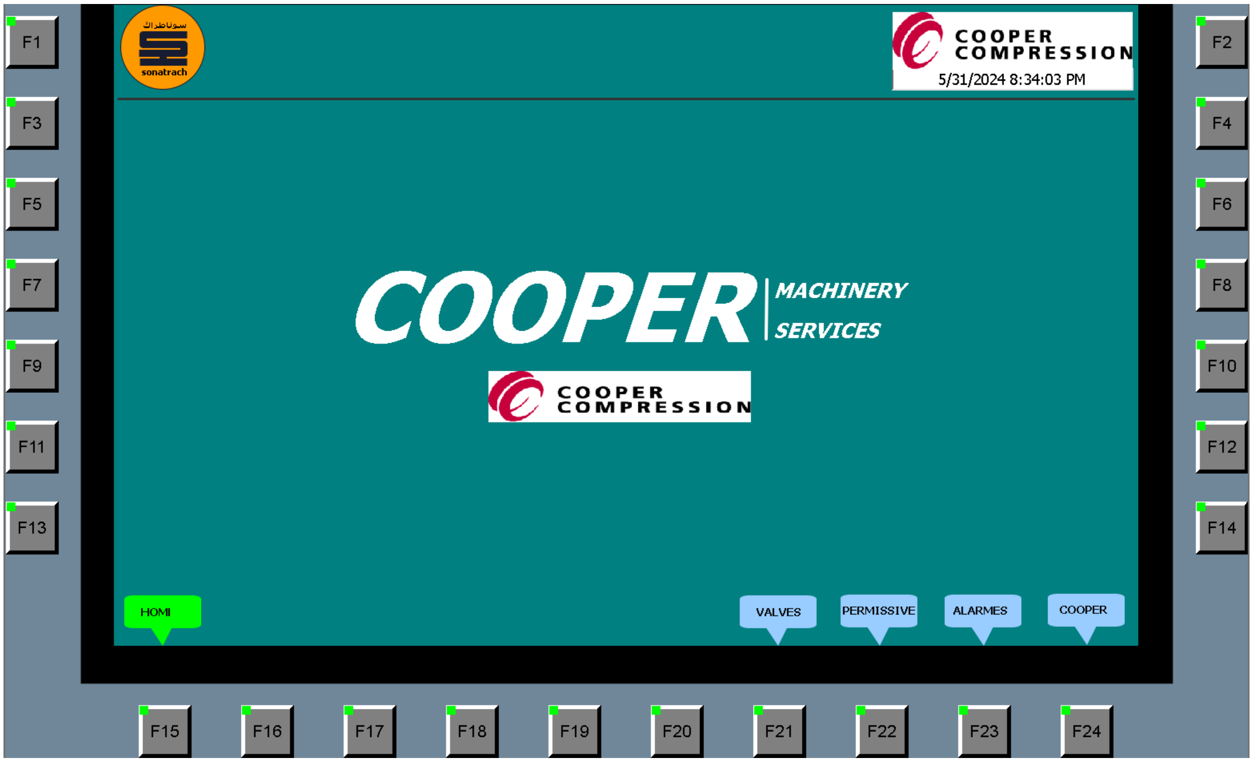


Figure 4.3. Home screen

- **Cooper Screen (compressor):**

This screen shows the compressor diagram above consisting of three compression stages labeled "Stage 1", "Stage 2", and "Stage 3". Each stage has a frame representing a corresponding pressure transmitter (PT-132, PT-133, PT-134) that displays pressure values in units of kg/cm^2. In addition to the compressor drive motor in blue on the left, and immediately to the right of it, we added a fan cooling the gas flowing from the compressor.

The flow chart shows the gas or liquid moving from left to right, with automatic control valves ,the inlet valve FCV-170 and recycle valve PCV-171, we put next to each valve a frame with a number representing the valve opening ratio, each valve is followed by a frame that represent her flow and pressure transmitters , we also added the three valves that we worked on in the form of a

TOR valve, the first one on the bottom left represents the isolation inlet valve, The second is connected to the compressor outlet and represents the isolation discharge valve, and the third on the bottom right represents the vent isolation valve(exhaust valve), next of it we placed the glow stack or vent represented by the flame symbol . All of the motor, the three stages, the fan, the automatic control valves and the INL/DISCH valves take the green color when the compressor is running similar to the torch valve that's red in color, and vice versa when the compressor turns of, in the center, we placed control buttons to turn the compressor on, off, and back on. If all compressor operating permissive are met, the start button flashes green, if one of the conditions is faulty, it flashes red and the compressor cannot be started, and it takes on a green color when it is running, on the right of the screen we placed a window to change the inlet valves mode from automatic to manual and vice versa, containing two MAN / AUTO buttons. Below the main interface, there are navigation buttons for other screens **Figure 4.4**.

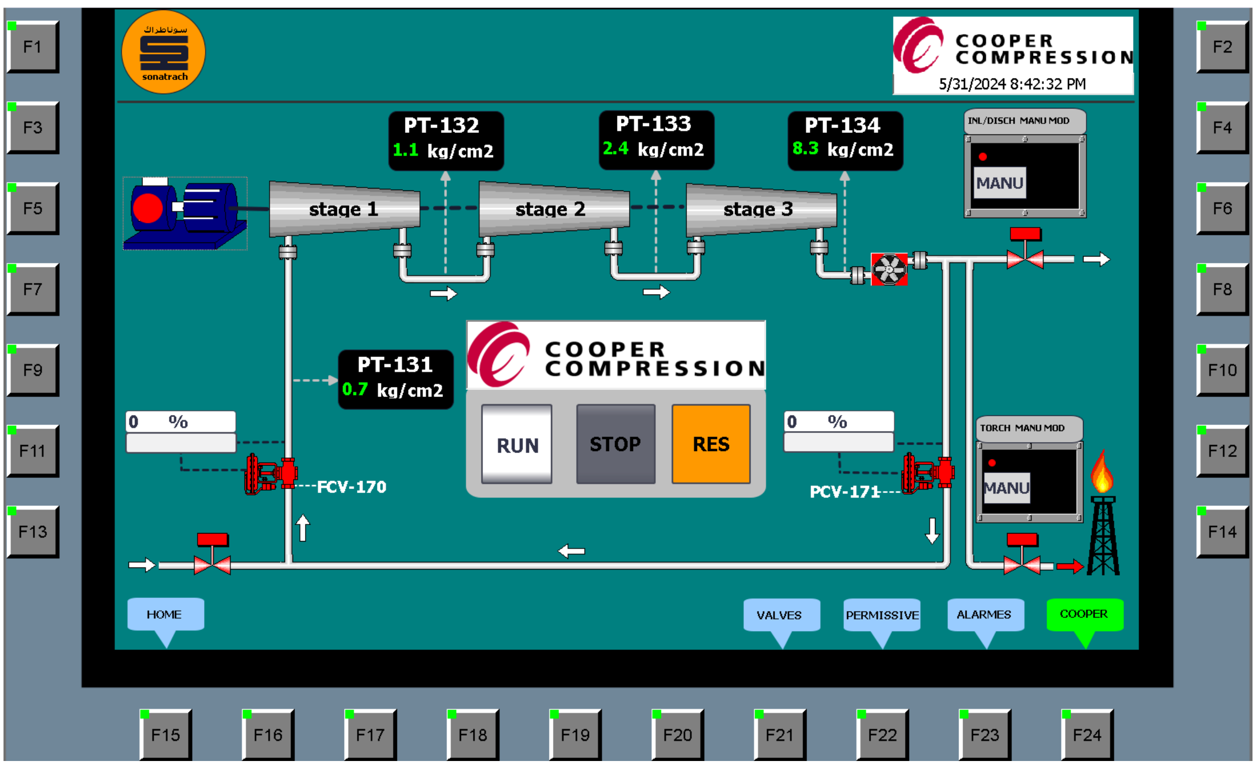


Figure 4.4. Compressor screen (COOPER)

- **Permissive screen:**

This screen presents the permissive essential for the operation of our compressor cooper. In the event of any permissive encountering an issue, the corresponding frame will flash in a distinctive red hue, signaling a malfunction. Conversely, when the permissive is functioning optimally, it will be indicated by a reassuring green color. The "Ready to Run" frame adopts the green coloration only when all permissive are successfully met. Positioned at the bottom are navigation buttons facilitating seamless transitions to other screens **Figure 4.5**.

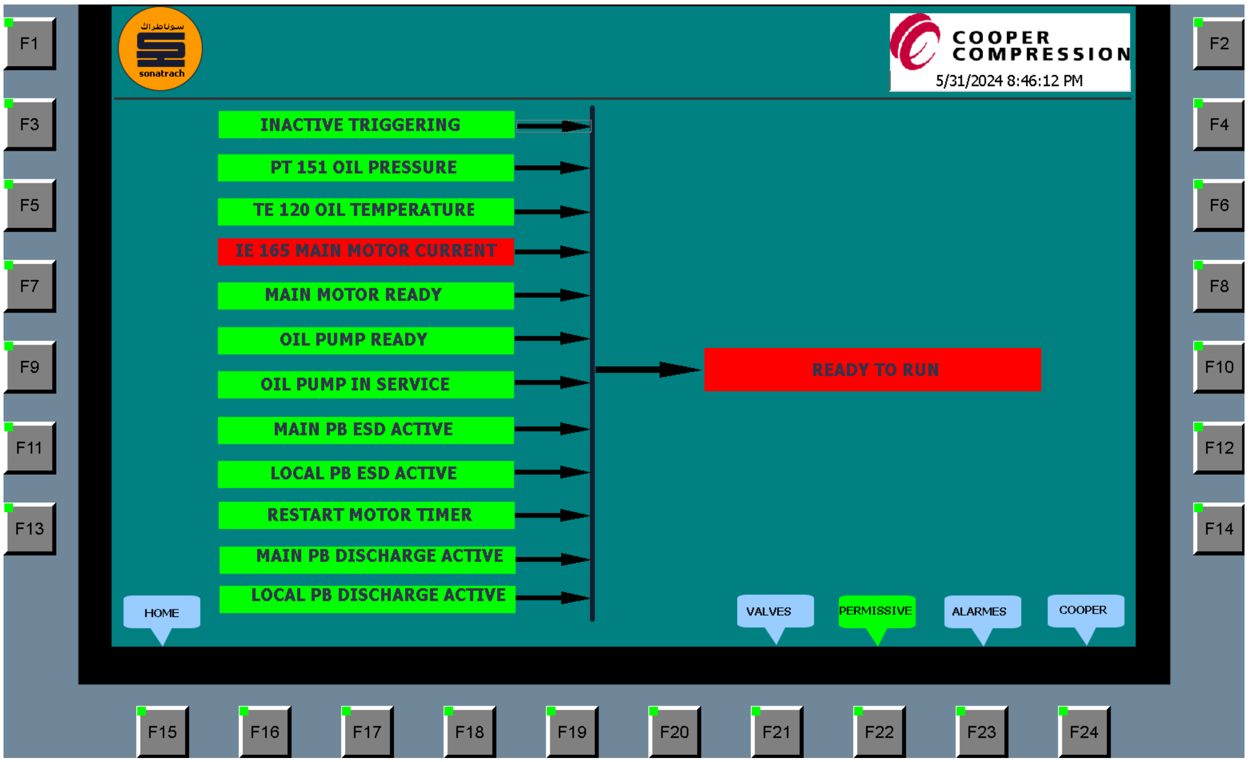


Figure 4.5. Permissive screen

- **Isolation valves screen:**

This interface enables monitoring of the isolation status of three valves in manual mode. Each valve is placed within its respective frame, with two buttons positioned at the bottom of each frame. The green button signifies the "open" function, while the red button denotes "close." Valve status is dynamically represented: a green hue indicates an open valve, whereas a red hue signifies closure. Consistent with the interface design, navigation buttons are located at the bottom for seamless access to other screens **Figure 4.6**.

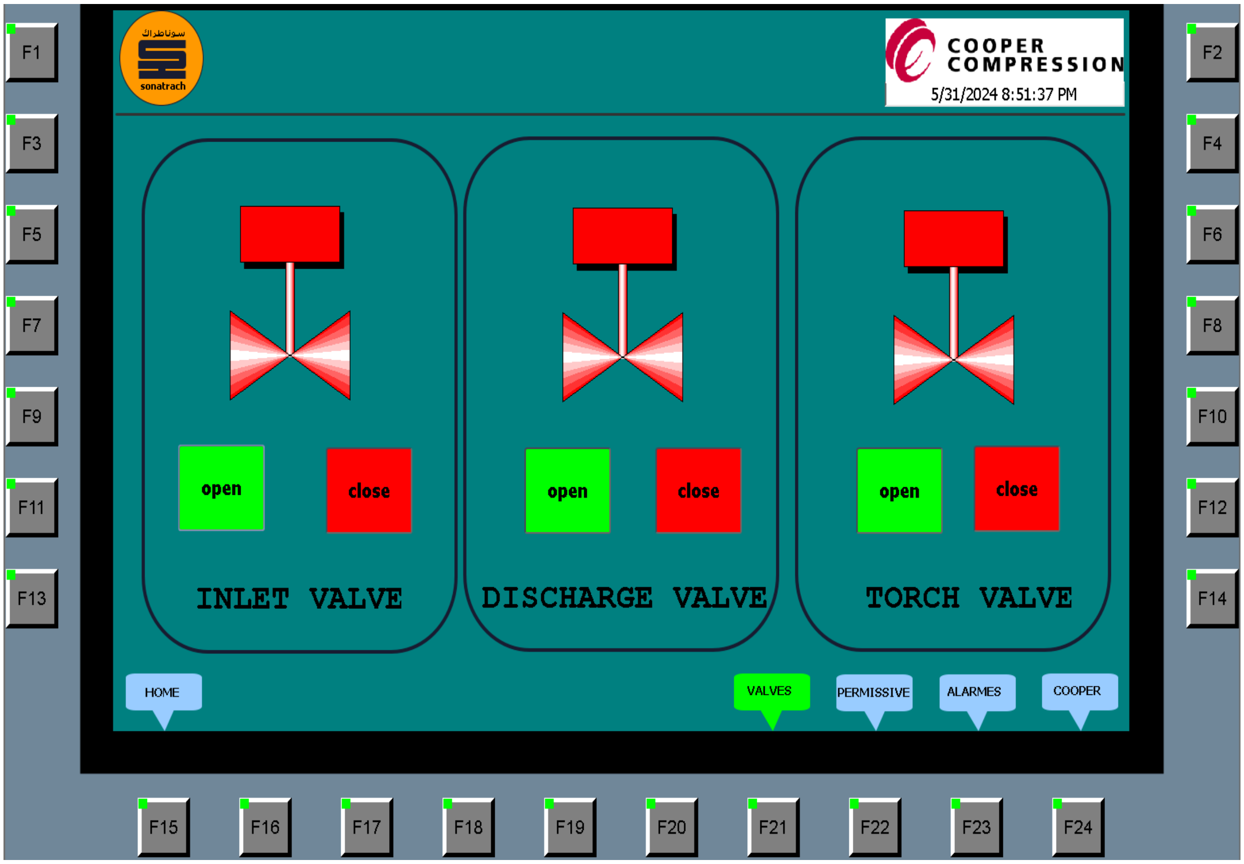


Figure 4.6. Isolation valves screen

- **Alarms screen:**

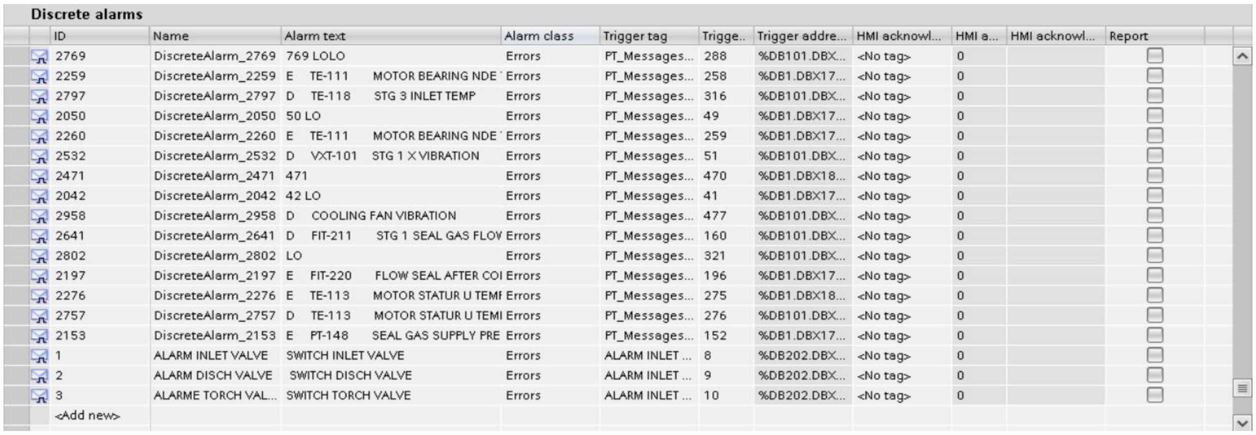
This screen features an alarm window dedicated to presenting comprehensive information regarding alarms. Included within are details such as the alarm name, timestamp including date and time, as well as the specific case associated with each alarm event **Figure 4.7**.

Figure 4.7. Alarms screen

4.3.2 System Alarms

Each alarm corresponds to a certain system fault.

If a fault is detected in our system, we need to draw up a list of alarms which will be used with the program as a reference as the picture below shows:



Discrete alarms

ID	Name	Alarm text	Alarm class	Trigger tag	Trigge..	Trigger addre...	HMI acknowl...	HMI a...	HMI acknowl...	Report
2769	DiscreteAlarm_2769	769 LOLO	Errors	PT_Messages...	288	%DB101.DBX...	<No tag>	0		
2259	DiscreteAlarm_2259	E TE-111 MOTOR BEARING NDE	Errors	PT_Messages...	258	%DB1.DBX17...	<No tag>	0		
2797	DiscreteAlarm_2797	D TE-118 STG 3 INLET TEMP	Errors	PT_Messages...	316	%DB101.DBX...	<No tag>	0		
2050	DiscreteAlarm_2050	50 LO	Errors	PT_Messages...	49	%DB1.DBX17...	<No tag>	0		
2260	DiscreteAlarm_2260	E TE-111 MOTOR BEARING NDE	Errors	PT_Messages...	259	%DB1.DBX17...	<No tag>	0		
2532	DiscreteAlarm_2532	D VXT-101 STG 1 X VIBRATION	Errors	PT_Messages...	51	%DB101.DBX...	<No tag>	0		
2471	DiscreteAlarm_2471	471	Errors	PT_Messages...	470	%DB1.DBX18...	<No tag>	0		
2042	DiscreteAlarm_2042	42 LO	Errors	PT_Messages...	41	%DB1.DBX17...	<No tag>	0		
2958	DiscreteAlarm_2958	D COOLING FAN VIBRATION	Errors	PT_Messages...	477	%DB101.DBX...	<No tag>	0		
2641	DiscreteAlarm_2641	D FIT-211 STG 1 SEAL GAS FLOV	Errors	PT_Messages...	160	%DB101.DBX...	<No tag>	0		
2802	DiscreteAlarm_2802	LO	Errors	PT_Messages...	321	%DB101.DBX...	<No tag>	0		
2197	DiscreteAlarm_2197	E FIT-220 FLOW SEAL AFTER COI	Errors	PT_Messages...	196	%DB1.DBX17...	<No tag>	0		
2276	DiscreteAlarm_2276	E TE-113 MOTOR STATUR U TEMI	Errors	PT_Messages...	275	%DB1.DBX18...	<No tag>	0		
2757	DiscreteAlarm_2757	D TE-113 MOTOR STATUR U TEMI	Errors	PT_Messages...	276	%DB101.DBX...	<No tag>	0		
2153	DiscreteAlarm_2153	E PT-148 SEAL GAS SUPPLY PRE	Errors	PT_Messages...	152	%DB1.DBX17...	<No tag>	0		
1	ALARM INLET VALVE	SWITCH INLET VALVE	Errors	ALARM INLET ...	8	%DB202.DBX...	<No tag>	0		
2	ALARM DISCH VALVE	SWITCH DISCH VALVE	Errors	ALARM INLET ...	9	%DB202.DBX...	<No tag>	0		
3	ALARME TORCH VAL...	SWITCH TORCH VALVE	Errors	ALARM INLET ...	10	%DB202.DBX...	<No tag>	0		
<Add new>										

Figure 4.8. HMI Alarms

4.4 HMI simulation and results

Main screen (COOPER):

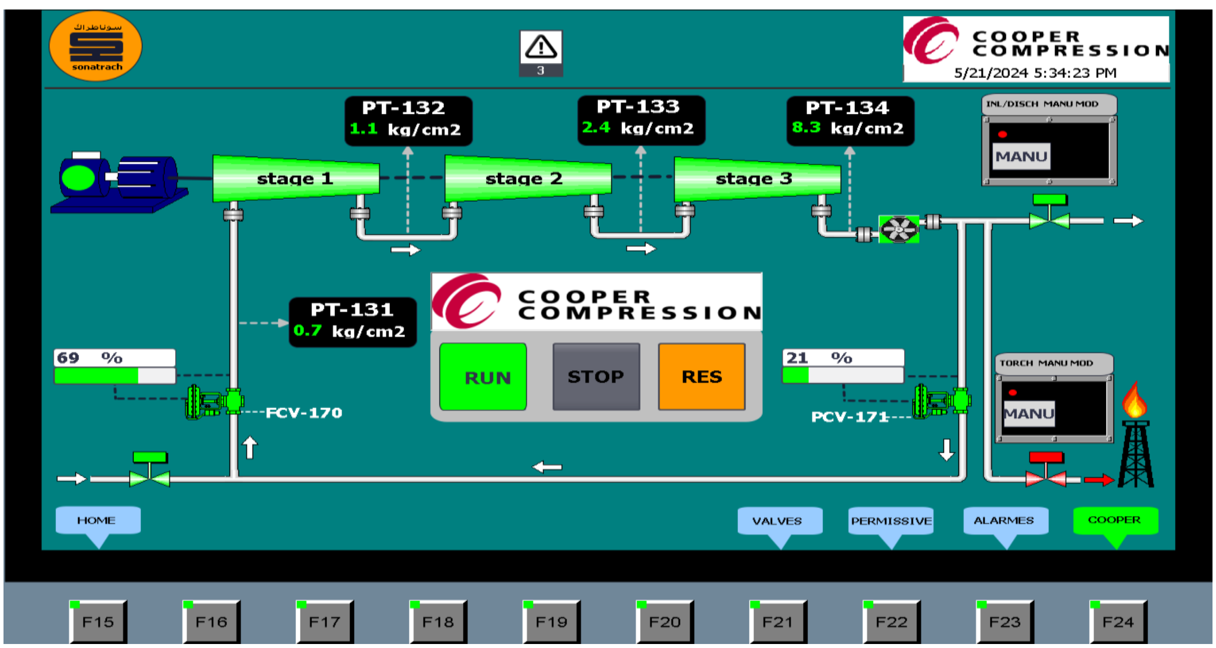


Figure 4.9. Simulation of compressor system

Before starting the compressor, the run button flashes green to indicate that the permissive are allowed. Once the run button is pushed, all stages, including the motor, fan, regulation valves (inlet/recycle), and inlet and discharge valves, turn green to signify that they are running. In contrast, the vent valve turns red to indicate it is closed. After initiating the stop mode, the manual mode of the isolation valves can be activated **Figure 4.9**.

Permissive screen:

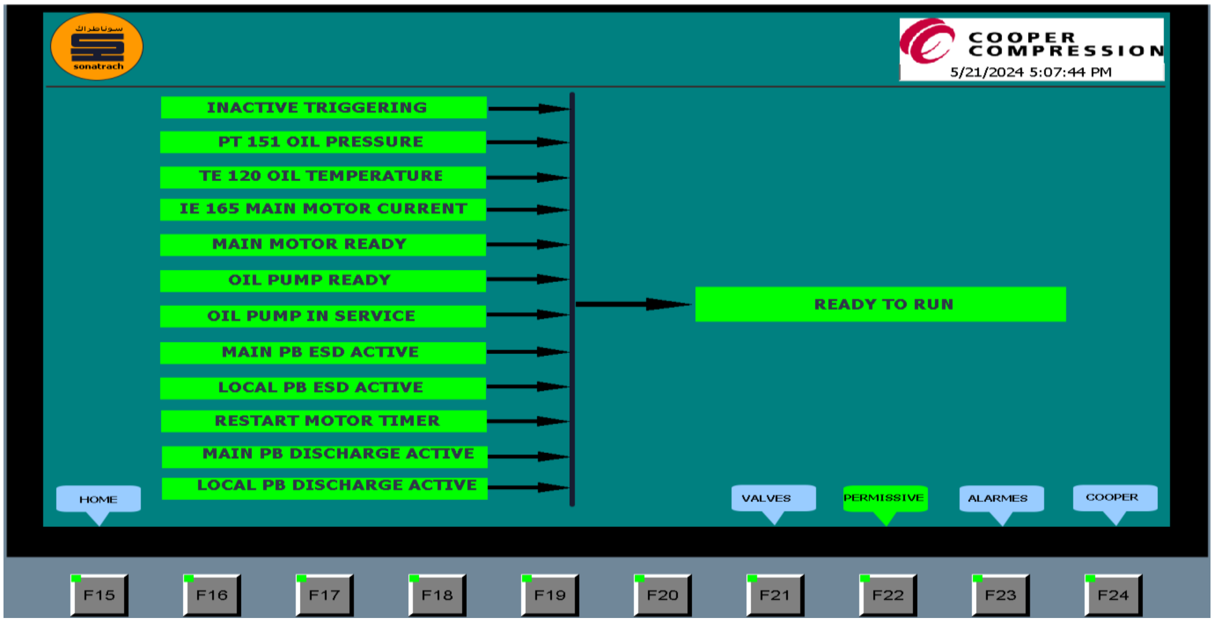


Figure 4.10. Simulation of permissive

This screen displays the permissive state of the system. If any permissive is not allowed, its frame will flash red, as will the "ready to run" indicator. Conversely, when all permissive are allowed their frames displayed in green, it indicates that the motor is ready to run **Figure 4.10**.

Isolation valves screen:

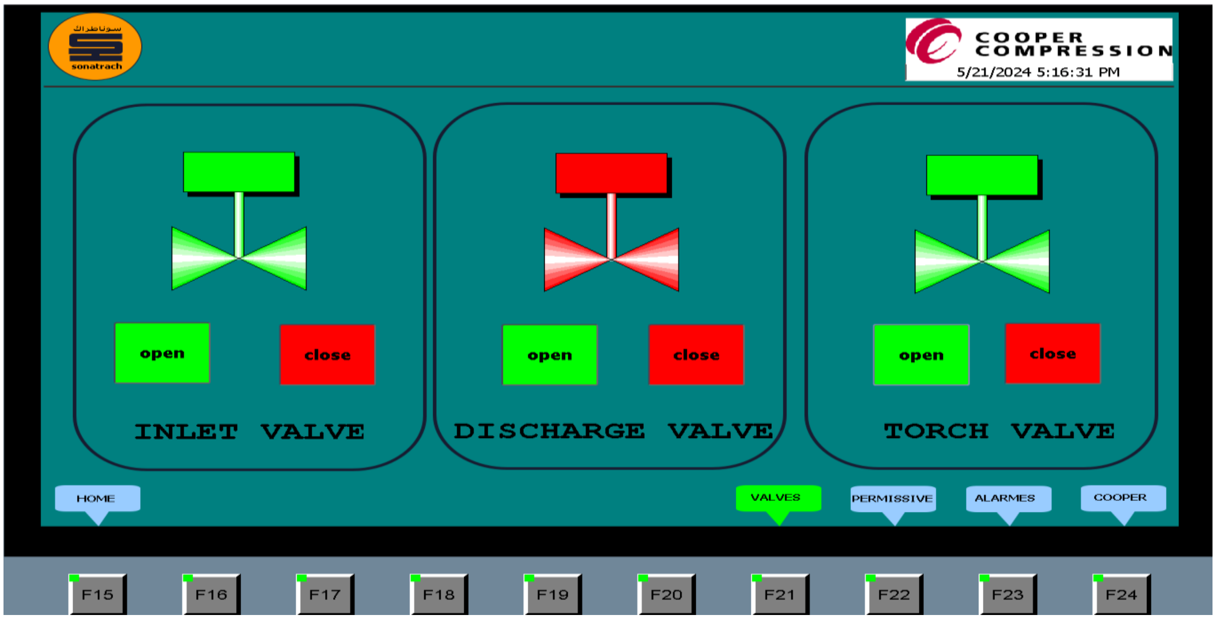


Figure 4.11. Simulation of isolation valves

When the compressor is stopped and the discharge gas pressure is in the safety range, we can go to the isolation valve manual mode, then from this screen we can close and open the three isolation valves as we wish **Figure 4.11**.

4.5 Conclusion

In this chapter, we presented the HMI views for supervision and communication with the PLC, which significantly minimizes physical effort and saves time. The interface provides a visual representation of the compression process, allowing operators to monitor pressures, control operations, and respond to any issues or alarms efficiently. By leveraging the advanced capabilities of HMIs, industrial systems can achieve higher levels of productivity, safety, and operational efficiency. The detailed exploration of the KP1200 Comfort Panel and its integration with COOPER compressors exemplifies the pivotal role HMIs play in modern industrial automation, offering enhanced user interaction, data visualization, and control capabilities.

General conclusion

General Conclusion

The work conducted within the scope of this study had a dual objective:

- ✓ Firstly, to comprehend and analyze the safety functionalities of a multistage centrifugal gas compressor.
- ✓ Subsequently, this understanding enabled us to immerse ourselves in the selection and sizing of isolation valves for this compressor to ensure its safety.

Safety relies on the development of a control logic for automatic valves and its implementation in the "TIA Portal" software. Command through the development of an instruction set has been beneficial for enhancing our knowledge in this area.

This endeavor has provided us with valuable experience and new knowledge, particularly in the realms of programming with TIA Portal software, simulation with PLCSIM, and supervision with WinCC software.

Ultimately, we hope that this work, focusing on automation with supervision, serves as an example for future students who will undoubtedly undertake more sophisticated projects.

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