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MASTER

In **Electrical and Electronic Engineering**

Option: **Control Engineering**

Title:

AUTOMATION OF A FIRE PUMPING STATION using SIEMENS S7-400 and SCADA

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Abstract

The objective of this project is to design and Realise a remote control solution for a fire pumping station of the Industrial Complex South of SONATRACH located at Hassi Messaoud wilaya of Ouargla. Fire water pumping station serves to deliver water and foam solution into fire fighting network of oil and gas production units for automatic fire extinguishment of oil vessels and process equipment. For supervision and control purpose a SCADA system is designed in such a way to allow the operator to command and monitor all different process of the station. The automation system was implemented using SIMATIC Step 7 for the Automating Station (AS) and WinCC Explorer for the Operating Station (OS).

Dedication

" When you're surrounded by people who share a passionate commitment around a common purpose, anything is possible.

Howard Schultz

First of all we thank God the most almighty and most merciful for guiding us during our life to follow the right ways and we pray him to show us the path to success.

I dedicate this work

In the memory of my father, who is always in my mind and in my heart, May God, the merciful god, welcome you in his eternal paradise.

To my mother and sister. May this modest work be an expression of the vows you had ceased to formulate in your prayers. May God preserve you in health and long life.

To all my friends, the students who I studied with.

Acknowledgment

We are grateful to God for the good health and well-being needed to complete this report and for the opportunity to be surrounded at IGEE Institute by great and helpful people.

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No acknowledgement would be complete without expressing our appreciation and thankfulness to my co-supervisor Mr Rahim BOURMOUCHE for his valuable encouragement, guidance and monitoring during our internship at SIEMENS, without which this work would not have reached the point of fruition, so we ask Allah to reward him on our behalf.

We wish to extend our sincere thanks to all Siemens staff for welcoming us, and specially the members of the industry division of Siemens who contributed directly or indirectly to the realization of this modest work including Samir BENALIA, Sofiane IBRAHIM and Fouad HAMEG

We would conclude with our deepest gratitude to our parents, and all our loved ones. Our full dedication to the work would have not been possible without their blessings and moral support.

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List of acronymes

AI: Analog Input

AUTO_DIST: Automatic Distance Command

BLK_LIB_AUTO: Block/Liberate Mode Automatic

CFC: Continuous Function Chart

CINA: Complex Industrial Naili Abdelhalim

CIS: Complex Industrial South

CPU: Central Processing Unit

DI: Digital Input

DO: Digital Output

FBD: Function Block Diagram

GPL: Liquified petroleum gas

IEC: International Electrotechnical Commission

IL: Instruction List

IM: Interface Module

IP: Internet Protocol

LD: Ladder

LIT: Level Indicator Transmitter

LSH: Level Switch High

LSL: Level Switch Low

LSLL: Level Switch Low Low

MANU_DIST: Manual Distance Command

NFPA: National Fire Protection Association

P&ID: Piping and Instrument Diagram

PIT: Pressure Indicator Transmitter

PLC: Programmable Logic Controller

PROFINET: Process Field Net

PS: Power Supply

SCADA: Supervisory Control And Data Acquisition

SFC: Sequential Function Chart

SM: Signal Module

ST: Structured Text

USD: Unit of Storage and Dosage

General Introduction

Automated system is a revolutionary domain for the development and the well performance of a production cycle where a system will be working by its own after a complete programming process using different components and programmers.

An automatic system has many advantages in the industrial domain and human safety where the human interference is not needed during the process since an HMI screen gives us the access to that.

Automation covers applications ranging from a household thermostat controlling a boiler, to a large industrial control system with tens of thousands of input measurements and output control signals. Control complexity can range from simple on-off control to multi-variable high level algorithms.

Unfortunately, in our country many industries are still not automated and even for those which are automated they do not have SCADA system implemented in their manufactures due to their high cost and lack of local providers for this technology.

One of the main important application of automation system is in fire protection, and mainly in oil and gas factories. Since fire may cause tremendous damage to human, equipment and environment, and also to the economics of the country.

Our contribution is centred on designing and programming an automated fire pumping system for the Industrial complex *CIS* of "*SONATRACH"* located at "*Hassi Messaoud wilaya* of *Ouragla"*, which is one of the most important oil and gas factory in Algeria.

In order to achieve our objective, we had to pass from different steps that are organized in four chapters each with a precise objective.

Chapter I: Throughout the first chapter, we will introduce the different related companies, give a general overview of the industrial complex (CIS) and present the problem related to the system.

Chapter II: In the second chapter we will present the different instruments as well as the sequential logic of the fire pumping stations.

Chapter III: The third chapter is dedicated for Hardware and Software solution.

Chapter IV: Finally, we will demonstrate the designed solution to supervise and control the process.

I. **Chapter 1:** General introduction of CIS.

I.1. Introduction

Oil and gas remain the most used energy sources for the good functioning of the world economy and they will continue to play this strategic role as long as man has not found other sources of energy, which can fill their roles with more profitability and efficiency. Meanwhile in the complex industries of oil and gas, there is a lot that could go wrong. One of the more serious risks for this industry is the potential for fires and explosions.

"On February 12, 2019, a fire broke out on a degassing tank at the industrial complex south (CIS) of Hassi Messaoud,"

In this chapter, we will introduce the companies as well as our case of study the industrial complex south (CIS) and the fire protection system.

I.2. Presentation of the Companies

Presentation de SONATRACH:

The national company for the transport, processing and marketing of hydrocarbons, more known by its abbreviation "SONATRACH" is a national of great economic weight, and international by its field of activity, oil and gas industry.

It is at the foreground by the importance of its activities prospecting, forage production, etc.

Presentation de SIEMENS:

Siemens is an international group of German origin specialized in high technologies and present in the sectors of the energy industry as well as that of health. In Algeria, Siemens SPA represents the Siemens group. SONATRACH is one of the many customers of Siemens Algeria.

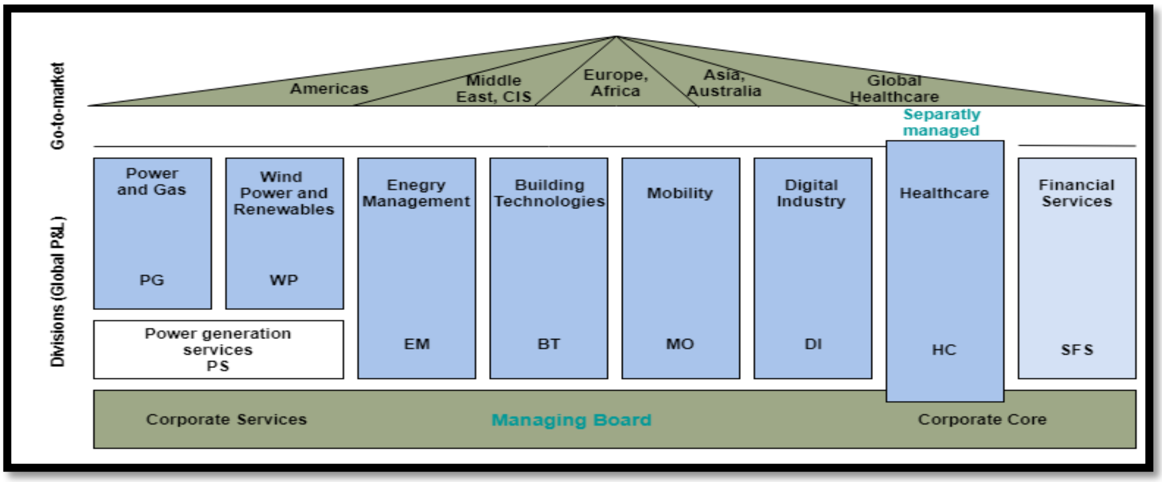


Figure I.1 Siemens organisation structure [5]

I.3. Description of the Industrial complex south

The Oilfield of *Hassi Messaoud* with a surface area of 2500 km² is geographically subdivided into two zones, north and south.

Initially these centres only include separation, processing, storage and expedition facilities for crude petroleum. Currently, all these numerous and diversified units form two industrial complexes south and north (CIS & CINA)

The industrial complex CIS is located in the region of *Hassi Messaoud* wilaya of *Ouargla*, and has 5 essential unities:

- GPL 1
- GPL 2
- RHM 2
- Compression unit (COMP 1 & COMP 2)
- Treatment unit (TRT)

The two complexes CIS and CINA are composed with a process chain more or less complex, and have the function of treating the effluents from the producing wells, these processes are made to support:

- Oil treatment
- The treatment of associated gases for the production of GPL and condensate
- The treatment of oily water for the protection of the environment
- Refining part of the crude for the production of fuels

- The reinjection of the residual gases to maintain the pressure of the deposit
- The injection of water to maintain the pressure of the deposit

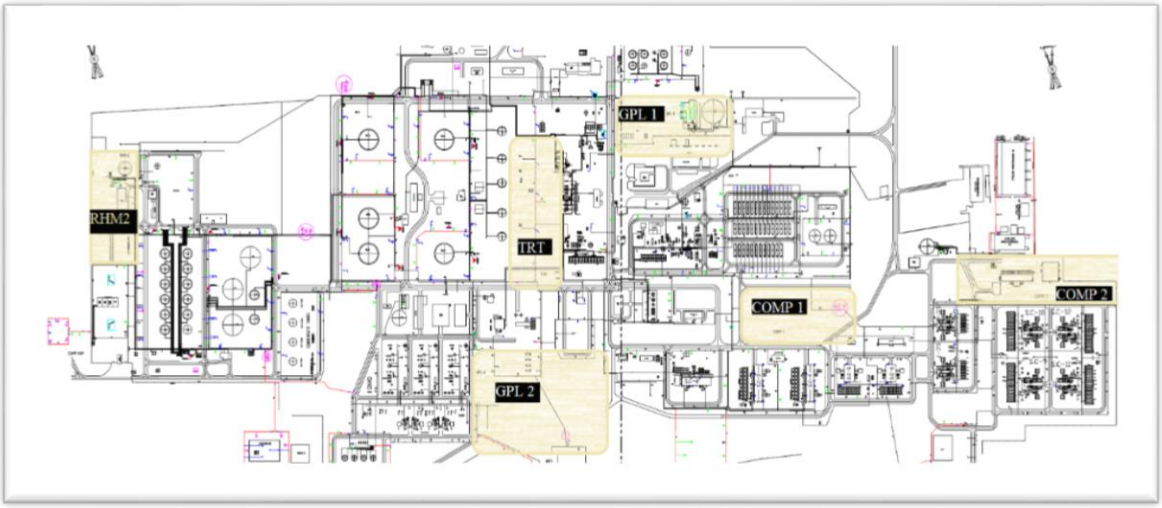


Figure I.2 Complex Industrial South

I.4. Description of the fire protection network

The fire protection network of the complex CIS will be insured by a main meshed network served by pump stations distributed in each unit.

The principal network is composed of sub networks interconnected by local and remote controlled motorized valves.

- GPL 1 unit:

The fire fighting unit is insured by a fire pumping system mainly composed of:

  - Two electric pumps
  - Two diesel pumps
  - Two Jockey pumps
  - Storage tank

- GPL 2, RHM 2 and COMP 2 units:

Each fire fighting unit of GPL 2, RHM 2 and COMP 2 is insured by a fire pumping system mainly composed of:

  - An electric pump
  - A diesel pump
  - Two Jockey pump
  - Storage tank

For the control of these pumping stations, different equipment and instruments are dedicated

  - Level measurement for the storage tank
  - Pressure and flow measurement
  - NFPA 20 controller for each pump
  - Motorised valve of bladder tank proportioning system

- Treatment unit:

  This unit composed of series of motorised valves that are controlled by the operator

Description of the NFPA controller:

NFPA *(National fire protection association)* controller is designed specifically to control fire pumps, whenever there is a pressure drop in the fire protection network, the controller starts automatically the pumps.

The controllers are located in the fire pump room and typically in visual contact with the fire pump to see them operate.

Since there is three different type of pumps, three different types of NFPA controller are used:

a) FTA Firetrol 550E for Jockey pump

It is used for pressure maintenance in fire pump installations to prevent unnecessary operation of the main fire pump.

Figure I.3 Firetrol FTA 550E for Jockey pump [9]

b) FTA Firetrol 2000 for Electric pump

FTA 2000 controller is a medium voltage controller that is intended to start a squirrel cage motors listed fire pump, they can operate either manually or automatically.

Figure I.4 Firetrol FTA2000 for electric pump [8]

c) FTA Firetrol 1000J for Diesel pump

FTA 1100J controller combines both manual and automatic working mode, they are design to control and monitor fire pump diesel engines. The controller monitors displays and records fire pump system information [1]

Figure I.5 Firetrol FTA 1000J for diesel pump [7]

I.5. Problem statement

CIS has five different units in which each unit seats a number of pumps and instruments, they are all controlled by NFPA type controller. However, controlling and monitoring the process can be done only locally via the interface of the NFPA controller located under each pump.

The object of this work is to propose an automated solution for the process, in which monitoring and controlling the process can be done from a remote location with two different mode, either automatic or manual.

It is asked to elaborate a study of the fire pumping station and design a solution to automate that process. Firstly we proceed by making a selection of the appropriate material for the process, creation of the hardware configuration and realisation of the program for the operation of the pumps, valves and the overall process in automatic and in manual mode. Then, we design a SCADA system to control and monitor the fire station.

I.6. Conclusion

In this chapter we described the main problem related to our system, we introduced the companies and presented the structure of CIS as well as its different pumping stations and their controlling system.

II. **Chapter 2:** Instruments and sequential logic.

II.1. Introduction

In case of a fire, water is still the extinguishing media number one. It is then important that enough water is immediately available for the fire fighters in order to save lives and to protect buildings from the fire. For this purpose several instruments and equipment are needed. In this chapter, we will present the different instruments used in the installation in addition to the sequential logic of the fire pumping station process.

II.2. Choice of instrumentation

In order to achieve a good choice of instruments, we must respect a set of criteria, exploitation and economical indices. The metrological indices are: scale interval, measurement method, accuracy, measurement range (interval). The exploitation and the economic indices are the cost and the reliability of measurement instruments, running time before repair is needed, inspection intervals, easy to use, inspection and repair costs including the measurement instrument.

Table summarizes the main criteria, which are taken into account in the selection of measuring instruments.

Main criteria
Given measurement task
Measured quantity
Measured range
Dimensions and tolerance

Table II-1 Criteria for the selection of instruments

II.3. Instruments

The instrumentation of CIS is divided into two distinct categories, which are:

- Sensors
- Actuators

II.3.1. Sensors

a) Pressure transmitter

This device infers the pressure of water in the discharge collector of the pumping station, its principal role is to control the fire pumps in case of pressure drop.

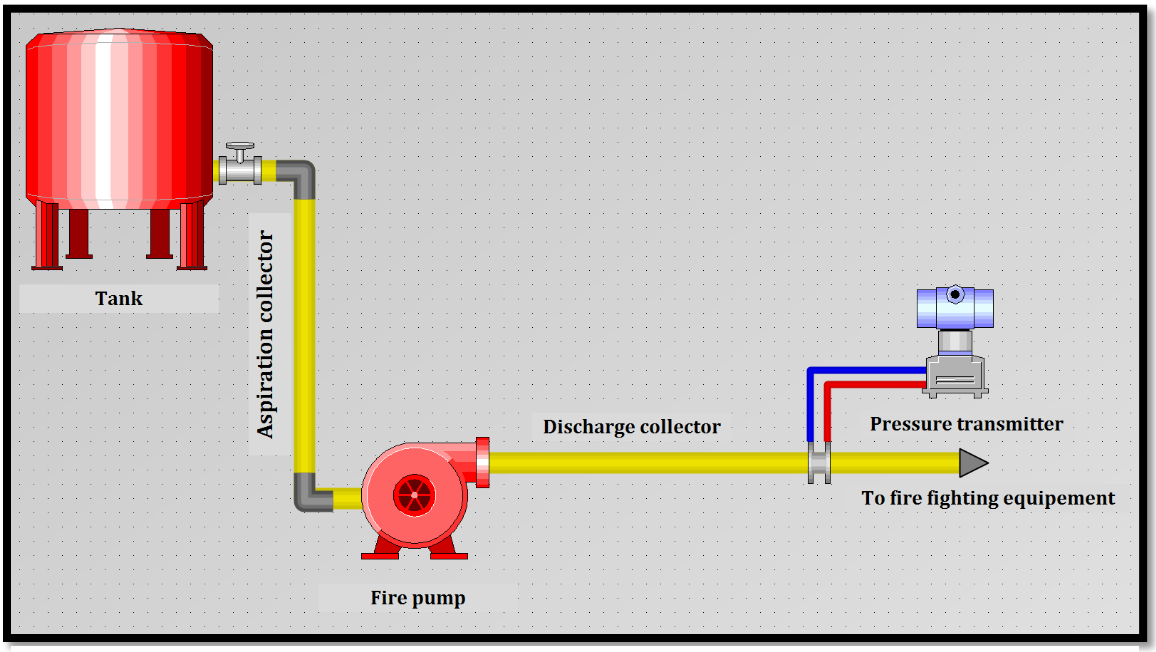


Figure II.1 Example of a pressure transmitter placement

Working principle:

The pressure transmitter is a transducer that converts pressure into an electrical signal, it outputs both analogue and digital signal corresponding to the pressure

The pressure transmitter senses the difference in pressure between two ports and produce an output signal with reference to a calibrated pressure range.

Characteristics:

- Input voltage : 11.5 … 45 VDC
- Type: Analogue
- Output voltage range : 4…20 mA
- Measure range: 0...20 bars
- Class of protection: IP67
- Communication: HART

Figure II.2 Differential Pressure transmitter from Siemens SITRANS P420 [13]

Application:

- A pressure transmitter **PIT 1001** placed on the discharge collector of **GPL 1** unit
- A pressure transmitter **PIT 1003** placed on the discharge collector of **GPL 2** unit
- A pressure transmitter **PIT 1004** placed on the discharge collector of **RHM 2** unit
- A pressure transmitter **PIT 1002** placed on the discharge collector of **COMP2** unit

b) Radar Level transmitter

A Radar level transmitter located on the top of each tank, ensures a continuous measurement of the tank's level

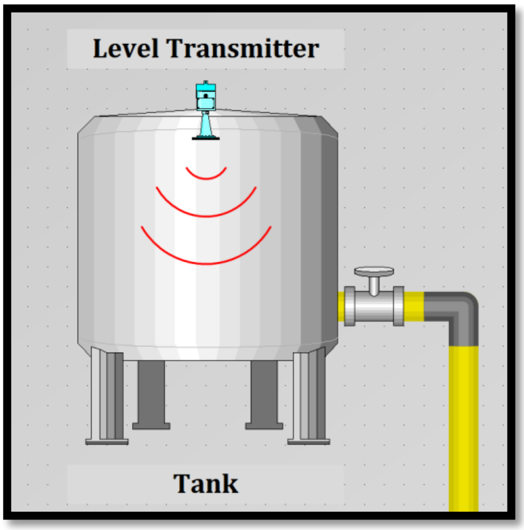


Figure II.3 Example of a radar level transmitter placement

Working principle:

The radar level transmitter measures the level of the liquid in the tank by measuring the time delay between the transmitted and received echo signal and the on board microprocessor calculates the distance to the liquid surface using the formula below:

$$D = (c * T)/2$$

D: Distance

C: Speed of light ($3*10^6$ m/s)

T: Time delay of the travelling wave

Characteristics:

- Input voltage : 24 VDC
- Operating frequency : 26 Ghz
- Output voltage range : 4…20 mA
- Measure range: 0...30 m
- Type: Analogue
- Class of protection: IP67
- Operating pressure : 12 bars
- Communication: HART

Figure II.4 Radar Level Transmitter from Siemens SITRANS LR260 [10]

Application:

- A radar level transmitter **LIT 1001** placed on the top of the tank of **GPL1** unit
- A radar level transmitter **LIT 1003** placed on the top of the tank of **GPL2** unit
- A radar level transmitter **LIT 1004** placed on the top of the tank of **RHM2** unit
- A radar level transmitter **LIT 1002** placed on the top of the tank of **COMP2** unit

c) Level switch

In addition to the level transmitter, level switches are mounted on the tank, to indicate three different level:

- HIGH level (H)
- LOW level (L)
- Very low level (LL)

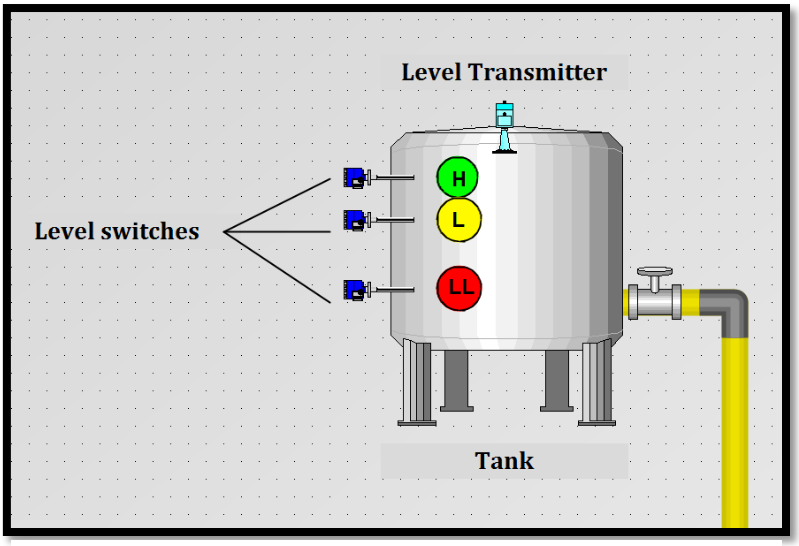


Figure II.5 Example of a level switch placement

Working principle:

The chosen level switch are of vibrating fork type. They consist of an oscillating or tuning fork, which resonate in air with known natural frequency. The resonance frequency will be reduced when the fork is brought into contact with a medium.

Characteristics:

- Input voltage : 19 to 55 V DC
- Output range : 0 or 24 V DC
- Type: Digital
- Class of protection: IP67

Figure II.6 Vibrating level switch from Siemens LVS200 [11]

Application:

- A three level switches (**LSH 1001, LSL 1001, LSLL 1001)** placed on the tank of **GPL1** unit
- A three level switches (**LSH 1003, LSL 1003, LSLL 1003)** placed on the tank of **GPL2** unit
- A three level switches (**LSH 1002, LSL 1002, LSLL 1002)** placed on the tank of **RHM2** unit

- A three level switches (**LSH 1002, LSL 1002, LSLL 1002)** placed on the tank of **COMP2** unit

d) Flow transmitter

This device is used to compute the flow of the liquid in the discharge manifold to the tank.

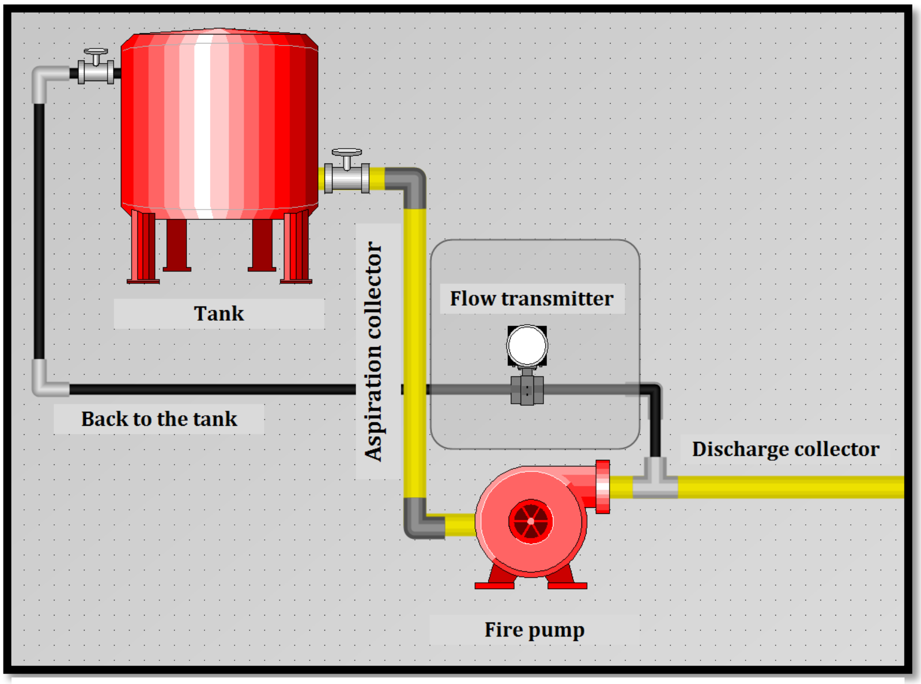


Figure II.7 Example of a flow transmitter placement

Working principle:

The installed flow transmitter uses electromagnetic to determine the flow the liquid in the pipe. Following Faraday's Law, flow of a conductive liquid through the magnetic field will cause a voltage signal to be sensed by electrodes located on the flow tube walls. When the fluid moves faster, more voltage is generated. The electronic transmitter processes the voltage signal to determine liquid flow.

Characteristics:

- Input voltage : 18 to 32 V DC
- Output voltage range : 4…20 mA
- Measure range: 0 to 2000 m^3/h
- Type: Analogue
- Class of protection: IP67
- Communication: HART

Figure II.8 Flow transmitter from Siemens MAG5100 [12]

Application:

- A flow transmitter **LIT 1001** placed in the back to the tank line of **GPL 1** unit
- A flow transmitter **LIT 1003** placed in the back to the tank line of **GPL 2** unit
- A flow transmitter **LIT 1004** placed in the back to the tank line of **RHM 2** unit
- A flow transmitter **LIT 1002** placed in the back to the tank line of **COMP2** unit

II.3.2. Actuators

a) Electric pump

The centrifugal electric pump ensures the water pressure in the network for extinguishing fire, if there is a pressure drop less than 6 bar it goes ON automatically and it has a capacity of 1000 m^3/h.

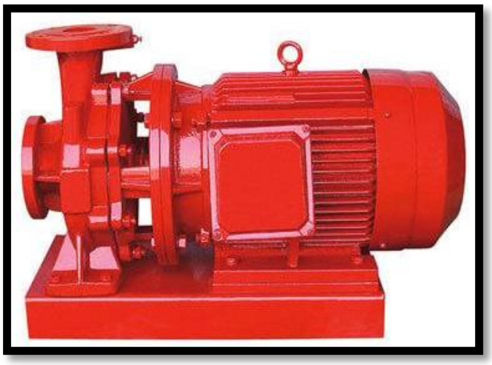


Figure II.9 Electric fire pump

Application:

- Electric pumps **GA2001** and **GA-S2001** located in **GPL 1** unit
- Electric pump **GA801-A** located in **GPL 2** unit
- Electric pump **GA931-A** located in **RHM 2** unit
- Electric pump **GA1340-A** located in **COMP 2** unit

The input and output signals of the Electric pumps are:

Name	Input	Output
ELECTRIC PUMP	State ON	MANU_DIST
	State OFF	AUTO_DIST
	State FAULT	BLK_LIB_AUTO
	Working Mode AUTO/MANU	

Table II-2 Input/output of the electric fire pump

b) Diesel pump

The centrifugal diesel pumps is used in case of failure of the electric pump to correct the pressure drop, it has a capacity of 1000 m^3/h.

Figure II.10 Diesel fire pump

Application:

- Diesel pumps **GA2002** and **GA-S2002** located in **GPL 1** unit
- Diesel pump **GA801-B** located in **GPL 2** unit
- Diesel pump **GA931-B** located in **RHM 2** unit
- Diesel pump **GA1340-B** located in **COMP 2** unit

The input and output signals of the Diesel pumps are:

Name	Input	Output
DIESEL PUMP	State ON	MANU_DIST
	State OFF	AUTO_DIST
	State FAULT	BLK_LIB_AUTO
	Position Selector AUTO/MANU	
	Working Mode AUTO/MANU	
	Alarm diesel fuel tank	

Table II-3 Input/output of the diesel fire pump

c) Jockey pump

A jockey pump, also known as a pressure-maintenance pump, is a small apparatus that works together with a fire pump as part of a fire-protection system. It is designed to keep the pressure in the system between 6 and 8 bars when the system is not in use, so that the electric or diesel pumps doesn't have to run all the time and the system doesn't go off randomly. It has a capacity of 15 m^3/h.

Figure II.11 Jockey fire pump

Application:

- Jockey pumps **GA2003** and **GA-S2003** located in **GPL 1** unit
- Jockey pumps **GA802-A**and **GA802-B** located in **GPL 2** unit
- Jockey pumps **GA932-A** and **GA932-B** located in **RHM 2** unit
- Jockey pumps **GA1350-A** and **GA1350-B** located in **COMP 2** unit

The input and output signals of the Jockey pumps are:

Name	Input	Output
JOCKEY PUMP	State ON	AUTO_DIST
	State OFF	BLK_LIB_AUTO
	State FAULT	
	Position Selector AUTO/MANU	

Table II-4 Input/output of the jockey fire pump

d) Motorised valve

The motorized valves are used to:

- Control the loading of the tanks.
- Control the Interconnection network of the unities.
- Control foam injection from USD unit.

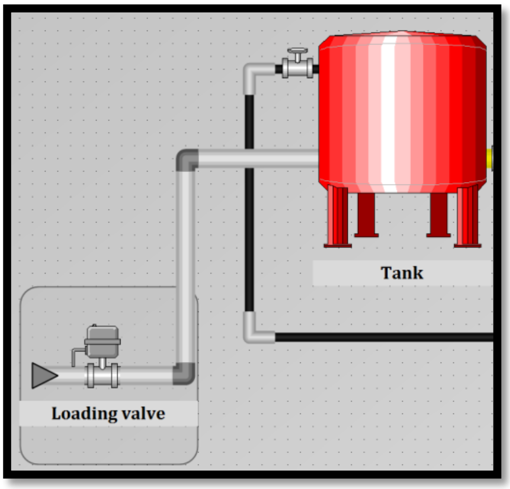


Figure II.12 Example of placement of the loading valve

Characteristics:

- Valve type: Butterfly motorized
- Power supply: 230 V AC
- Output range: 0 or 24 V DC
- Runtime: 30s
- Angle of rotation: 90° max
- Class of protection: IP67

Figure II.13 Butterfly valve from Honeywell [14]

Application: as an example of their application:

- Loading valve **MOV1001** to control the tank's filling of **GPL 1** unit
- Loading valve **MOV1003** to control the tank's filling of **GPL 2** unit
- Loading valve **MOV1002** to control the tank's filling of **RHM 2** unit
- Loading valve **MOV1004** to control the tank's filling of **COMP 2** unit

The input and output signals of the Diesel pumps are:

Name	Input	Output
MOTORIZED VALVE	State OPEN	OPEN_COMMAND
	State CLOSED	CLOSE_COMMAND
	State FAULT	
	State LOCAL/REMOTE	

Table II-5 Input/output of the motorized valve

II.4.Piping and instrumentation diagram

In order to illustrate the installation of the previous equipment, a piping and instrumentation diagram **(P&ID)** has been designed. It is a detailed diagram in the process industry, which shows the piping and process equipment together with the instrumentation and control devices.

The P&ID is used for the identification of measurements within the process. The identifications consist of up to 5 letters. This is followed by loop number, which is unique to that loop, as illustrated in the figure

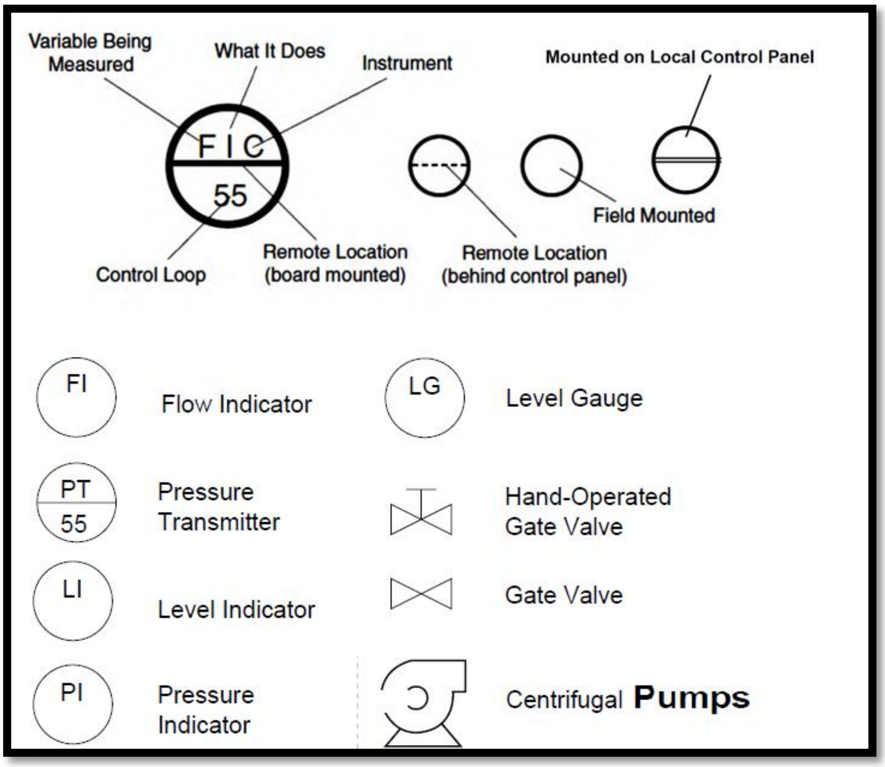


Figure II.14 P&ID schematic symbol

As an example, *Figure* II.14 illustrates P&ID of GPL 1:

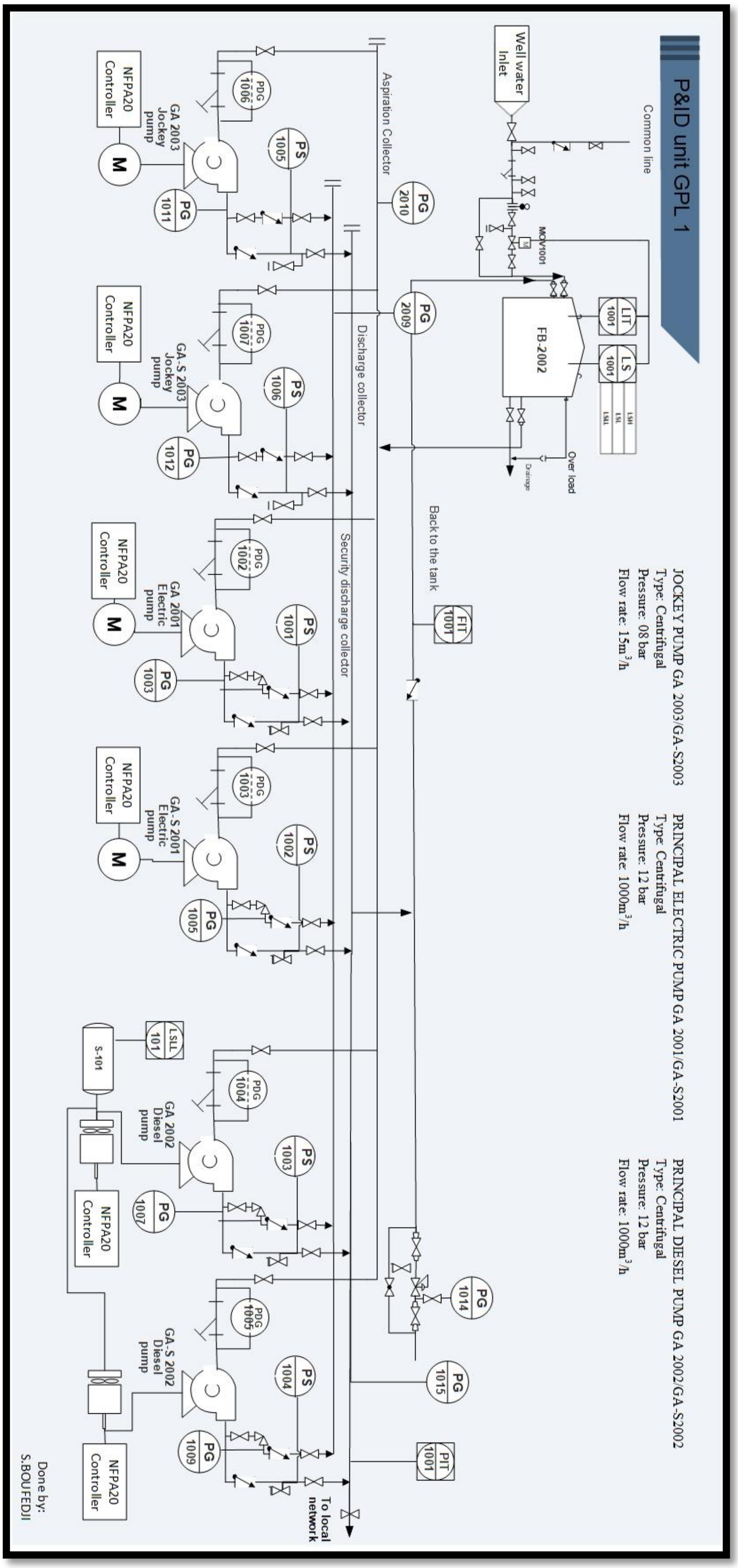


Figure II.15 Example of a P&ID of GPL 1 unit

II.5.Overall Input/output assessment of the system

The hardware configuration is mainly based on the number of Input and output of the system. Moreover, an addition 20% of the number of I/O of each unit need to be considered as a reserve.

Localisation	Input/Output				Total I/O	
	Equipment	Nbr Input	Nbr Output	Quantity	Input	Output
GPL 1	Motorized valve	4	2	13	52	26
	Jockey pump	5	2	2	10	4
	Electric pump	4	3	2	8	6
	Diesel pump	6	3	2	12	6
	Level switch	1	0	3	3	0
	Level transmitter	1	0	1	1	0
	Flow transmitter	1	0	1	1	0
	Pressure transmitter	1	0	5	5	0
GPL 2	Motorized valve	4	2	7	28	14
	Jockey pump	5	2	2	10	4
	Electric pump	4	3	1	4	3
	Diesel pump	6	3	1	6	3
	Level switch	1	0	3	3	0
	Level transmitter	1	0	1	1	0
	Flow transmitter	1	0	1	1	0
	Pressure transmitter	1	0	3	3	0
RHM 2	Motorized valve	4	2	17	68	34
	Jockey pump	5	2	2	10	4
	Electric pump	4	3	1	4	3
	Diesel pump	6	3	1	6	3
	Level switch	1	0	3	3	0
	Level transmitter	1	0	1	1	0
	Flow transmitter	1	0	1	1	0
	Pressure transmitter	1	0	2	2	0
COMP 2	Motorized valve	4	2	1	4	2
	Jockey pump	5	2	2	10	4
	Electric pump	4	3	1	4	3
	Diesel pump	6	3	1	6	3
	Level switch	1	0	3	3	0
	Level transmitter	1	0	1	1	0
	Flow transmitter	1	0	1	1	0
	Pressure transmitter	1	0	1	1	0
TRT	Motorized valve	4	2	17	68	34
	Pressure transmitter	1	0	1	1	0
Total					**342**	**156**

Table II-6 Overall Input/output of CIS fire station

II.6. Sequential logic of CIS

II.6.1. Introduction of fire pumping process

Fire pumps are required to provide adequate pressure of water for the fire fighting equipment, they are supplied from a water storage tank. The fire pumps starts when the pressure in the fire fighting system drops below the threshold caused by the opening of one or more fire fighting connection.

Fire pump cannot operate when their corresponding water supplying tank is in low level, therefore the water storage tank is also supplied from a fixed water source, and its filling process is controlled by a motorised valve.

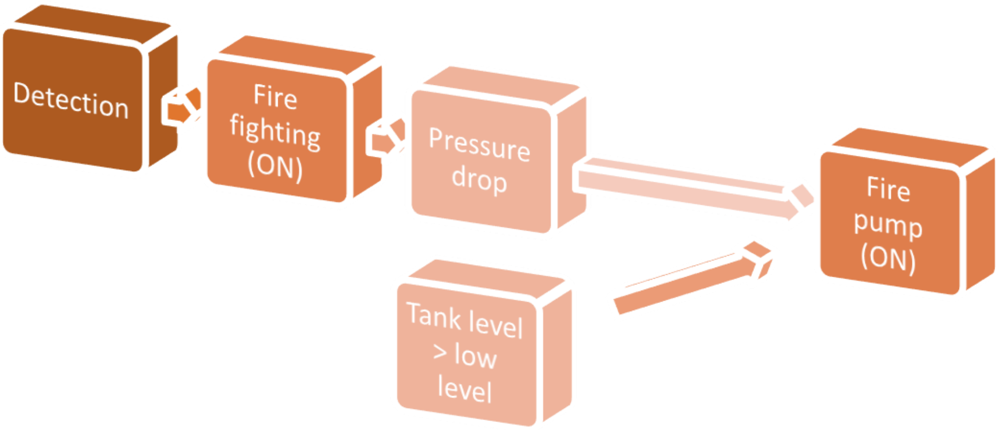


Figure II.16 Fire fighting system process

II.6.2. Description of the fire station process

Fire protection process can divided into three sub processes:

- The first one is fire detection system, mainly based on gas and temperature sensor.
- The second sub process is the fire fighting, which includes all type of fire fighting equipment (Fire Extinguisher, Fire Blankets, Fire Hose… etc.).
- The third sub process in which our work is based on, is the fire pumping system where the fire pumps are located, and their role consist of serving the fire fighting equipment with water.

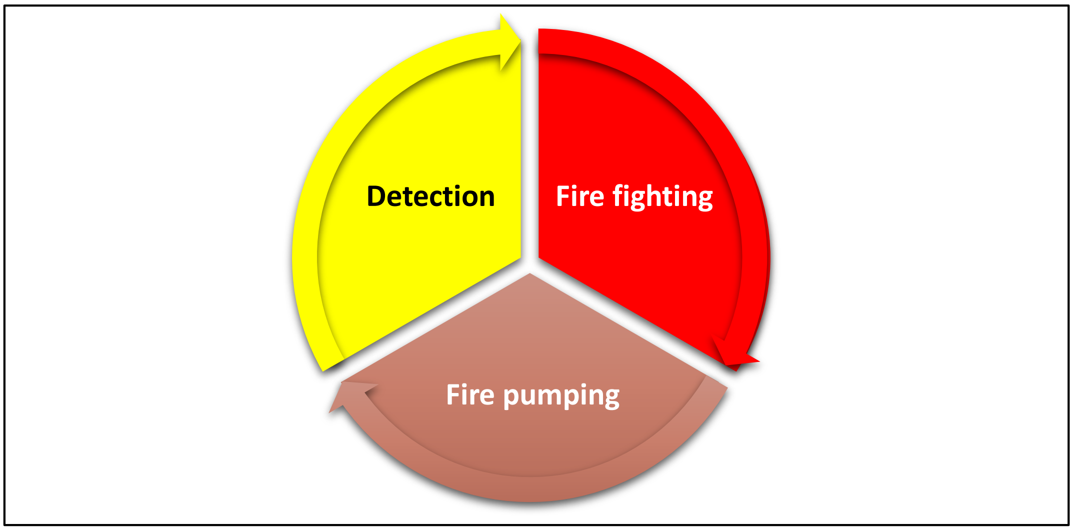


Figure II.17 Fire protection process

II.6.3. Sequential logic of the fire pumping process of CIS

As it is mentioned in the precedent section, CIS has five different unites GPL1, GPL2, RHM2, COMP2 and treatment unit. And they are interconnected between them through a series of motorised valves that operate either in automatic mode or manually by the operator.

The proposed solution should be an alternative for the NFPA controller, in other word in case of a failure of NFPA controller, our solution must backup and insure the continuity of the process. Moreover the solution should provide the possibility of control from a remote location.

In the following, the sequential logic of each unit that is asked to follow in the statement scope:

GPL 1:

Electric pumps GA2001 & GAS2001:

(AUTOMATIC MODE)

A delay of 5 seconds is triggered If the pressure transmitter **PIT1001** indicates a value less or equal then 5.5 bars. After this delay, if the first electric pump (**GA2001**) doesn't start from it local controller and the above conditions are still valid, the PLC interpret and start **GA2001**.

A delay of 10 seconds is triggered If the pressure transmitter **PIT1001** indicates a value less or equal then 5.5 bars. After this delay, if the second electric pump (**GAS2001**) doesn't start from it local controller and the above conditions are still valid, the PLC interpret and start **GAS2001**.

- In both cases, **GA2001** and **GAS2001** must be in automatic mode and not in a faulty case.
- When **PIT1001** reaches 12 bars, **GA2001** and **GAS2001** are automatically stopped by the PLC
- The automatic mode of these pumps is controlled from the output **AUTO_DIST**
- When operating in automatic mode the output **BLK_LIB_AUTO** should be '0' indicating that the automatic mode released.

(MANUAL MODE)

The manual mode of these pumps is insured by the operator from the control and monitoring interfaces (SCADA system) located in the control room

- **GA2001** and **GAS2001** must be operating in manual mode and not in a faulty case.
- The manual mode of these pumps is controlled from the output **MANU_DIST**
- When operating in manual mode the output **BLK_LIB_AUTO** should be '1' indicating that the automatic mode blocked.

Diesel pumps GA2002 & GAS2002:

(AUTOMATIC MODE)

A delay of 25 seconds is triggered If the pressure transmitter **PIT1001** indicates a value less or equal then 5.5 bars. After this delay, if the first electric pump (**GA2002**) doesn't start from it local controller and the above conditions are still valid, the PLC interpret and start **GA2002**.

A delay of 30 seconds is triggered If the pressure transmitter **PIT1001** indicates a value less or equal then 5.5 bars. After this delay, if the second electric pump (**GAS2002**) doesn't start from it local controller and the above conditions are still valid, the PLC interpret and start **GAS2002**.

- In both cases **GA2002** and **GAS2002** must be in automatic mode, not in a faulty case and the diesel fuel tank must be greater than the low level.
- When **PIT1001** reaches 12 bars, **GA2002** and **GAS2002** are automatically stopped by the PLC
- The automatic mode of these pumps is controlled from the output **AUTO_DIST**
- When operating in automatic mode the output **BLK_LIB_AUTO** should be '0' indicating that the automatic mode released.

(MANUAL MODE)

The manual mode of these pumps is insured by the operator from the control and monitoring interfaces (SCADA system) located in the control room

- **GA2002** and **GAS2002** must be operating in manual mode and, not in a faulty case and the diesel fuel tank must be greater than the low level.
- The manual mode of these pumps is controlled from the output **MANU_DIST**

When operating in manual mode the output **BLK_LIB_AUTO** should be '1' indicating that the automatic mode blocked.

Jockey pumps GA2003 & GAS2003:

Jockey pump is operated only in automatic mode.

(AUTOMATIC MODE)

If the pressure transmitter **PIT1001** indicates a value less or equal then 6 bars and PLC starts **GA2003**.

A delay of 5 seconds is triggered If the pressure transmitter **PIT1001** indicates a value less or equal then 6 bars, after this delay and if the above condition is still valid, the PLC interpret and start **GAS2003**.

- In both cases, **GA2003** and **GAS2003** must be in automatic mode and not in a faulty case.
- When **PIT1001** reaches 8 bars, **GA2003** and **GAS2003** are automatically stopped by the PLC

- The automatic mode of these pumps is controlled from the output **AUTO_DIST**
- When operating in automatic mode the output **BLK_LIB_AUTO** should be '0' indicating that the automatic mode released.

Faulty case in the pumps of GPL 1:

The faulty cases are treated by the PLC when the instrument is operating in the automatic mode.

- In case of a fault in **GA2001** when it is in ON state, **GAS2001** is automatically started.
- If both **GA2001** and **GAS2001** indicates a fault when they are in there ON state, **GA2002** is automatically started.
- In case of a fault in **GA2002** when it is in ON state, **GAS2002** is automatically started.
- In case of a fault in **GA2003** when it is in ON state, **GAS2003** is automatically started.

Water storage tank:

The fire pumps of GPL 1 are supplied by water from a water storage tank located in the unit, the tank is 12500 mm height, and it is equipped with level transmitter **LIT1001** with a measuring rang up to 20000 mm placed on its top and a level switch **LSH1001**, **LSL1001**, **LSLL1001** with floats, these latter are positioned as follows:

- **LSH1001** placed at a height of 11500 mm
- **LSL1001** placed at a height of 10000 mm
- **LSLL1001** placed at a height of 2000 mm

As well as the tank will be equipped with motorized valve **MOV1001** that ensure its filling, and it operates in the following way:

- If the high level (11500 mm) in the **FB-2002** tank is reached, the **LSH1001** level switch closes the **MOV 1001** loading valve to prevent tank overflow.
- If the low level (10000 mm) of water in the **FB-2002** tank is reached, the **LSL1001** level switch opens the **MOV 1001** loading valve.

GPL2, **RHM2**, and **COMP2** unities have a similar structure, and they operate in the same manner. For this, their sequential logic will be explained all in one

(AUTOMATIC MODE)

A delay of 5 seconds is triggered If the pressure transmitter **PIT** of the unit indicates a value less or equal then 5.5 bars and if the electric pump doesn't start from it local controller, after this delay and if the above conditions are still valid, the PLC interpret and start the electric pump.

A delay of 10 seconds is triggered If the pressure transmitter **PIT** of the unit indicates a value less or equal then 5.5 bars and if the diesel pump doesn't start from it local controller, after this delay and if the above conditions are still valid, the PLC interpret and start diesel pump.

- In both cases the electric and diesel pump must be in automatic mode and not in a faulty case.
- For the diesel pump, the diesel fuel tank 'level must be greater than the low value
- When **PIT** of the unit 12 bars, electric and a diesel pump are automatically stopped by the PLC
- The automatic mode of these pumps is controlled from the output **AUTO_DIST**
- When operating in automatic mode the output **BLK_LIB_AUTO** should be '0' indicating that the automatic mode released.

(MANUAL MODE)

The manual mode of these pumps is insured by the operator from the control and monitoring interfaces (SCADA system) located in the control room

- Electric and diesel pump must be operating in manual mode and not in a faulty case.
- The manual mode of these pumps is controlled from the output **MANU_DIST**
- When operating in manual mode the output **BLK_LIB_AUTO** should be '1' indicating that the automatic mode blocked.

Jockey pumps:

Jockey pump is operated only in automatic mode.

(AUTOMATIC MODE)

If the pressure transmitter **PIT** of the unit indicates a value less or equal then 6 bars and PLC starts the first Jockey pump.

A delay of 5 seconds is triggered If the pressure transmitter **PIT** of the unit indicates a value less or equal then 6 bars, after this delay and if the above condition is still valid, the PLC interpret and start the second Jockey pump.

- In both cases, the two Jockey pumps have in the automatic mode and not in a faulty case.
- When **PIT** of the unit reaches 8 bars, the two Jockey pumps are automatically stopped by the PLC
- The automatic mode of these pumps is controlled from the output **AUTO_DIST**
- When operating in automatic mode the output **BLK_LIB_AUTO** should be ‘0’ indicating that the automatic mode released.

Faulty case the pumps:

The faulty cases are treated by the PLC when the instrument is operating in the automatic mode.

- In case of a fault in **the electric pump** when it is in ON state, **the diesel pump** is automatically started.
- In case of a fault in **the first jockey pump** when it is in ON state, **the second one** is automatically started.

Water storage tank:

Similar to GPL 1. GPL2, RHM2 and COMP2 have a water storage tank each with the same characteristics, sensors and loading valve.

The loading valve operates in the same manner for each unit

- If the high level (11500 mm) in the **tank's unit** is reached, the **high level switch** of the unit closes its corresponding **loading valve** to prevent tank overflow.
- If the low level (10000 mm) of water in the **tank's unit** is reached, the **low level switch** of the unit opens its corresponding **loading valve** to fill the tank

All the previous units are connected to a USD unit (dosage and storing unit) or bladder tank system. This system is designed to inject foam concentrate into a suitable water supply and to automatically proportion foam concentrate over a wide range of flows and pressures.

The connection between the unit and the USD is done by a number of motorized valves that are controlled by the operator manually.

Interconnection network:

The five units of CIS are interconnected between them through a series of motorized valves (**Interconnection valves)**, and a pressure transmitters.

These valves can operate in manually via the SCADA system or in automatic mode following the conditions related to the different faults at the level of fire pumping stations.

The purpose of the interconnection network is to rescue a fire pumping station whenever:

- All the pumps are in faulty case, and it corresponding pressure transmitter is under 5.5 bars
- If electric and diesel pump are ON and the pressure is under 5.5 bars, after 1 minute of delay if the pressure is still under 5.5 bars.

Whenever one of these two conditions is satisfied, the fire pumping station unit is rescued by another unit through the opening of the interconnection valve relating them.

After 1 minute and if the first intervention was not sufficient by mean the pressure transmitter is still under the threshold (5.5 bars), another interconnection valve is open to rescue the two previous ones by another fire pumping unit.

Finally, after 1 minute since the second intervention and if the pressure is under the threshold, a third interconnection valve is opened relating the previous units to the main water storage tanks of CIS.

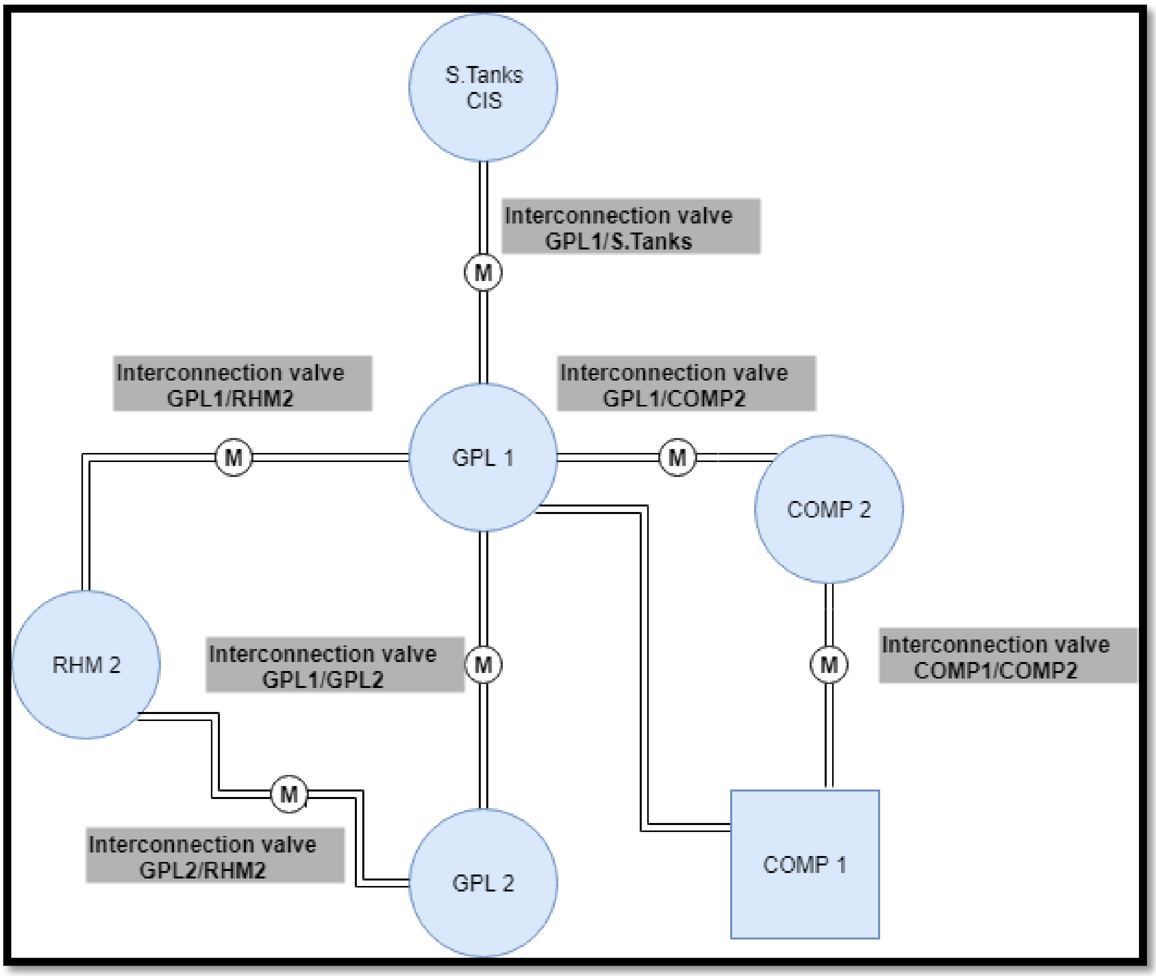


Figure II.18 interconnection and rescue sequences for CIS units

II.7.Conclusion

During this chapter, we demonstrated the principle instruments used and their characteristic as well as the sequential logic for the operation of the system.

That being said, the next chapter will cover the details about the proposed hardware and software for the solution.

III. Chapter 3: Automation tool

III.1. Introduction

In the previous chapter presented the different instrument included in the system, and the sequential logic of the process. During this chapter, we will present our automation solution including the hardware and software solution, which is based on the Input/output assessment presented above.

III.2. Automated systems

An industrial process is a set of equipment that enables a number of tasks to be performed. The automation of a process means that it is placed under the control of a system which, despite the disturbances it is experiencing, leads it to a given objective, an automated system consist of three part (see *Figure III.1*): process operating and monitoring part, control unit and process control parts.

- **Process operating and monitoring:** is the part that gives the system instructions and can monitor the signals sent back to it by the control unit.
- **Control part:** receives the instructions from the process operating and monitoring part and the reports of the process controllers. Also sends orders to the controllers of the process and signals to the operating and monitoring part of the process. All this operations are managed by the its program.
- **Process controller:** Performs actuator operations (motor, solenoid valve, etc.) Orders are received from the control part but also status and measurements are sent to the control part.

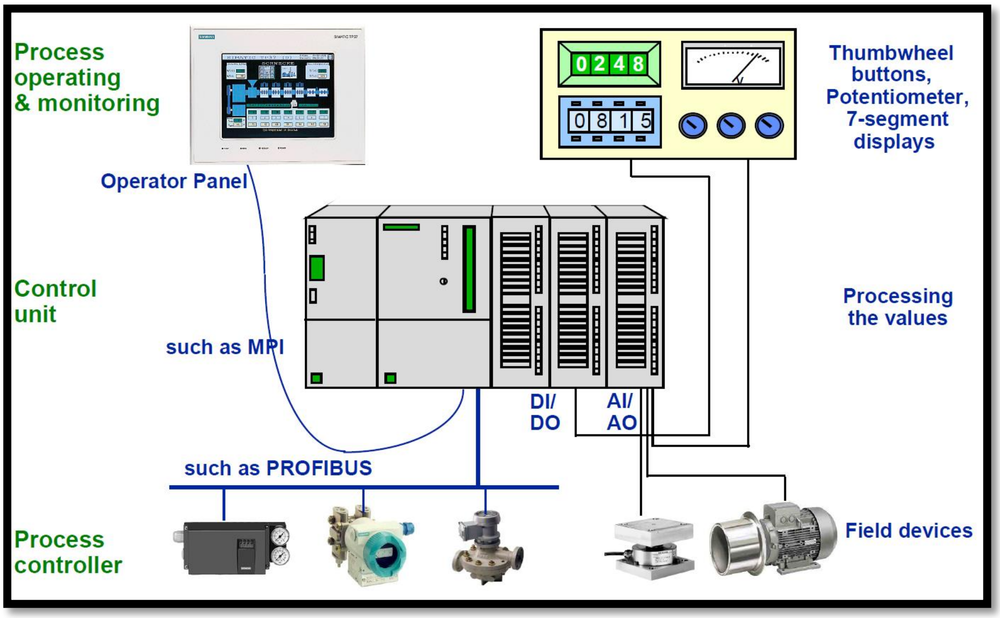


Figure III.1 Automation system configuration [15]

III.2.1. Programmable logic controller (PLC)

Programmable Logic Controller (PLC) is a programmable device that is designed to meet the needs of the industrial application. PLCs are now widely spread across the various industries such as agribusiness, energy production, nuclear power, etc.

PLCs have the distinctive feature of working with the programmed logic that, unlike its ancestor (hardwired logic), is more efficient and less expensive.

Figure III.2 Example of a PLC from Siemens S7-300 [15]

Architecture of PLC:

To better understand the functioning of PLCs in an industrial environment, we must first explain what constitutes a PLC. Next, we describe the functioning of all these components assembled.

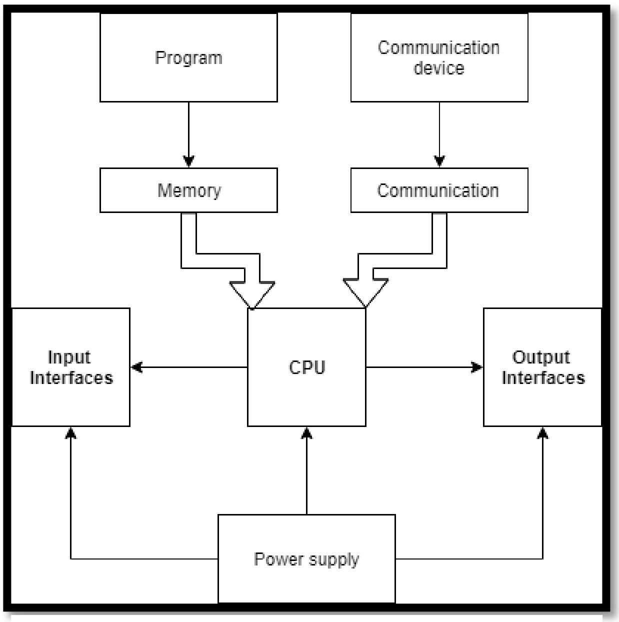


Figure III.3 Architecture of a PLC

The figure above shows an internal architecture diagram of the PLC. The input / output interfaces are used to communicate the PLC with the external environment, as is easily seen in this diagram. This requires the connection of the process sensors to the input interface and the connection of the pre-actuators to the output interface. The CPU as defined by the user's program processes the data acquired from these interfaces. Once done, the output interfaces will perform the actions in the process.

III.2.2. PLC programming

The standard IEC61131-3 developed by the International Electro technical Commission (IEC) is based on five different programming languages for PLCs.

Ladder Diagram (LD), Instruction List (IL), Function Block Diagram (FBD), Structured Text (ST) and Sequential Function Chart (SFC) are the programming languages. The three first languages are explained further:

- **LD:** Ladder Diagram is very similar to a circuit diagram. Symbols such as contacts and coils are used. This programming language often appeals to those who have a drafting or electrical background.
- **IL:** is a text-based programming language in which each line of code represents a single operation. This language is similar to assembler language and has a high importance where the execution time in the PLC is important.
- **FBD:** The Function Block Diagram uses "boxes" for the individual functions. The character in the box indicates the function (such as & --> AND Logic Operation). This programming language has the advantage that even a "non-programmer" can work with it.

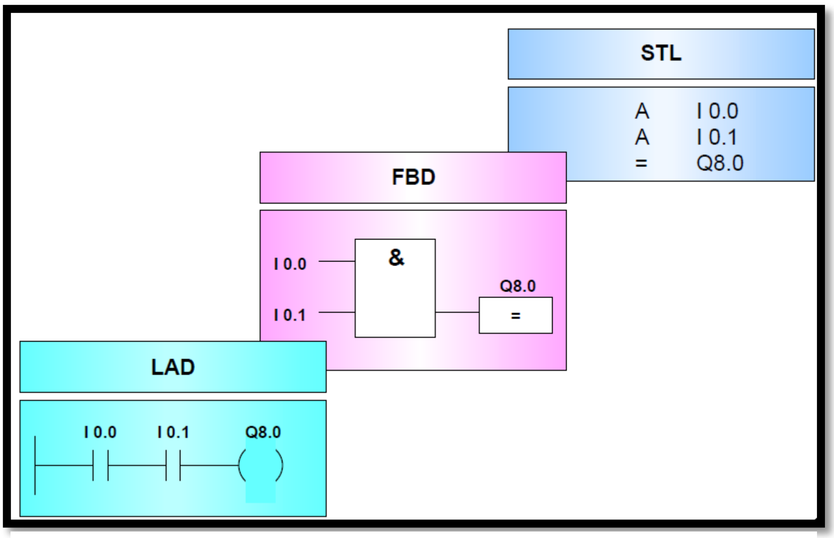


Figure III.4 Programming languages used in Siemens software [15]

III.2.3. Choice of PLC

The choice of PLC is based on several factors, mainly:

- System (task) requirements.
- Number and type of Input / output of the process.
- What speed is required of the CPU?
- Electrical requirements.
- Speed of operation.
- Communication requirements.
- Disponibility on the market and its cost.
- External influences (humidity, temperature, vibrations … etc.)

III.2.4. Advantage of PLC

PLCs were designed to eliminate assembly line relays during model changeovers. PLC can be changed easier than relay panels. This reduced the control system's installat ion and operating costs compared to the electromechanical relay. The benefits of PLCs are as follows:

- PLC accept to control complex systems
- Mode information: Continuous visualization of the state of the inputs / outputs indicated by indicator lights is easy to maintain and set up an automatism.
- A terminal programming and adjustment provides dialog between the man and the machine through its conversational mode and the messages shown on the screen.
- More functionality: The PLC provides specifically integrated solutions for special machines where their installations are complicated.

III.3. Structure of the solution

III.3.1. Architecture of the solution

a) Hardware solution

In the precedent chapter, we mentioned that NFPA controls the fire pumps locally and that the station needed a solution to remotely control and monitor the station from the control room. Having said that, and based on the structure and characteristics of CIS fire station, we proposed an automation architecture that is divided in two levels:

- Level 1 ⟶ Field level, this level mainly consist of sensors and actuators.
- Level 2 ⟶ This level of automation is the control room comprising the CPU and SCADA system.

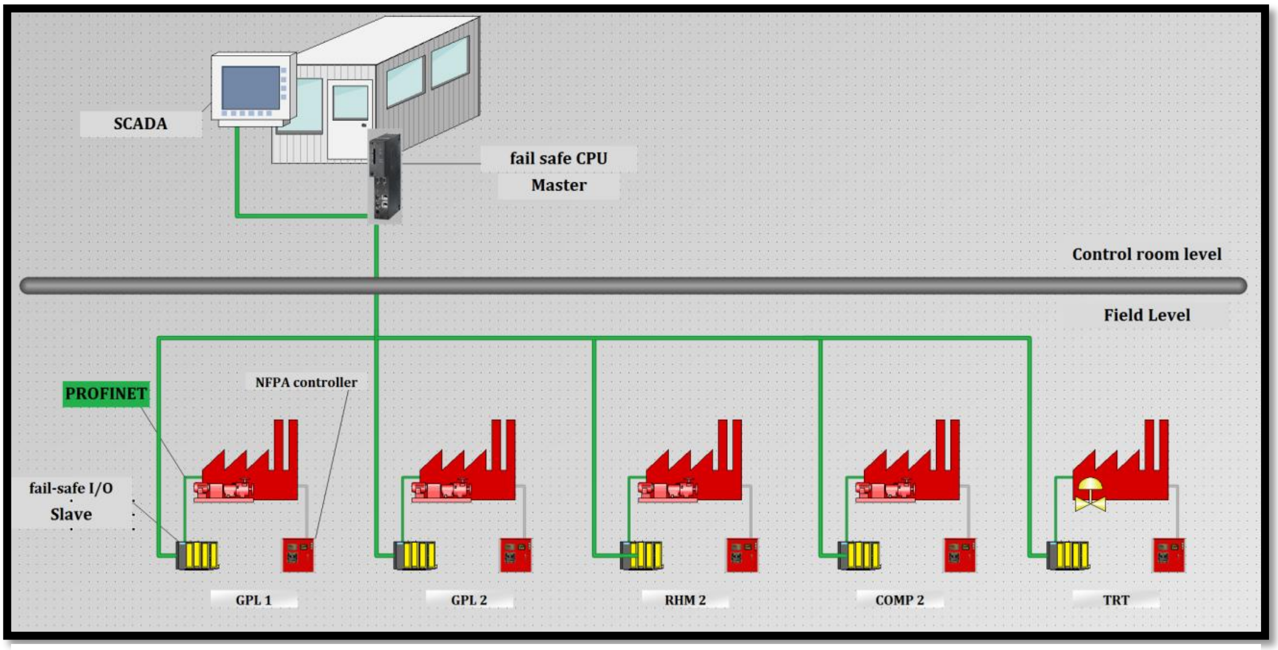


Figure III.5 Architecture of Hardware solution

a) Apparatus Type

In such kind of process, the design and implementation requires a certain level of safety, and this applies for all the equipment held to create the process. To that goal, we chose **fail-safe** automation components from *SIEMENS* for safety related tasks.

The fail-safe I/O ensure safe processing of field information. They contain all of the required hardware and software components for safe processing in accordance with the required safety class.

b) Redundancy

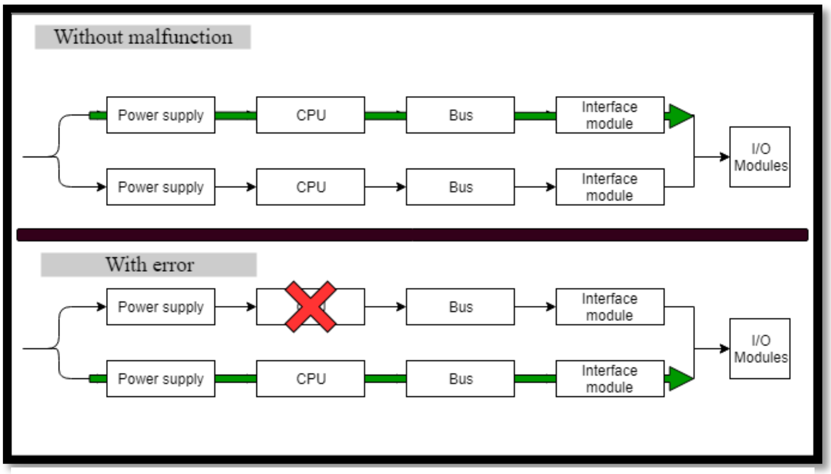


Figure III.6 Example of a redundant hardware configuration

A redundant fail-safe CPU is chosen in the system for reducing risk by means of parallel operation as well as protecting life, environment and equipment.

CPU is considered redundant when there is two of this latter and it is configured and operated as redundant pairs, as shown in *Figure* III.7

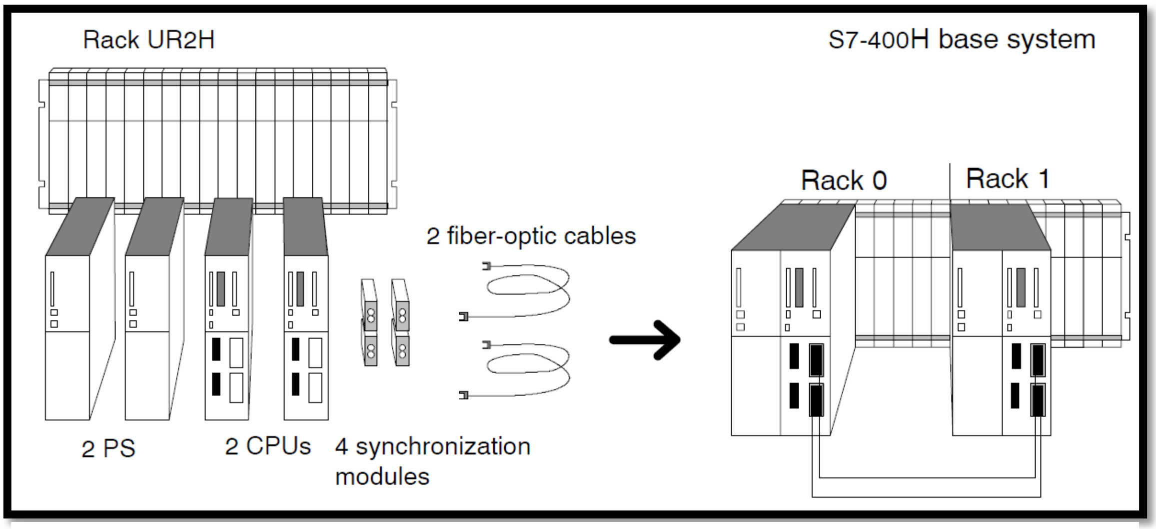


Figure III.7 Example of a redundant configuration fail safe CPU (S7-400H) [16]

c) Communication

We chose to communicate with PROFINET for the distributed I/O, SCADA and the PLC. Indeed, for a better speed and long range.

The following step sequence describes the procedure for configuration of the PLC for a PROFINET I/O connection:

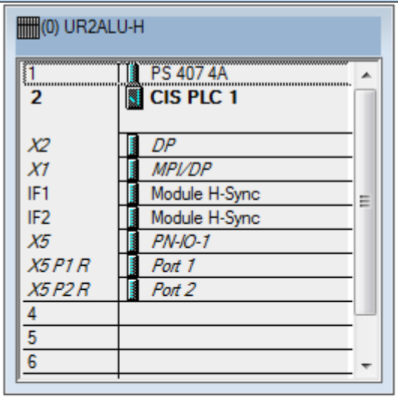
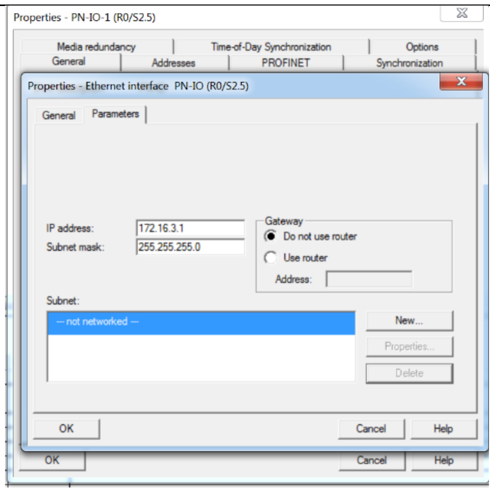
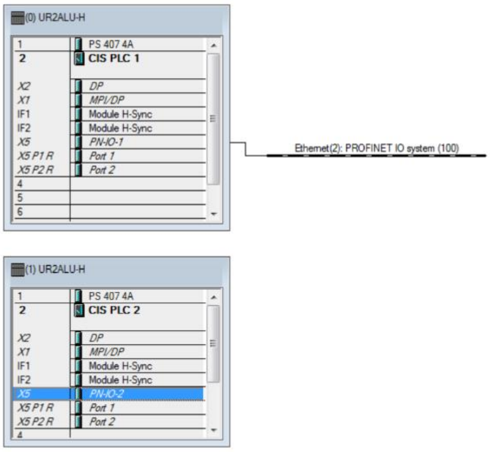
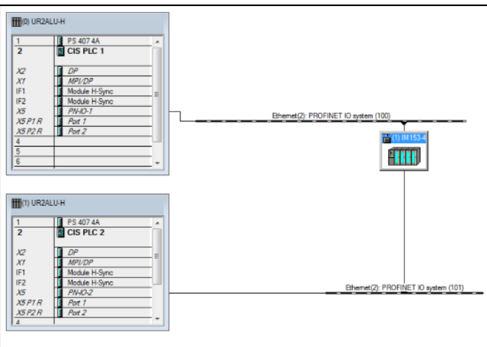
<table>
<tr><th>N°</th><th>Action</th><th>Comment</th></tr>
<tr><td>1</td><td>The first step is to select the rack and the CPU with PROFINET protocol in the catalogue</td><td>
</td></tr>
<tr><td>2</td><td>After selecting the CPU, we chose PN –IO. In properties, we can enter the IP address desired, and we select “New” to create a new PROFINET network.</td><td>
</td></tr>
<tr><td>3</td><td>The CPU is inserted into the S7 controller with PROFINET IO network.
For redundancy, we connect the two PLCs with the PROFINET IO network.</td><td>
</td></tr>
<tr><td>4</td><td>Finally, we pick up our I/O module from the catalogue using drag and drop, the two connection with the addresses will be automatically created.</td><td></td></tr>
</table>

Table III-1 PROFINET configuration steps using Siemens software

b) Software solution

The software program is implement using the industrial software-programming tool from Siemens **SIMATIC Step 7 V5.6**.

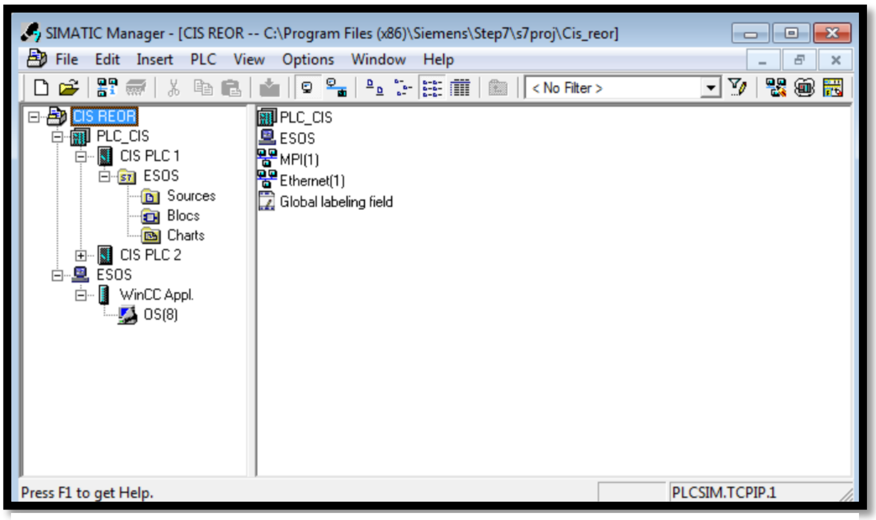


Figure III.8 SIMATIC Step 7 interface

To write STEP 7 user program we can use three programming languages: Ladder diagram (**LAD**), Statement list (**STL**) which is similar to Instruction list (**IL**) and function block diagram (**FBD**).

In addition to these programming languages, we will be using **CFC** (Continuous Function Chart) which is a graphic editor that can be used in conjunction with the STEP 7 software package. It is used to create the entire software structure of the CPU from ready-made blocks.

The SIMATIC Manager is used for all PLCs as the graphic interface to coordinate the tools and objects. The SIMATIC Manager manages tools and data and is used, for example, for creating and modifying a project structure (CPU, CFC charts) and to start the CFC Editor.

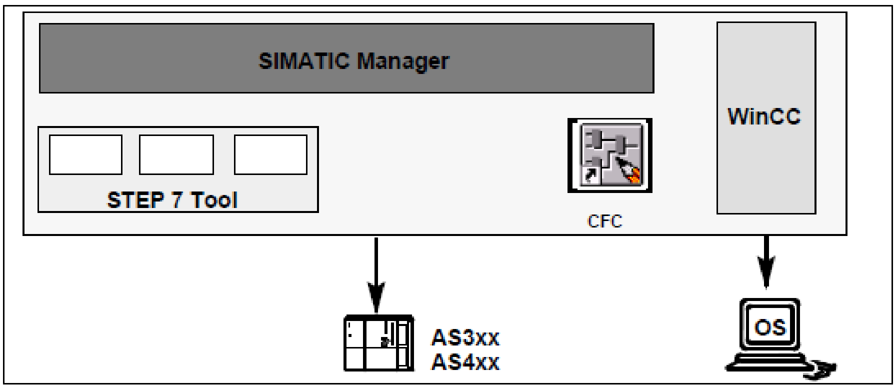


Figure III.9 CFC in Step 7 Environment [17]

The STEP 7 programming software allows structuring the user program, in other words to break down the program into individual, self-contained program sections. There are several different types of within an S7 user program:

- **Organization Blocks (OB):** Cyclic program processing is the “normal" type of program execution on programmable logic controllers.
- **Functions (FC):** The user programs the FCs and they contain program routines for frequently used functions. Moreover, it is without memory.
- **Function Blocks (FB):** FBs are blocks with a “memory” which they are programmed by the user
- **Instance Data Blocks:** An instance data block is assigned to every function block call that transfers parameters. The actual parameters and the static data of the FB are saved in the instance DB.
- **Data Blocks (DB):** DBs are data areas for storing user data. In addition to the data that are assigned to a function block, shared data can also be defined and used by any blocks.

Since we had a fail-safe hardware configuration, the software must be compatible, that is why our S7 program consists of a standard user program in which we programmed sections that are not necessary for the safety function and a safety program for safety function.

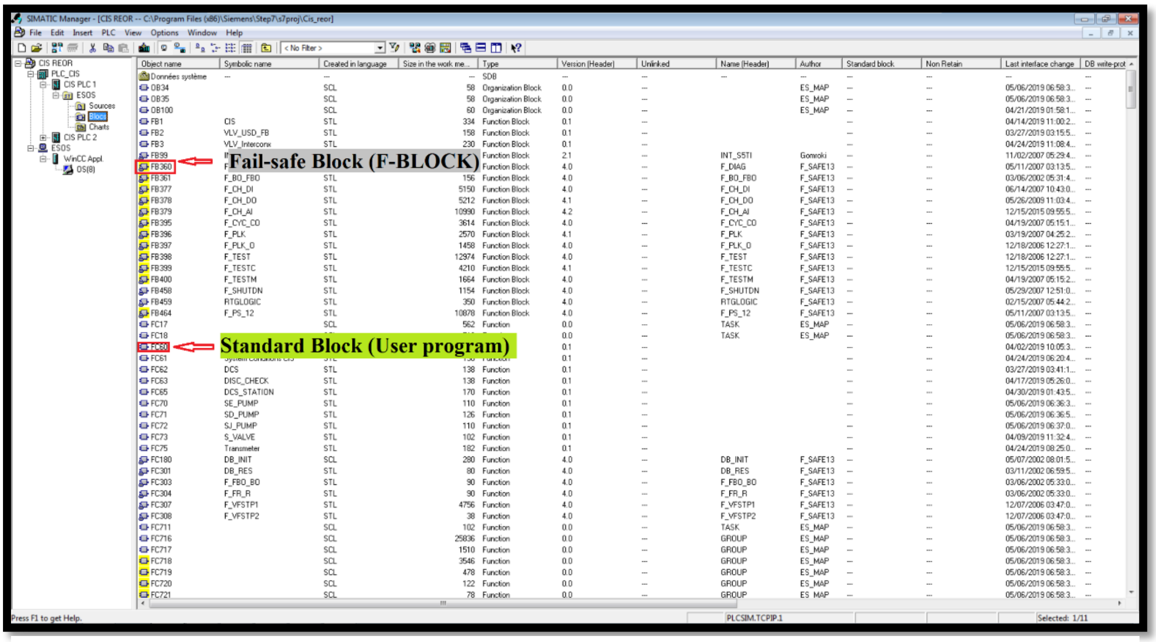


Figure III.10 Program view of CIS fire station

A safety program consists of fail-safe blocks that the user select from an F-Library (fail-safe Library) and interconnect using the CFC (Continuous function chart) programming languages and fail-safe blocks that are automatically added when the safety program is compiled.

Figure III.12 provides an overview of the hardware and software components required to configure and operate an S7 Distributed Safety fail-safe system.

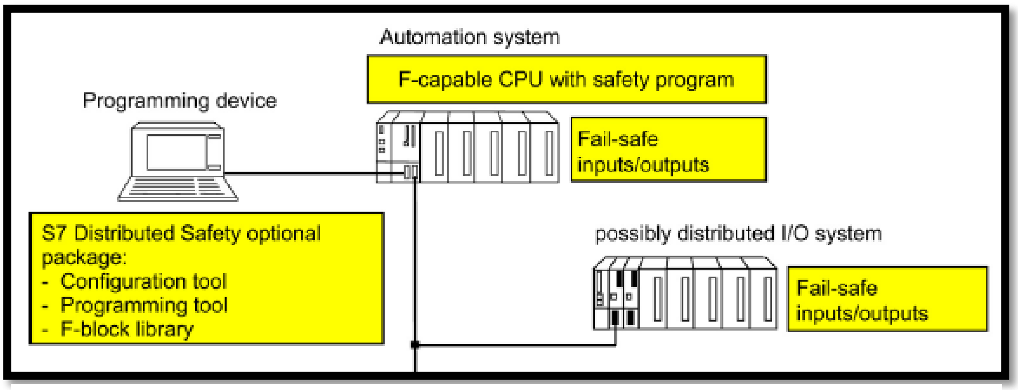


Figure III.12 Merging hardware and software solution [18]

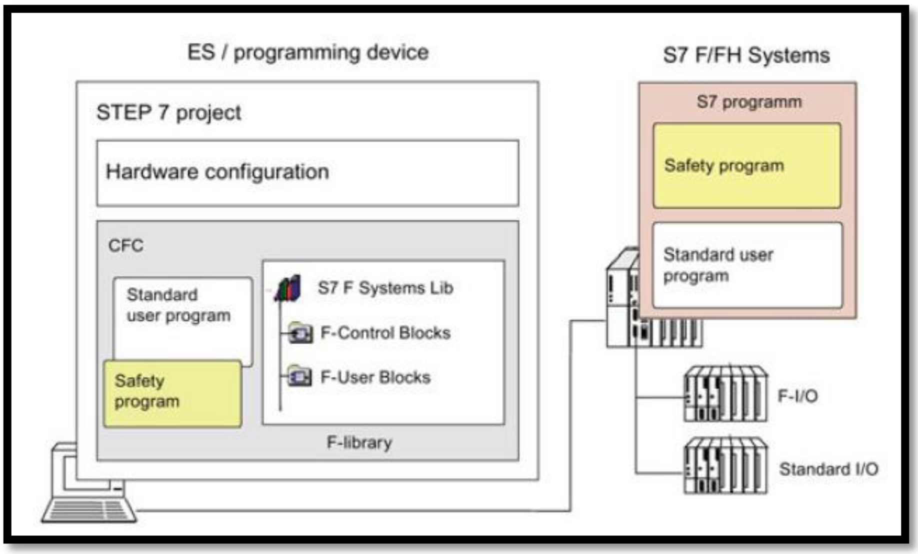


Figure III.11 Schematic structure of a S7 safety program [18]

III.3.2. Hardware component of the solution

a) Mounting Rail (Rack)

It is the main carcass of the PLC where the different modules and cards will be placed. The rack used in this system is **UR2ALU-H** as shown in *Figure* III.13

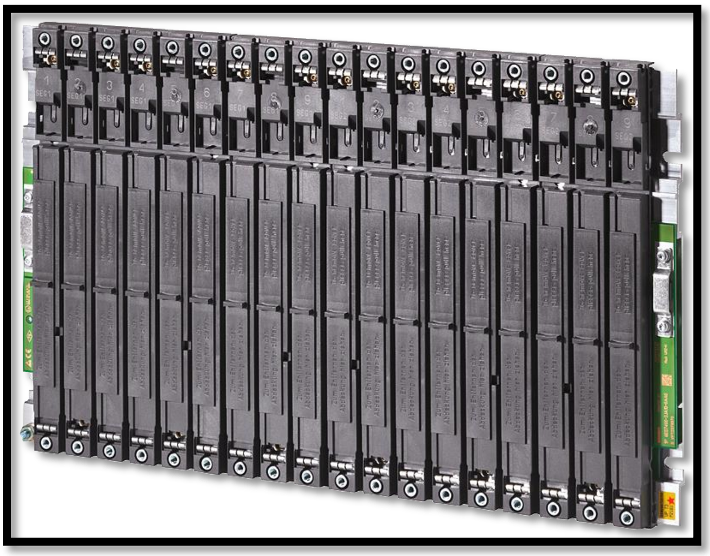


*Figure III.13 2*9 slots rack from Siemens (UR2ALU-H) [19]*

It is a central aluminium rack, 2*9 slots, split backplane bus, suitable for compact configuration of standard and redundant PLCs

b) Central Processing Unit (CPU)

After studying our system and based on the list of criteria to satisfy when choosing a CPU, as well as taking into account the availability of the materiel. We opted for **S7-412-5H** as CPU to control our system which support both fail safe and redundant configuration.

Figure III.14 Fail safe CPU from Siemens (S7 412-5H) [20]

Characteristics of the CPU:

Table III-2 shows the characteristics of the CPU S7-412-5H dedicated for our application:

General information	
Product Type designation	CPU 412-5H PN/DP
Supply voltage	24 V DC
Fail-Safe	Yes
Memory	
Integrated	1 Mbyte
Integrated (for program)	512 Kbyte
Integrated (for data)	512 Kbyte
Interface module (IM)	
Number of connectable IMs (max)	6
Protocols	
MPI	Yes
PROFIBUS DP master	Yes
PROFINET DP master	Yes

Table III-2 Characteristic of CPU S7 412-5H

c) Power supply (PS)

We selected **PS 407 4A** as power supply.

Figure III.15 Power supply from Siemens (PS 407 4A) [21]

Its characteristics are given in following table:

General information	
Product Type designation	PS 407
Supply voltage	120 V DC 230 V DC
Output voltage	5 V DC 24 V DC
Output Current	For backplane bus (5 V DC) 4A For backplane bus (24 V DC) 0.5A
Short circuit protection	Yes

Table III-3 Characteristic of the power supply (PS 407)

Figure III.16 demonstrates the redundant configuration of the equipment discussed below:

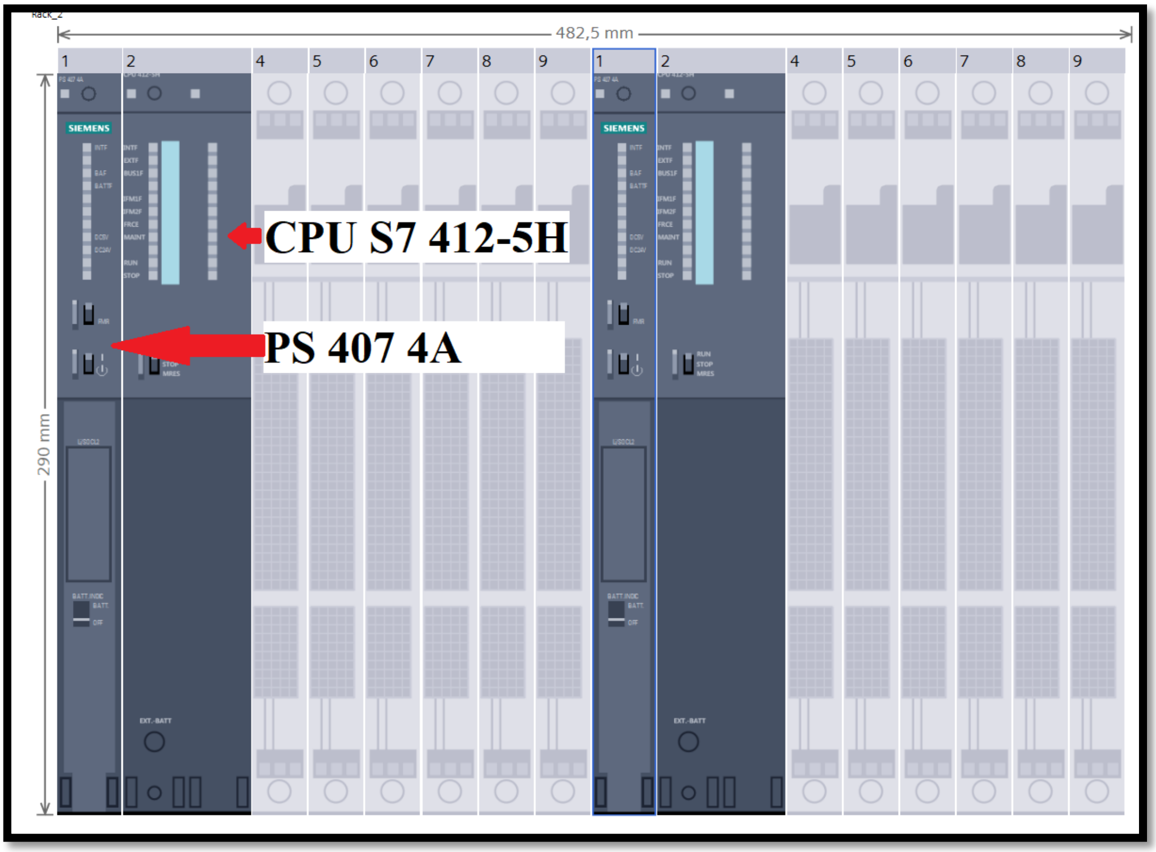


Figure III.16 Redundant configuration of the CPU and the power supply

d) Interface module (IM)

In order to interface between the different instrument in the field and the CPU, and Interface module is required. For our case we opted for **IM153-4 PN HF,** The High Feature (HF) variant of the IM 153-4 PN Interface module is used for connecting failsafe I/O modules as well as intelligent field devices (HART).

Figure III.17 Interface module from Siemens (IM153-4 PN HF) [22]

General information	
Product Type designation	CPU 412-5H PN/DP
Supply voltage	24 V DC
Current consumption	600 mA
Output voltage	5 V
Fail-Safe	Yes
Hardware configuration	
Number of signal modules (max)	12
Protocols	
PROFINET IO (salve)	Yes

Table III-4 Characteristic of the interface module (IM153-4 PN HF)

e) Signal modules (SM)

Signal modules (SM) consists of Input and output modules, their role is to interface between the control part and the operative part.

The different signal modules and their characteristics are shown the *Table* III-5:

Digital Input		
Product Type designation	SM 326 F-DI [2]	
Supply voltage	24 V DC	
Input current	450 mA	
Number of digital inputs	24	
Fail-Safe	Yes	
Digital Output		
Product Type designation	SM 326 F-DO [3]	
Supply voltage	24 V DC	
Output voltage	24 V DC	
Number of digital output	10	
Fail-Safe	Yes	
Analogue Input		
Product Type designation	SM 336 F-AI 15 bit [4]	
Supply voltage	24 V DC	
Input range	4 to 20 mA	
Number of Analogue output	6	
Fail-Safe	Yes	

Table III-5 Characteristic of the signal modules

The following figure demonstrates an example for the configuration of the equipment discussed above. This configuration includes a power supply, which is required for the operation of these devices.

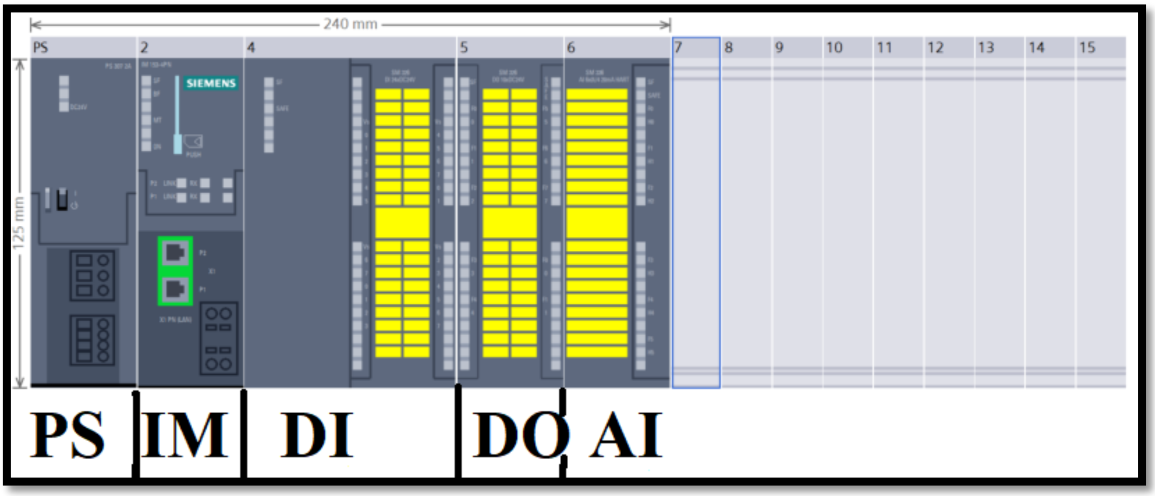


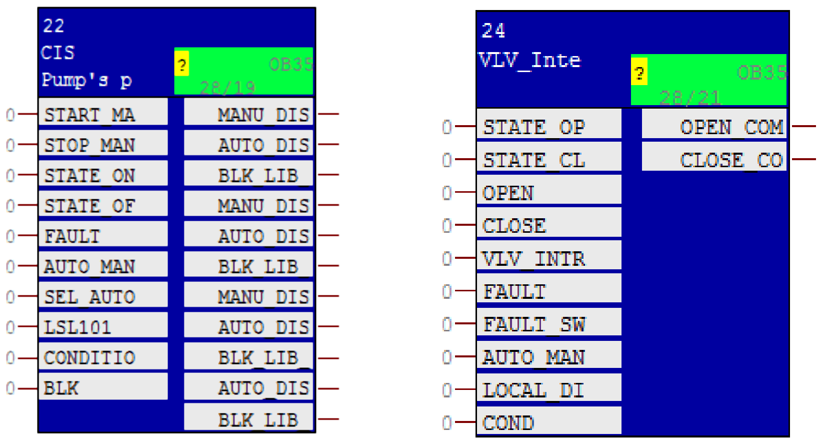
Figure III.18 Configuration of the distributed I/O

III.4. Software solution

III.4.1. Programing the software solution

Programming is the crucial step in our solution to achieve a concrete result that will interest our customer. We split the program into several blocks to simplify the programming and organize our program with the language Statement list "STL".

As an example of the block created, *Figure* III.19 demonstrates the programmed blocks for the pumps, valves:



(a) *(b)*

Figure III.19 (a) Program of the pumps, (b) program of the valve

In order to understand the program of the different part of the fire station, flowchart were created to each part, and they are organized as follow:

- Program of each unit in the Industrial complex
- Program of interconnection between the units
- Program of the valves

a) Program of CIS units

GPL 1:

As it is illustrated in the *Figure* III.20, whenever there is a pressure drop in the system, and if the PLC does not receive an ON state from the pump, this latter starts the pump automatically, and stops it at the desired pressure level.

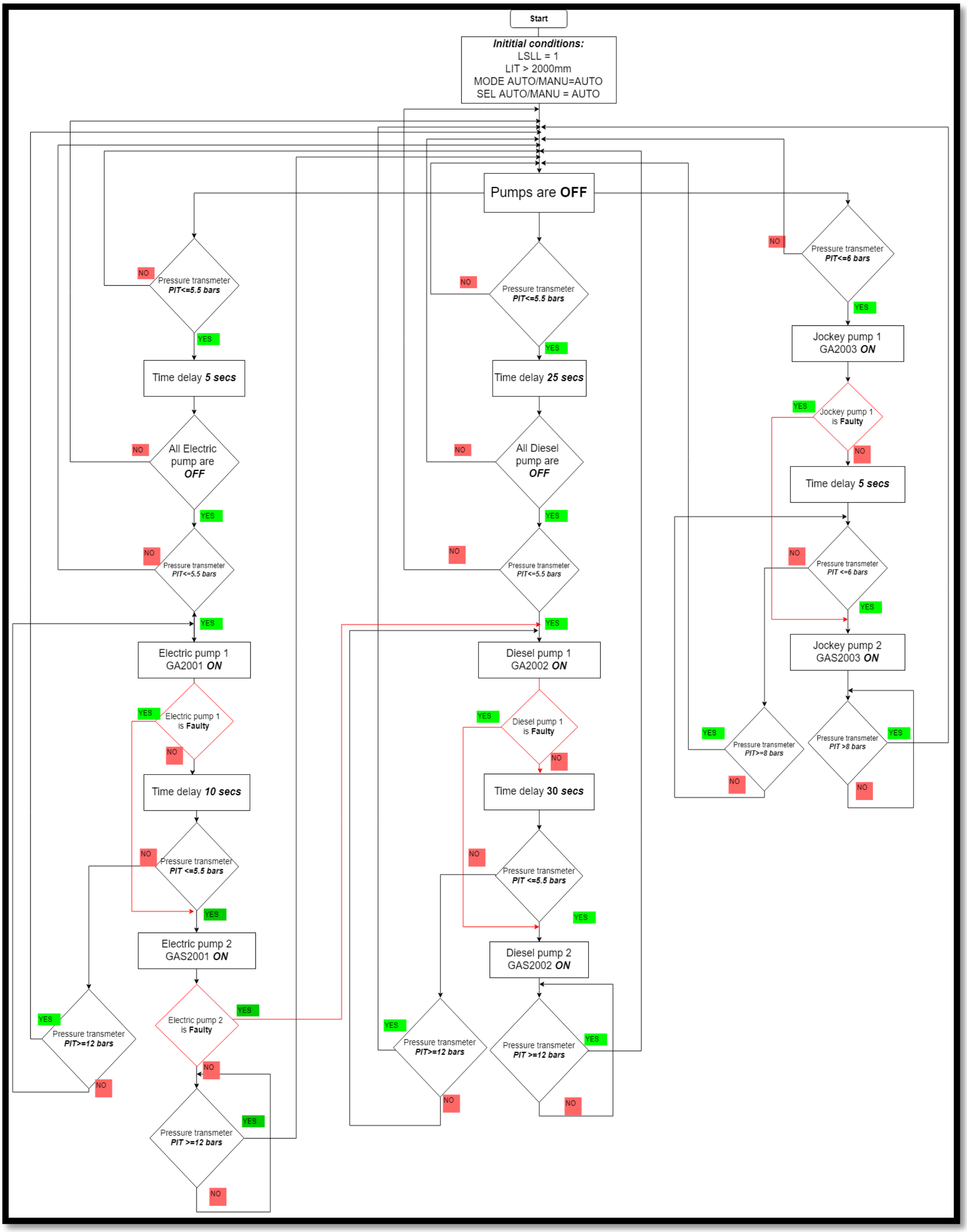


Figure III.20 Flowchart of GPL 1 fire pumps process

The faulty cases are treated by the PLC when the instrument is operating in the automatic mode.

- In case of fault in **GA2001** when it is in ON state, **GAS2001** is automatically started.
- If both **GA2001** and **GAS2001** indicates a fault when they are in there ON state, **GA2002** is automatically started.
- In case of fault in **GA2002** when it is in ON state, **GAS2002** is automatically started.
- In case of fault in **GA2003** when it is in ON state, **GAS2003** is automatically started.

Since RHM2, GPL2 and COMP2 have the same configuration and the same working structure, their program is illustrated in *Figure* III.21.

The faulty case in those units is treated as follow:

- In case of fault in **the electric pump** when it is in ON state, **the diesel pump** is automatically started.
- In case of fault in **the first jockey pump** when it is in ON state, **the second one** is automatically started.

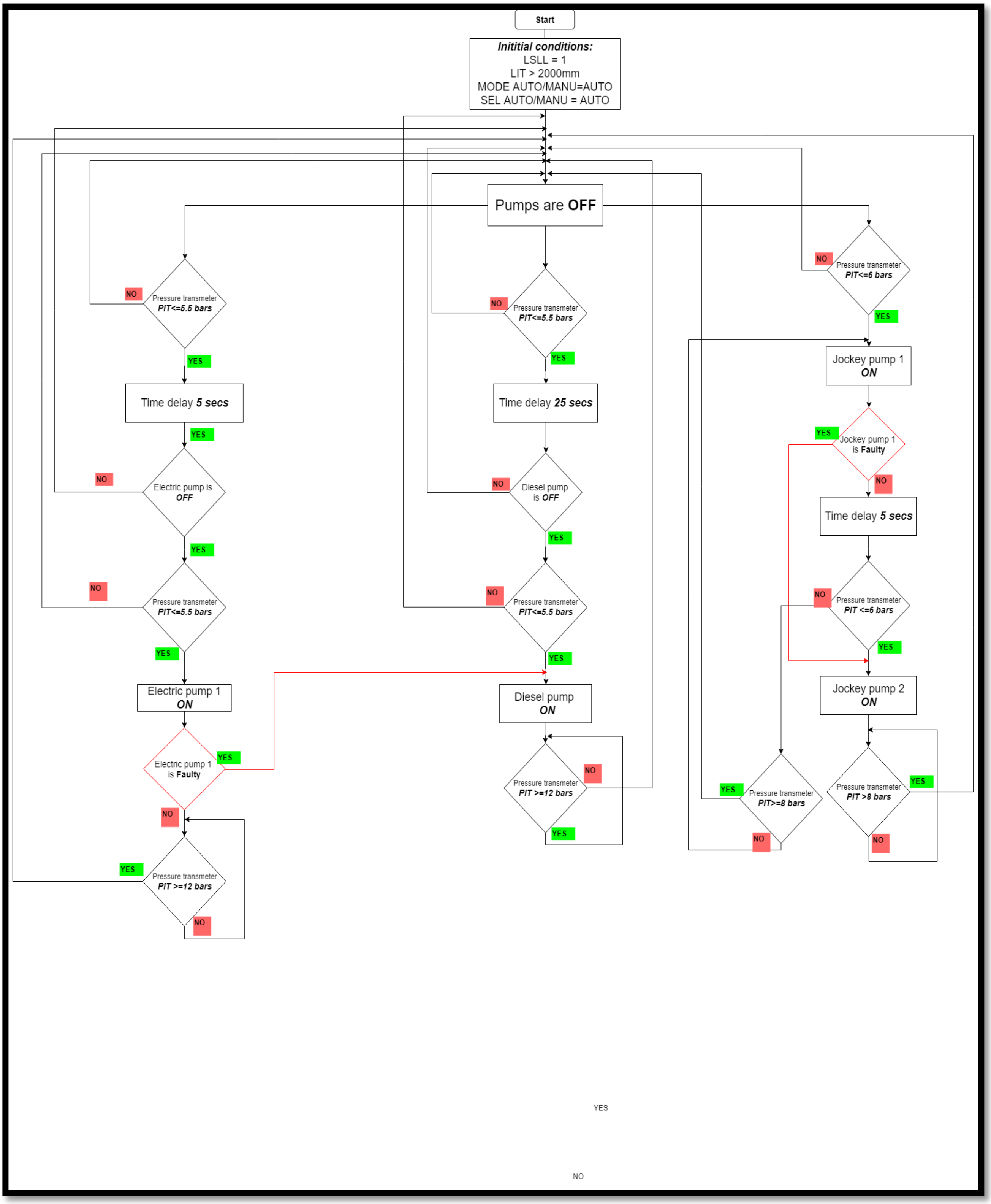


Figure III.21 Flowchart of GPL2, RHM2 and COMP2 fire pumps process

b) Program of the interconnecting units

The purpose of this step as explained in chapter 2, is to rescue a failing unit by another unit through the opening of the valve interconnecting them. The two principal condition for this operation are:

- All the pumps are in faulty case, and it corresponding pressure transmitter is under 5.5 bars
- If electric and diesel pumps are ON and the pressure is under 5.5 bars, after 1 minute of delay if the pressure is still under 5.5 bars.

The following figure demonstrates the program of interconnection between GPL 1, GPL 2, RHM 2 and COMP 2.

Table III-6 demonstrates the sequential working of the interventions

Active fire pumping station	GPL 1
1st Intervention	Valve GPL1/GPL2
2nd Intervention	Valve GPL1/COMP 2
3rd Intervention	Valve GPL1/S.Tanks
Active fire pumping station	GPL 2
1st Intervention	Valve GPL2/GPL 1
2nd Intervention	Valve GPL2/RHM 2
3rd Intervention	Valve GPL1/S.Tanks
Active fire pumping station	COMP 2
1st Intervention	Valve COMP2/GPL 1
2nd Intervention	Valve GPL1/GPL 2
3rd Intervention	Valve GPL1/S.Tanks
Active fire pumping station	RHM 2
1st Intervention	Valve RHM2/GPL 1
2nd Intervention	Valve RHM2/GPL 2
3rd Intervention	Valve GPL1/S.Tanks

Table III-6 Sequential working of the interventions

a) Interconnection network of GPL 1 & GPL 2:

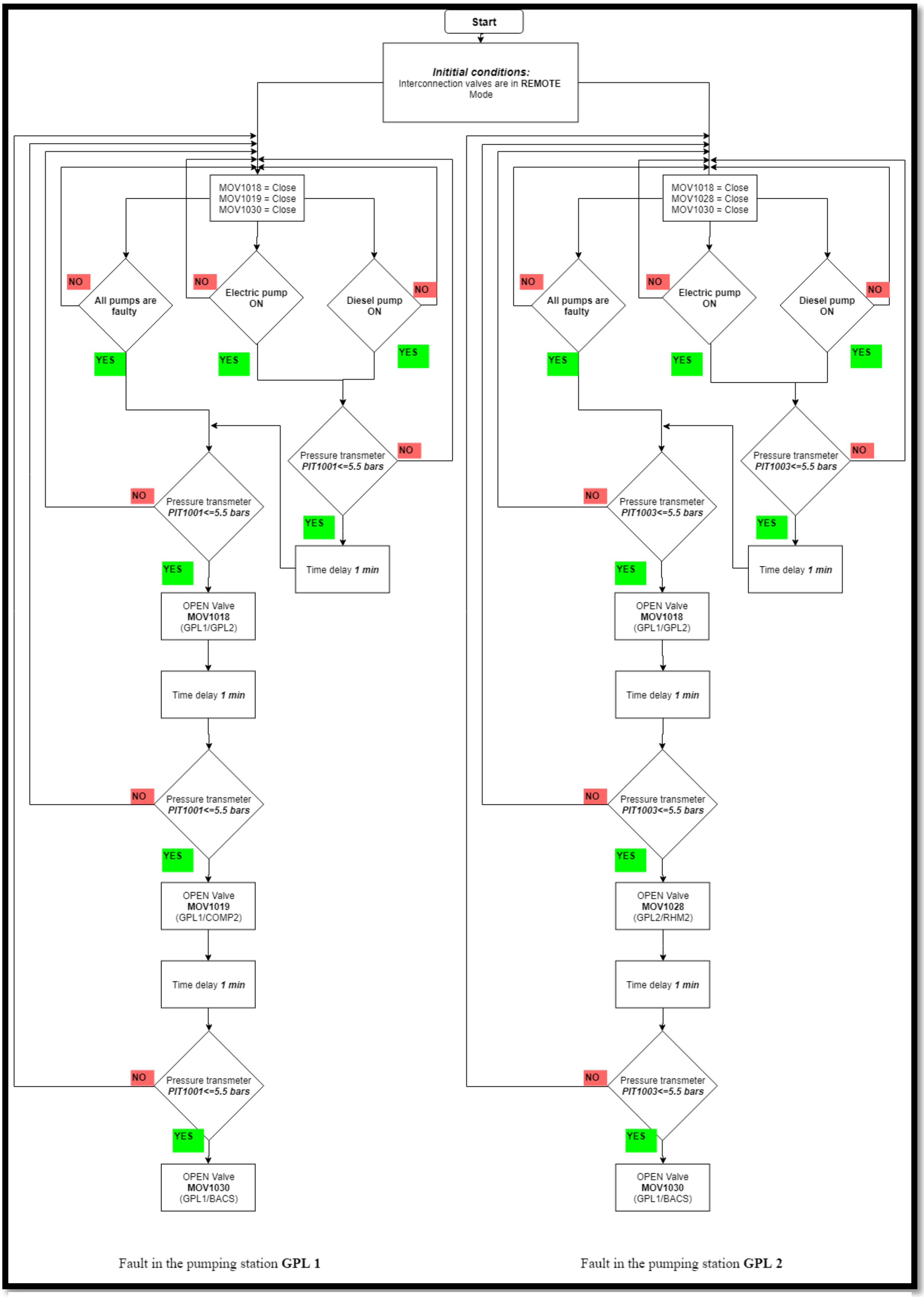


Figure III.22 Flowchart of the interconnection process in GPL 1 & GPL 2

b) Interconnection network of RHM 2 & COMP 2

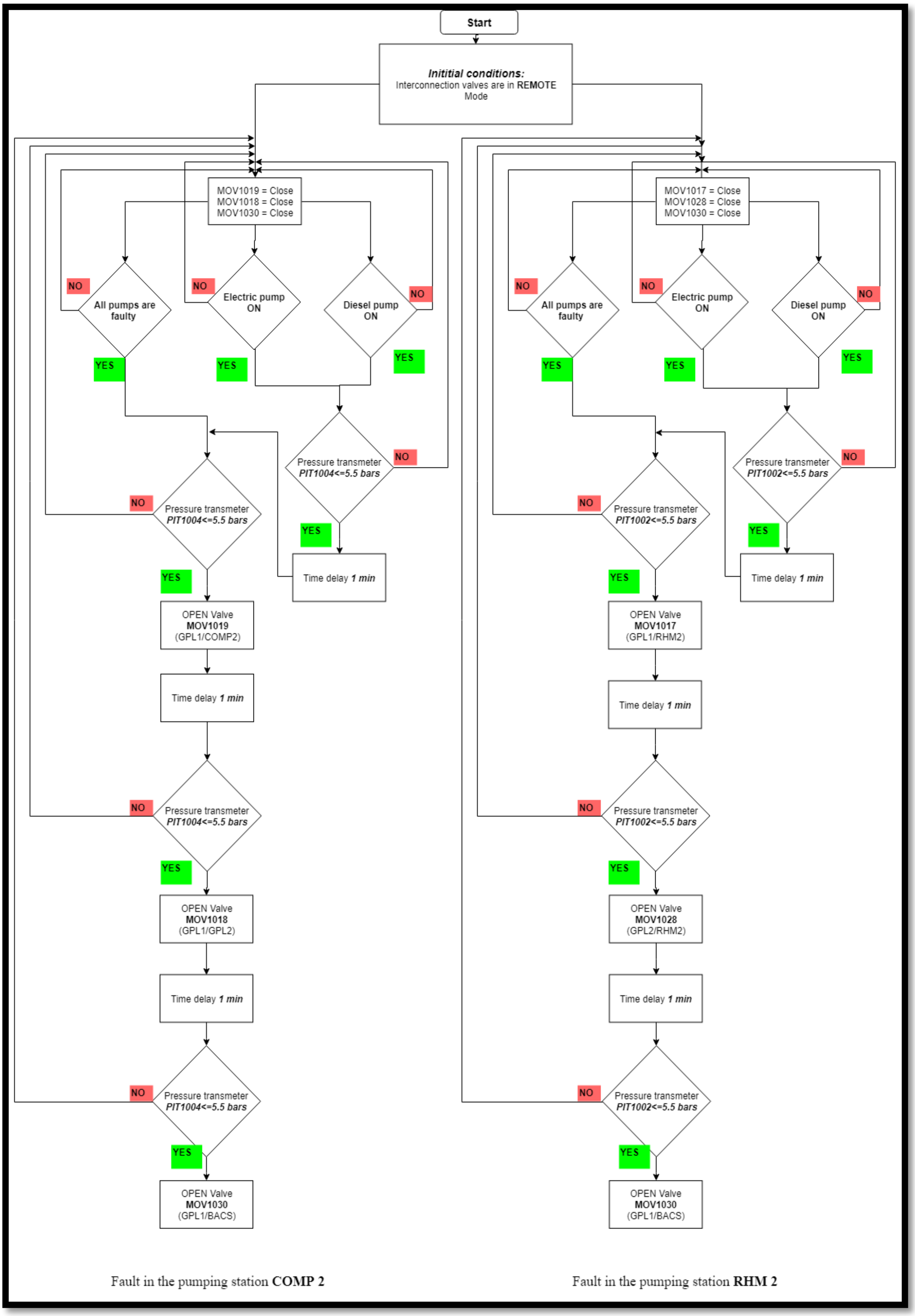


Figure III.23 Flowchart of the interconnection process in COMP2 and RHM2

c) Program of the valves

Loading valve:

The loading valve operates in the same manner for each unit, it controls automatically the filling of the tank that supplies the pumps.

- If the high level (100%) in the **tank's unit** is reached, the **high level switch** of the unit closes the its corresponding **loading valve** to prevent tank overflow.
- If the low level (50%) of water in the **tank's unit** is reached, the **low level switch** of the unit opens the its corresponding **loading valve** to fill the tank

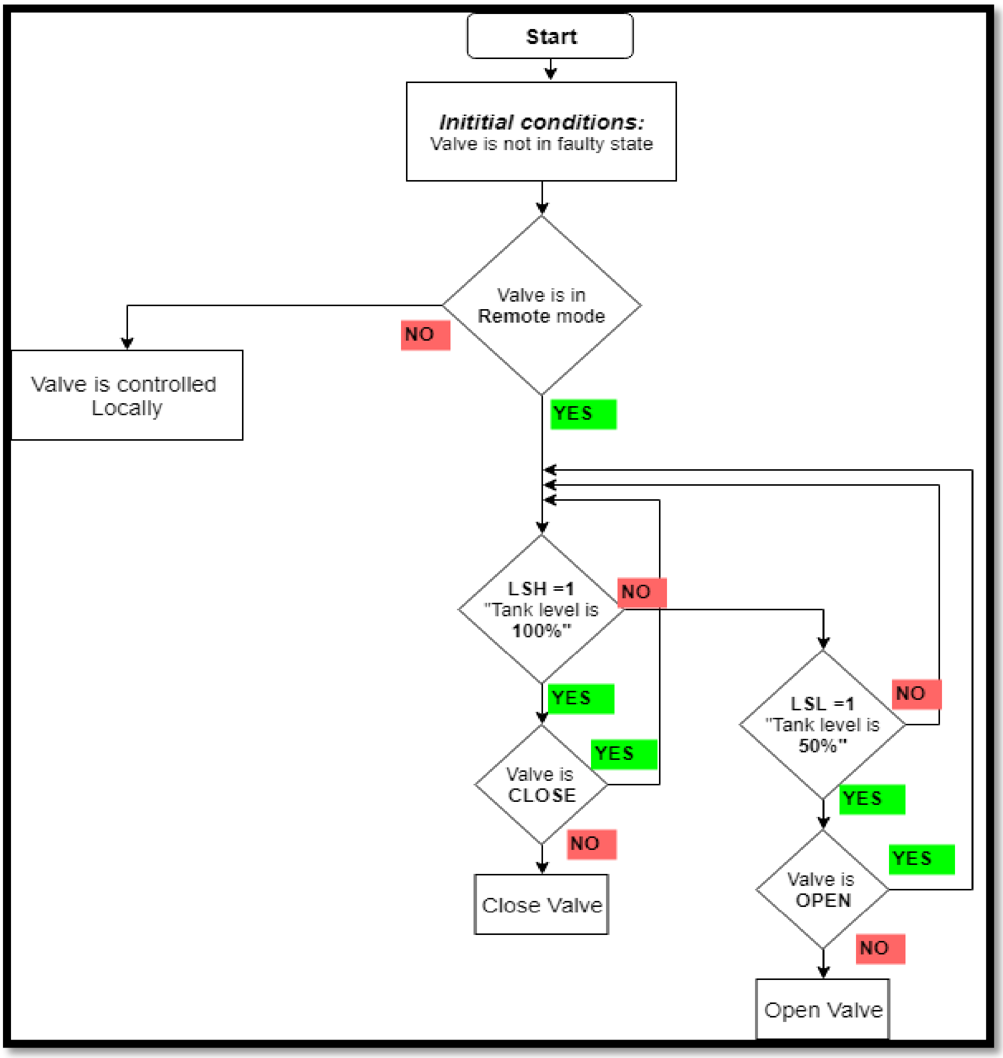


Figure III.24 Flowchart of the loading valve

USD valve:

USD valves are used to connect the units to the USD unit. These motorized valves are manually controlled either locally or remotely.

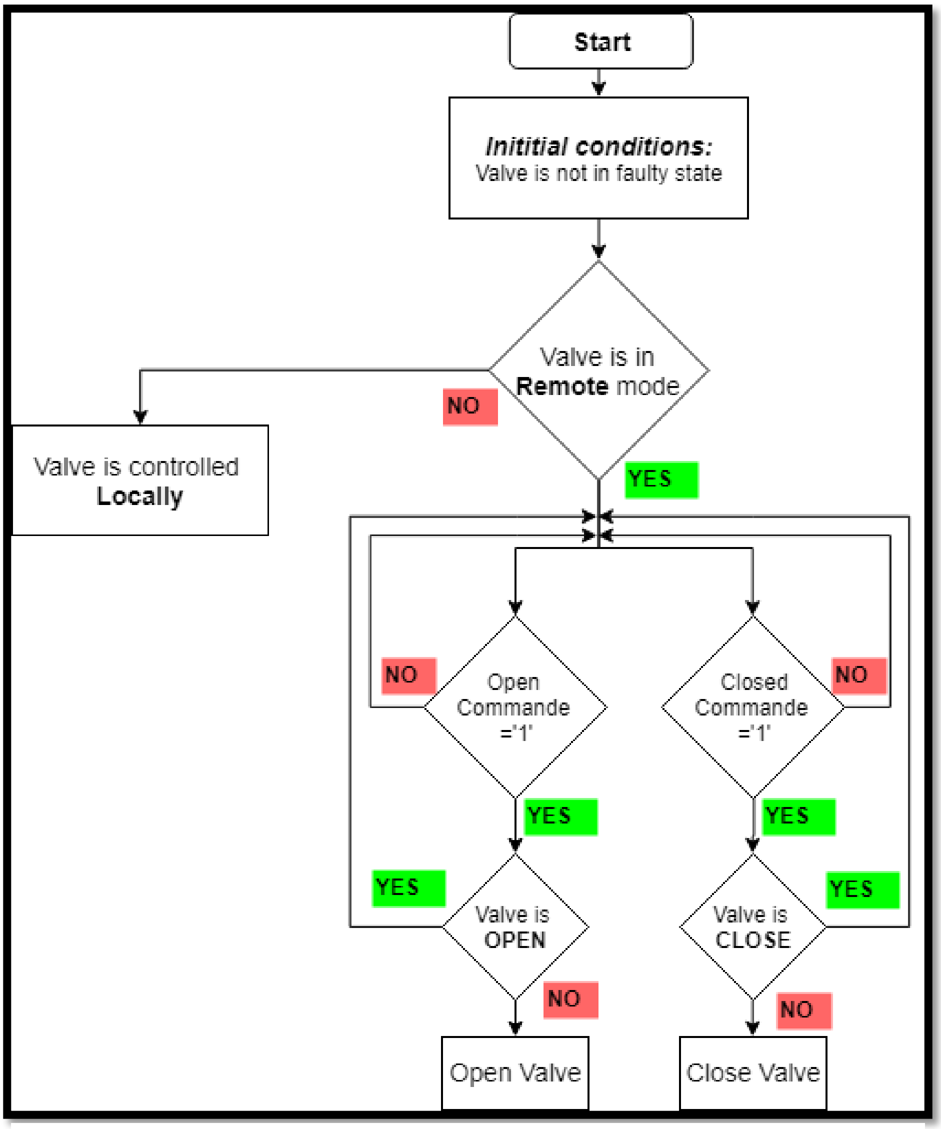


Figure III.25 Flowchart of the USD valves

III.5. Conclusion

The fire station groups several instruments and devices that are connected with the PLC. The program has been realized with using CFC and organized in blocks specific to each pump, valve. The process can also act automatically or manually with intervention of the operator on the supervision system.

IV. **Chapter 4:** Supervision & Control

IV.1. Introduction

Supervision is a technique for monitoring and controlling the operation of one or more processes. The supervision concerns the acquisition of data (measurements, alarms, return of operating status) and control parameters of the processes generally entrusted to programmable controllers, the current CIS fire network installation does not have supervision system.

After completing the programming task, we move on to designing a supervision solution.

IV.2. Generalities about supervision & control

Supervision is a computerized industrial process control and monitoring technique. It facilitates the operator to directly observe, analyse and interfere with the system. It also provides the ability during diagnosis to archive data for analysis.

The main characteristics of an application for supervision are:

- Data acquisition.
- Process control
- Graphical representation of information
- Alarm processing and event management
- Historical archiving and calculation
- Follow-up and production traceability

Supervision software Works Generally on A computer in communication (SCADA application) via a local or remote industrial network, equipped with one or more devices: industrial programmable logic controller, computer, specialized card.

Supervision software consists of a set of pages (screens), often presented as a synoptic operator interface. The application can be a single or multi-user application.

The supervision realized in this project is a SCADA application, developed with the software **SIMATIC WinCC Explorer** that is proper to Siemens PLCs.

SCADA Interface:

A supervision control and data acquisition is a large-scale telemetry system that makes it possible to process a large number of telemeters in real time and to remotely control technical and industrial installation.

The field information of the SCADA device is centralized on a central unit. This allows the operator to control all or part of the actuators of an often very extensive installation such as a plant or a distribution network.

Field control is performed by automatic measure and control instruments called Remote Terminal units (RTU) or through Programmable logic controllers (PLC).

A SCADA device, used as a safety lockout tool for electrical devices, usually consists of the following subsystems:

- A human-machine interface that presents the data to a human operator and allows him to supervise and control the processes,
- A computer control supervision system, acquiring process data and sending commands (instructions) to processes,
- PLCs used in the field for their flexibility versatility due to their ability to be configurable.
- A communication infrastructure linking the supervisory control system to the terminal elements.

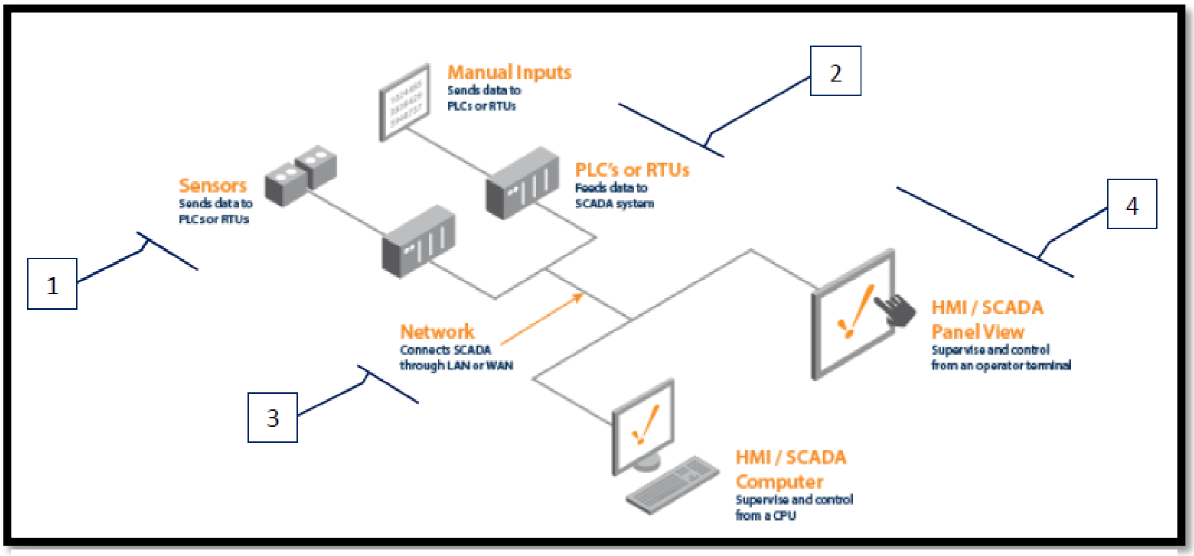


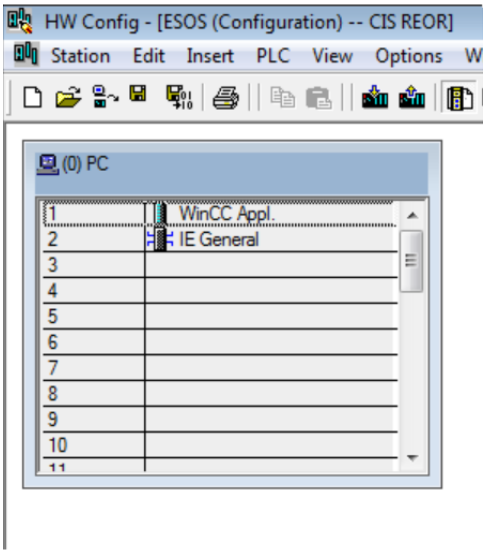
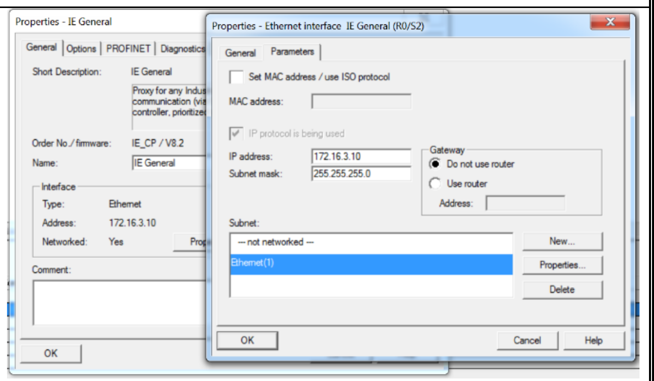
Figure IV.1 SCADA system components [23]

WinCC Explorer:

It is a supervisory control and data acquisition (SCADA) system from Siemens, and stands for Windows Center Control, This software package can be handled like a standard Windows application and includes all necessary tools for programming of the SIMATIC S7-400 ,from the high-performance SIMATIC instruction set to IEC 611131-3 compliant programming and all the way to trend charts and wizards.

IV.3. Configuration of SCADA system

To establish communication with the supervisory position, the PLC must be connected to the PC trough a Profinet protocol. For this, the communication network must be configured from SIMATIC Manager, *Table* IV-1 demonstrates the step for the configuration

N°	Action	Comment
1	In the hardware configuration of the PC station created in SIMATIC manager, we inserted “WinCC Appl” and “IE General” modules in the rack.	
2	In the properties dialog of the “IE General” module, we select the Ethernet network already created in the hardware solution.	

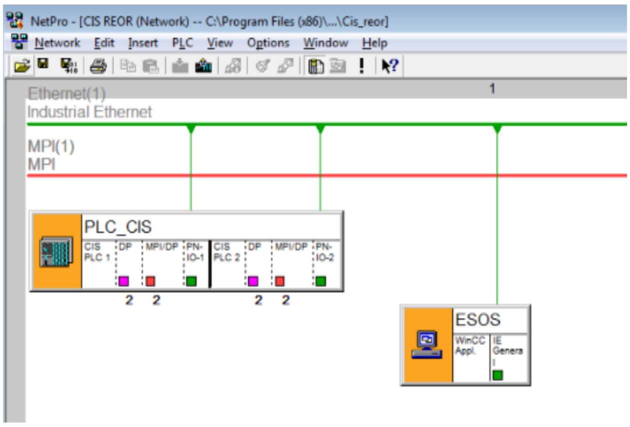
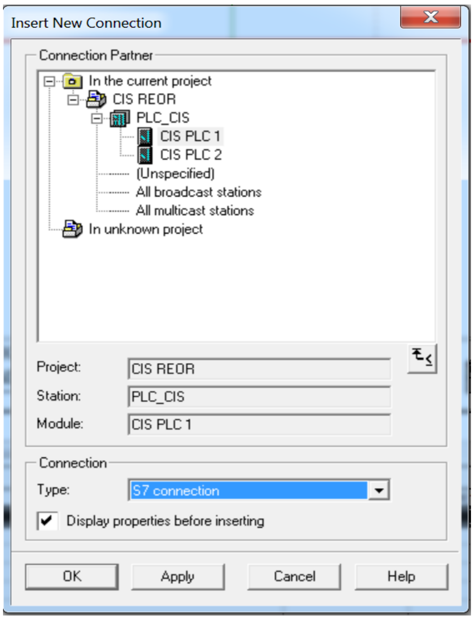
3	In the SIMATIC Manager open NetPro via the menu "Options > Configure Network".	
4	In NetPro we inserted an S7 connection for data communication between SIMATIC PC station and S7 station. The last step is saving and compiling the configuration.	

Table IV-1 SCADA Profinet configuration with automation station

IV.4. Structure of the supervision

Once the communication has been set up, the variables must be imported in WinCC Explorer using Data blocks (DBs), Graphics Development is then done on the pages, faceplates are used to created POPUP windows to show states and commands of the instruments, finally alarms are configured to alerts the operator in case of fault or problem.

The graphical interface of CIS supervision are:

IV.4.1. Home view

From this view, we have the access to all other views of CIS

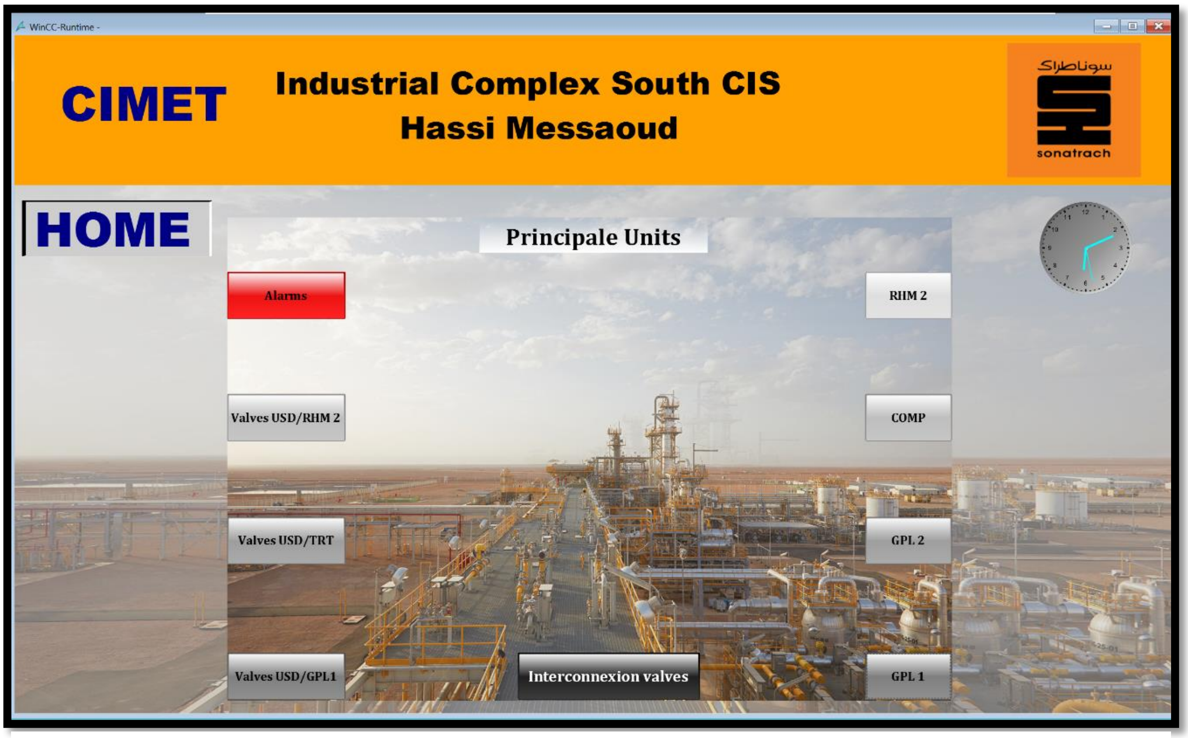


Figure IV.2 Home (General) view.

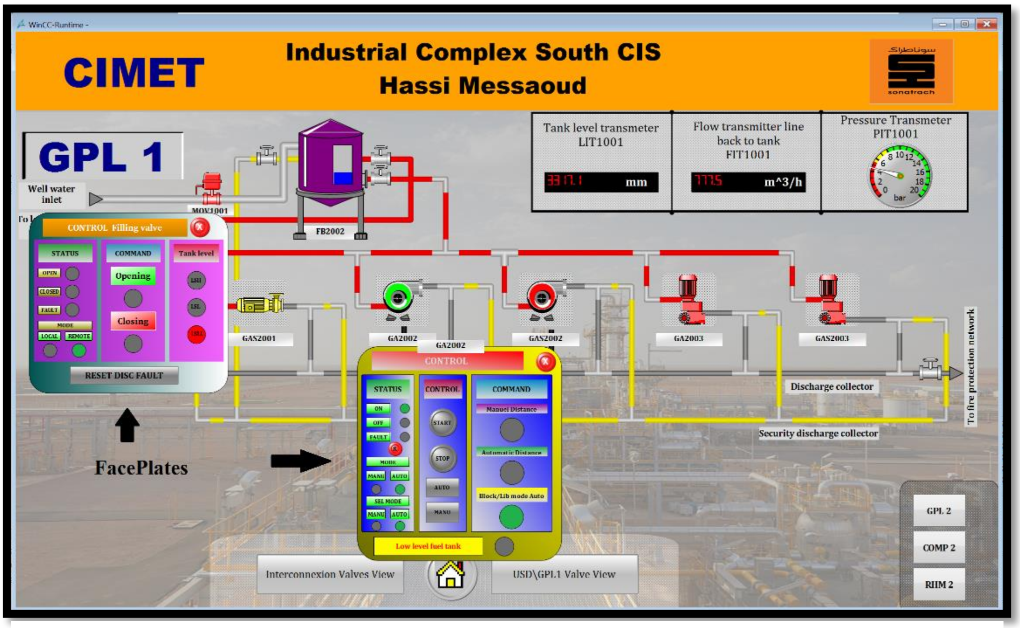
- **GPL 1, GPL 2, COMP, and RHM 2:** Allows the user to access the unit view.
- **Interconnection valve:** Give access to the view that includes the interconnection valves
- **Valve (USD/RHM 2, USD/TRT, and USD/GPL 1):** These views controls the valves that connect the system to USD unit.
- **Alarms:** Grants a direct access in order to visualize the alarms.

IV.4.2. Units view

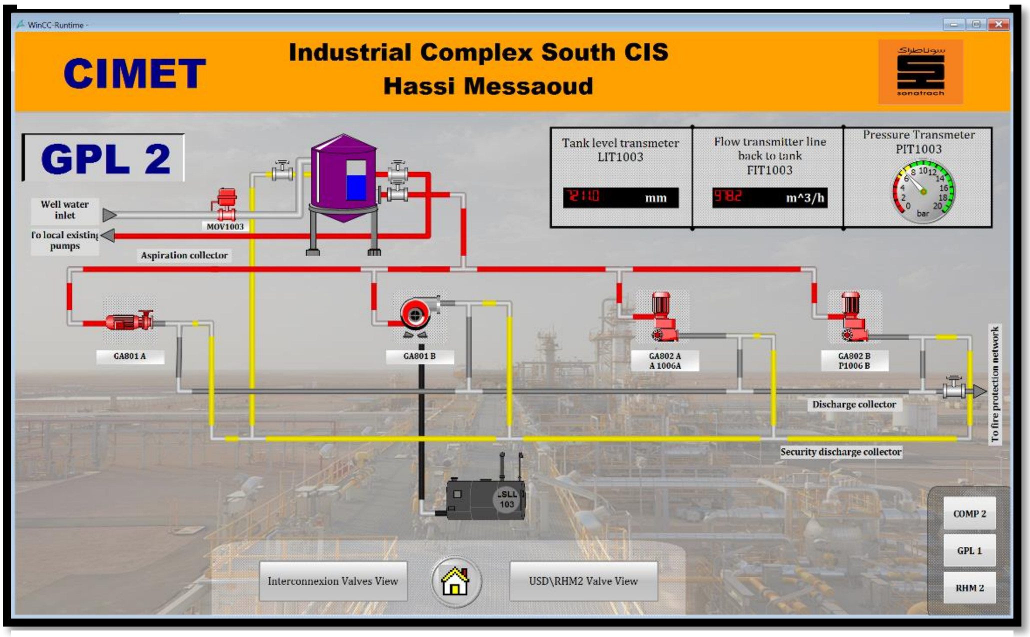
This view allows the user to supervise and control the different instruments of GPL 1 unit. It gives the following information:

- States of the pumps (ON, OFF, fault, Automatic, manual)
- State of the loading valve (OPEN, CLOSE, fault, Automatic, manual, Local, remote)

- The pressure and flow in GPL 1 unit
- The level of the GPL 1's Tank.



(a)



(b)

Figure IV.3 (a) Unit GPL1 view, (b) Unit GPL2 view.

IV.4.3. Interconnection valve view

This view is dedicated for the interconnection valves, it allows the operator to monitor and control their states, and a pressure indicator is included to indicate the pressure level in the pressure transmitter mounted with valve.

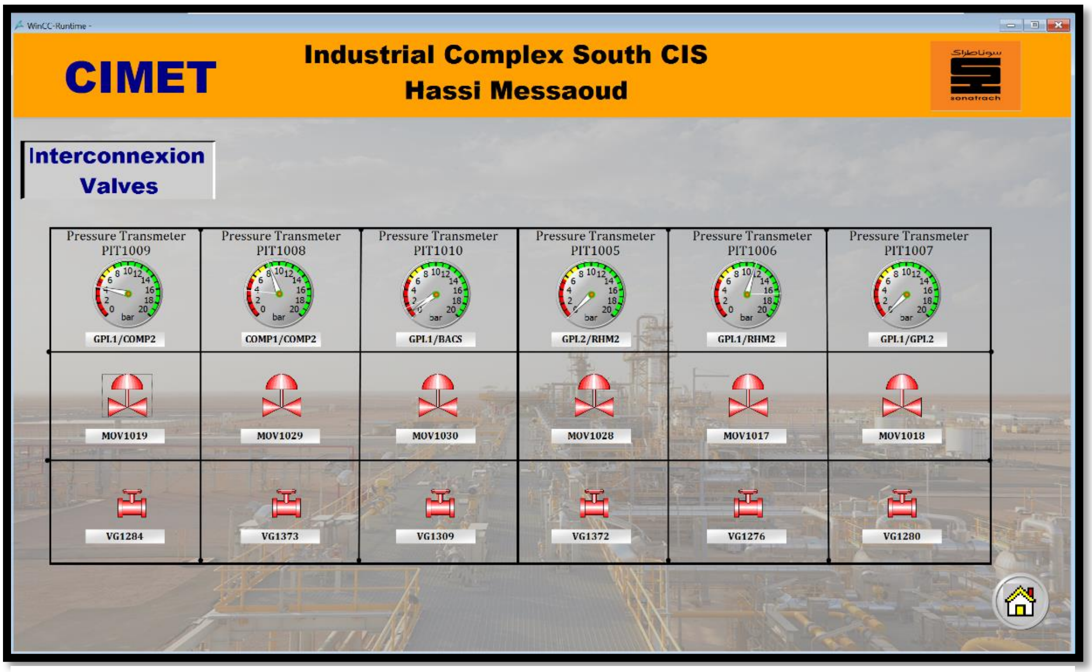


Figure IV.4 interconnection valve view.

IV.4.4. USD valve view

Three views are dedicated for the valves interconnecting the fire pump stations with the USD unit, through these views the operator can control and monitor the state of valves

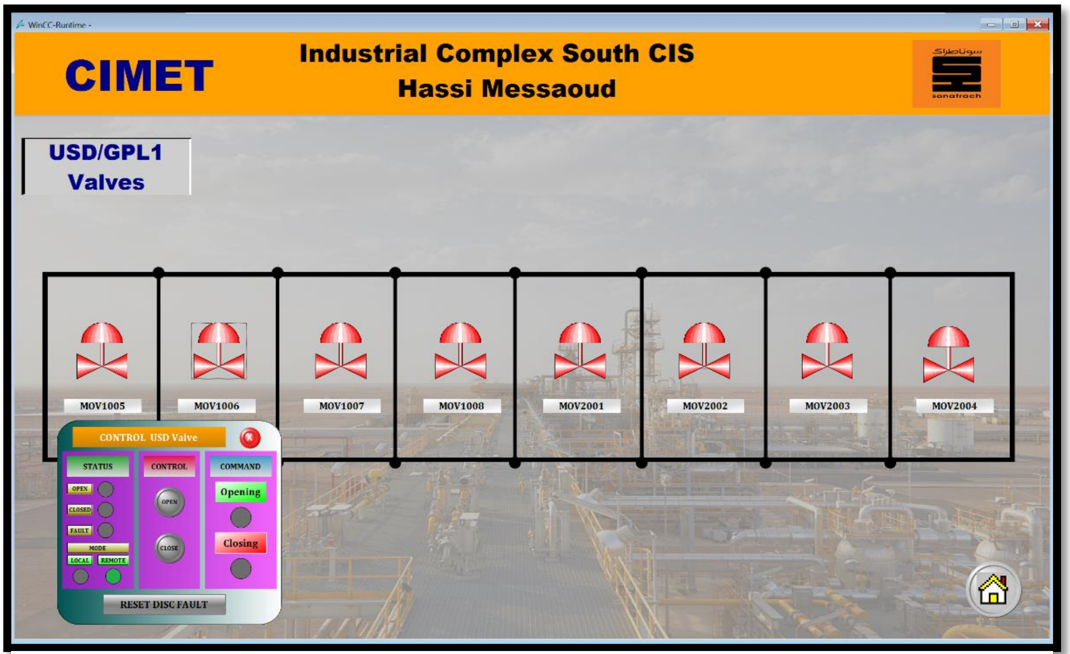


Figure IV.5 USD/GPL1 valve view.

IV.4.5. Alarms view

The alarms display on the SCADA control interface the events or states that occur during the operation of the installation and that are usually triggered by the PLC., as well as the time, date and location of the occurrence of the fault.

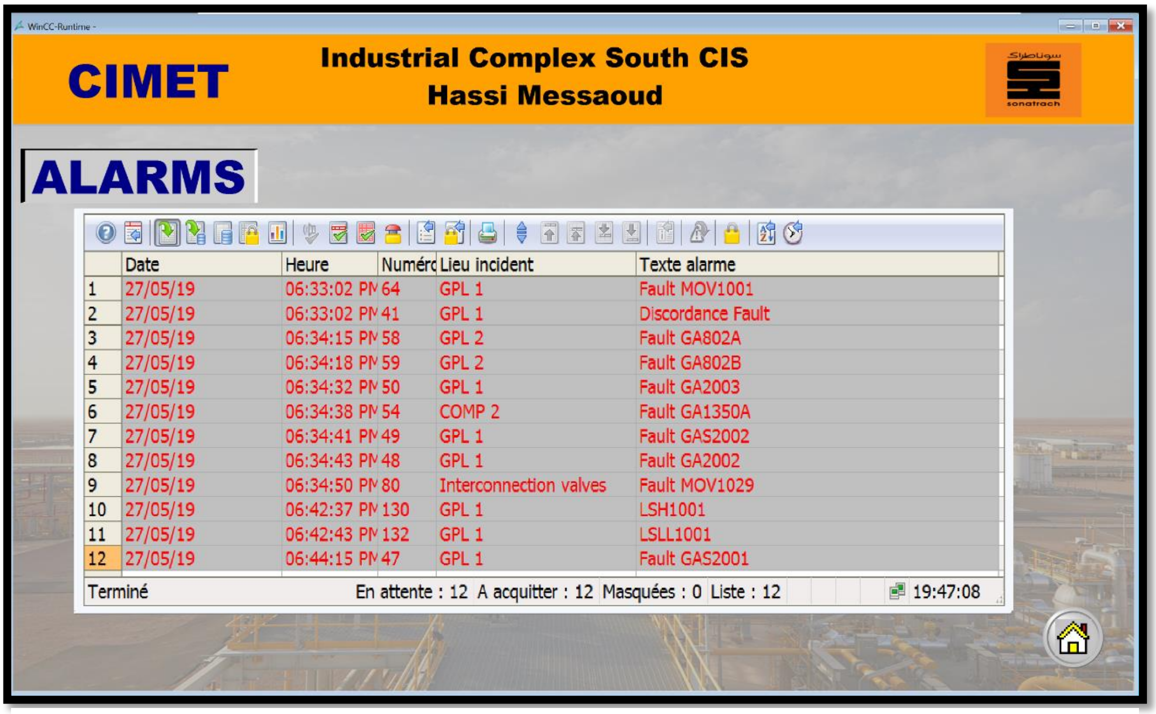


Figure IV.6 Alarms view.

IV.5. Conclusion

We have presented through this last chapter, the communication used between the automaton and the chosen supervision computer.

Thus, we explained the supervision of all fire-fighting network, because from the latter, the operator will manage and control the entire installation centrally from the views of different sites.

General Conclusion

General Conclusion

The realization of this project within the company Siemens allowed us to experience the essential steps by which an engineer must pass through in order to dimension a complete and operational automation solution, and also know how to interpret the specifications to meet the customer's requirements.

The purpose of our work was to design a remote control system for the fire pumping stations of CIS as well as to install a supervision and control system for them.

To realise the project we followed these steps:

- ✓ Study the operation of this system, hence identify the problem.
- ✓ Propose of an adequate automation system.
- ✓ Realise the hardware configuration.
- ✓ Program the different part of fire pumping stations according to the functional analysis
- ✓ Design a supervision and control interface SCADA to allow the operator to control and command the station through the different views.

In the absence of time, we would have liked to put in place the following actions:

- ✓ Conception of the electrical cabinets.
- ✓ Implementation of the proposed solution.

Finally, this project has allowed us to learn new concepts in industrial automation. We have also learned how to interpret and provide adequate solutions to the needs of the customer.

Appendices

Appendix A: PLC Datasheets

Power supply (PS 407 4A):

SIEMENS

Data sheet 6ES7407-0DA02-0AA0

SIMATIC S7-400, Power supply PS407: 4 A, wide range, UC 120/230V, 5 V DC/4 A

Figure similar

General information	
Product type designation	PS 407
Supply voltage	
Rated value (DC)	
• 120 V DC	Yes
• 230 V DC	Yes
permissible range, lower limit (DC)	88 V
permissible range, upper limit (DC)	300 V
Rated value (AC)	
• 120 V AC	Yes
• 230 V AC	Yes
permissible range, lower limit (AC)	85 V
permissible range, upper limit (AC)	264 V
Line frequency	
• Rated value 60 Hz	Yes
• Rated value 60 Hz	Yes
• permissible range, lower limit	47 Hz

Central Processing Unit (CPU S7 412-5H PN/DP):

SIEMENS

Data sheet 6ES7412-5HK06-0AB0

SIMATIC S7-400H, CPU 412-5H, central processing unit for S7-400H and S7-400F/FH, 5 interfaces: 1x MPI/DP, 1x DP, 1x PN and 2 for sync modules, 1 MB memory (512 KB data/512 KB program)

General information	
Product type designation	CPU 412-5H PN/DP
HW functional status	1
Firmware version	V6.0
Engineering with	
• Programming package	As of STEP 7 V5.5 SP2 with HF1
CiR – Configuration in RUN	
CiR synchronization time, basic load	100 ms
CiR synchronization time, time per I/O byte	0 µs
Supply voltage	
Rated value (DC)	
• 24 V DC	No; Power supply via system power supply
Input current	
from backplane bus 5 V DC, typ.	1.6 A
from backplane bus 5 V DC, max.	1.9 A
from backplane bus 24 V DC, max.	150 mA; 150 mA per DP interface
from interface 5 V DC, max.	90 mA; At each DP interface

Interface Module (IM 153-4 PN HF):

SIEMENS

Data sheet 6ES7153-4BA00-0XB0

SIMATIC DP, Connection ET 200M IM 153-4 PN IO High Feature for max. 12 S7-300 modules, supports fail-safe module, HART modules, shared device, Medium Redundancy Protocol

General information	
Product type designation	IM 153-4 PN HF
Vendor identification (VendorID)	002AH
Device identifier (DeviceID)	0302H
Supply voltage	
Rated value (DC)	24 V
• 24 V DC	Yes
permissible range, lower limit (DC)	20.4 V
permissible range, upper limit (DC)	28.8 V
external protection for power supply lines (recommendation)	In a construction with grounded reference potential, a fuse is necessary for redundant interface modules (Recommendation: 2.5 A)
Mains buffering	
• Mains/voltage failure stored energy time	5 ms
Input current	
Current consumption, max.	600 mA; with 24 V DC supply
Inrush current, typ.	4 A
I^2t	0.09 $A^2 \cdot s$

Signal Module (SM 326 F-FI 24x24V DC)

SIEMENS

Data sheet **6ES7326-1BK02-0AB0**

SIMATIC S7, Digital input SM 326, F-DI 24x24 V DC, Fail-safe digital input for SIMATIC S7 F-systems with diagnostic alarm, up to Category 4 (EN 954-1)/ SIL3 (IEC61508)/PLE (ISO13849), 1x 40-pole

Figure similar

Supply voltage	
Rated value (DC)	24 V
Reverse polarity protection	Yes
Input current	
from load voltage L+ (without load), max.	450 mA
from backplane bus 5 V DC, max.	100 mA
Encoder supply	
Number of outputs	4; Isolated
Output current	
• Rated value	400 mA
Power loss	
Power loss, typ.	10 W
Digital inputs	
Number of digital inputs	24
Number of simultaneously controllable inputs	
all mounting positions	

Signal Module (SM 326 F-DO 10x24 V DC/2A)

SIEMENS

Data sheet 6ES7326-2BF10-0AB0

SIMATIC S7, digital output SM 326, F-DO10x 24 V DC/2A PP, fail-safe digital output for SIMATIC S7F systems, with diagnostic alarm, LVV, up to Category 4 (EN 954-1)/ SIL3 (IEC61508)/PLE (ISO13849), 1x 40-pole

Supply voltage	
Rated value (DC)	24 V; 1L+
Reverse polarity protection	Yes
Load voltage L+	
• Rated value (DC)	24 V; 2L+, 3L+
• Reverse polarity protection	No
Input current	
from supply voltage 1L+, max.	100 mA
from load voltage 2L+ (without load), max.	100 mA
from load voltage 3L+ (without load), max.	100 mA
from backplane bus 5 V DC, max.	100 mA
Power loss	
Power loss, typ.	6 W
Digital outputs	
Number of digital outputs	10
Short-circuit protection	Yes
Switching capacity of the outputs	
• on lamp load, max.	5 W

Signal Module (SM336 6 AI; 15 BIT; HART)

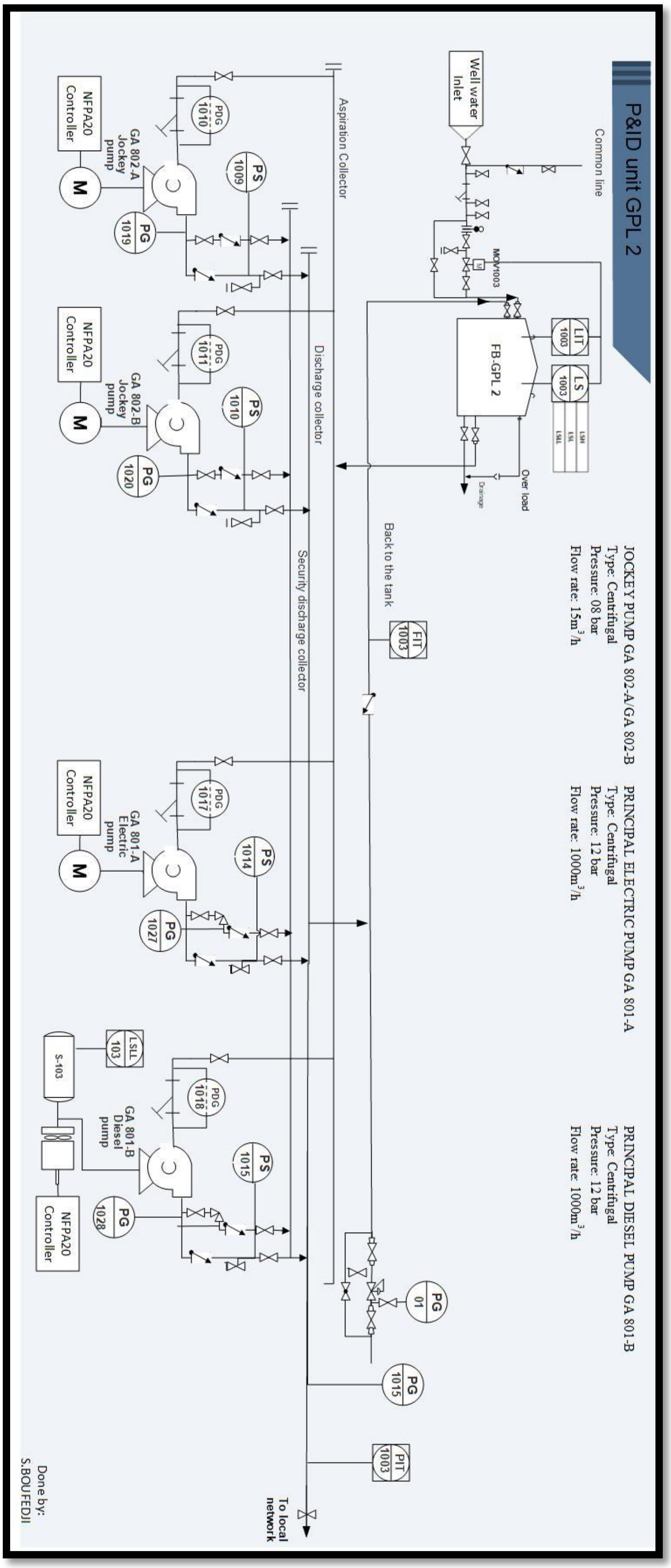
SIEMENS

Data sheet 6ES7336-4GE00-0AB0

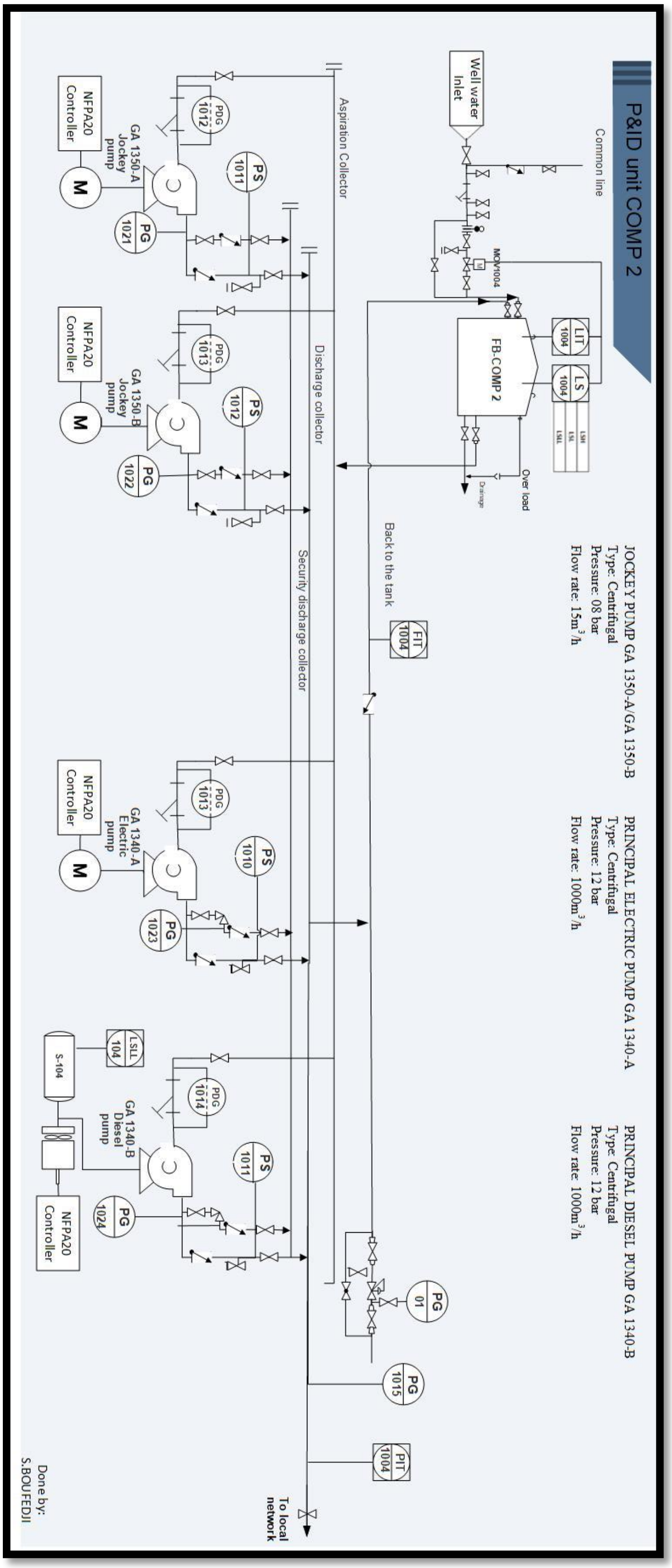
SIMATIC S7, ANALOG INPUT SM336 6 AI; 15 BIT; FAILSAFE ANALOG INPUTS FOR SIMATIC SAFETY, WITH HART SUPPORT, UP TO CATEGORY 4 (EN954-1)/ SIL3 (IEC61508)/PLE (ISO13849), 1 X 20 PIN,

Input current	
from supply voltage L+, max.	150 mA; Typical
from backplane bus 5 V DC, max.	90 mA
Power losses	
Power loss, typ.	4.5 W
Analog inputs	
Number of analog inputs	6
permissible input current for current input (destruction limit), max.	40 mA
Input ranges	
• Voltage	No
• Current	Yes
Input ranges (rated values), currents	
• 0 to 20 mA	Yes
• Input resistance (0 to 20 mA)	150 Ω; typ. 150 ohms max. 175 ohms
• 4 mA to 20 mA	Yes
• Input resistance (4 mA to 20 mA)	150 Ω; typ. 150 ohms max. 175 ohms
Cable length	
• shielded, max.	1 000 m
Analog value generation for the inputs	
Integration and conversion time/resolution per channel	
• Resolution with overrange (bit including sign), max.	16 bit; 15 bits + sign
• Integration time (ms)	20 ms @ 50 Hz, 16.7 ms @ 60 Hz

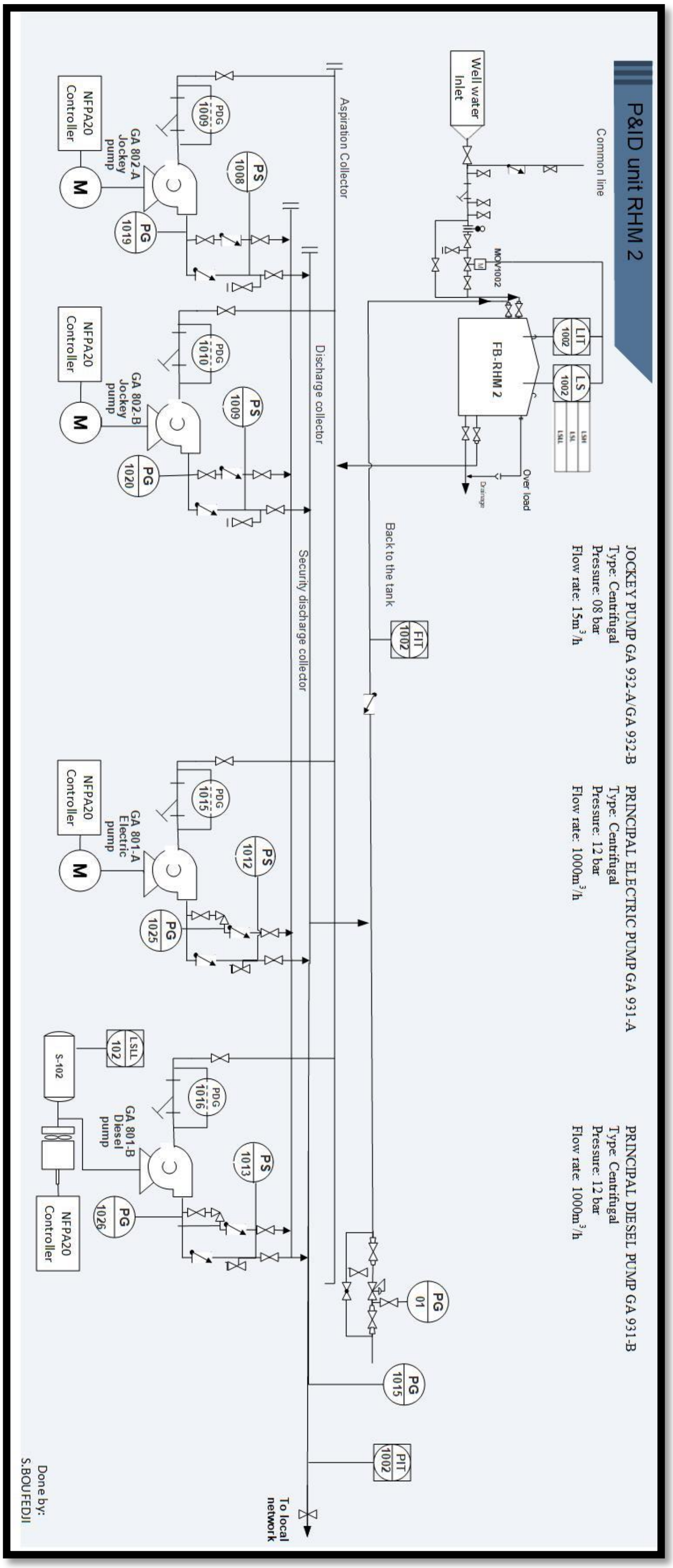
Appendix B: P&ID of CIS
GPL 2



COMP 2

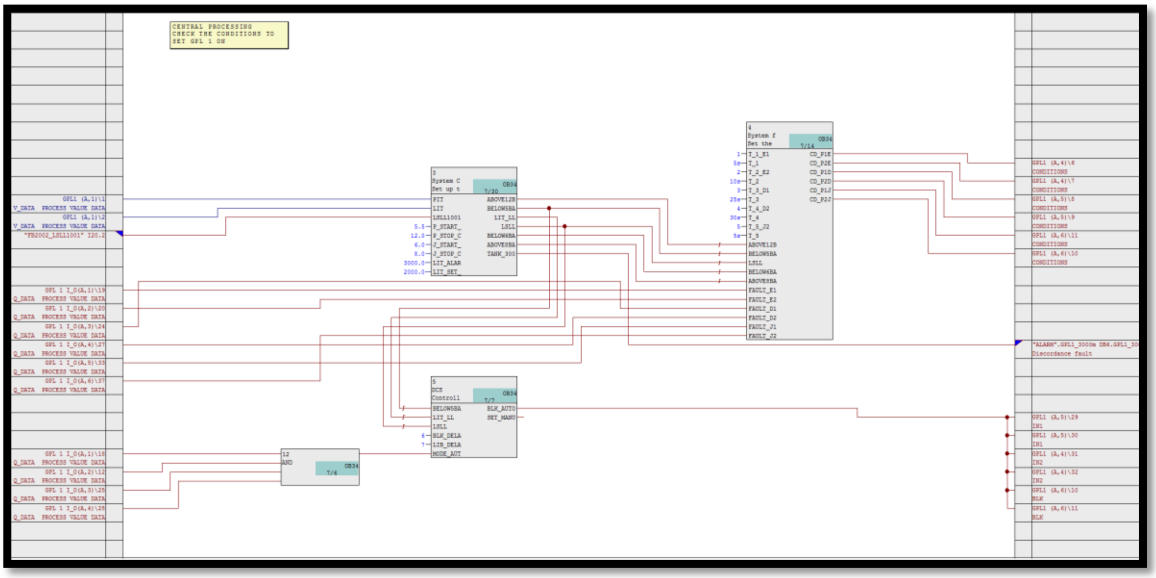

P&ID unit COMP 2
Common line
Well water Inlet
MOV1004
LIT 1004
LS 1004
LSH
LSL
LSLL
FB-COMP 2
Over load
Drainage
Aspiration Collector
Discharge collector
Security discharge collector
Back to the tank
FIT 1004
JOCKEY PUMP GA 1350-A/GA 1350-B
Type: Centrifugal
Pressure: 08 bar
Flow rate: 15m3/h
PRINCIPAL ELECTRIC PUMP GA 1340-A
Type: Centrifugal
Pressure: 12 bar
Flow rate: 1000m3/h
PRINCIPAL DIESEL PUMP GA 1340-B
Type: Centrifugal
Pressure: 12 bar
Flow rate: 1000m3/h
PDG 1012
PS 1011
PG 1021
GA 1350-A Jockey pump
NFPA20 Controller
M
PDG 1013
PS 1012
PG 1022
GA 1350-B Jockey pump
NFPA20 Controller
M
PDG 1013
PS 1010
PG 1023
GA 1340-A Electric pump
NFPA20 Controller
M
LSLL 104
S-104
PDG 1014
PS 1011
PG 1024
GA 1340-B Diesel pump
NFPA20 Controller
PG 01
PG 1015
PIT 1004
To local network
Done by:
S.BOUFEDJI

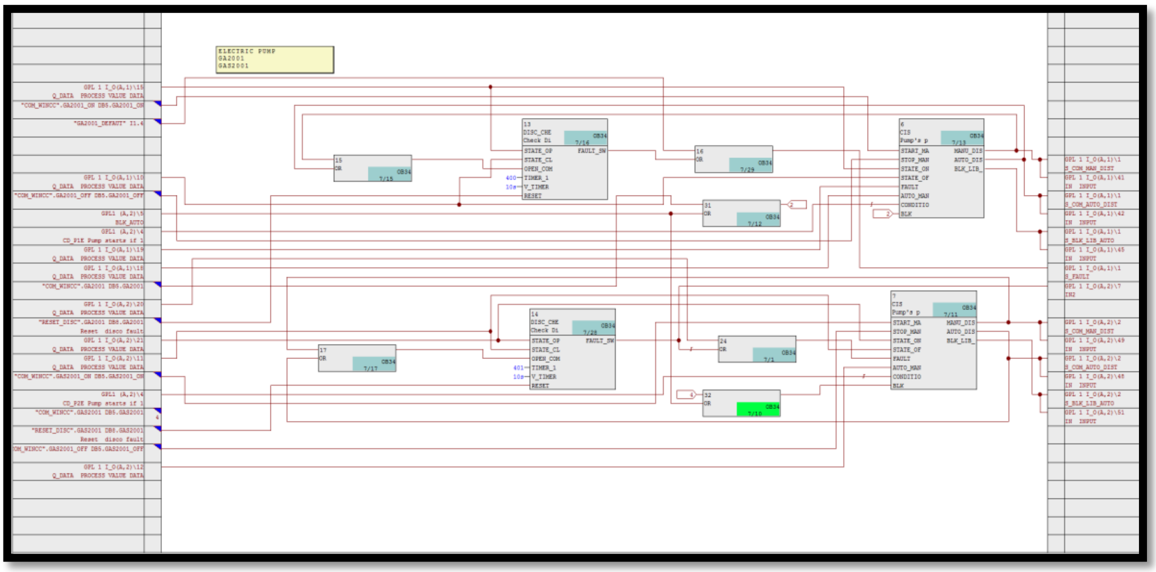
RHM 2

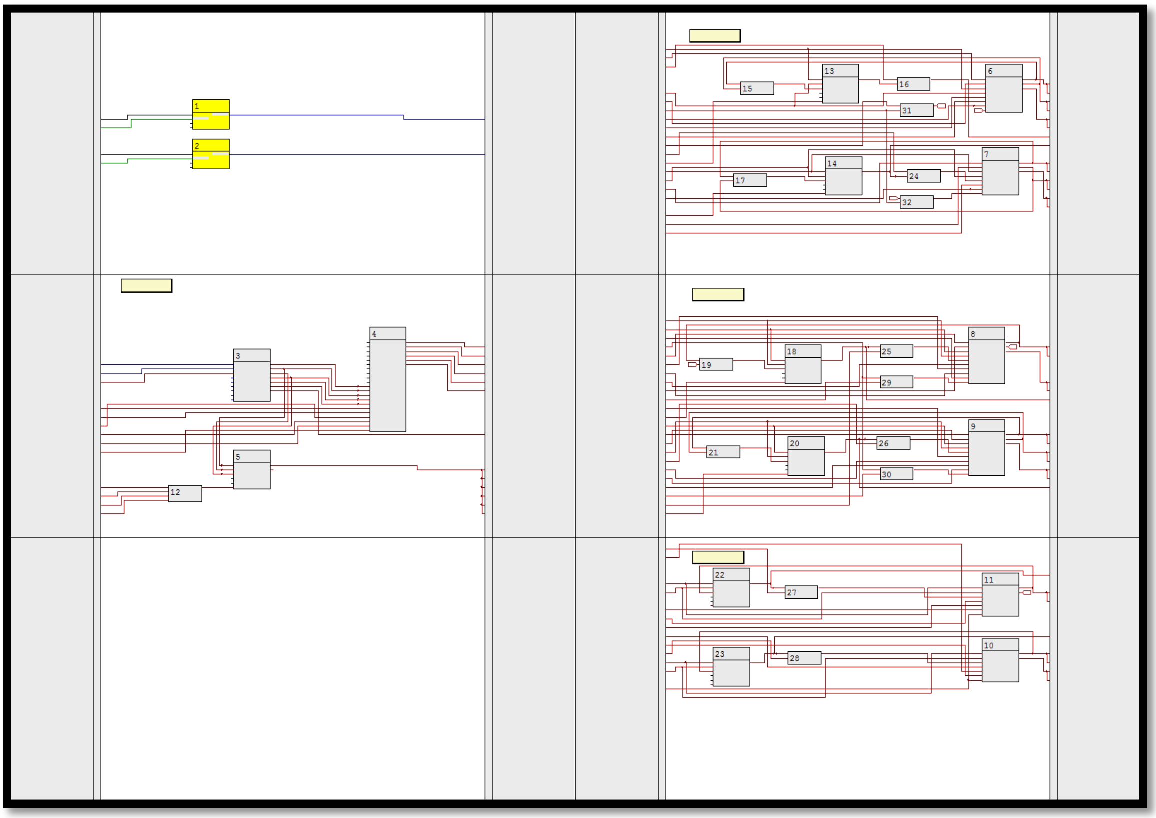

P&ID unit RHM 2
Common line
Well water Inlet
MOV1002
LIT 1002
LS 1002
FB-RHM 2
Over load
Drainage
Back to the tank
FIT 1002
JOCKEY PUMP GA 932-A/GA 932-B
Type: Centrifugal
Pressure: 08 bar
Flow rate: 15m3/h
PRINCIPAL ELECTRIC PUMP GA 931-A
Type: Centrifugal
Pressure: 12 bar
Flow rate: 1000m3/h
PRINCIPAL DIESEL PUMP GA 931-B
Type: Centrifugal
Pressure: 12 bar
Flow rate: 1000m3/h
Aspiration Collector
Discharge collector
Security discharge collector
PDG 1009
PS 1008
PG 1019
GA 802-A Jockey pump
NFPA20 Controller
M
PDG 1010
PS 1009
PG 1020
GA 802-B Jockey pump
PDG 1015
PS 1012
PG 1025
GA 801-A Electric pump
PDG 1016
PS 1013
PG 1026
GA 801-B Diesel pump
LSLL 102
S-102
PG 01
PG 1015
PIT 1002
To local network
Done by: S.BOUFEDJI

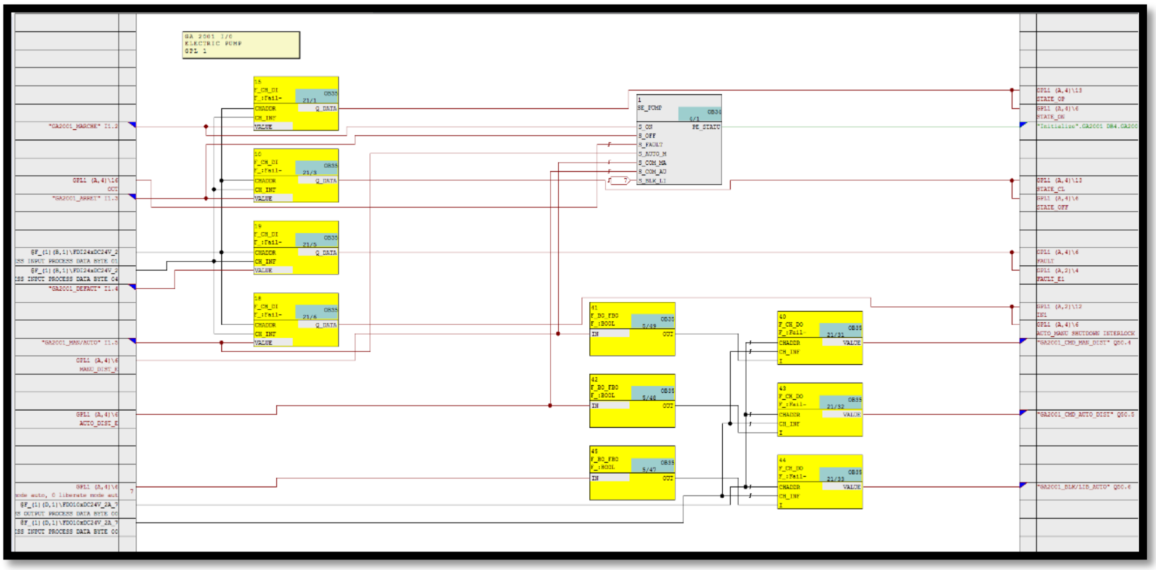
Appendix C

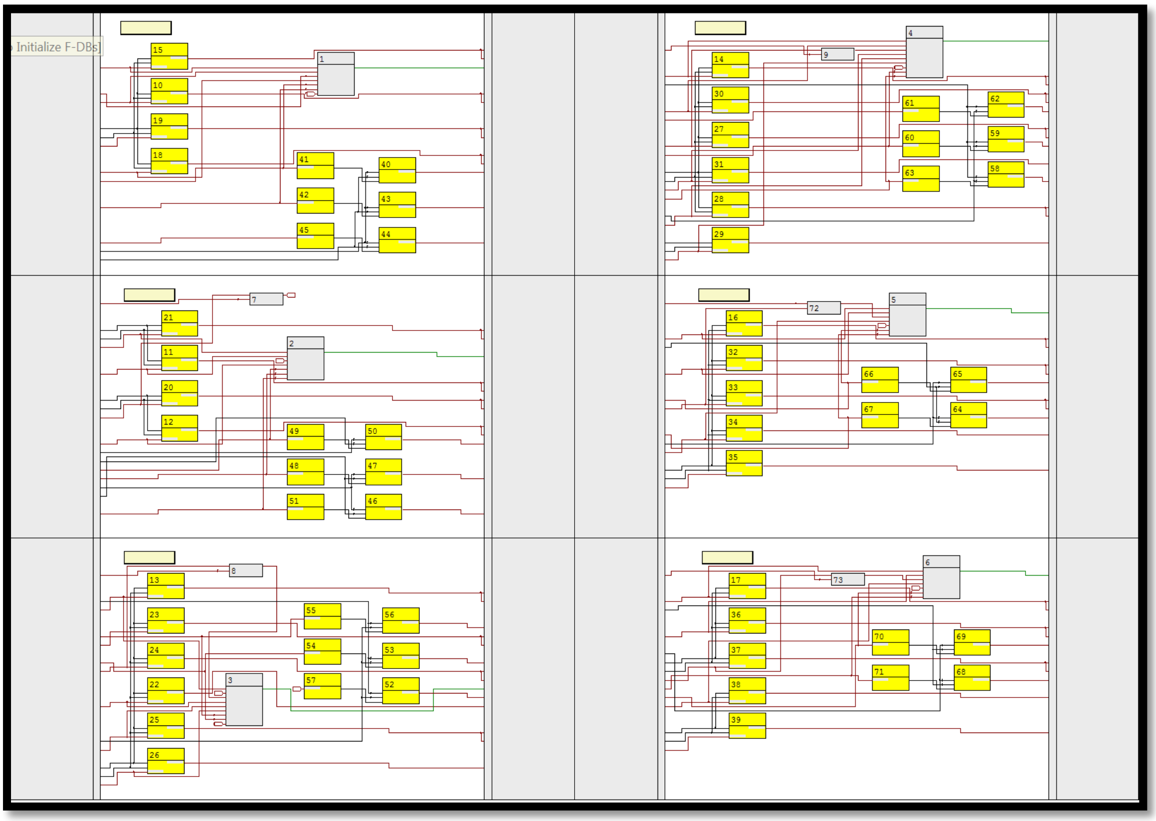
GPL 1: The following figures illustrates the connection of the different blocks constituting the program of GPL 1



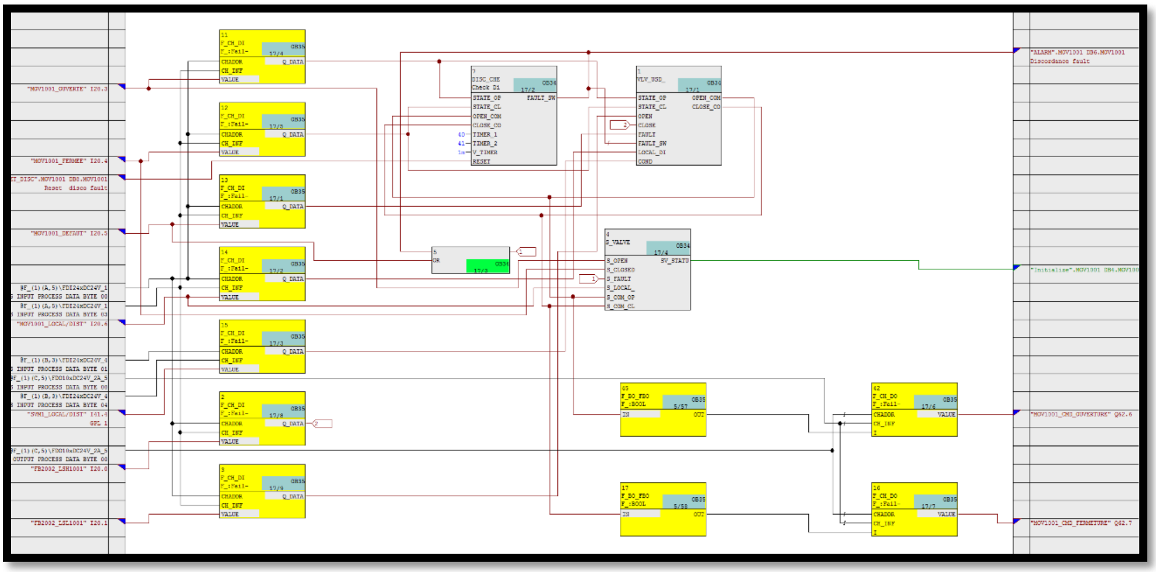








Loading valve: the figure below shows the program of a loading valve



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