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Theme

A Re-Instrumentation Solution Proposition for an industrial Boiler, integrated into a Yokogawa centum VP type DCS System

Presented by

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ملخص

تحتل الجزائر مكانة رائدة في إنتاج الغاز الطبيعي في العالم، حيث تحتل المرتبة الرابعة عالميا والأولى إفريقيا، ويلعب حقل الغاز حاسي الرمل دورا محوريا في إنتاجه. وهذا الحقل معترف به دوليا باعتباره واحدا من أهم احتياطيات الغاز. تركز هذه الأطروحة على الإشراف والمراقبة على الأنظمة الصناعية، والفكرة هي تطوير نظام التحكم الموزع (DCS) والاهتمام بأتمتة غلايات اوبمعنى آخر فرن الشركة الوطنية سوناطراك باستخدام برنامج البرمجة DCS YOKOGAWA CENTUM VP. الهدف الأساسي هو إعادة تشغيل غلاية (فرن) تجديد الجليكول (H301) وتوفير واجهة رسومية تسمح بالتحكم عن بعد، وبالتالي تقليل التدخل البشري. تم وصف العملية اللازمة لمعالجة الغاز في منطقة "حاسي الرمل"MPP3 ، بالإضافة إلى الوصف الهيكلي والوظيفي لنظام تجديد الجليكول.

الكلمات المفتاحية: التحكم، التحكم في النظام الموزع (DCS)، الغلايات الصناعية، حاسي الرمل MPP3، برنامج YOKOGAWA CENTUM VP، سوناطراك ، الجليكول.

Abstract:

Algeria stands among the world's leading natural gas producers, ranking 4th globally and 1st in Africa, with the Hassi R'mel gas field playing a pivotal role in its production. This field is internationally acknowledged as one of the foremost gas reserves. This thesis focuses on the supervision and control of industrial systems, the idea is to develop a distributed control system (DCS) and concerns to automate the boiler of the national company SONATRACH using the DCS YOKOGAWA CENTUM VP programming software. The primary objective is to re-instrument a Glycol regeneration boiler (H301) and provide a graphical interface allowing remote control, thereby minimizing human intervention. The necessary process of gas treatment in the "Hassi R'mel MPP3" area is described, along with a structural and functional description of a Glycol regeneration system.

Keywords: Control, Distributed System control (DCS), industrial boiler, Hassi R'mel MPP3, YOKOGAWA CENTUM VP Software, SONATRACH, Glycol.

Résumé

L'Algérie est classée parmi les principaux producteurs mondiaux de gaz naturel, occupant le4ème rang mondial et le 1er en Afrique, le gisement gazier de Hassi R'mel jouant un rôle crucial dans sa production. Ce champ est reconnu internationalement comme l'une des plus importantes réserves de gaz. Ce mémoire se concentre sur la supervision et le contrôle des systèmes industriels, l'idée est de développer un système de contrôle distribué (DCS) et concerne l'automatisation de la chaudière de la société nationale SONATRACH à l'aide du logiciel de programmation DCS YOKOGAWA CENTUM VP. L'objectif principal est de réinstrumenter une chaudière de régénération de Glycol (H301) et de fournir une interface graphique permettant un contrôle à distance, reduisant ainsi l'intervention humaine. Le processus nécessaire de traitement des gaz dans la zone « Hassi R'mel MPP3 » est décrit, ainsi qu'une description structurelle et fonctionnelle d'un système de régénération du glycol.

Mots clés : Contrôle, Système de contrôle distribué (DCS), chaudière industrielle, Hassi R'mel MPP3, YOKOGAWA CENTUM VP Software, SONATRACH, Glycol.

Dedication

I dedicate this modest work to my symbol of tenderness, who has sacrificed for my happiness and success

To my mother.

To my father, my childhood teacher, who has been my shadow throughout all the years of study, and who has always been there to encourage, help, and protect me.

To my dear brothers and sister for all the complicity and understanding that unite us, I could never express the respect and love I have for you. Your prayers, encouragement, and support have always been a great help to me.

To my dear friends No words or expressions, no matter how eloquent, can express my gratitude and appreciation.

Thank you.

Fidaa

Dedication

dedicate this modest work to my dear family who made me who I am.

To my friends and classmates at the University

and the entire Instrumentation class of the year 2023/2024.

To all those who are dear to me, and who keep me in their hearts.

To my teachers and mentors who have guided me along the way.

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*Our thanks go to the members of the jury for the honor they have bestowed upon us by agreeing to review this modest work, ''****Dr ZEBENTOUT Abdeldjawed, Dr MENDEZ Kheira*** *and* ***Dr BENTAIEB Samia****''*

We express our gratitude to the entire instrumentation team at SONATRACH Hassi-R'mel Module 3.

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IV. : REBUILDING AND HMI DEVELOPMENT FOR ENHANCED BOILER CONTROL

Nomenclature

Nomenclature

A: Alarme

AH: Alarme haute

AL: Alarme basse

AUT: position Automatique

BOOSTING: Station de compression

C: Colonne de distillation

CAS: position Cascade

CNDG: Centre National de Dispatching Gaz

CPU: Control Processor Unit

CTG: Centre de Traitement de Gaz

CTH: Centre de Traitement d'Huile

CSTF: Centre de Stockage et de Transfert des Fluides

DCS: Système de contrôle distribué (Distributed Control System)

E: Aéroréfrigérant/ Echangeur

FCS: Field Control Station

FCU: Field Control Unit

FI: Indicateur de débit

FIC: Contrôleur de débit (Flow Indicator Controller)

GPL: Gaz Pétrole Liquéfier

H: Four

HIS: Human Interface Station

I/P: Convertisseur électropneumatique

I/O Unit: Input/Output Unit

IOM: Input Output Module

K: Compresseur

LC: Logic Chart

LI: Indicateur de niveau

LIC: Contrôleur de niveau (Level Indicator Controller)

MPP: Module Processing Plant

MV: Valeur de la commande (Manipulated Value)

PD: Pression différentielle

PI: Indicateur de pression

P/I: Convertisseur pneumo électrique

PIC: Contrôleur de pression (Pressure Indicator Controller)

PLC: Programmable Logic Controller

PV: Valeur mesurée (Process Value)

SCN: Station de Compression et de réinjection Nord

SCS: Station de Compression et de réinjection Sud

SNC: Station de Compression et de réinjection Nord

SRGA: Station de Récupération des Gaz Associés

ST: Sequence Table

SV: La consigne (Set Value)

TI: Indicateur de température

TIC: Contrôleur de température (Temperature Indicator Controller)

V-NET: Bus de contrôle en temps reel (very high frequency network)

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General Conclusion

In a context of development and progress, companies in the oil and gas production sector, specifically SONATRACH, are increasingly required to automate their production facilities. The supervision of units and machines falls within this scope.

This supervision is an advanced form of Human-Machine interaction, which involves monitoring the operational status of a process, extending beyond traditional operation and monitoring functions with interfaces. The new techniques for renovating industrial installations rely on automation through remote control and supervision systems such as the DCS (Distributed Control System). Consequently, SONATRACH is obliged to supervise its stations using the DCS to improve resource management, reduce delays, and optimize expenses.

To introduce our final year project, it is framed within this context and focuses on developing a solution based on the YOKOGAWA Centum VP DCS to supervise the Glycol Regeneration Unit. The study we conducted is divided into four chapters.

To successfully conduct our study, we first examined the operation, structure, and processing of gas. This was carried out during our practical training at "Hassi R’mel".

Then, in the second chapter, we studied the Glycol Regeneration Unit, which is an essential set of equipment in gas processing modules. We also described the existing control sequence and the various equipment and instruments of the Glycol Regeneration Unit.

For the control and supervision of the boiler, we dedicated the third chapter to presenting the DCS control system we described its architecture, mentioned the various communication networks compatible with this system (DCS), and provided an overview of the Centum VP programming software from YOKOGAWA. This included its main applications, how to create a project on Centum VP, and a presentation of the elements we used.

In the final chapter, we installed a new control panel to improve the management of the system. After conducting simulation tests on centum VP to validate the project, we proposed solutions for the instrumentation that would allow this project to be implemented in the field.

Chapter I

Generalities on Gas Processing in Hassi R'mel

I.1. Introduction

Energy holds a paramount position worldwide, driving Algeria to prioritize its hydrocarbon sector since its nationalization on February 24, 1971. Hydrocarbons are globally recognized as crucial resources, fueling industries and exerting significant influence across domains. The primary goal of producing nations is to maximize reserves recovery and sustain production through various extraction methods. Natural gas, increasingly valued as a clean energy source, ranks second only to oil in demand and is pivotal for environmental preservation. Algeria ranks 4th globally and 1st in Africa in natural gas production, with the Hassi R'mel gas field at the forefront. This chapter explores the location of Hassi R'mel and delves into its significance as one of the world's foremost gas reserves.

I.2. Geographical Location of Hassi R'mel

Hassi R'Mel, located 525 km south of Algiers within the Laghouat province at an altitude of 760 meters, sits amidst a rugged plateau landscape. Characterized by a climate featuring an average humidity of 66.20°C in summer and 34°C in winter, the region experiences significant temperature fluctuations ranging from -5°C in winter to 45°C in summer. Known for its vast reserves, Hassi R'Mel harbors a substantial gas field rich in condensate, with an

Figure I.1. Fields of the Hassi R'mal Wells [1] oil fraction on its periphery. Spanning an expansive area of 3,500 square kilometers (70 km long by 50 km wide), the Hassi R'mel field boasts reserves estimated at over 2800.10^9 3 1 cubic meters

I.3. The Hassi R'Mel Gas Field

The Hassi R'Mel gas field is one of the largest gas fields globally (Figure 1). It takes the shape of anellipse spanning over **3500 square kilometers**, stretching **70 kilometers** from north to south and **50 kilometers** from east to west. Situated at a depth of **2200 meters**, the field has a recoverable capacity estimated at around **3000 billion** cubic meters.

The Hassi R'Mel field contains the following elements:

- **Natural gas**
- **Liquefied Petroleum Gas (LPG) - a gas**
- **in liquid formCondensate - Gasoline - Liquid**

This natural wealth attracts numerous national and international companies for exploitation and investment plans, including SONATRACH, SONELGAZ, ENGTP, GENERAL ELECTRIC, NOUVOPIGNONE, JGC, among others.

Five modules are in place for production: of **natural gas, LPG (C3, C4)**, and condensate **(C5+),** each with a unit capacity of **60 million** cubic meters per day, operational since the late **1970s/early 1980s**.

The oldest module, Module **0**, with a capacity of **30 million cubic meters per day**, is complemented by a sixth module serving the smaller **DJEBEL BISSA** field, with a capacity of **6 million cubic meters per day**,referred to as **the DJB** gas treatment center.

Modules 1 and 0 supplemented by a complementary unit known as "communs," representing Phase 2 ofthese two modules.
The gas treatment modules are connected for the storage of liquid hydrocarbons (**LPG, condensate**) at **theCSTF** and two compression stations for gas reinjection.

The **XP** function involves gas treatment, separation of liquid fractions for better valorization, with aportion of the gas directed for reinjection and the rest designated for sale [1].

Figure I.2 : The gaz field of Hassi R'mal[1]

I.4. Historical Background and Development of the Hassi R'mel Field

- The development of Hassi R'mel has been achieved through various phases in response to the technological advancements in the natural gas market:
- **1961:** Construction of 2 gas treatment units with a capacity of 1.3 billion cubic meters per year.
- **1969:** Addition of 4 additional units to increase capacity to 4 billion cubic meters per year.
- **1972-1974:** Construction of 6 additional units to reach a capacity of 14 billion cubic meters per year.
- **1975-1980:** Successful implementation of the development plan aimed at:
  - ✓ Increasing gas treatment capacity from 14 to 94 billion cubic meters per year.
  - ✓ Maximizing LPG and condensate recovery through partial cycling of dry gas..
- **1985:** Installation of a unit for flare gas recovery and LPG production from modules 0 and 1.
- **1981-1993:** Completion of the oil treatment center.
- **1987-2000:** Commencement of oil treatment center operations.
- **1999:** Installation of the associated gas recovery unit.

- **2000:** Launch of the Boosting project.
- **2005:** Commissioning of the Boosting project.
- **2017:** Installation of the new Phase 3 gas boosting stations in the south, north, and center.
- **2019:**la mise en service des nouvelles stations de boosting phase3.
- **2024:** Launch of the project to install the new Phase 4 boosting stations.

I.5. Presentation of the Sectors of Hassi R'mel

The Hassi R'mel field comprises three sectors:

a. **North Sector:** This sector includes:

- Module 3: supplied by wells from the North, consisting of three identical and independent trains with significant processing capacity.
- A North Compression and Rejection Station.

b. **Central Sector:** This sector includes:

- Three modules: 0, 1, and 4.
- CSTF (Center for Storage and Transfer Facility).
- CTH (Oil Treatment Center).
- Phase B unit.

c. **South Sector:** This sector includes:

- Module 2: identical to Module "3," supplied by wells from the South.
- A South Compression and Rejection Station, identical to the one in the North. Djebel Bissa: a crude gas treatment center.
- HR South: a crude gas treatment center.

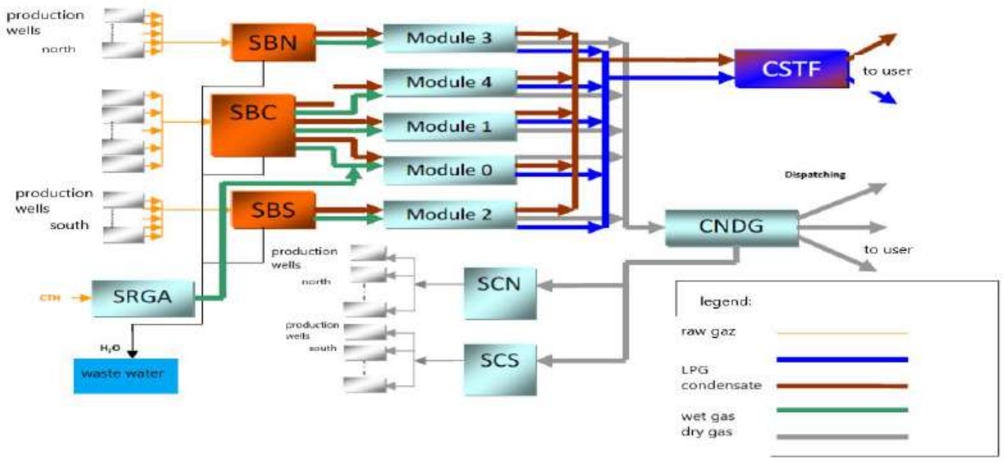


Figure I.3. Diagram of the Industrial Process at Hassi R'mel[5].

The four gas treatment units, 1, 2, 3, and 4, have significant capacity. However, Module 0 and Djebel Bissa have less capacity than the four modules.

The North and South compression centers are designed for dry gas reinjection into injector wells to drive heavy components and reinjection of sales gas or gas for LNG in case of unit problems or maintenance.

Another compression station, called Boosting, is currently in operation. It is designed to increase the inlet pressure of the gas into the gas treatment modules to ensure continuous field gas exploitation. [5]

I.6. General Description of the Hassi R'Mel Operating Direction

At the Hassi R'mel field, there are 8 units, namely:

a. Oil Treatment Center (CTH): This facility comprises a set of equipment for separating all undesirable components from crude oil, before it is dispatched to transport networks.

b. Gas Treatment Center (CTG): This center consists of equipment for the separation and production ofdehydrated natural gas and a mixture of liquid hydrocarbons consisting of condensate and LPG.

c. Central Storage and Fluid Transfer (CSTF): This center is for storing and transferring liquid hydrocarbons. It consists of cylindrical tanks for condensate storage, spherical tanks for LPG storage, a tank gauging system, a system for counting the quantities of condensate and LPG dispatched for commercialization, and a set of pumps for product dispatch.

d. Associated Gas Recovery Station (SRGA): This station is designed to recover associated gases from the CTHsafter processing and stabilizing crude oil. It mainly consists of turbo compressors to raise the pressure of associated gases and dispatch them to Module 4 for processing with crude gas.

e. Module MPP: Short for "module processing plant" (MPP), it refers to a processing unit comprising equipment designed and built to enable specific treatment of crude gas to produce natural gas, condensate, and LPG according to an appropriate process and commercial specifications.

f. Boosting: The inlet pressure of crude gas to the modules decreases over time, affecting the quantity and quality of products in each category and gas treatment units, as they are designed to operate at a minimum pressure of 100 bars at the inlet. The role of Boosting stations is to compress these crude gases from wells to have significant expansion and thus better separation. The compression and reinjection station in the northern sector has a capacity of 90 million cubic meters per day of dry gas. The compression and reinjection station in the southern sector is identical to that in the northern sector.

The gas treatment center (CTG/DJEBEL-BISSA) has a processing capacity of 4 million cubic meters per day [2].

I.7. Presentation of Module 3

The Module 3, where we completed my induction internship, is a natural gas processing plant located south of Hassi R'mel, 23 km away from the city center. It was commissioned in 1979. The facilities of this module are designed to recover heavy hydrocarbons (condensate and LPG) from the gases collected from 39 feed wells. Module 3 comprises the following :

- 3 identical processing trains.
- 1 common area (manifold, degassing, storage, and transfer).
- 2 glycols units.
- 1 utilities unit (inert gas, water treatment, and air compression).
- Boosting.

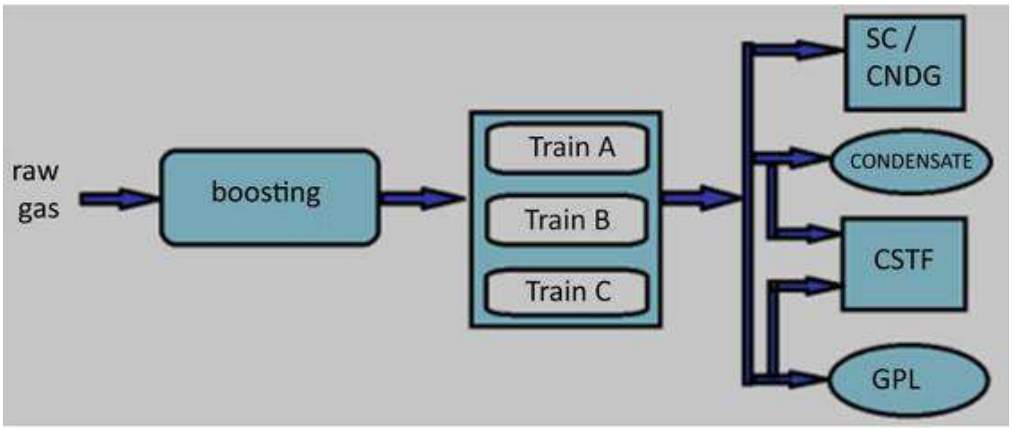


Figure I.4. General descriptive diagram of module 3[2]

I.7.1. Exploitation Service

The Exploitation Service typically refers to the operational aspect of resource extraction in industries suchas oil and gas. Some of the key functions of the Exploitation Service include:

a. **Resource Management:** This involves planning and managing the extraction of resources in a manner that maximizes production while minimizing costs and environmental impact. It includes determining optimal extraction methods, scheduling production activities, and allocating resources efficiently.

b. **Well Operations:** The Exploitation Service oversees the operation and maintenance of wells used for resource extraction. This includes drilling new wells, completing and stimulating existing wells, and monitoring well performance to optimize production.

c. **Production Optimization:** The service is responsible for optimizing production processes to maximize output and efficiency. This may involve implementing production enhancement techniques, managing reservoir pressure, and addressing production bottlenecks.

d. **Safety and Compliance:** Ensuring safety and regulatory compliance is a critical aspect of the Exploitation Service. This includes implementing safety protocols, conducting risk assessments, and adhering to environmental regulations to minimize hazards and mitigate risks associated with resource extraction.

e. **Data Analysis and Reporting:** The Exploitation Service collects, analyzes, and reports data related to production operations. This includes monitoring production rates, analyzing reservoir performance, and providing regular reports to stakeholders on production metrics and performance indicators.

I.7.2. Maintenance Service

The Maintenance Service is a critical component of industrial operations, responsible for ensuring the reliability, safety, and efficiency of equipment and facilities. Here are some key aspects of the Maintenance Service:

a. **Preventive Maintenance**: This involves regular inspections, servicing, and repairs conducted according to a predetermined schedule to prevent equipment failures and minimize downtime. Preventive maintenance tasks include lubrication, calibration, and replacement of worn components.

b. **Corrective Maintenance:** Corrective maintenance involves repairing equipment after a failure has occurred. Maintenance technicians respond to equipment breakdowns promptly to restore functionality and minimize production disruptions. Corrective maintenance may involve troubleshooting, repair, and replacement of faulty components.

c. **Safety Compliance:** Maintenance activities must adhere to safety regulations and protocols to ensure the well-being of personnel and the integrity of equipment. Maintenance technicians receive training on safety procedures, use appropriate personal protective equipment (PPE), and follow established safety guidelines when performing maintenance tasks.

d. **Documentation and Reporting:** Maintenance Service personnel maintain detailed records of maintenanceactivities, including work orders, inspection reports, and equipment histories. Accurate documentation facilitates compliance with regulatory requirements, informs decision-making, and provides a basis for continuous improvement initiatives

I.7.3 Security Service

The security service is responsible for ensuring the safety of personnel and equipment withinthe module (prevention and intervention) [2].

I.8. Gas Processing Method

It consists two processes [5]:

I.8.1"HUDSON" Process:

It is based on gas cooling through thermal exchange and a series of expansions. First, there is an expansion at the JOULE THOMSON (JT) valve level, which allows reaching a temperature of -15°C, followed by another expansion performed at a dynamic machine called a turbo- expander, where a temperature of -35°C is achieved. The turbo-expander is more efficient as itallows for better recovery of liquid hydrocarbons. It has an autonomous cooling system.

In Module 3, the "HUDSON" process is used.

I.8.2 "PRITCHARD" Process:

It is based on gas cooling through thermal exchange and expansion using a propane loop as arefrigeration system to finally reach temperatures around -23°C [5].

I.9. Description of the Gas Processing Process

Following the pressure drop in the HASSI R'mel field, the raw gas passes through a section called the Boosting Section (SBC), placed three years ago. Its role is to increase the pressure of theraw gas to ensure the proper functioning of the modules in the central sector.

The parameters of the gas leaving the Boosting unit are: suction pressure 70 Kg/Cm2, discharge pressure 121Kg/Cm2, T = 65°C. Then it passes through the D001 vessel where it isdistributed into three identical loads to feed each of the module's trains [6].

I.10. Description of a Train Process

Module 3 is a processing plant; it consists of three trains A, B, and C, each of which producesthe following products: CONDENSATE, LPG, and DRY GAS, **Figure I.5.** Illustrate the diagram of the Process.

The three trains operate in the same manner; therefore, we will describe the process of one ofthese trains: TRAIN A (for example).

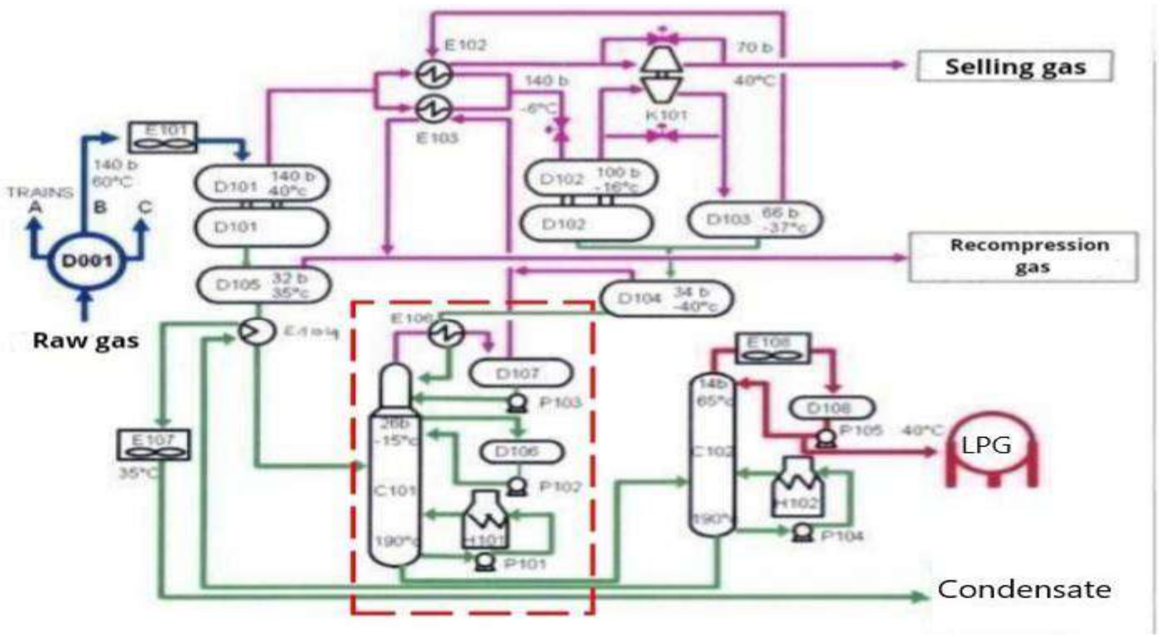
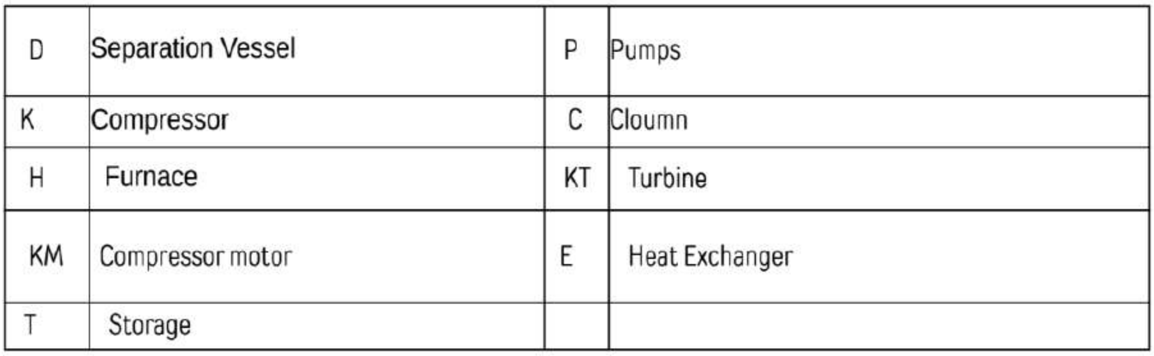


Figure I.5. Diagram of the process[5]

The nomenclature of the different compartments of a train is defined as follows:



D	Separation Vessel	P	Pumps
K	Compressor	C	Cloumn
H	Furnace	KT	Turbine
KM	Compressor motor	E	Heat Exchanger
T	Storage		

Table I.1. Abbreviations of the diver

a. High-Pressure Section

The raw gas is cooled by a battery of air coolers (E101 A-K) from 60°C to 40°C and then directed to the vessel (D101 A-B) for the initial separation of heavy hydrocarbons (liquids), light hydrocarbons (gas), and water based on product density. The gas exiting the separator head passes through the series of heat exchangers, E102AB/CD/EF, and E103AB, arranged in series to cool the gas on the tube side with cold gas counter-flowing on the shell side, resulting in an outlet temperature of around -6°C, controlled by a regulating valve (TRC102) that adjusts the gas flow bypassing the shell side. The gas exiting the heat exchangers (pressure 107Kg/Cm2) passes through an expansion called the JT valve (PRC 108), and the pressure drops to 100Kg/Cm2 followed by a temperature drop to around -14°C, then directed to another vessel (D102 A-B) for a second hydrocarbon separation. To prevent hydrate formation in the heat exchanger tubes, a solution of 80% mono ethylene glycol and 20% water (by mass) is injected at the tube inlet. The gas from the vessel feeds the Turbo-Expander (K101), undergoesan isentropic expansion. The machine rotates due to gas pressure at a speed of around 9500 rpm. The gas/liquid mixture obtained at the machine outlet is collected in vessel D103 (P=65Kg/Cm2, T= -35°C) after separation. The gaseous phase passes through the shell side heat exchangers E102 and then compressed through the Turbo-Expander (compressor side) to 72Kg/Cm2 and sent to the national gas dispatching center for potential sale to the customer.

b. Low-Pressure Section

The liquid hydrocarbons discharge from (D101) under the control of the level regulating valve (LIC101A) undergo flashing down to a pressure of 32 Kg/cm2 and a temperature of 30°C at the rich condensate separation vessel (D105). It's worth noting the presence of a second regulating valve (LIC 101 B) at (D101), which will open for the discharge of off-spec liquid hydrocarbons to a storage buffer vessel (D003 A) for reprocessing. The dry gas discharged from the head of vessel (D105) will be dispatched under the control of the pressure regulating valve (PIC 116) to the heat exchanger battery (E103 AB) on the shell side, then directed to the recompression station (K002) to increase the pressure and send it to the sales gas network. The liquid hydrocarbons from vessel (D105) pass through a liquid\liquid exchanger (E104), shell side to be preheated under the control of the valve (TIC 104) to a temperature around 120°C and will feed the column (C 101). The liquids recovered from vessels (D102) and (D103) are directed to vessel (D104) and then to the upper section of deethanizer C101 (cold side). The gas from separator D104 and that from the reflux accumulator of deethanizer D107 pass through heat exchanger E103 to cool the raw gas and then flow to the recompression section K002.

c. Fractionation Section

The main function of this section is to obtain condensate and LPG from condensed hydrocarbons, fractionation is performed by two separation columns: the deethanizer and the debutanizer. The liquid hydrocarbons from vessel D104 at a temperature of -40°C and a pressure of 30 bars are preheated in the reflux exchanger E106 and then fed to the deethanizerthrough the 5th tray. The hydrocarbons from separator D105 at a temperature of 25°C and a pressure of 32 bars are preheated in the feed exchanger E104 and then fed to the deethanizer at the 21st tray. The gas exiting the deethanizer head passes through condenser E106, the condensed liquids are separated from the gas at the reflux accumulator vessel D107, to preventhydrate formation in the vessel, glycol solution injection is provided. The liquid descending from the upper trays accumulates in the accumulator tray, from which it gravity flows to separator D106, which allows gas/hydrocarbon/glycol separation, pump P102 ensures the return of hydrocarbons to the column at the 13th tray of the lower part of the deethanizer. From the bottom of the deethanizer, a quantity of liquid flows to the reboiler H101 via pump P101, to be heated up to 150°C then returns to column C101, the other quantity will feed column C102 (Debutanizer) at the 21st tray.

- **Deethanizer**

The liquid hydrocarbons from vessel D104 at a temperature of -40°C and a pressure of 30 bars, are preheated in the reflux exchanger E106 and then feed the deethanizer through the 5th tray. The hydrocarbons from separator D105 at a temperature of 25°C and a pressure of 32 bars, are preheated in the feed exchanger E104 and then feed the deethanizer at the 21st tray. The gas exiting the deethanizer head passes through the condenser E106, the condensed liquids are separated fromthe gas at the reflux accumulator vessel D107, to prevent hydrate formation in the vessel, a glycol solution injection is provided. The liquid descending from the upper trays accumulates in the accumulator tray, from which it gravity flows to the separator D106, which allows gas/hydrocarbon/glycol separation, pump P102 ensures the return of hydrocarbons to the column at the 13th tray of the lower part of the deethanizer. From the bottom of the deethanizer, a quantity of liquid flows to the reboiler H101 via pump P101, to be heated up to 150°C then returns to column C101, the other quantity will feed column C102 (Debutanizer) at the 21st tray.

- **Debutanizer**

The overhead vapors are fully condensed in the reflux cooler E108 to enter the reflux accumulator D108, the liquid pressure exiting the accumulator increases under the action of pump P105. Part ofthis liquid returns as cold reflux to the first tray of Debutanizer C102, the other part constitutes the produced LPG, it is sent to the Fluid Storage and Transfer Center "FSTC". A quantity of the bottom product of the Debutanizer will be transferred by the pump P104, to the reboiler H102 from where itexits with a temperature of 200°C then returns to the lower part of column C102 [5].

l.11. Conclusion

In this chapter, we have presented the HASSI R'MEL field and specifically module 3 (MPP3) and its functional organization. This overview allowed us to understand that gas production involves the use of various treatment techniques, equipment of different technologies, and parameter adjustments. A prominent issue at this site is the lack of automation for some instruments, particularly, especially the boiler, which serves as the site's heartbeat. To unravel this issue, we propose a re-instrumentation of the boiler. In the next chapter, we will unveil the boiler's secrets, describing, defining, and detailing its various characteristics.

Chapter II

Structural and Functional Description Of A Glycol Regeneration Boiler

II.1. Introduction

The glycol regeneration unit is an essential set of equipment in gas treatment modules. It heats the glycol that has absorbed water in order to achieve a solution concentration of 80% by weight. The operating and safety sequences are managed by a relay system. Triggering factors are integrated at different levels for maximum protection of this equipment. We will get into descriptions of glycol, its properties, and the entire glycol regeneration process, including the workings and functions of the boiler and its associated instruments. The reliability of relay systems is limited compared to the advantages offered by a programmable logic controller (PLC):

- Less bulky installation and wiring.
- Short response time.
- Quick fault localization.

II.2. Unit description of glycol

A solution of monoethylene glycol (chemical formula $C_2H_6O_2$) is injected into each module train to

- Remove water contained in the liquid gas.
- Prevent the formation of hydrates and frost in the piping.
- Reduce the water content in the treated gas.

II.2.1. Glycol injection part

It allows for mixing pure glycol and water to obtain an 80% by weight glycol solution. Monoethylene glycol (liquid) is first poured into the sump after increasing the pressure of this liquid using the dehydration pump P204. It is then directed to the glycol storage tank T201. The process of preparing the 80% by weight glycol solution involves:

- Adding potable water to the glycol storage tank while monitoring the flow indicator FI-202, with an approximate mixing ratio of 3L of water to 6L of glycol.
- Mixing the glycol and injected water in the tank (T201) using the booster pump (P202) and sprayers.
- Measuring the glycol concentration of this solution through sampling.

- Sending the glycol solution to the injection part and the regeneration part by operating the booster pump P202 or pump P204. The glycol storage tank must always be filled with the booster solution."

II.2.2. Regeneration part

The unit is supplied from various separators where the glycol has been collected after its use for hydrate prevention. The monoethylene glycol, at 73.5% by weight, is preheated from 3°C to 57% by heat exchange with the glycol in the reflux vessel of the unit (D302). The MEG leaving (D302) reaches a temperature of 61°C by heat exchange with the glycol regenerated in heat exchangers No. 2 and 3 (E303 A/B). It is then sent to the oil separator D301, where it is rid of entrained natural gas, and the hydrocarbon condensate is separated from the glycol. The separator pressure is maintained at 4.22 kg/cm2G using a pressure regulator PIC-301. The hydrocarbon condensate is removed from the overflow pipe by a level regulator LC-301 and sent to the burn pit F405.

The glycol from the separator goes to one of the glycol filters S302 A or B. Each filter is designed to filter out 100% of the debris and to remove particles equal to or greater than 5 microns. A side draw of 5 to 10% then goes to the activated charcoal glycol filter S303. This filter removes some dissolved hydrocarbons and certain fine particles that were not removed by the glycol filters.

The rich glycol is then heated by the hot lean glycol in the glycol heat exchanger E302 to a temperature of 84°C before entering the distillation column C301. In the distillation column, the glycol mixes with the reflux on the 3rd tray from the top of the column and comes into contact with the hot water vapor generated in the glycol regenerator H301. A certain amount of water is removed on the perforated trays, and the glycol is heated to a temperature close to that of the regenerator.

The steam from the distillation top products from the column goes at 99°C to the reflux condenser of the regenerator E301, where it cools to 100°C and 848 kg/h of steam are condensed and received in the accumulator D302. Approximately 800 kg/h of rich glycol is used to cool the reflux to 65°C before being returned to the top tray of the distillation column using the regenerator reflux pumps P302 A or B.

The glycol regenerator H301 purges the remaining water at 123°C and about 0.17 kg/cm2G. The regenerated glycol is then sent to the bottom pump of the regenerator P301 A or B at about 40°C through the heat exchangers E302, E303 A and B, as described above, and it is pressurized to at least 2.0 kg/cm2G and returned to the glycol buffer vessel D202 or to the glycol storage tank T201 using the level controller LIC-303. A bypass around the exchangers E303A and B allows the temperature of the regenerated glycol to be adjusted to 80% by weight.

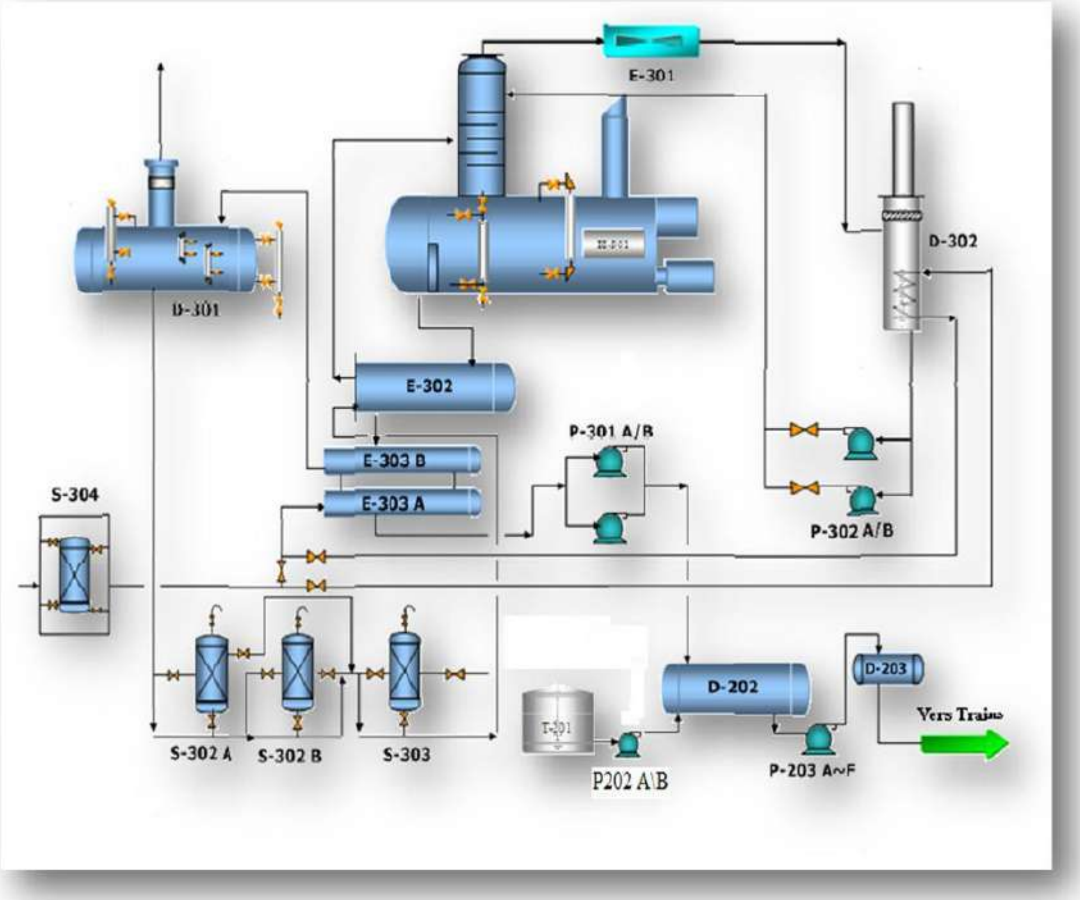


Figure I.6. Glycol regeneration process[6]

II .2. GENERAL DESCRIPTION OF THE GLYCOL REGENERATION UNIT

The glycol regeneration unit is an important part of module 3 and is mainly composed of:

- Boiler section
- Control and signaling section
- Air blower
- Filters and tanks
- Heat exchangers

II .2.1. Boiler Section H301

This section contains the following elements, as shown in **Figure II.1(a, b)**:

- Distillation column C301
- 3 pilots
- 3 burners

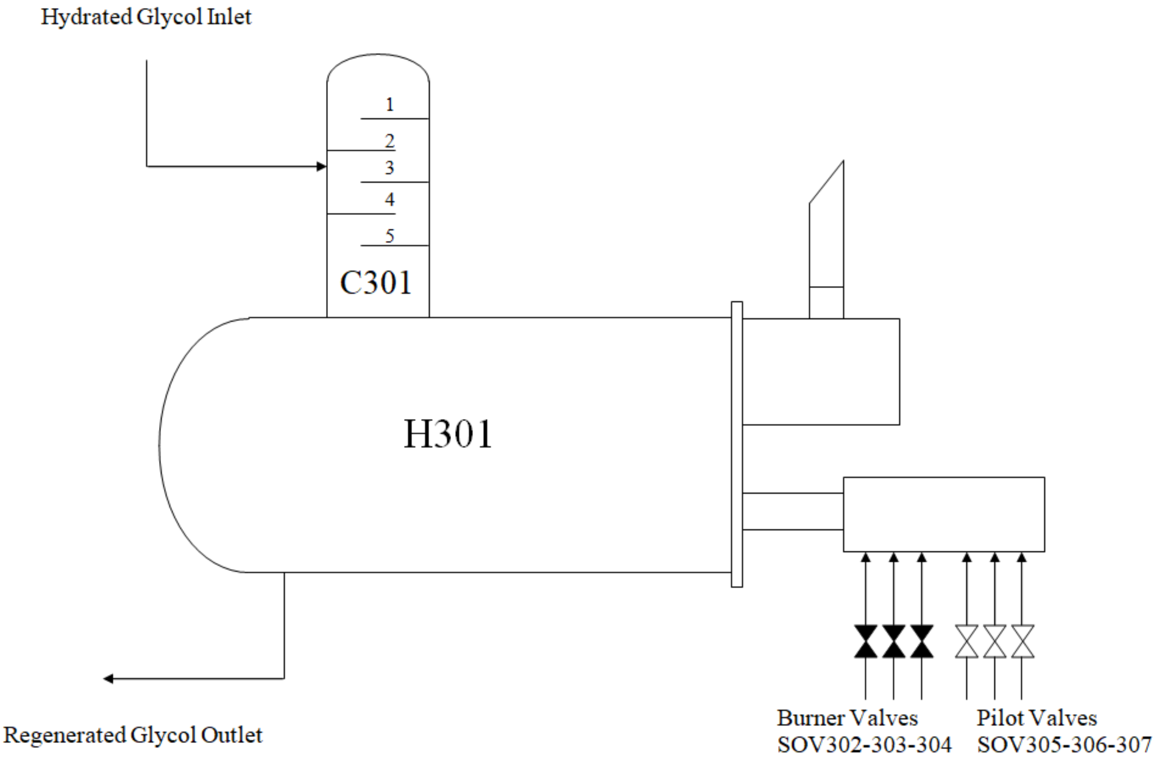


Figure II.1.a. Boiler H301[7]

Figure II.1.b. Real picture of Boiler H301

II .2.2. Control And signaling Section

The control of the unit is managed from the local panel (**Figure II.2. (a, b)**). The startup sequence is carried out in several steps, which are indicated by indicator lights on this panel (purge position, complete startup condition, purge finished, etc.).

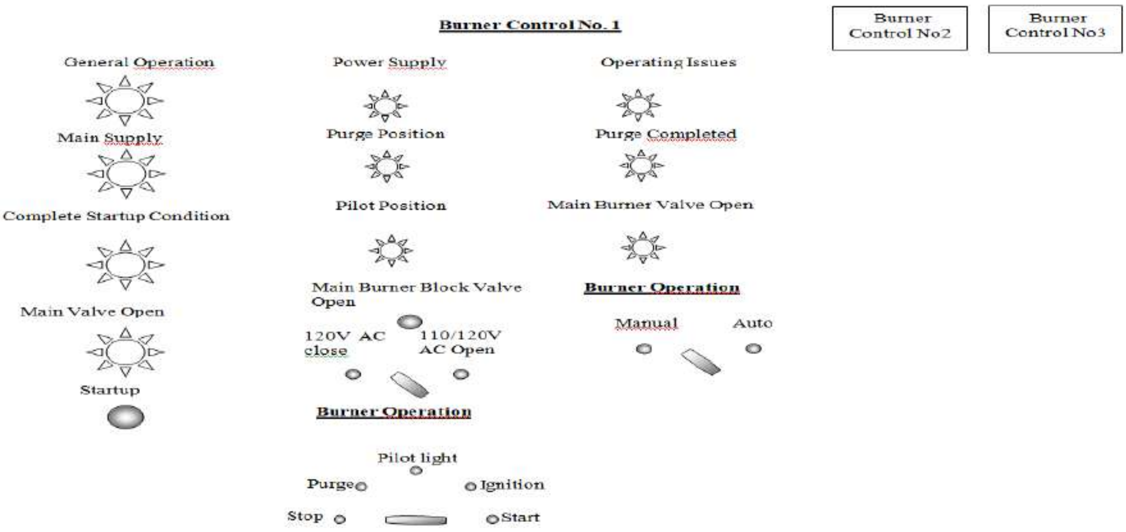


Figure II.2.a. Control and Signaling Panel [7]

Figure II.2.b. Real picture of Control and Signaling Panel

II .2.3. Air Blower

The unit is equipped with 2 air blowers (figure II.3), one operating and the other on standby. The blower is used to purge the inside of the furnace before each startup. This procedure is crucial for the safety of the furnace and its installations.

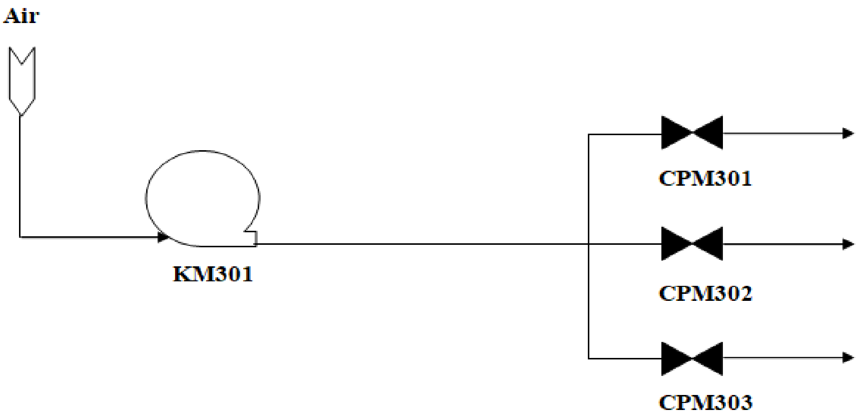


Figure II.3. Air Blower KM301[7]

II .2.4. Filters and Balloons

a. Filters S302A/B and S303:

They absorb liquid hydrocarbons and degraded components dissolved in the solution.

b. Tanks D301, D302, and D202:

- **Tank D301:** Oil separator where the glycol solution separates from liquid and gaseous hydrocarbons based on density.
- **Tank D302:** Collects water vapors exiting column C301, which are then cooled and condensed in this tank.
- **Tank D202:** Collects the regenerated glycol.

Figure II.4. Real picture of Tanks

II .2.5. Heat Exchangers E303A/B, E302, and E301

- E303A/B: Preheat the incoming feed from the three trains (tube side) to raise the temperature from (-8°C) to (+40°C). They also cool the regenerated glycol (shell side).

- E302: Heat the feed exiting the filters (tube side) up to 80°C to supply column C301. It also cools the regenerated glycol (shell side).
- Air cooler E301: Cools the water vapors exiting column C301. [7]

II.3. Description of the gas fuel circuit

The combustible gas flows through a main line, and the pressure of this gas is controlled by a pressure control valve PCV-306 and an emergency shut-off valve UZ-304. Then, this line branches out into two different circuits:

II.3.1. Main Burner Circuit

The flow of gas through this circuit is controlled by on/off valves (SOV302, SOV303, SOV304) operated in sequence.

II.3.2. Pilot Circuit

The flow of gas through this circuit is controlled by the pressure control valve PCV-305 (**Figure II.5**) and by the on/off valves (SOV305, SOV306, SOV307).

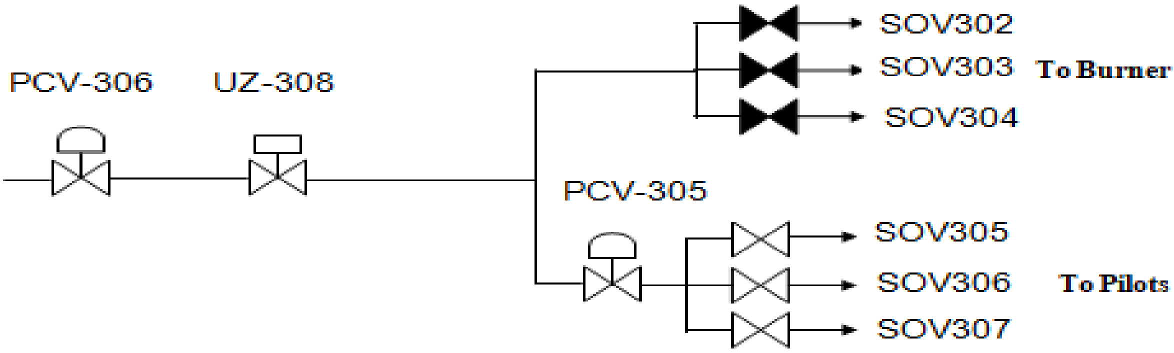


Figure II.5. Gas Fuel Circuit H301[7]

II.5. Commissioning

II.5.1. Preparation

- Boiler filled with glycol.
- Gas fuel circuit.
- Electrical supply on.

- No trigger alarms displayed.

II.5.2. Startup Of Furnace H301

1. **Gas Fuel Circuit:**
   - Adjust pressure (PG308) to 1.5 kg/cm2 and (PG310) to 600 mmH2O.
2. **Local control panel:**
   - Purge air pressure at 80-100 mmH2O.
   - Main power button in "IN SERVICE" position.
   - Press "START PURGE PANEL" button.
   - After 20 minutes, the "MAIN POWER" lamp lights up.
3. **Air Purge of the Furnace:**
   - Turn the burner power button to the "ON" position (circuit power lamp lights up).
   - Place the CPM valve in the "PURGE" position (manual) so that the purge lamp lights up.
   - Start air blower K301A or B and set the setpoint to 250 mmH2O (PIC309).
4. **Startup of Regenerator H301:**

   If no triggering factor is displayed (the "complete startup condition" lamp lights up):

   - Press "START REGENERATOR" button.
   - Rearm the main gas fuel valve (UZV_308).

   Red lamp "MAIN VALVE OPEN" lights up.

5. **Burner Ignition:**
   - Open the CPM valve and turn the burner selector to the "PURGE" position for 3 minutes ⟶ the "PURGE COMPLETED" lamp lights up.
   - Close the CPM valve until the switch gives ⟶ the "PILOT POSITION" lamp.
   - Turn the selector from the purge position to the pilot position, after 10 seconds of priming ⟶ the pilot light lights up, and the "FLAME DETECTION" lamp lights up (check the flame).
   - Turn the selector knob to "IGNITION".
   - Open the gas fuel block valve to ignite the burner (check the flame).
   - Switch the burner function from MAN to AUTO.

Note:

- If the pilot does not ignite, turn the selector to the "PURGE" position and retry ignition.
- Increase the heat by controlling the CPM valve (manually).
- Proceed to ignite the other burners using the same procedure.
- At 100°C, switch the CPM valve control from MANUAL to REMOTE.

To achieve a good flame, adjust the Air/Gas ratio by adjusting the damper. [7]

II.6. Electrical Startup Sequence

II.6.1. Electrical Supply

The unit's electrical supply is 110V AC uninterrupted, coming from substation 22. It is protected at the panel level by cable fuses.

II.6.2. Panel Purge:

The control circuit for the sequence is powered only after the local panel purge, simply to sweep the gases inside the panel. The circuit below represents this procedure:

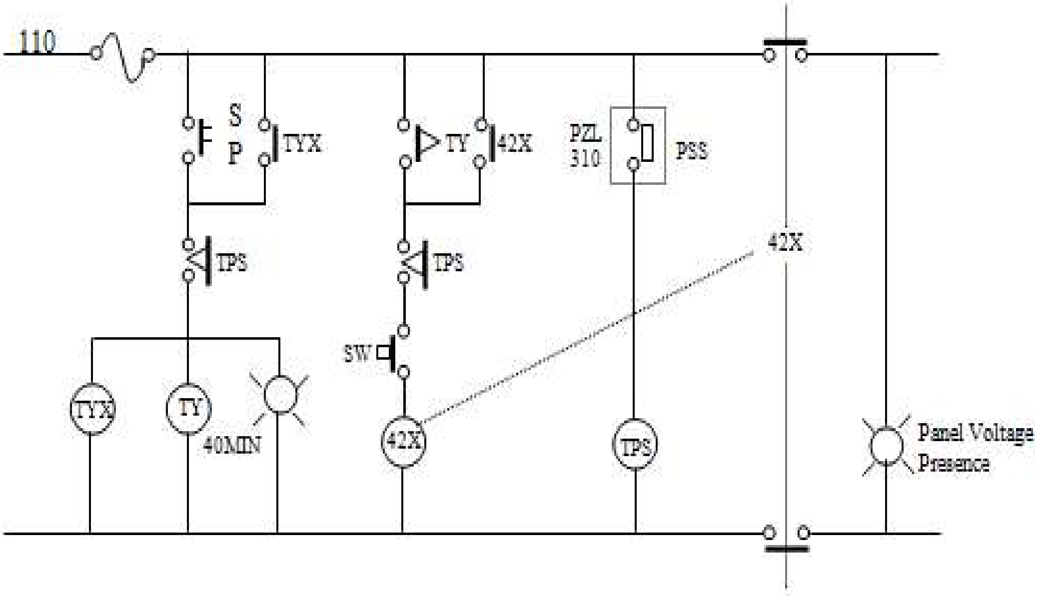


Figure II.6. Panel Purge[7]

- SP: Start push button for panel purge.
- SW: Stop push button for purge.
- TY: Timer for purge stop.
- TY: 40-minute timer.

  - PSS: Pressure switch for panel pressurization (PZL310).
  - 42X: Contactor.
- Startup relays and triggering factors:
  - RAPS: PZL308; Low combustion air pressure.
  - RGPH: PZH304; High fuel gas pressure.
  - RGPL: PZL304; Low fuel gas pressure.
  - RTH: TZH302; High temperature in combustion chamber.
  - RWLS: LZL304; Low level in boiler (H301).

When the SP (Start Push Button) is pressed, it energizes the TYX relay, initiating the purge cycle. The TY (Purge Timer) and 40-minute timer start, while the PSS (Pressure Switch) ensures safe pressurization. The 42X contactor allows power flow, sustaining the process. If any safety conditions monitored by RAPS, RGPH, RGPL, RTH, or RWLS are triggered, the system responds accordingly to prevent hazards. Pressing the SW (Stop Push Button) de-energizes the TYX relay, stopping the purge and resetting the system

II.6.3. Boiler Startup Conditions:

The boiler can only start if the following conditions are met:

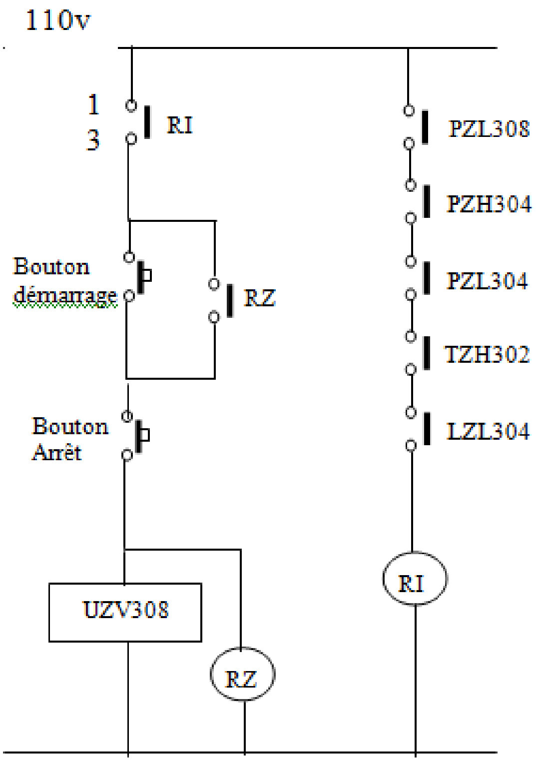


Figure II.7. Boiler H301 Startup Conditions[7]

When the Bouton démarrage (Start Button) is pressed, it energizes the RZ relay, which then maintains its state through its own contact. This allows the RI relay to be activated, completing the circuit. The circuit remains active until the Bouton Arrêt (Stop Button) is pressed, which de-energizes the RZ relay, breaking the circuit and deactivating the RI relay. Safety switches (PZL308, PZH304, PZL304, TZH302, LZL304) monitor critical conditions and will de-energize the RI relay if any unsafe condition is detected.

Note:

If any of these factors occur, relay RI will de-energize, opening its contact (3-1), which will cause the main Fuel-Gas valve (UZV308) to close.

II.7. Pilot Ignition Procedure

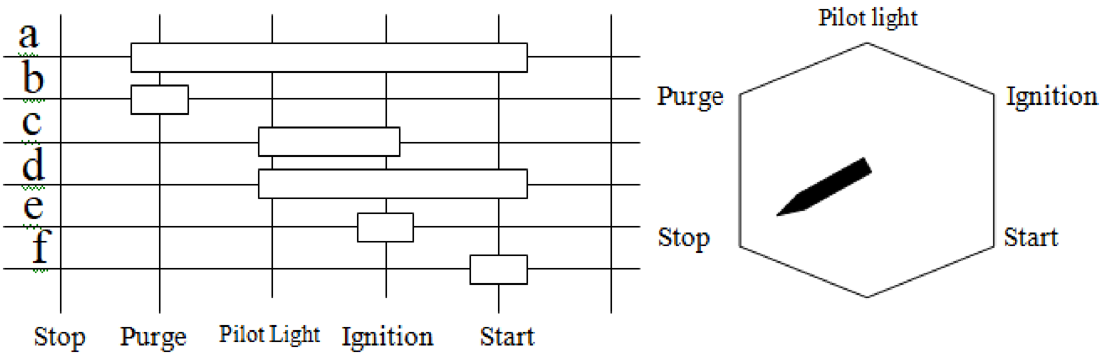


Figure II.8. Pilot Ignition Procedure. [7]

The diagram shows the operational phases of a burner control system. Starting from the Stop phase, the process moves to Purge, clearing any residual gases. Next, the Pilot Light ignites to prepare for the main Ignition phase. After ignition, the system enters the Start phase, indicating full operation. The timing chart on the left details the duration of each phase for different components, while the control sequence diagram on the right visualizes the step-by-step progression from Stop to Start.

After the startup conditions are established, the pilots and burners will be ignited as follows:

a. Purge Position

Set the selector (SC) to the purge position while fully opening the CPM valve; this activates Timer PT-1 (burner No. 1).

after 5 seconds, its contact will cause the relay RI-1 to energize, lighting up the LPC-1 lamp (purge completed). The circuit below represents this procedure:

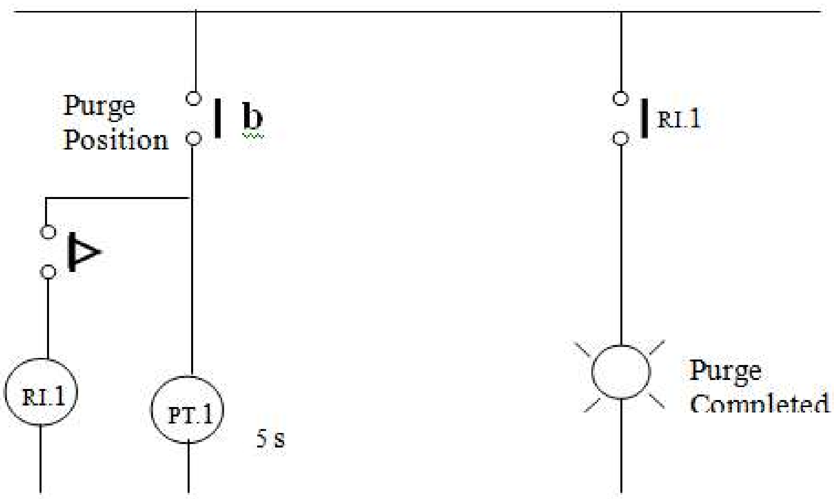


Figure II.9. Purge Position[7]

b. Pilot Light

- Fully close the CPM valve; the end switch will energize the RLFS relay.
- Turn the selector (SC) from the purge position as you can see in the circuit below (figure II.10) to the pilot position (C), which will energize the ignition transformer ITX1 for 15 seconds, and simultaneously open the pilot fuel gas valve PCV305. A flame should be detected by the UV-1 flame detector, keeping the PCV305 valve open through the RPG-1 relay contact. [7]

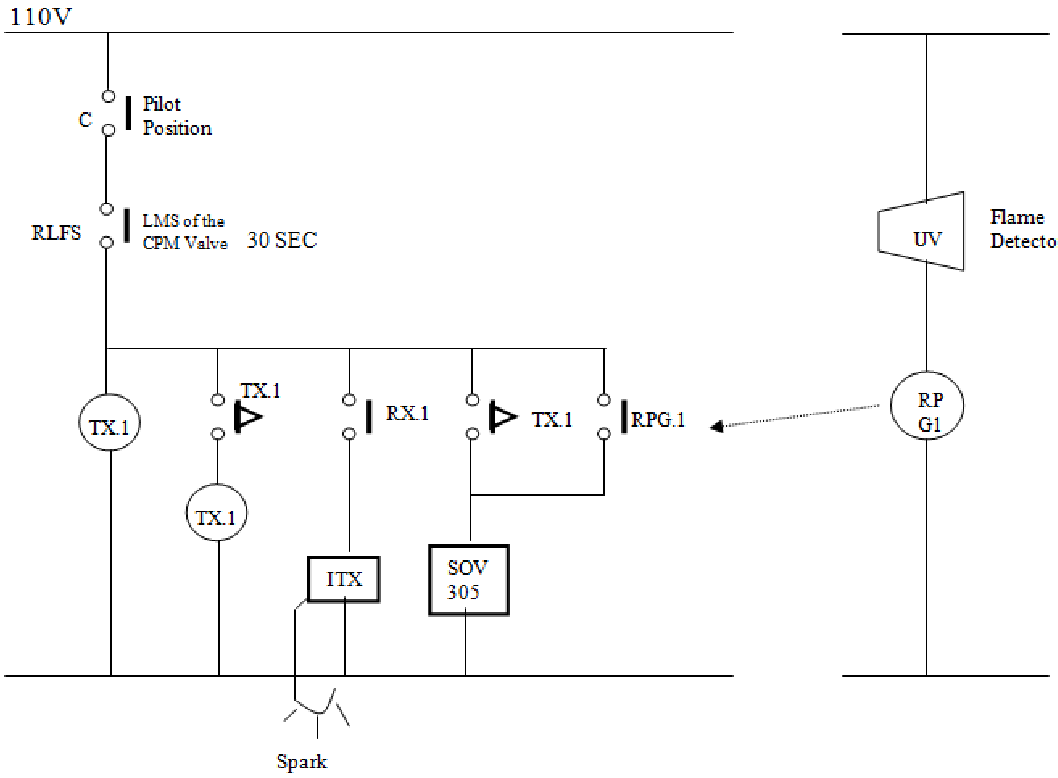


Figure II.10. Pilot Position[7]

Note:

If no flame is detected after 30 seconds, the fuel gas valve PCV_305 closes.

c. Ignition and Operation

- Set the selector to the ignition position (figure II.11). The valve SOV302 fully opens (allowing a high flow of fuel gas). Adjust the CPM valve to achieve a good air/gas ratio.
- After igniting the burner, set the Auto/Man switch on the local panel to the Auto position; the control of the CPM valve will be managed by the temperature regulator signal (TIC301) from the control room.

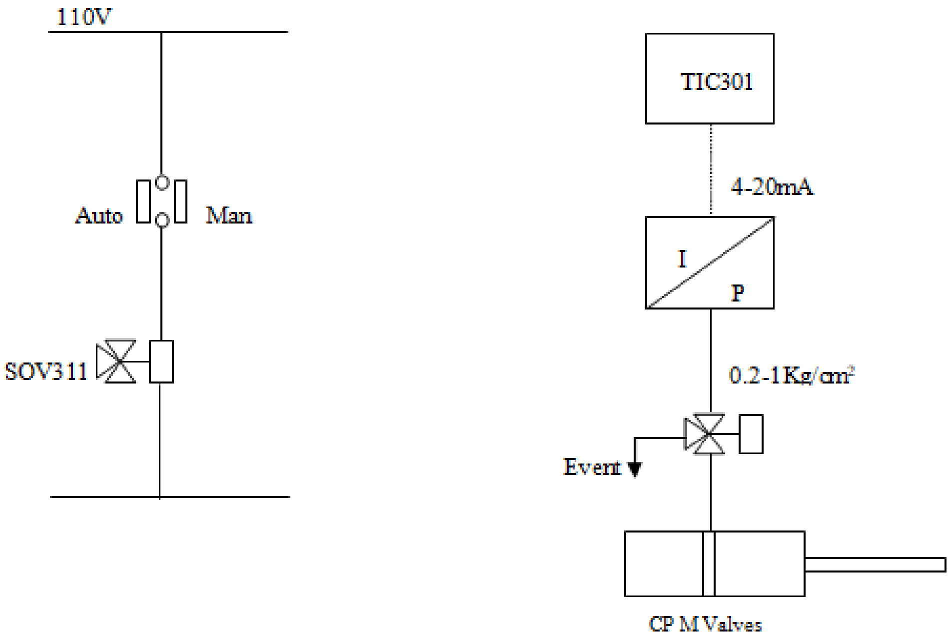


Figure II.11. Ignition and Operation Position[7]

Note:

For the other two burners, the ignition procedure is identical to that of burner No. 1.

II.8. Functional Analysis

When the glycol regeneration unit is in service, the regulation of various parameters is managed as follows:

a. PIC301

The pressure in tank D301 is detected by an electronic transmitter (4-20 mA) with a cell functioning as a variable capacitor (a change in capacitance causes a current variation in the circuit). This signal (4-20 mA) is sent to the control room to the DCS, where it interfaces with an Analog-to-Digital conversion card AAM11.

This signal is processed and sent to the processor (containing regulator blocks, etc.). The regulator block, based on the setpoint, compares PV (Process Variable) and SV (Setpoint Value) and corrects the error according to the PI (Proportional-Integral) algorithm. The digital output signal (MV) is converted back to an analog signal (AAM51) via the I/P converter to control the automatic valve PIC301V.

b. **The level in tank D301** (separation tank for hydrated glycol from condensate)

- **LIC302:** The level of hydrated glycol is measured by a displacement transmitter using the "Archimedes principle." Its regulation is done locally, with the indication only configured to the DCS.
- **LIC301 (hydrocarbon level)** The control of the condensate level is done locally.

c. **Parameters in the boiler**

- The boiler is filled with hydrated glycol coming from D301. The level of dehydrated glycol is controlled by loop LIC303. It is crucial that the fire tubes (burners) are submerged in the liquid (hydrated glycol) to prevent burner deterioration.

  The level of dehydrated glycol is constantly monitored by LIC303. The regenerated glycol is extracted by one of the pumps P301A or P301B and sent to the buffer tank D202, to be re-injected into the gas coming from the wells. If the level of regenerated glycol reaches the trigger threshold detected by switch LZL307, it stops the operating pump P301.
- While boiler H301 is in operation, temperature TIC301 is measured by a type K (CA) thermocouple, generating a voltage (MV). The potential difference is transmitted to the DCS. The regulator's output signal is sent to the three CPM (Air/Gas ratio) valves.
- CPM valves are ratio valves, controlling boiler combustion as follows:

Two blowers are available (one in service, the other on standby). The air pressure is controlled by PIC309, a pneumatic PI action regulator. Combustion occurs as follows:

- Upon an opening signal from the CPM, an articulating arm transmission opens the Fuel-Gas and combustion air valves at a defined ratio.
- LIC305 loop: This regulates the level of condensed water vapor, which is sent to the top of column C301 via one of the pumps P302A or P302B. If the water level in D302 decreases, switch LZL306 stops the operating pump P302 to prevent cavitation.

Note: The glycol regeneration unit is protected by various triggering factors:

- ✓ Very low combustion air pressure; PZL308.
- ✓ Very high Fuel-Gas pressure; PZH304.
- ✓ Very low Fuel-Gas pressure; PZL304.
- ✓ Very high temperature in the combustion chamber; TZH302.
- ✓ Very low level in the boiler (H301); LZL304.

- If any of these factors are triggered, the entire unit will shut down.

II.9. Unit Shutdown

a. Normal shutdown:

A normal shutdown is initiated by pressing a push-button (SBS) on the local panel or from the control room, typically for:

- Scheduled maintenance.
- Any issue (leaks, etc.).
- Switching to the standby unit.

b. Emergency shutdown:

The boiler shutdown is triggered by one or more of the following factors:

- Very low combustion air pressure (PZL308).
- Very high Fuel-Gas pressure (PZH304).
- Very low Fuel-Gas pressure (PZL304).
- Very high temperature in the combustion chamber (TZH302).
- Very low level in the boiler H301 (LZL304).

These factors trigger the shutdown by directly acting on the main Fuel-Gas valve UZV-308 (which closes). [7]

II.10. INSTRUMENTATION

Instruments are devices that allow us to measure, regulate, and monitor process parameters to ensure the proper operation and safety of the installations. The instrumentation of the glycol regeneration unit consists of:

II.10.1. Sensors:

A sensor is a device that detects and converts a physical quantity, such as flow, level, pressure, or temperature, into a measurable electrical signal. These signals can then be used for monitoring, control, and data collection in various applications. Sensors are critical components in many systems, providing essential information that ensures accurate operation and safety. [8]

1. Temperature Sensors:

Temperature sensors are crucial for tasks such as regulating building temperatures, controlling water temperature, and managing refrigeration systems. They are also vital in consumer electronics, medical devices, and industrial applications. Each application has specific temperature sensing needs, determined by what is being measured (air, mass, or liquid), where it is measured (indoors or outdoors), and the temperature range. The four primary types of temperature sensors used today are thermocouples, RTDs (resistance temperature detectors), thermistors, and semiconductor-based integrated circuits (IC). In our case, we will utilize K-type and T-type thermocouples. [W1]

Figure II.12. K-type thermocouples

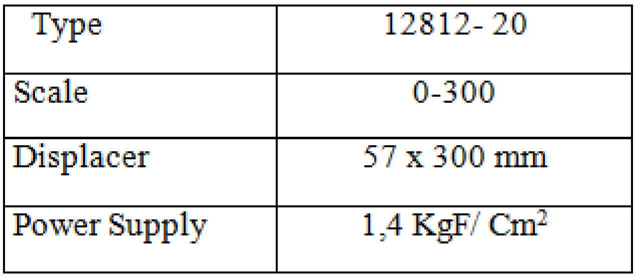
Specification	Details
Type	K (Chromel–Alumel)
Temperature Range	-270 to 1260°C (-454 to 2300°F)
Accuracy	±2.2°C or ±0.75% of reading
Sensitivity	~41 µV/°C
Material Composition	Chromel: 90% Ni, 10% Cr; Alumel: 95% Ni, 2% Mn, 2% Al, 1% Si
Common Insulation	Fiberglass, Teflon, Ceramic
Common Sheathing	Inconel, Stainless steel, Ceramic
Applications	Industrial, HVAC, Research
Standards Compliance	IEC 60584-1, ASTM E230

Table II.1. Technical Specifications of K-type thermocouples[8]

2. Level sensors:

a. Displacement Transmitter (Plunger Type):

The plunger is a cylinder whose length is at least equal to the maximum height of the liquid in the tank. The table (**Table II.1**) below will show how plunger type work, The volume of the submerged plunger is subjected to an upward force from the liquid, known as Archimedes' buoyant force.

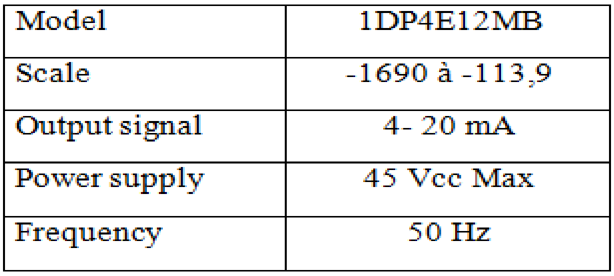


Type	12812- 20
Scale	0-300
Displacer	57 x 300 mm
Power Supply	1,4 KgF/ Cm^2

Table II.2. Technical Specifications of plunger type[8]

b. ΔP Cell Transmitter:

The transmitter present in the unit is a two-chamber differential pressure transmitter, with one chamber for HP (High Pressure) and another for LP (Low Pressure). It detects the upstream-downstream pressure of a flow element (such as an orifice, venturi tube, nozzle, etc.).



Model	1DP4E12MB
Scale	-1690 à -113,9
Output signal	4- 20 mA
Power supply	45 Vcc Max
Frequency	50 Hz

Table II.3. Technical specifications of The transmitter[8]

c. Flow Sensors:

The unit is equipped with diaphragm flow sensors for flow detection. Flow, represented by Q, is calculated using the Bernoulli's equation:

$Q = \sqrt{\Delta P}$ (K) is a constant.

$\Delta P = P_1 - P_2\ (P_1 > P_2)$

P1 refers to the fluid pressure at the diaphragm inlet, while P2 denotes the fluid pressure at the diaphragm outlet.

d. Flame detectors:

Flame detection is a critical factor in a furnace, and it is ensured by ultraviolet flame detectors located at each burner. The detectors used for flame monitoring in the glycol unit are of type C7012F(Table II.3), semiconductor-based, and self-checking. They are sensitive to ultraviolet light and compatible with the monitoring device R4075, equipped with an amplifier and a flameproof housing for hazardous atmospheres. [8]

Figure II.13. Flame detectors

Reference	C7012F	
Electrical regime	Frequency	50/ 60 Hz
	Voltage	120 Vca
Consumption	"7 watts maximum"	
"Permissible ambient temperatures in operation (outside the enclosure)."	-29 a +79°C	

Table II.4. Technical specifications of Flame detectors[8]

II.10. 2. Actuators:

1. Solenoid Valves:

Solenoid valves are monostable devices, meaning they operate with a single effect. They are equipped with coils and pistons. The piston acts directly on the valve.

The solenoid valve opens when its coil is energized by a control electric current. The magnetic field generated by the coil causes the displacement of a core (electromagnet), which in turn operates the valve mechanism.

Figure II.14. Solenoid valves

The operational state of the valve directly depends on the control electric current. The Technical specifications below represent this procedure:

	SOV302, 303, 304	SOV305, 306, 307
Control:	Solenoid valve ASCO	
Power supply voltage	110 Vca	
Frequency	50 Hz	
Valve:	On/Off with actuator	
Fluid	Fuel Gas	
Supply pressure	4 Kgf/ Cm^2	
Valve mechanism	Plug	
Valve mechanism size	2"	1/2"
Type	On/off	
Action	Air Open	

Table II.5. Technical specifications of Solenoid valves[8]

2. Pneumatic Control Valves:

The pneumatic control valve is the final element of the control loop. It is used as a regulating device that varies the flow rate of a fluid based on the variations of the signal received from the controller (**Table II.5**).

	Fluid	Scale KgF/Cm2	Power supply	Valve	Valve size	Action
CPM301, 302, 303	Air/ Gaz	0,4- 2	2KgF/Cm2	Equal % V	/	Air open
UZV308	Fuel Gaz	/	4KgF/ Cm2	Plug	3"	
PCV306V		/		Equal % V	3"	
PCV305V		/			1"	
PIC301V	Gaz	0,4- 2	2,5 KgF/Cm2		2"	
LC301V	Condensate	0,2- 1	1,4 KgF/Cm2		1"	
LC302V	Hydrated Glycol				4"	
LIC303V	Regenerated Glycol				4"	
LIC305V	Water			Vaned	/	

Table II.6 Technical specifications of The pneumatic control valve[8]

3. Limit Switches:

Limit switches are position switches equipped with micro-switches that have C (Common), N.O (Normally Open), and N.C (Normally Closed) contacts. The role of a limit switch is to indicate whether a valve is open or closed.

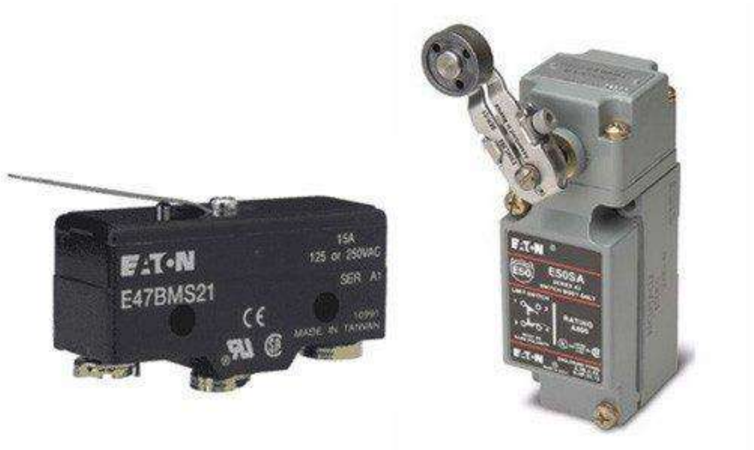


Figure II.15. Limit switches [W2].

II.11. Conclusion

The description section of the glycol regeneration unit allows us to:

- Understand the importance of glycol in a gas treatment unit, where its required concentration necessitates regeneration after fulfilling its function in the production trains at hydrate formation points.

- Study the startup and shutdown sequence of the unit.
- Understand the operating principles of the equipment.
- Learn the characteristics and specifications of the various equipment and instruments within the unit.

In parallel with studying the instruments used in this unit, we also gained hands-on experience in calibrating and adjusting them, including transmitters and pressure switch valves. Furthermore, the primary issue in this section is the manual operation of the boiler. It is crucial to simplify the control system to make it more user-friendly for the operator. In the next chapter, we will explore this topic in more detail.

Chapter III

The YOKOGAWA DCS CENTUM VP CONTROL and Supervision System

III.1. Introduction

In industrial contexts, Distributed Control Systems (DCS) are pivotal for monitoring and managing geographically dispersed processes efficiently. This chapter explores DCS architecture, focusing on Yokogawa Centum VP. Centum VP integrates microprocessors and networks to enable real-time data processing, storage, and transmission, enhancing control device communication across industrial sites. Its modular design supports scalability and flexibility, making it a cornerstone in modern industrial automation for optimizing operational efficiency and reliability. In this chapter, we have also seen descriptions of DCS, its functions, and the specifics of Yokogawa Centum VP.

III.2. Presentation of the DCS (Distributed Control System)

DCS distributed control refers to the basic functions that are rather entrusted to different devices (stations) connected by a communication network. The unavailability of a device only results in the loss of the function it is responsible for. [W4]

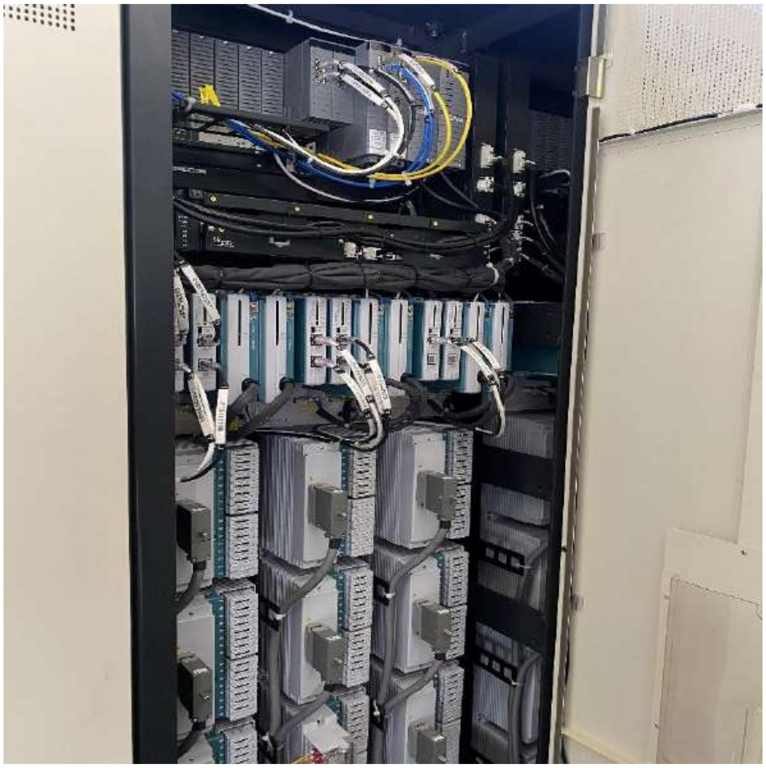


Figure III.1. Distributed Control System

III.3. Historical Background of the Control System

Technological progress in the fields of electronics and computing has led to considerable evolution in the control of industrial processes.

This evolution is reflected in a change in control techniques: from pneumatic systems to analog and then digital electronic systems, from centralized control to distributed control (DCS), and from relay-based systems to systems based on Programmable Logic Controllers (PLCs).
Before the advent of DCS, the control of industrial processes went through several generations of systems:

1. **Manual Control:** The operator closes the control loop by observing the sensor and manipulating the control device: Process => Sensor => Operator => Control Device The basic concept of closed-loop process control is adhered to.
2. **Local Pneumatic Regulators:** The operator does not directly intervene on the control device but provides a set point to the local regulator on-site.
3. **Centralized Pneumatic Regulation:** The operator controls the process from the control room. In this mode of operation, signals arrive at the control room in pneumatic form.
4. **Analog and Digital Electronic Regulators**: The development of electronics led to the design of electronic regulators with single-loop control and sensors capable of converting all physical variables into electrical quantities.
5. **Data Acquisition System (DAS):** Graphical animation, historical data, trends, logging. The control function is ensured by simple single-loop controllers.
6. **Distributed Control System (DCS):** In general, industrial processes consist of a set of equipment and production facilities distributed throughout the site. This constraint led to the distributed architecture of the DCS, hence the name: Distributed Control System (DCS).

III.4. Description of the DCS

The DCS consists of several subsystems including:

1. Input/output arrangements.
2. Individual controllers (regulatory PLCs)

3. Operator interfaces (screen, mouse, keyboard)
4. Engineer workstation
5. Communication network (bus) for information exchange

III.5. Characteristics of the DCS

It is characterized by:

1. Better-controlled processes with less energy waste.
2. Availability of historical data and real-time access to information.
3. Visualization, graphical representation, and data printing.
4. Electronic data acquisition and paperless recording.
5. Introduction of redundancy with a dual objective.
6. Maximizing process security and minimizing spurious triggers
7. Self-monitoring and detailed diagnostic function of systems have contributed to reducing maintenance call costs. Improved safety, reduced risks for humans, installations, and the environment.

III.6. DCS Architecture

The DCS system consists of four levels, as below:

Level 1: is quite comparable to the traditional system, representing the instruments installed in the field.

Level 2: represents the automation installed in the technical room, consisting of process input/output modules.

Level 3: represents the part where process control is carried out through operator stations consisting of electronic units.

Level 4: is the supervision and management part of the plant. Levels 2, 3, and 4 are connected by communication buses. As Figure III.2. Architecture du DCS shows. [W4]

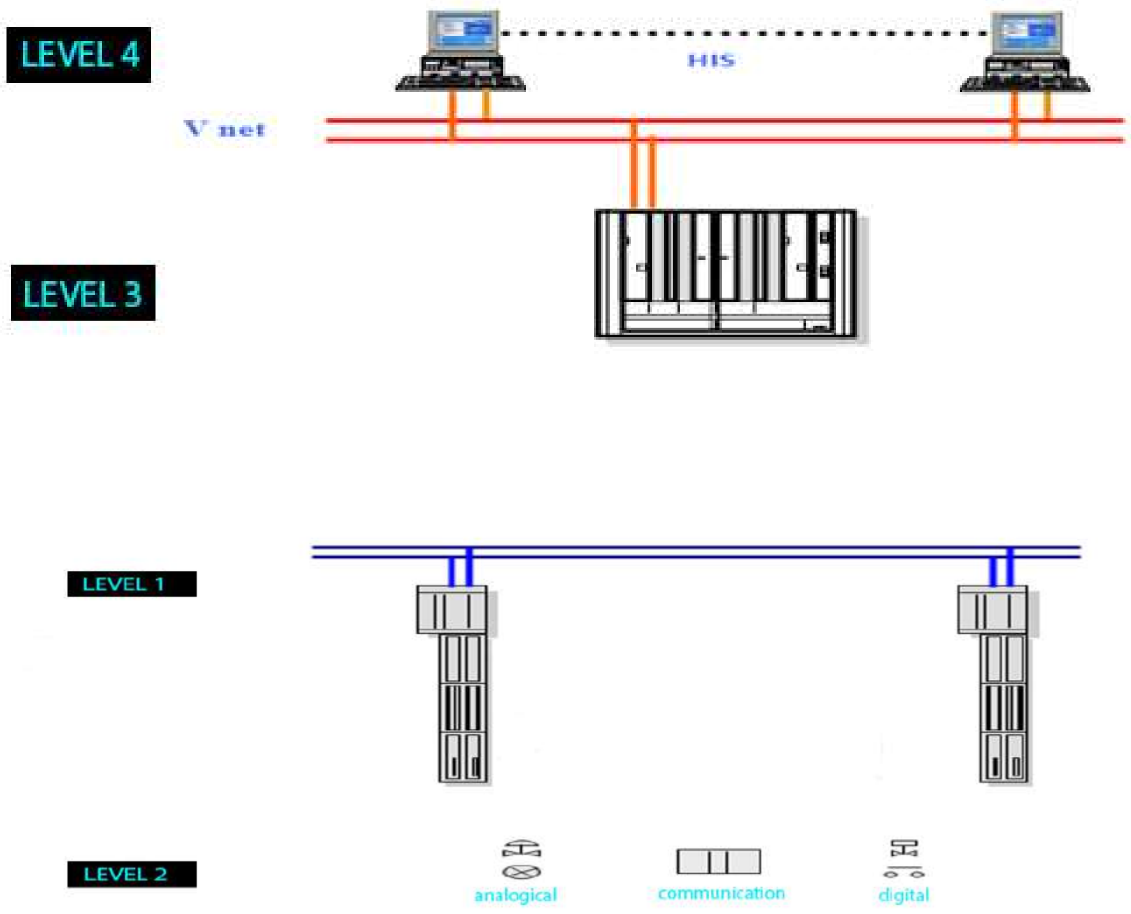


Figure III.2. Architecture du DCS[W4]

III.7. Adaptation of Input and Output Signals

Industrial signals are classified into two standard categories:

a. **Inputs and outputs are of analog type**: these are processes where the I/O signals quantify a measurement or action into an electrical value. For example, parameters (level, pressure, flow rate, temperature) are electrical quantities. Sensors are used to convert the pressure or temperature value into a standard value **(4-20mA**) for an electrical signal and (**0.2-1 kg/cm2**) for a pneumatic signal. The technological device used consists of a sensor-regulator-actuator.

b. Inputs and outputs are of Boolean (digital) type

these are logical processes (All or Nothing). For example: PLC systems that handle safety for tanks, pumps, compressors to activate either the opening or closing without any intermediate state. The technological device consists of a sensor, a logic circuit composed of relays, and an actuator.

It is therefore essential to convert the signals exchanged with the process as follows:

- Acquisition and conversion of industrial signals into binary.
- Control and conversion of binary numbers into industrial signals.
- Real-time processing of data exchanged with the process:
- Regulation and calculation.
- Sequential functions (sequences of start-ups or shutdowns...).
- Alarm detection.
- Deferred processing of data exchanged with the process:
- ✓ Recording and manipulation of historical data.
- ✓ Retrieval of recorded data (curves, reports).
- ✓ Optimization.
- ✓ Assessment. [W5]

III.8. Task Distribution in DCS (Distributed Control System)

In a centralized system, most basic functions can be performed by a single device (processor or computer). However, the unavailability of this device results in the loss of all functions it is responsible for.

In a distributed or decentralized system, basic functions are assigned to different devices (stations) interconnected by a communication network. If one device becomes unavailable, only the function it is responsible for is lost.

Each station can access information stored in the database of another station via the communication network.

- **Human-Machine Interface**: Visualization and execution of control operations driven by the display of consoles facilitate the dialogue between the operator and the control system.
- **Online Modification:** The operator can make online modifications to the current program, process parameters, and timing/counting parameters via the host computer on the secondary computers.
- **Real-time Fault Diagnosis and Warning**: If equipment malfunctions, the system diagnoses the issue and locates it by emitting an alarm signal displayed on the console, along with advice on how to acknowledge the alarm.

- **Data Recording, Management, Display, and Copying:** Once an alarm is displayed, all data and operations performed by the operator will be recorded, copied, and printed to monitor the operator and maintain a history for further maintenance operations, for example.

- **Production Safety Function**: The system will raise an alarm on the console and provide advice on the monitor when an operator makes an operational mistake. [11]

III.9. Application Fields of DCS

The DCS system is widely used in the petroleum, gas, chemical, metallurgical, pharmaceutical, agri-food, paper manufacturing, and other industrial sectors, given its control and command performance, as well as its openness from both software and hardware perspectives.

The digital control system designed by YOKOGAWA heralds a new era in DCS system implementation. It incorporates the latest technologies into an open and modular architecture while ensuring full upward compatibility with previous generations and unparalleled legendary reliability. It ensures reliability and adaptability through:

- Combining the flexibility and reliability of its CENTUM family predecessors with the user-friendliness of a PC.

- Ease of use, with superior control functions and excellent cost/performance ratio, allowing the system to quickly integrate into demanding industrial environments.

- The open architecture of its interfaces defines information exchange with management and planning systems and facilitates the establishment of a strategic management system for a company.

- It adapts to existing systems and follows the evolution of production units, reducing the total cost of ownership.

- The CENTUM VP control system embodies the concept of "Integrated Solutions," offering the user total integration of process control and production management. [11]

III.10. CENTUM VP System by YOKOGAWA

The CENTUM VP control system embodies the concept of "Integrated Solutions," offering users total integration of process control and production management:

- **Open and Homogeneous Architecture**: An open environment using standardized interfaces facilitates the integration of different subsystems or software packages, as well as the creation of a high-performance user interface.
- **Multiscreen Operation:** The operator station has a multiscreen function that allows views to be called up using the mouse. Additionally, the operator stations can be dual screen.
- **FCS (Field Control Station)**: The control station integrates continuous or batch control functions. The redundancy function, achieved through the "Pair and Spare" system, ensures complete availability of the station.
- **Efficient and Optimized Engineering:** The simplification of engineering tools reduces application development time. Reusable libraries reduce the time and cost of system extensions or modifications.

The CENTUM VP controller uses the unique "Pair and Spare" architecture. It is based on the use of a pair of processors within the central units ("Pair") associated with a second central unit (also "Pair") to ensure redundancy. The set, comprising four processors, is then in a "Pair and Spare" structure. Additionally, the CENTUM VP has other redundancy options for I/O, various communication buses, and power supplies. [15]

III.11. Programming a project on YOKOGAWA CENTUM VP software

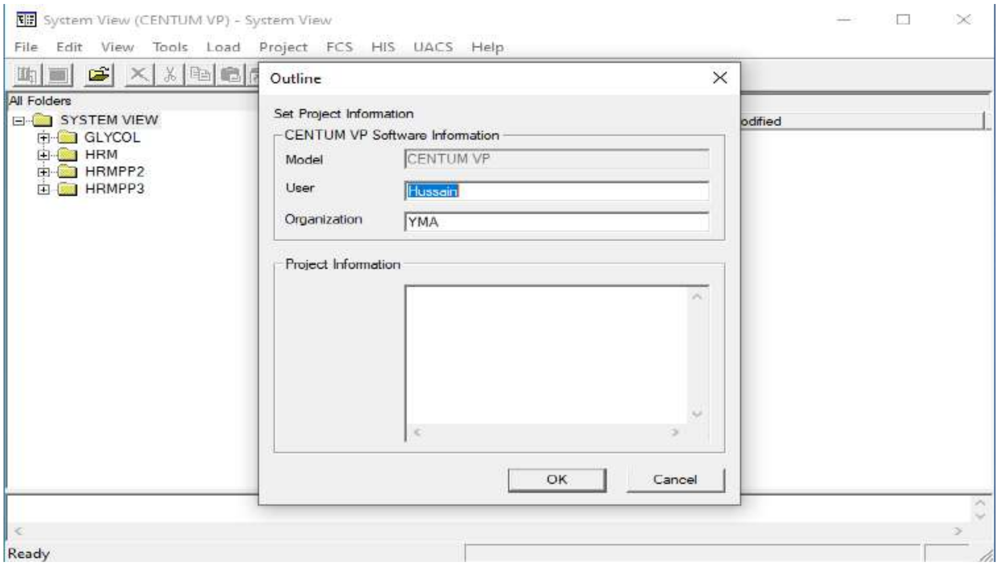
In this section, we will discuss the various stages involved in designing a DCS system With YOKOGAWA CENTUM VP:

III.11.1 Creating a New Project

Once the "system-view" system is launched, click on the menu bar:

- File
- Create new.
- Project

A window will appear asking us to provide information related to the project, (As seen in **Figure III.3.** Creating a New Project)**.**



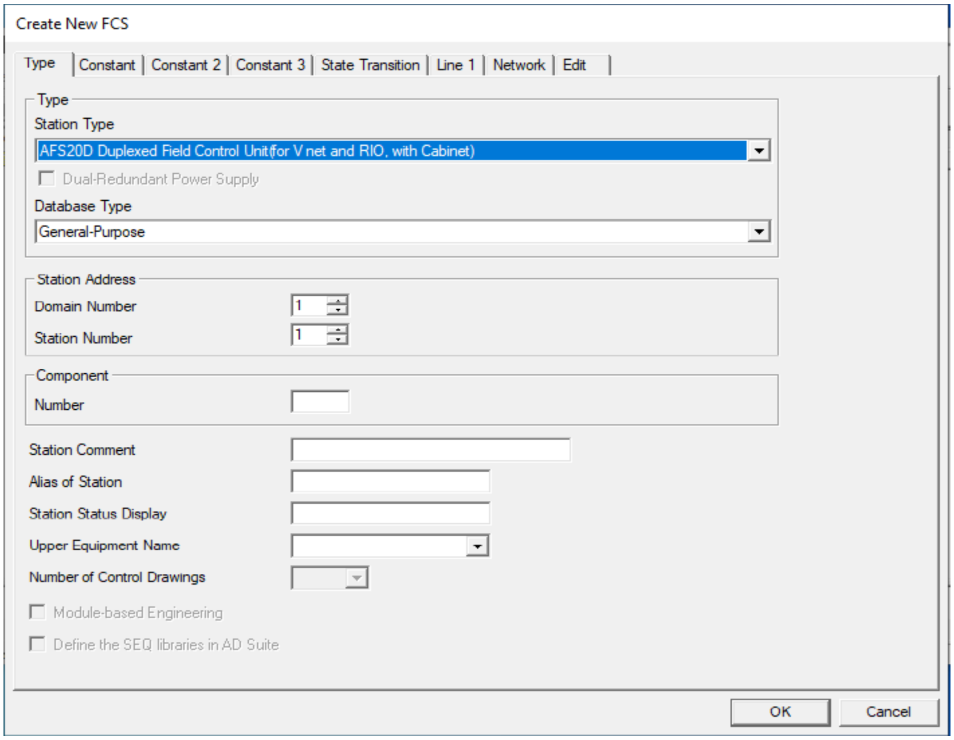
Model: CENTUM VP
User: Hussain
Organization: YMA

Figure III.3. Creating a New Project

III.11.2 Creating an FCS

The window for creating a control station will automatically appear once the new project is created. If not, proceed in the same way as for creating the project (select from the File menu or right-click: create new "FCS"), where you will have programming elements available. Then:

- **Choose the type of control station from the predefined list** (e.g., in our project, it is the AFS20D "Duplexed Field Control Unit").
- **Define the type of FCS, the database, and the station address** (e.g., Code 101: the first '1' refers to the domain and the second '1' gives the station number).
- **Verify the characteristics in the other tabs** (they are taken by default).
- **Finally, click the OK button to execute.** [9]



Type
Station Type: AFS20D Duplexed Field Control Unit(for V net and RIO, with Cabinet)
☐ Dual-Redundant Power Supply
Database Type: General-Purpose

Station Address
Domain Number: 1
Station Number: 1

Component
Number:

Station Comment:
Alias of Station:
Station Status Display:
Upper Equipment Name:
Number of Control Drawings:
☐ Module-based Engineering
☐ Define the SEQ libraries in AD Suite

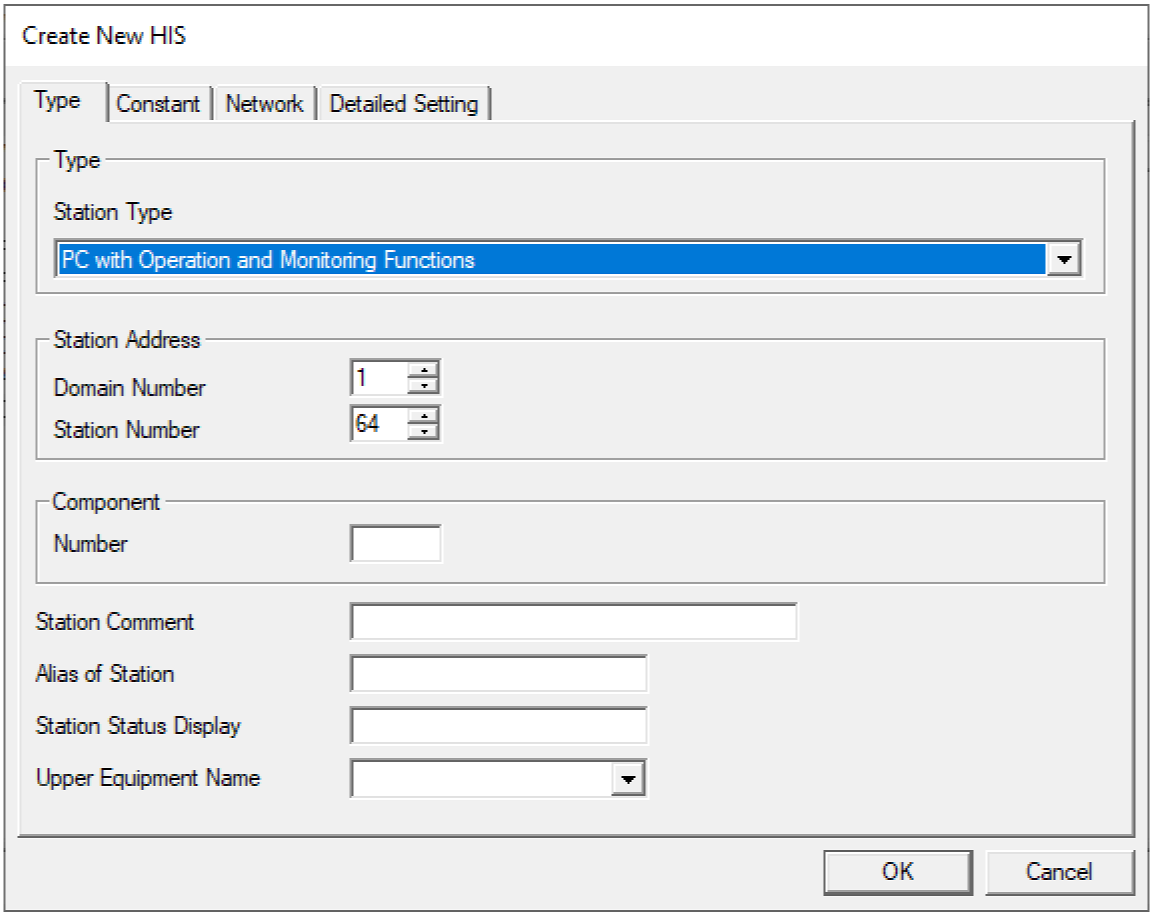
Figure III.4. Creating an FCS

III.11.3 Creating an HIS

The window for creating an operator station will automatically appear after the FCS creation window during the creation of a new project. If not, proceed in the same way as for creating the project (select from the File menu or right-click: create new, then HIS). Then:

- Define the type of PC and the station address.

- Assign a domain number (default is 1) and a station number (default is 64).
- Verify the network characteristics in the "Network" tab.
- Check the characteristics in the other tabs. [10]



Station Type: PC with Operation and Monitoring Functions
Domain Number: 1
Station Number: 64
Number:
Station Comment:
Alias of Station:
Station Status Display:
Upper Equipment Name:

Figure III.5. Creating an HIS

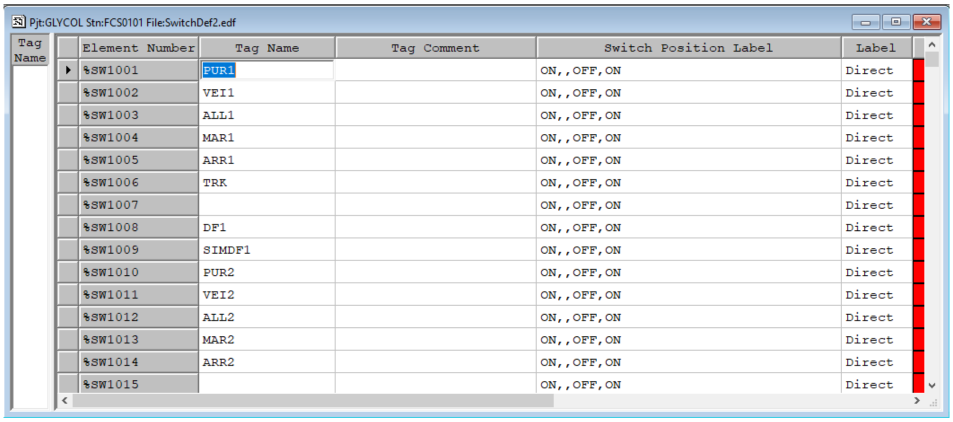
III.11.4 Creating FCS Inputs and Outputs

In a real case (design for on-site implementation), the inputs/outputs are physical (analog or digital signals). In this case, the FCS inputs/outputs must be created as follows:

- **Creating an IOM (Input Output Module):**
  - ✓ Select the IOM directory in the FCS.
  - ✓ In IOM, right-click and choose the "create new" option and select NODE.
  - ✓ Then, choose the type of chassis and the type of card (analog or digital)

- **Creating an Input/output Card:**

Based on the selected chassis (IOM), choose, for example, the AMN11, which is a chassis capable of receiving analog cards. Then select the type of card and its address from the list shown on the left side of Figure III.6.



Element Number	Tag Name	Tag Comment	Switch Position Label	Label
%SW1001	PUR1		ON,,OFF,ON	Direct
%SW1002	VEI1		ON,,OFF,ON	Direct
%SW1003	ALL1		ON,,OFF,ON	Direct
%SW1004	MAR1		ON,,OFF,ON	Direct
%SW1005	ARR1		ON,,OFF,ON	Direct
%SW1006	TRK		ON,,OFF,ON	Direct
%SW1007			ON,,OFF,ON	Direct
%SW1008	DF1		ON,,OFF,ON	Direct
%SW1009	SIMDF1		ON,,OFF,ON	Direct
%SW1010	PUR2		ON,,OFF,ON	Direct
%SW1011	VEI2		ON,,OFF,ON	Direct
%SW1012	ALL2		ON,,OFF,ON	Direct
%SW1013	MAR2		ON,,OFF,ON	Direct
%SW1014	ARR2		ON,,OFF,ON	Direct
%SW1015			ON,,OFF,ON	Direct

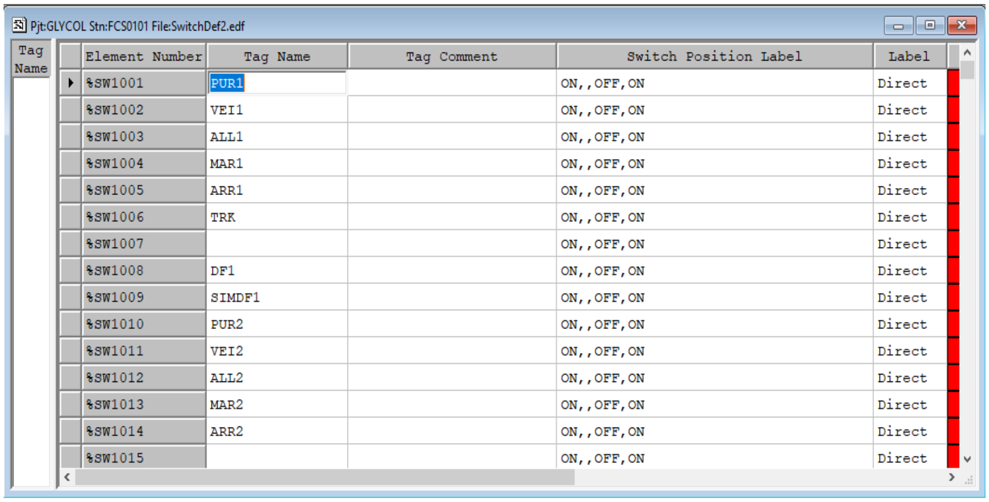
Figure III.6. Creating an Input/output Card

III.11.5 Creating Function Blocks

To create function blocks:

- From the FCS, select the "Function Block" program.
- Choose a drawing (e.g., DR0001).

From the function block selector (Control Drawing Builder: insert → Function block), insert the blocks (see **Figure III.7.** Inserting Function Blocks).



Element Number	Tag Name	Tag Comment	Switch Position Label	Label
%SW1001	PUR1		ON,,OFF,ON	Direct
%SW1002	VEI1		ON,,OFF,ON	Direct
%SW1003	ALL1		ON,,OFF,ON	Direct
%SW1004	MAR1		ON,,OFF,ON	Direct
%SW1005	ARR1		ON,,OFF,ON	Direct
%SW1006	TRK		ON,,OFF,ON	Direct
%SW1007			ON,,OFF,ON	Direct
%SW1008	DF1		ON,,OFF,ON	Direct
%SW1009	SIMDF1		ON,,OFF,ON	Direct
%SW1010	PUR2		ON,,OFF,ON	Direct
%SW1011	VEI2		ON,,OFF,ON	Direct
%SW1012	ALL2		ON,,OFF,ON	Direct
%SW1013	MAR2		ON,,OFF,ON	Direct
%SW1014	ARR2		ON,,OFF,ON	Direct
%SW1015			ON,,OFF,ON	Direct

Figure III.7. Inserting Function Blocks

There are several types of function blocks. The following focuses on the most important ones:

a) Logic Diagram Blocks (LC16, LC64)

- The logic diagram block describes the relationships between input and output signals using logic elements. This block is suitable for describing combinational functions.
- **LC16 Block**: 8 inputs, 8 outputs, and 16 logic operators.
- **LC64 Block**: 32 inputs, 32 outputs, and 64 logic operators.

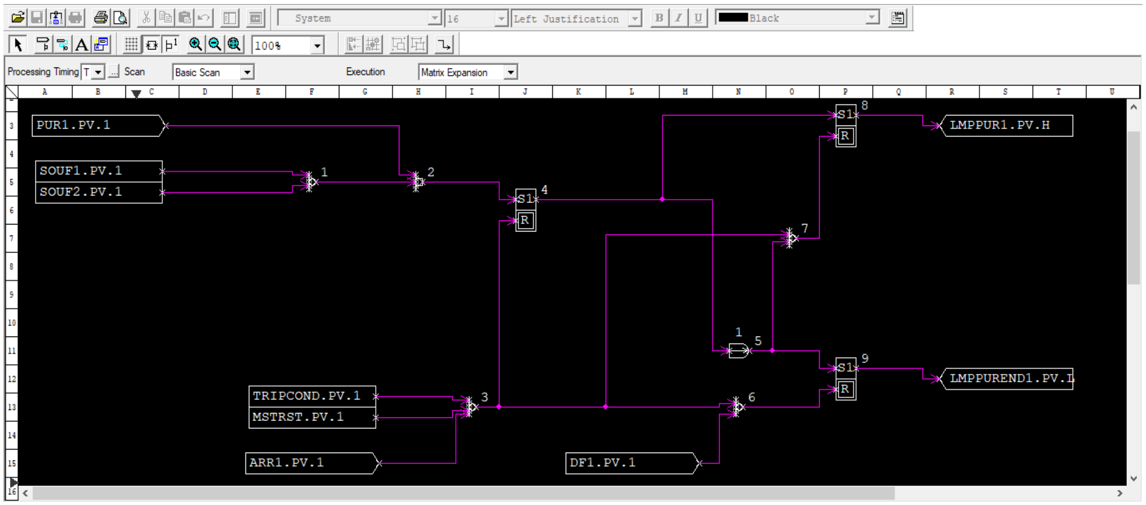
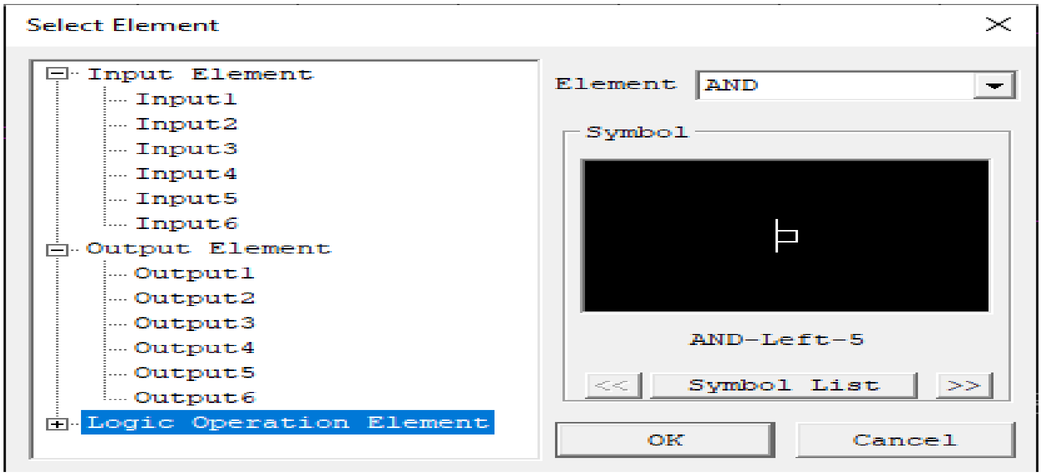


Figure III.8. Example of a Logic Diagram

To add logic elements to the logic diagram, simply click on "function block," then "edit detail." A blank window will appear. To choose the element, the following dialog box will appear.



Element: AND

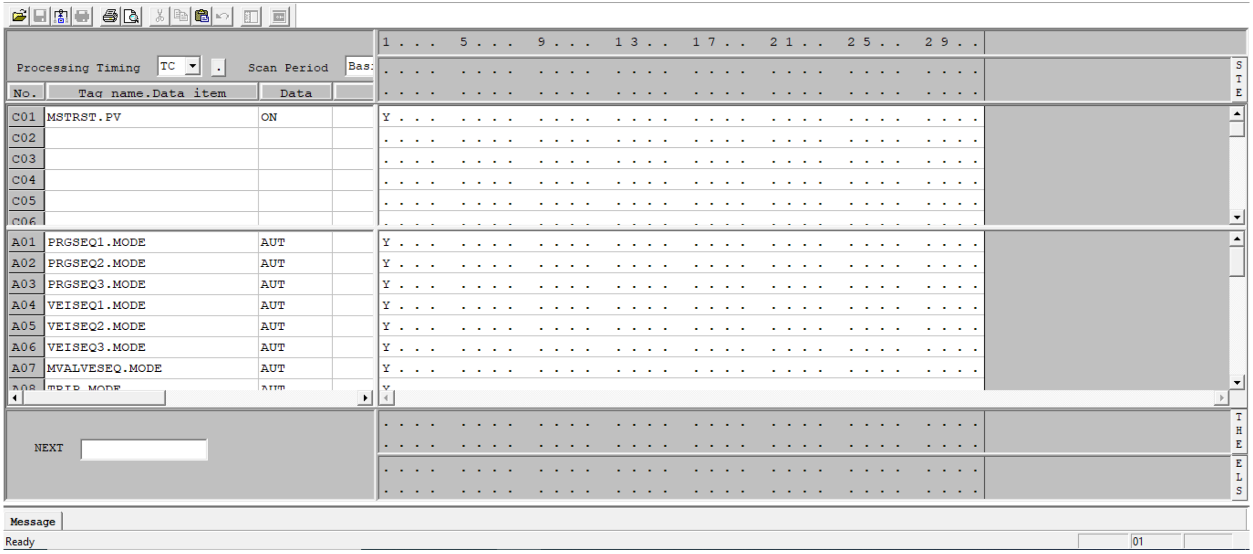
Figure III.9. Dialog Box for Selecting Elements

b) Sequence Block – ST016

- The "sequence table" blocks are used to describe dynamic sequences. During operation, actions are conditioned through conditions. These relationships between condition signals and action signals are described with yes or no (Y/N) on a grid table in a matrix form.

There are two types of sequence tables:

- **Combinatorial**: Evaluates conditions for all rules and executes actions associated with the verified rules.
- **Sequential**: Evaluates conditions for the rules belonging to the current step, executes actions of this step, and moves to the next step. [15]


Processing Timing: TC
Scan Period: Bas:

No.	Tag name.Data item	Data	1
C01	MSTRST.PV	ON	Y
C02			.
C03			.
C04			.
C05			.
A01	PRGSEQ1.MODE	AUT	Y
A02	PRGSEQ2.MODE	AUT	Y
A03	PRGSEQ3.MODE	AUT	Y
A04	VEISEQ1.MODE	AUT	Y
A05	VEISEQ2.MODE	AUT	Y
A06	VEISEQ3.MODE	AUT	Y
A07	MVALVESEQ.MODE	AUT	Y

NEXT

Message
Ready

Figure III.10. Editing Window for an ST016 Sequence Table

c) Regulation and Control Block (PID):

This is a regulatory block that ensures adjustment based on the process variable PV (Process Value) and the set value SV (Set Value).

In the case of a simulation of a loop in offline mode (not connected to the site), the "LAG" block is used, which acts as the real loop. [15]

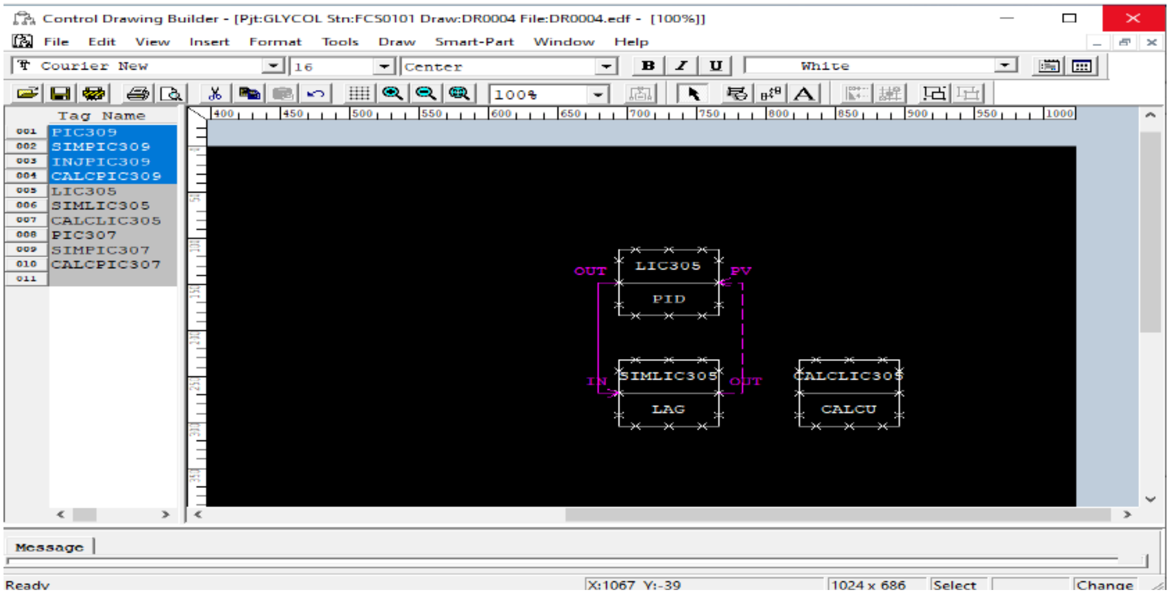
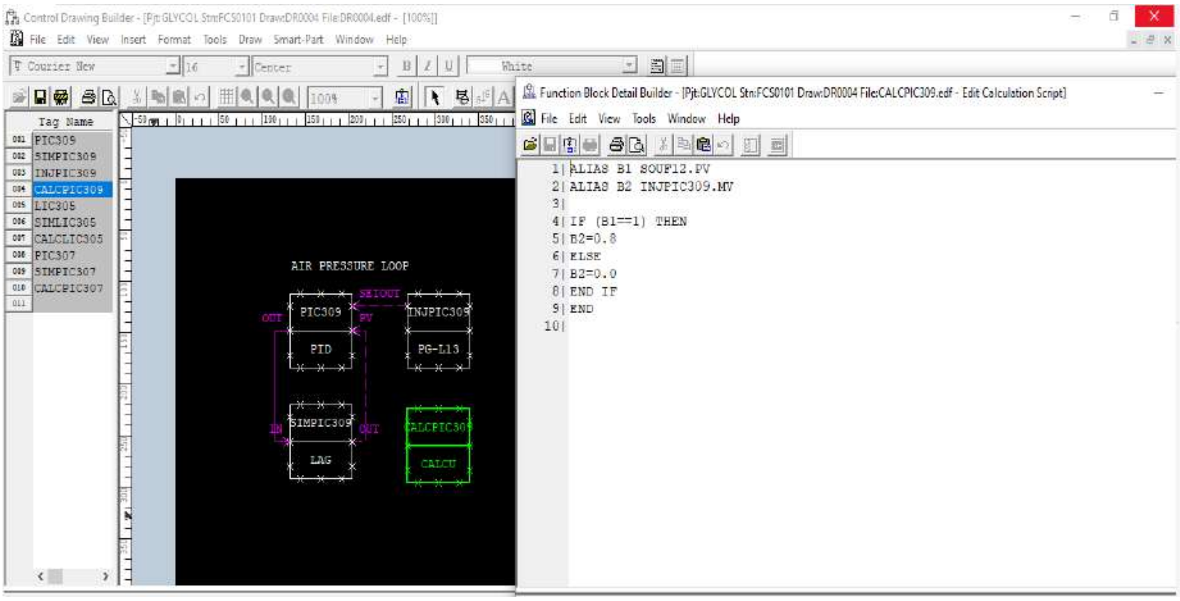


Figure III.11. Creation of a Loop in the Case of Simulation

Remark III.1: In the real case, the PID receives the Process Value (PV) from the input card. After processing, the Manipulated Value (MV) is transmitted to the instrument (on-site) through an output card.

d) Calculator Block (CALCU):

The "CALCU" block allows us to program using the SEBOL language, which uses instructions similar to those of the C language. [15]



```
ALIAS B1 SOUF12.PV
ALIAS B2 INJPIC309.MV

IF (B1==1) THEN
B2=0.8
ELSE
B2=0.0
END IF
END
```

Figure III.12. Programming Window of the "CALCU" Block.

e) Process Value Input Block (PVI):

The PVI block is used to indicate the process variable from a physical input. To create the PVI block, click on the "select function block" button, open the "Regulatory Control Block," and go to "input indicators" to access the PVI block.

f) Simulation Block (LAG):

Since we are initially interested in an offline simulation of the project, meaning the physical inputs/outputs do not exist, we are therefore required to use the LAG block, which is used here as a simulator of process characteristics (sensor, actuator).

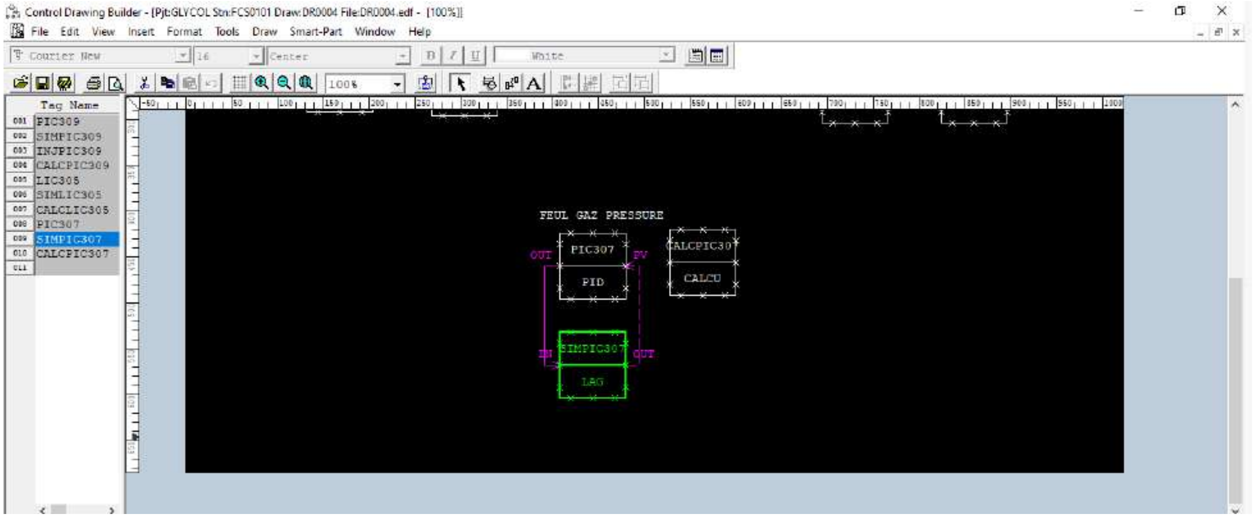


Figure III.13. Insertion of the LAG Block

III.12. Hardware Architecture of CENTUM VP

The VP: rent parts of the CENTUM VP are organized according to a hierarchical structure, designed to efficiently manage a large-scale system, and facilitate system integration and expansion. The system includes the following elements:

- Human-Machine Interface (HIS), composed of multiple stations known as Information Command Stations (ICS), with a maximum of 16 stations.
- Maintenance and Engineering Interface called Engineering Workstation (EWS).
- Cabinet assembly forming Field Control Stations (FCS) for process control units. [15]

- Networks: V-NET (real-time control bus).
- Ethernet (LAN network).

III.12.1 Field Control Station (FCS)

The Field Control Station (FCS) is the core of the CENTUM VP system, known for its advanced, reliable, and high-performance functions. It ensures maximum availability through fully integrated redundancy of central processing units, communication buses, and input/output cards.

Functions of the FCS include:

- Performing control functions (regulation or sequencing).
- Executing control algorithms.
- Processing user programs.
- Communicating with I/O modules.
- Communicating with other stations within the system and subsystems. [15]

III.12.2. Input/Output Module

An Input/Output (I/O) module consists of a set of input/output cards designed to interface between the process and the system. These cards play a crucial role in adapting signals exchanged between the process and the system. Specifically, these modules convert industrial input signals into a suitable digital format for the system, and they convert digital output signals into an industrial format appropriate for the process.

These modules facilitate seamless communication and interaction between the automated system (such as the CENTUM VP) and the physical processes they control or monitor. They are essential for ensuring compatibility and reliability in data transmission and control operations within industrial environments.

III.12.3. Human Interface Station (HIS)

The Human Interface Station (HIS) is built around the Windows operating system. It serves as a monitoring station providing an overview of the site, displaying process variables, control parameters, and essential alarms for operations. The HIS also includes engineering and supervisory functions.

Hardware choices for the HIS can range from standard PCs to operator consoles known for their reliability. The HIS plays a critical role in facilitating operator interaction with the CENTUM VP system, ensuring efficient monitoring, control, and management of industrial processes. [15]

III.13. Conclusion

The details presented in this chapter will be useful in developing the proposed solution under DCS (Distributed Control System). The final chapter will introduce the process to be studied, formulate the problem statement, and discuss the various stages of remote-control implementation and interface design.

Chapter IV

Rebuilding and HMI Development for Enhanced Boiler Control

IV .1. Introduction

Currently, the H301 boiler is operated using a local panel with relays. In this chapter, we will propose a comprehensive solution to upgrade the existing system to a state-of-the-art computer-based supervision system using the YOKOGAWA Centum VP DCS. This enhancement will significantly improve control, monitoring, and overall efficiency.

IV.2. Problem Statement

Several factors contribute to the various anomalies encountered in the installation. Notably, the boiler H301 and its accessories were constructed forty years ago (in 1978), leading to numerous operational and maintenance constraints, as well as safety standards that do not comply with new HSE (Health, Safety, and Environment) recommendations. The main problems with the current system include:

- Advanced obsolescence of spare parts (flame detectors, control cassettes, relays, etc.).
- The sequence is controlled using outdated technology based on wired logic, making maintenance particularly difficult, especially for troubleshooting.
- Unavailability of replacement relays.
- The control panel is located locally near the boiler, requiring the operator to move to the site to identify the nature of an alarm since only a general alarm is displayed in the control room.
- Difficulty in coordinating all the instruments during startup.
- Considerable maintenance time required.
- Difficulty or impossibility of changing the program (lack of flexibility).
- Inability to interconnect with other systems.

IV.3. Proposed Solutions

The study conducted on the boiler and the issues encountered during the manual ignition of the torch led us to integrate the automation of pilot ignition under DCS. The proposed solution includes:

- Developing a control and real-time supervision solution for the process and integrating the startup sequence of the boiler under a DCS (distributed control system);
- Acquiring new technology that allows for easy maintenance and upgrades;

- Providing operators with reliable, consistent, and accurate means of control and operation.

IV.4. Boiler instruments

In pursuit of enhanced boiler performance and compatibility with our automation scheme, we recommend incorporating these modern components. These suggested instruments have been utilized in our simulation to ensure optimal re-instrumentation of the boiler and to achieve superior operational efficiency.

IV.4.1. Temperature Transmitter YTA610

The YTA610 (Figure IV.1) is the highly accurate temperature transmitter that accepts Thermocouple, Resistant Temperature Detector (RTD), ohms or DC millivolts inputs and converts it from 4 to 20 mA DC or Field bus signal for transmission. The YTA610 supports HART and FOUNDATION Field bus communication protocols. [12]

Figure IV.1. Temperature Transmitter

IV.4.2.Displacer Level Switch

DISPLACER OPERATED The KLV Level Switch is designed for internal Mounting through the top of the Process Vessel and is also furnished with Chambers for External Mounting from the Process Vessel. Displacer operated Level Switch offer control features not found in float operated controls. The basic sensing means utilizes displacer heavier than the liquid which is suspended from a spring. When the liquid contacts the displacer, a buoyancy force is produced, which causes the effective weight of the displacer to change, in turn causing the spring to seek a new balance position which moves the attraction sleeve into the field of the magnet. This principle provides for wide switching differential and allows the desired level switching point to be adjusted by moving the displacers up or down the suspension cable. Further advantage allows for adoption to high pressure applications since displacers have substantial heavier wall thickness than floats and in many cases are made out of solid materials(Figure IV.2). [13]

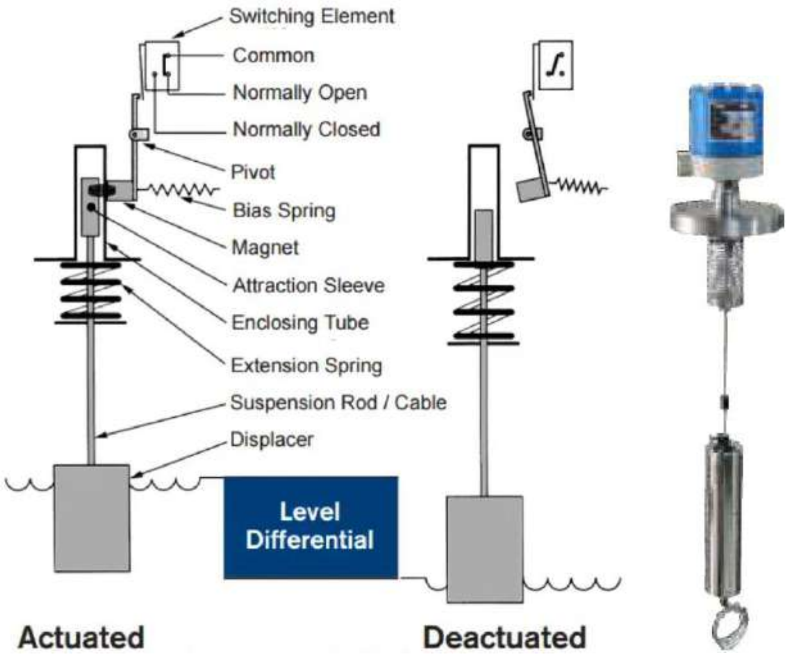


Figure IV.2. Displacer Level Switch [W3]

IV.4.3. Flame Scanner

The Fireye Phoenix Series 2 type 85UVF/IRF flame scanners (Figure IV.3) are microprocessor based devices utilizing a solid state flame detection sensor. The Phoenix flame scanners incorporate an internal flame relay with automatically set ON/OFF thresholds, thereby eliminating the need for a remote flame amplifier or flame switch, figure 3 shown the 85UVF/IRF flame.

Phoenix scanners detect the amplitude of the modulations (the flame “flicker”) that occur within the targeted flame, over a wide frequency. During the scanner setup procedure, the amplitudes of the target flame are automatically stored by the flame scanner, together with optimum ON/OFF criteria. The appropriate sensor gain is automatically selected. Phoenix scanners incorporate full self-diagnostics and electronic self checking. [13]

Figure IV.3. Flame scanners

IV.5. Boiler Configuration on DCS System

To establish and implement this solution on the DCS, we need to define all the inputs and outputs of the boiler.

IV.5.1. Declaration of Inputs/Outputs

A phase is necessary before any implementation. All inputs and outputs are declared in the table in APPENDIX A.

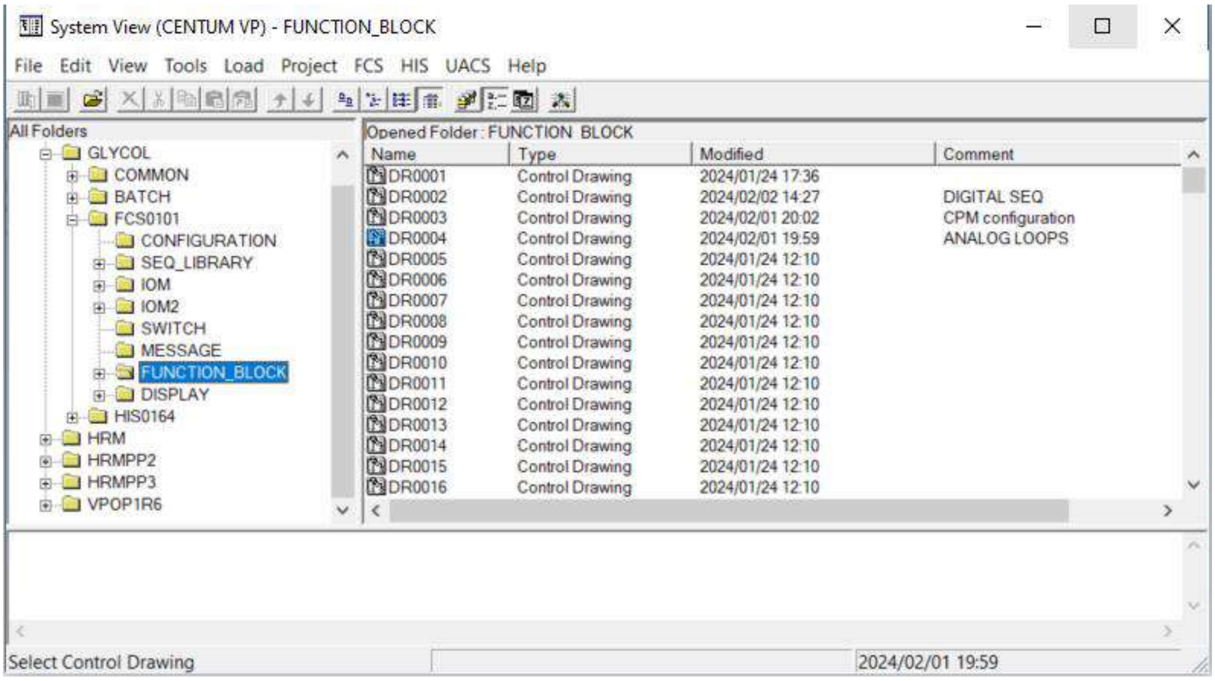
Remark IV.1: After defining the inputs and outputs, each input/output will correspond to a switch. This switch is used for simulation purposes because the program is in offline mode (not connected to the site).

- The switch is ON if it represents logical state 1.

- The switch is OFF if it represents logical state 0.

IV.6. Programming the Operating Sequences

Once the new project is created in the CENTUM VP system view, it becomes possible to access the various configurations (type of FCS, type of HIS, etc.). The general overview project is presented as shown in the following window:



Opened Folder : FUNCTION BLOCK

Name	Type	Modified	Comment
DR0001	Control Drawing	2024/01/24 17:36	
DR0002	Control Drawing	2024/02/02 14:27	DIGITAL SEQ
DR0003	Control Drawing	2024/02/01 20:02	CPM configuration
DR0004	Control Drawing	2024/02/01 19:59	ANALOG LOOPS
DR0005	Control Drawing	2024/01/24 12:10	
DR0006	Control Drawing	2024/01/24 12:10	
DR0007	Control Drawing	2024/01/24 12:10	
DR0008	Control Drawing	2024/01/24 12:10	
DR0009	Control Drawing	2024/01/24 12:10	
DR0010	Control Drawing	2024/01/24 12:10	
DR0011	Control Drawing	2024/01/24 12:10	
DR0012	Control Drawing	2024/01/24 12:10	
DR0013	Control Drawing	2024/01/24 12:10	
DR0014	Control Drawing	2024/01/24 12:10	
DR0015	Control Drawing	2024/01/24 12:10	
DR0016	Control Drawing	2024/01/24 12:10	

Figure IV.4. General overview of the project.

DR0001: free drawing.

DR0002: A drawing containing the blocks of:

- Purge sequences (PRGSEQ1, PRGSEQ2, PRGSEQ3)
- Pilot sequences (VEISEQ1, VEISEQ2, VEISEQ3)
- Burner sequences (ALLSEQ1, ALLSEQ2, ALLSEQ3)
- Trip condition (TRIP)
- Main valve sequence (MVALVESEQ)
- Blowers sequence (STSPB)
- Master Reset Button (MASTERRST)
- Panel buttons (Panel 1, Panel 2, Panel 3)
- ALARM (ANNUNICATOR)
- Initialization (INIT 1).

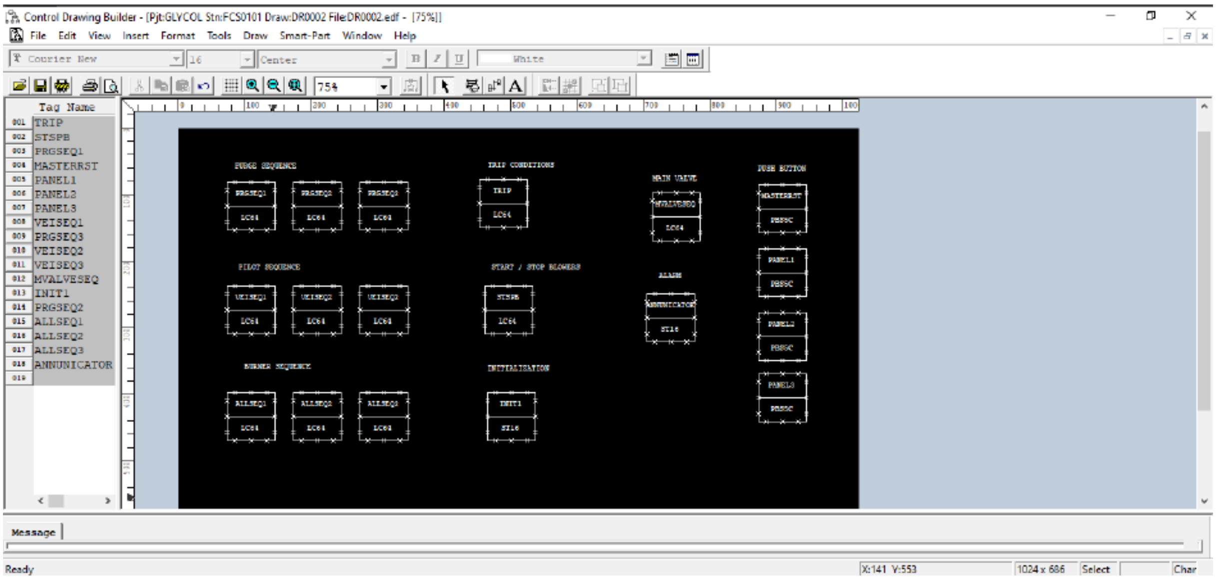


Figure IV.5. View of drawing DR0002.

DR0003: A drawing includes CPM configuration:

- TIC302 to control the temperature of the boiler.
- Three controllers for valve CPM

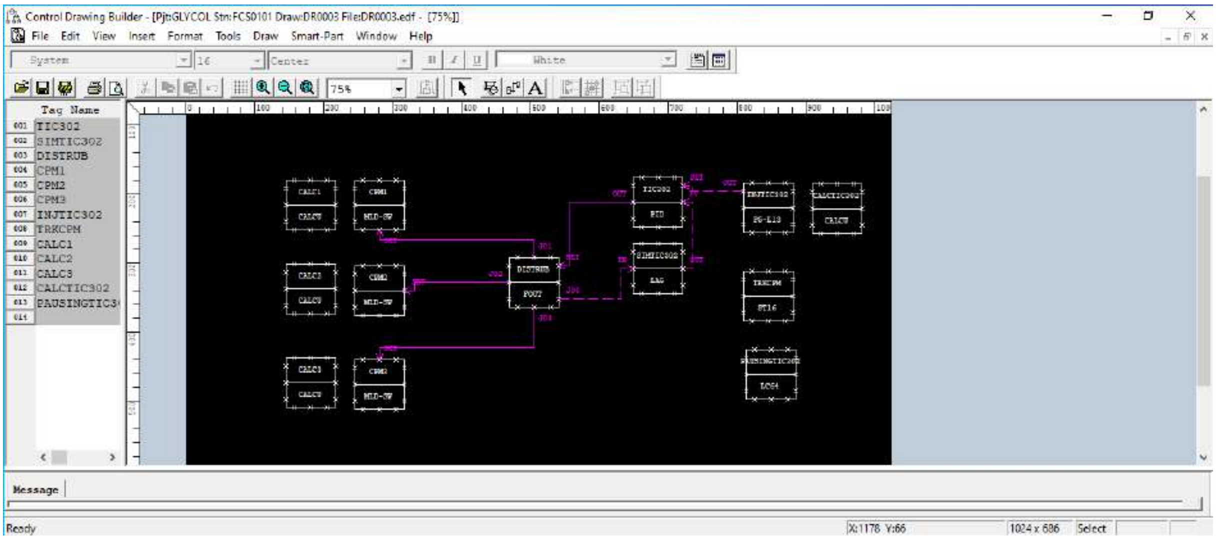
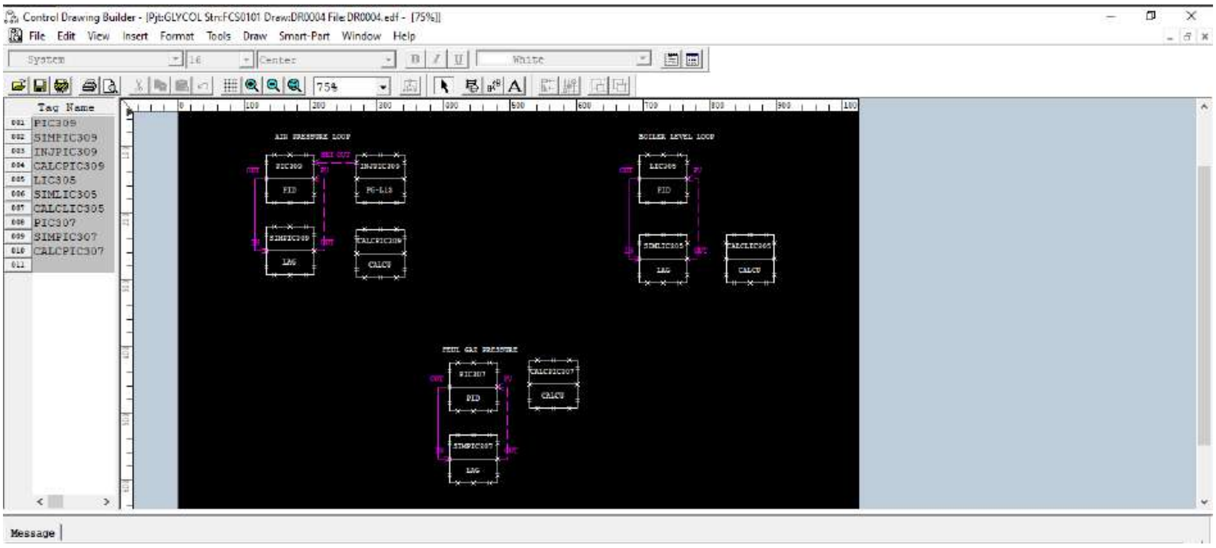


Figure IV.6. View of drawing DR0003

DR0004: A drawing includes 3 PID blocks:

- PIC307 to control the fuel gas pressure
- LIC305 to control the glycol level in the boiler
- PIC309 to control the pressurized air.



Control Drawing Builder - [Pjt:GLYCOL Stn:FCS0101 Draw:DR0004 File:DR0004.edf - [75%]]

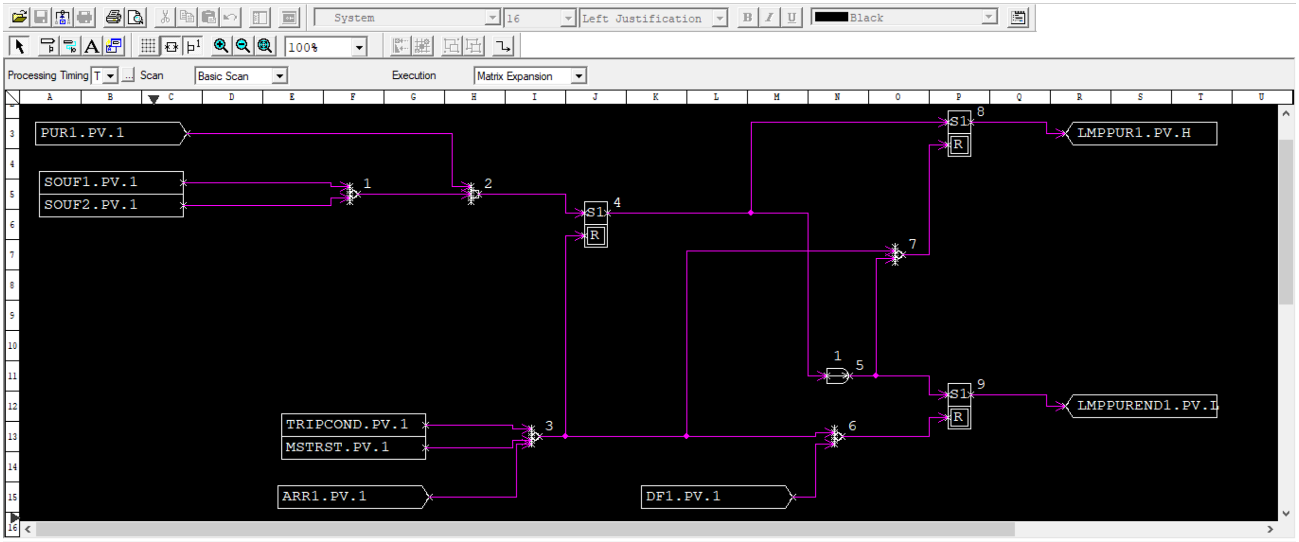
	Tag Name
001	PIC309
002	SIMPIC309
003	INJPIC309
004	CALCPIC309
005	LIC305
006	SIMLIC305
007	CALCLIC305
008	PIC307
009	SIMPIC307
010	CALCPIC307
011	

Figure IV.7. View of drawing DR0004

IV.6.1. Programming the Operating Sequences with Logic Chart LC64

IV.6.1.1. Purge Sequence

- Input elements used for digital inputs;
- Output elements used for digital outputs;
- RS flip-flops with R (RESET) priority;
- 1 timer, which allows some time after the purge is finished, then lights the purge end lamp;
- Logic gates, AND, OR, NOT, used for sequential linking between inputs and outputs.



Processing Timing T Scan Basic Scan Execution Matrix Expansion

Figure IV.8. Purge sequence with LC64

IV.6.1.2. Main Valve Sequence

For UZ308 to operate, at least one of the three LMPALL (1, 2, 3) and one of the three LMPVEI (1, 2, 3) must be functioning.

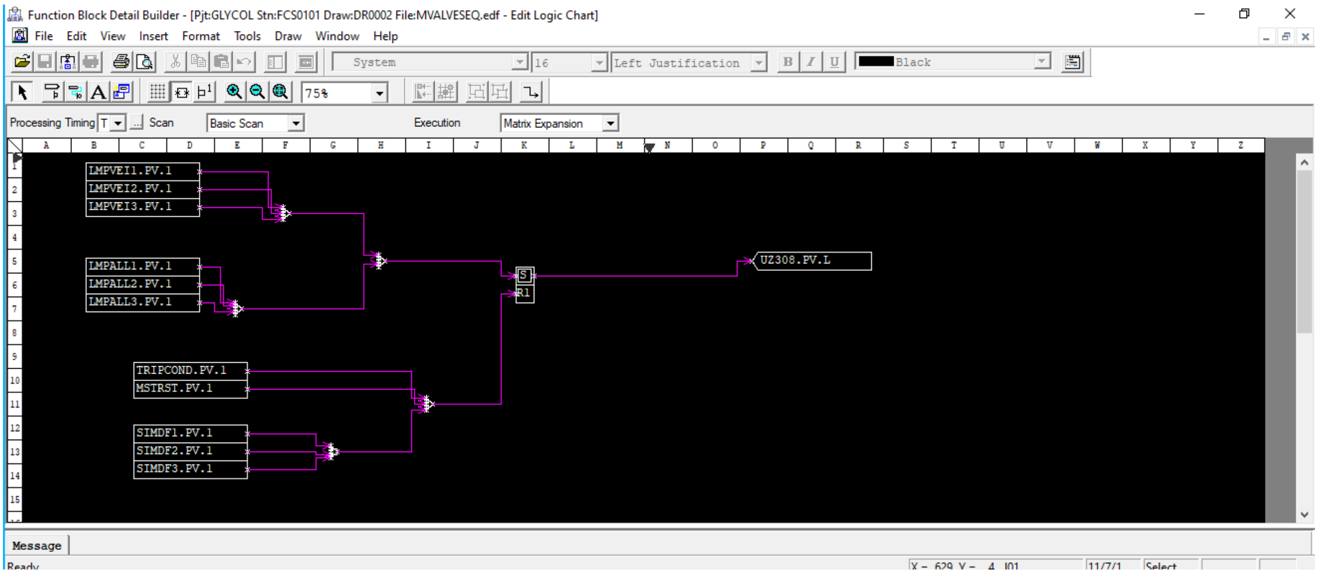


Figure IV.9. Main Valve sequence with LC64

IV.6.1.3. Blowers Sequence

When the "PBSOUF1" or "PBSOUF2" button is pressed, the blower will start working.

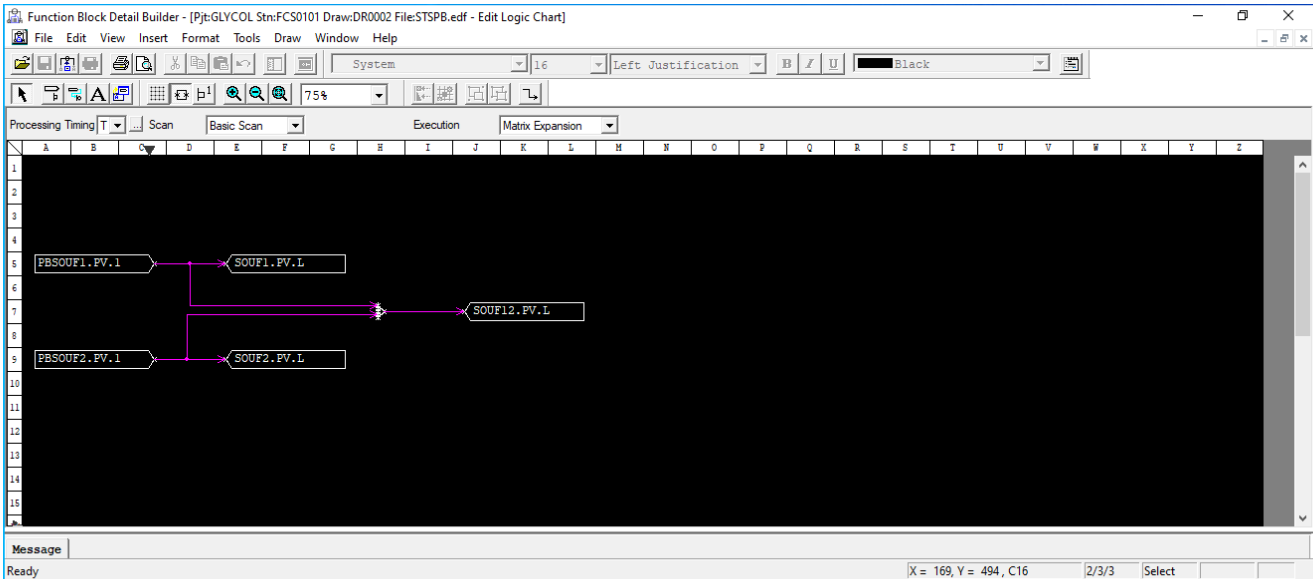
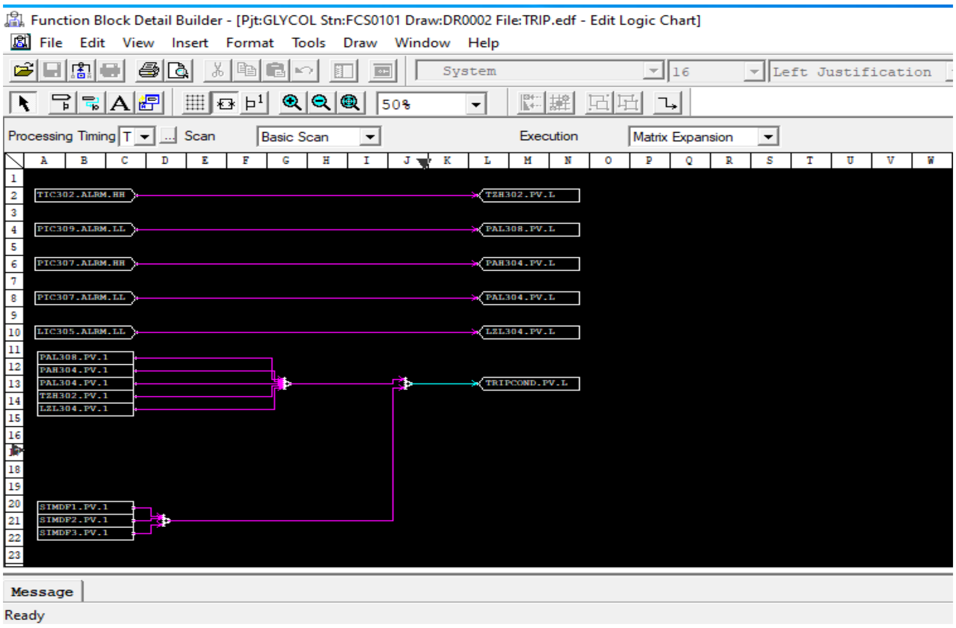


Figure IV.10. Blowers sequence with LC64

IV.6.1.4. Trip conditions

If there is a trip, the fuel gas valves will close, meaning there is no gas to ignite the pilots and burners, resulting in the furnace shutting down.



Function Block Detail Builder - [Pjt:GLYCOL Stn:FCS0101 Draw:DR0002 File:TRIP.edf - Edit Logic Chart]

Processing Timing: T

Scan: Basic Scan

Execution: Matrix Expansion

Ready

Figure IV.11. Trip conditions with LC64

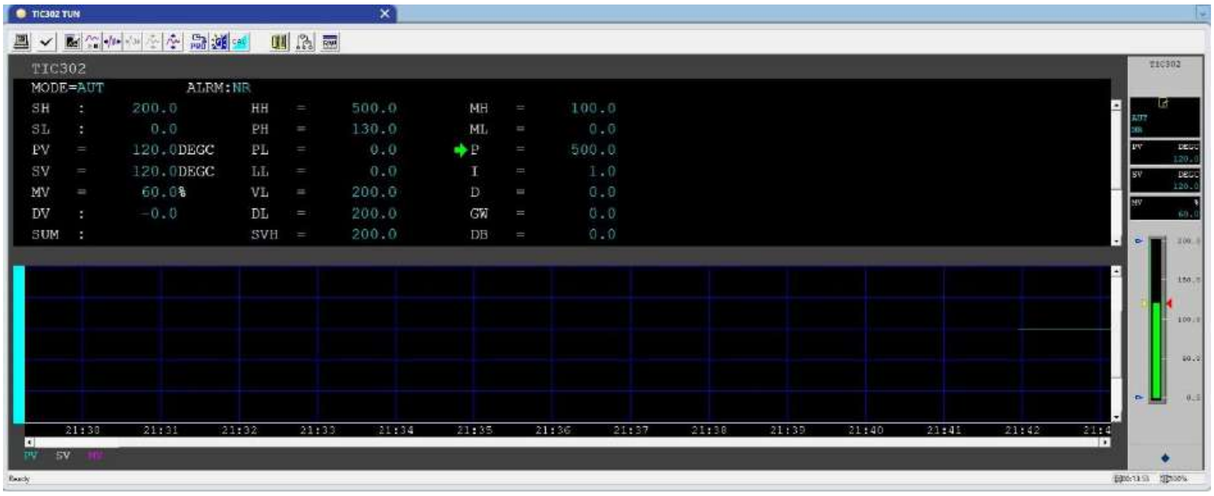
IV.7. Programming the Control Loops

As part of this study and in order to improve the precision and stability of the system, we chose a (PI) controller with parameters determined experimentally.

IV.7.1. Temperature Control Loop (TIC302)

The TIC is a temperature indicator controller. The parameters of the controller (P, I, D) are chosen by the manufacturer (the one who knows the system best, its order, the nature of the differential equation) or by identifying the system and determining the various actions.

The parameter values are P = 500 and I = 1,D=0.

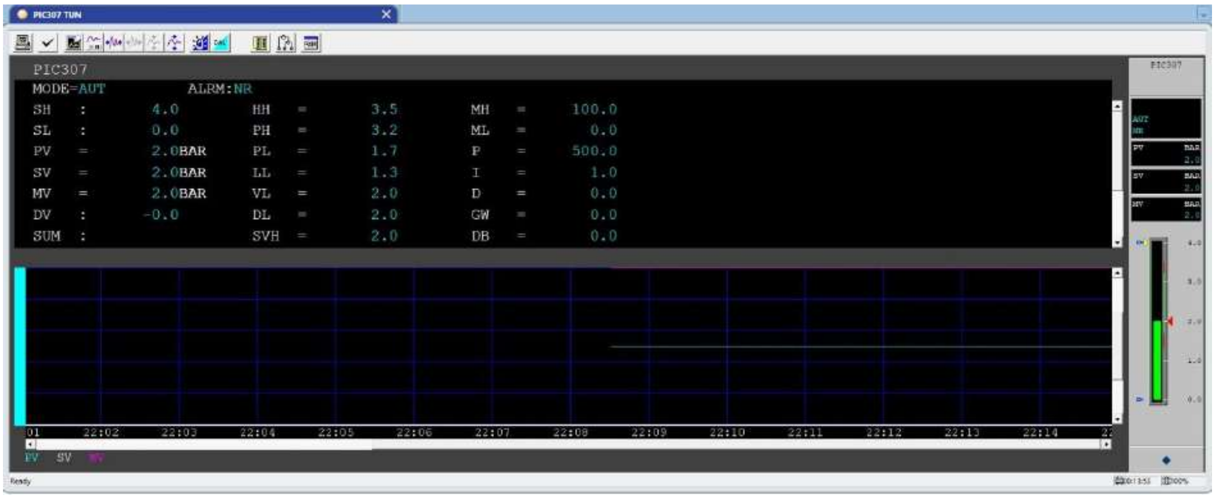


```
TIC302
MODE=AUT          ALRM:NR
SH   :   200.0      HH  =  500.0     MH  =  100.0
SL   :     0.0      PH  =  130.0     ML  =    0.0
PV   =   120.0DEGC  PL  =    0.0     P   =  500.0
SV   =   120.0DEGC  LL  =    0.0     I   =    1.0
MV   =    60.0%     VL  =  200.0     D   =    0.0
DV   :    -0.0      DL  =  200.0     GW  =    0.0
SUM  :              SVH =  200.0     DB  =    0.0
```

Figure IV.12. Detail of the TIC Controller

IV.7.2. Fuel Gas Pressure Control Loop (PIC307)

The PIC307 is a fuel gas pressure indicator controller with the following values: P =500 and I = 1, D=0.

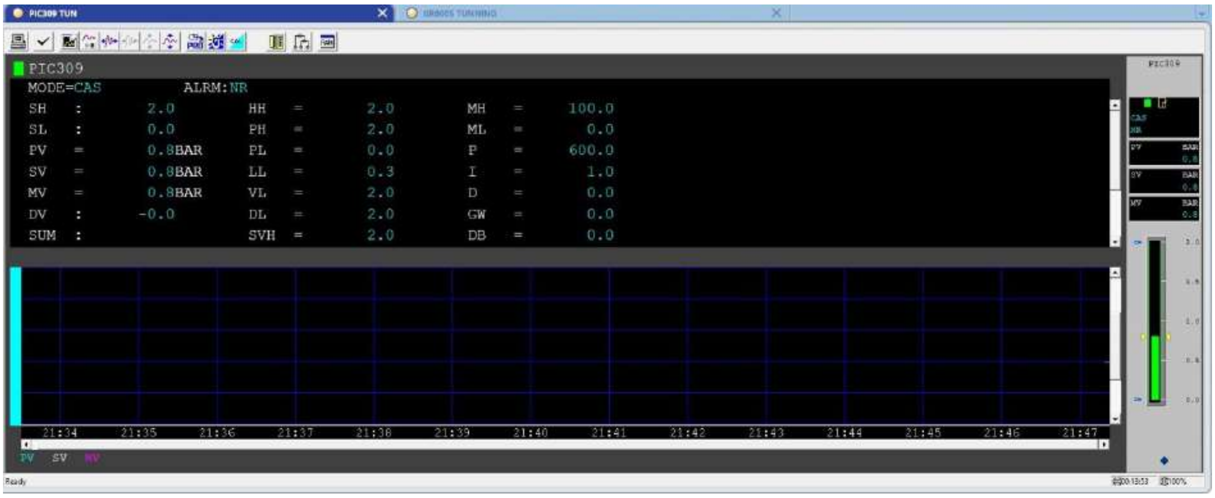


```
PIC307
MODE=AUT          ALRM:NR
SH   :     4.0      HH  =    3.5     MH  =  100.0
SL   :     0.0      PH  =    3.2     ML  =    0.0
PV   =     2.0BAR   PL  =    1.7     P   =  500.0
SV   =     2.0BAR   LL  =    1.3     I   =    1.0
MV   =     2.0BAR   VL  =    2.0     D   =    0.0
DV   :    -0.0      DL  =    2.0     GW  =    0.0
SUM  :              SVH =    2.0     DB  =    0.0
```

Figure IV.13. Detail of the PIC Controller

IV.7.3. Air Pressure Control Loop (PIC309)

The PIC309 is a Air Pressure indicator controller with the following values: P = 600 and I =1, D=0

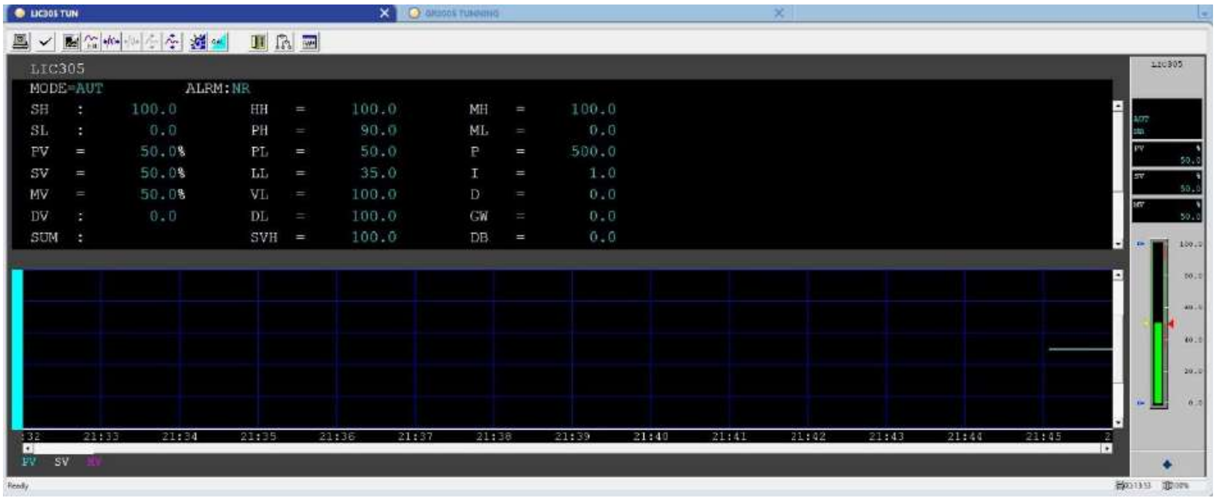


```
PIC309
MODE=CAS            ALRM:NR
SH   :      2.0     HH   =      2.0     MH   =    100.0
SL   :      0.0     PH   =      2.0     ML   =      0.0
PV   =      0.8BAR  PL   =      0.0     P    =    600.0
SV   =      0.8BAR  LL   =      0.3     I    =      1.0
MV   =      0.8BAR  VL   =      2.0     D    =      0.0
DV   :     -0.0     DL   =      2.0     GW   =      0.0
SUM  :              SVH  =      2.0     DB   =      0.0
```

Figure IV.14. Detail of the PIC Controller

IV.7.4. Glycol Level Control Loop of the Boiler (LIC305)

The LIC305 is a Glycol Level indicator controller with the following values: P = 500 and I =1, D=0



```
LIC305
MODE=AUT            ALRM:NR
SH   :    100.0     HH   =    100.0     MH   =    100.0
SL   :      0.0     PH   =     90.0     ML   =      0.0
PV   =     50.0%    PL   =     50.0     P    =    500.0
SV   =     50.0%    LL   =     35.0     I    =      1.0
MV   =     50.0%    VL   =    100.0     D    =      0.0
DV   :      0.0     DL   =    100.0     GW   =      0.0
SUM  :              SVH  =    100.0     DB   =      0.0
```

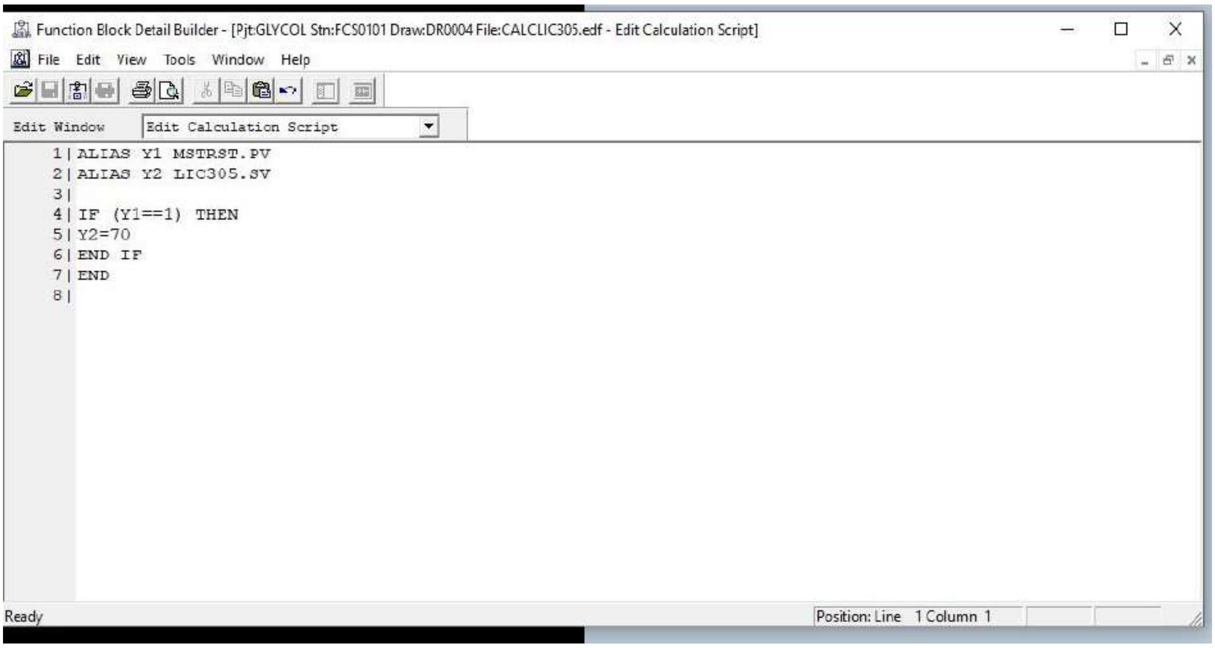
Figure IV.15. Detail of the LIC Controller

IV.8. Programming the TIC and LIC and PIC with the "CALCU" Calculator Block

The CALCU block is a programmable block using a special language that is a mix of Visual Basic and C++, called "SEBOL". It includes:

- The declaration of variables to be manipulated by ALIAS;

- Conditional IF...THEN loop, ending with END IF.



```
ALIAS Y1 MSTRST.PV
ALIAS Y2 LIC305.SV

IF (Y1==1) THEN
Y2=70
END IF
END
```

Figure IV.16. Programming of the CALCU block

In the above example, the program is used to increase the glycol level to 70% (normal function). And it all start When we click the master reset button.

IV.9. Development of the Graphical Supervision Interfaces for the Boiler

These interfaces include several views (auxiliary views and a main view).

IV.9.1. Maintenance View of the Sequences

This window shows the buttons corresponding to the sequence logic for verification.

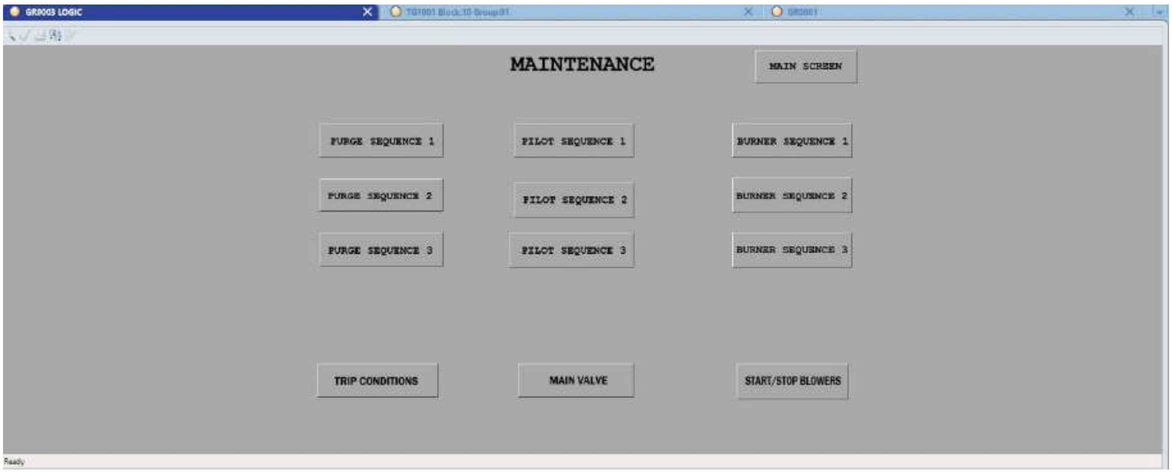


Figure IV.17. Maintenance View of the Sequences

IV.9.2. Tuning view

This window shows the buttons corresponding to Control Loops for verification.

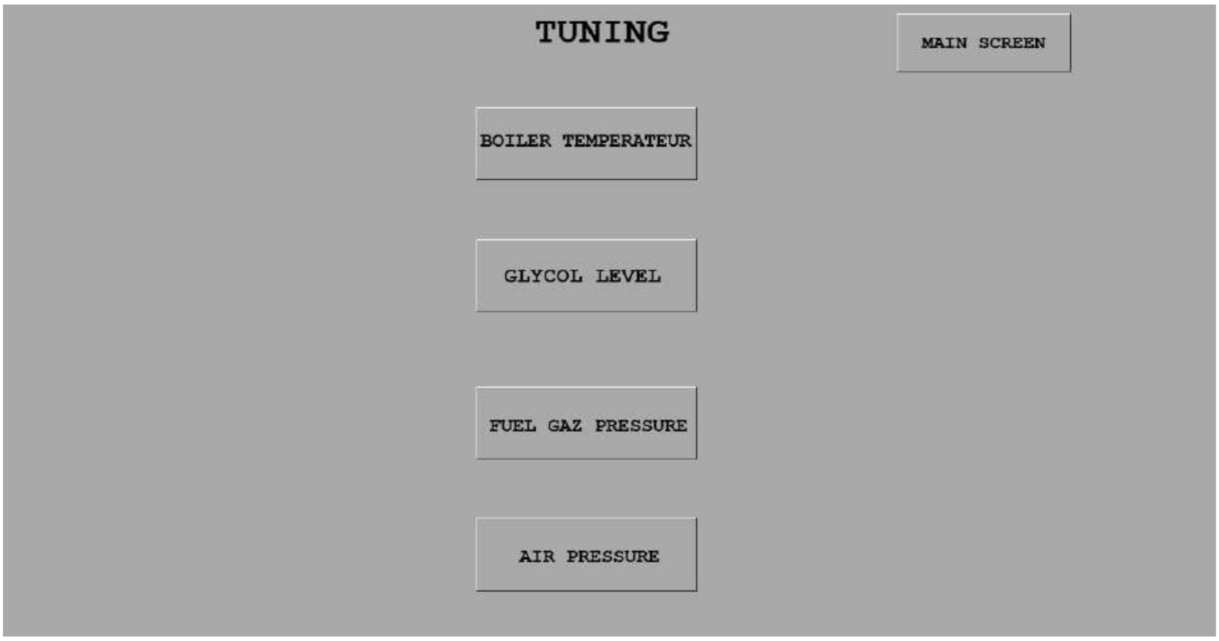


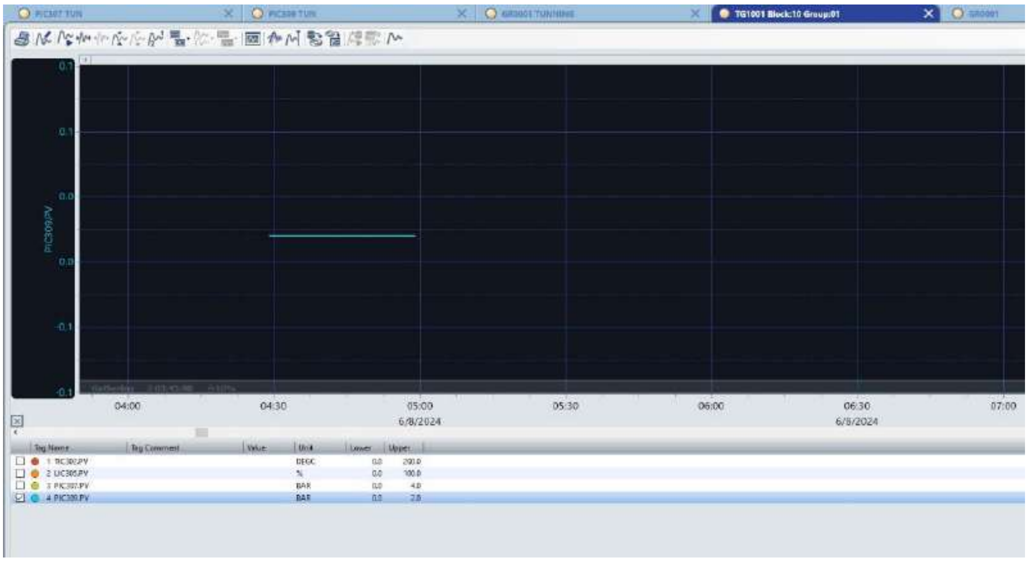
Figure IV.18. Tuning view

IV.9.3. Graph view

This graphs is check the control loops

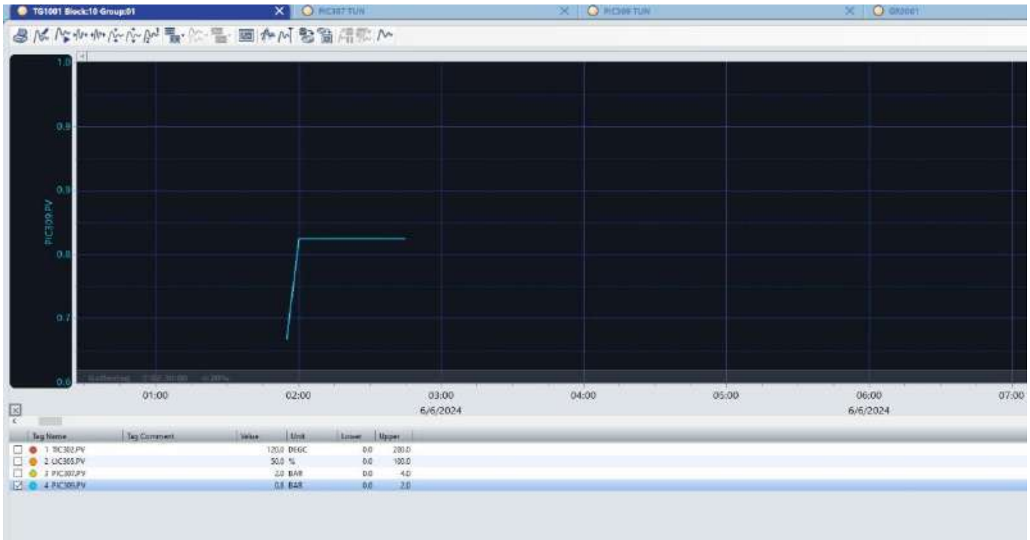
PIC309:

Air pressure, the initial stage of the process, shown on the graph. As Figure IV.18 illustrates, the air pressure is initially at 0 BAR. Nevertheless, the air pressure rises to 0.8 BAR when the boiler starts on. A trip will occur if the pressure starts to drop, signaling a serious issue that needs to be handled right away.



	Tag Name	Tag Comment	Value	Unit	Lower	Upper
☐ ●	1 TIC302.PV			DEGC	0.0	200.0
☐ ●	2 LIC305.PV			%	0.0	100.0
☐ ●	3 PIC307.PV			BAR	0.0	4.0
☑ ●	4 PIC309.PV			BAR	0.0	2.0

Figure IV.19. PIC309 Graph view



	Tag Name	Tag Comment	Value	Unit	Lower	Upper
☐ ●	1 TIC302.PV		120.0	DEGC	0.0	200.0
☐ ●	2 LIC305.PV		50.0	%	0.0	100.0
☐ ●	3 PIC307.PV		2.0	BAR	0.0	4.0
☑ ●	4 PIC309.PV		0.8	BAR	0.0	2.0

Figure IV.19.1 PIC309 Graph view

PIC307:

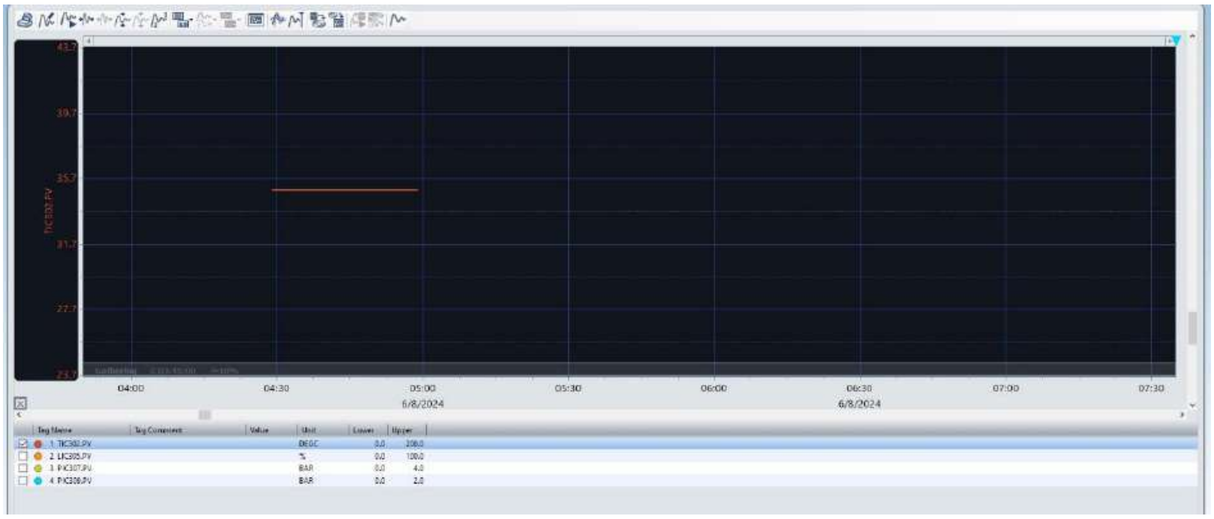
As seen in Figure IV.19, the graph displays the fuel gas pressure at the starting 2 BAR. When the boiler starts up, this pressure, unlike the air pressure, stays constant at 2 BAR. On the other hand, a trip will occur if the fuel gas pressure starts to change, signaling a serious issue that requires quick treatment.

	Tag Name	Tag Comment	Value	Unit	Lower	Upper
☐ ●	1 TIC302.PV			DEGC	0.0	200.0
☐ ●	2 LIC305.PV			%	0.0	100.0
☑ ●	3 PIC307.PV			BAR	0.0	4.0
☐ ●	4 PIC309.PV			BAR	0.0	2.0

Figure IV.20. PIC307 Graph view

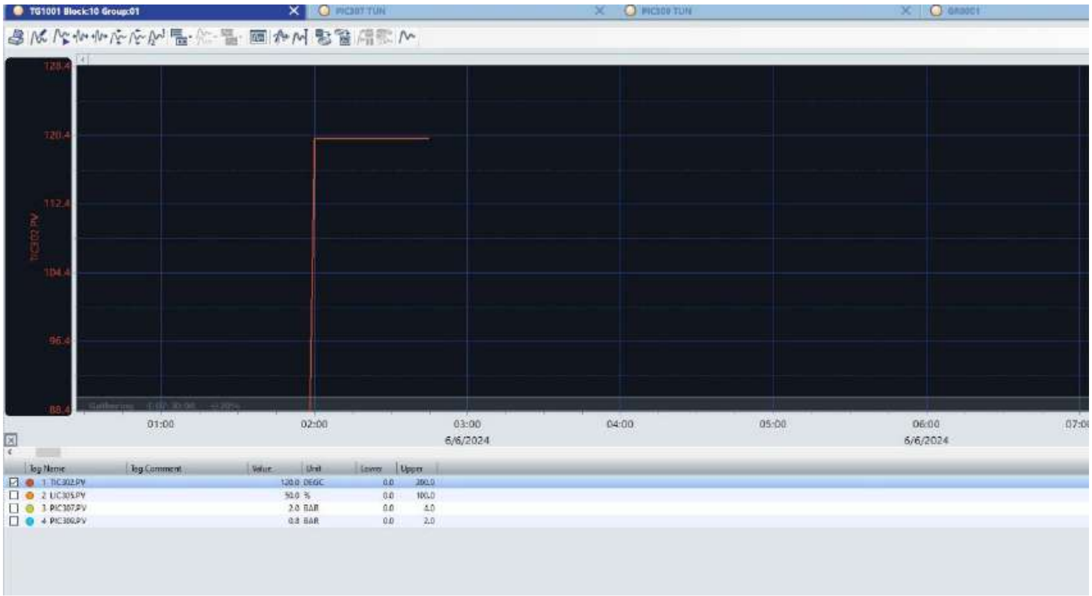
TIC302:

According to figure IV.20, this figure depicts the boiler temperature starting at 35°GC. As the procedure starts and proceeds through the several steps outlined in this document, the temperature progressively rises. At a certain level, it reaches 120°GC. This development shows the necessity of controls to guarantee the safety and effectiveness of boilers as well as the maintenance of the proper temperature for optimal operation.



	Tag Name	Tag Comment	Value	Unit	Lower	Upper
☑ ●	1 TIC302.PV			DEGC	0.0	200.0
☐ ●	2 LIC305.PV			%	0.0	100.0
☐ ●	3 PIC307.PV			BAR	0.0	4.0
☐ ●	4 PIC309.PV			BAR	0.0	2.0

Figure IV.21. TIC302 Graph view

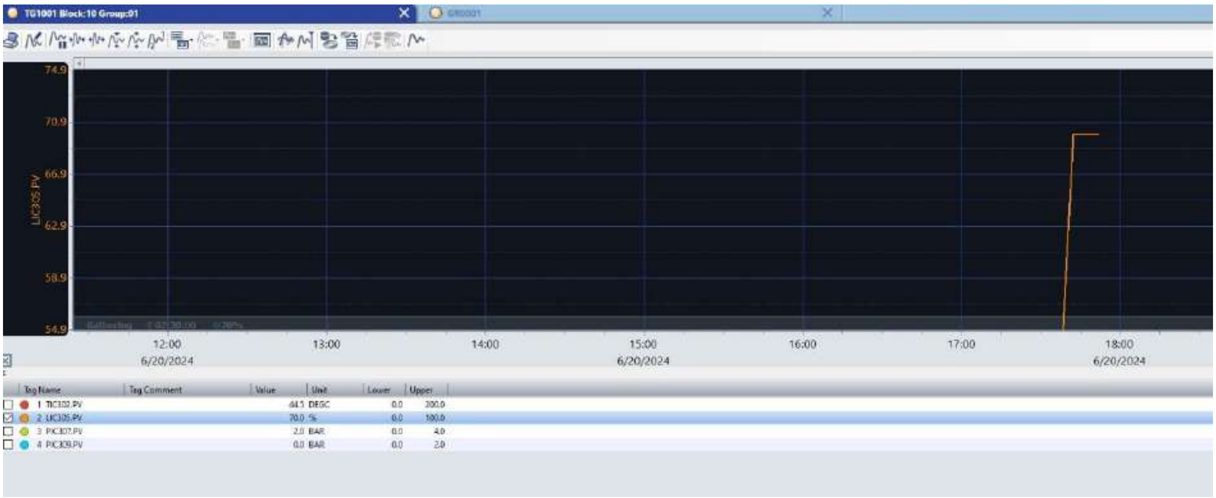


	Tag Name	Tag Comment	Value	Unit	Lower	Upper
☑ ●	1 TIC302.PV		120.0	DEGC	0.0	200.0
☐ ●	2 LIC305.PV		50.0	%	0.0	100.0
☐ ●	3 PIC307.PV		2.0	BAR	0.0	4.0
☐ ●	4 PIC309.PV		0.8	BAR	0.0	2.0

Figure IV.21.1. TIC302 Graph view

LIC305:

According to the diagram (Figure IV.21), the boiler's glycol level stays steady at a safe level of 70%. The device will trip if it begins to rise or fall below this level. It's essential to keep your boiler's glycol level constant for both safety and performance.



	Tag Name	Tag Comment	Value	Unit	Lower	Upper
☐ ●	1 TIC302.PV		44.5	DEGC	0.0	200.0
☑ ●	2 LIC305.PV		70.0	%	0.0	100.0
☐ ●	3 PIC307.PV		2.0	BAR	0.0	4.0
☐ ●	4 PIC309.PV		0.0	BAR	0.0	2.0

Figure IV.22. LIC305 Graph view

IV.9.4. Trip view

These are all the trip conditions to stop the entire unit. This view is to check where the problem is.

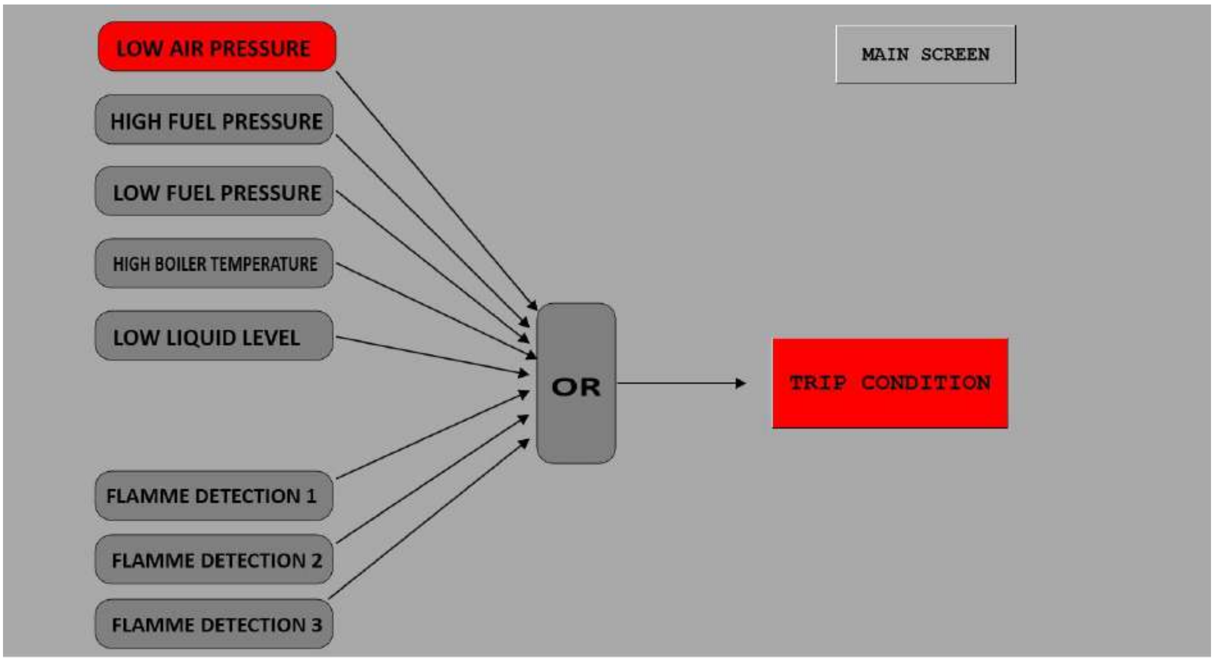
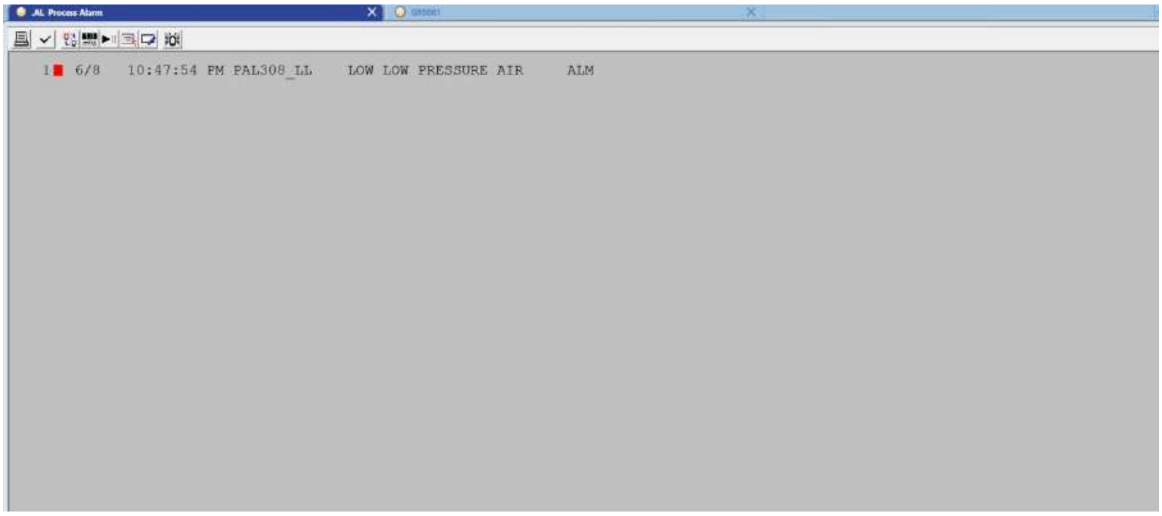


Figure IV.23. Trip view

IV.9.5. process alarm view

This view will display the annunciators when there's a problem in the unit. it will show as an alarm.



```
1■ 6/8   10:47:54 PM PAL308_LL    LOW LOW PRESSURE AIR     ALM
```

Figure IV.24. Process alarm view

IV.9.6. Main View of the Boiler

This graphic includes:

- The Boiler is shown in grey (H301);
- 3 control panels;
- All the views;
- Emergency shutdown button shown in red;
- 2 blowers shown in red if it’s off and green if it’s on;
- Start/stop button for each blower;
- Main valve (UZ308) shown in red if it’s off and green if it’s on;
- 3 burners and 3 pilots (UZ302, UZ303, UZ304) (UZ305, UZ306, UZ307);
- The flame detectors shown in white circles in the boiler;
- The pilot and burner valves shown in red if it’s off and green if it’s on;
- Fuel gas shown in orange;
- Three controllers for valve CPM shown in white rectangles.

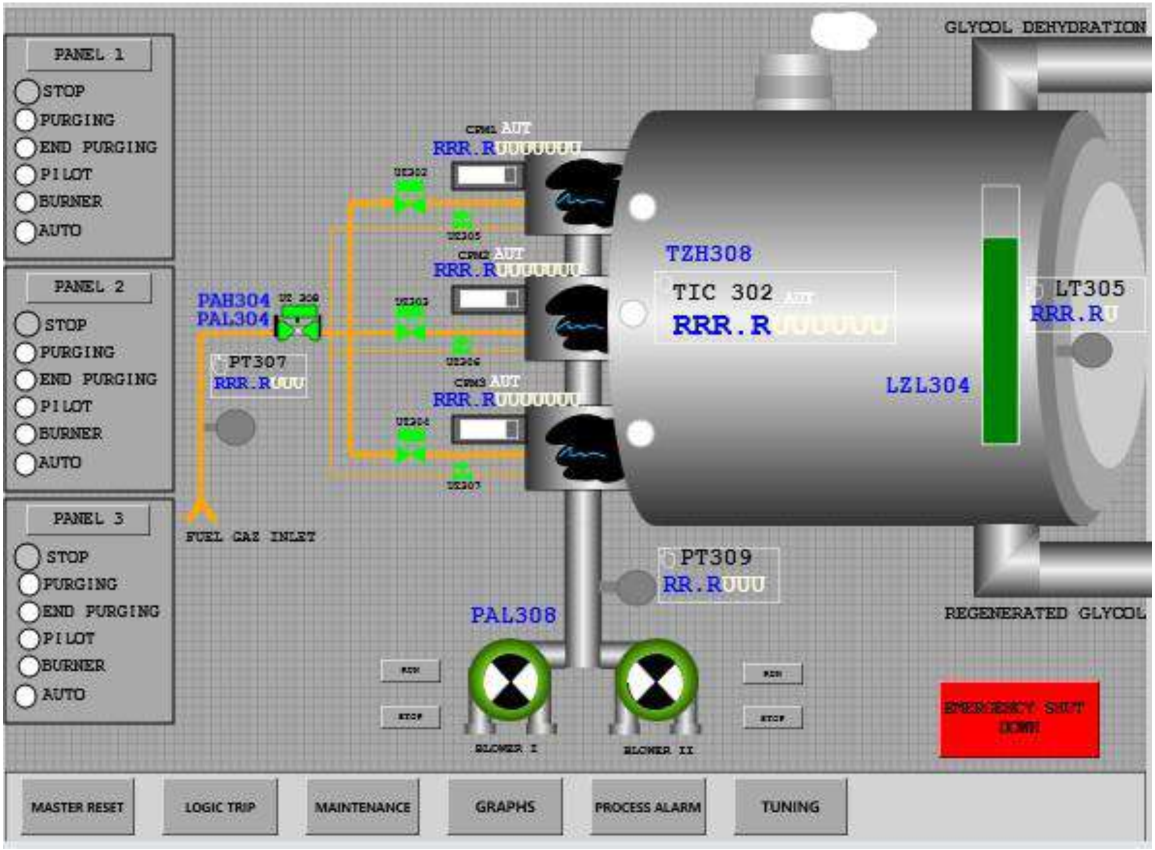


Figure IV.25. Main View of the Boiler

IV.10. Conclusion

In this chapter, we discussed the instrumentation, automation, and supervision of the glycol regeneration boiler. The solution was implemented under the DCS system, and several views were created for the control and monitoring of all regulation loops. Simulation tests were conducted in different operating modes, demonstrating the effectiveness of the developed supervision system.

General Introduction

General Conclusion

This document constitutes an account of the project undertaken during our professional induction internship. Our final year project focused on the automation of the H301 boiler control system within the natural gas processing unit at SONATRACH, Module 3, Hassi R'Mel.

In this study, we proposed a solution for controlling the furnace by replacing the local control panel system with remote supervision via a graphical interface, automating its operation under a DCS to replace hardwired logic controls.

The work involved automating the furnace control and integrating external regulation loops and the startup sequence of the boiler furnace into a graphical interface. The tests conducted demonstrated the effectiveness of the proposed solution.

The project provided us with the opportunity to deepen our theoretical and practical knowledge, particularly in the use of the DCS CENTUM VP software. Furthermore, this experience allowed us to familiarize ourselves with the professional environment, maintenance work, and emergency solutions for various equipment.

APPENDIX A

Tag Name	**Commentary**	**Input**	**Output**	**Memory**
PUR1	Selects the purge operation 1	X		
PUR2	Selects the purge operation 2	X		
PUR3	Selects the purge operation 3	X		
VEI1	Selects the pilot light operation 1	X		
VEI2	Selects the pilot light operation 2	X		
VEI3	Selects the pilot light operation 3	X		
ALL1	Ignition selection1	X		
ALL2	Ignition selection2	X		
ALL3	Ignition selection3	X		
MAR1	Start selection1	X		
MAR2	Start selection2	X		
MAR3	Start selection3	X		
ARR1	Stop selection1	X		
ARR2	Stop selection2	X		
ARR3	Stop selection3	X		
DF1	Flame detector1	X		
DF2	Flame detector2	X		
DF3	Flame detector3	X		
PZL308	Low combustion air pressure.	X		
PZH304	High fuel gas	X		

	pressure			
PZL304	Low fuel gas pressure	X		
TZH302	High temperature in combustion chamber	X		
LZL304	Low level in boiler (H301)	X		
UZ308	Main fuel gas valve		X	
UZ302	Burner valve		X	
UZ303	Burner valve		X	
UZ304	Burner valve		X	
UZ305	Pilot valve		X	
UZ306	Pilot valve		X	
UZ307	Pilot valve		X	
SOUF1	Air blowers		X	
SOUF2	Air blowers		X	
IGN1	Spark ignition		X	
IGN2	Spark ignition		X	
IGN3	Spark ignition		X	
LMSPUR1	PURGE LIMIT SWITCH		X	
LMSPUR2	PURGE LIMIT SWITCH		X	
LMSPUR3	PURGE LIMIT SWITCH		X	
LMSVEI1	PURGE LIMIT SWITCH		X	
LMSVEI2	PILOT LIGHT		X	

	LIMIT SWITCH			
LMSVEI3	PILOT LIGHT LIMIT SWITCH		X	
LMPPUR1	Lamps		X	
LMPPUR2	Lamps		X	
LMPPUR3	Lamps		X	
LMPENDPUR1	Lamps		X	
LMPENDPUR2	Lamps		X	
LMPENDPUR3	Lamps		X	
LMPVEI1	Lamps		X	
LMPVEI2	Lamps		X	
LMPVEI3	Lamps		X	
LMPALL1	Lamps		X	
LMPALL2	Lamps		X	
LMPALL3	Lamps		X	
TRIPCOND	Trip condition		X	
SIMDF1				X
SIMDF2				X
SIMDF3				X

Table IV.1: Declaration of Inputs/Outputs for the Boiler

Bibliography

[1] Hammoudi Djamel et Djouadi Younes, «rapport de stage », 2004.

[2] Documentation interne SONATRACH.

[3] Achache Bouhadjar Hakim, «Rapport de stage », 2010.

[4] Aouimeir Nassim et Hamladji Ammar, « Proposition d'une solution de Commande numérique et supervision de l'unité glycol sous DCS (CS3000) », Projet de fin d'étude d'ingéniorat en électronique, Université Mouloud Mammeri de Tizi- Ouzou, 2010.

[5] Koudache Karim et Ait Ouarab Samir, « Etude et Reinstrumentation du Rebouilleur sous Dcs-CS3000», Projet de fin d'étude d'ingéniorat en électronique, Université Mouloud Mammeri de Tizi-Ouzou, 2010.

[6] Ferhat Amhis, « Étude et simulation de DCS I /A Séries de FOXBORO sur le four rebouilleurH101 »,Projet de fin d'étude d'ingéniorat en automatique, Université Mouloud Mammeri de Tizi-Ouzou, 2011

[7] Manuel opératoire Glycol vol1/2, documentation interne, JGC, MPPIII, 1978.

[8] Spécification pour instrument (unité de glycol), JGC, MPPIII, 1978.

[9] CENTUM VP Reference Function Block Details Vol.1 IM 33M01A30-40E

[10] CENTUM VP HIS Operation IM 33M05D10-40E

[11] Modern Distributed Control System (DCS) Using the ABB Advant Controller - Technical Articles

[12] YTA Series GS 01C50H01-01EN Sep. 2016

[13] KLEEV USAINC.

[14] RU C-US.HA65.B.00172/19

[15] CENTUM VP Engineering Test Guide IM 33M10D20-40E

Site web et Compact disk (CD)

[W1] https://www.digikey.pt/en/blog/types-of-temperature-sensors

[W2]https://www.eaton.com/us/en-us/products/controls-drives-automation-sensors/sensors---limit-switches/limit-switch.html

[W3]https://instrumentationtools.com/

[W4] What is Distributed Control System (DCS)? (wevolver.com)

[W5] Distributed Control Systems History and Applications (automationcommunity.com)