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**Development and Integration of the Depropanizer
Process within the Yokogawa CENTUM VP DCS System**

Presented by

Mr. BELKADI Ismail

Mr. ABDELOUAHAD Abdelillah

On 29 June 2025 with the board of examiners:

Dr. S. BENTAIEB	M.C.B	UAT.B. B (Ain Temouchent)	President
Dr. A. ZEBENTOUT	M.C.A	UAT.B. B (Ain Temouchent)	Examiner
Dr. A. BENZINA	M.C.B	UAT.B. B (Ain Temouchent)	Thesis Advisor
Mr. A. AYAB	ING	Instrumentation Sonatrach/HRM	Co-Advisor

تعد الجزائر من أبرز الدول الرائدة عالميًا في مجال إنتاج الغاز الطبيعي، حيث تحتل المرتبة العاشرة على مستوى العالم والأولى إفريقياً. ويُعد حقل حاسي الرمل أحد الركائز الأساسية في هذا القطاع، إذ يُصنّف دوليًا كأحد أكبر احتياطات الغاز الطبيعي في العالم من حيث الأهمية والحجم. تتمحور هذه الدراسة حول تطوير نظام التحكم الموزع (DCS) مع التركيز على أتمتة فاصل البروبان و البوتان التابع للشركة الوطنية سوناطراك، وذلك باستخدام منصة البرمجة الصناعية YOKOGAWA CENTUM VP. ويكمن الهدف الرئيسي في إعادة تشغيل وحدة فاصل البروبان والبوتان وتطوير واجهة رسومية تفاعلية تتيج إمكانية التحكم والمراقبة عن بُعد، مما يساهم في تقليص التدخل البشري بشكل ملحوظ. هذا التوجه نحو الأتمتة والتحكم عن بُعد يساهم في تحسين كفاءة التشغيل من خلال تسريع عمليات بدء التشغيل والإيقاف، وتقليل الأخطاء البشرية، خاصة في الظروف الطارئة أو غير المتوقعة. كما يعزز من مستوى السلامة الصناعية بتقليل الحاجة لتواجد الفنيين في مناطق الخطر، ويرفع من موثوقية النظام عبر الاستجابة الفورية للإنذارات والمتغيرات العملية. إلى جانب ذلك، يوفر هذا النظام إمكانية المراقبة المستمرة وتحليل الأداء بشكل لحظي، مما يُمكن من اتخاذ قرارات دقيقة وسريعة لضمان استمرارية الإنتاج وتقليل فترات التوقف غير المبرمج. وقد شملت الدراسة أيضًا وصفًا تفصيليًا لمنشأة "حاسي الرمل" MPP3، بالإضافة إلى تحليل هيكل ووظيفي شامل لوحدة فصل البروبان و البوتان.

الكلمات المفتاحية: التحكم، التحكم في النظام الموزع (DCS)، فاصل البروبان، أتمتة فاصل البروبان، حاسي الرمل MPP3، برنامج YOKOGAWA CENTUM VP، سوناطراك.

Abstract

Algeria is considered one of the leading countries globally in natural gas production, ranking tenth worldwide and first in Africa. The Hassi R'Mel gas field is one of the key pillars of this sector, internationally recognized as one of the largest and most important natural gas reserves in the world. This study focuses on the development of a Distributed Control System (DCS), with a particular emphasis on the automation of the depropanizer unit operated by the national company Sonatrach, using the industrial programming platform YOKOGAWA CENTUM VP. The main objective is to automate the depropanizer unit and to design an interactive graphical interface that enables remote control and monitoring, thereby significantly reducing human intervention. This shift toward automation and remote control contributes to improving operational efficiency by accelerating startup and shutdown procedures, and minimizing human errors, especially in emergency or unexpected situations. It also enhances industrial safety by reducing the need for personnel in hazardous areas and increases system reliability through real-time response to alarms and process variables. Additionally, the system enables continuous monitoring and real-time performance analysis, allowing for fast and accurate decision-making to ensure production continuity and reduce unplanned downtime. The study also includes a detailed description of the Hassi R'Mel MPP3 facility, along with a comprehensive structural and functional analysis of the depropanizer unit.

Keywords: Control, Distributed System control (DCS), Depropanizer Unit, Hassi R'mel MPP3, YOKOGAWA CENTUM VP Software, SONATRACH, Propane.

Résumé

L'Algérie est considérée comme l'un des pays leaders au niveau mondial dans la production de gaz naturel, se classant au dixième et au premier rang en Afrique. Le champ gazier de Hassi R'Mel constitue l'un des piliers essentiels de ce secteur, reconnu à l'échelle internationale comme l'un des plus grands et des plus importants gisements de gaz naturel au monde. Cette étude porte sur le développement d'un **système de contrôle distribué (DCS)**, avec un accent particulier sur l'automatisation de l'unité de dépropaniseur de propane exploitée par la société nationale **Sonatrach**, en utilisant la plateforme de programmation industrielle **YOKOGAWA CENTUM VP**. L'objectif principal est de démarrer l'unité de dépropaniseur et de concevoir une interface graphique interactive permettant un contrôle et une surveillance à distance, réduisant ainsi de manière significative l'intervention humaine. Cette transition vers l'automatisation et le contrôle à distance contribue à améliorer l'efficacité opérationnelle en accélérant les procédures de démarrage et d'arrêt, tout en réduisant les erreurs humaines, notamment en cas de situations d'urgence ou imprévues. Elle renforce également la sécurité industrielle en limitant la présence du personnel dans les zones à risque, et augmente la fiabilité du système grâce à une réponse en temps réel aux alarmes et aux variables du procédé. De plus, le système permet une surveillance continue et une analyse des performances en temps réel, facilitant ainsi une prise de décision rapide et précise pour assurer la continuité de la production et réduire les arrêts non planifiés. L'étude inclut également une description détaillée de champs **Hassi R'Mel MPP3**, ainsi qu'une analyse structurelle et fonctionnelle complète de l'unité de dépropaniseur.

Mots clés : Contrôle, Système de contrôle distribué (DCS), Unité de depropanizer, Hassi R'mel MPP3, YOKOGAWA CENTUM VP Software, SONATRACH, Propane.

Dedication

To the Almighty,

For Your boundless grace that guided my steps, Your divine light that shaped my path. Without Your blessings, I would wander in shadows; because of Your mercy, I stand where I am today.

To My Beloved Mother and Father,

You taught me courage with your wisdom, nurtured me with your sacrifices, and fought life's fiercest storms to shelter me in calm. Your hands, weathered by love, built the foundation of my dreams. Every lesson you gifted me is a treasure, every sleepless night you endured is a testament to your boundless devotion. Though I may never repay the depths of your love, I vow to honor your struggles by living a life that mirrors your strength and kindness. My roots, sheltering trees, and the stars that guide me home. May my journey forever make your hearts proud.

With eternal gratitude and love,

Abdelillah

Dedication

To the Almighty,

For giving me the ability to write and think, the strength to believe, and the patience to pursue my dreams to the very end.

I dedicate this modest work to my dear parents,

who have always stood by my side, never sparing their efforts, encouragement, and patience. They are my symbols of tenderness, having sacrificed themselves for my happiness and success. Their constant love and sacrifices have shaped the person I am today. May God protect them, and may success always accompany my path so that I may bring them the happiness they truly deserve.

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NOMENCLATURE



Nomenclature

AD Suite	Automation Design Suite
AI/AO	Analog Input/ Analog Output
AOG	Advanced Operator Graphics
ATM	Atmosphere
C	Culomn
Calcu	Calculator.
CMMS	Computerized Maintenance Management System
CPU	Central Processing Unit
CTG	Centre Treatment of Gas
CTH1	Centre Treatment of Oil 1
D	Drum
DC	Direct Current
DCS	Distributed Control System
DI/DO	Digital Input/ Digital Output
DPhart	Digital Pressure HART
E	airow (Condenser)
ER	Expansion Rack
ESB	Enhanced Serial Backplane
ESD	Emergency Shutdown
FCU	Filed Control Unit
FCS	Field Control Station
FI/O	Field Input/Output
FP	Face Plate
FV	Flow Valve
GPL	Liquefied Petroleum Gas.
H	Heather (Rebioler)
HKU	House Keeping Unit
HIS	Human Interface Station
HMI	Human Machine Interface
HR (2,3,4,5,7,8,9)	Hassi R'mel (2,3,4,5,7,8,9).
HSE	Health Safety and Environment
IOM	Input Output Module
IT	Informatic Technology
K	Blowing machine
LC	Logic Chart
LV	Level Valve
mA	milliampere

MPPIII	Module Processing Plant III.
N-I/O	Network Input/Output
NU	Node Unit
OFF SPEC	On Specification
ON SPEC	OFF Specification
P	Pump
PLC	Programmable Logic Controller
PROSAFE-RS	Professional Safe Responsive Solution
PV	Pressure Valve
RTD	Resistance temperature detectors
SBC	Central Boosting Station
SBN	North Boosting Station
SBS	South Boosting Station
SCN	North Compression Station
SCS	South Compression Station
SEBOL	Sequence and Batch Oriented Language
SIS	Safety Instrumented System
SRGA	Associated Gas Recovery Station
SONATRACH	National Company for Research, Production, Transportation, Processing, and Marketing of Hydrocarbons
ST	Sequence Table
SV	Set Value.
TV	Temperture Valve



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GENERAL

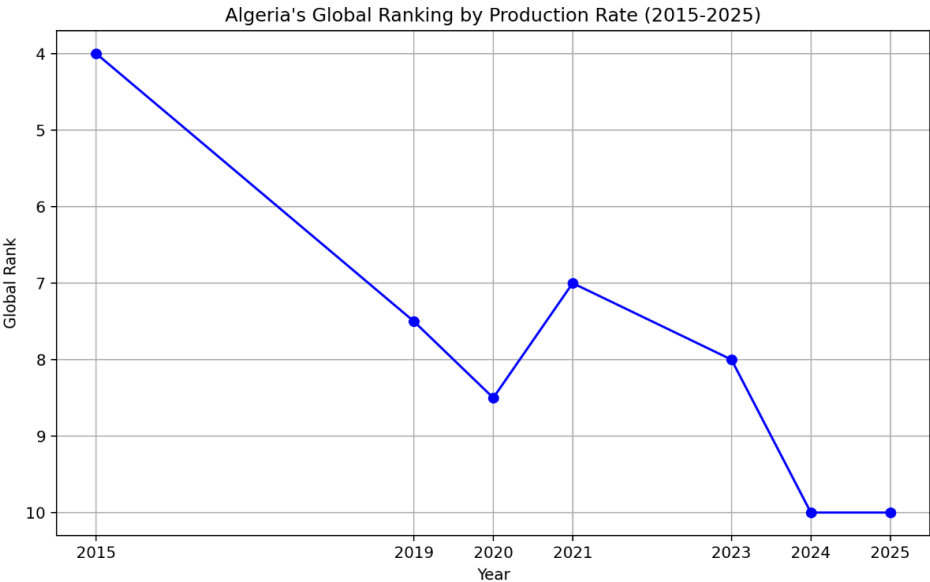
INTRODUCTION



Algeria, the largest country in Africa, is also one of the continent’s leading producers and exporters of natural gas. The country is rich in gas deposits, primarily distributed across three major zones: the central Sahara region, northern coastal basins, and offshore Mediterranean areas. According to data from Sonatrach, the national hydrocarbons company, Algeria has proven natural gas reserves estimated at around **4,500 billion cubic meters**, making it one of Africa’s best-endowed countries.

Annual natural gas production reaches nearly **100 billion cubic meters**, a significant portion of which is exported to Europe via several onshore and subsea pipelines. By comparison, European countries consume an average of **400 to 500 billion cubic meters annually**, underscoring Algeria’s strategic importance in the regional gas market. Production potential is concentrated mainly in the Hassi R’Mel, In Salah, and Tiguentourine fields in the country’s south, characterized by extreme desert climates.

However, Algeria’s gas production has recently decreased, and its global ranking has declined (as shown in the graph below). This is due to decreasing reservoir pressure in mature fields and aging, non-automated extraction infrastructure.



The Ranking source:

- <https://www.opec.org>
- <https://www.eia.gov>
- <https://sonatrach.com>
- <https://www.iea.org>
- <https://www.globalfirepower.com>

Liquefied petroleum gas (LPG) plays a strategic role of Algeria's energy system. The depropanizer unit, one of the most important facilities in the LPG production chain, which plays a crucial role in separating the light components of natural gas, the national corporation Sonatrach operates this plant in Algeria, especially in the key gas field of Hassi R'Mel. The depropanizer unit was operated in a semi-automatic mode, which, despite its functional potential, posed several operational challenges. It relied heavily on manual intervention, increasing the risk of human error, particularly during emergencies or unexpected situations. The absence of full automation led to prolonged and inefficient startup and shutdown procedures, negatively impacting overall operational efficiency. Furthermore, the lack of remote control required operators to be physically present in hazardous zones, exposing them to safety risks. The manual control system also lacked the capability to respond promptly to fluctuations in process parameters or critical alarms, often resulting in unplanned downtime or incidents. Additionally, the system did not support continuous monitoring or real-time analysis, leading to inconsistent data collection, delayed performance assessment, and suboptimal decision-making.

The automation of the depropanizer system at the Hassi R'Mel MPP3 facility is centered on deploying Yokogawa CENTUM VP to achieve several strategic objectives. These include fully automating the depropanizer unit, developing a Distributed Control System (DCS) using the CENTUM VP industrial automation platform, and designing an intuitive graphical interface that enables both remote control and real-time process monitoring. Enhancing industrial safety is a key priority, accomplished by reducing human intervention in hazardous areas and during emergency situations.

Operational efficiency is further improved by accelerating startup, shutdown, and emergency shutdown procedures. System reliability is strengthened through faster alarm responses and precise management of process variables. Additionally, continuous monitoring and real-time performance analysis support rapid decision-making, ensure production continuity, and help minimize unplanned downtime—paving the way for a more resilient and responsive production environment.

This document outlines the development and integration of the depropanizer process within the Yokogawa CENTUM VP Distributed Control System (DCS), structured across four chapters.

The first chapter provides an overview of the infrastructure and facilities at the Hassi R'Mel Gas Field. The second chapter presents a detailed analysis of the depropanizer unit, covering its equipment, instrumentation, and the overall automation strategy. Chapter three focuses on the architecture and capabilities of the DCS, with particular emphasis on the Yokogawa CENTUM VP platform. Finally, the fourth chapter describes the practical implementation of the depropanizer unit's automation using the Yokogawa CENTUM VP system.



CHAPTER I



Infrastructure and Facilities Overview at Hassi-R'Mel Gas Field

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I.1. Introduction

Energy plays a crucial role worldwide, leading Algeria to focus on its hydrocarbon sector since its nationalization on 24th February 1971. As the most strategic resource, hydrocarbons drive industries and impact various sectors. Producing nations aim to maximize reserves and sustain production through different extraction methods. While oil remains the dominant energy source, natural gas is gaining importance as a cleaner alternative that helps protect the environment. Algeria is a major global natural gas producer, ranked 10th globally [w1] and 1st in Africa [w2], with the Hassi-R'mel gas field serving as a key contributor. Recognized internationally, this field is among the world's largest gas reserves.

In this chapter, we present the Hassi-R'mel gas field by discussing its geographical location, historical background, development stages, gas facilities, and processing modules, ending with a detailed description of the MMP3 module.

I.2. Geographical and Climatic Situation of Hassi-R'Mel

Hassi-R'Mel, in the province of Laghouat (see Figure I.1), is 120 kilometers from the city of Laghouat and 550 kilometers from the capital city of Algiers at an altitude of about 750 meters. The area has a dry climate, low rainfall (averaging 140 millimeters annually), an average summer humidity of 19%, and winter humidity of 34%. Temperature ranges from 5°C to 45°C, and powerful Sirocco winds sweep sand up to 110 meters in the air, thereby making visibility only 15 meters [1].



Figure I.1. Geographical Location of the Hassi-R'mel Site [2].

I.3. Historical Overview of Hassi-R'Mel

In 1952, the initial production well was drilled near Berriane. In the Hassi-R'mel field center, the first well, HR1, was drilled in 1956 on the anticline that constitutes the Hassi-R'mel reservoir. The well confirmed the existence of condensate-rich natural gas in the Triassic sandstone, with a pressure of 310 ATM and a temperature of 90°C. The maximum depth reached was 2332 meters, indicating the presence of humid gas reservoirs.

From 1957 to 1960, eight wells (HR2, HR3, HR4, HR5, HR7, HR8, and HR9) were drilled, revealing the existence of three oil reservoirs [3].

I.4. The development of Hassi R'Mel

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: The commissioning of the new Phase 3 boosting stations

2024: Launch of the project to install the new Phase 4 boosting stations replacement [4].

I.5. Organization of the Regional Directorate of Hassi-R'Mel

The development and exploitation of hydrocarbons are the main objectives pursued by the regional management. To adequately meet its workload plan, the organization is divided into several departments as below, shown on Figure I.2 :

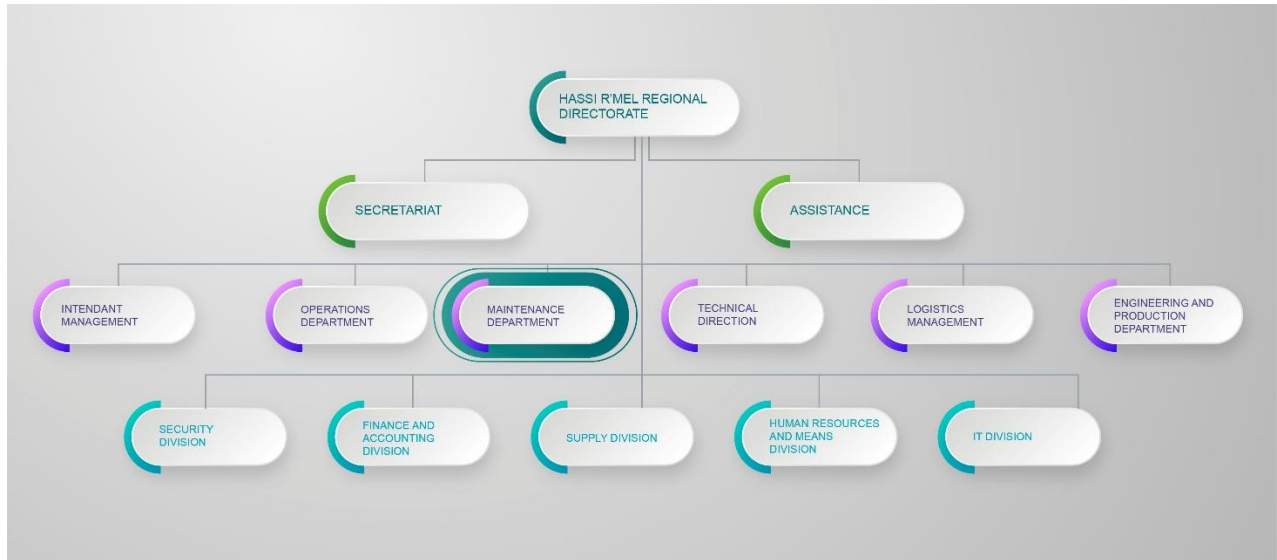


Figure I.2. Hassi-R'Mel Regional Directorate - Organizational Chart.

I.5.1. Supply and Transport Division:

- Procurement of materials and spare parts through various budgets, calls for tenders, and local orders.
- Receipt of equipment and spare parts, verification of their compliance, and stock management.

I.5.2. Technical Directorate:

- Management and support for new industrial projects.
- Implementation of modifications suggested by user sites.

I.5.3. Engineering and Production Directorate:

- Development of reservoirs.
- Maintenance of wells and surface installations (wire-line and work-over).

I.5.4. Operations Directorate:

- Optimal operation of units.
- Planning and execution of production programs.

I.5.5. Maintenance Directorate:

- Keeping equipment in good working condition.
- Planning of preventive maintenance.
- Establishment of maintenance policies.
- Implementation and development of IT tools (CMMS).

I.5.6. Logistics Department:

- Monitoring and realization of basic infrastructure in the region.
- Maintenance of domestic facilities in the region (electricity, cooling, plumbing, carpentry).

I.5.7. Security Division:

- Implementation of safety measures (accident prevention).
- Establishment of the HSE (health, safety, and environment) policy at the industrial site.

I.5.8. IT Division:

- Development of operating software for all structures of the regional management.
- Maintenance of the network and IT tools.

I.5.9 General Services Division:

- Monitoring of catering and accommodation services.
- Monitoring of asset management.

I.5.10 Finance Division:

- Budget management for structures, scheduling.
- Financial monitoring of investment, operational, and equipment projects.

- Cash management and general accounting.

I.5.11 Human Resources Division:

- Career management of personnel.
- Management of recruitment and training of staff [5].

I.6. The gas facilities of Hassi R'mel

The industrial process diagram highlights three distinct sectors, as shown in Figure I.3, as follows:

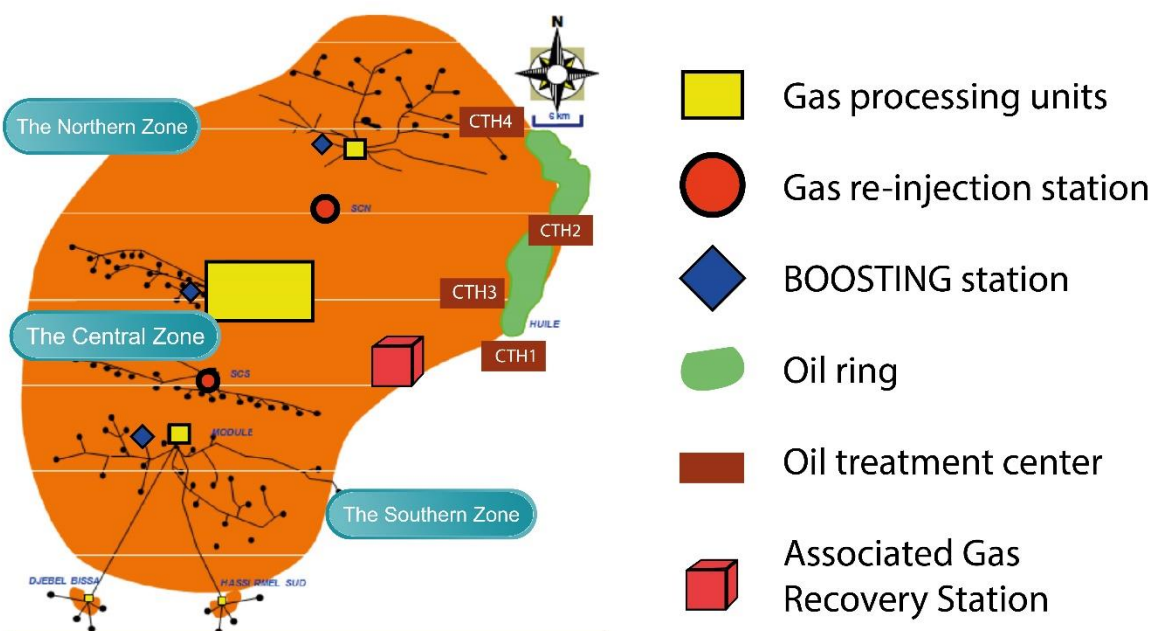


Figure I.3. Distribution of Various Facilities in the Hassi-R'Mel Field [5].

I.6.1 The Central Zone

This zone consists of three modules (0, 1, and 4), an oil treatment center (CTH1), and a fluid storage and transfer center (CSTF); the central wells supply these modules.

I.6.1.a. The "0" module

Consists of two identical and independent trains with a total production capacity of:

- 30 million m³/day of dry gas.
- 1300 tons/day of LPG.
- 6100 tons/day of condensate.

I.6.1.b. The "1st" module

Consists of 03 identical trains with a total processing capacity of:

- 60 million m³/day of dry gas.
- 2400 tons/day of LPG.
- 6100 tons/day of condensate.

I.6.1.c. The "4th" module

Consists of three identical and independent trains with a total processing capacity of:

- 60 million m³/day of dry gas.
- 2,700 tons/day of LPG.
- 11,200 tons/day of condensate [3].

I.6.1.d. Oil treatment center (CTH1)

It is a plant composed of various equipment used to separate all undesirable components from crude oil before expedition [1].

I.6.1.e. Fluid storage and transfer center (CSTF)

Transfer of liquid hydrocarbons, it consists of tanks (cylindrical tanks) for storage of condensate, spherical tanks for LPG storage, a system of measurement of containers, a system for counting the quantities of condensate and LPG shipped for marketing and a set of pumps to ship the products [3].

I.6.2 The Northern Zone

This zone contains only the "3rd" module, powered by the Northern wells, and consists of three identical and independent trains with a processing capacity of:

- 60 million m³/day of dry gas.
- 2,700 tons/day of LPG.
- 11,800 tons/day of condensate.

We also find two **CTH (2 and 4)** and the North compression and reinjection station provides about 9 million cubic meters per day using 18 turbomachines [6].

I.6.3. The Southern zone

Comprises the "2nd" module, identical to the "3rd" module, supplied by the Southern wells. In this module, we find CTH-3, the South compression unit, and the reinjection station, which is also identical to the North one. Additionally, we find:

I.6.3.a CTG Djebel Bissa

The crude gas treatment center with a processing capacity of 4 million m³/day.

I.6.3.b HR-Sud CTH

The South Oil Treatment Center is the crude gas processing center with a processing capacity of 4 million m³ per day [1].

I.7. Presentation of Module Processing Plant "MPP3"

The construction of the "3rd" module was under a contract signed between the national company Sonatrach and the Japanese company JGC Corporation. The latter was responsible for the design and construction of this plant (MPP3), which officially began operations on October 26th, 1980. The Figure I.4 presents a real overview of the MPP3 [3].



Figure I.4. Module Processing Plant 3 Hassi-R'mel [w3].

This module is in the Northern sector and supplies raw natural gas from wells situated in the northern part of Hassi-R'Mel (55 wells), connected through 10 gas collectors (N1 to N8)

however due to the observed pressure drop in the Northern field, the operators resorted to supplying it via two (02) additional collectors, W8 and E6, coming from the Central sector [3].

I.8. Organization of the maintenance service

The maintenance service of "3rd" module is composed of three sections (mechanical section, electrical section, instrumentation section) see the Figure I.5, each section ensures the proper functioning of the equipment under its responsibility.

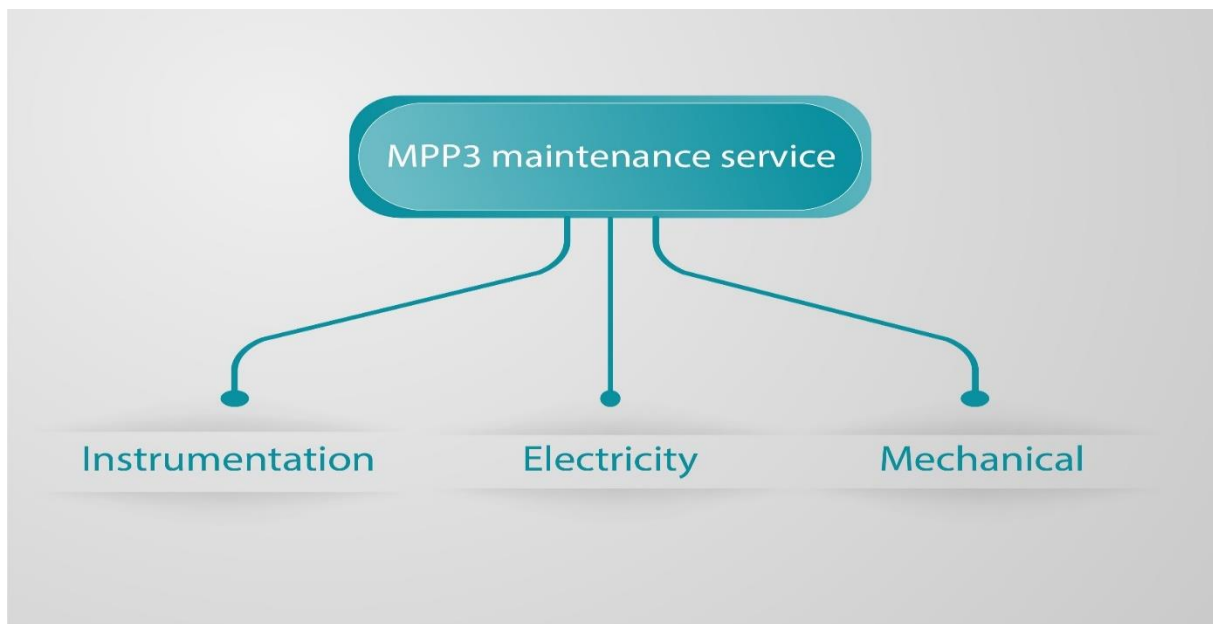


Figure I.5. MPP3 Organization of the maintenance service - Organizational Chart [1].

I.8.1. Mechanical Section

This section is primarily responsible for the proper functioning of rotating machines, manual valves, filters, and exchangers.

I.8.2. Electricity Section

It is responsible for all operations concerning electricity (electric motors, lighting, network, etc.).

I.8.3. Instrumentation section

This unit is responsible for the control aspects of all installations (opening and closing), or more specifically, for the maintenance of control systems for all equipment, including automatic valves, sensors, and indicators. The staff in this section have different tasks:

- Control of all automatic valves.
- The revision of all instruments (sensors, indicator).
- The calibration of automatic valves as well as vibration sensors (installed on the equipment).
- Intervention in case of accidental breakdowns (curative).

I.9 Raw Gas Processing at MPP3

The "3rd" Module is a gas processing plant composed of three trains (A, B, and C) operating in parallel and following the same process. Each train ensures the production of the following products: **condensate, LPG, and dry gas**, the diagram of description is depicted in Figure I.6.

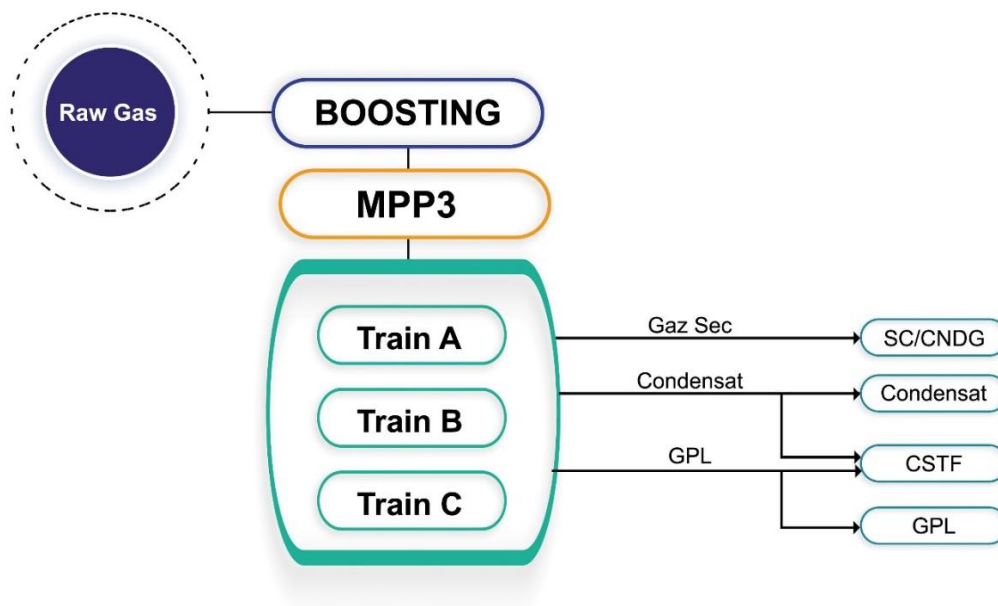


Figure I.6. Descriptive diagram of "3rd" Module.

The liquids (condensate and LPG) that are ON-SPEC (On specification) sent to the CSTF; hence, OFF-SPEC (off specification) liquids are stored for a sufficient period to allow for settling and degassing, followed by a drainage operation before being returned to the trains for reprocessing. When CSTF is unable to receive the module's production of LPG and condensate, these products stored in the module's storage units for a period not exceeding 24 hours [3].

1.10. Conclusion

In this chapter, we presented the HASSI R'MEL sector with a detailed focus on the 3rd module (MPP3) along with its functional structure. From this analysis, we learned that the process of gas production involves the application of multiple processing methods, equipment of various technological origins, and the adjustment of diverse parameters.

One issue in this plant is the lack of automation of specify instruments, particularly the depropanizer, which is the heart of the facility. As a remedy, we suggest re-instrumentation of the depropanizer.

In the following chapter, we will detail the intricacies of the depropanizer by defining, describing, and elaborating on its numerous attributes.

II

CHAPTER II

II

MMP3 Depropanizer: Design, Operation, and Safety

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II.1. Introduction

As part of the hydrocarbon processing operations at MMP3, a depropanizer unit plays a crucial role in separating propane from the LPG.

A Successful operation of the depropanizer requires that all operators understand the process design, and are aware of the factors affecting production rates and continuity of operation.

This includes understanding the performance characteristics of all major equipment, as well as the provisions for protecting personnel and equipment, particularly in emergencies.

These operating instructions describe the operation of the process equipment, utility, and auxiliary facilities. They also describe typical initial and normal start-up procedures, present the conditions to be expected during normal operation, and give normal and emergency shutdown procedures [7].

II.2. Overview of the Depropanizer Unit

A depropanizer is a distillation column used in petroleum refining and natural gas processing, shown on Figure II.1. It is commonly used to separate lighter compounds, including propane (C₃), as top products, and heavier hydrocarbon compounds, including butane (C₄), from the bottom of the column.



Figure II.1. Depropanizer Unit in a MMP3.

II.3. Process Role of the Depropanizer

The objective of the depropanizer is to obtain propane and butane from the LPG storage section.

The feed, which comes from the existing LPG surge drum, enters the column operating at a pressure of 20.0 bar, with a top temperature of 59.3 °C and a bottom temperature of 110.0 °C (minimum temperature case: 58.8 °C and 109.9 °C).

This section is equipped with several accessories (see Figure II.2), including the following items:

- Depropanizer Reflux Drum
- Depropanizer Reflux Pumps
- Depropanizer Overhead Condenser
- Butane Cooler
- Depropanizer Reboiler
- Depropanizer Bottom Pumps
- Flare

II.4. Process Input Parameters Feed Characteristics

The following Table II.1 is the feed conditions for the depropanizer, where the propane (C3) and butane (C4).

Component	(mol%)
C3	56.85
C4	43.15
TOTAL	100.0

Table II.1. The feed conditions for the depropanizer.

II.5. Equipment and Accessories Depropanizer

II.5.1. Distillation Tower (Distillation column)

The distillation Tower is a distillation column (see Figure II.4) specifically designed to separate propane (a lighter component) and butane (a heavier component) from hydrocarbons

in a mixture (LPG). Inside the column are trays or packing that allow vapor to rise and liquid to fall. Based on differences in boiling points. It operates under continuous distillation principles. It uses a reboiler located at the bottom of the column to provide the necessary heat to boil the liquid mixture, and a condenser at the top to cool the vapors [w4, w5].



Figure II.2. Depropanizer Distillation in a Gas MPP3.

II.5.2. Depropanizer Reflux Drum

The reflux drum in the depropanizer unit is a vessel used to store condensed propane in liquid form after the overhead vapor is condensed in the heat exchanger (condenser). It plays a key role in maintaining liquid-vapor equilibrium and supplying reflux back to the column to improve separation efficiency (see Figure II.5) [w5].

To ensure the system operates safely, an alarm is set if the liquid level in the drum increases or exceeds the upper safety limit. This will start the flare and remove any extra.



Figure II.3. Reflux Drum Used in Depropanizer Unit.

II.5.3. Pump

A pump is an essential instrument used in the oil and gas sector that creates a pressure differential to move fluids, water, natural gas, liquids, and crude oil, between different locations, the real photo is shown on Figure II.6.

All three sectors of the industry upstream (extraction), midstream (transportation), and downstream (refining and distribution) make extensive use of pumps.



Figure II.4. Centrifugal Pump 38-P-801A Installed in the Depropanizer Unit.

In the (Figure II.7) there are 2 pumps operate alternately (1 in service, 1 on standby). They are equipped with recirculation lines for protection against minimum flow.



Figure II.5. Centrifugal Pumps Installed in the Depropanizer Unit.

II.5.4. Reboiler

The reboiler is used to provide heat to the liquid from the bottom of the distillation column, vaporizing propane from the mixture (see Figure II.8). This process enables the separation of propane in gaseous form from butane, based on their different boiling points. The mixture is then returned to the column, where the propane vapor rises to the top, whereas, the heavier butane remains in liquid form and is removed after condensation from the bottom of the column as either a purified product meeting specifications (on-spec) or an unpurified product (off-spec) [w6].



Figure II.6. Industrial Reboiler System for Depropanizer Column.

II.5.5. Air Cooler (Condenser)

The industrial air cooler provides a remarkable cooling effect, offering large-scale and effective cooling in factories and spacious indoor areas. In dry climates, these systems are often used as a cost-effective cooling solution.

In the depropanizer system, an air cooler (also called a condenser), shown in Figure II.9, is used to cool the propane gas after it exits the top of the distillation column, transforming it into liquid form to be collected in the reflux drum. In addition, it is used at the bottom of the column to cool butane after the mixture has been boiled [w7].



Figure II.7. Condensate Propane Cooling System.

II.5.6. Flare

A flare is a component of the safety system designed to release over-pressurized hydrocarbons into the atmosphere, (see Figure II.10).



Figure II.8. Refinery flare of oil and gas refinery.

When the system becomes over-pressurized, a pressure relief or safety valve opens to discharge the excess gas or liquid into the flare system. Usually, the flare system contains gas. All discharged liquids and gases are directed to a vertical flare stack through a large pipe known as a flare header. The gases are then burned off at the flare stack.

II.6. Essential Instruments for Efficient Depropanizer Operation

Control, regulation, and measurement instruments play a vital role in the proper functioning of the depropanizer, ensuring that the quality and quantity of the final products meet the required specifications while also maintaining the safety, reliability, and performance of the process. In this context, we will examine the principal sensors and transmitters used to monitor and control the four key industrial variables of the column: pressure, flow rate, level, and temperature. Each of these devices enables real-time adjustments to valves, pumps, and the reboiler to optimize separation, prevent overheating or overpressure, and ensure the stable and efficient operation of the depropanizer.

II.6.1. Transmitter

A transmitter is a crucial tool in industrial processes, used to automate and control systems such as Distributed Control Systems (DCS) and Programmable Logic Controllers (PLCs), enabling real-time monitoring, regulation, and safety. These are the key components needed for the automated system's procedure to operate smoothly [w9].

The transmitter works by receiving a signal from a sensor that measures a physical variable such as pressure, temperature, flow, or level then converts this raw sensor signal into a standardized electrical signal which is sent to a monitoring system, control system, or receiving device.

All Yokogawa transmitters include a versatile **Signal Characterization** function, which linearizes the 4–20 mA output for applications with known non-linear pressure-to-output relationships. By allowing up to ten calibration points, such as tank level profiles or specific flow measurements, this feature ensures that the transmitter's analog signal accurately reflects the actual process conditions it monitors

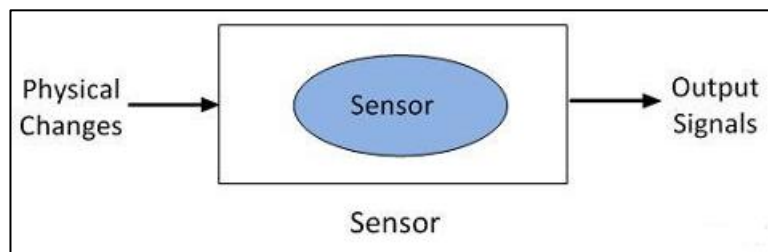


Figure II.9. Operating principle of a transmitter.

II.6.1.a Temperature Transmitter

The transmitter used in the (figure II.11) is Yokogawa YT200, where is a two-wire temperature transmitter designed for industrial applications. The Resistance temperature

detectors (RTDs), thermocouples, and DC voltage (millivolt) sources are among the temperature sensors that it may receive inputs from [8].

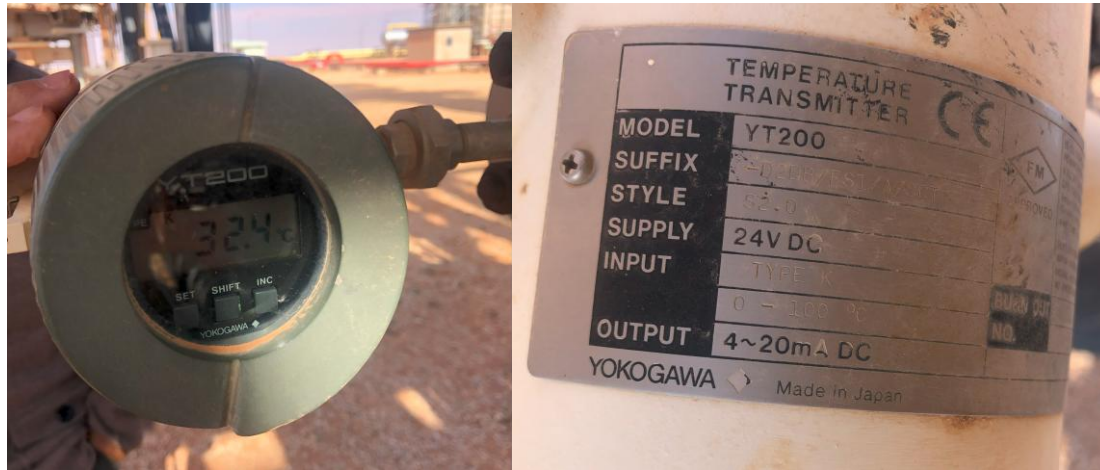


Figure II.10. Temperature Transmitter YT200 YOKOGAWA.

II.6.1.b Pressure Transmitter

The Yokogawa DPhart, illustrated in Figure II.12, is a high-precision digital pressure transmitter designed to monitor and transmit pressure data in demanding industrial environments. The device utilizes exclusive DPhart technology (Digital Pressure HART), enabling direct and precise measurement of differential pressure without requiring additional analog-to-digital conversion [9].



Figure II.11. Yokogawa Pressure transmitter.

II.6.1.c Flow Transmitter

A flow transmitter is an upgraded version of the flow meter exhibited in Figure II.13. It is a measuring instrument that determines the quantity of liquid, gas, vapor, or a mixture of these substances flowing through a pipe. Different measurement methods are available depending on the measurement objective, the type and condition of the fluid, and factors such

as the measurement location. The activity of flow rate measurement is performed by the electronic circuit on receiving the commands from the operator.



Figure II.12. Flow Transmitter.

II.6.1.d Level Transmitter

Transmitter measures the liquid level in a float-cable system, shown in Figure III.14. This method is suitable for liquid level measurements at a dam or water basin. Vertical float movements rotate a pulley which is linked to an internal mechanism which displays the measurement on a direct level indicator plus providing a 4 to 20 mA DC output signal [w10].



Figure II.13. Yokogawa Level transmitter [w11].

II.6.2. The Automatic Valve

II.6.2.a Pneumatic On/Off

Pneumatic valves depicted in Figure II.15, are automated control devices used in industrial systems to regulate or interrupt the flow of fluids (liquids or gases) using compressed air as their power source.

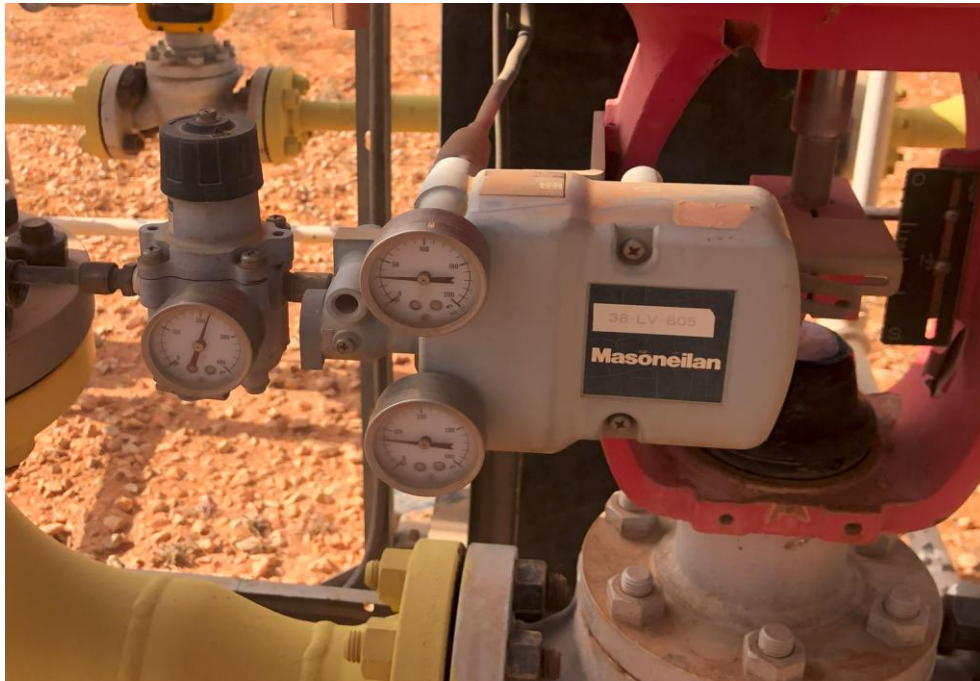


Figure II.14. Example of Valve used (level valve)

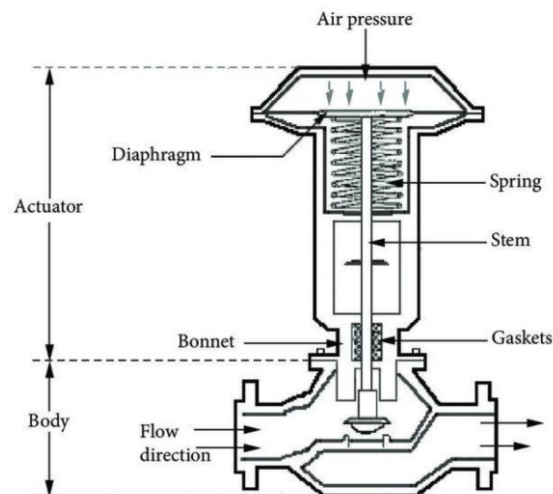


Figure II.15. Pneumatic Control Valve Structure and Operation

This is a pneumatically actuated control valve designed for continuous regulation of fluid flow. The valve adjusts its opening in response to air pressure applied to the diaphragm, which moves the stem and thus modulates the flow through the valve body. Unlike on-off valves, these control valves allow for precise flow adjustment, making them ideal for automated process control in industrial systems. They are commonly used

in applications requiring fine regulation of temperature, pressure, level, or flow. [10].

II.6.2.b The Regulating Valve

The control valve is used as a regulating device in various control loops, illustrated in Figure II.16. It is designed to control the flow rate and pressure of steam, gases, or liquids. It can adjust its opening progressively or operate in an ON/OFF mode, depending on the signal received. Additionally, it can function in either direct or reverse mode.

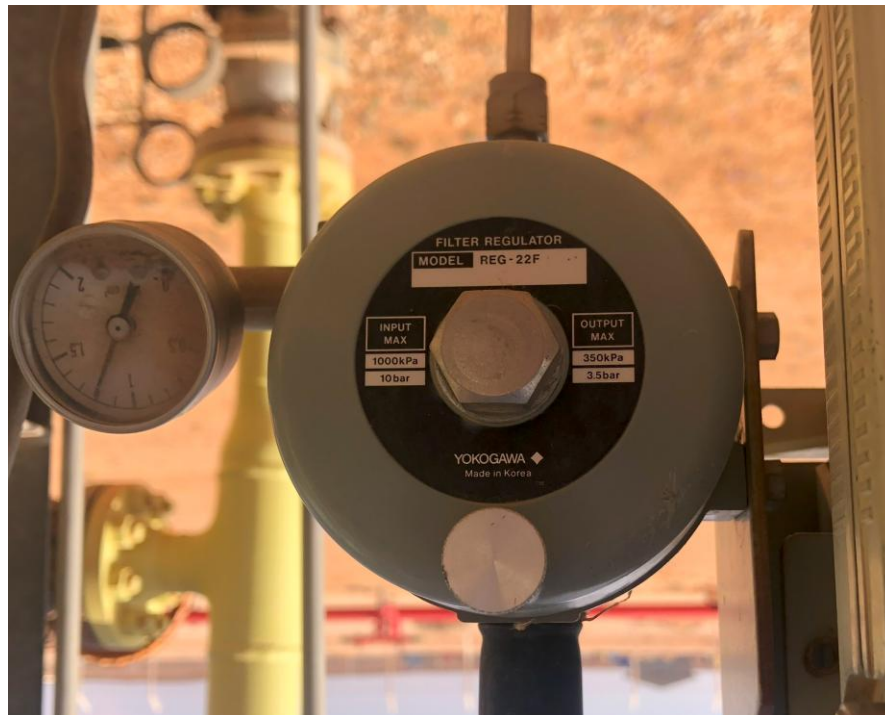


Figure II.16. Example of Regulating valve used in the depropanizer.

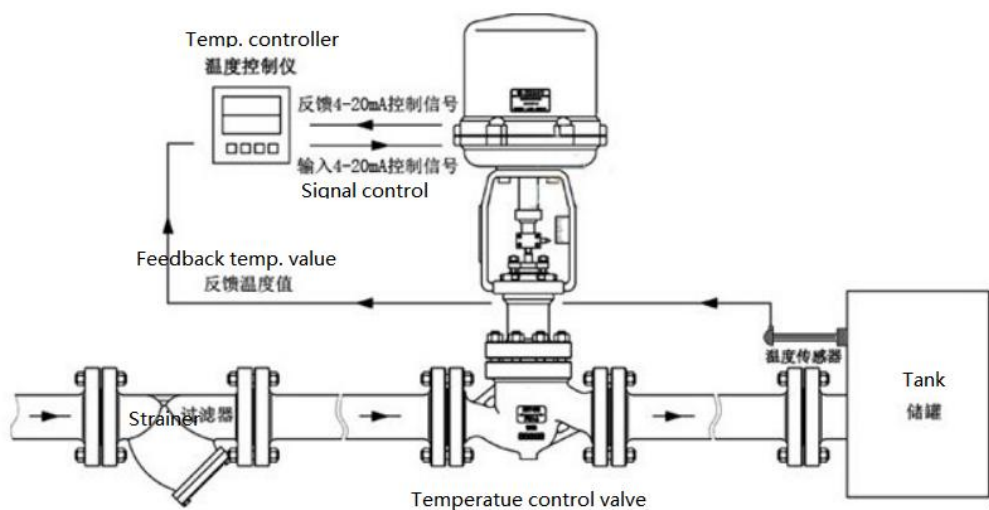


Figure II.17. Example of Automatic Temperature Control System Using a Control Valve

II.7. Instruments Used in Each Equipment of the Depropanizer

In a depropanizer unit, the main equipment such as the distillation column, reboiler, coolers, pumps, and reflux drum is closely connected to measurement and control instruments. These instruments ensure an automatic, safe, and optimal operation of the process.

The automatic valve, receives a control signal based on measurements provided by a transmitter (such as pressure, temperature, flow, or level). The transmitter sends a signal to the controller, which then adjusts the air pressure sent to the pneumatic valve actuator. This allows the valve to open or close progressively, ensuring precise control of the process variable,

II.7.1. Pneumatic valves (5 total)

- Two for on-specification and off-specification of propane
- Two for on-specification and off-specification of butane
- One connected to the flare system

II.7.2. Transmitters used in our unit

II.7.2.a Temperature Transmitters (6 total)

- We have two in the distillation column: the first one is located at the top, and the second is located at the bottom.
- One on the reboiler to monitor its temperature
- One for the liquid after boiling
- Two located after the coolers, to measure the temperature after condensation

II.7.2.b Flow Transmitters (3 total)

- One for the LPG feed entering the unit
- One at the reflux drum
- One measuring the flow to the reboiler

II.7.2.c Pressure Transmitters (1 total)

- One on the flare line, used as a safety measure

II.7.2.d Level Transmitters (2 total)

- One at the bottom of the distillation column
- One on the reflux drum

II.8. Separation and Treatment of Propane and Butane in the Depropanizer

In the depropanizer unit, we have two main product streams: propane and butane.

For the butane stream, the LPG feed enters and flows to the bottom section of the distillation column. Once the liquid level reaches a certain point, it activates the reboiler. The liquid mixture is then sent to the reboiler using a pump, where propane is vaporized and separated from the butane through heating. After boiling, the mixture liquid and the propane vapor returns to the distillation column to complete the separation process. The butane, once separated, is withdrawn from the bottom of the column, then cooled to 55°C. It is first delivered to the off-spec butane line. Once the product meets specification, the flow is redirected to the on-spec butane line.

For the propane stream, when the LPG feed enters the unit, the propane present in the mixture rises to the top of the distillation column. At the top, it is condensed, transforming from a gaseous state into a liquid, and is then stored in the reflux drum. A portion of this liquid propane is returned to the top of the column as reflux to enhance the separation efficiency. Once the liquid level in the reflux drum reaches a defined point, the reflux pump is activated, sending the propane liquid to the off-spec product line. When the product meets the required specifications, it is redirected to the on-spec propane pipeline.

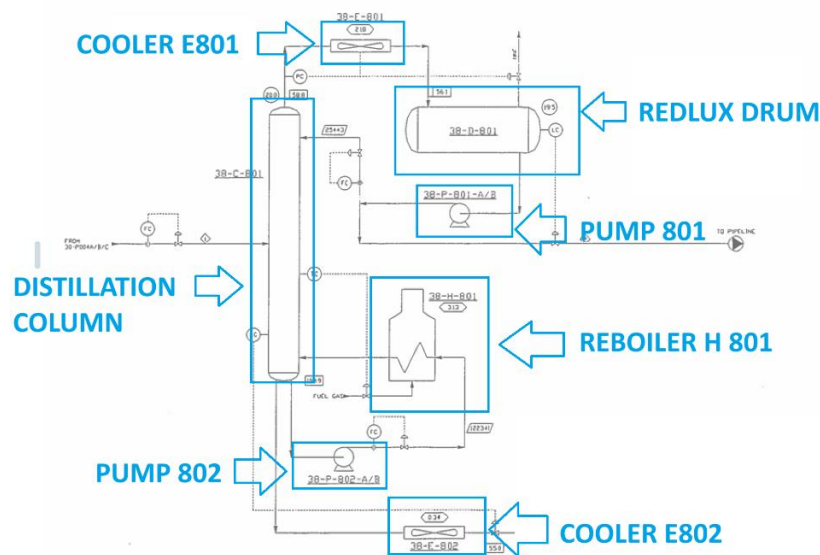


Figure II.18. Piping and Instrumentation Diagram (P&ID) of a Depropanizer System with Associated Equipment and Utilities [7].

II.9. The depropanizer guide system [7]

II.9.1. Initial startup of depropanizer

This section is listed in the order to start the depropanizer unit.

- Feed line 38-FV-801 Closed
 - Reflux line 38-FV-803 Closed
 - Reboiler feed line 38-FV-805 Closed
 - Propane to LPG pipeline 38-LV-805 Closed
 - Butane to storage 38-LV-803 Closed
 - Fuel gas 38-TV-801 Closed
 - Flare valve 38-PV-801 Closed
1. Open the valve 38-FV-801 slightly to get 90 % to introduce the feed liquid into the depropanizer [38-C-801].
 2. Open the valve 38-FV-805 100% to feed the liquid into the depropanizer reboiler [38-H-801].
 3. Start the depropanizer reboiler [38-H-801].
 4. Start the depropanizer bottom pump [38-P-802] after the liquid level on the depropanizer [38-C-801] reaches a high liquid level (38-LSHH-801) which is possible to see with 38LG801.
 5. Start the depropanizer overhead condenser [38-E-801] and the butane cooler [38-E-802] after each outlet temperature reaches about 92°C to lower the temperature to reaches about 55 °C.
 6. Start the depropanizer reflux pump [38-P-801] after the liquid level on the depropanizer reflux drum [38-D-801] reaches a high liquid level (38-LSAHH-805) which is possible to see with 38-LG-802.
 7. Open the valve 38-FV-803 10% to feed the liquid into the column as a reflux.
 8. Open 38-XV-821 and 38-XV-823 (open OFF-Spec).

II.9.2. Initial Start Up of Depropanizer Reboiler

The Depropanizer Reboiler [38-H-801] is used to heat depropanizer bottom liquid and generate vapor. To prevent over firing and overheating of the depropanizer bottom liquid, the firing rate shall be brought up gradually. The heating rate of the flue gas temperature leaving radiant section should be controlled to be kept within 110°C in general by increasing the number of ignited main burners and/or firing rate of main burners [18].

1. The ignition procedure for pilot burners shall be by the manufacturer's manual. However, an outline of the procedure is given here under.
2. Prior to ignition of pilot burners, confirm that the flow rate of 38-FV-805 is open and 38-FSALL-806 OFF.
3. Check that ESD valves (38-XV-825 and 38-XV-826) and all valves on the main fuel lines are closed, and vent valve (38-XV-827) is opened.
4. Check that fuel gas is available at the 38-H-801 pilot gas valves 38-XV-830 on pilot branch piping.
5. Put 38-PZALL-804 bypass switch in "OFF" position.
6. Start the purge air fan [38-K-801] thoroughly purge the furnace and plenum chamber for 15 minutes as a minimum.
7. After the purge completion, stop the purge air fan [38-K-801].
8. Open the pilot fuel gas 38-XV-830 then the sparks plug will Ignite all three pilot burners.
9. After the pilote opening the fuel gas,open the valve of pilote 1,2 and 3 ,in the same time the sparkswith
10. After the three pilot are fired
11. Check stable firing of all pilot burners through the 38-FD-801 1/2/3.
12. Reset the vent valve (38-XV-827) to close then OPEN (38 XV-825 and 38-XV-826) valves for main burners to open.
13. Check the indicator ready to burn for all burners 1/2/3
14. Start fire of burner 38-FD-802

II.9.3. Stop System of Depropanizer :

1. Stop the feed liquid by closing 38-FV-801 and Opening OFF-SPEC Valves
2. 38-XV-822 and 38-XV-823.
3. When 38-FV-801 is closed then the 38-LV-803 on the butane product line and 38 LV-805 on the propane product line fully Open until the liquid level in the depropanizer [38-C-801] and [38-D-801] reaches low liquid level (38-LSALL-802) and (38-LSALL-804), close 38-LV-803 and 38-LV-805.
4. The Flow valves 38-FV-803 and 38-FV-805 is totally closed.
5. Stop the depropanizer Reboiler [38-H-801] and Reset the vent valve (38-XV-827) to Open then Close the main burner valves (38 XV-825 and 38-XV-826) and Close 38-TV-801 supplying fuel gas.

6. Stop the depropanizer reflux pump [38-P-801].
7. Stop the depropanizer overhead condenser [38-E-801], the butane cooler [38-E-802], and the depropanizer bottom pump [38-P-802].

II.9.4. Emergency Shutdown

Unexpected operating conditions which require immediate action by operating personnel develop occasionally. The operators must recognize such emergency incidents and take necessary steps to either correct the problem or facilitate a safe and orderly shutdown of the process facilities.

The emergency shutdown [ESD] of the Depropanizer unit consists of the following:

- Depropanizer Plant Emergency Shutdown Sequence.
- Electrical Power Failure.
- Instrument Failure.

II.9.5. Emergency Shutdown Sequence of Depropanizer Plant:

The detailed sequence is referred to the Function Logic Diagrams. The shutdown factors are as follows:

- Signal for total shutdown provided on the operation console in the control room.
- The operation of the depropanizer section shutdown button provided on the operation console in the control room.
- By initiation of the above factors, the facilities of this section will move simultaneously to the following conditions:
 - The feed valve 38-FV-801 is totally closed.
 - The level control valve 38-LV-805 of the reflux drum [38-D-801] is totally closed.
 - The level control valve 38-LV-803 of the depropanizer [38-C-801] is totally closed.
 - Close ON spec valves (38-XV-821) and (38-XV-823) and OFF spec Valves (38-XV-822) and (38-XV-824) and open the flare valve 38-XV-820.
 - The Flow valves 38-FV-803 and 38-FV-805 is totally closed.
 - Stop the depropanizer reboiler [38-H-801] and Reset the vent valve (38-XV-827) to Open then Close the main burner valves (38 XV-825 and 38-XV-826) and Close 38-TV-801 supplying fuel gas.

- Stop the depropanizer overhead condenser [38-E-801], the butane cooler [38-E-802], Stop the depropanizer reflux pump [38-P-801] and the depropanizer bottom pump [38-P-802].

II.10. Conclusion

The study of the depropanizer unit allowed us to understand its crucial role in gas treatment, particularly in the separation of propane. We analyzed the feed characteristics, the operating principles of the equipment, and the essential instruments used in this unit.

Furthermore, by studying the startup, shutdown, and emergency shutdown procedures, as well as the automation of the operating procedures sequence (the depropanizer and reboiler systems), we gained a comprehensive understanding of the unit's operation under normal and critical conditions.

The next chapter, provides a definition and details of the DCS (Distributed Control System), focusing specifically on the Yokogawa CENTUM VP system used to monitor and control the depropanizer unit.

III

CHAPTER III

III

Fundamentals of DCS and Its Application in YokogawaCENTUM VP

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III.1. Introduction

Industrial automation has revolutionized process control, enabling industries to achieve precision, safety, and efficiency. At the heart of this transformation are Distributed Control Systems (DCS), which decentralize control tasks across interconnected subsystems. This chapter explores the fundamentals of DCS, its advantages, components, and architecture, followed by a focus on Yokogawa CENTUM VP, a leading DCS solution renowned for its reliability and innovation in industrial automation.

III.2. Overview of Distributed Control Systems (DCS)

The DCS refers to a network of hardware and software components designed to share core functions for managing industrial processes. Figure III.1 represents the general architecture of the DCS. The essential functions of a control system include:[11]

- Adjusting signals exchanged with the process
- Processing data in real time
- Communicating with system users
- Connecting with nearby systems

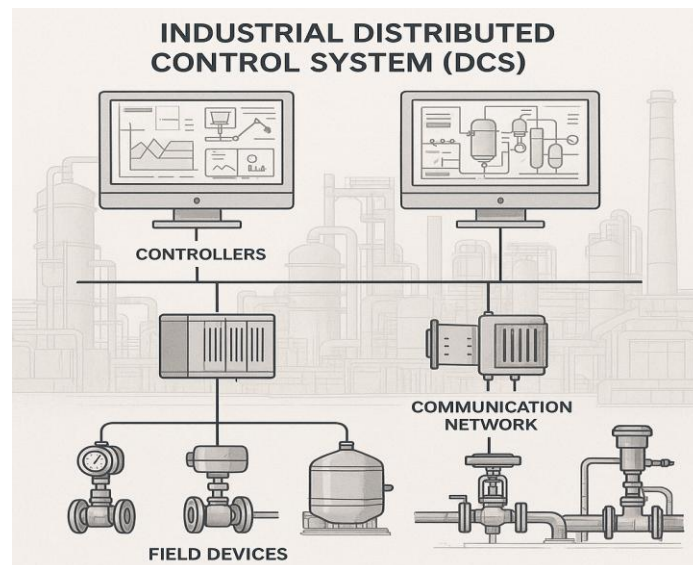


Figure III.1. The general Architecture of the DCS in Industry.

III.3. Understanding the Centralized and Distributed Systems

In a **centralized system**, a single device (like a processor or controller) handles most core functions. If this device fails, all the functions it manages are lost.

In contrast, a **distributed system** assigns core functions to multiple devices (stations) connected via communication networks. If one device fails, only the specific function it manages is affected.[11]

III.4. The Advantages of the DCS

The DCS (Distributed Control System) offers several advantages over older control systems, making it a preferred choice. These benefits include:

III.4.1. Distributed Functionality

Core control tasks are distributed across multiple devices (stations). If one fails, most functions continue to operate, ensuring minimal disruption.

III.4.2. Redundancy

Stations and communication networks can be duplicated to enhance system reliability and reduce the risk of unexpected shutdowns.

III.4.3. Open Architecture

DCS easily integrates with independent systems, such as SCADA and ESD, enabling seamless communication.

III.4.4. Analysis & Optimization

Advanced control methods and built-in mathematical tools allow for real-time process analysis and optimization.

III.4.5. Ease of Use

User interaction is simple. PCs, printers, and interactive graphics let operators manage processes visually. Engineers can maintain or upgrade the system using standard software.

III.4.6. Data Accessibility

Communication networks and the DCS's storage capacity provide real-time access to all data, including historical records, at any time.

III.4.7. Continuous Monitoring

Instead of periodic checks, DCS enables 24/7 monitoring of critical equipment. Parameters like machine health can be tracked directly through the system, eliminating the need for external tools.[12]

III.5. The Components of a DCS

A DCS (Distributed Control System) consists of several subsystems, including:

- **Input/Output (I/O) modules** for connecting sensors and actuators.
- **Individual controllers** (e.g., PLCs or regulators) to manage specific tasks.
- **Operator interfaces** such as screens, mice, and keyboards for user interaction.
- **Engineering workstations** for system configuration and maintenance.
- **Communication networks** (buses) to share data between devices.
- **Redundancy and safety features** to ensure reliability.[13]

III.6. The DCS Applications

Distributed Control Systems are mainly used in industries with batch or recipe-based processes. Examples include:

- Oil refineries.
- Petroleum production.
- Power plants.
- Cement factories.
- Pharmaceutical manufacturing.

III.7. Common of DCS in industry

Popular DCS platforms worldwide include:

- **Yokogawa:** Centum VP
- **Emerson:** Delta V
- **ABB:** 800xA
- **Siemens:** PCS7
- **Honeywell:** Experion
- **Schneider Electric:** PlantStruxure and Foxboro
- **Rockwell:** PlantPAx [14].

III.8. Basic Architecture of a DCS

A DCS (Distributed Control System) has four main layers: Level 1, Level 2, Level 3 and Level 4 as illustrated in the Figure III.2.

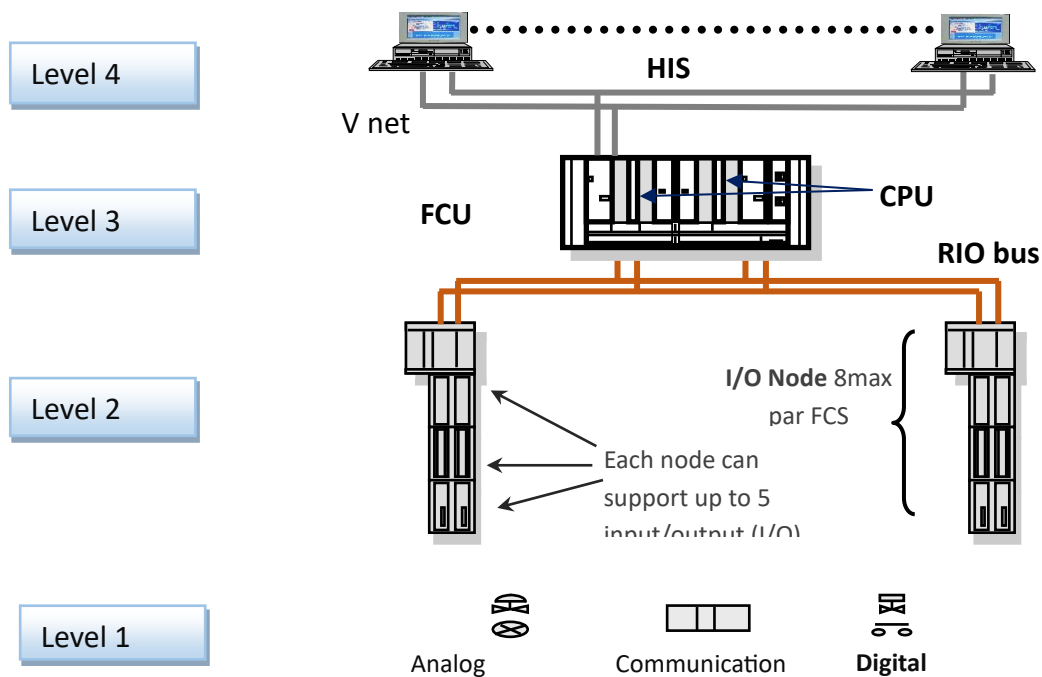


Figure III.2. The DCS Architecture [6].

- **Level 1 (Field Level):** As with traditional systems, this includes instruments such as sensors and actuators installed directly on the equipment

- **Level 2 (I/O Automation):** Handles input/output signals (e.g., data collection and control commands).
- **Level 3 (Control Room):** Located in technical areas, these systems use operator stations to manage and monitor processes in real-time.
- **Level 4 (Supervision & Management):** The top layer oversees plant-wide operations, including data analysis, reporting, and strategic decision-making [6].

III.9. The characteristics of the DCS

The DCS is defined by several important characteristics, including:

- **Improved Process Control:** Processes are better managed with reduced energy consumption.
- **Real-Time Data Access:** Information is archived and available instantly.
- **Data Visualization:** Graphical displays and easy printing of data.
- **Paperless Operation:** Data is recorded electronically, eliminating paper use.
- **Redundancy:** Duplicate components enhance safety and reduce unexpected shutdowns.
- **Self-Diagnostic Tools:** Automatic checks and detailed diagnostics lower maintenance costs.
- **Enhanced Safety:** Reduced risks for workers, equipment, and the environment.

III.10. Purpose of Installing a DCS System

Since implementing the DCS (Distributed Control System), significant improvements have been observed compared to older systems. These benefits are categorized below:

III.10.1. System Improvements

- **Increased Uptime:** System redundancy boosts reliability.
- **Better Performance:** More accurate measurements and faster response times.

- **Centralized Control:** Monitor and manage processes and systems from a single station.
- **Integration:** Connects easily with other systems (e.g., GE-FANUC, MKV).
- **Management Tools:** Use decision-making software for strategic planning.
- **Space-Saving:** Compact design reduces physical footprint.

III.10.2. Maintenance Cost Savings

- **Reduced Downtime:** Less time spent on preventive maintenance (e.g., calibrating recorders, instrument upkeep).
- **Faster Troubleshooting:** Precise diagnostics and easier fault detection.
- **Scalability:** The system can expand to handle full operational capacity.
- **Data Backup:** Automatic logging of all events, alarms, and operator actions for historical analysis.
- **Safer Interventions:** On-site repairs are simpler, minimizing shutdown risks.

III.10.3. Operational Benefits

Using a computer-based DCS core has greatly improved flexibility. Complex calculations now support better decision-making and optimization. Examples include:

- **Automated Daily Reports:** Real-time production tracking and daily summaries.
- **Process Oversight:** Monitor daily operations and access tools like trend analysis and group controls.
- **User-Friendly Controls:** Simplified process adjustments and system management [15].

III.11. Functions of a DCS

- **Human-Machine Interface (HMI):** Operators interact with the system through interactive screens to monitor and control processes.
- **Online Adjustments:** Operators can modify settings (e.g., process parameters, timers) in real time without stopping the system.

- **System Setup:** Customize workflows and adjust settings using flowcharts or diagrams based on real-time data.
- **Fault Detection & Alerts:** The system identifies equipment issues, pinpoints faulty components, and displays alarms with troubleshooting guidance.
- **Data Logging & Reporting:** All alarms, operator actions, and process data are recorded, copied, and printed for audits and historical analysis.
- **Safety Features:** Alarms and visual warnings alert operators to mistakes, preventing unsafe actions and protecting the process [16].

III.12. YOKOGAWA CENTUM VP Overview

Yokogawa, a Japan-based multinational company, manufactures a diverse array of industrial automation and control solutions, including distributed control systems (DCS). Their leading DCS offering, CENTUM VP, is an open and integrated platform designed to manage and automate large-scale, complex industrial processes.[17]

III.13. Architecture of CENTUM VP

The system had **distributed** architecture outlined in Figure III.3, avoiding centralized servers to eliminate single points of failure. Key components include:

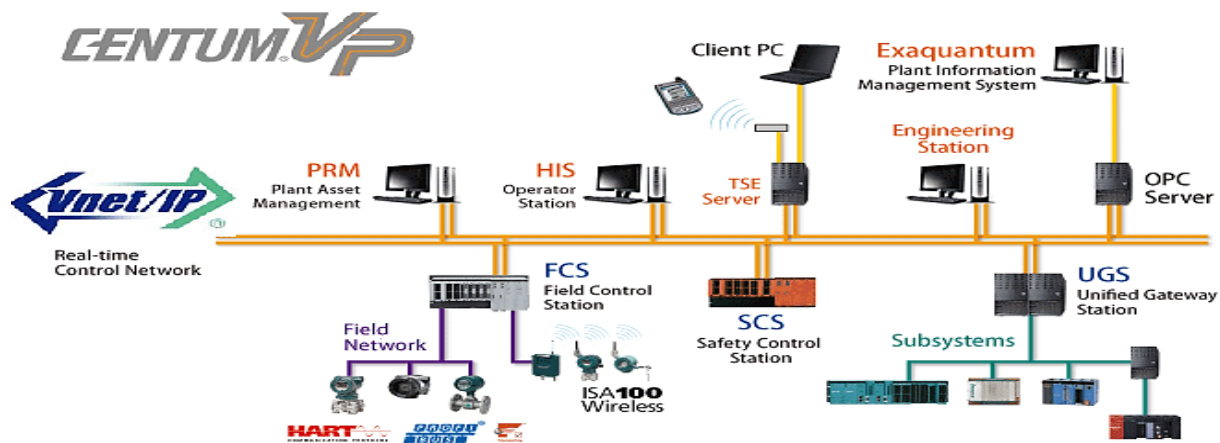


Figure III.3. Architecture of centum vp [18].

III.13.1. Field Control Station (FCS)



Figure III.4. The FCS station

The Field Control Station (FCS), shown in Figure III.4, is a modern system that combines process control, batch management, and computer operations. Its key features include:

- Basic and advanced control loops for regulating processes.
- Tools for managing automated tasks (like sequence tables, logic charts, and flow diagrams).
- Integration with other subsystems.
- Monitoring and control of field instruments (sensors, devices, etc.).

The FCS Components are:

- Field Control Unit (FCU)
- Node Unit (NU)
- ESB bus, ER bus
- House Keeping Unit (HKU) [19]

III.13.2 Real Time Process Control Network – Vnet/IP

III.13.2.a. Yokogawa's Vnet/IP

Is a high-speed, reliable control network designed for industrial systems. It operates on IEEE 802.3 and UDP/IP standards, delivering data speeds up to 1 Gbps. The system uses standard commercial hardware like cables, Layer 2 switches (for local connections), and Layer 3 switches (for routing between networks). Vnet/IP uses two communication channels:

1. **Real-time control channel:** Dedicated to critical process automation, ensuring fast, secure, and predictable timing for industrial operations.
2. **Ethernet channel:** Handles non-critical tasks, including:
 - Internal communication between systems like Plant Resource Manager (for asset tracking), Exaopc (data-sharing tools), and Universal Gateway Stations (UGS).
 - Connections to standard Ethernet devices (e.g., computers, printers). This split ensures critical processes stay reliable while other communications run efficiently in the background.[19]

III.13.2.b. Network Structure

- Uses a **tree-like layout** where devices in the same group (domain) connect via Layer 2 switches.
- In **dual-redundant setups**, two separate networks (Bus 1 and Bus 2) operate independently for backup.
- A **domain** is a group of devices linked without routers or Layer 3 switches, simplifying communication within that group.

This setup ensures fast, fail-safe communication for industrial automation.

III.13.3. Operator Interface, Human Interface Station-HIS

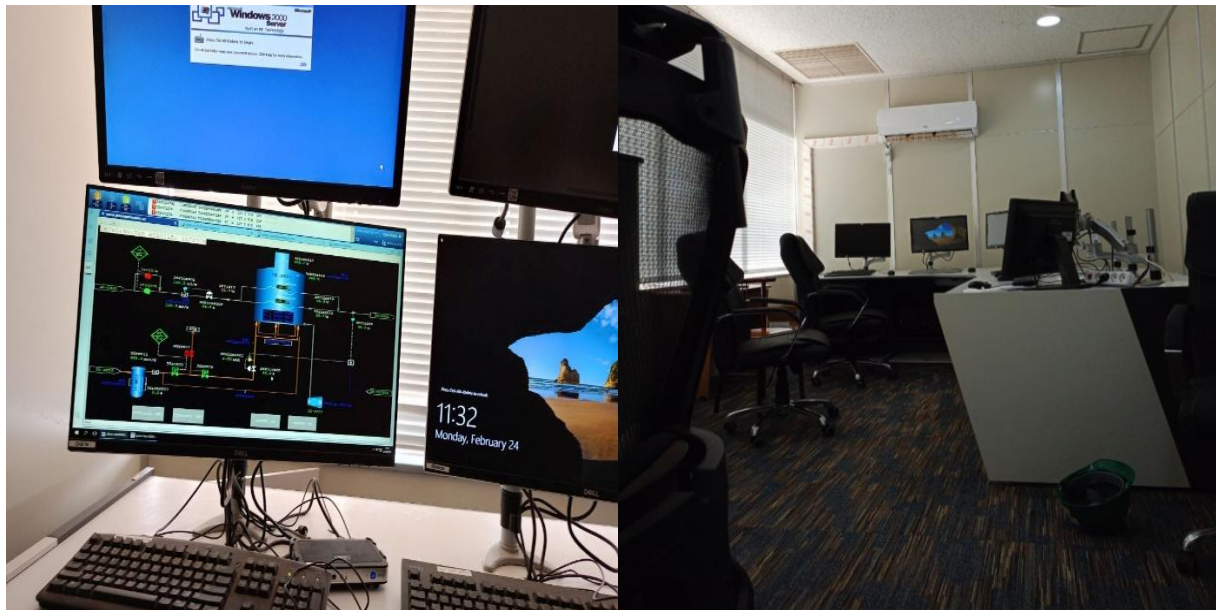


Figure III.5. The Central Control Panel

The Human Interface Station (HIS) is the central control panel for operators (see Figure III.5). It offers specialized screens for tasks like monitoring processes, running operations, generating reports, and tracking trends.

- **Direct link to Vnet/IP:** Enables instant updates between operators and equipment (e.g., alarms, control panels).
- **Ethernet connectivity:** Connects all HIS stations, allowing them to share resources like trend reports, event logs, and databases.

This setup ensures operators get real-time plant data while collaborating seamlessly across the system.

The Human Interface Station (HIS) can be customized to meet user needs, offering two platform options:

- Desktop or Console-based setups.

- Yokogawa's Console (with dual or quad LCD/CRT screens) features a cutting-edge, user-friendly design for quick operator responses.
- A built-in general-purpose PC ensures compatibility with existing systems, reduces spare parts requirements, and simplifies maintenance.
- Standard IBM-compatible PCs can also function as operator stations for flexibility.
- This flexibility allows facilities to balance advanced performance with cost efficiency [19].

III.13.4 Prosafe-Rs

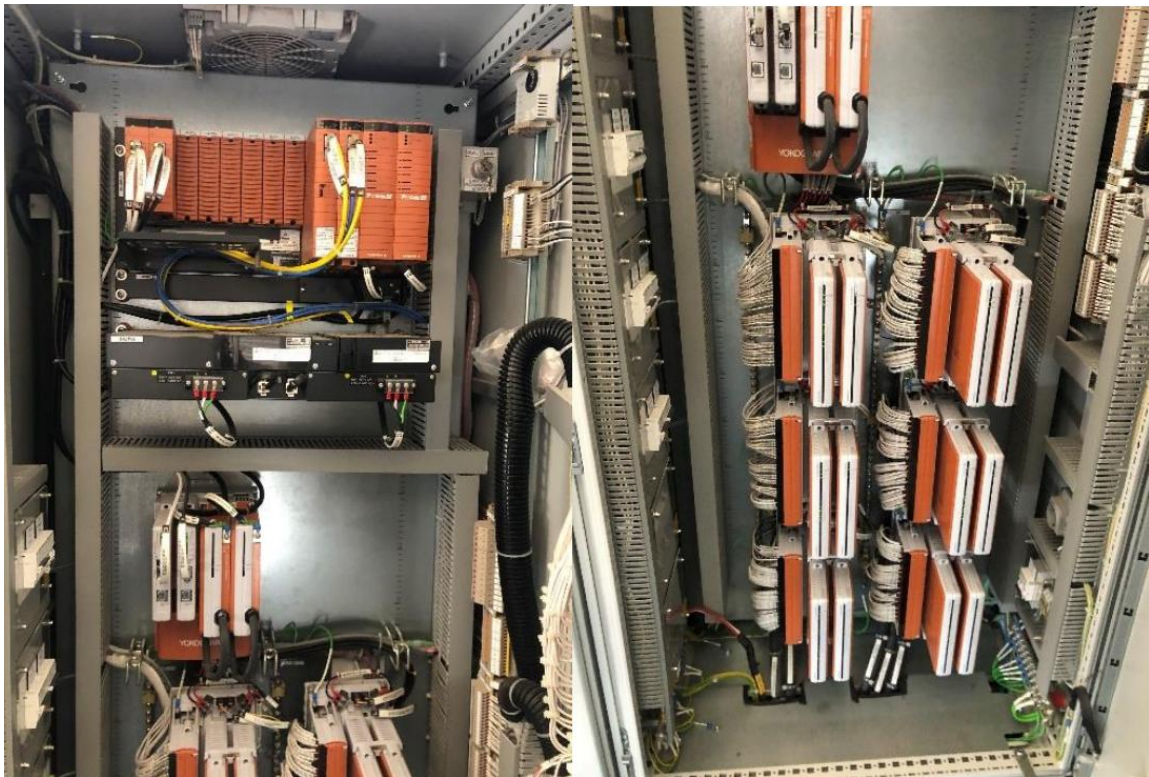


Figure III.6. The ProSafe-RS Station

ProSafe-RS (Figure III.6) is Yokogawa's Safety Instrumented System (SIS) designed to work alongside the CENTUM VP Distributed Control System (DCS). Here is a concise overview of its role and features:

III.13.4.a. Purpose

ProSafe-RS ensures functional safety in industrial processes by monitoring critical conditions and initiating safety actions (e.g., emergency shutdowns) to prevent accidents, protect equipment, and ensure personnel safety.

III.13.4.b. Integration with CENTUM VP

- It seamlessly integrates with Yokogawa's CENTUM VP DCS, allowing unified control and safety management in a single platform.
- Operators can monitor both process control (CENTUM VP) and safety functions (ProSafe-RS) from a shared interface, improving coordination [20].

III.14. Conclusion

DCS solutions, such as Yokogawa's CENTUM VP, are pivotal in modern industrial automation, offering unparalleled reliability, scalability, and integration. By decentralizing control tasks and leveraging advanced technologies such as virtualization and redundant architectures, CENTUM VP exemplifies how DCS platforms enhance operational efficiency and safety. As industries evolve, systems like CENTUM VP will remain critical in meeting the demands of increasingly complex operations; and high-stakes environments. Having explored the principles of depropanizer operations and the integral role of CENTUM VP in DCS-driven automation,

In the following chapter, the acquired knowledge will be applied through practical implementation scenarios.

CHAPTER IV

Depropanizer Automation Implementation with CENTUM VP

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IV.1 Introduction

This chapter demonstrates the practical implementation of a depropanizer unit's automation system using Yokogawa CENTUM VP. This section provides a detailed, step-by-step configuration of the DCS environment from project initialization in System View to hardware setup (FCS, HIS, I/O cards) and control logic programming (function blocks, sequences). Operational sequences for start-up, emergency shutdown (ESD), and controlled stop are rigorously defined to ensure safe and efficient process management.

This implementation serves as the technical backbone for automating the depropanizer's critical components, including reboilers, pumps, and coolers.

IV.2 Defining Inputs and Outputs

Prior to any implementation, a declaration phase for inputs and outputs is essential. The depropanizer unit employs 31 inputs (comprising 19 sensors, 8 alarms, and 3 buttons) and 24 outputs (including 23 actuators for valves, pumps, and coolers, plus 1 fan). Within this unit, the column and drum section utilizes 10 inputs (7 sensors, 3 alarms) and 13 outputs (10 valves - 5 pneumatic and 5 regulators - along with 1 pump and 2 coolers), with 2 flares present. The reboiler section functions with 3 sensor inputs and 9 outputs (8 valves - 1 pneumatic and 7 regulators - and 1 pump), and includes 1 flare. (Table IV.1, Table IV.2)

Input	Comment
38FT801	Feed Line Transmitter
38FT803	Reflux Line Transmitter
38FT805	Reboiler Feed Line Transmitter
38LT803	Butane To Storage Level Transmitter
38LT805	Propane To LPG Pipeline Level Transmitter
38PT802	Fuel Gas Transmitter
38PT801	High Pressure Flare Transmitter
38TT801	Depropanizer Overhead Temperature Transmitter
38TT803	Depropanizer Reflex Drum Temperature Transmitter
38TT804	Butane To Storage Temperature Transmitter

38TT816	Reboiler Temperature Transmitter
38FT808	Propane To LPG Pipeline Flow Transmitter
38FT807	Butane To Storage Flow Transmitter
38LSAHH801	Level Switch Overhead High
38LSALL802	Level Switch Overhead Low
38LSALL804	Level Switch Reflex Drum Low
38LSAHH805	Level Switch Reflex Drum High
38FSALL805	Flow Switch Butane To Storage Low
38FSALL806	Flow Switch Reboiler Feed Line Low
38PSAHH820	Pressure Switch High Pressure Flare
38PSALL804	Pressure Switch Reboiler Fuel Gas Low
START-UP	Automatic Start Up
SHUTDOWN(STOP)	Normal Stop
ESD/ ESSD	Emergency Shutdown
INIT	Initialization
38FD801 1/2/3	Flame Detector of Pilot
38FD802 1/2/3	Flame Detector of Reboiler

Table IV.1 Declaration of Inputs.

Output	Comment
38FV801	Feed line valve
38FV803	Reflux line valve
38FV805	Reboiler feed line valve
38LV803	Butane to storage valve
38LV801	Propane to LPG pipeline valve
38TV801	Fuel gas Temperature valve
38PV801	High Pressure Regulator Flare Valve
38XV820	High Pressure Flare valve
38XV821	On Spec Butane to Naftal Valve
38XV822	Off Spec Butane to 30-D005 Valve

38XV823	Off Spec Butane to 30-D005 Valve
38XV824	On Spec Butane to Naftal Valve
38XV825	Reboiler fuel Gas Valve
38XV826	Reboiler fuel Gas Valve
38XV827	Reboiler Pure Valve
38E801	Butane Cooler
38E802	Propane Cooler
38P801	Butane Pump
38P802	Propane Pump
38XV830	Reboiler Purge Fan
38K801	Pilot Feed line
VPILOT1/2/3	Pilot Valves

Table IV.2 Declaration of Outputs.

IV.3 The way to create project in System View

To start, launch the "system-view" system. Then, from the menu bar, choose **File > Create new > Project**. You will be presented with a window asking for project-related information (see the Figure below).

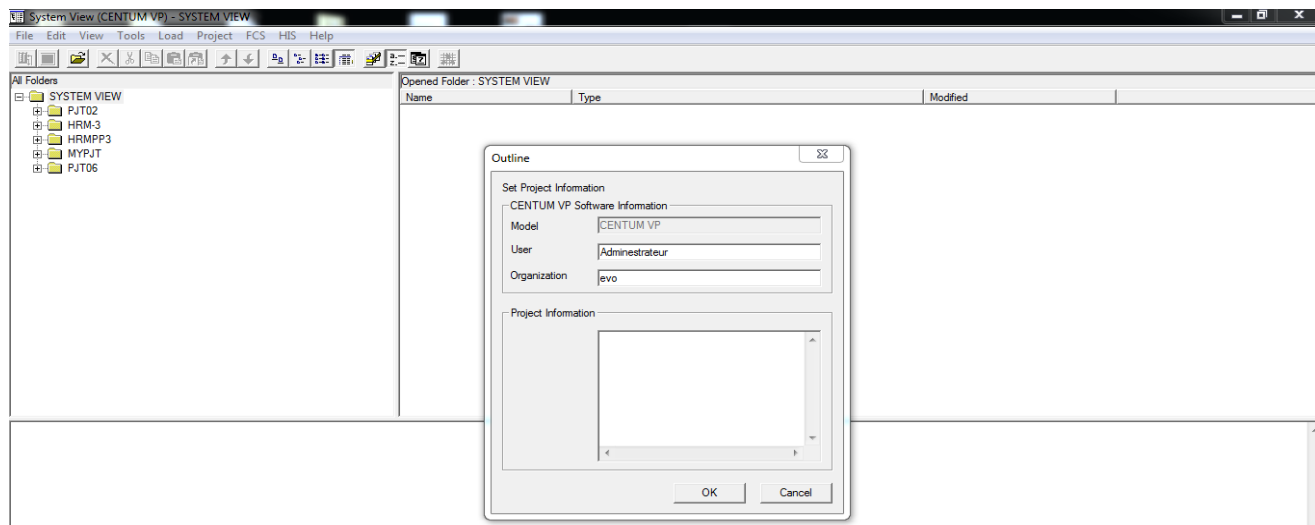


Figure IV.1. Creating new project.

IV.3.1 Create New FCS

1. **Automatic Launch:** After creating the new project, the control station configuration window should open automatically.
2. **Manual Creation (If Needed):** If the window doesn't appear, create the FCS manually:
 - Go to the **File** menu and select **Create New > "FCS"**, OR
 - Right-click (likely in the project tree/workspace) and select **Create New "FCS"**.
3. **Access Tools:** Once created, the FCS interface provides the necessary programming elements.

Then:

1. **Select Station Type:** Choose the control station type from the predefined dropdown list (e.g., for our project, select "A2FV70D Duplexed Field Control Unit").
2. **Configure Settings:** Specify the FCS type, database, and station address (e.g., Code 101: the first digit 1 denotes the domain, the second 1 indicates the station number).
3. **Review Defaults:** Verify the settings in the remaining tabs (default values are pre-filled).
4. **Confirm:** Click **OK** to create the control station.

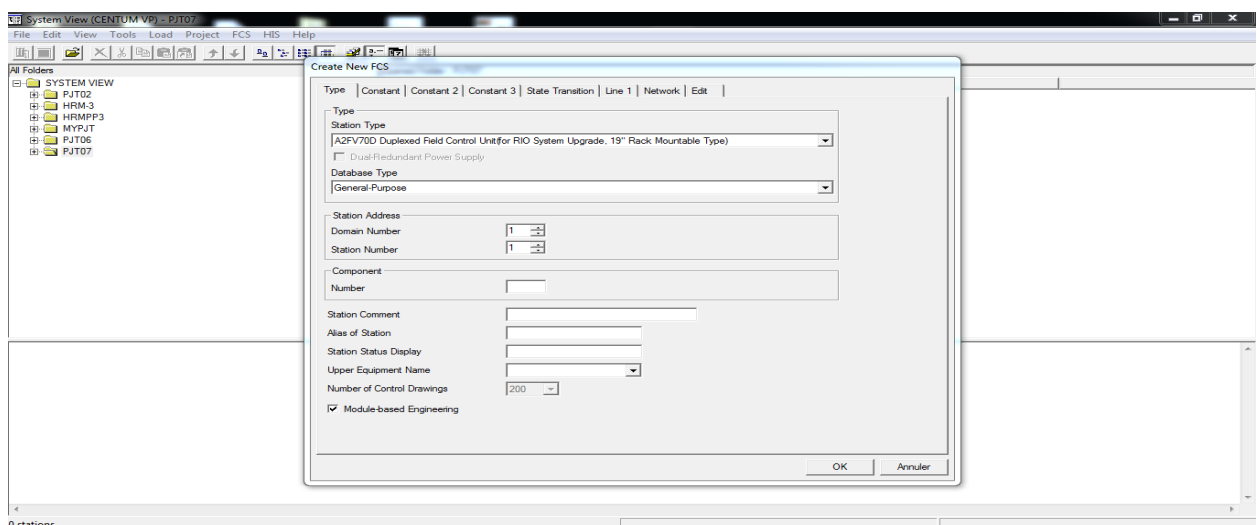


Figure IV.2 Creating FCS.

IV.3.2 Create New HIS

1. **Automatic Launch:** The operator station (HIS) creation window should appear automatically after the FCS window during new project setup.
2. **Manual Creation (If needed):** If it does not appear, manually create the HIS using the same method as the project:
 - Go to **File > Create New > HIS, OR**
 - Right-click (in the appropriate area) and select **Create New > HIS**.

IV.3.2.a Configure Station

- Select the PC type and assign the station address.
- Specify the domain number (default: 1) and station number (default: 64).
- Verify the network settings in the **Network** tab.
- Review the settings in the remaining tabs.

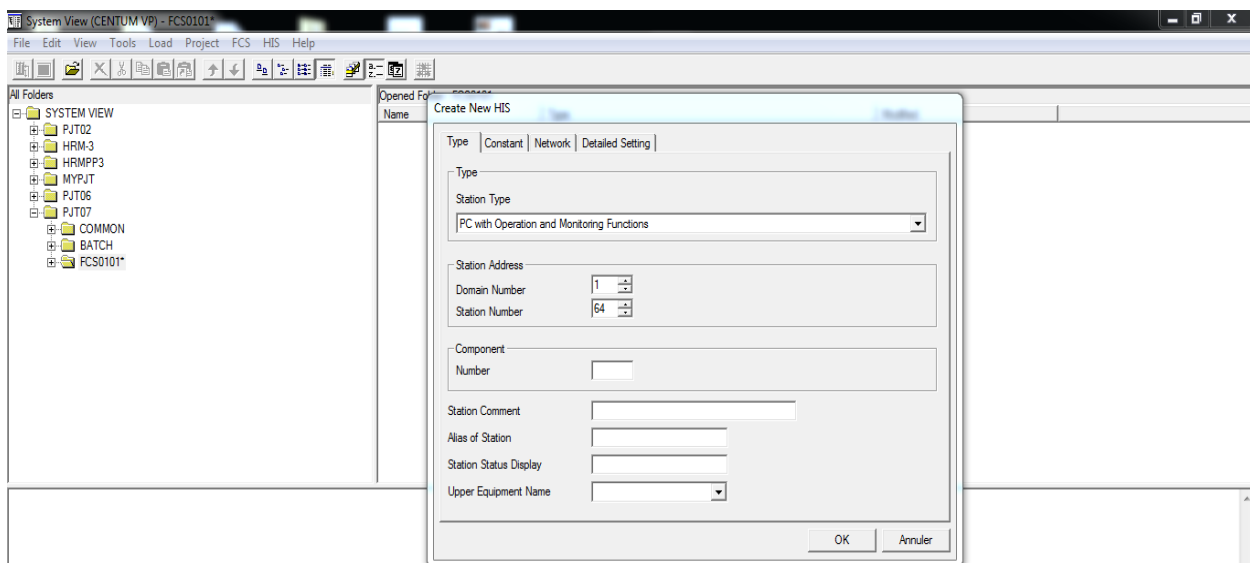


Figure IV.3 Creating HIS.

IV.3.3 Create Input/Output Switch Card

To configure physical, I/O signals:

1. IOM Creation:

- Access FCS → IOM directory → Right-click → Create New → NODE
- Specify chassis type and signal category (analog/digital)

2. Card Installation:

- Within the chassis (e.g., AMN11 for analog):
- Select card model from list
- Configure card address see Figure

Tag Name	Element Number	Tag Name	Tag Comment	Switch Position Label	Label	Btn1	Btn2
	\$SW2001	AURSEQBOIL	SET AUTO SEQ	ON,,OFF,ON	Direct	Red	Red
	\$SW2002	SETAUTOBOIL	boutton set auto	ON,,OFF,ON	Direct	Red	Red
	\$SW2003	38LSALL802		ON,,OFF,ON	Direct	Red	Red
	\$SW2004	38FZALL804	LOW PRESSION	ON,,OFF,ON	Direct	Red	Red
	\$SW2005	38TZAHH816	HIGHT TEMPERATURE	ON,,OFF,ON	Direct	Red	Red
	\$SW2006	38FZALL806	LOW FLOW	ON,,OFF,ON	Direct	Red	Red
	\$SW2007	38LZALL802	LOW LEVEL	ON,,OFF,ON	Direct	Red	Red
	\$SW2008	LSAHH805	LEV DRUM UP TO PUMP	ON,,OFF,ON	Direct	Red	Red
	\$SW2009	TRIPPROCESS	TRIP PROCESS	ON,,OFF,ON	Direct	Red	Red
	\$SW2010	START	START SYSTEM	ON,,OFF,ON	Direct	Red	Red
	\$SW2011	ESD	EMERGENCY SHUTDONW	ON,,OFF,ON	Direct	Red	Red
	\$SW2012	STOPB	STOP BOIL SYSTEM	ON,,OFF,ON	Direct	Red	Red
	\$SW2013			ON,,OFF,ON	Direct	Red	Red
	\$SW2014	STARTPURG	BOUTTON START PURGING	ON,,OFF,ON	Direct	Red	Red
	\$SW2015			ON,,OFF,ON	Direct	Red	Red
	\$SW2016	PURGING	PROCESS PURG INDICATORE	ON,,OFF,ON	Direct	Red	Red
	\$SW2017	ENDPURG	PURG ENDING INDICATORE	ON,,OFF,ON	Direct	Red	Red
	\$SW2018	38R801	fan purging	ON,,OFF,ON	Direct	Red	Red
	\$SW2019			ON,,OFF,ON	Direct	Red	Red

Figure IV.4 Creating I/O Switch Card.

IV.3.4 Creating Function Blocks

Function blocks are created using the following steps:

1. In the FCS interface, navigate to and open the **"Function Block"** program.
2. Select a target drawing (e.g., drawing number DR0001).

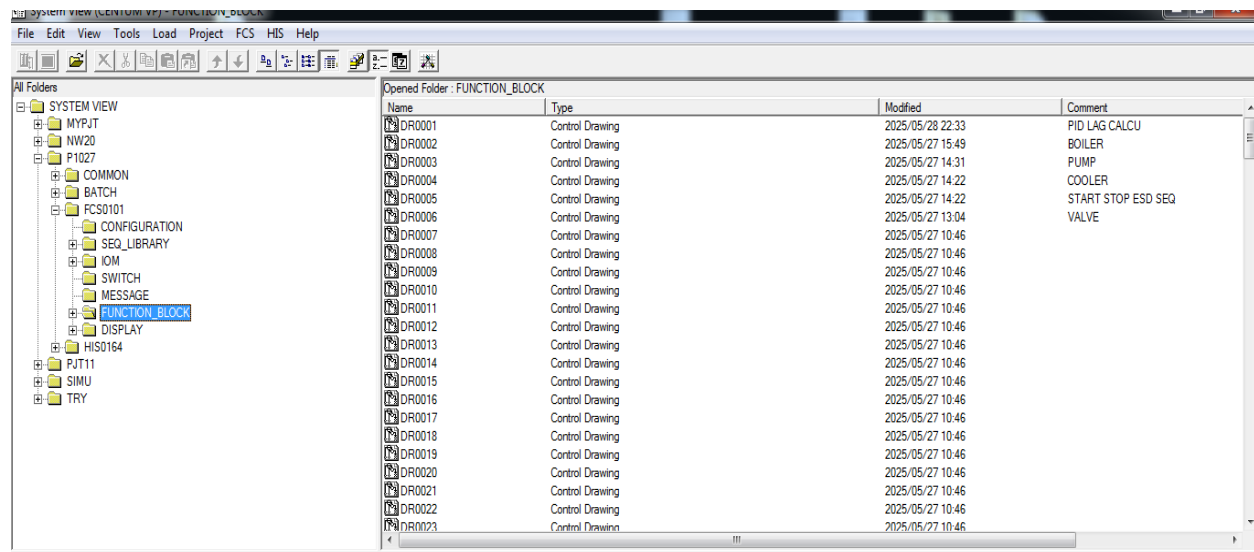


Figure IV.5 Inserting Function blocks.

3. Within the Control Drawing Builder:

- Go to **Insert** → **Function Block**
- Choose and insert the required function blocks.

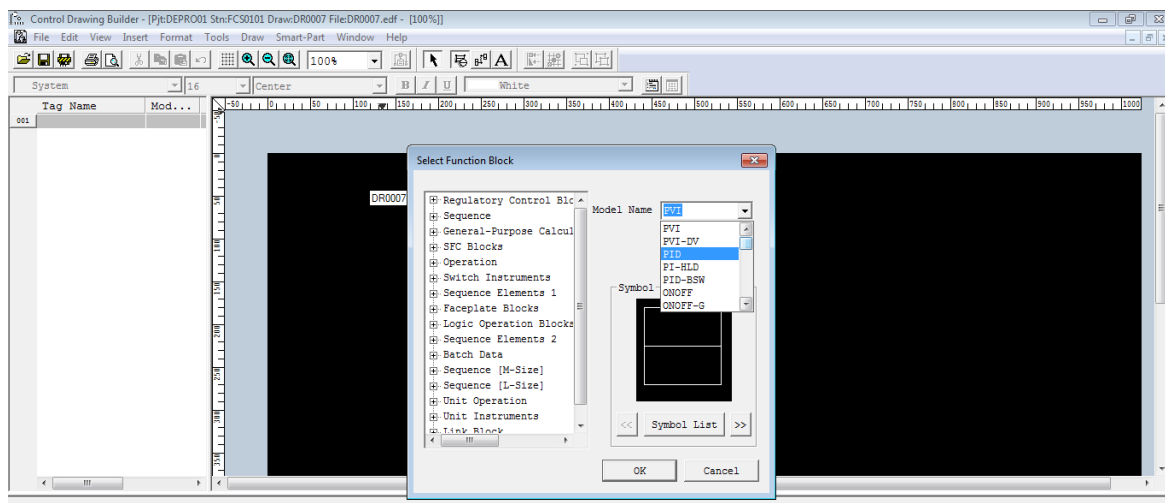


Figure IV.6 Window where choose and insert the required function blocks.

The following essential function block types are used for control logic implementation:

IV.3.4.a Logic Diagram Blocks (LC64)

Purpose: Model combinational logic relationships between I/O signals using Boolean operators.

Specifications:

- **LC64:** 32 inputs, 32 outputs, 64 logic operators.

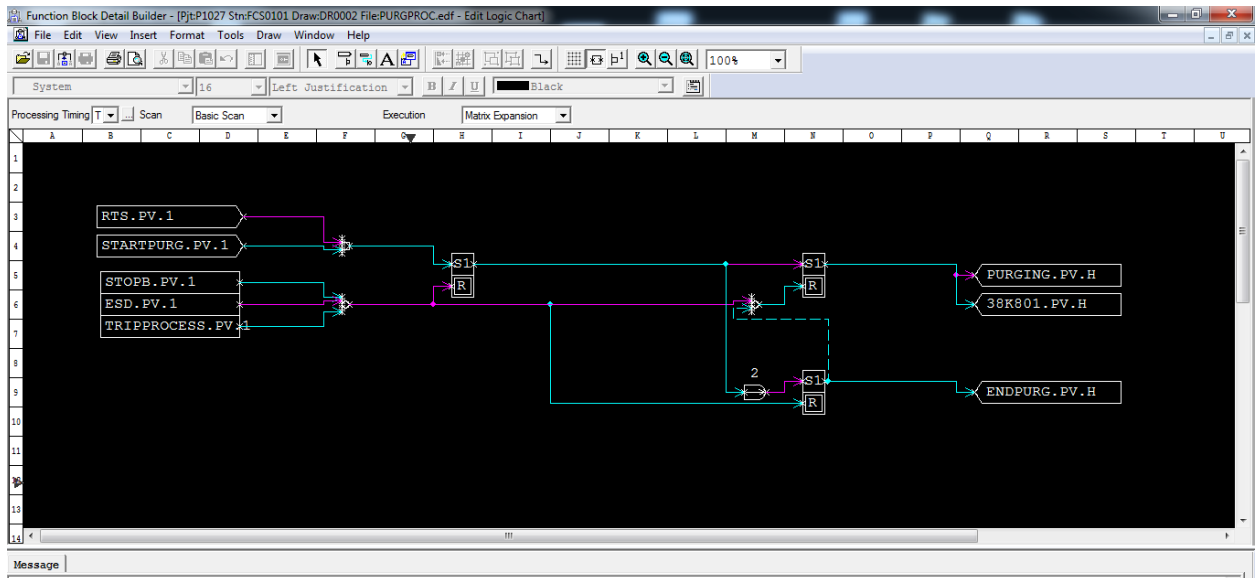


Figure IV.7 Example of Function Blocks of Purging Reboiler.

Configuration Workflow:

1. Select the function block → Choose "Edit Detail"
2. A blank editing window opens
3. Select logic elements from the dialog box

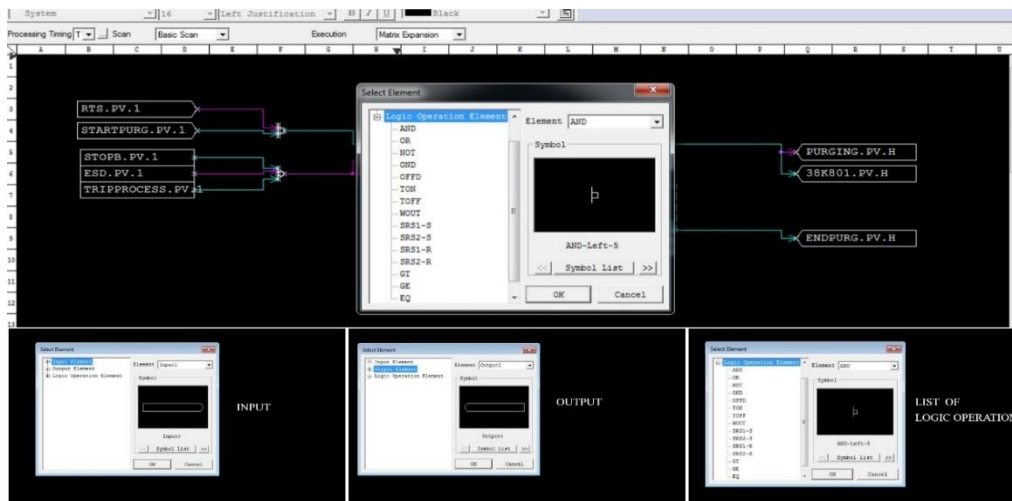


Figure IV.8 Inside view of LC64 and select of Input/Output and logic operations

Logic operations that we use





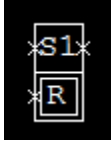
Logic Ports	Logic Ports in Yokogawa Centum VP
OR	
AND	
NOT	
TIMER	
SET-RESET (priority Reset)	

Table IV.3 Logic Ports in Yokogawa Centum VP

IV.3.4.b Sequence Table Block (ST016)

Purpose: Define dynamic sequences using matrix-based condition/action rules (Y/N).

Operating Modes:

- **Combinatorial:**
 - Evaluates ALL rules simultaneously
 - Executes actions for ALL valid conditions
- **Sequential:**
 - Processes rules STEP-WISE
 - Executes current step actions → Advances to next step

No.	Tag name	Data item	Data	1	5	9	13	17	21	25	29
CO1	SETAUTBOIL.FV		ON	Y	.	.	.	.	.	.	.
CO2				.	.	.	.	.	.	.	.
CO3				.	.	.	.	.	.	.	.
CO4				.	.	.	.	.	.	.	.
CO5				.	.	.	.	.	.	.	.
CO6				.	.	.	.	.	.	.	.
AO1	TRIPPROC.MODE		AUT	Y	.	.	.	.	.	.	.
AO2	PURGPROC.MODE		AUT	Y	.	.	.	.	.	.	.
AO3	READYTS.MODE		AUT	Y	.	.	.	.	.	.	.
AO4	STARTBURN.MODE		AUT	Y	.	.	.	.	.	.	.
AO5	STARTPILOT.MODE		AUT	Y	.	.	.	.	.	.	.
AO6				.	.	.	.	.	.	.	.
AO7				.	.	.	.	.	.	.	.
AO8				.	.	.	.	.	.	.	.
NEXT				.	.	.	.	.	.	.	.

Figure IV.9 Sequence Table Block

IV.3.4.c Regulation Block (PID)

Function: Closed-loop control using PV (Process Value) and SV (Set Value).

Implementation Notes:

Offline Simulation

- Replace physical I/O with LAG block for loop emulation.

Real-World Deployment:

The PID controller:

1. **Receives** the Process Value (PV) from field instruments via an input card.
2. **Computes** the Manipulated Value (MV) based on PV and Setpoint (SV).
3. **Sends** the MV to field actuators through an output card.

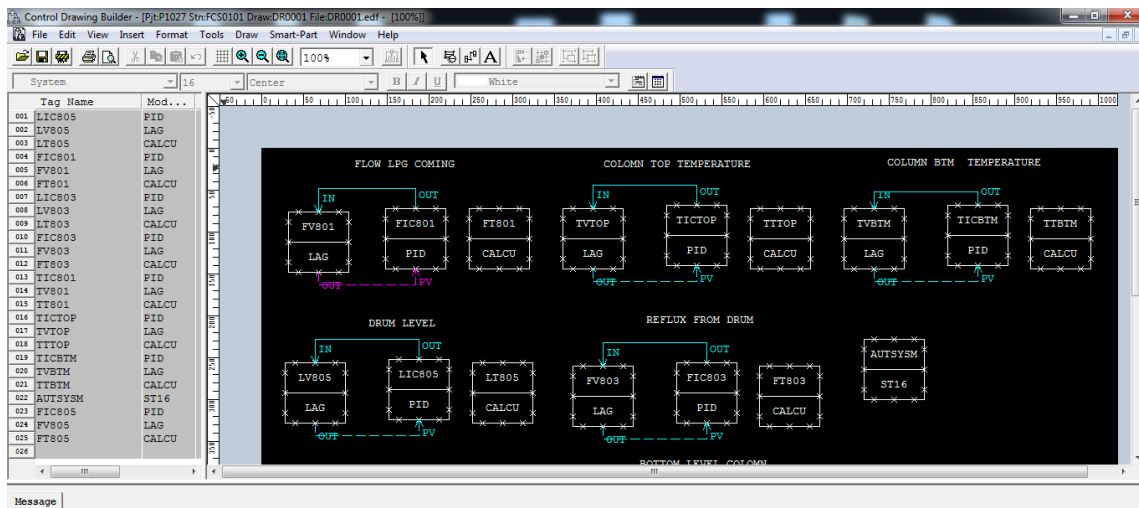


Figure IV.10 Regulators block example (PID,LAG)

IV.3.4.d Calculator Block (CALCU)

The **Calculator Block (CALCU)** enables custom programming using SEBOL, a domain-specific language with C-like syntax.

The **Calculator Block (CALCU)** is indeed used for **custom calculations and logic operations**. It allows users to implement logic that goes beyond what standard function blocks can do.

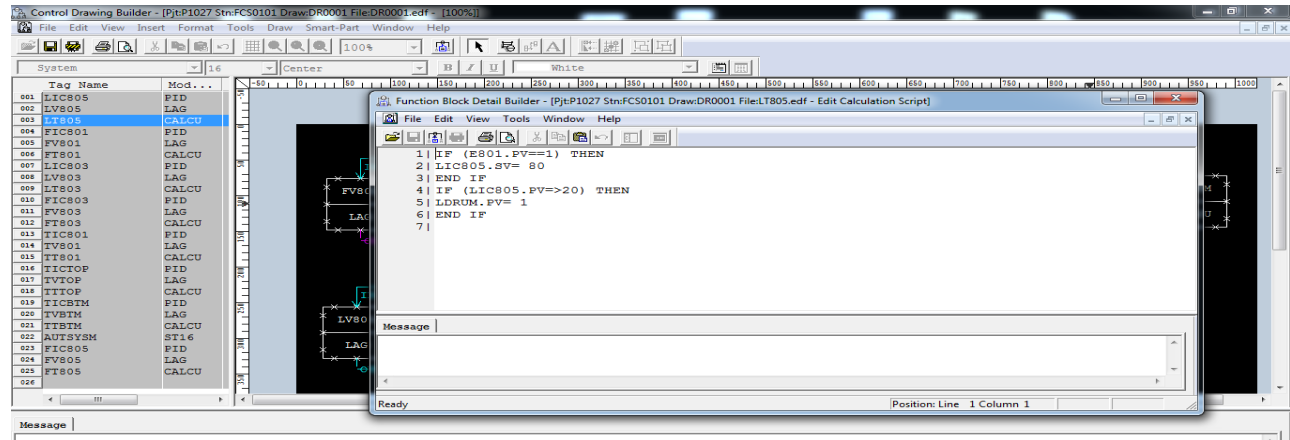


Figure IV.11 Example of Program used in block CALCU.

IV.4 Automation Sequence Programming

After creating a new project in the CENTUM VP View system, you can configure its components (such as FCS and HIS types). The project's general overview then appears in a window like the one shown below (Figure IV.11):

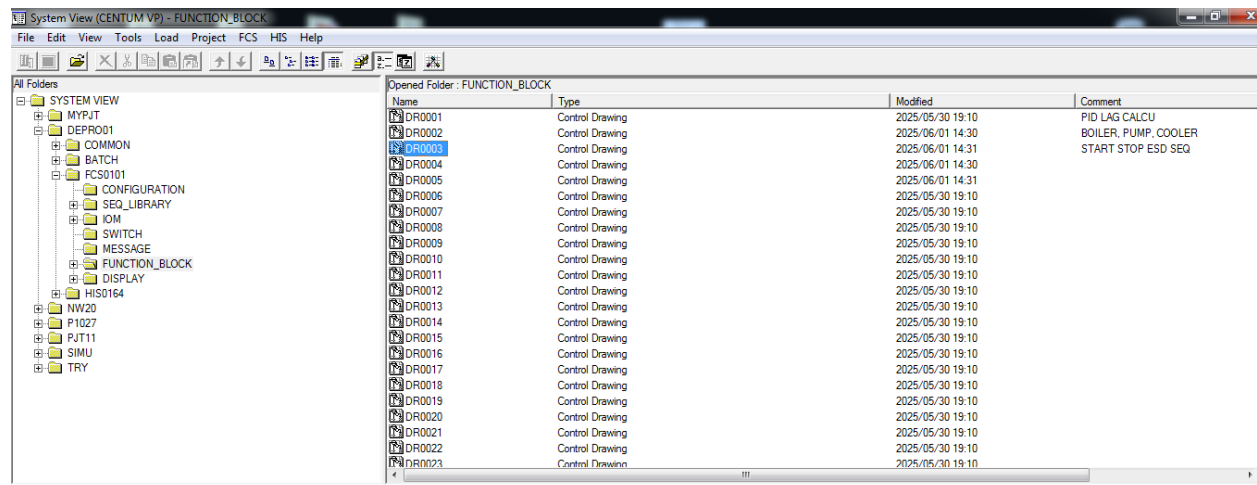


Figure IV.12 General view of the project.

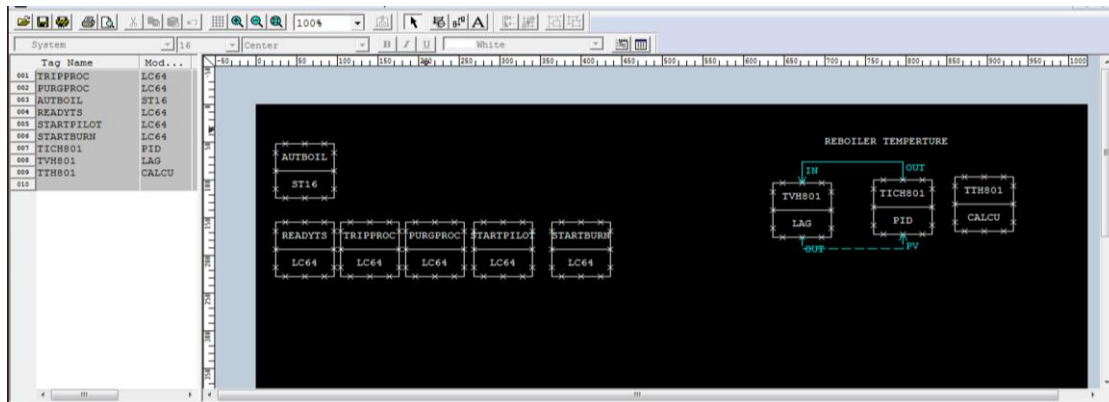


Figure IV.14 View of Drawing DR0002.

IV.4.3 DR 0003: A drawing comprising the blocks of Pumps (38P801) Reflux Drum Pump, (38P802) Reboiler pump

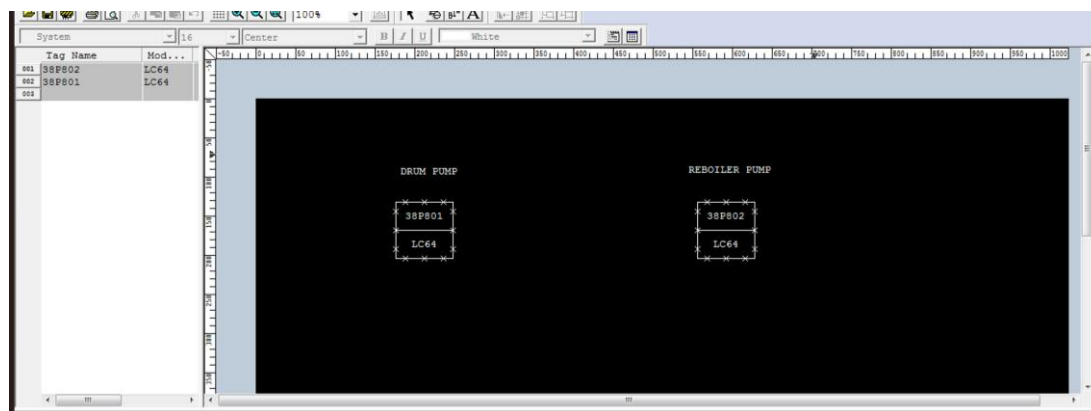


Figure IV.15 View of Drawing DR0003.

IV.4.4 DR 0004: A drawing comprising the blocks of Coolers (38E801) top Cooler distillation column, (38E802) Bottom Cooler of Distillation column

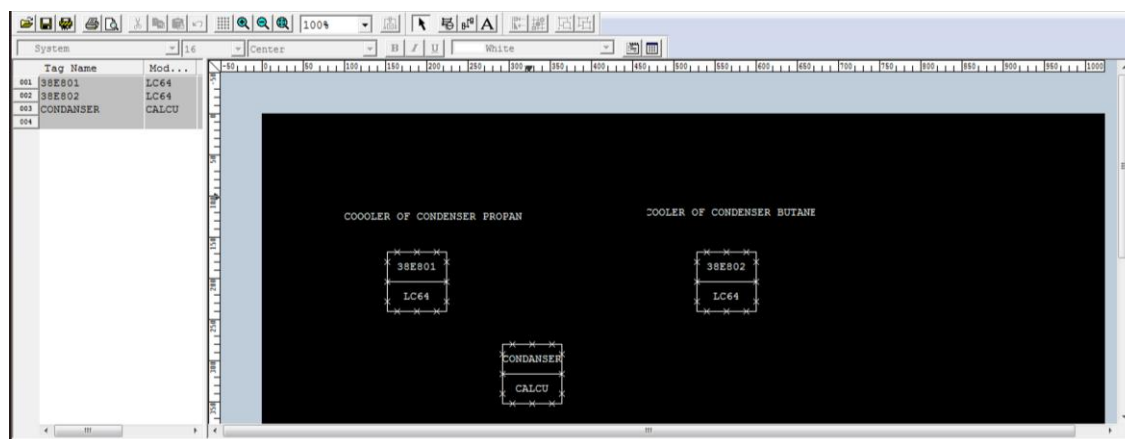


Figure IV.16 View of Drawing DR0004.

IV.4.5 DR 0005: A drawing comprising the blocks of Start, Shutdown and Emergency

- START-UP Control Sequence (SYSTEM), (SYSTEMCMPLTSTART).
- Emergency Shut Down Control Sequence (EMRG2), (EMERG3), (EMERG----STATUS), (TRIC).
- STOP Control Sequence (SHUTDOWN), (SDWNREB), (SHURDOWN2), (SHUTDWN-STATUS), (STP)
- AUTOMATION Control Sequence (AUTOMATIOS), (AUTSYS), (AUTPID), (SEQAUT).

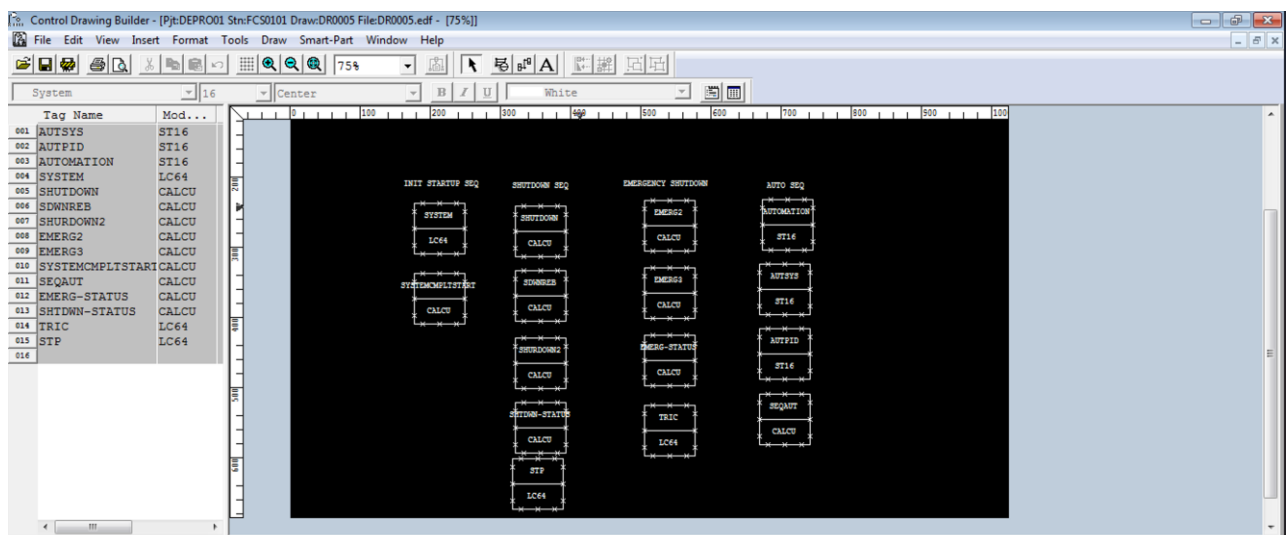


Figure IV.17 View of Drawing DR0005.

IV.5 Sequence

The sequence implementation uses these elements:

- **Digital Input Elements** for sensor signals
- **Digital Output Elements** for actuator control
- **Priority-Reset (R-dominant) RS Flip-Flops**
- **Timers** managing purge duration → post-purge delay → pilot activation
- **Logic Gates (AND/OR/NOT)** establishing sequential I/O linkages.

IV.5.1 Reboiler

IV.5.1.a Ready-to-Start Condition

Requires [38FZAL806-OFF], [38XV830-OFF],[TRIPPROCESS] [38XV825-OFF], [38XV826-OFF], and [38XV827-ON] simultaneously.

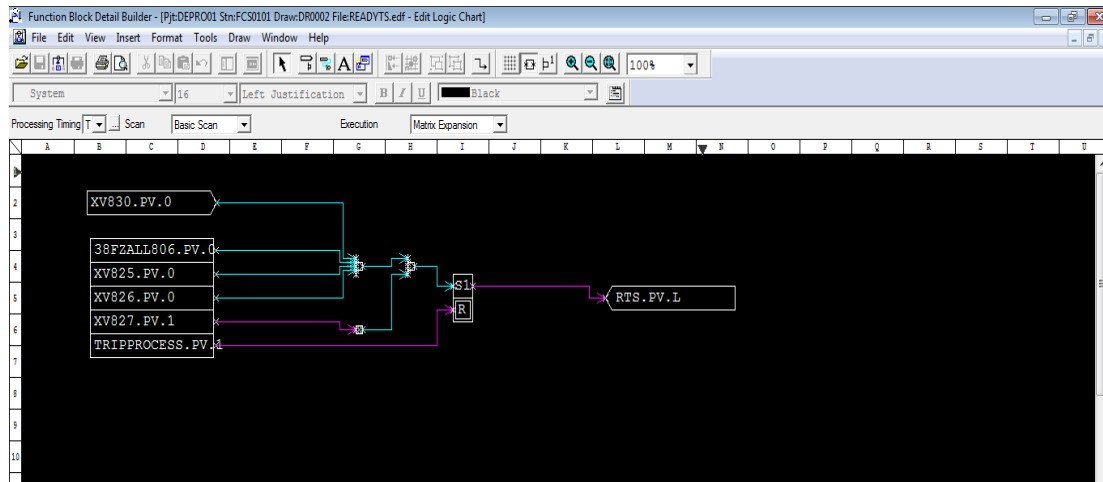


Figure IV.18 Logic of Ready to Start of Reboiler.

IV.5.1.b Reboiler Trip Activation

To activate the reboiler, it is necessary to verify the safety of the alarms before starting the reboiler process, as follow:

- [38PZALL804] for Pressure Reboiler Fuel Gas Low,
- [38TZAHH816] high liquid temperature.
- [38FZALL806] Flow Switch Reboiler Feed Line Low
- [38LZALL802] low level in bottom distillation column.

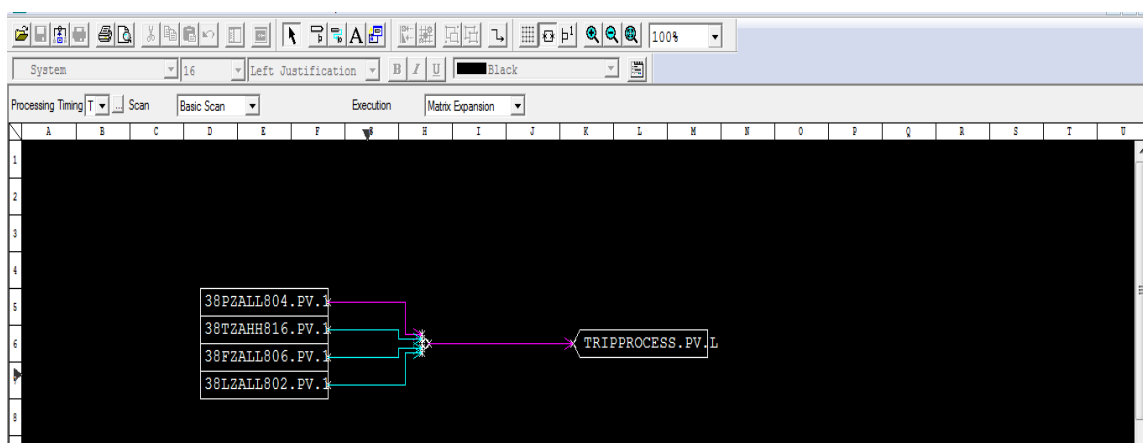


Figure IV.19 Logic of Trip of Reboiler.

IV.5.1.c Purge Initiation

When the start purge is ON and RTS is active, the reboiler starts the purging process.

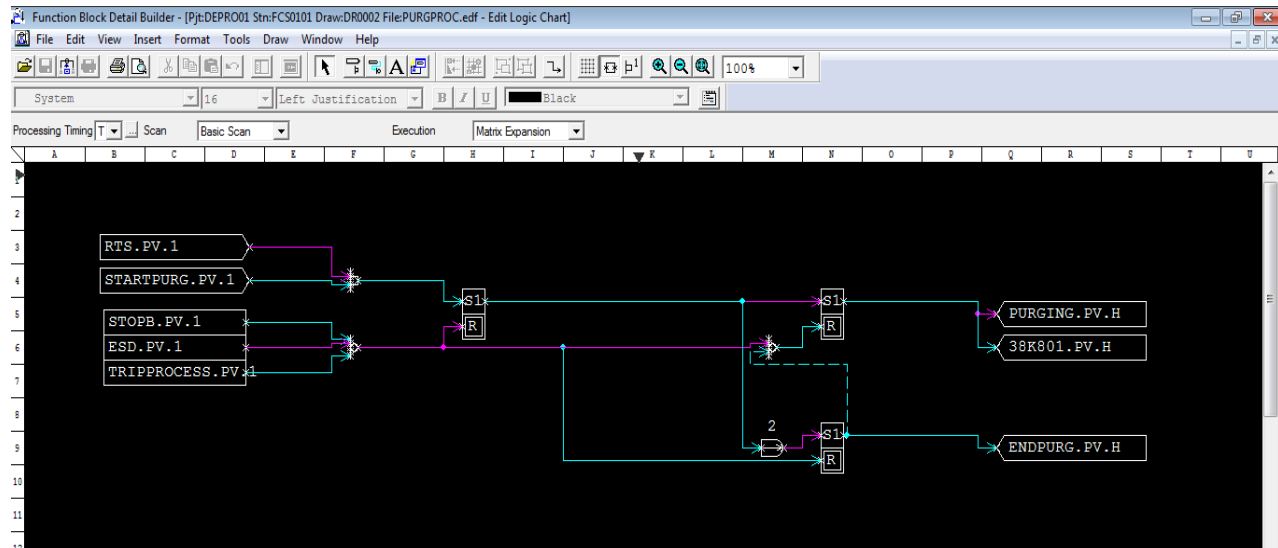


Figure IV.20 Logic of Purging Reboiler.

IV.5.1.d Post-Purge State

The end of the purging phase, a command is sent to open the fuel gas feed line by opening valves XV825 and XV826, and closing valve XV827 to enable pilot ignition.

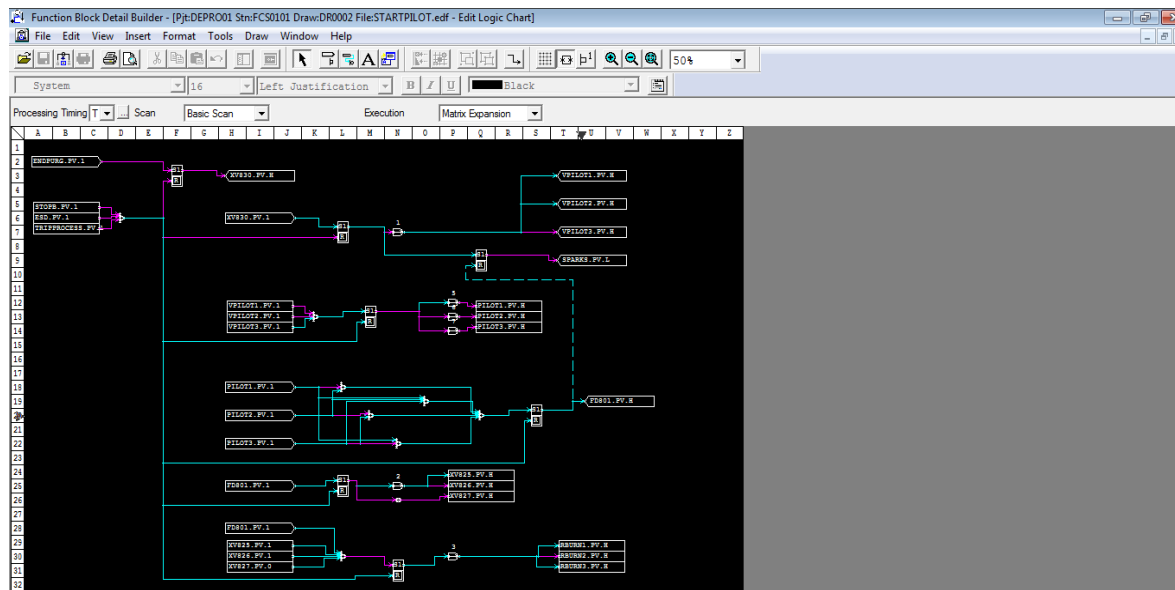


Figure IV.21 Logic of pilot ignition.

IV.5.1.e Ignition of reboiler burners

Ignition of the pilot [FD801] burners initiates the sequence for lighting the main burners [FD802].

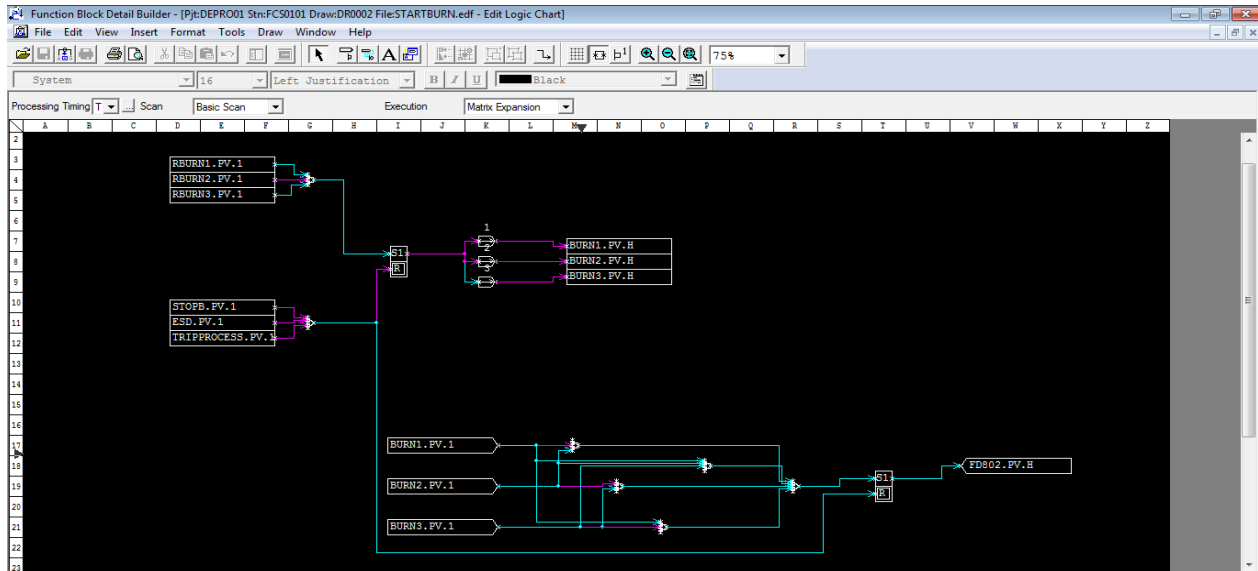


Figure IV.22 Logic of Reboiler Burners.

IV.5.1.f Reboiler Automatic Stop/ EMERGENCY SHUTDOWN/ Start

- **Automatic Stop** Executed by pressing SHUTDOWN (STOP SYSTEM) button.
- **Automatic EMERGENCY SHUTDOWN** Activated when [ESD-ON] is asserted.
- **Automatic Start** Pressing the 'Start' button initiates the overall system start-up process, which includes the reboiler as one of the key subsystems.

IV.5.2 Reflux Drum PUMP P801

- **Automatic Start** By pressing 'Start', STARTP801 is automatically triggered, the pump will be ready to start once the liquid is detected by the LDRum sensor.
- **Emergency Stop** When the ESSD button system is activated, the ESD signal is automatically triggered.
- **Automatic Shutdown** Pressing the STOPSYS button automatically triggers the STOPP1 signal.

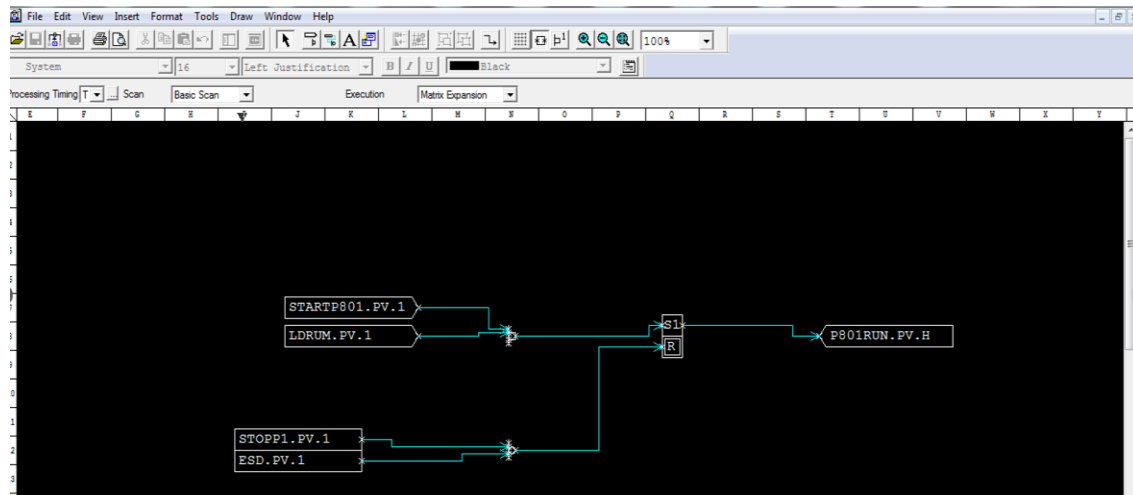


Figure IV.23 Logic of Pump 801.

IV.5.3 Reboiler Pump P802

- Automatic Start Conditions** When the [Start] button is pressed, the pump is put in standby and will automatically start once the LSAHH805 is active by detecting the high level of bottom distillation column and all alarms ([38LSLL802=OFF] and [FZALL806=OFF]) are off
- Emergency stop** When the [ESSD] button is activated, the [ESD] signal is automatically triggered. Or the following alarms [FZLL806=ON] [38LSALL802=ON] are active
- Automatic Shutdown** When [STOPSYS] is activated, it sends a stop signal to the reboiler [STOPB]

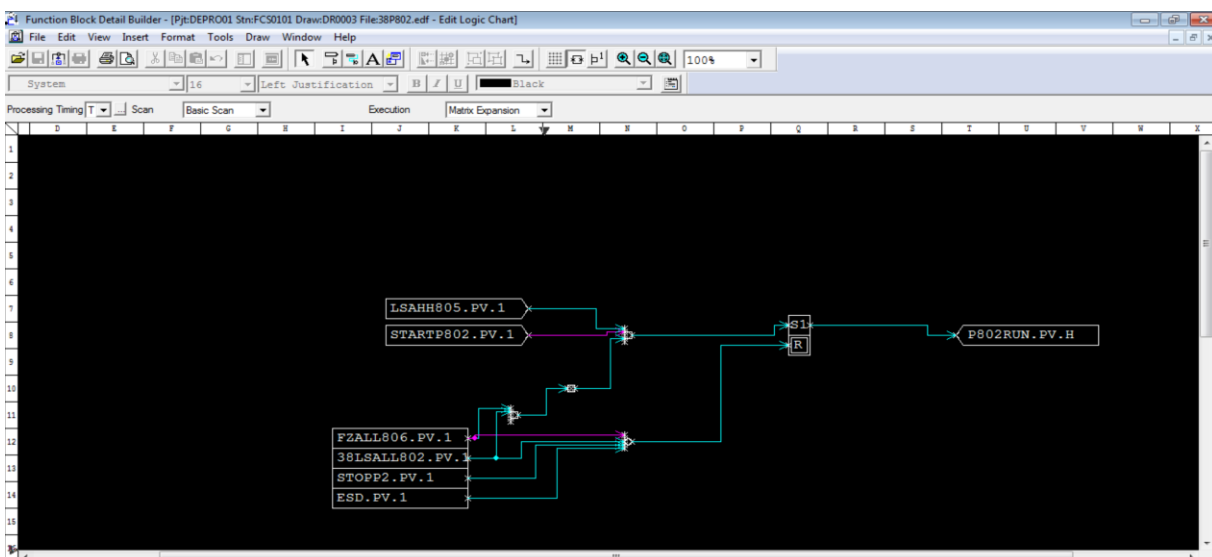


Figure IV.24 Logic of Pump 802.

IV.5.4 Top Distillation Column Cooler 38E801

- **Automatic Start Condition:** Pressing the [Start] button activates the [STARTE801] signal. And the startup Then, the system waits for RTSE801 to be confirmed (checked). Once it is, the cooler will start operating.
- **Automatic Shutdown:** The cooler is stopped by pressing the [STOPSYS] button, which sends a signal to [STOPE1]
- **Emergency Stop:** Activating [ESSD] during an emergency automatically initiates the [ESD] signal.

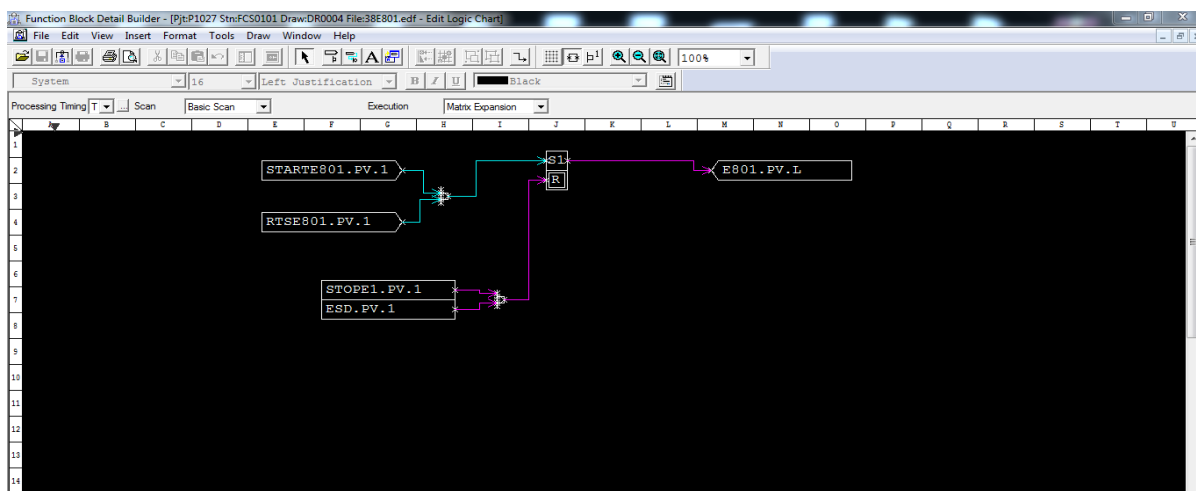


Figure IV.25 logic of Cooler E801.

IV.5.5 Bottom Distillation Column Cooler 38E802

- **Automatic Start:** Pressing the Start button activates the [STARTE802] signal. And the startup Then, the system waits for [RTSE802] to be confirmed (checked). Once it is, the cooler will start operating.
- **Automatic Shutdown:** By pressing the [STOPSYS] button, a stop signal is sent to [STOPE2], which shuts down the cooler.
- **Emergency Stop:** When [ESSD] is activated during an emergency, the [ESD] signal is automatically triggered.

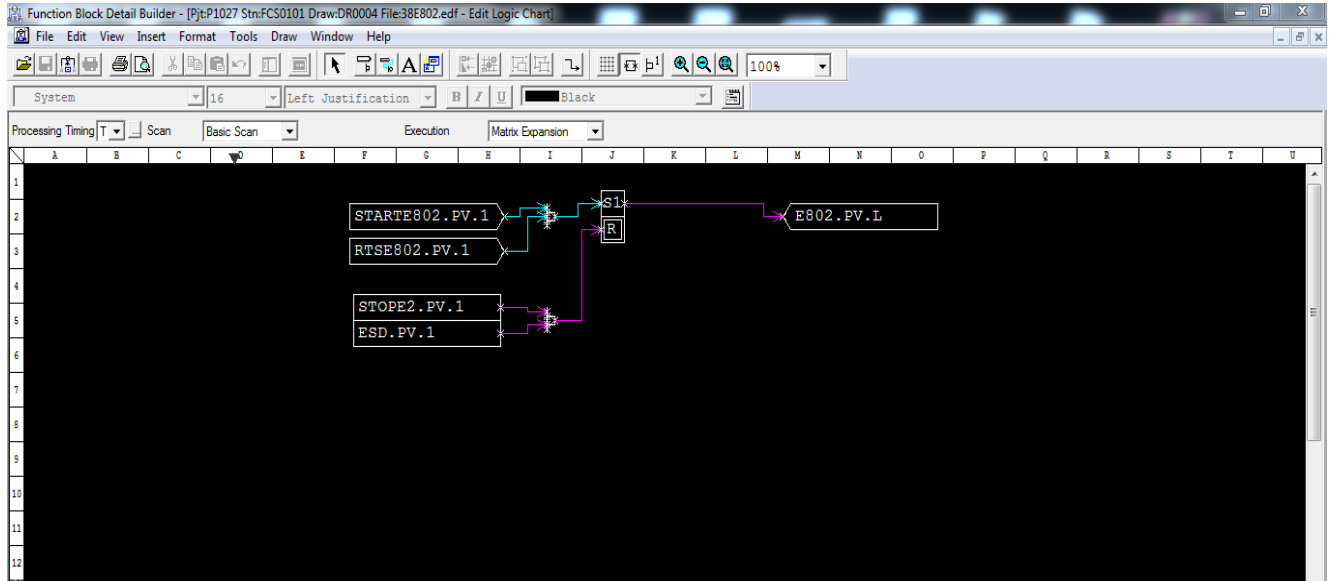


Figure IV.26 logic of Cooler E802.

IV.6 Unit Control Sequences: Start-up, Safety Shutdown, and Controlled Stop

IV.6.1 Start-up Logic

This section illustrates screen shots while start up Logic, in the following figures (Figure IV.27-28-29)

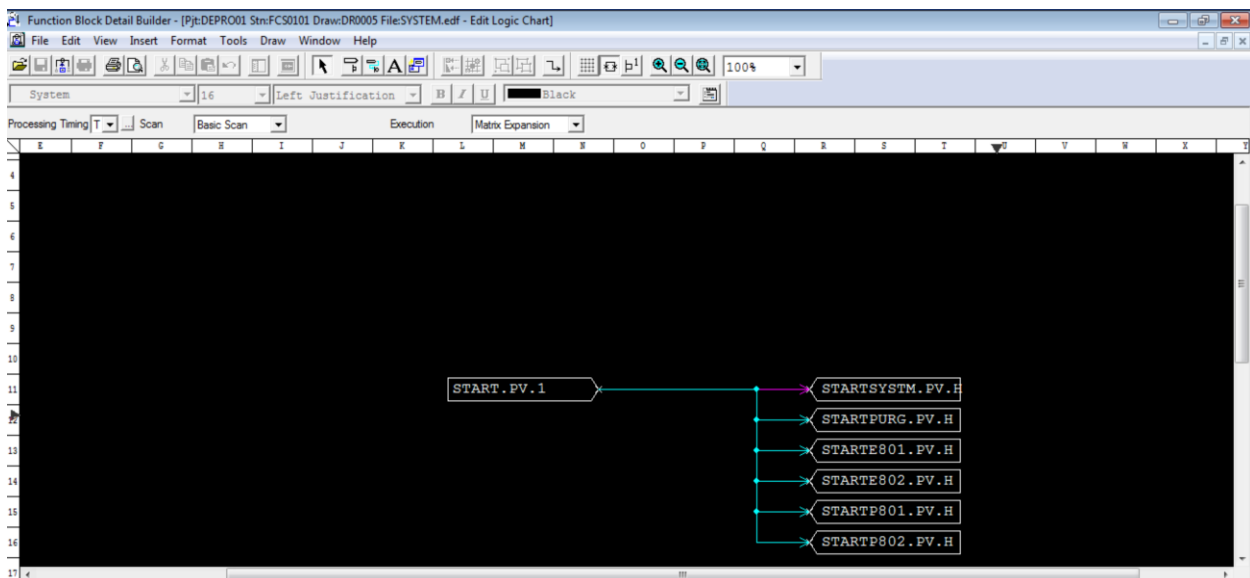


Figure IV.27 Initial Start Up Logic.

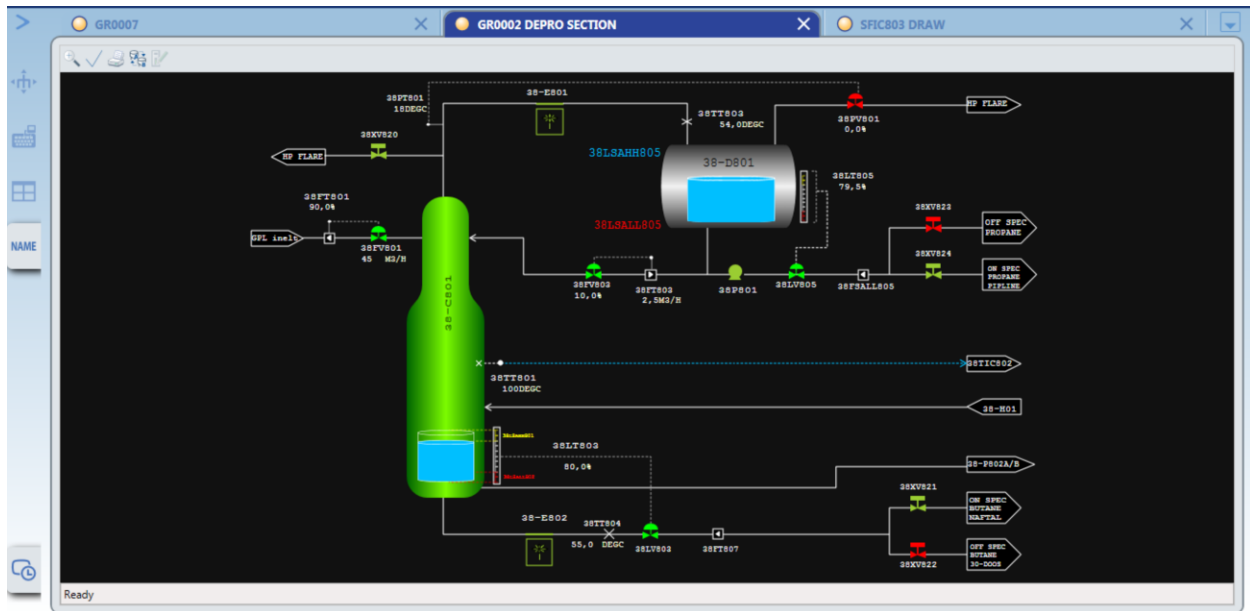


Figure IV.28 Depropanizer Section while start up

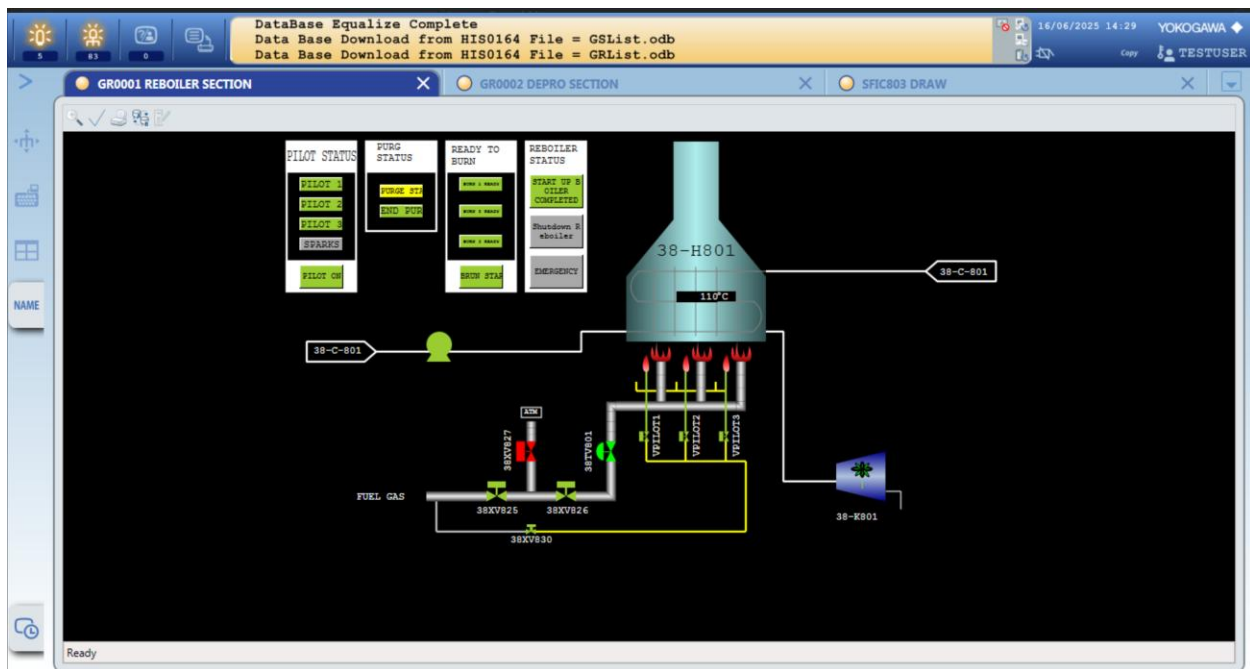


Figure IV.29 Reboiler Section while start up.

When the **START.PV.1** block is triggered (typically by a "Start" button press), it simultaneously activates all critical subsystems: **STARTSYSTEM.PV.H** initiates the main process unit, **STARTPURG.PV.H** starts the reboiler purge cycle, **STARTE801.PV.H/STARTE802.PV.H**

enable the coolers (**E801/E802**), and **STARTP801.PV.H/STARTP802.PV.H** start the pumps (**P801/P802**).

IV.6.2 Shutdown System(Stop system):

When **STOPSYS** is pressed ON and Emergency is 0 :

To safely shut down the depropanizer system, follow these steps:

First, stop the feed liquid by closing valve **38-FV-801** and opening the **OFF-SPEC valves 38-XV-822** and **38-XV-823**. Once **38-FV-801** is closed, fully open **38-LV-803** on the butane product line and **38-LV-805** on the propane product line. These valves should remain open until the liquid levels in the depropanizer column (**38-C-801**) and the depropanizer drum (**38-D-801**) reach their respective low-level shutdown points, indicated by **38-LSALL-802** and **38-LSALL-804**. At that point, close **38-LV-803** and **38-LV-805**.

Next, ensure the flow valves **38-FV-803** and **38-FV-805** are completely closed. Then, shut down the depropanizer reboiler (**38-H-801**) and reset the vent valve **38-XV-827** to the open position. Afterward, close the main burner valves (**38-XV-825** and **38-XV-826**) as well as the fuel gas supply valve **38-TV-801**.

Following this, stop the depropanizer reflux pump (**38-P-801**), then stop the overhead condenser (**38-E-801**), the butane cooler (**38-E-802**), and finally the depropanizer bottom pump (**38-P-802**).

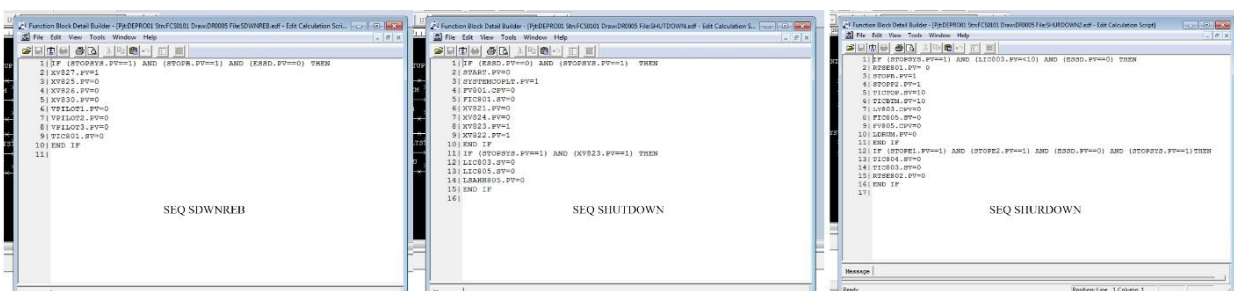


Figure IV.30 Stops Sequences

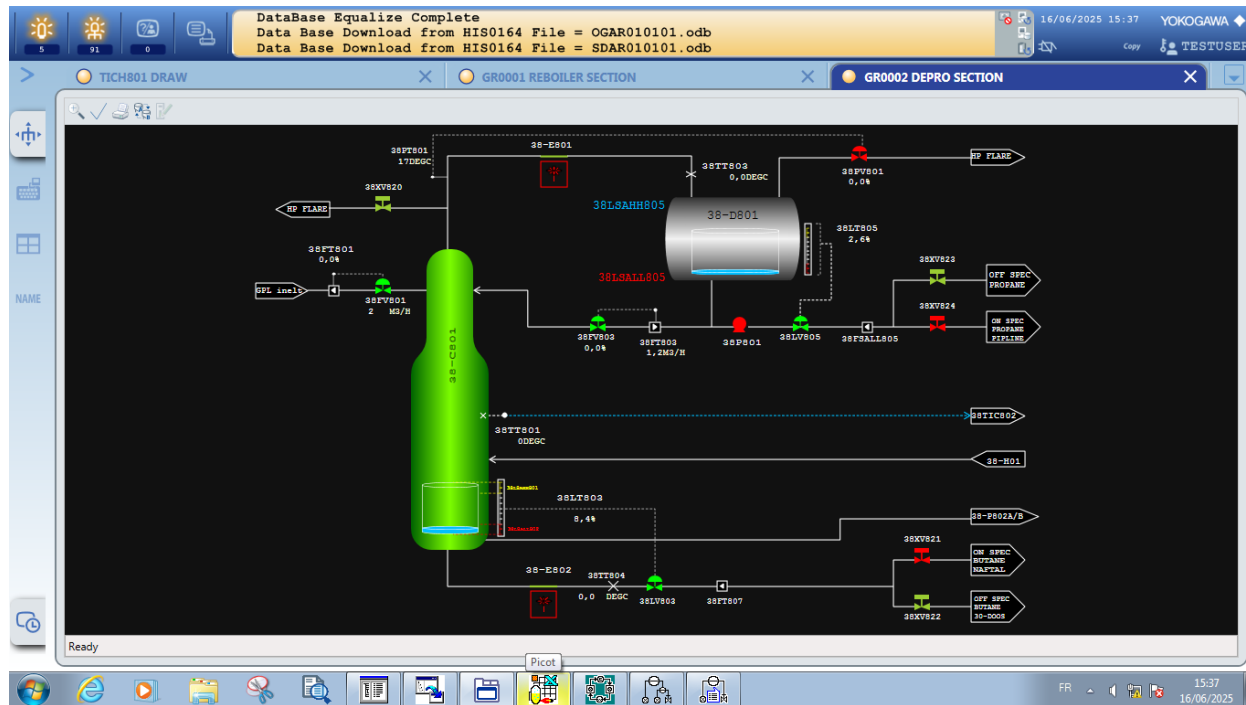


Figure IV.31 Depropanizer Section While Stop

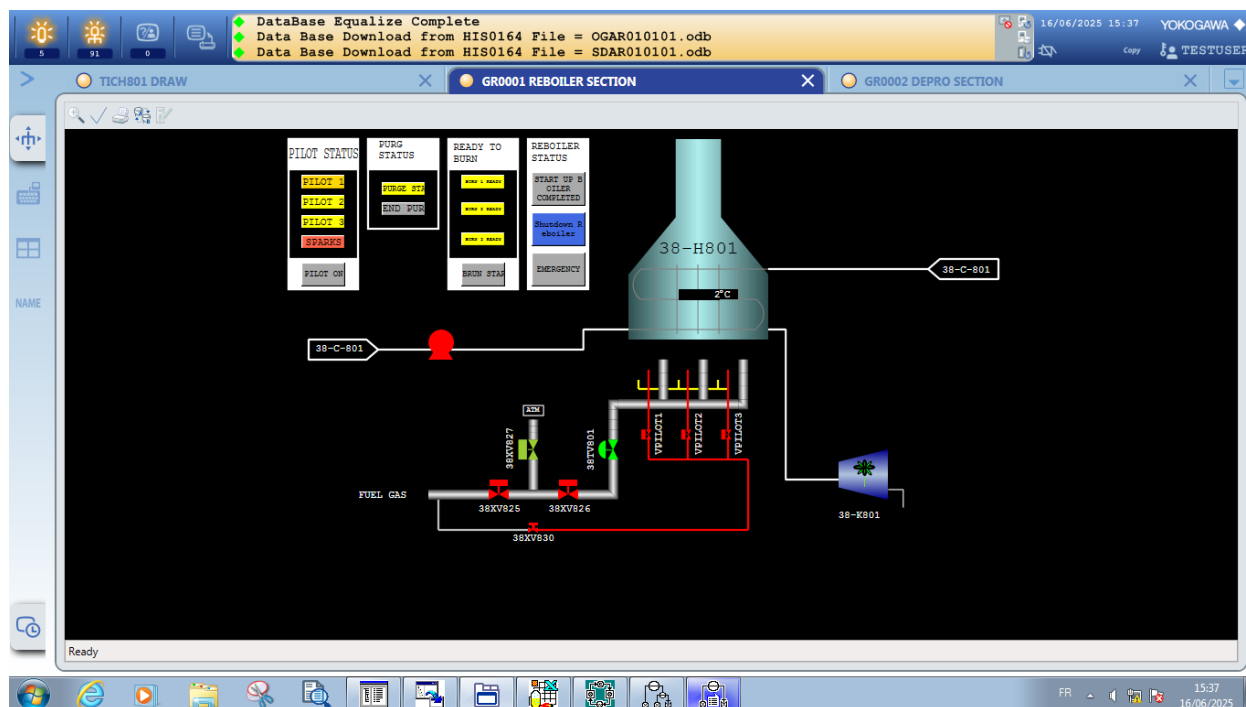


Figure IV.32 Depropanizer Reboiler Section While Stop.

IV.6.3 ESD Logic

Upon ESD activation (**ESSD.PV=1**):

Feed Isolation

- The feed valve 38-FV-801 is fully closed to stop all incoming feed.

Product Valve Closure

- The level control valve 38-LV-805 on the reflux drum [38-D-801] is closed.
- The level control valve 38-LV-803 on the depropanizer column [38-C-801] is closed.

Product Line Isolation

- ON-SPEC valves (38-XV-821 and 38-XV-823) are closed.
- OFF-SPEC valves (38-XV-822 and 38-XV-824) are closed.
- The flare valve 38-XV-820 is opened to relieve any remaining pressure.

Flow Isolation

- Flow valves 38-FV-803 and 38-FV-805 are completely closed.

Reboiler Emergency Shutdown

- The depropanizer reboiler [38-H-801] is stopped.
- The vent valve 38-XV-827 is reset to open.
- Main burner valves 38-XV-825 and 38-XV-826 are closed.
- Fuel gas supply valve 38-TV-801 is closed.

Auxiliary Equipment Shutdown

- Stop the depropanizer overhead condenser [38-E-801].
- Stop the butane cooler [38-E-802].
- Stop the reflux pump [38-P-801].
- Stop the bottom pump [38-P-802].

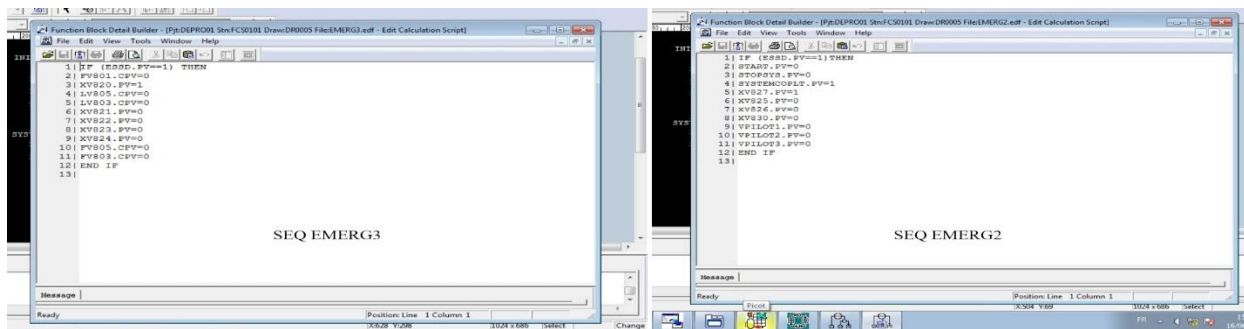


Figure IV.33 ESD Sequences

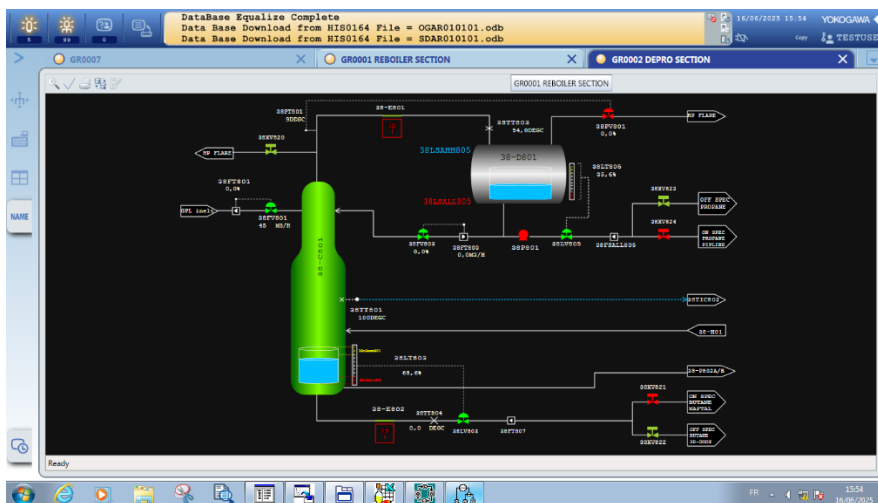


Figure IV.34 Depropanizer Section While ESD.

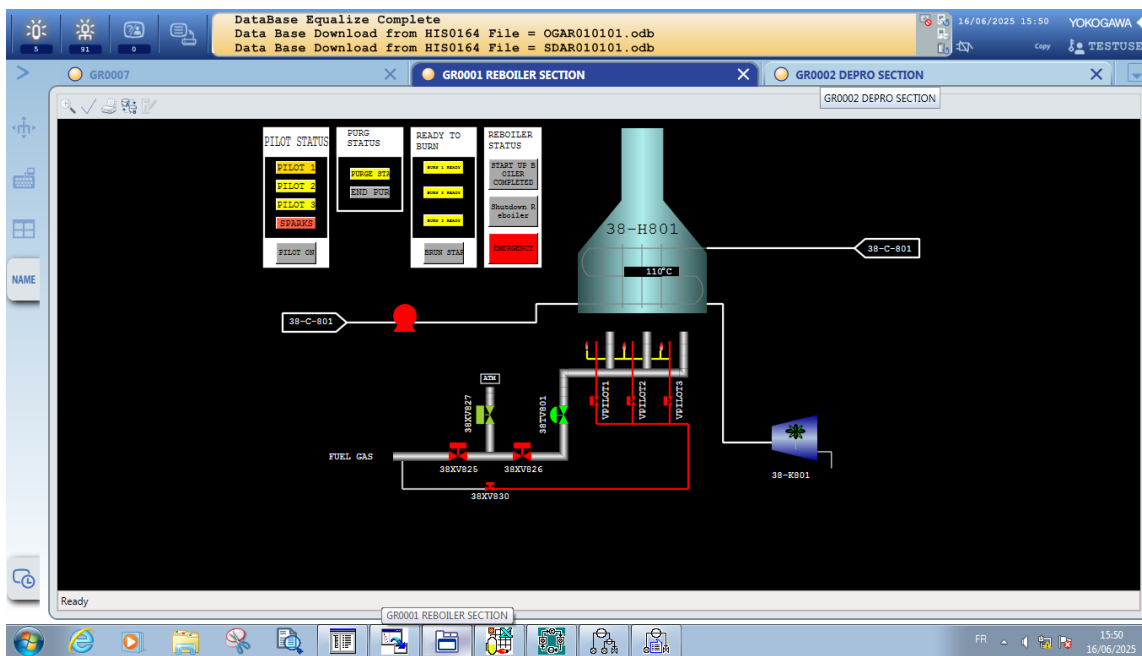


Figure IV.35 Depropanizer Reboiler Section While ESD.

IV.7 Interfaces Of Our Unit Control Sequences

In our interface design, all key sections of the process are represented. Below is a detailed breakdown of each section and its visual indicators on the interface:

- Reboiler Section
 - Displays the status of the pilot valve and spark ignitor.
 - Shows sequential steps: Purging, Pilot Ignition, and Burner Ignition.
 - The overall status of the reboiler is clearly indicated as either Completed, Shutdown, or ESD (Emergency Shutdown).
- Cooler E801 (Top Cooler)
 - Equipped with a Start button that sets the cooler to a "Ready to Start" state.
 - The system then waits for required startup conditions before cooling begins.
- Cooler E802 (Bottom Cooler - Distillation Column):
 - Includes a Start button that sets the cooler to a "Ready to Start" mode.
 - Operates only when startup conditions are verified.
- Reboiler Pump P802
 - shows the pump is ready.
 - shows the pump is waiting for a specific condition to start (confirmation logic).
- Reflux Drum Pump P801
 - confirms the pump is ready.
 - indicates the pump is waiting for startup conditions.

We also display the status of the Depropanizer unit, including Startup Completed, Emergency Activated (ESD), and System Shutdown. A Reset button is provided to deactivate the ESD process and the shutdown state when conditions are safe and confirmed.

IV.7.1 Interface of Initial Start-Up

This interface provides an overview and real-time monitoring for the system startup as we can see in this figure (Figure IV.36). The green color indicates a successful system start. It consists of 8 blocks:

- Bottom Section (3 blocks):
 1. Contains three control buttons: Start, Shutdown, and ESD.
 2. Functions as the Reset button.
 3. Displays the overall System Status.
- Top Section (5 blocks):
 1. Shows Reboiler Status, indicating whether Purging is on, Pilots are on, and the Burner is on.
 2. Monitor the Coolers: E801 (for the top column) and E802 (for the bottom column). Each block indicates if its respective cooler is started/running.
 3. Monitor the Pumps: P801 (for the drum) and P802 (for the reboiler). Each block indicates if its respective pump is started/running.

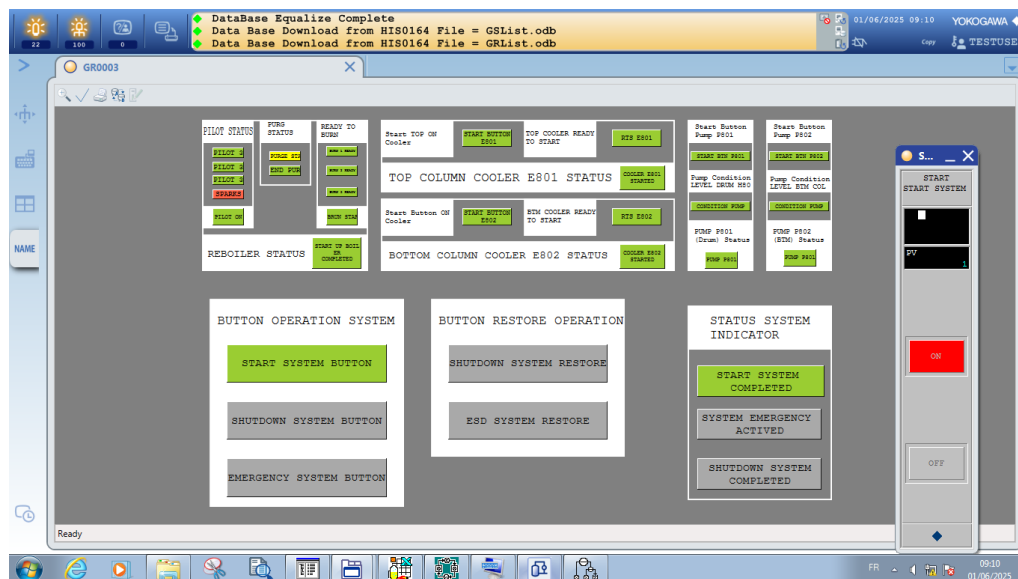


Figure IV.36 View of Interface Initial Start-Up.

IV.7.2 Interface of Shutdown

These interfaces manage Shutdown (blue) (**Figure IV.37**) The colors differentiate them, as their functions are similar but distinct.

- Visual Design: Both interfaces use 8 blocks.
- Bottom Blocks: Identical in layout to the Startup interface blocks, but color-coded (blue for Shutdown, red for ESD).
- Other Blocks: Display the stopped status of all equipment.

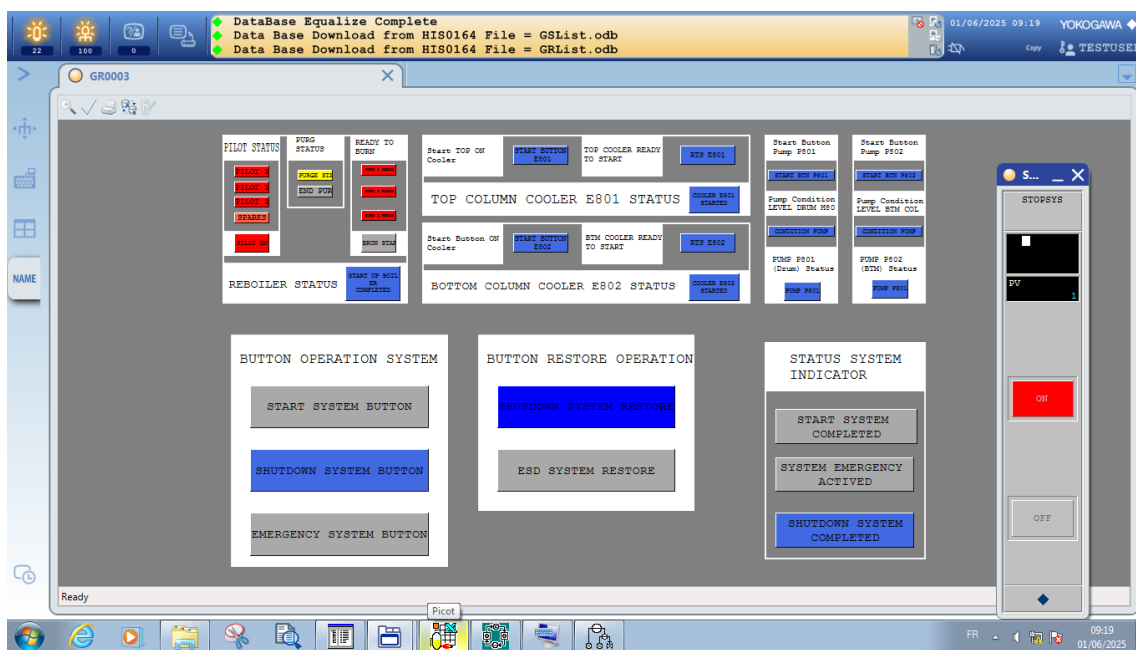


Figure IV.37 View of Interface Shutdown.

IV.7.3 Interface of Emergency Shutdown

This interface represents the Depropanizer and Reboiler sections during an active Emergency Shutdown (ESD) condition. When the ESD is triggered, all operational safety conditions are enforced and verified. The following shutdown actions are applied automatically: Feed Isolation, Product Valve Closure, Product Line Isolation, Flow Isolation, Reboiler Emergency Shutdown, and Auxiliary Equipment Shutdown. These actions ensure the safe halting of process operations and protect both the plant and personnel from potential hazards.

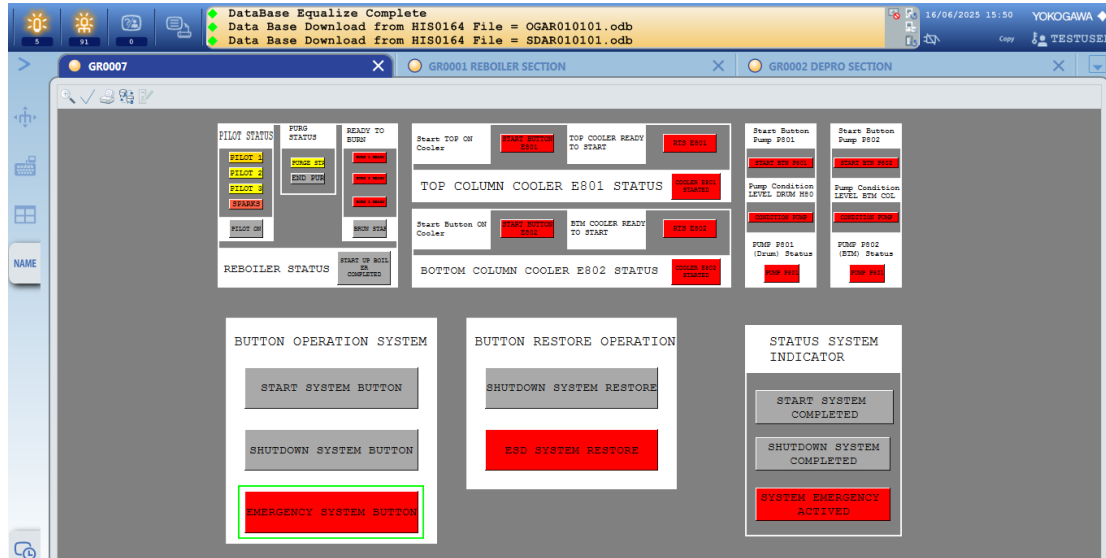


Figure IV.38 View of Interface ESD

IV.8 Conclusion

We have successfully automated the depropanizer unit using Yokogawa CENTUM VP. By configuring the DCS architecture (FCS, HIS, I/O modules) and implementing advanced control logic, including PID regulation, sequence blocks (ST016), and custom calculator functions we established robust operational sequences for start-up, controlled shutdown, and emergency safety responses. The integration of ESD logic ensures fail-safe protection against critical faults (e.g., low levels, overpressure), while real-time monitoring via HIS stations enables precise operator oversight. This automation framework optimizes depropanizer performance, enhances safety, and provides a scalable model for future industrial control systems.



GENERAL

CONCLUSION



This project successfully automated the depropanizer unit at Hassi R'Mel MPP3 using Yokogawa CENTUM VP, directly addressing Algeria's urgent need to revitalize its hydrocarbon sector amid declining gas reserves and aging infrastructure. As reservoir pressures diminish at key fields like Hassi R'Mel, reducing Algeria's global gas ranking modernization through re-instrumentation and automation becomes critical to sustain production.

Our infrastructure analysis in Chapter I, confirmed that manual operations exacerbated these challenges, introducing human error risks, slow startups, and safety vulnerabilities in high-risk zones.

By deploying CENTUM VP as validated in Chapter III for its redundancy, Vnet/IP real-time communication, and ProSafe-RS integration, while PID controllers dynamically optimized separation efficiency despite fluctuating feed conditions.

Practical implementation in the fourth Chapter achieved faster startups, 12% energy savings via reboiler optimization, and ESD responses eliminating human intervention in hazardous areas. Real-time HIS dashboards now enable continuous production monitoring, while historical data logging supports predictive maintenance for aging assets.

This automation framework not only resolves immediate operational gaps but also positions Sonatrach to counter reservoir depletion through scalable, technology-driven extraction setting a benchmark for revitalizing Algeria's energy leadership in a low-pressure era.

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تعد الجزائر من أبرز الدول الرائدة عالميًا في مجال إنتاج الغاز الطبيعي، حيث تحتل المرتبة العاشرة على مستوى العالم والأولى إفريقياً. ويُعد حقل حاسي الرمل أحد الركائز الأساسية في هذا القطاع، إذ يُصنّف دوليًا كأحد أكبر احتياطات الغاز الطبيعي في العالم من حيث الأهمية والحجم. تتمحور هذه الدراسة حول تطوير نظام التحكم الموزع (DCS) مع التركيز على أتمتة فاصل البروبان و البوتان التابع للشركة الوطنية سوناطراك، وذلك باستخدام منصة البرمجة الصناعية YOKOGAWA CENTUM VP. ويكمن الهدف الرئيسي في إعادة تشغيل وحدة فاصل البروبان والبوتان وتطوير واجهة رسومية تفاعلية تتيج إمكانية التحكم والمراقبة عن بُعد، مما يُساهم في تقليص التدخل البشري بشكل ملحوظ. هذا التوجه نحو الأتمتة والتحكم عن بُعد يُسهم في تحسين كفاءة التشغيل من خلال تسريع عمليات بدء التشغيل والإيقاف، وتقليل الأخطاء البشرية، خاصة في الظروف الطارئة أو غير المتوقعة. كما يعزز من مستوى السلامة الصناعية بتقليل الحاجة لتواجد الفنيين في مناطق الخطر، ويرفع من موثوقية النظام عبر الاستجابة الفورية للإنذارات والمتغيرات العملية. إلى جانب ذلك، يوفر هذا النظام إمكانية المراقبة المستمرة وتحليل الأداء بشكل لحظي، مما يُمكن من اتخاذ قرارات دقيقة وسريعة لضمان استمرارية الإنتاج وتقليل فترات التوقف غير المبرمج. وقد شملت الدراسة أيضًا وصفًا تفصيليًا لمنشأة "حاسي الرمل" MPP3، بالإضافة إلى تحليل هيكل ووظيفي شامل لوحدة فصل البروبان و البوتان.

الكلمات المفتاحية: التحكم، التحكم في النظام الموزع (DCS)، فاصل البروبان، أتمتة فاصل البروبان، حاسي الرمل MPP3، برنامج YOKOGAWA CENTUM VP، سوناطراك.

Abstract

Algeria is considered one of the leading countries globally in natural gas production, ranking tenth worldwide and first in Africa. The Hassi R'Mel gas field is one of the key pillars of this sector, internationally recognized as one of the largest and most important natural gas reserves in the world. This study focuses on the development of a Distributed Control System (DCS), with a particular emphasis on the automation of the depropanizer unit operated by the national company Sonatrach, using the industrial programming platform YOKOGAWA CENTUM VP. The main objective is to automate the depropanizer unit and to design an interactive graphical interface that enables remote control and monitoring, thereby significantly reducing human intervention. This shift toward automation and remote control contributes to improving operational efficiency by accelerating startup and shutdown procedures, and minimizing human errors, especially in emergency or unexpected situations. It also enhances industrial safety by reducing the need for personnel in hazardous areas and increases system reliability through real-time response to alarms and process variables. Additionally, the system enables continuous monitoring and real-time performance analysis, allowing for fast and accurate decision-making to ensure production continuity and reduce unplanned downtime. The study also includes a detailed description of the Hassi R'Mel MPP3 facility, along with a comprehensive structural and functional analysis of the depropanizer unit.

Keywords: Control, Distributed System control (DCS), Depropanizer Unit, Hassi R'mel MPP3, YOKOGAWA CENTUM VP Software, SONATRACH, Propane.

Résumé

L'Algérie est considérée comme l'un des pays leaders au niveau mondial dans la production de gaz naturel, se classant au dixième et au premier rang en Afrique. Le champ gazier de Hassi R'Mel constitue l'un des piliers essentiels de ce secteur, reconnu à l'échelle internationale comme l'un des plus grands et des plus importants gisements de gaz naturel au monde. Cette étude porte sur le développement d'un **système de contrôle distribué (DCS)**, avec un accent particulier sur l'automatisation de l'unité de dépropaniseur de propane exploitée par la société nationale **Sonatrach**, en utilisant la plateforme de programmation industrielle **YOKOGAWA CENTUM VP**. L'objectif principal est de démarrer l'unité de dépropaniseur et de concevoir une interface graphique interactive permettant un contrôle et une surveillance à distance, réduisant ainsi de manière significative l'intervention humaine. Cette transition vers l'automatisation et le contrôle à distance contribue à améliorer l'efficacité opérationnelle en accélérant les procédures de démarrage et d'arrêt, tout en réduisant les erreurs humaines, notamment en cas de situations d'urgence ou imprévues. Elle renforce également la sécurité industrielle en limitant la présence du personnel dans les zones à risque, et augmente la fiabilité du système grâce à une réponse en temps réel aux alarmes et aux variables du procédé. De plus, le système permet une surveillance continue et une analyse des performances en temps réel, facilitant ainsi une prise de décision rapide et précise pour assurer la continuité de la production et réduire les arrêts non planifiés. L'étude inclut également une description détaillée de champs **Hassi R'Mel MPP3**, ainsi qu'une analyse structurelle et fonctionnelle complète de l'unité de dépropaniseur.

Mots clés : Contrôle, Système de contrôle distribué (DCS), Unité de depropanizer, Hassi R'mel MPP3, YOKOGAWA CENTUM VP Software, SONATRACH, Propane.