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PLC CONTROL SYSTEMS IN NATURAL GAS PROCESSING: SOLUTIONS FOR BACK PRESSURE PROBLEMS

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“Everything has a reality, and the servant will not reach the reality of faith until he knows that what afflicted him could never miss him, and that what missed him could never have afflicted him.”

– Prophet Muhammad (PBUH)

Dedication

IN THE NAME OF ALLAH THE MOST BENEFICIANT THE MERCIFULL

This thesis is dedicated to my beloved parents, whose unwavering support, encouragement, and love have been my guiding light. To my friends, who have been my pillars of strength and shared in my joys and challenges. To my teachers, whose wisdom and guidance have shaped my path and inspired me to strive for excellence. And to everyone I have met in the faculty, each of whom has contributed to my journey in unique and meaningful ways.
Thank you all for being a part of this incredible experience.
ANIS

This work is dedicated to my loving and caring parents who are the cause of my success, And great gratitude and love to my family, brothers and sisters for their love and support, This work is also dedicated to my closest friends and especially Bennour Abderrahim for their continuous encouragement and motivation.
AIMEN

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Praise be to the Almighty God who has given me faith, courage, and patience to carry out this work.

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ملخص

تتناول هذه الأطروحة معالجة مشاكل رجوع الضغط في أنظمة تجفيف الهواء الصناعية من خلال استبدال صمامات عدم الرجوع بصمامات ملف لولبي واستبدال المؤقت بوحدة تحكم منطقية قابلة للبرمجة، تم إجراء الدراسة في منشأة سوناطراك بسكيكدة، حيث محاكاة النظام المعاد تصميمه باستخدام برمجيات تريكونيكس بي أل سي و أفيفا إن تاتش، مما أكد على تحسين الوظائف والموثوقية وإيجاد حلول لمشكل رجوع الضغط، تعزيز أداء المجفف، والتقليل من تكاليف الصيانة.

Abstract

This dissertation addresses back pressure issues in industrial air dryer systems by replacing check valves with solenoid valves and a cam timer with a PLC. Conducted at Sonatrach GL1/K, the study achieve the reengineered setup using Triconex PLC and AVEVA InTouch HMI software, confirming improved functionality and reliability. This solution solves back pressure problem, enhances performance of the air dryer and reduces maintenance costs.

keywords: Back Pressure, , Check Valves, Solenoid Valves, Cam Timer, Triconex PLC, Engineering Solutions, Process Optimization.

Résumé

Cette dissertation aborde les problèmes de contre-pression dans les systèmes industriels de séchage de l'air en remplaçant les clapets anti-retour par des électrovannes et un temporisateur à cames par un PLC. Réalisée à l'installation Sonatrach GL1/K, l'étude met en œuvre la configuration réingénierée en utilisant le PLC Triconex et le logiciel AVEVA InTouch HMI, confirmant une fonctionnalité et une fiabilité améliorées. Cette solution résout le problème de contre-pression, améliore la performance du sécheur d'air et réduit les coûts de maintenance.

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Nomenclature

Acronymes / Abréviations

AGRU	Acid Gas Removal Unit
aMDEA	activated methyldiethanolamine
APCI	Air Products and Chemicals, Inc.
BASF	Badische Anilin und Soda Fabrik, a chemical company in Germany.
CPU	central processing unit
DCS	Distributed Control System
ERAP	Entreprise Régionale des Activités Pétrolières
HMI	Human Machine interface
I/O	Input/Output
KV	KILO VOLTS
LNG	Liquefied Natural Gas
MARG	Magnetic, Angular Rate, and Gravity
MTPA	Million Tons Per Annum
MW	MEGA WATT
PLC	Programmable Logic Controllers
VDC	Volts Direct-Current

General Introduction

The successful functioning of industrial operations largely depends on the dependability and effectiveness of supplementary systems, such as air dryers.

In facilities for liquefying natural gas, such as the GL1/K complex in Skikda, Algeria, it is vital to maintain superior air quality to ensure both the efficiency of operations and the durability of equipment, this Master's Thesis, entitled "PLC Control Systems in Natural Gas Processing: Solutions for Back Pressure", explores the design, enhancement, and application of sophisticated air dryer systems to tackle existing operational issues and boost overall system efficiency.

Air dryers play a crucial role in extracting moisture from compressed air, averting corrosion, and facilitating the uninterrupted operation of pneumatic devices and controls, nonetheless, conventional air dryer systems frequently encounter problems like back pressure, which can affect their efficiency and dependability, this thesis pinpoints these problems and suggests creative solutions for addressing them.

The investigation starts with an exhaustive review of the GL1/K complex, outlining its historical evolution, organizational framework, and the pivotal role of SONATRACH in the oil and gas sector of Algeria.

Subsequently, the research examines different air dryer models, including refrigerated, membrane, and desiccant types, offering thorough explanations of their operational principles and uses, There is a strong emphasis on the operational procedures and challenges linked to air dryer systems.

The thesis introduces an innovative solution to the issue of back pressure by implementing a 9-valve system that excludes check valves, aimed at enhancing overall performance, the adoption of control devices, such as sensors and valves, is investigated to guarantee accurate monitoring and control of the air dryer system, moreover, the thesis discusses the programming elements of the new air dryer system utilizing TRICONEX PLC, it delves into the creation of control logic, system architecture, and the incorporation of control strategies.

The visualization and diagnostics of the air dryer system are illustrated using AVEVA InTouch HMI software, highlighting the procedures for configuration, monitoring, and alarm management.

By merging theoretical research and practical application, this thesis strives to advance air dryer technology, it provides essential solutions for enhancing industrial processes at natural gas liquefaction plants, aiming for improved efficiency, reliability, and operational excellence.

Chapter 1

Presentation of the GL1/K complex

1.1 Introduction

As part of the strategic objective of developing natural gas resources mainly from the HASSI R'MEL deposit, LNG plants were built in the north of the country, whose main purpose is the export of LNG to Europe and the USA by LNG tankers.

Among these factories, we mention the complex of GL1/K of Skikda whose work began in March 1969 and production in November 1972. This complex covers an area of 90 hectares and receives by pipeline a length of 580 km and 40 inches in diameter of the GN of the deposit of HASSI R'MEL.

Its annual production capacity is 6.7 million m^3 of LNG and a storage capacity of 196,000 m^3 of LNG. It employs 1200 permanent workers.

1.2 Complex History (GL1/K)

1.2.1 SONATRACH

Was created on 31/12/1963 by decree 63-491 to ensure responsibility for the transport and marketing of hydrocarbons. Soon expanded Decree No.: 66-296 of 22/09/1966 to become an enterprise for the research, production, transport, processing and marketing of hydrocarbons.

In 1996, SONATRACH's powers were extended to prospecting for the production, refining and manufacture of chemicals. It held only 20% of the production of foreign companies established in Algeria as S.N.REPAL CAMEL.

1.2.2 The nationalization of hydrocarbons

The nationalization of hydrocarbons took place in 24/02/1971; in addition, in 1972 SONATRACH held the total contract for gas reserves, was 100% involved in transport and 77% in the production of oil and condensates, foreign companies no longer exist in 1972 except at the level of production and research with the strict minimum of participation.

Subsequently it decided to launch a series of natural gas processing complexes across the national territory, such as the GL1/K complex of Skikda and Arzew.

Currently SONATRACH has become one of the most important companies in the economic and social development of Algeria.

Figure 1.1: Panoramic view of the GL1K complex

1.3 Local location

The plant is located 3 km east of the city of Skikda, it currently covers about 92 hectares.

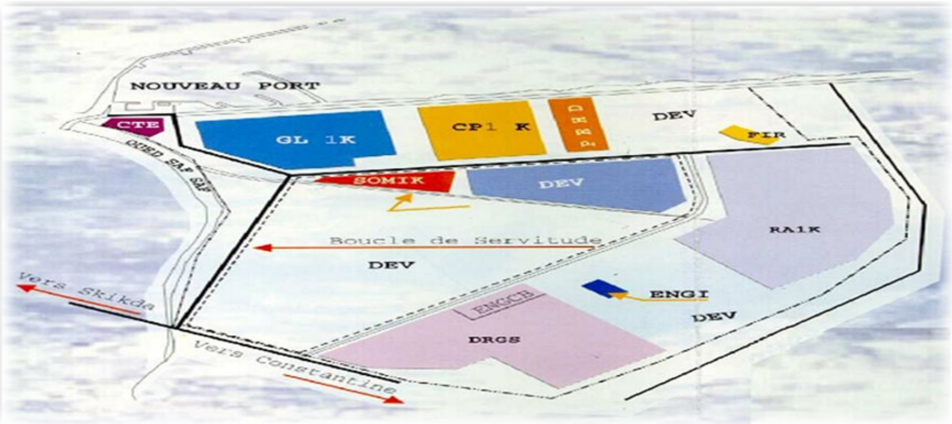

Figure 1.2: Situation of the GL1/K complex in the industrial zone

1.4 Construction

The GL1/K natural gas liquefaction and processing plant in Skikda was built up to 50% use by SONATRACH and ERAP.

After the agreement of December 1971 with ERAP the factory and under the exclusive control of SONATRACH.

1.4.1 GL1/K Complex Organizational Chart

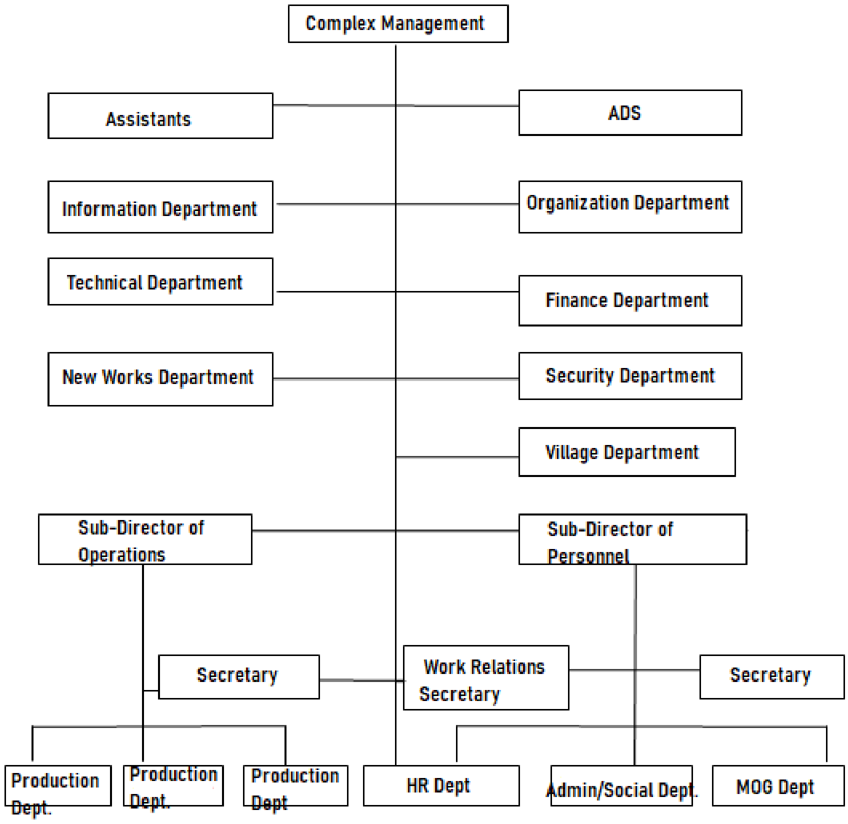

Figure 1.3: Complex Flow Chart

1.4.2 GL1/K Organization

The complex (GL1/K) comprises eleven departments and one directorate, there are functional departments for the management of operational departments focused on production.

1.4.3 Functional Departments

- Administrative Department
  - Administrative Management.
  - Compensation.
  - Social presentation.
- Finance Department

  - Analytical Accounting.
  - Treasury Management.
- General Resources Department
  - Material Presentation to Staff and Facilities.
  - Transportation and Catering.
- Camps Management Department
  - Personnel Accommodation Management.
- New Works Department
  - Execution of Major Modifications within the Complex.
  - Renovation Monitoring.

1.4.4 Operational Departments (Production)

These are structures entirely dependent on production, with interventions either directly managing production units or indirectly through procurement.

- Production Department
  - Responsible for ensuring production according to defined schedules and product specifications.
- Maintenance Department
  - Exists to serve and maintain production efficiency.
  - Addresses maintenance issues that cannot be resolved solely through organizational improvements, systems, and controls.
  - Directly influenced by the functions of production, procurement, safety, etc.
  - The mission is to maintain equipment and facilities.
- Procurement Department

- Manages procurement of spare parts, products, machinery, and equipment, as well as stock management.

- Technical Department
  - Inspects all production installations.
  - Assists the Maintenance and Production Departments.
  - Controls product quality and conducts improvement studies.
- Safety Department
  - Responsible for monitoring intervention installations in case of incidents, whether material or human.
- HR Department
  - Manages employee careers.
  - Provides training for information center staff.

1.5 Skikda GL1/K Complex Overview

Skikda's GL1/K natural gas liquefaction complex is located approximately 3.8 km east of Skikda, It covers a total area of 93 hectares; the plant is bounded to the north by the Mediterranean Sea to the east by CP1/K, to the south by the refinery and terminal and to the west by SONELGAZ.

The GL1/K complex construction project was carried out in three phases according to a schedule developed as a follow-up:

- In 1967 the tender was launched, the bidders of which were foreign companies.
- The studies of the project were spread over three years from 1965 to 1967.
- Construction began in 1967.

The GL1/K complex is supplied with natural gas (NG) from the HASSI deposit. After processing, liquefaction and storage, then loading the LNG carriers.

The annual production capacity of GL1/K is 13.2 million m^3 of (LNG), and a storage capacity of 308 thousand m^3 of (LNG).
In addition to LNG, the complex produces:

- 1029 t/d ethane (C2).
- 978 t/d propane (C3).
- 680t/d butane (C4).
- 373 t/d light naphtha (C5).

Six (06) finished product liquefaction units: U10, U20, U40, U5p, U6p, The first three units U10, U20, U30 were built by French companies TECHNIP according to the process (TEAL), and began to produce from November 1972.

The U40 unit was built 85% by Prichard Rhods and taken over by Pulman Kellog in March 1979, its capacity is 6000 m^3/d of LNG.
One (01) auxiliary plant to supply the liquefaction units with:

1.5.1 Demineralized water

This is the feed water for the various boilers in the complex. The circuit includes: A raw water treatment consisting of:

- Four (04) parallel freshwater production lines by resin ion exchangers from seawater.
- Two (02) stations of fresh water production by vacuum distillation of water, the production of these two systems is 500 t/h.

1.5.2 Electricity and steam

The unit has three (03) turbo-generator sets with a rated output of 7.5 megawatts (MW), their turbines are driven by steam from the three (03) boilers equipping the plant with a capacity of 45 t/h of steam for each.

Part of the steam produced is used to start the boilers of the units. The rest is for other equipment such as seawater desalination equipment. . .

1.5.3 The instrument air

It is dust-free air, dried and compressed to seven (07) bars. It is produced by a battery of filters, dryers, and compressors installed at the plant in these annexes.

1.5.4 Nitrogen

Crucially obtained via the distillation of atmospheric air, is predominantly employed in metering operations. The production capacity stands at 400 m^3/d.

- One (01) finished product storage and operations unit and two LNG tanker loading centers.

It is responsible for storing LNG:

- Three (03) storage bins (LNG).
- Two (02) LNG tanker loading centers.

The storage capacity of 315,000 m^3 of liquid and its shipment on the salaries to be loaded in the LNG carriers. It also handles butane and propane shipments, and LNG and LPG subsidies.

- One (01) LPG processing unit:

Its role is the separation of butane and bu-pro mixture (butane-propane) from the liquefaction units.

1.6 Overview of existing units:

The Skikda LNG natural gas liquefaction complex currently includes:

- (03) liquefaction units in production.
- (01) a storage and shipping unit.
- (01) LPG unit.
- Auxiliary plant.

The complex mainly includes:

- Three (03) LNG liquefaction trains U10, U5p and U6p.
- An LPG unit for the treatment and storage of propane and butane.
- A storage park and substantial collection facilities including:
  - Three (03) LNG storage bins with a total capacity of 196000m^3.
  - Two (02) LNG firefighters.
  - Two 02 LNG loading stations

A central unit for the production of utilities:

- Demineralized and distilled water.
- Steam.
- Air instrument and service.
- Nitrogen.
- Fuel gas.

In addition to LNG, the complex produces:

- 1915 t/d of ethane.
- 1818 t/d of propane.
- 1554 t/d of butane.
- 917 t/d of light naphtha.

Following the incident on 19/ 01/ 2004 the production capacity of the complex was reduced by 40%.

1.6.1 Auxiliary plant:

The auxiliary power plant is a self-contained system for supplying 10-5p-6p units with electricity, air, cooling water and nitrogen.

1.6.2 Storage and Shipping:

The LNG storage unit includes 05 tanks, 3 of capacity 56000 m^3 each, and 02 of 70000 m^3.

This unit has two LNG shipping pumps. The loading rate of the first is 6000 m^3/h and the second 12000 m^3/h.

1.6.3 LPG Unit:

This unit built by the Japanese company I.H.I, initially started in September 1973, its purpose is the processing of the product of units 10, 20, 30 and 40 in order to separate it into propane and commercial butane. It stores these products as well as those from units 5 and 6. It also provides cooling and storage of propane and butane from RA1/K. Its storage capacity is:

- 02 propane tanks: 12,500 tones each, mainly for export.
- 01 butane tank: 20000 tones, mainly for national consumption.

1.7 Mega Train:

The New LNG Train project in Skikda (Algeria) consists of an independent LNG train of 4.5 MTPA, utilities and offsites (storage), to replace the capacities of units 20, 30 and 40 which were destroyed by fire in 2004.

The train consists of the following sections: Natural Gas Counting and Compression, Supply System, The treatment of aMDEA according to the BASF process, Natural Gas Processing (Decarbonation, Dehydration, Demerrcurization), APCI liquefaction process and fractionation of ethane, propane, butane and natural gas.

Products	Quantity (kg/h)
LNG	611,999
Enriched helium gas	20,205
Ethane	22,404
Propane	28,235
Butane	23,312
Natural gasoline	14,786

Tableau 1.1: Products of the Mega Train

1.7.1 Overview of Mega Train Units:

1.7.1.1 Utilities:

A - Unit 51 Production of electrical energy: There are five 51-MJ01-A/B/C/D/E generators driven by gas turbines powered by fuel-gas from the fuel-gas balloon. Each generator can produce 21.74 MW at 11 KV and 50HZ for a total of 110 MW when all generators are running. And five groups of Diesel generators (DEG's) 51-MJ02-A/B/C/D/E backup and start-up of 1.719 MW for each diesel. The Skikda plant requires about 80 MW when operating with its design capacity.

B - Unit 56 Air Instrument and Air Service Systems: The Air Instrument and Air Service systems (Unit 56) produce compressed air and instrument air for all plant users. There are three (03) sets of 56-MJ01-A/B/C air compressors that operate at 100% : one is in service and the other two in stand-by. The compressed air from the compressors passes through the 56-ML02 Air Separator and then through two (02) sets of 56-ML01-A/B Air Dryers that operate at 100%, one is in service and the other in standby.

C - Water Systems: The purpose of the cooling water system, (Unit 09) is to:

- Provide cooling water or make-up water for mega train unit machines.

The water objective of Unit 59 is:

- Store and deliver industrial water (service) to be used in the new LNG train at the fire water system, treat to make it drinkable, store and deliver drinking water.
- Store and deliver demined water for use in the new LNG train.

D - Hot oil systems: The hot oil used in Units 08, 18 and 58 is a Shell Thermia Oil Boil that consists mainly of hydrocarbons with a carbon number between C20 and C50.

- **Unit 08 Storage bin:** The 08-MF01 hot oil storage tank is atmospheric type designed to hold all hot oil inventory of the LNG train plus a 10% safety margin, this bin is under nitrogen cover.
- **Unit 18 Hot Oil System:** Unit 18 hot oil system is intended to satisfy the heat demand of the rewinders of the train unit.
- **Unit 58 Fractionation hot oil system:** Unit 58 hot oil system is intended to meet the heat demand of the fractionation unit rewinders (Unit 07), the 15-MC15 scrubber column rewinder and the GN 01-MC02 heater.

Unit 65 Torch System: The purpose of the torch system (Unit 65), is to ensure safe treatment, disposal of hydrocarbon vapor and liquid currents that are generated by plant commissioning, shutdowns, malfunctions, failures and emergencies.

1.7.1.2 Train and fractionation:

A - Unit 01 Supply Gas Compression/Counting: The NG supply gas comes from the Hassi R'mel fields, passes through a 01-IC03 counting system and then to the NG compression system to compress this gas to a pressure required for downstream processes.

B - Unit 12 Decarbonation (AGRU): Its goal is to reduce the CO2 contained in the GN to less than 50 ppmv using the aMDEA under BASF license, in order to avoid clogging (CO2 solidification) on downstream unit equipment (Liquefaction, unit 15).

C - Unit 13 Dehydration: Its objective is to dry the gas until a residual water content of less than 01 ppmv, in order to prevent the formation of hydrates in lines and equipment operating at low temperatures. The principle of operation of this unit is based on the use of three molecular sieve bed dryers, the 1st is in adsorption mode, the 2nd is in stand-by (waiting) and the 3rd is in regeneration.

Regeneration is carried out using the heated and relaxed gas from liquefaction.

D - Unit 14 de-mercurization: Its purpose is to reduce the level of mercury in the natural gas through adsorption using a bed of activated carbon impregnated with sulfide. If the mercury is not removed, there will be a risk of mechanical damage to downstream units and equipment made of aluminum.

E - Liquefaction and Refrigeration:

- **Unit 15 Liquefaction:** The objective of liquefaction is to:
  - Cool the NG entering the purification column in which the heavy hydrocarbons are separated from the NG and the production of a liquid supply current to the fractionation unit (Unit 07).
  - Cool and partially liquefy the head of the purification column in the main exchanger
  - Cool LPG and iso-pentane from fractionation with MR refrigerant and mix with NG to produce LNG in the main exchanger.
  - Cool and liquefy CNG (removed from heavy hydrocarbons) to produce LNG in the main exchanger.
  - Produce a gas rich in Helium for export.
  - Eliminate nitrogen from LNG and produce HP fuel gas.
  - Mix the BOG from new and existing LNG storage tanks with a certain amount of NG and regeneration gas from the dehydration system to produce fuel gas for the plant.
  - Evacuate LNG to the new LNG storage bin.
  - Produce methane for coolant backup.
- **Unit 16 Refrigeration:** The purpose of refrigeration (Unit) 16 is to:
  - Produce and circulate refrigerant MR and propane using turbo-compressors and condensers.

  - Cool and partially liquefy the MR using the refrigerant propane.
  - Cool and liquefy NG using refrigerant MR in 15-MC05.

F - Unit 07 Fractionation: The objective of the fractionation unit (Unit 07) is to:

- Produce quantities of ethane, propane, butane and gasoline at least equal to those produced by existing units 20, 30 and 40.
- Produce ethane and propane required for coolant backup.

The fractionation unit consists of the following distillation columns and their associated equipment:

- Demethanizer - 07-MD01;
- Demethanizer - 07-MD02;
- Depropanizer - 07-MD04;
- Debutante - 07-MD06;
- Deionizer - 07-MD11;
- Re-injection of GPL 07MD08;

1.7.1.3 Storage and shipping:

- **Unit 71 of LNG:** Ensure the storage of LNG produced by the new train and existing Skikda units through the 71-MF01 LNG storage bin.
- **Propane Unit 76:** Ensure the storage of propane produced by the new LNG train in the new 76-MF01 propane storage tank.
- **Butane Unit 76:** Store and transfer butane from SKIKDA's new LNG train using the 76-MF02 butane storage bin.
- **Gasoline Unit 76:** Ensure the storage and transfer of the gas line produced by the new LNG train of SKIKDA at the sphere 76MD03.

1.8 Lab Overview

The laboratory is operational 24 hours to answer all the necessary analyses requested by the different units without forgetting the analyses requested by the department engineers, for example the analyses of oil, imported product. . . , The analyses are done according to a program described by the laboratory officials and a different department. The laboratory is the service of product and material control that enters the production. It serves as an indicator of the proper functioning of the complex.
Two types of analysis are carried out in the GL1/K laboratory:

- Gas analysis by chromatography.
- Analysis specific to water.

1.9 Conclusion

The GL1/K complex in Skikda, Algeria, plays a vital role in the country's natural gas industry. It was built to process and liquefy natural gas from the Hassi R'Mel deposit for export to Europe and the USA. The complex, which began production in 1972, covers 90 hectares and employs 1200 permanent workers.

It includes several units for liquefaction, storage, and shipping of LNG, as well as auxiliary plants for utilities like demineralized water, electricity, steam, instrument air, and nitrogen. The GL1/K complex is strategically important for Algeria's economic development and international energy trade.

Chapter 2

Plant and Instrument Air System

2.1 Introduction

In industrial settings, air-dryer systems are indispensable to ensure the reliability and quality of compressed air, which is a fundamental premise. Furthermore, air dryers help to remove contaminants and play a pivotal role in maintaining optimal conditions by effectively removing moisture and contaminants from compressed air. By eliminating moisture, air dryers prevent corrosion and freezing within pneumatic systems, safeguarding the integrity of crucial components like valves.

In addition, air dryers help to remove contaminants such as oil, dirt, and particulate matter, which can compromise the performance of pneumatic equipment and cause valve blockages.

2.2 Types of Air Dryers

There are several types of air dryers used in various industries refrigerated air dryers work by cooling the air, which condenses the water vapor into liquid that is then drained out, desiccant air dryers use a desiccant material to absorb moisture and contaminants from the air, membrane air dryers use a semi-permeable membrane to separate moisture and contaminants from the air.

2.2.1 Refrigerated Air Dryers

Refrigerant dryers are the most commonly used dryers in the industry and consist of an air-to-air heat exchanger and an air-to-refrigerant heat exchanger, the heat exchangers remove moisture from the compressed air by condensation of water within, this is essential to protect compressed air systems and every piece of equipment fed by compressed air from the harmful effects of moisture.

Basically, the dryers cool down the warm wet air coming from the compressor, when the temperature of compressed air reduces, moisture condenses and is drained from the compressed air with the help of a high-efficiency water separator.

After that, compressed air is reheated to around room temperature so that condensation does not form on the outside of the pipe system.

This heat exchange between ingoing and outgoing compressed air also reduces the temperature of the incoming compressed air, and as such reduces the required cooling capacity of the refrigerant circuit [1].

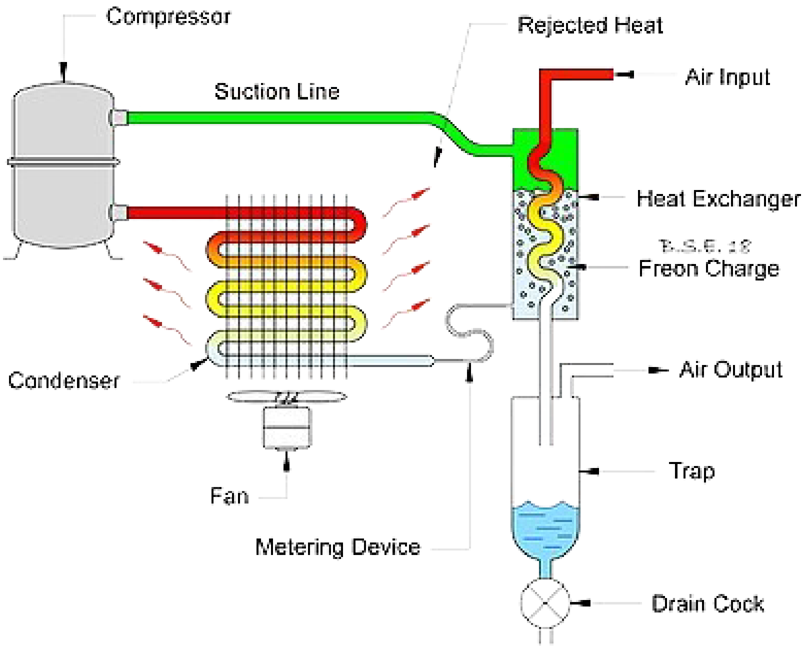

Figure 2.1: Refrigerated Air Dryer Mechanism

2.2.2 Membrane Air Dryers

Membrane air dryers utilize a highly selective, permeable membrane to dehumidify compressed air, making them an essential component in various industrial applications where moisture-free air is critical.

The core of the dryer is a bundle of hollow fibers or flat sheets made from a special polymer that is permeable to water vapor but not to air.

As compressed air, laden with moisture, enters the dryer, it passes over or through these membrane structures, the principle that drives the drying process is selective permeation, water molecules due to their smaller size and higher kinetic energy under compressed conditions, diffuse through the membrane material more readily than the larger molecules of nitrogen and oxygen that make up the bulk of the air, this diffusion is driven by a concentration gradient inside the membrane, where the air is moist, and outside, where it is drier.

As the water vapor permeates through the membrane, it reaches the other side where it is continuously swept away, typically by a stream of ambient air, which maintains a low vapor pressure on the exterior of the membrane, this gradient is crucial as it enhances the efficiency of the moisture removal process.

Despite the simplicity of their design, membrane air dryers are highly effective and advantageous due to their lack of moving parts, which minimizes maintenance and operational costs, they are also valued for their compactness and the fact that they do not require electrical energy to operate, relying solely on the physical properties of the membranes and the dynamics of air flow and pressure.

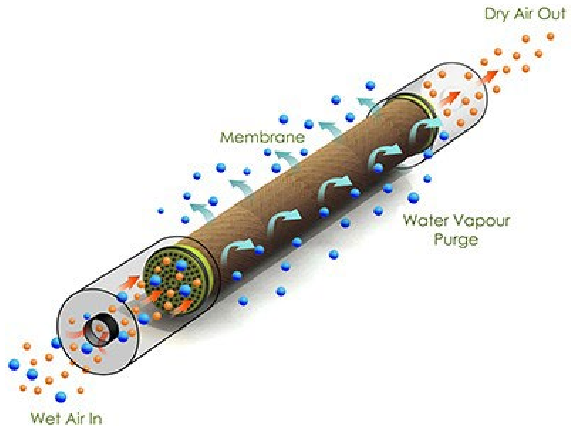

Figure 2.2: Membrane Air Dryer Mechanism

2.2.3 Desiccant Air Dryers

A desiccant air dryer is a crucial device used to remove moisture from compressed air, essential in many industrial and commercial settings to prevent damage and inefficiency caused by water vapor.

It operates by passing compressed air through a bed of desiccant material, such as silica gel or activated alumina, which adsorbs moisture.

These dryers typically feature dual towers one for drying air and the other for regenerating the desiccant through heat or pressure swing processes.

Desiccant air dryers are particularly valued for their ability to achieve very low dew points, making them ideal for sensitive applications requiring stringent moisture control, such as in oil and gas industries, pharmaceuticals, electronics.

2.2.3.1 Desiccant

Desiccant is a type of material with the ability to attract and hold liquids and other gases. In an air dryer, desiccant beads are used to adsorb water vapor to provide dry air downstream. This works great in achieving very low dew points early on in the drying cycle, but as the desiccant beads continue capturing moisture, their performance begins to diminish.

Figure 2.3: Desiccant Sieve

When the desiccant beads are saturated, they are no longer able to absorb moisture. At this point, the moisture trapped by the desiccant must be removed by one of two methods.

Regeneration using dry air:

The regeneration of saturated beads is achieved by diverting a portion of the dry processed air back through the desiccant bed that needs regeneration. This diverted air is moisture-free and can effectively absorb the moisture from the desiccant beads. The process operates on a pressure swing adsorption (PSA) principle, where the pressure in the regenerating tower is reduced to release the trapped moisture, which is then carried away by the dry air flow.

Regeneration using heated air:

These dryers incorporate an external blower to draw in ambient air, which is then heated and passed through the saturated desiccant bed. The high temperature of the heated air strips the moisture from the desiccant beads more effectively and rapidly than ambient air alone. This method does not consume the dry air produced for process needs, which can result in energy savings and increased efficiency. After the heating phase, a cooling phase occurs, typically with ambient air, to prepare the desiccant for effective operation in the drying cycle.

Types of Desiccants:

Most desiccant materials are stable chemically, but a few are toxic and can only be used under special conditions. The most common types of desiccants include:

- **Silica:** A commonly used desiccant made from silicon dioxide, known for its high adsorption capacity and versatility.
- **Activated charcoal:** Known for its porous structure, activated charcoal is used to adsorb moisture and impurities.
- **Calcium chloride:** An effective desiccant, calcium chloride is often used in the form of moisture-absorbing pellets or bags.

2.2.4 Types Of Desiccant Air Dryer

2.2.4.1 Heatless Regenerative Desiccant Dryers

Heatless desiccant dryers operate with two towers that alternate between drying and regenerating. Process air enters one tower, where desiccant material adsorbs moisture based on its pore structure and water affinity. Once the desiccant is saturated, the system switches to the second tower, allowing the first to regenerate.

Regeneration occurs by depressurizing the tower and passing a portion of the dried compressed air backward through the desiccant. This reverse flow picks up the moisture and expels it from the system. This method, known as pressure swing adsorption, does not require external heat.

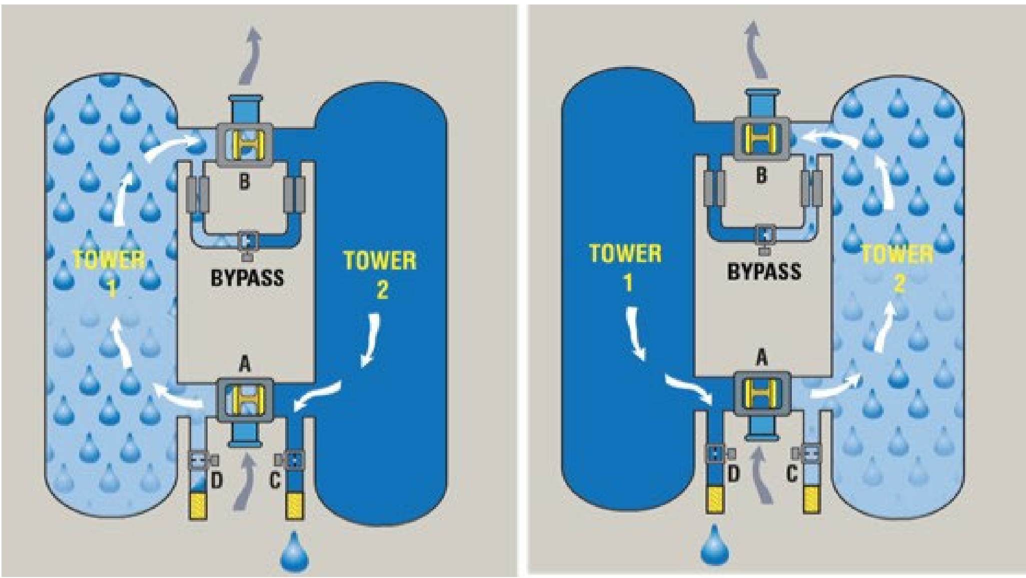

Figure 2.4: Heatless regenerative desiccant air dryer Mechanism

Advantages:

- Heatless dryers are simpler in design with fewer components, making them easier to maintain and operate.
- They generally have a lower initial purchase cost compared to heated dryers.
- With fewer moving parts and no external heating elements, they are often more reliable and less prone to mechanical failure.
- These dryers are usually more compact and require less installation space.

Disadvantages:

- They use a significant amount of compressed air for the regeneration process (typically around 15-20% of the total air flow), which can lead to higher operational costs.
- Heatless dryers are generally less suitable for high-capacity applications due to their higher air consumption for regeneration.
- The frequent and intense purge cycles can reduce the lifespan of the desiccant material.

2.2.4.2 Heated Desiccant Dryers

Similar to heatless dryers, heated desiccant dryers also utilize a dual-tower design to efficiently process compressed air. In these systems, the regeneration of the desiccant is significantly enhanced by the integration of an external heating element. This element raises the temperature of the desiccant, greatly improving its ability to release absorbed moisture, which is more effective than the simple depressurization used in heatless systems.

Following the heating phase, it is crucial to bring the temperature of the desiccant back down to ensure optimal performance in the drying cycle. To achieve this, a controlled amount of purge air, which is dry and cool, is circulated through the heated desiccant.

This step is essential as it prevents the desiccant from introducing unwanted heat into the freshly dried compressed air stream, maintaining the integrity and effectiveness of the drying process. This careful balance of heating and cooling ensures that the heated desiccant dryer operates efficiently, providing consistently dry air for critical applications.

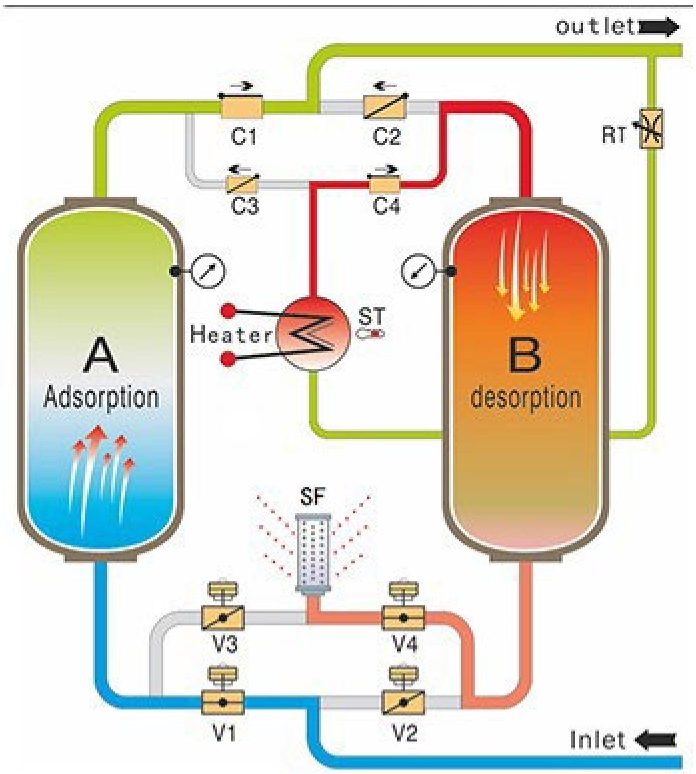

Figure 2.5: Heated Regenerative Desiccant Air Dryer Mechanism

Advantages:

- Although heated dryers require energy to heat the desiccant, they generally use less purge air compared to heatless systems, which can lead to overall energy savings in systems with high air flows.
- The use of heat accelerates the regeneration of the desiccant, allowing these dryers to handle higher flow rates and operate more efficiently under continuous use.
- By using heat rather than large amounts of purge air, the physical stress on the desiccant material is reduced, potentially extending its service life.

- Heated dryers are typically more suitable for larger systems where the volume of air and operational demands justify the energy costs of heating.

Disadvantages:

- Heated dryers tend to be more expensive initially due to the additional components such as heaters and blowers.
- They are more complex with more components, which can lead to higher maintenance requirements and potential downtime.
- The need to manage and dissipate the heat generated during the regeneration process can be challenging and may require additional cooling systems.
- They typically require more space for installation due to the additional components and heat management systems.

2.3 Air Dryer Operation

2.3.1 System Description

There are three Air Compressor Packages, designated as 56-MJ01-A/B/C, one is operational while the other two are on standby,e Each compressor is rated for 3345 Nm^3/h at a nominal discharge pressure of 10 barg.

These compressors are motor-driven, oil-free screw-type, two-stage systems that provide pulsation-free air and are water cooled, it compresses air, which heats it up as well to be re-cooled next, and increasing the air pressure to about 9 bar helps desiccant to absorb more of the moisture.

The compressed atmospheric air from the compressors undergoes separation of any con- densed water in the Wet Air Separator, labeled as 56-ML02, The cold outside temper- ature of the wet air separator re-cooled the compressed air and condenses it so some of the moisture is removed and drained, following this separation, the air is distributed to utility stations through the plant air headers.

Additionally, there are two Air Dryer Packages, designated as 56-ML01-A/B, with one operational and the other on standby, each dryer package consists of two vessels: one for drying and one for regenerating, these are heat-less type dryers that lower the water dew point of the air to -40°C at an operating pressure of approximately 9.0 barg, after filters are included in each package to eliminate desiccant fines.

Within each dryer package, wet compressed air enters the bottom and is directed by switching valves to the in-service dryer where dry desiccant removes moisture, the dry air then flows upward through the dryer and exits the package outlet, approximately fifteen percent of the dry air is diverted into the regenerating dryer where it is depressurized to atmospheric pressure which facilitates the subsequent removal of moisture from the desiccant and utilized to regenerate the desiccant in the second dryer, the purge air, after removing moisture from the desiccant, exits the dryer through a muffler to the atmo- sphere.

Upon a preset time or based on dew point control, the dryer shifts, during a shift, the regenerated dryer gradually pressurizes, we aim to balance the pressure levels between the two absorber towers, this balancing act is essential for a seamless transition during the operational cycle, switching valves sequentially shift, and the off-stream tower is depressurized.

The instrument-quality air from the dryers flows into the Instrument Air Receiver, labeled as 56-MD02, before distribution to users, this receiver ensures there is enough instrument air at normal flow for 5 minutes to allow for a controlled shutdown of the plant in the event of total air compressor failure.

2.3.2 Operations

This section provides a description of the operating parameters for the Plant and Instrument Air System.

2.3.2.1 Air Compressor Package, 56-MJ01-A/B/C

Under normal conditions, one of the Air Compressor Packages (56-MJ01-A, B, or C) operates, if the Instrument Air Header pressure drops to 8.5 barg at 56-PT-1015 near 56-MD02, a second compressor starts automatically, the third compressor remains offline as a maintenance spare. Cooling water systems for both operating and standby compressors run continuously. Low cooling water pressure prevents compressor motor startup as a safety measure, compressors can be controlled locally or remotely via the Distributed Control System (DCS).

Figure 2.6: Air Compressor Package, 56-MJ01-A/B/C

2.3.2.2 Wet Air Separator, 56-ML02

The air from the compressors flows through the Wet Air Separator, labeled as 56-ML02, where any free water is separated and removed before the air is distributed to both the plant air header and the dryers. The water level in the separator is monitored and indicated by 56-LI-1010, with the data displayed on the Distributed Control System (DCS). Additionally, an electronic water drain is installed on the separator drain line to automatically remove and drain the separated water to the oily water sewer.

Figure 2.7: Wet Air Separator, 56-ML02

2.3.2.3 Air Dryer Package, 56-ML01-A/B

All operations of the Air Dryer Package, designated as 56-ML01-A/B, are controlled locally at the control panel. They are started and stopped locally when the panels are powered.

The status of the dryer, discharge pressures, and dew points are indicated on the Distributed Control System (DCS).

Within each Air Dryer Package, wet air is directed by the switching valves to the in-service dryer. The dry air is then directed to the package outlet, while a portion of it is diverted into the regenerating dryer.

In the regenerating dryer, the air is depressurized to atmospheric pressure and utilized to regenerate the desiccant. After a preset time or based on dew point control, the package shifts dryers.
During a dryer shift, the regenerated dryer is gradually pressurized, the switching valves sequentially shift, and the off-stream tower is depressurized.

2.3.2.4 Instrument Air Receiver, 56-MD02

The pressure indicator 56-PI-1015 monitors the discharge pressure of the Instrument Air Receiver, 56-MD02, to the instrument air header, this pressure serves as the measured variable for controllers 56-PY-1015A/B/C, which control the activation or deactivation of the Air Compressor Packages, 56-MJ01-A/B/C.
The Instrument Air Receiver, 56-MD02, is designed to ensure a sufficient supply of instrument air at normal flow for up to 5 minutes, facilitating a controlled shutdown of the plant in the event of a total air compressor failure.

Additionally, an air trap is installed on the drain line of the Instrument Air Receiver, 56-MD02, to automatically remove any water collected in the receiver.

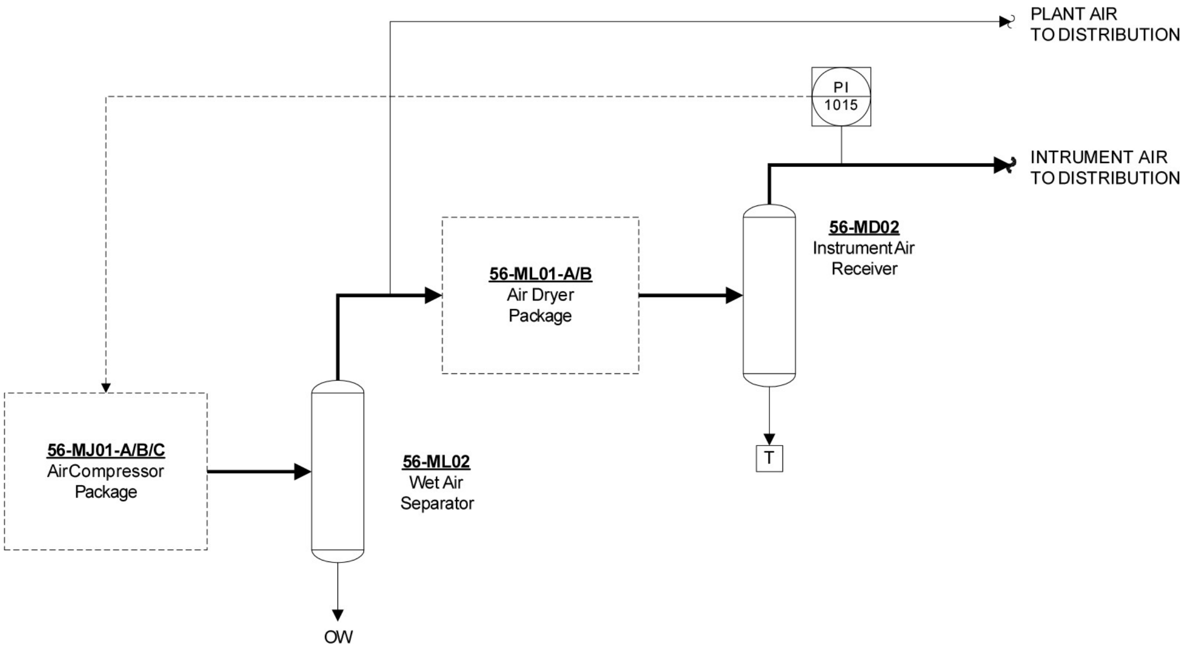

Figure 2.8: Process Flow Diagram

2.4 Systems Working Principle

2.4.1 Current System (Using 5 Valves)

Wet compressed air enters the dryer at the bottom and is directed by non-lubricated switching valves V1 and V2 into the drying tower, the wet air encounters dry desiccant and moisture is transferred from the air to the desiccant.

At the top of the dryer, the dry process air is directed to the outlet of the dryer through check valves, 15% of the dry air is directed into the regenerating tower, where it is depressurized to atmospheric pressure and is used to regenerate the desiccant.

While removing the moisture from the desiccant, the purge air exits the dryer through V3 or V4 to a muffler and is blown out to the atmosphere.

After a preset time (depending on the length of cycle time) the dryer will shift towers.

At tower shift, the regenerating tower is gradually re-pressurized through V5, to make the two tower have the same pressure for shifting.

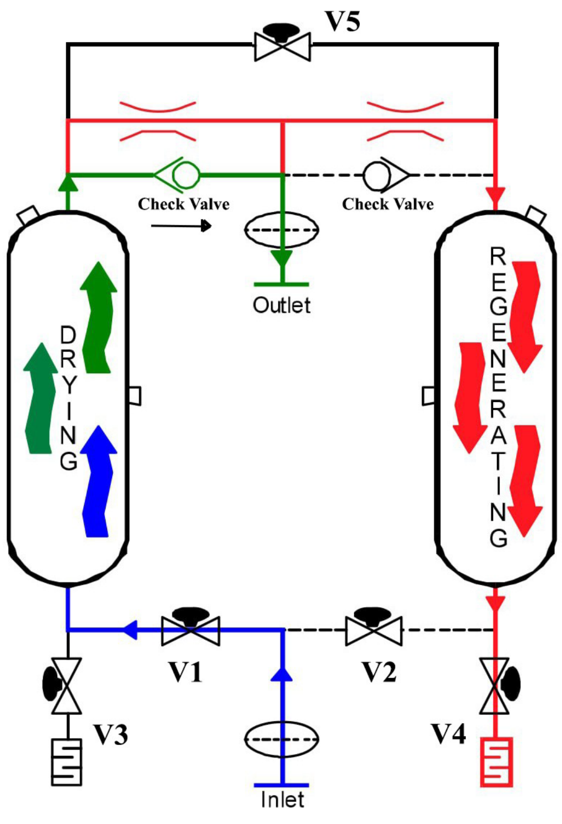

Figure 2.9: Theory of Operation of 5 valves

2.4.1.1 Sequence of Operation

Here is the sequence of operation:

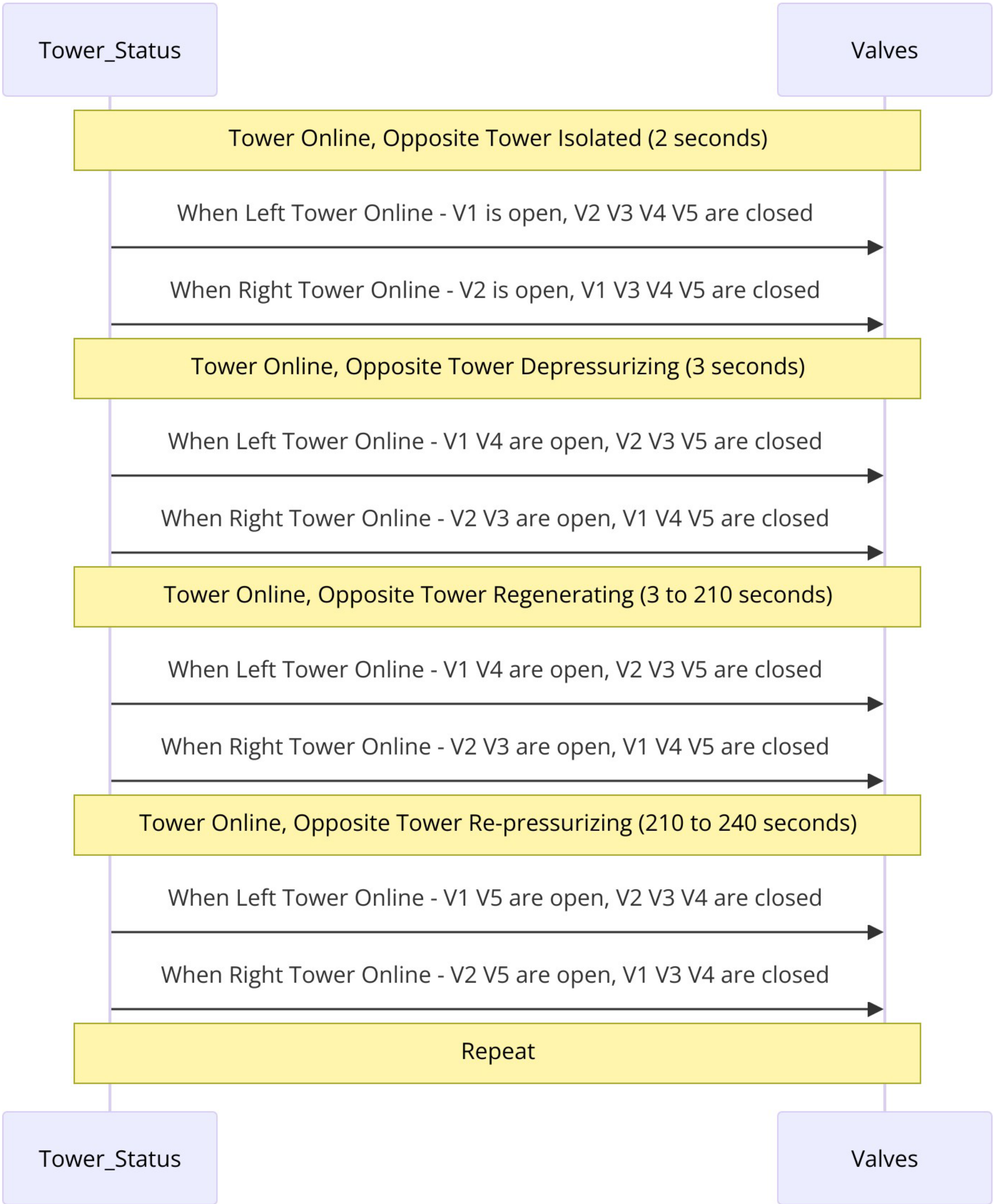

Figure 2.10: Sequence of Operation Of 5 Valves

Note. Purge valve for the tower being re-pressurized is closed to facilitate the process.

2.4.2 Problem Explanation

In the oil and gas industry, air dryers are crucial for maintaining the quality and reliability of compressed air, preventing moisture-related issues that compromise equipment performance and safety.
However, conventional air dryer systems with check valves face significant challenges due to back pressure.
Additionally, cam timers in these systems suffer from mechanical wear and tear, environmental susceptibility, and limited flexibility, leading to inaccuracies and difficulties in adjusting drying sequences.

The back pressure issue with check valves in air dryer systems arises when the pressure on the outlet side of the check valve exceeds the pressure on the inlet side, preventing the valve from closing properly. check valves are designed to allow flow in one direction and prevent backflow, ensuring that air flows from the drying vessel to the outlet and avoiding the flow from the regenerating vessel to the outlet.
However, several factors can cause this back pressure problem:

- **Pressure Imbalance:** During the switching of vessels (from drying to regenerating and vice versa), a temporary pressure imbalance can occur.

- **Valve Malfunction:** Incorrect system design or improper valve selection, where valves are not correctly matched to the system's pressure and flow requirements, can result in insufficient pressure differentials needed for proper valve operation.

- **Contamination:** Particulate matter or moisture can prevent the check valve from sealing properly, causing leakage.

- **Cam Timer Issues:** Cam timers face several issues affecting their reliability, mechanical wear and tear degrade their components, while environmental factors like temperature and humidity impact their precision, additionally, their limited flexibility makes adjusting drying sequences challenging, leading to inaccuracies and difficulties in optimizing processes.

These factors collectively contribute to the back pressure problem, compromising the effectiveness of the air dryer system.

2.4.3 Solution Proposal

The solution enhances air dryer systems by substituting check valves with solenoid valves and adding limit switches, improving control and reliability.

- **Adoption of Solenoid Valves:**

  Replacing conventional check valves with solenoid valves offers a precise solution to back pressure issues in air dryer systems. Solenoid valves provide superior control over airflow, allowing for more accurate regulation and adjustment. This enhanced control eliminates the common back pressure problems associated with traditional check valves. By integrating solenoid technology and increasing the number of solenoid valves, the system can achieve finer control of airflow, leading to improved efficiency and reliability. This solution not only addresses back pressure concerns but also optimizes the overall performance of the air dryer system.

- **Integration of Limit Switches:**

  To further enhance system reliability and monitoring, limit switches have been added to monitor the status of the valves. These switches will provide real-time feedback on valve positions, ensuring that the valves are functioning correctly and aiding in the detection of any operational anomalies. This addition is crucial for maintaining the integrity and efficiency of the air dryer system.

- **Use of PLC Instead of Cam Timer:**

  Transitioning from cam timers to programmable logic controllers (PLCs) provides greater flexibility and precision in controlling the air dryer system. PLCs allow for easier adjustments to timing sequences and can handle complex control algorithms, enhancing overall system performance and reliability.

2.4.4 Proposed System (Using 9 valves)

2.4.4.1 Description of the PFD

The updated process flow diagram illustrates a system featuring an inlet and outlet connected to two vessels, controlled by several valves and equipped with mufflers. In the inlet section, valves V1 and V2 manage the primary flow into the vessels, while V3 and V4 offer additional control or isolation. Mufflers are installed to reduce noise and vibration. In the outlet section, the system includes a main valve, V5 for equalizing the pressure of the vessels, and newly added valves V6, V7, V8, and V9, which replace two previously installed check valves. This modification improves flow control, operational flexibility, and maintenance, optimizing the system's functionality, safety, and efficiency.

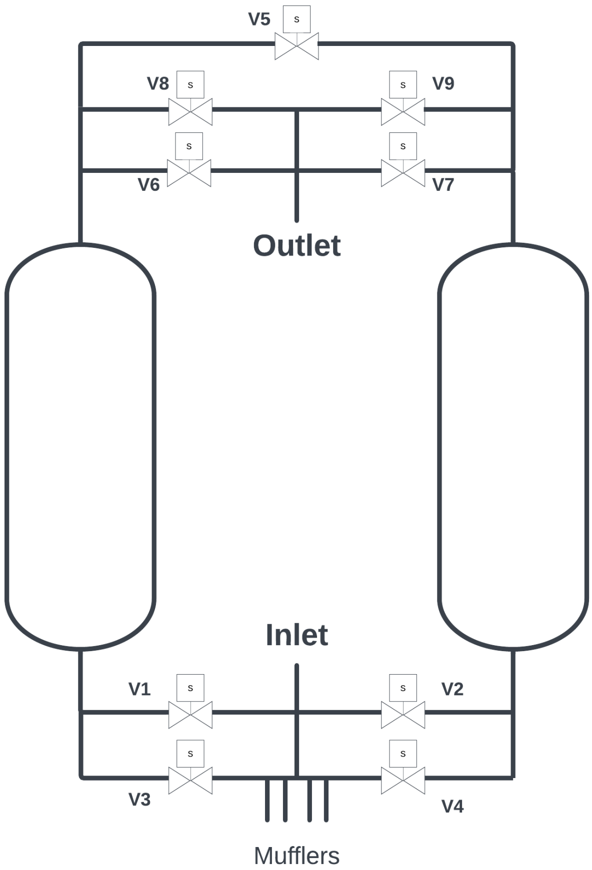

Figure 2.11: Theory of Operation of 9 valves

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2.4.4.2 Sequence of Operation

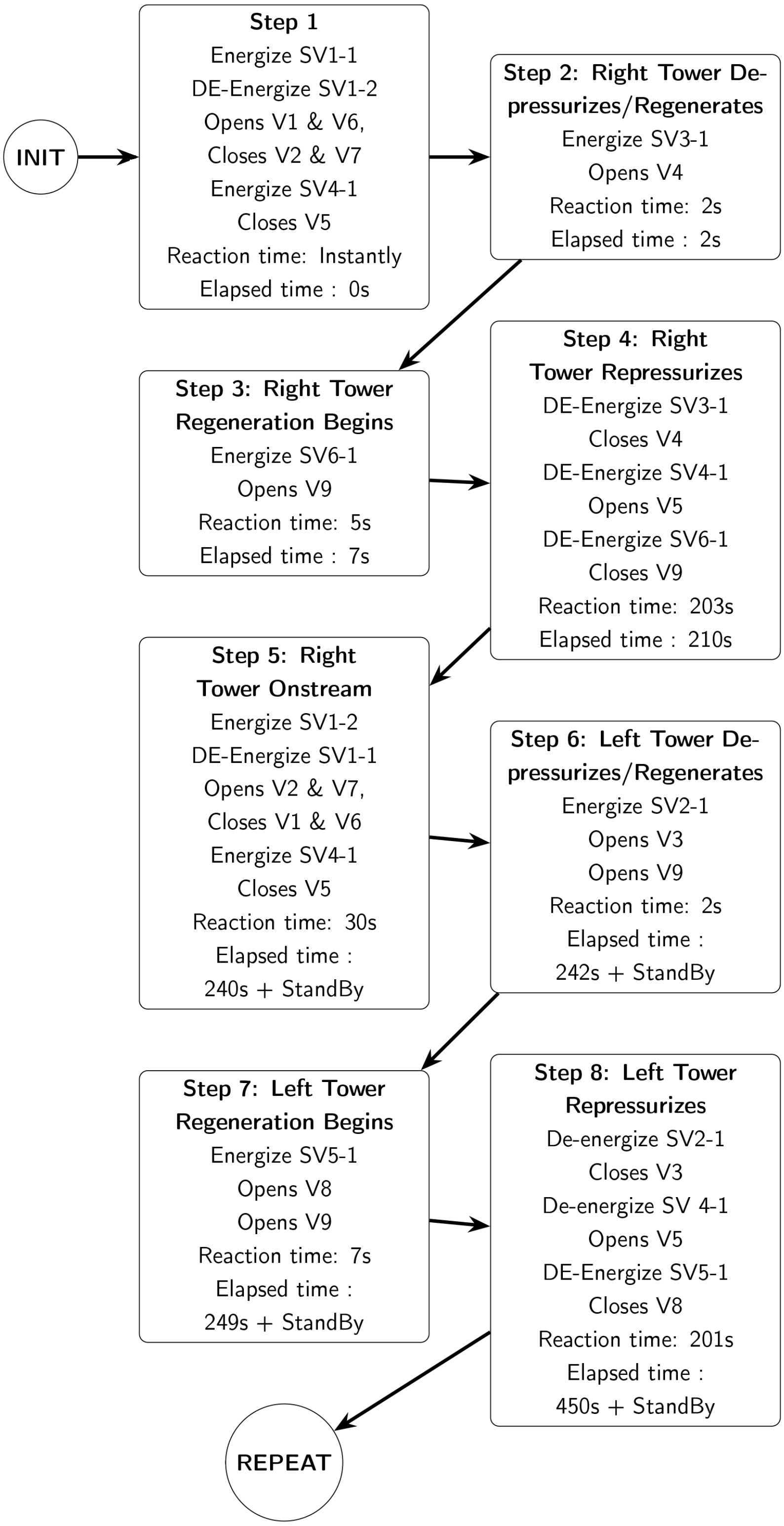

Figure 2.12: Sequence of Operation of 9 valves

2.5 Conclusion

This chapter extensively explores different types of air dryers and their operational functions. It delves into the use of desiccant air dryers in industrial settings, focusing on a practical case study. Initially, challenges were faced with check valve reliability in a desiccant air dryer equipped with five valves and two check valves. However, after optimization efforts, a revised system with nine valves was implemented, effectively resolving check valve issues and improving drying process efficiency and reliability. This real-world example highlights the importance of continuous improvement in industrial practices and the need to address operational challenges through innovative engineering solutions. The insights from this study can lay a solid groundwork for further research in air drying technology, aiding in optimizing industrial processes and enhancing operational effectiveness.

Chapter 3

Control Instruments

3.1 Introduction

Instrumentation is a crucial aspect of industrial processes and manufacturing systems. Instrumentation refers to devices and systems used to measure and monitor various parameters in a process, such as temperature, pressure, flow rate, and chemical composition. These measurements are essential for controlling and optimizing the process to achieve the desired performance and quality.

Control instruments are the foundation of the interdisciplinary discipline of Instrumentation and Control (I & C) engineering, which covers several scientific domains. These instruments cover the spectrum from straightforward measurement tools to complex control loops including transducers, sensors, and actuators and valves as final control elements. They act as the brains behind power plants, industrial complexes, and other operations, having a direct impact on the productivity, profitability, and caliber of the final good or service.

3.2 Control Instruments

3.2.1 Sensors

A sensor is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena.

The output is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing. The uses of sensors have expanded beyond the traditional fields of temperature, pressure, or flow measurement, for example, to MARG sensors. Moreover, analog sensors such as potentiometers and force-sensing resistors are still widely used.

The types of instruments used in the industry include indicators, switches, and transmitters:

- **Indicators:** are non-signaling devices placed on-site to display the value of a measured quantity for various interventions such as calibration.
- **Switches:** provide a binary signal to open and close circuits based on process conditions.
- **Transmitters:** convert the signal from a sensor into a standard signal, typically 4-20 mA, and connect the sensor to the control system.

The 4-20 mA technology is widely used in industrial automation for transmitting measurement or control signals over electrical cables. It is considered safe for the operation of control and measurement circuits, as a 4 mA current is the minimum required for proper equipment function, and a 20 mA current is the maximum the equipment can handle without damage.

3.2.1.1 Pressure Sensor

Pressure is a fundamental measure of the force exerted by a substance on a surface, defined as the force per unit area. Pressure can be expressed in units such as pascals (Pa), pounds per square inch (psi), or bar.

Local Indicator:

A local indicator is a device that displays the pressure of a system at the location where it's installed. It gives you a quick readout of the pressure without having to reference a remote gauge or instrument.

Pressure gauge:

A pressure gauge measures the pressure of a fluid in a closed system. It typically contains a U-tube filled with liquid like mercury, connected to the fluid being measured. As pressure changes, the liquid in the U-tube moves and the measurement can be read from a scale on the gauge.

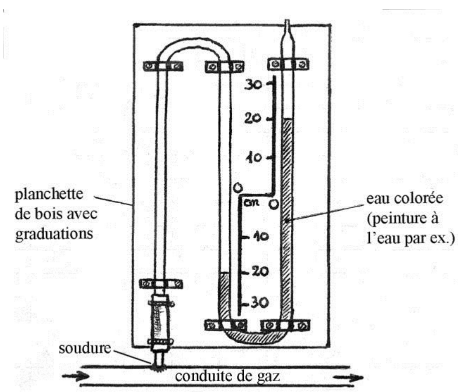

Figure 3.1: Pressure gauge

Bourdon tube:

Bourdon tube pressure gauges are widely employed in- struments for measuring the pressure of fluids in closed systems. They rely on a C-shaped tube, which deforms in response to fluid pressure. When the pressure in- creases, the Bourdon tube straightens, causing it to move. This movement is transmitted via a lever mech- anism connected to a needle, which then indicates the pressure on a graduated scale. This design allows for accurate and reliable measurement of pressure across various applications and industries.

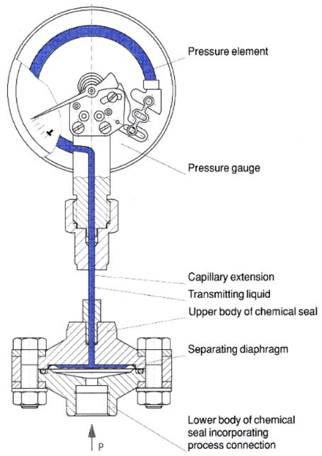

Figure 3.2: Bourdon tube

Pressure switch:

A pressure switch is a crucial electrical component that controls equipment operation in response to pressure changes, ensuring system integrity, particularly in vacuum applications. Serving as safety mechanisms, these switches prevent equipment damage and promote efficient operation. They come in various types, including mechanical and electronic; electronic switches use sensors to detect pressure changes, while mechanical ones use springs or diaphragms. Differential pressure switches, on the other hand, sense pressure differences between two points and activate accordingly. Accurate pressure measurement is vital, as the switch continuously monitors pressure levels and triggers equipment on or off based on application needs.

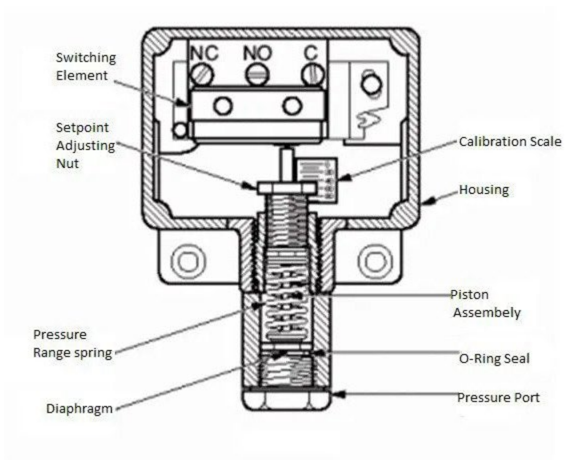

Figure 3.3: Pressure switch

Pressure Transmitter:

A pressure transmitter converts pressure into an analog electrical signal, commonly using strain gauges or diaphragm-based sensors. In this design, strain gauges bonded to a transducer membrane are arranged in a Wheatstone bridge configuration. Pressure changes deform the strain gauges, altering their electrical resistance and generating a corresponding electrical signal.

The diaphragm in a pressure transmitter converts fluid pressure into mechanical force, made of flexible metal or plastic, it is fixed around its perimeter, when fluid pressure varies, the diaphragm deforms, creating mechanical displacement, a displacement sensor then measures this movement and converts it into an electrical signal, accurately reflecting pressure changes.

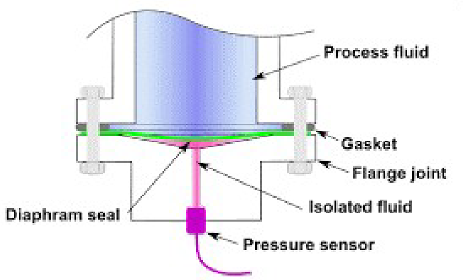

Figure 3.4: Pressure transmitter

Pressure difference measurement:

Pressure difference, or Delta P, is the variation in pressure between two points within a system, measured in units like pascals (Pa). It is essential in industrial and engineering applications for analyzing fluid dynamics, system performance, and process efficiency. Delta P measurements are used to assess pressure drops in pipes or systems, which helps optimize system performance and energy efficiency, and to monitor the purity state of filters, additionally, these measurements regulate flow rates in pipelines and industrial processes, ensuring optimal performance through precise valve adjustments.

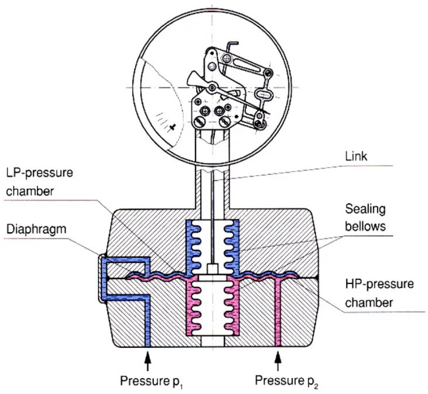

Figure 3.5: Pressure difference measurement

3.2.1.2 Dew Point Sensor

Humidity is a measure of the amount of water vapor present in the air. It can be expressed in several ways, but the most common is relative humidity, which indicates how much moisture the air contains compared to the maximum amount it can hold at a given temperature. For example, if the relative humidity is 50%, the air is holding half of the moisture it could potentially hold at that temperature. High humidity makes the air feel warmer and can cause discomfort, while low humidity can make the air feel cooler and dry out skin and respiratory passages [2].
There are two primary measurements of humidity:

- Absolute Humidity: Expressed as either mass of water vapor per volume of moist air (in grams per cubic meter) or as mass of water vapor per mass of dry air (usually in grams per kilogram).
- Relative Humidity: Often expressed as a percentage, it indicates a present state of absolute humidity relative to a maximum humidity given the same temperature.

The dew point is the temperature at which air becomes saturated with moisture and water vapor begins to condense into liquid water. This means that the air has reached 100% relative humidity at that specific temperature. The dew point is a direct measure of the moisture content in the air; the higher the dew point, the more moisture the air contains.

The dew point sensor:

The dew point sensor is a device that operates on the principle of impedance, it's composed of several layers, including two electrodes on either side of an absorbent layer, as gas passes over the sensor, it absorbs water vapor onto a porous hygroscopic dielectric area between conductive layers built atop a base ceramic substrate, this dielectric area is crucial because it's where the water molecules are absorbed, and it's this absorption that changes the dielectric constant (K) which results in a change in the sensor's impedance.

Impedance is a measure of how much a circuit resists the flow of electric current, and in this case, it's used to detect the presence of water vapor [3].

The sensor works by detecting the moisture content in the air and converting it into a temperature reading, this information is then used to determine the dew point temperature [4].

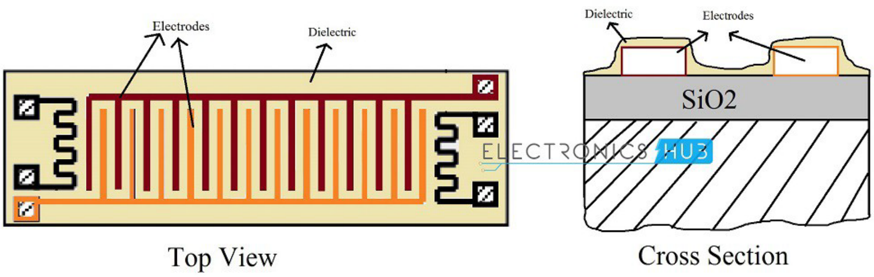

Figure 3.6: Dew Point Sensor Working Principle

Sensor Installation

To ensure accurate moisture content measurements in compressed air systems, proper installation of a dew point sensor is essential:

Position the sensor downstream of the air dryer to gauge the air quality post-drying and assess the dryer's performance.

Mount the sensor vertically to prevent particulates or moisture from accumulating on the sensor element, which could distort readings.

Avoid installing the sensor in pipe bends, near valves, or fittings, as these can disrupt airflow and affect accuracy.

Align the sensor with the airflow direction, as indicated by arrows on the housing.

Lastly, choose a location that allows easy access for maintenance and calibration.

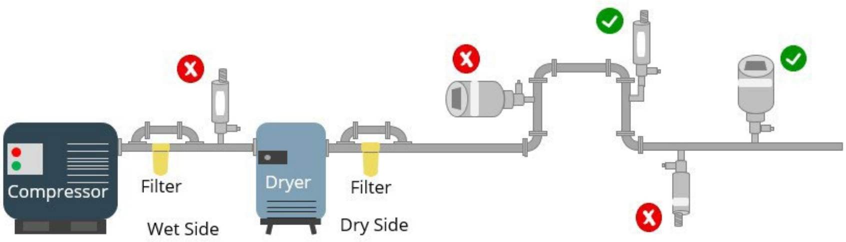

Figure 3.7: Sensor Installation

3.2.2 Valves

Valves are mechanical devices engineered to regulate the flow, pressure, or direction of fluids, whether liquid or gas, within piping or conduit systems, they serve as indispensable components in numerous industrial setups, where precise fluid control is essential for tasks such as temperature regulation, liquid distribution, and ensuring process safety. These devices play a pivotal role in maintaining the integrity and efficiency of fluid dynamics within complex industrial networks, their diverse designs and functionalities cater to a wide range of applications, from fine-tuning flow rates to redirecting fluid streams with utmost precision.

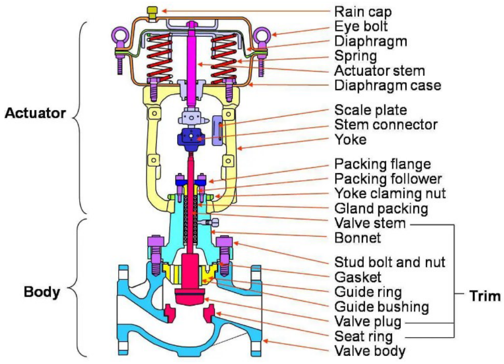

Figure 3.8: Valve Components

3.2.2.1 Components of a valve

A - Actuators:

Valves are often equipped with actuators—manual, electric, pneumatic, or hydraulic—that enable them to open, close, or regulate fluid flow in response to control signals, actuators enhance valve functionality and automation, allowing dynamic adjustments to operational changes. Whether through manual handles, precise electrical movements, rapid pneumatic responses, or robust hydraulic force, actuators ensure swift and accurate valve operation.

Single-Acting and Double-Acting:

- **Single-acting actuator:** In a single-acting actuator system, the control valve is operated by compressed air from the positioner on one side, either for opening or closing, while a spring or membrane actuates the other side.
- **Double-acting actuator:** A double-acting actuator uses compressed air from the control valve positioner on both the opening and closing sides, enabling bidirectional operation for both extending and retracting movements.

The choice between single and double-acting actuators depends on the application's requirements, single-acting actuators are ideal for tasks requiring force in one direction and are well-suited for lighter duties where bidirectional movement isn't necessary, in contrast, double-acting actuators excel in applications that demand speed and power for quick and strong bidirectional movements.

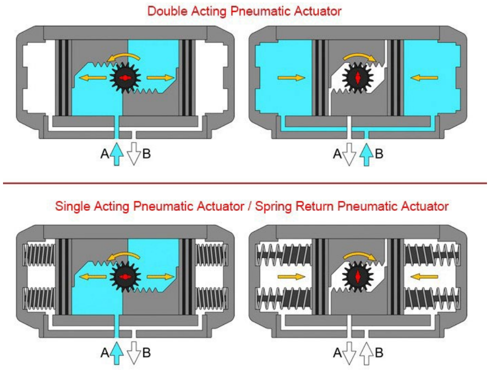

Figure 3.9: Single-Acting and Double-Acting

Direct-Acting And Reverse-Acting:

Direct-acting and reverse-acting control valves are essential components in control systems, facilitating the regulation of fluid flow or pressure.

- **Direct-Acting:** The circuit is open by default and requires action to close it.
- **Reverse-Acting** The circuit is closed by default and requires action to open it.

Choosing between direct-acting and reverse-acting valves depends on safety needs and how the system should behave during failures. If it's crucial to keep fluid flowing during a problem, direct-acting valves that are Normally Open are best, but if stopping fluid flow quickly is more important, reverse-acting valves set as Normally Closed are the way to go.

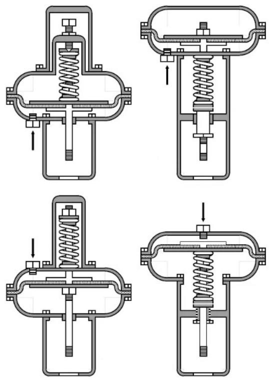

Figure 3.10: Direct-acting and reverse-acting

Manual actuators:

Manual actuators are basic tools used in industrial settings to open, close, or adjust valves by hand, they're handy when operators need direct control over valves without relying on automatic or electrical systems, whether it's tweaking flow rates or responding

to emergencies.
manual actuators provide a straightforward way for operators to manage valve operations, ensuring smooth functioning of industrial systems.

B - Body:

Valve bodies are essential components that regulate fluid flow within a pipeline, they house internal parts like the stem, disc, and seat, ensuring proper operation and sealing, valve bodies maintain control over fluid flow, pressure, and temperature in various industrial systems [5].

B.1 Rotary Valves:

Rotary valves, also known as rotary feeders or airlocks, are mechanical devices used in bulk handling and pneumatic conveying industries to regulate solid bulk material flow between components with different pressures, they feature a rotating cylindrical rotor with pockets, housed in a tightly fitting casing to minimize air leakage.

As the rotor turns, material is picked up from the inlet, carried in the pockets, and discharged at the outlet, maintaining an airlock to prevent backflow.

B.2 Linear Valves:

Linear valves, also known as globe valves, are essential in fluid handling systems requiring precise flow regulation, they operate via a linear motion of the valve stem, adjusting flow by moving a disc or plug against a stationary ring seat, this design ensures a tight seal and fine flow control, making them ideal for managing flow rate and pressure.

B.3 Miscellaneous Valves

B.3.1 Solenoid Valve:

A solenoid valve is an electromechanically operated valve that controls the flow of liquids or gases, it consists of a solenoid coil, which generates a magnetic field when energized, moving a plunger or armature to open or close an orifice within the valve body, this mechanism allows for precise control of fluid flow.

Solenoid valves come in various types, including direct-acting and pilot-operated, and can have configurations like two-way, three-way, or four-way, catering to different applications, these valves offer advantages such as precision control, rapid switching, and fewer moving parts, making them essential components in modern automation and fluid management systems [6] [7].

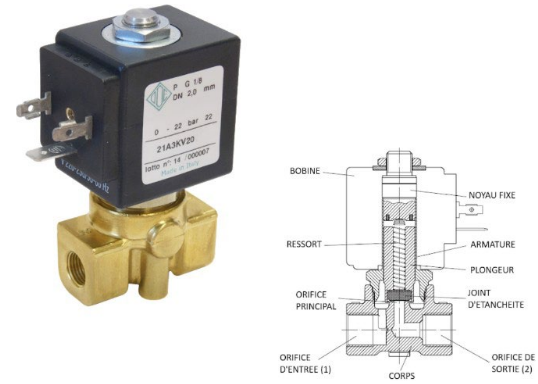

Figure 3.11: Solenoid Valve

Solenoid Valve 4-way,2- position Configuration:

A 4-way, 2-position solenoid valve is a directional control valve used in pneumatic and hydraulic systems to manage fluid flow to actuators, it has four ports: pressure (P), two actuator ports (A and B), and tank or exhaust (T), when the solenoid is energized, it shifts the internal spool to connect P to A and B to T, allowing fluid to flow to one side of the actuator while exhausting the other. When de-energized, the spool returns, connecting P to B and A to T, reversing the flow direction, this enables the actuator to extend and retract or change rotational direction, making it essential for controlling mechanical movements in automated systems. [6].

B.3.2 Check Valves:

A check valve, also known as a one-way or non-return valve, is a mechanical device used in pipeline systems to prevent backflow, it allows fluid to flow only in the forward direction, operating on the principle of differential pressure: the valve opens when upstream pressure exceeds downstream pressure and closes when downstream pressure is higher, preventing reverse flow, closure can be achieved by the weight of the check mechanism, a spring, or a combination of both, a primary application of check valves is at pump outlets to protect equipment from flow reversal. [8].

Working principle:

A check valve operates on the principle of differential pressure, requiring a minimum upstream pressure, known as cracking pressure, to open, this cracking pressure varies with the valve's design and size, when upstream pressure reaches the cracking pressure, the valve opens, allowing fluid flow, if upstream pressure drops below the cracking pressure, back pressure causes the valve to close, preventing reverse flow, the closing mechanism can be assisted by a spring or gravity, depending on the valve design.

Since check valves function in one direction, manufacturers mark the flow direction with an arrow on the valve body.

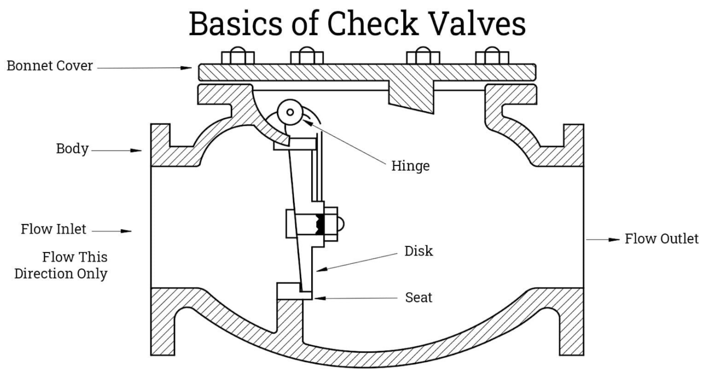

Figure 3.12: Basics of check valves

B.3.3 Bleed Valve:

A bleed valve is a valve that typically utilizes a threaded bleed screw to open or close, generally, these valves vent pressure or release media from within a system, this is often necessary before starting maintenance work on a line that contains pressurized liquids or gasses, at other times, system operators use bleed valves to drain off media for analysis or while calibrating other control equipment.

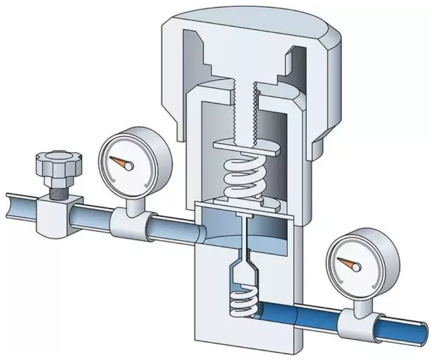

Figure 3.13: Bleed Valve

3.3 Cam Timers

Cam timers are essential components, responsible for controlling the timing and sequencing of various operations to ensure efficient and effective moisture removal.
These timers can be either mechanical or electromechanical:

3.3.1 Mechanical Cam Timers

Operate using a camshaft with multiple cams, each designed with specific profiles corresponding to the timing and sequencing requirements, the camshaft rotates at a pre-determined speed, driven by a motor or clockwork mechanism, as it rotates, the cams actuate switches or levers at specific intervals, controlling components such as heaters, fans, or valves.
The shape and position of the cams determine the precise timing and duration of each operation.

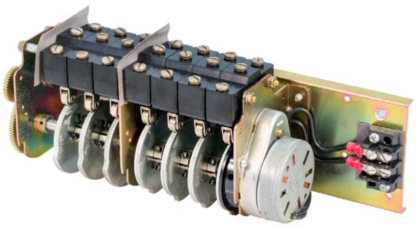

Figure 3.14: Mechanical Cam Timer

3.3.2 Electromechanical Cam Timers

Integrate mechanical camshafts with electrical control systems for enhanced precision and flexibility, a motor drives the camshaft, controlled by an electronic circuit for precise speed adjustments, instead of purely mechanical switches, these timers use electronic relays or sensors actuated by the cams to control electrical circuits powering the air dryer components, many electromechanical timers are programmable, allowing users to adjust timing and sequences without physical modifications.
They can also include feedback mechanisms to monitor performance and optimize timing in real-time.

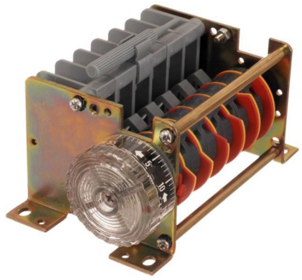

Figure 3.15: Electromechanical Cam Timer

3.4 Air Treatment Components

3.4.1 Filter

Coalescing Filter:

A coalescer is a piece of industrial equipment used in the oil and gas processing and petrochemical industries to perform coalescence.

Coalescence is the process of causing an agglomeration (coming together) of liquid aerosols to form larger droplets which are large enough to be drained away gravitationally, it operates in reverse to an emulsifier which creates emulsions.

A coalescer may be used on its own, or as a component of a larger separation unit. [9].

Working principle:

A wet gas stream, laden with water droplets, enters the coalescer through its inlet, inside, a network of baffle walls or screens orchestrates the separation.

As the gas flows through, the filter's baffles guide the gas molecules, allowing them to diffuse through the filter element while coaxing the heavier water molecules to gather and coalesce, these water droplets, now united and denser, descend to the bottom of the tank, drawn by gravity, where they are collected and drained away.

Meanwhile, the gas emerges from the coalescer's outlet port rejuvenated, stripped of its watery burden, this filtration ballet, choreographed by the physical properties of the substances involved, ensures that the gas emerges purified and the water is efficiently separated for disposal or further treatment [10].

Particulate Filter:

A particulate filter is a filtration device designed to trap and remove solid particles,

such as dust, dirt, rust, and other debris, from a stream of compressed air, it's typically a cylindrical or cartridge-shaped device made of materials like polyester, or other porous materials capable of capturing particles of varying sizes.
The working principle of a particulate filter involves the passage of compressed air through a porous medium, where solid particles are trapped while the cleaned air continues its flow.

3.4.2 Muffler

A silencer in an air dryer is typically a component designed to reduce the noise produced by the air dryer during operation, it's usually integrated into the exhaust system of the dryer to dampen the sound of air rushing out.
The silencer consists of several baffles or chambers that the air passes through before exiting the dryer, these chambers are constructed in a way that disrupts and absorbs the sound waves generated by the airflow, effectively reducing the overall noise level.
Additionally, some silencers may incorporate sound-absorbing materials such as foam or fiberglass within the chambers to further attenuate the noise. The design and placement of the silencer are crucial to ensure optimal noise reduction without compromising the efficiency of the air dryer.

Overall, a silencer in an air dryer plays a vital role in creating a quieter operating environment, particularly in industrial settings where air dryers are often used.

3.5 Conclusion

In conclusion, the integration of advanced instrumentation with air dryer systems represents a pivotal advancement in ensuring optimal air quality across various industries. By leveraging sophisticated monitoring and control mechanisms, these integrated systems not only enhance operational efficiency but also mitigate potential risks associated with moisture contamination. Through real-time data acquisition and analysis, operators can proactively address issues, minimize downtime, and extend the lifespan of critical equipment.

Chapter 4

Programming

4.1 Software Description

4.1.1 Programmable Logic Controller

Programmable Logic Controllers (PLCs) are specialized industrial computers designed to control and monitor machinery through customized programming, they come in various sizes and designs, ranging from compact models that fit in the hand to large units requiring heavy-duty mounting racks.

Some PLCs feature basic modularity with essential I/O capabilities, which can be expanded with additional backplanes and specialized modules such as analog I/O, communication modules, or display modules, catering to diverse industrial requirements. [11].

4.1.2 PLC Timeline

The history of Programmable Logic Controllers (PLCs) spans several decades, beginning in 1968 with the development of the first programmable controller concept. The initial hardware CPU controller was introduced in 1969, featuring logic instructions, 1 KB of memory, and 128 I/O points, over time, PLCs evolved to incorporate multiple processors, remote I/O systems, and microprocessors.

By the 1980s, PLCs became more affordable and widely adopted across various industries. The 1990s marked a significant milestone with the introduction of the IEC 61131-3 Standard, which standardized PLC software programming. Since then, PLCs have continued to advance in power, speed, and memory, solidifying their role in modern industrial automation and control systems. [12].

4.2 PLC Components Overview:

4.2.1 Types of PLCs

4.2.1.1 Compact PLC:

A Compact PLC is a type of Programmable Logic Controller with integrated input and output sections built into the microcontroller. The types and numbers of inputs and outputs are fixed by the manufacturer and cannot be expanded. Compact PLCs are designed for simplicity and ease of use in small to medium-sized automation tasks.

Figure 4.1: OMRON Compact PLC

4.2.1.2 Modular PLC:

A Modular PLC is a type of Programmable Logic Controller that features a flexible design with separate modules for input, output, and processing. These modules can be easily added, removed, or replaced, allowing for customization and scalability to meet varying industrial automation needs. Modular PLCs are ideal for complex applications requiring frequent updates or expansions.

Figure 4.2: OPTO22 Modular PLC

4.2.2 Hardware components

The hardware components of a PLC include the following: Processor, Power Supply, Input/Output Modules, a Programming Device, Communication modules, and Redundancy.

1. **Power Supply**

   The Power Supply is connected to an AC main for the supply voltage, it provides a DC voltage output used to power all other modules associated with the PLC, however, it does not supply power to field devices.

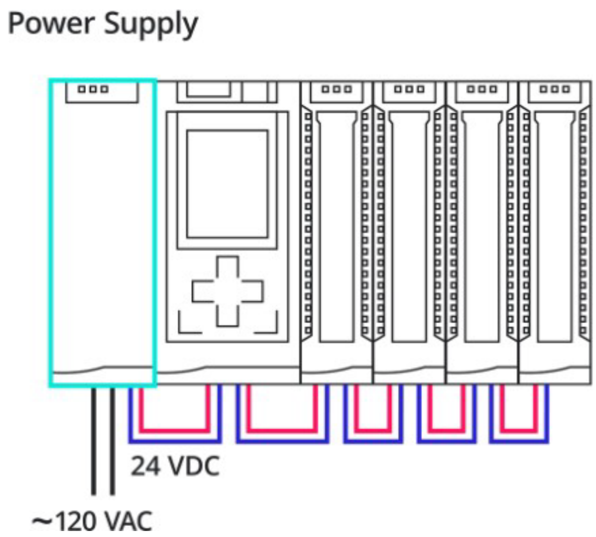

Figure 4.3: Power Supply

2. **Input/Output Modules (I/O Modules)**

   The input/output modules are connected to digital or analog field devices, input field devices include switches, encoders, and transmitters, while typical output field devices are relays, lamps, and proportional valves.

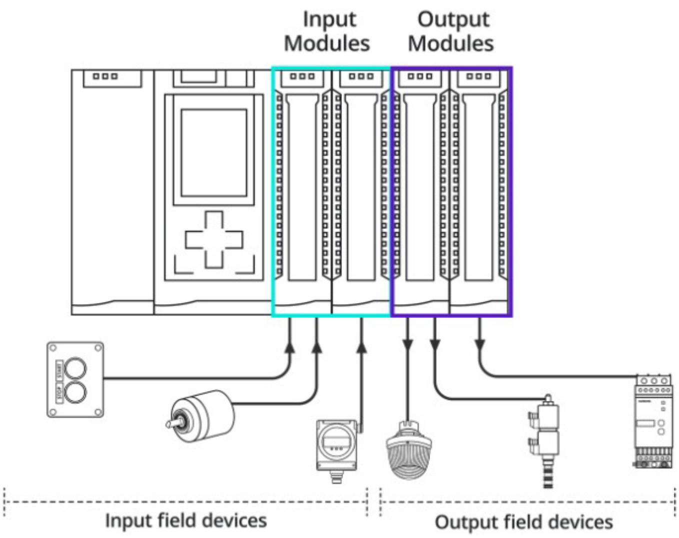

Figure 4.4: I/O Modules

3. **Processor**

   The Processor consists of the CPU (central processing unit) and memory, it makes decisions needed to observe and operate the field devices connected to the Input/Output modules, these decisions are based on a user-created program saved in memory, the memory also stores data representing the condition of all input field devices and contains the data telling the output field devices what to do.

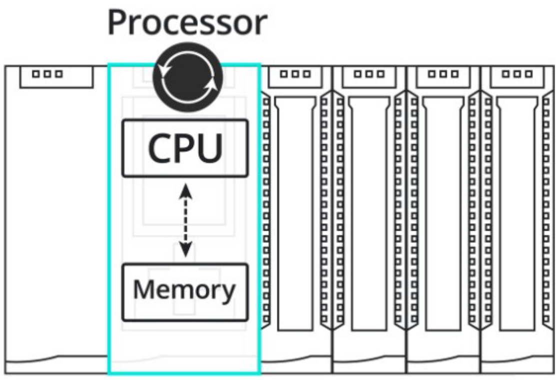

Figure 4.5: Processor

4. Programming Device

The programming device in today's industrial applications is usually a laptop or desktop computer that facilitates the creation of decision-making programs destined for the PLC. Examples of the programming software residing on the laptop are Studio 5000 for Allen Bradley PLCs or SIMATIC Step 7 for Siemens PLCs.

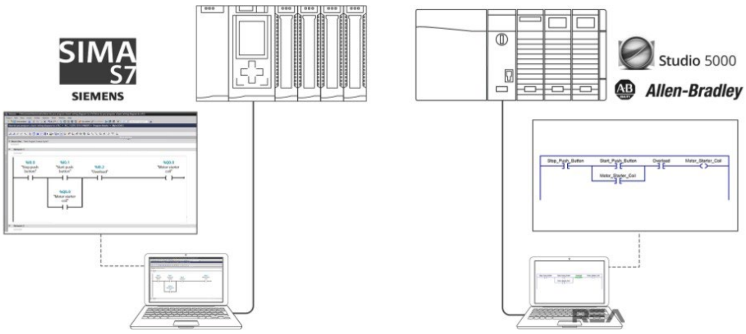

Figure 4.6: Programming Device

5. **Communications modules:**

   Communications modules are available for a wide range of industry-standard communication network connections, these allow digital data transfer between PLCs and to other systems within the facility, some PLCs have communications capability built into the processor, rather than using separate modules.
   The most commonly used modules are Modbus communication cards or Serial communication.

6. **Redundancy:**

   Many PLCs are capable of being configured for redundant operation in which one processor backs up another, this arrangement often requires the addition of a redundancy module, which provides status confirmation and control assertion between processors, in addition, signal wiring to redundant racks is an option [13].

4.2.3 Programming Languages

The International Electrotechnical Commission (IEC) has standardized several PLC programming languages under the IEC 61131-3 standard.
The most common ones include:

4.2.3.1 Ladder Diagram (LD):

Ladder Diagram, originally modeled from relay logic, uses internal logic to replace physical devices like switches and relays, except those needing an electrical signal. It features horizontal rungs and two vertical rails representing electrical connections, this format allows programming of input conditions to affect output conditions, both logical and physical.

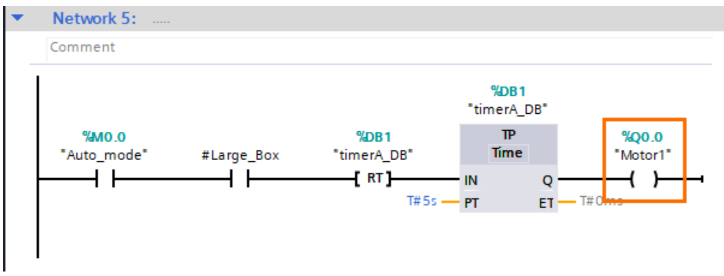

Figure 4.7: Ladder Diagram

4.2.3.2 Function Block Diagram (FBD):

The Function Block Diagram (FBD) is a graphical programming language that describes functions between inputs and outputs connected by lines, originally developed for common, repeatable tasks like counters, timers, and PID loops, FBD allows you to program blocks onto sheets, the PLC then scans these sheets in numerical order or based on programmed connections between the blocks.

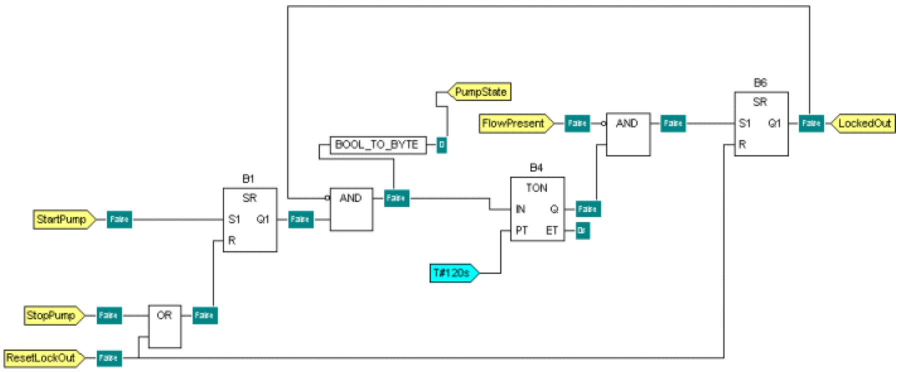

Figure 4.8: Function Block Diagram

4.2.3.3 Structured Text (ST)

Structured Text (ST) is a textual programming language similar to Basic, Pascal, and C, it is powerful for executing complex tasks using algorithms and mathematical functions, as well as repetitive tasks. The code consists of statements separated by semicolons, which modify inputs, outputs, or variables, ST uses functions like FOR, WHILE, IF, ELSE, ELSEIF, and CASE, requiring each line of code to be written out.

```
IF #start = 1 THEN
    //comment
    "Max_nr" := #Array[0];
    FOR #i := 1 TO 10 DO
        // Statement section FOR
        IF #Array[#i] > "Max_nr" THEN
            "Max_nr" := #Array[#i];
        END_IF;
    END_FOR;
END_IF;

```

Figure 4.9: Structured Text

4.2.3.4 Sequential Function Charts (SFC):

Sequential Function Charts (SFC) use steps and transitions to achieve desired outcomes, steps perform major functions in the program, triggered by timing, process phases, or equipment states. Transitions move the program from one step to another based on true or false conditions, unlike traditional flowcharts, SFCs can have multiple paths, using branches to initiate several steps simultaneously.

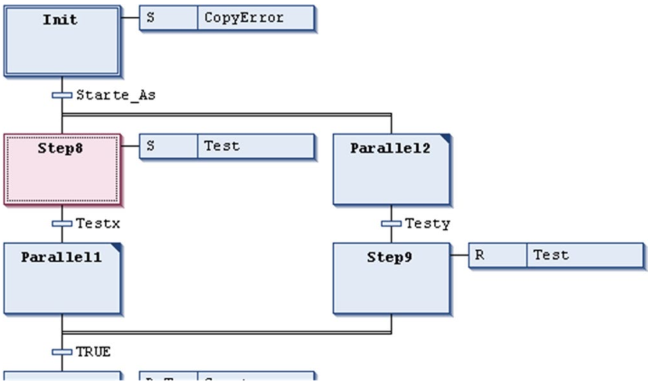

Figure 4.10: Sequential Function Charts

4.2.3.5 Instruction List (IL):

The Instruction List (IL) is a textual programming language resembling Assembly Language, it uses mnemonic codes like LD (Load), AND, and OR. Each instruction is on a new line, with optional comments at the end of the line [14] [15].

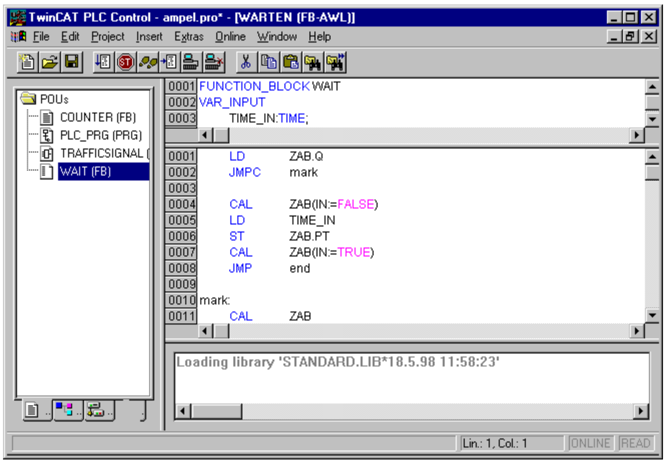

Figure 4.11: Instruction List

4.2.4 PLC Working Principle

1. Detecting Input Device States

PLC operation begins by detecting the state of input devices connected to it. There are two types of data inputs:

- **Discrete Inputs:** These inputs have two states, such as on/off, 1/0, or open/closed, examples include push-button switches or valve states.
- **Analog Inputs:** These inputs have a range of values rather than a simple on/off state, examples include temperature sensors, pressure sensors, CO_2 sensors, and weight scales.

2. Executing Program Instructions

After detecting input states, the PLC executes program instructions based on the input received.

3. Operating Output Devices

Once program instructions are executed, the PLC operates all output devices connected to it, these devices may include alarms, indicator lights, valves, and visual display outputs [16].

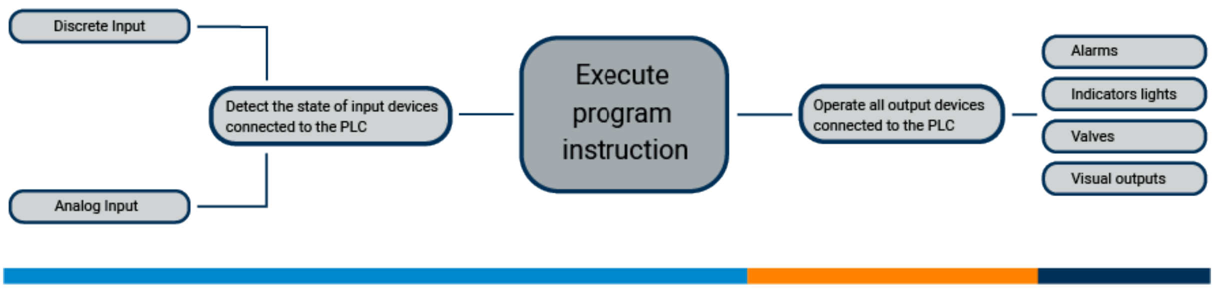

Figure 4.12: Working Principle of a PLC

4.3 Triconex: Flagship Schneider PLC

4.3.1 Introduction to Triconex

Triconex is a specialized PLC designed for high-reliability applications, particularly in safety-critical environments, its robust architecture and fault-tolerant features make it suitable for industries such as oil and gas, nuclear power, chemical processing, and transportation.

4.3.2 Triple Modular Redundancy (TMR)

The Triconex PLC, specifically designed for safety and critical control applications, employs a Triple Modular Redundancy (TMR) architecture to ensure fault tolerance and provide error-free, uninterrupted control in the presence of failures. This architecture is based on the principle of safety and high plant availability, which identifies and compensates for failed control system elements and allows on-line replacement while continuing uninterrupted process operation.

The TMR system consists of three identical system legs (except for the Power Modules which are dual redundant), each independently executing the control program in parallel with the other two legs. Each leg is isolated from the others, ensuring that no single-point failure in any leg can pass to another. If a hardware failure occurs in one leg, the faulty leg is overridden by the other legs, and the system reconfigures itself to full TMR operation.

4.3.3 Triconex Voting Methods

- **2oo3 Voting:**

  In 2/3 voting, there are three redundant components or voters. The system will take action based on the majority decision of these voters. If at least two out of the three voters agree on a particular action or state, that action will be taken. This setup ensures a certain level of fault tolerance; even if one voter fails or provides incorrect information, the system can still make the correct decision based on the agreement of the other two.

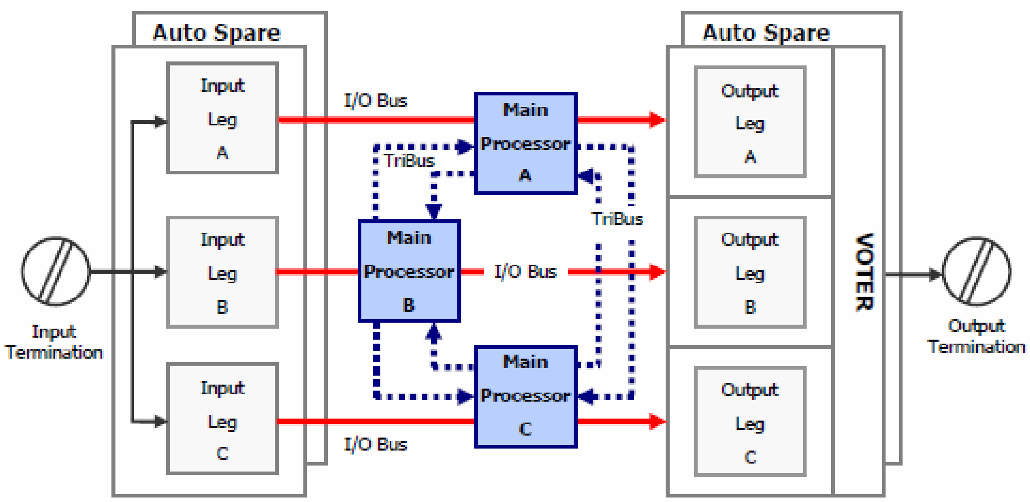

Figure 4.13: 2OO3 Voting Method

- **Median:**

  In median voting, the system calculates the median value from the inputs provided by the redundant components. The median is the middle value when all the values are arranged in ascending order. If there are an odd number of inputs, the median is the middle value; if there are an even number, it's the average of the two middle values. The system then takes action based on this median value. This method is useful for filtering out outliers or erroneous readings from individual components.

- **Mean:**

  Mean voting involves calculating the arithmetic mean or average of the inputs provided by the redundant components. The system then takes action based on this mean value. While this method also considers inputs from all components, it might be more sensitive to outliers compared to median voting. However, it can be simpler to compute, especially when dealing with a large number of redundant components.

4.3.3.1 Fault Tolerance

Triconex employs several fault-tolerant mechanisms:

- **Diverse Processing:**

  The three controllers execute the same logic using different hardware components. This diversity minimizes the risk of common-mode failures affecting all controllers simultaneously.

- **Continuous Self-Checking:**

  Triconex continuously monitors its own health. If a fault is detected (e.g., memory corruption or processor failure), the faulty component is isolated, and the system continues to operate with the remaining healthy controllers.

- **Hot Standby:**

  In case of a controller failure, the hot standby controller seamlessly takes over without disrupting the process. This ensures uninterrupted operation even during maintenance or component replacement.

4.4 Program Overview

The system explained here controls how a desiccant air dryer with nine valves operates, controlled by solenoids, it integrates a suite of monitoring capabilities, including the surveillance of dew point, differential pressure across filters, and overall system working conditions.

These monitoring functions, coupled with sophisticated control logic, enable the system to respond dynamically to changing conditions, preemptively addressing issues before they escalate into critical failures.

4.4.1 System Architecture

The control system governs the operation of a desiccant air dryer featuring 9 valves, each controlled by 7 solenoids. When energized, the solenoids operate as follows:

- **SV1-1:** Opens V1 & V6, Closes V2 & V7.
- **SV1-2:** Opens V2 & V7, Closes V1 & V6.
- **SV2:** Opens V3.
- **SV3:** Opens V4.
- **SV4:** Closes V5.
- **SV5:** Opens V8.
- **SV6:** Opens V9.

Among these valves, V5 is normally open, while the rest are normally closed.
In addition to valve control, the system integrates a suite of monitoring capabilities to ensure optimal performance and safety:

- **Limit Switches:** Strategically placed limit switches provide additional safety measures, triggering alarms in case of any irregularities or malfunctions.
- **Pressure Sensors:**

- **PT1:** Measures the pressure in the left tower.
- **PT2:** Measures the pressure in the right tower.
- **PT3:** Monitors the overall system pressure.
- **DPT1:** Monitors the differential pressure for the pre-filter.
- **DPT2:** Monitors the differential pressure for the after-filter.

- **Dew Point Sensor:** Measures the dew point value, facilitating the switching of towers for efficient drying operation.

This comprehensive setup ensures effective control over the air drying process, enabling the system to maintain optimal conditions while promptly detecting and responding to any abnormalities or potential failures.

4.4.2 Variables

In the control system architecture, variables play a crucial role in managing inputs, outputs, and facilitating communication between different blocks. These variables can be categorized into two main types: local variables, and tag-names which are inputs, outputs and memories.

A- Local Variables:

Local variables are specific to individual blocks or components within the system and are not accessible from outside their respective contexts. They are used for temporary storage or calculations within a particular block and are not shared with other parts of the system.

B- Tagnames:

B.1 - Inputs:

Inputs represent signals received from external sources, typically sensors or other devices. In this system, inputs originate from a physical address within the module 01.02, specifically a Discrete Input module with a 48 V power supply, offering 32 points of input.

B.2 - Outputs:

Outputs correspond to signals sent from the control system to actuators or other devices. In our setup, outputs are directed to a physical address within the module 01.03, which is a Discrete Output module operating at 48 VDC and providing 16 points of output.

B.3 - Memories:

Memory variables are those accessible by multiple blocks or components within the system. These variables serve as a means of communication, allowing different parts of the system to exchange data. They are typically represented by tag names and can be accessed by both the control logic and the HMI software.

4.4.3 Control Logic

Operational Condition Checker:

The algorithm used in the Operational Condition Checker is represented by an RS (Reset-Set) block, a common component in industrial control systems. Here's a breakdown of its functionality:

- **Inputs:**
  - **S (Set):** This input serves as a trigger to start or initiate the operational condition checking process. It is typically a normally open signal.
  - **R (Reset):** This input acts as a reset signal. When activated, it halts the operational condition checking process. It is usually a normally closed signal, ensuring that in the event of a power loss or emergency stop, the system automatically ceases its operation.
- **Output:**
  - **Q (Output):** This output indicates the status of the operational condition checking process. When active, it signifies that the system is running and monitoring operational conditions.

Explanation:

TurnOn (S): When the "TurnOn" input is activated (set to true), the system transitions into the running state. This signifies the start of the process.

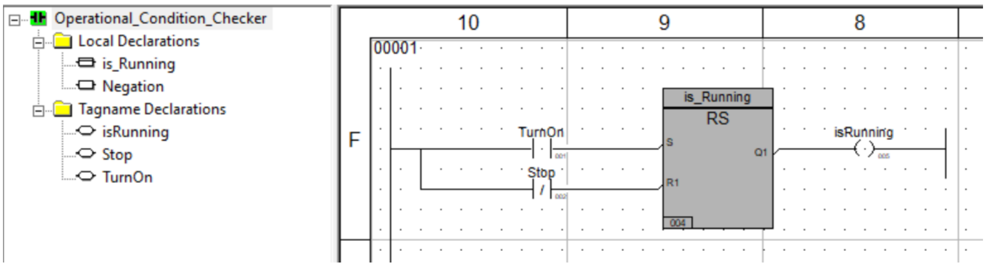

Figure 4.14: Operational Condition Checker

Stop (R): Conversely, when the "Stop" input is activated (set to false), the process is halted, and the system transitions back to the stop state. This allows for manual intervention or cessation of monitoring when necessary.
inRunning (Q): The output "inRunning" reflects the current state of the process.

Note. The Stop input is normally open, meaning it stays open when not energized. This design interrupts current flow when the Stop signal is activated, either manually or during a power loss. When powered or manually triggered, the Stop input closes the circuit, immediately halting operations.

Control Valve Management:

In the control code architecture, managing control valves is crucial for regulating fluid flow and directing operations. The code controls valve energization and de-energization based on the process state and operational sequence step. A preset time delay ensures smooth transitions between stages.

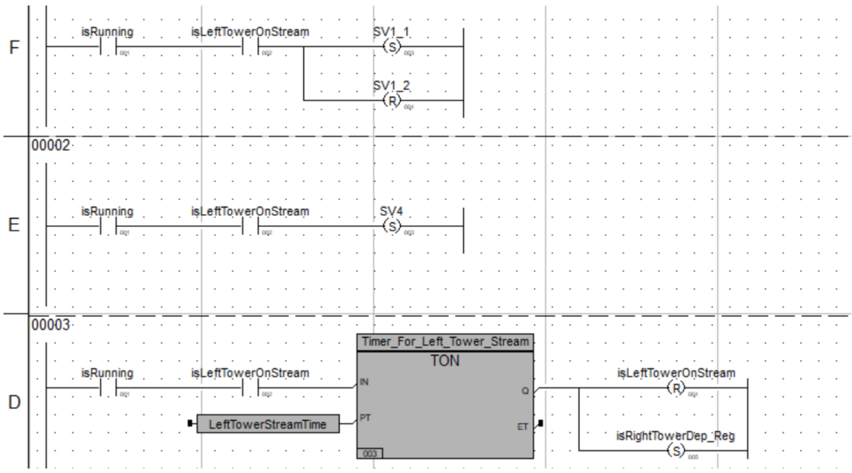

Figure 4.15: Valve Control Sample

Based on the current process state and the requirements of the ongoing step, the code activates (energizes) or deactivates (de-energizes) the appropriate valves.

After initiating valve actions, the code initiates a predetermined time delay, allowing sufficient time for the current step to execute effectively. Upon completion of the time delay, the control code progresses to the next step in the operational sequence, initiating a new cycle of valve control and process management.

Note. To see the full code, check the Appendix, or from this link [17].

Limit Switch Status:

In the control code, a timer with a specified time delay is implemented to verify the status of limit switches after energizing the solenoids. The logic assumes that when the solenoid is energized, the corresponding valve is considered open. Therefore, it's imperative to ensure that the associated limit switch is activated to confirm the valve's open position.

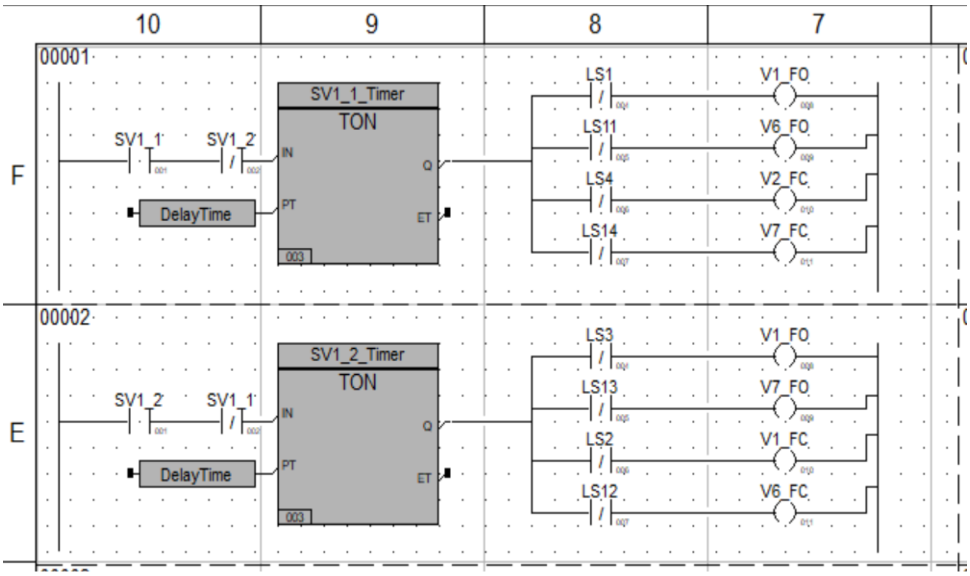

Figure 4.16: Limit Switch Status

The procedure involves initiating a timer upon energizing the solenoid to wait for the specified delay period. Subsequently, the system checks whether the corresponding limit switch is activated within this timeframe. If the limit switch is indeed activated within the allotted time, it confirms that the valve has successfully opened, and the system proceeds with normal operation.

However, if the limit switch fails to activate within the specified time delay, it indicates a potential issue with the valve's operation. In such cases, the system bypasses an alarm to notify operators or initiates appropriate corrective actions, ensuring the integrity and safety of the overall system.

This approach of utilizing timers and monitoring limit switch status provides an effective means of verifying valve positions and detecting any anomalies in real-time, thereby enhancing the reliability and functionality of the control system.

TON (Timer On-Delay): The TON timer function block initiates timing when it receives an input signal or becomes enabled. Upon activation, the timer begins counting elapsed time from zero. Once the preset time duration, known as the time base, has elapsed, the output of the TON timer function block becomes active.

Safety Monitoring Alarm System:

The safety monitoring alarm system is a critical component of the overall control system, responsible for continuously monitoring various parameters to ensure the safe and efficient operation of the desiccant air dryer.

To see the full code, check the Appendix, or from this link [17].

Dew Point Monitoring:

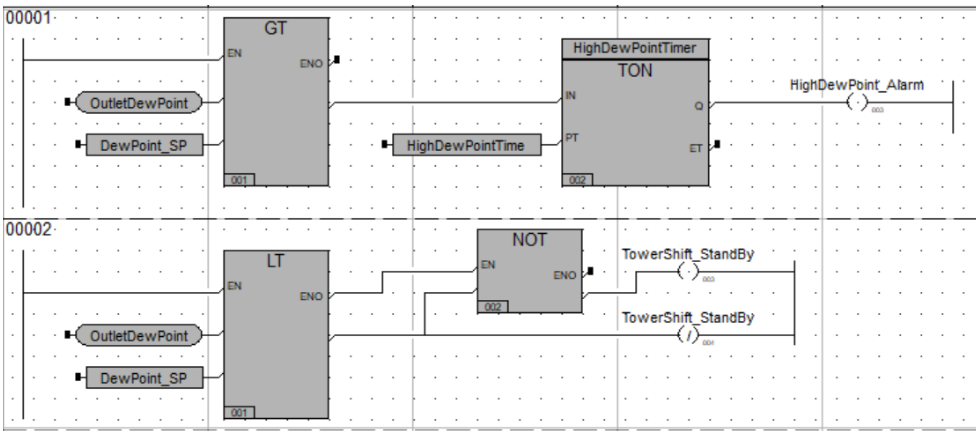

Figure 4.17: Dew Point Monitoring

The system employs a logic to monitor the dew point level. If the dew point exceeds the predefined set point, indicating elevated moisture levels in the air stream, a timer is activated.

If the timer exceeds a specified duration, typically set to 60 seconds, and the dew point remains above the set point, it indicates a persistent issue. In such cases, an alarm is bypassed to alert operators of the abnormal condition.

Additionally, the system ensures that the outlet dew point reaches the required level before shifting towers. This condition ensures that the desiccant material has adsorbed the maximum moisture it can adsorb, before transitioning to the next tower.

GT (Greater Than): The GT function block compares two numerical values and determines whether the first value is greater than the second value.

LT (Less Than): The LT function block compares two numerical values and determines whether the first value is less than the second value.

System Pressure Monitoring:

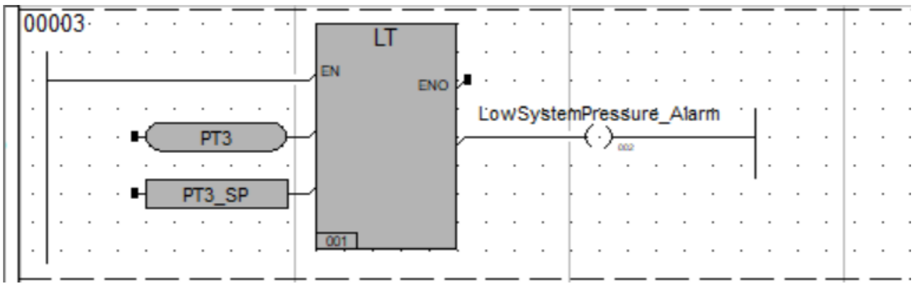

Figure 4.18: System Pressure Monitoring

System pressure, monitored by pressure transmitter PT3, is crucial for maintaining system integrity. If the pressure exceeds the predefined set point, it could indicate potential over pressure conditions or system leaks.

In such instances, an alarm is triggered to notify operators, prompting them to investigate and take necessary corrective actions to mitigate risks.

Filter Monitoring:

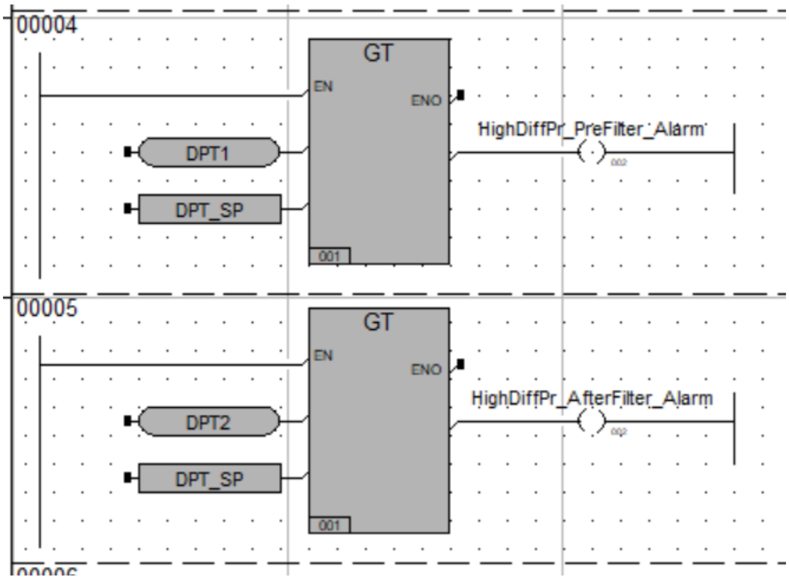

Figure 4.19: Filter Monitoring

The system incorporates separate monitoring logics for pre-filters and after-filters to ensure the integrity of filtration processes.

If the pressure difference between pre-filters or after-filters exceeds the set point, it suggests potential clogging or inefficiencies in the filtration system.
In response, alarms are triggered to alert operators to inspect and possibly replace the affected filters, ensuring continuous and effective air filtration.

Note. In the event of any alarm being triggered, the control system activates the CR1 logic. This logic serves as a centralized response mechanism, indicating that corrective actions may be necessary to address the identified issue promptly.

4.4.4 Simulation Integration

Within the control system environment, the simulation component serves as a vital tool for validating the functionality and logic of the control code. By accessing the controller interface and navigating to the emulator panel, operators gain the capability to connect and initiate simulations, enabling thorough testing and verification of the code's behavior.

1. Navigate to the controller interface provided by Triconex.
2. Locate and access the emulator panel within the controller interface.
3. Within the emulator panel, initiate the connection process to establish a link with the simulation environment.
4. Once connected, initiate the simulation process to execute the control code in the simulated environment.

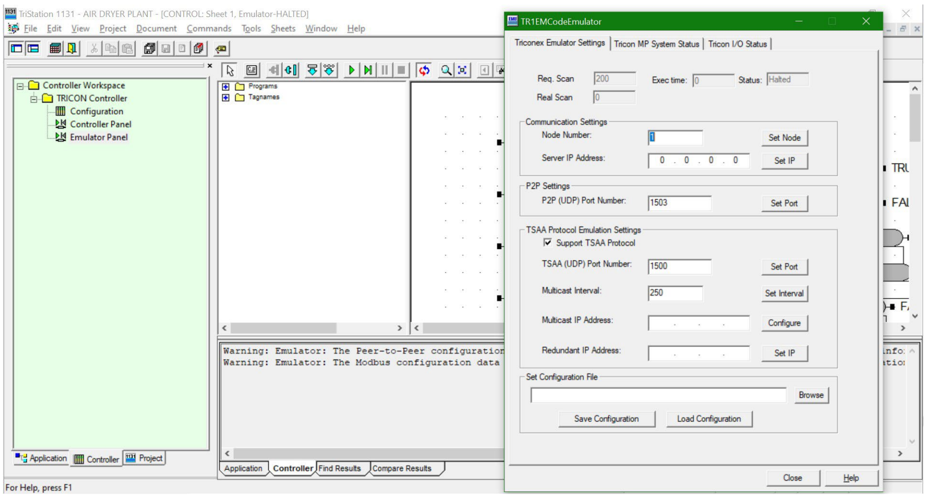

Figure 4.20: Emulator Sample

During the code logic verification phase, the simulation environment serves as a crucial tool to validate the logic and functionality of the control code. Operators closely monitor how the control code interacts with system components, observing its responses to various inputs and conditions. Concurrently, error detection and debugging are integral aspects of the process, with operators vigilant in monitoring system behavior for any errors or unexpected outcomes. Utilizing debugging tools and diagnostic features within the simulation environment, operators swiftly identify and address root causes of anomalies. Subsequently, simulation analysis and refinement take center stage, as operators analyze simulation results to assess the performance and reliability of the control code. Based on insights gleaned from simulation, the control code is refined to optimize its functionality and ensure seamless operation within the intended system environment.

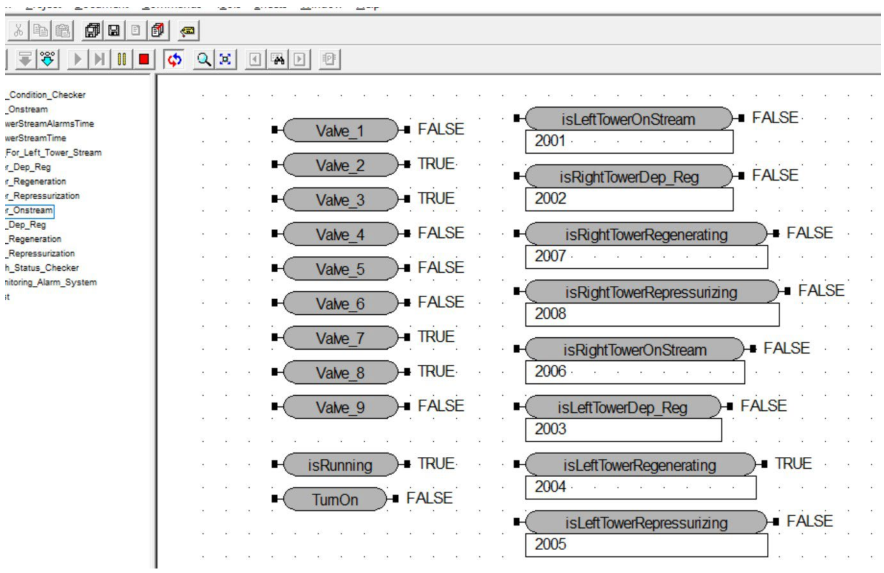

Figure 4.21: Running Emulator Sample

4.4.5 Integration with Overall System

The control program deployed in the desiccant air dryer system is engineered for seamless integration with various Human-Machine Interface (HMI) software platforms, ensuring universal compatibility and effortless interoperability across diverse industrial environments.

Notably, the program harmonizes effortlessly with prominent HMI solutions such as InTouch, delivering an intuitive interface for operators to monitor and manage system operations effectively.

- **Real-Time Monitoring:** Operators can access comprehensive real-time insights into critical parameters such as dew point levels, system pressure, valve positions, and filter status. This data is presented through intuitive graphical representations and trend displays, empowering operators with actionable information for informed decision-making.

- **Alarm Management:** The integrated alarm management system provides operators with timely notifications and alerts concerning abnormal conditions or system faults. These alerts enable swift response and troubleshooting, minimizing downtime and maximizing operational efficiency.

- **Control and Visualization:** The HMI software facilitates seamless interaction with the control program, enabling operators to initiate manual control actions, adjust set points, and visualize system configurations.

4.5 Conclusion

This section delves into the programming of the desiccant air dryer system using Triconex PLCs. It outlines the system architecture and the roles of solenoids, valves, pressure sensors, and dew point sensors, emphasizing precise control and monitoring for optimal performance and safety.

The programming aspect covers control valve management, operational condition monitoring, and safety alarms. It highlights the use of timers, limit switches, and pressure sensors to maintain safe operations. The integration with HMI software, particularly AVEVA InTouch, is discussed for real-time monitoring and control.

Simulation integration is also covered, where the control code is tested using an emulator to ensure proper functionality before deployment. The importance of seamless integration with HMI software for effective system management is emphasized.

Chapter 5

Visualisation and Diagnostics

5.1 Introduction

This chapter provides a thorough simulation of an industrial air dryer system utilizing AVEVA InTouch, a prominent program for industrial automation. The simulation's objective is to offer an in-depth understanding of the operational stages of the air dryer, which encompass repressurization, regeneration, and depressurization.

An important feature of this model is the optimization of the valve system, The old system, which had five valves and check valves, experienced problems associated with back pressure. Excessive pressure in the opposite direction might cause inefficiencies in the system, which can negatively impact the overall efficiency of the air dryer. To solve this, the simulation demonstrates an enhanced system that includes nine valves, boosting the system's efficiency and performance.

This chapter will go into the inner workings of these operational stages and the valve system improvement, providing a full grasp of the industrial air dryer system. The simulation, conducted using AVEVA InTouch, will serve as a vital tool for seeing and comprehending the intricate workings of the system.

5.2 AVEVA Company

AVEVA Company AVEVA Group PLC is a British multinational information technology consulting company headquartered in Cambridge, England. The company was originally established as the Computer-Aided Design Centre (CADCentre) in Cambridge in 1967 by the UK Ministry of Technology and Cambridge University.

AVEVA provides engineering software solutions, including design, engineering, operations, data management, digital transformation, cloud services, and subscription solutions. It also offers consulting, integration, and lifecycle management services [18].

5.2.1 AVEVA InTouch

AVEVA InTouch is an award-winning Human-Machine Interface (HMI) visualization software. It empowers customers to achieve operational excellence by going beyond simplistic graphics to create meaningful content that drives enterprise-wide operations productivity and cost savings.

AVEVA InTouch HMI optimizes routine human interactions with industrial automation systems, resulting in a quantifiable net increase in operator effectiveness. It is used in more than one-third of the world's industrial facilities, in virtually every country and industry [19].

5.3 Monitoring

5.3.1 File and Window Configuration

5.3.1.1 Opening a Project File in Aveva InTouch

- Launch the Aveva InTouch HMI software on your computer.
- From the main menu, navigate to "File" > "new" to create a new project file.

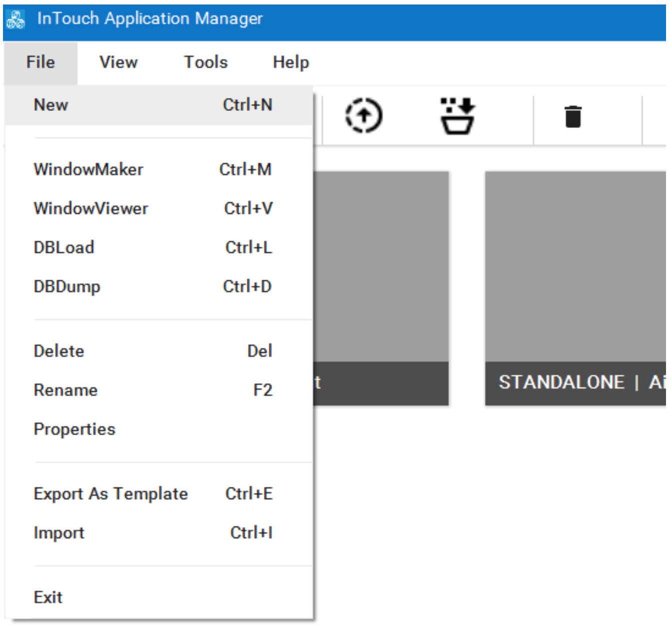

Figure 5.1: Opening a project file in Aveva InTouch

5.3.1.2 Configuring Window Layout

- After opening the project file, you can customize the window layout according to your preferences.
- In the WindowMaker interface, you can modify the window name, resolution, extra... within the project.

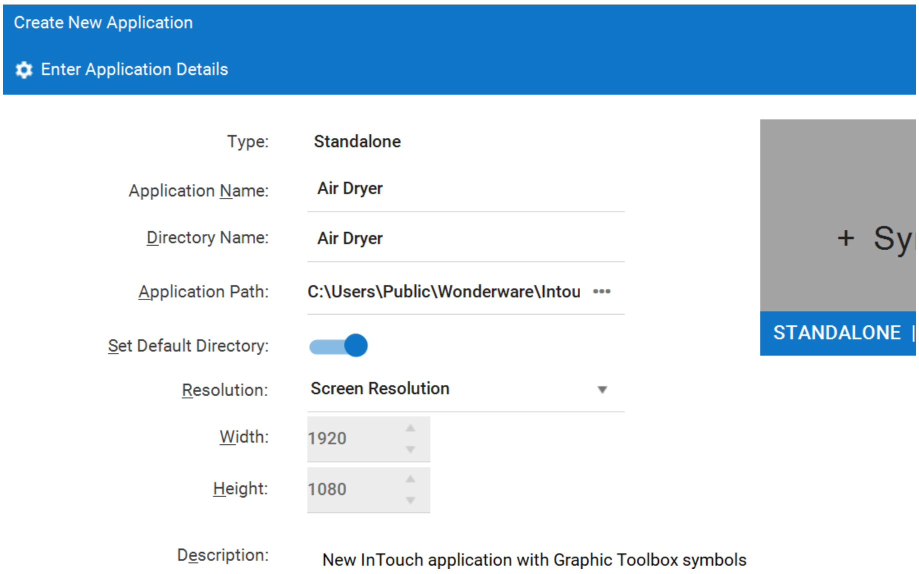

Figure 5.2: Configuring window layout in Aveva InTouch

5.3.2 Window Creation and Object Placement

5.3.2.1 Creating a New Window

- Click on "File" > "New Window" to create a new window within your project.
- Name your new window and select its properties, such as size and background color, then click "OK" to proceed.

5.3.2.2 Adding Objects

- Once your new window is created, proceed to add objects such as graphics, text, buttons, and interactive elements.
- Navigate to the "Embed Industrial Graphic" menu to access a variety of pre-built objects and animations.
- Choose the desired object from the Industrial Graphic Library menu and drag it onto your window canvas.
- Arrange the objects within the window by dragging and dropping them to the desired positions.
- Utilize alignment and spacing tools to ensure a neat and organized layout.

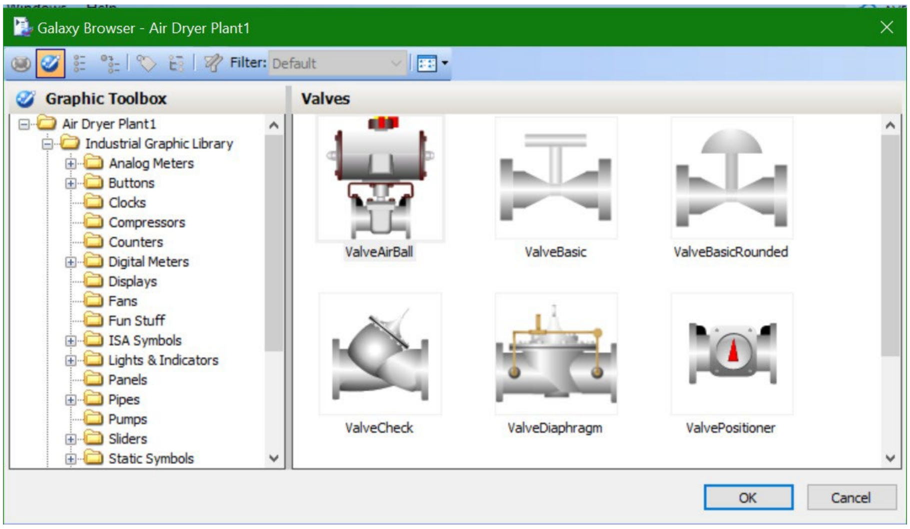

Figure 5.3: Adding objects to the window in Aveva InTouch HMI

5.3.2.3 Arranging Objects and Animations

- After adding objects, arrange them on the window canvas to optimize visibility and functionality.
- Use alignment and spacing tools to ensure objects are evenly distributed and aligned.
- For animations, select the object and navigate to its properties to configure animation settings such as color, type, and trigger conditions.

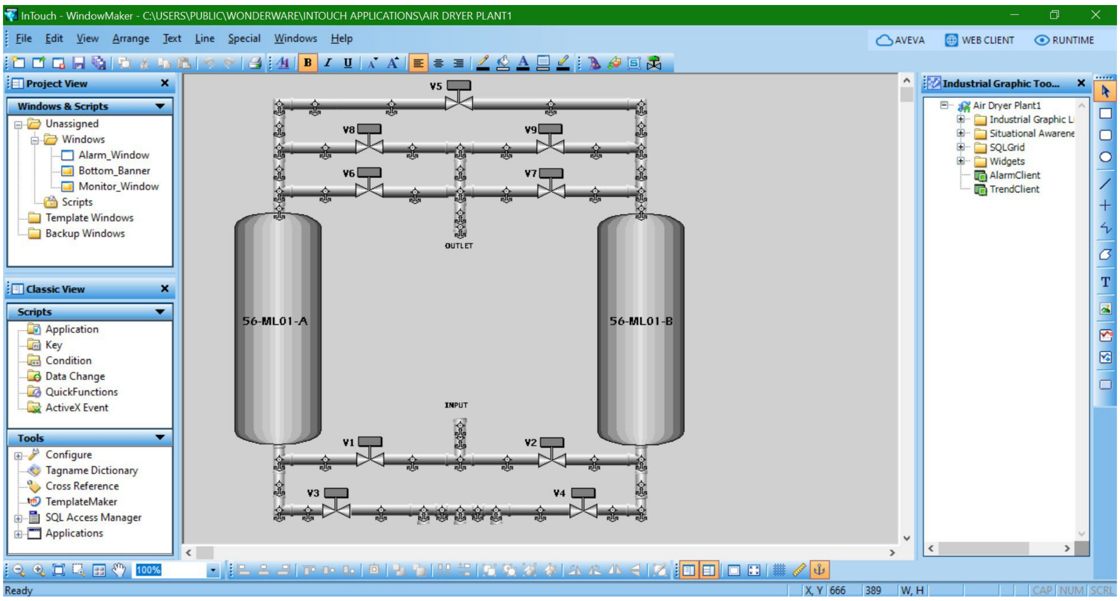

Figure 5.4: Arranging objects and configuring animations in Aveva InTouch HMI

5.3.2.4 Displaying Monitor

5.3.3 Navigation

- To configure the behavior of tab switching, navigate to the options of the buttons.
- Click on "Touch Pushbuttons", then "Action".
- Write the script that switch between windows, using the command "Show".

Figure 5.5: Navigation script for a button for switching between windows in Aveva InTouch HMI

5.3.4 Project Integration

5.3.4.1 Tag Linking

Adding Triconex Access Name:

- Navigate to the "Tagname Dictionary" section in Aveva InTouch HMI.
- Click on "Access Names" and then click "Add" to add the Triconex Access name.
- Enter the appropriate Triconex access name, specifying the application and topic names for communication.

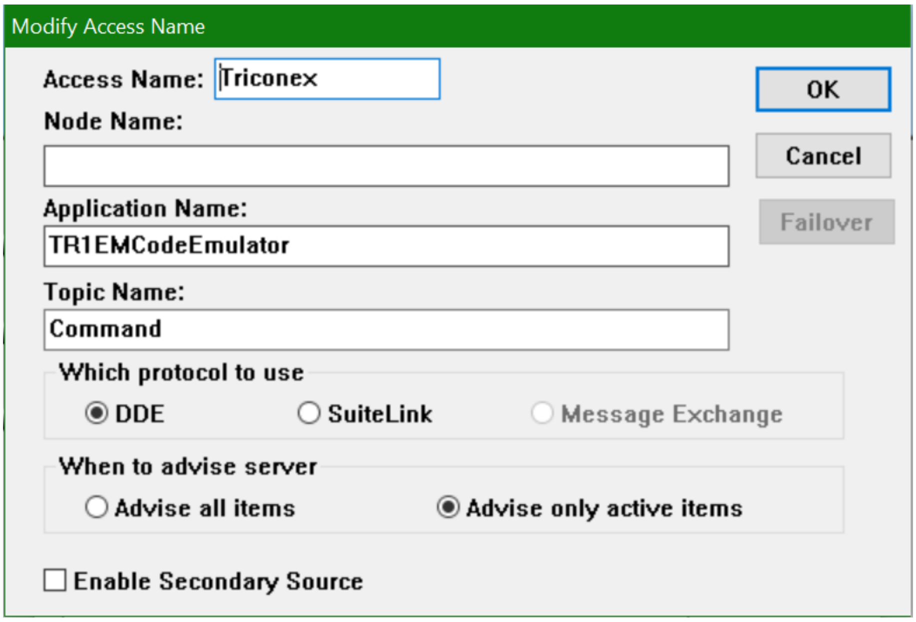

Figure 5.6: Adding Triconex access name in Aveva InTouch HMI

Defining Items:

- After adding the Triconex access name, proceed to define items for communication with the Triconex controller.
- Click on "New" and specify the item name, data type, and address corresponding to the Triconex variable.

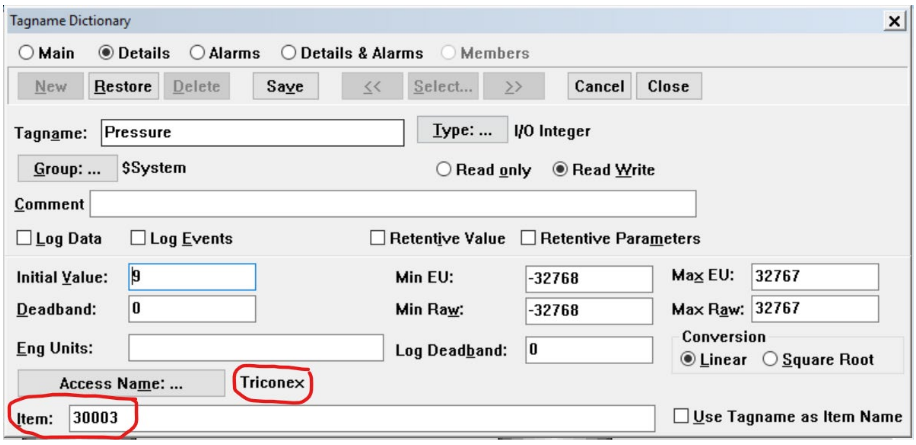

Figure 5.7: Defining items for tag linking in Aveva InTouch HMI

5.3.4.2 Triconex Configuration

Starting a DDE Client:

- Navigate to the DDE Client program in your laptop.
- Click on "connect" to initiate the DDE client service.

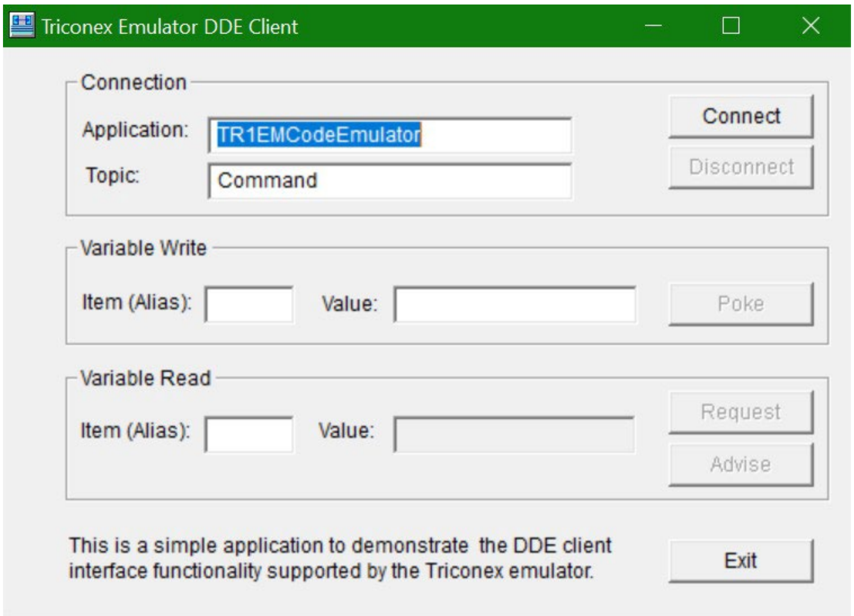

Figure 5.8: Start a DDE Client

Dynamic Data Exchange (DDE) allows Aveva InTouch HMI to communicate in real-time with external DDE-enabled applications, such as the Triconex controller, by establishing a client-server relationship, Aveva InTouch HMI (the client) requests data from the external application (the server), which responds with the requested information.

This setup enables seamless data exchange, including reading real-time sensor data or sending control commands, the integration supports real-time updates and can work alongside other protocols like SuiteLink and OPC, enhancing Aveva InTouch HMI's ability to monitor and control industrial processes efficiently

5.3.5 Simulation

In this simulation, we'll demonstrate four phases of operation for an air dryer system, including left tower on stream, right tower depressurizing, right tower regenerating, and right tower re-pressurizing.

5.3.5.1 Left Tower On Stream

As we initiate the system, our primary objective is to activate the left tower to commence the drying process, this foundational step involves strategically manipulating Valve 1 and Valve 6 to channel the airflow through the left tower.

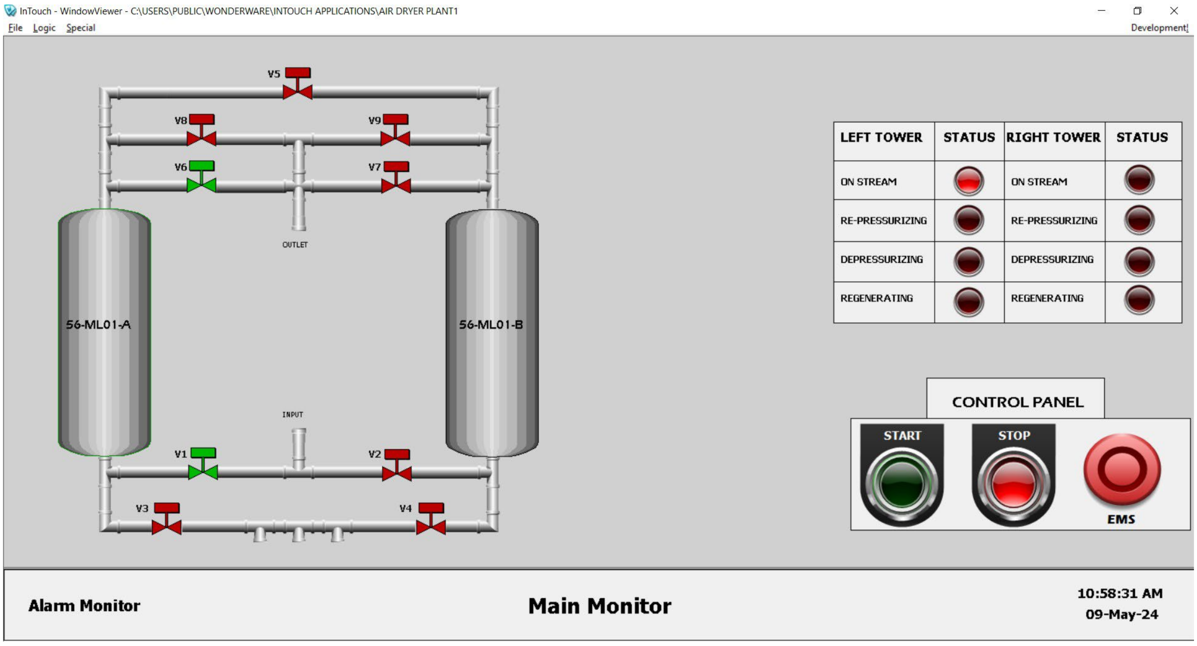

Figure 5.9: Left Tower Onstream

5.3.5.2 Right Tower Depressurizing

Transitioning seamlessly to the subsequent phase, our focus shifts to the depressurization of the right tower to facilitate moisture removal. By selectively opening Valve 4, the depressurization process is initiated.

Observing the purging of air through mufflers offers valuable insight into the mechanisms governing moisture elimination.

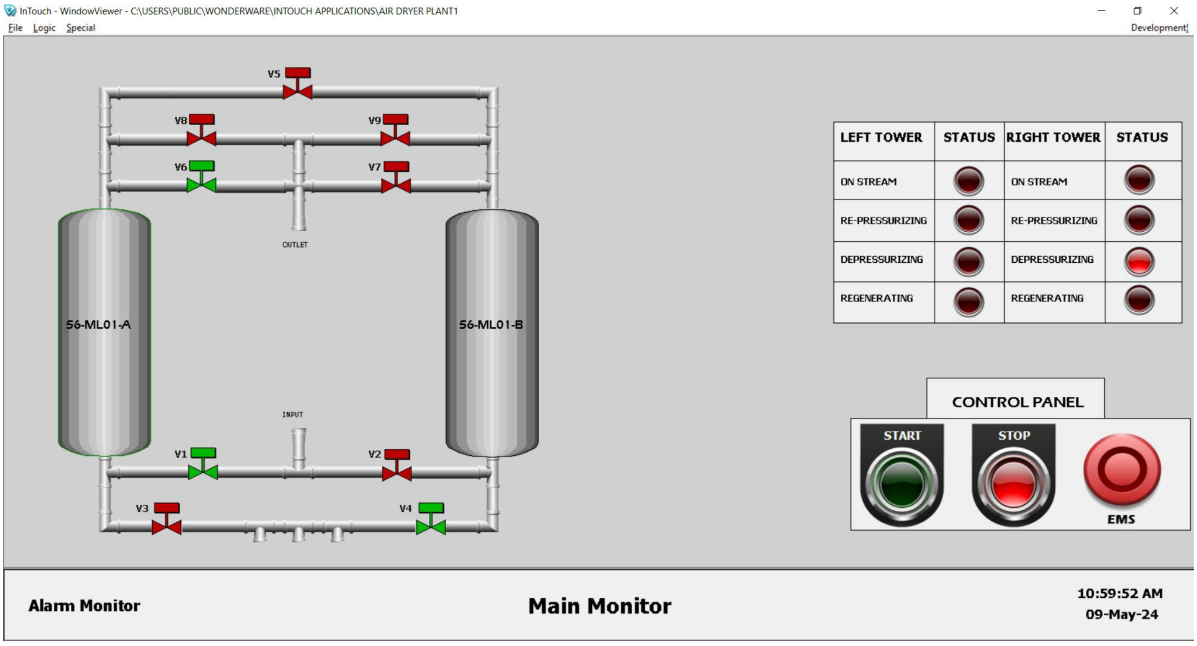

Figure 5.10: Right Tower Depressurizing

5.3.5.3 Right Tower Regenerating

In this critical phase, our attention turns to the regeneration of molecular sieves within the right tower, crucial for sustaining operational efficiency, through the strategic opening of Valve 9, a portion of dried air is directed to the right tower for regeneration.

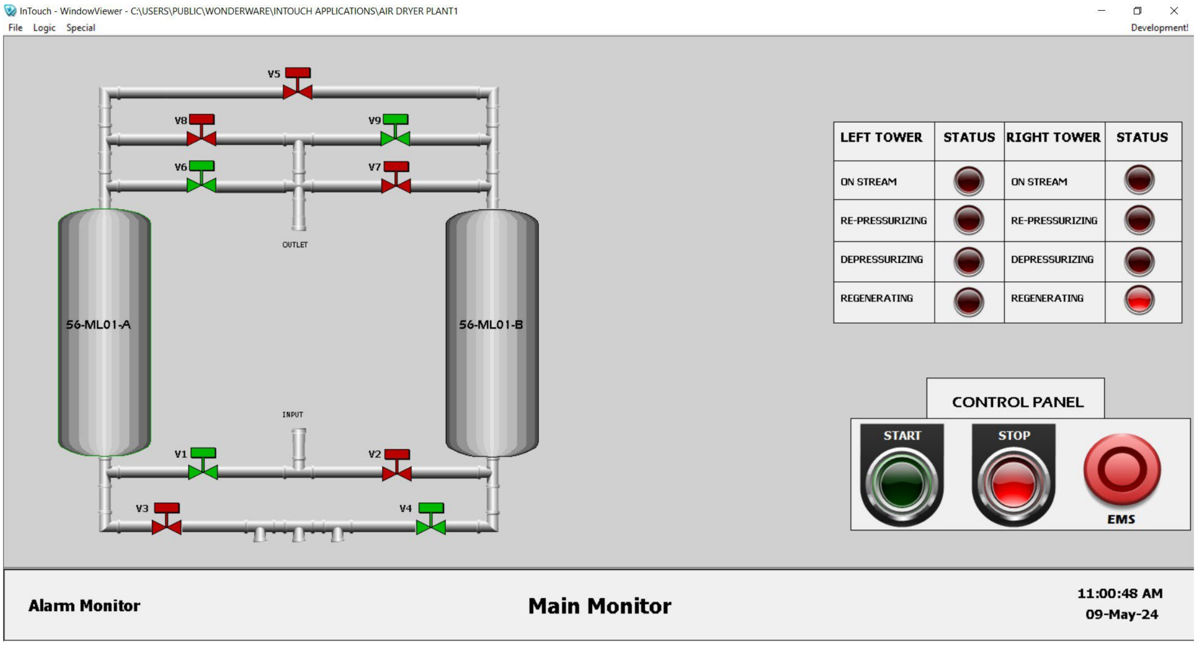

Figure 5.11: Right Tower Regenerating

5.3.5.4 Right Tower Re-pressurizing

Concluding the simulation, we navigate the system towards equilibrium by re-pressurizing the right tower and equalizing pressure between the two towers, through meticulous manipulation of Valve 9, Valve 4 by closing them, and opening Valve 5, we can transit between towers.

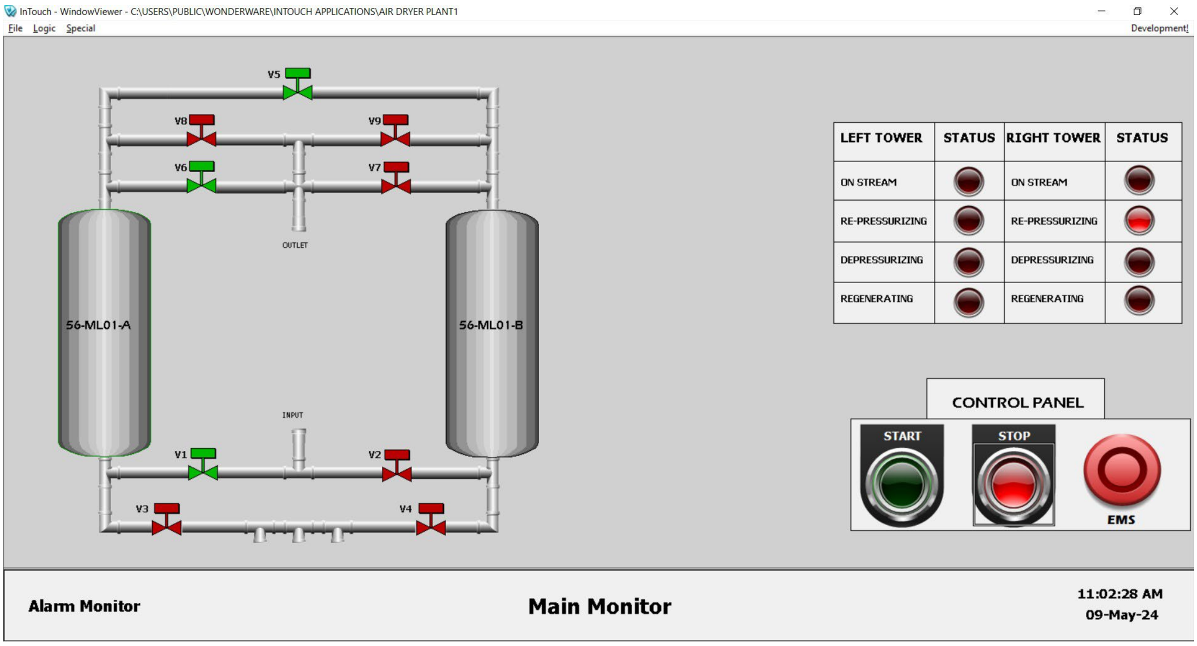

Figure 5.12: Right Tower Re-pressurizing

5.4 Alarm Management

In human-machine interface (HMI) systems, alarms play a crucial role in ensuring operational safety, efficiency, and system integrity. Alarms serve as real-time indicators of deviations from normal operating conditions, alerting operators to potential issues that require attention. Understanding the nuances of alarm management is paramount for effective system monitoring and response.

In HMI terminology, alarms are categorized based on severity levels, typically denoted as "high high," "high," "low," and "low low." Each severity level signifies the magnitude of deviation from the normal operating range and the urgency of response required. "High high" and "low low" alarms indicate extreme deviations that demand immediate attention, while "high" and "low" alarms signify less critical deviations that warrant monitoring and corrective action.

For limit switches, pressure, and filter systems, alarms serve as early warning mechanisms for malfunctions or abnormal conditions. Limit switch alarms may indicate equipment malfunctions or process interruptions, while pressure alarms alert operators to deviations from safe operating pressures. Filter alarms signal potential clogging or failure of filtration systems, highlighting the need for maintenance or replacement.

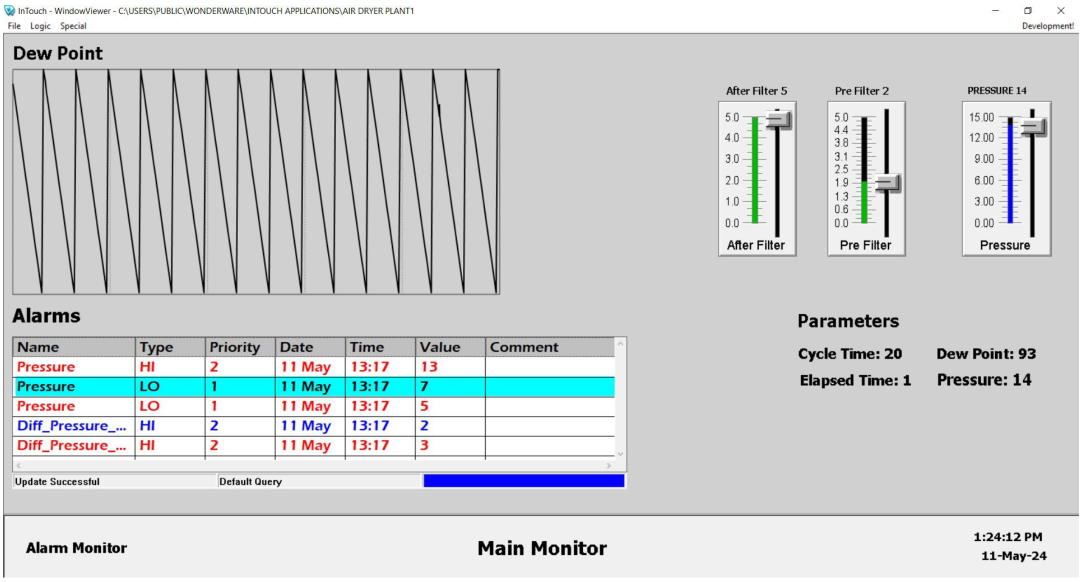

Figure 5.13: Alarms interface in HMI

- **Alarm Prioritization:** HMI systems often allow for the prioritization of alarms based on severity levels, ensuring that critical alarms receive prompt attention while less urgent alarms are managed accordingly.

- **Alarm Logging and Documentation:** HMI systems often feature alarm logging capabilities, recording alarm occurrences, timestamps, and operator responses for documentation, analysis, and regulatory compliance purposes.

5.5 Conclusion

In this chapter, the simulation of an industrial air dryer system using AVEVA InTouch was meticulously detailed. The simulation showcased the operational phases of the air dryer, including repressurization, regeneration, and depressurization. By replacing the traditional 5-valve system with a more efficient 9-valve configuration, the system's performance and reliability were significantly enhanced. This approach effectively addressed the back pressure issues associated with check valves.

The integration of real-time monitoring and alarm management in the HMI provided comprehensive insights and control, ensuring optimal operation and prompt response to any anomalies. This simulation serves as a valuable tool for visualizing and understanding the intricate workings of the air dryer system, demonstrating the benefits of advanced control and monitoring solutions.

General Conclusion

This Master's Thesis has explored the optimization and implementation of advanced air dryer systems within the GL1/K natural gas liquefaction complex in Skikda, Algeria, with a particular focus on addressing the operational challenges associated with traditional air dryer setups. The research identified significant issues such as back pressure caused by the existing 5-valve system with check valves, which compromised the efficiency and reliability of the air drying process.

To address these challenges, a novel solution was proposed and implemented, involving the use of a 9-valve system without check valves. This innovative approach was designed to mitigate back pressure and enhance the overall performance of the air dryer system. The integration of advanced control instruments, including sensors and valves, played a crucial role in maintaining optimal air quality and ensuring precise system control.

The programming of the new air dryer system was accomplished using Triconex Programmable Logic Controllers (PLCs), which provided a robust and flexible platform for developing and implementing the necessary control logic. The detailed programming efforts included the development of control strategies, system architecture, and the integration of these strategies into the overall system.

Furthermore, the visualization and diagnostics of the air dryer system were enhanced using AVEVA InTouch HMI software. This allowed for comprehensive monitoring, configuration, and alarm management, ensuring that the system could be effectively managed and any issues promptly addressed. The simulation of the air dryer system's operational phases demonstrated the effectiveness of the proposed solution in a virtual environment, validating its practical applicability.

Through a combination of theoretical analysis and practical implementation, this thesis has contributed to the advancement of air dryer technology, providing valuable insights and innovative solutions for improving industrial processes in natural gas liquefaction facilities. The findings underscore the importance of continuous improvement and the adoption of advanced technologies to enhance operational efficiency, reliability, and overall system performance.

The successful implementation of the proposed solutions at the GL1/K complex serves as a model for other industrial settings facing similar challenges, highlighting the potential for widespread application and significant operational benefits.

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A- Comprehensive Program

A.1 Left Tower Onstream

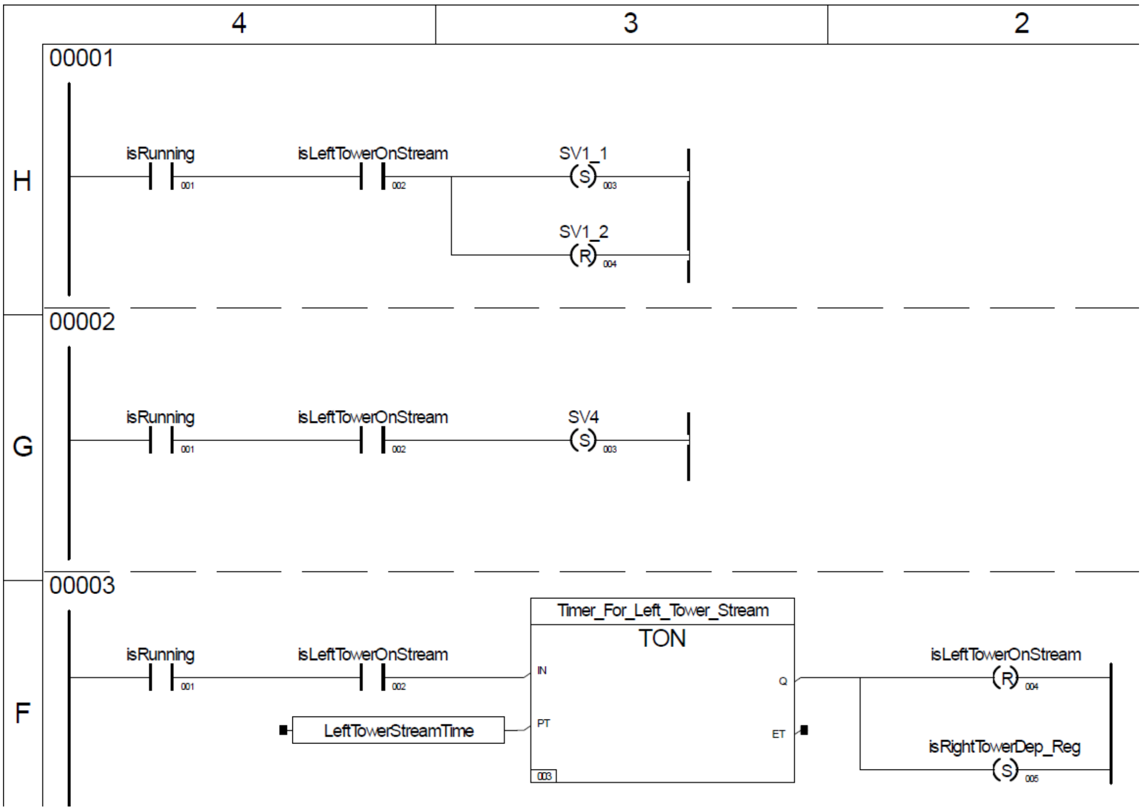

Figure A.1: Left tower Onstream

A.2 Left Tower Regeneration

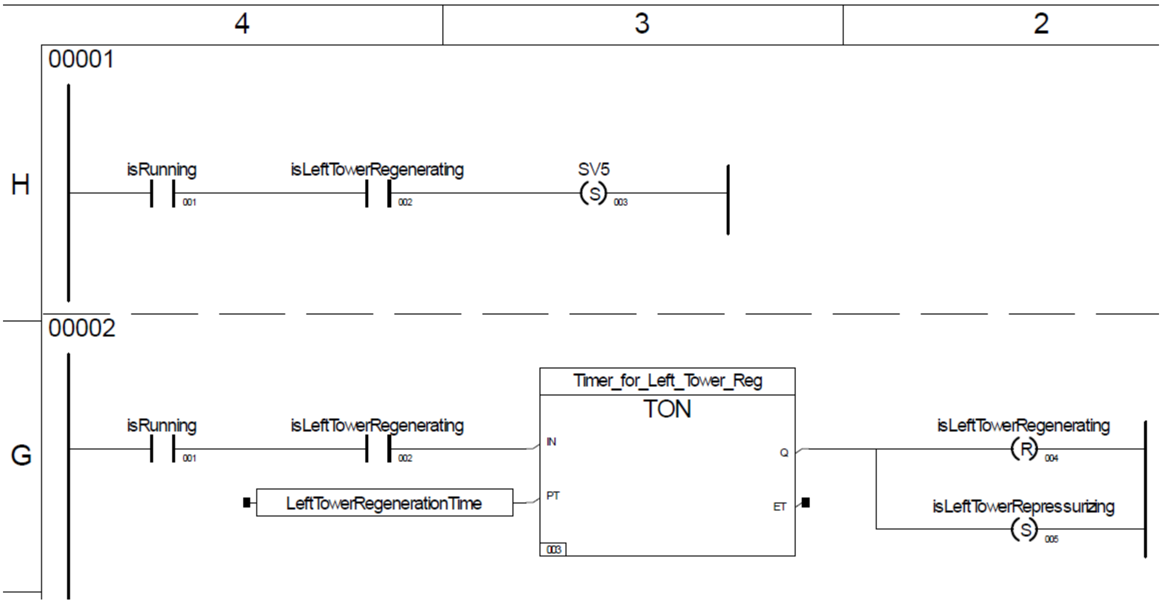

Figure A.2: Left tower regeneration

A.3 Left Tower Repressurization

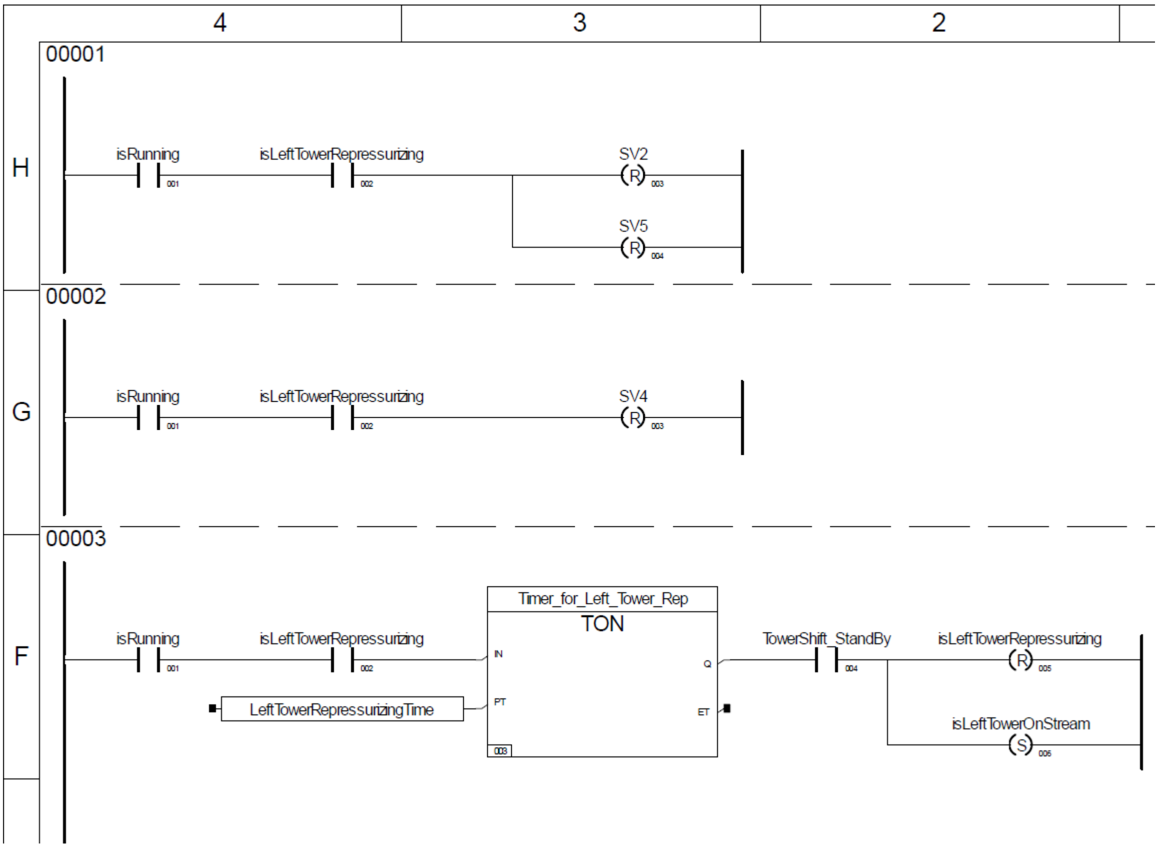

Figure A.3: Left Tower Repressurization

A.4 Left Tower Depressurization/Regeneration

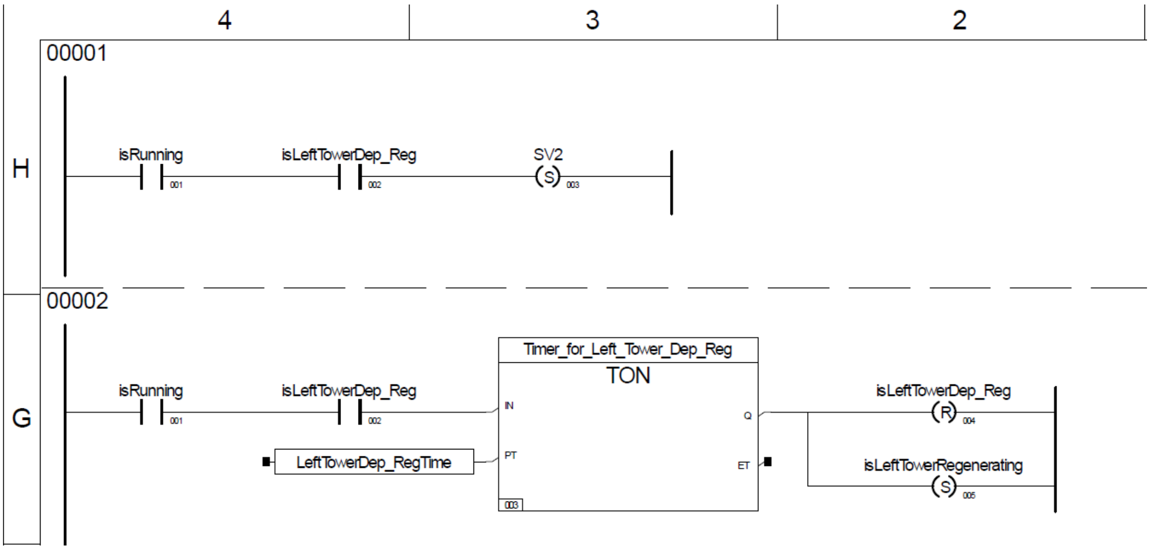

Figure A.4: Left Tower Depressurization/Regeneration

A.5 Right Tower Depressurization/Regeneration

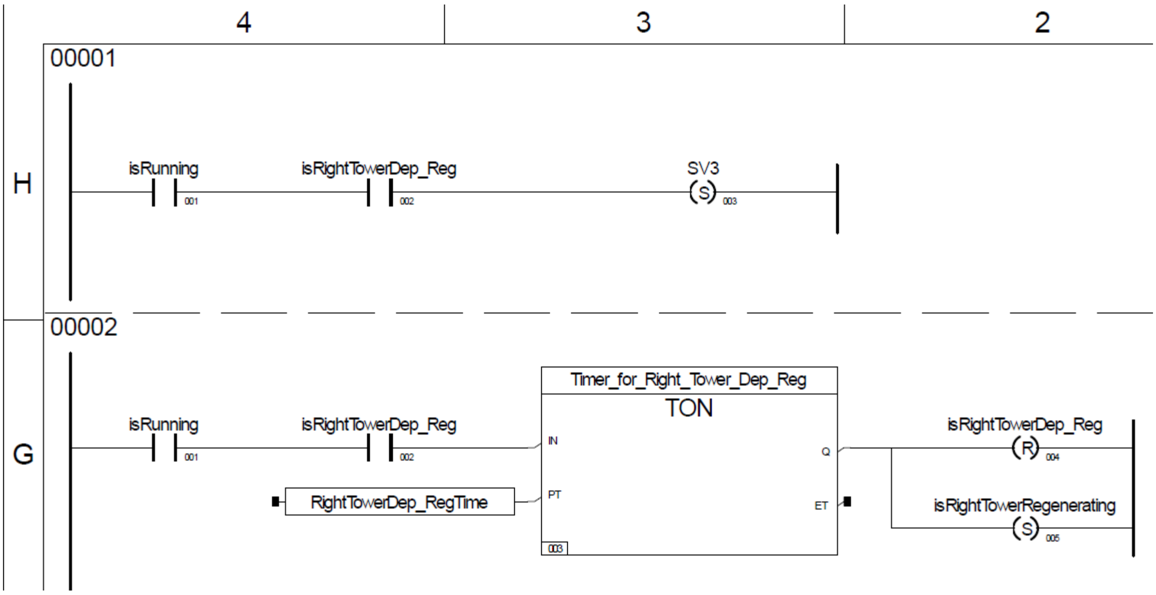

Figure A.5: Right Tower Depressurization/Regeneration

A.6 Right Tower Onstream

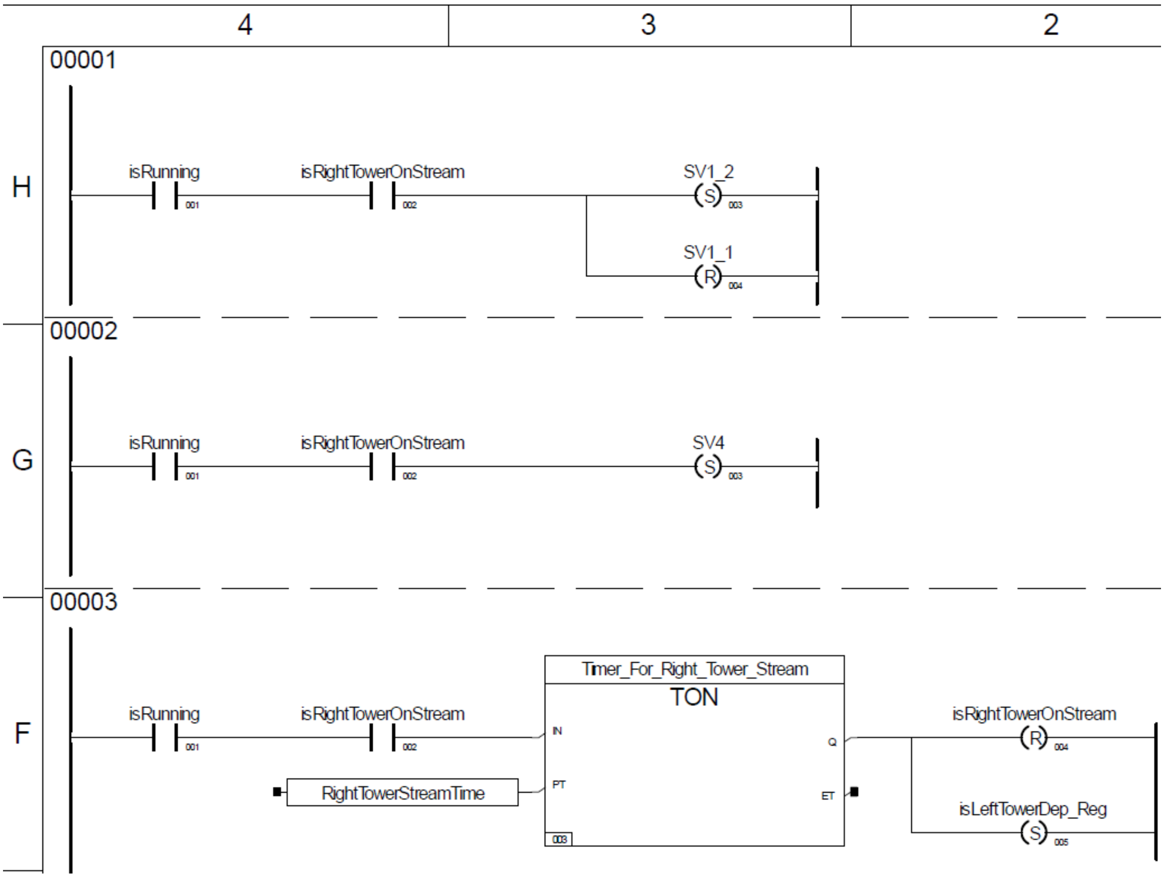

Figure A.6: Right Tower Onstream

A.7 Right Tower Regeneration

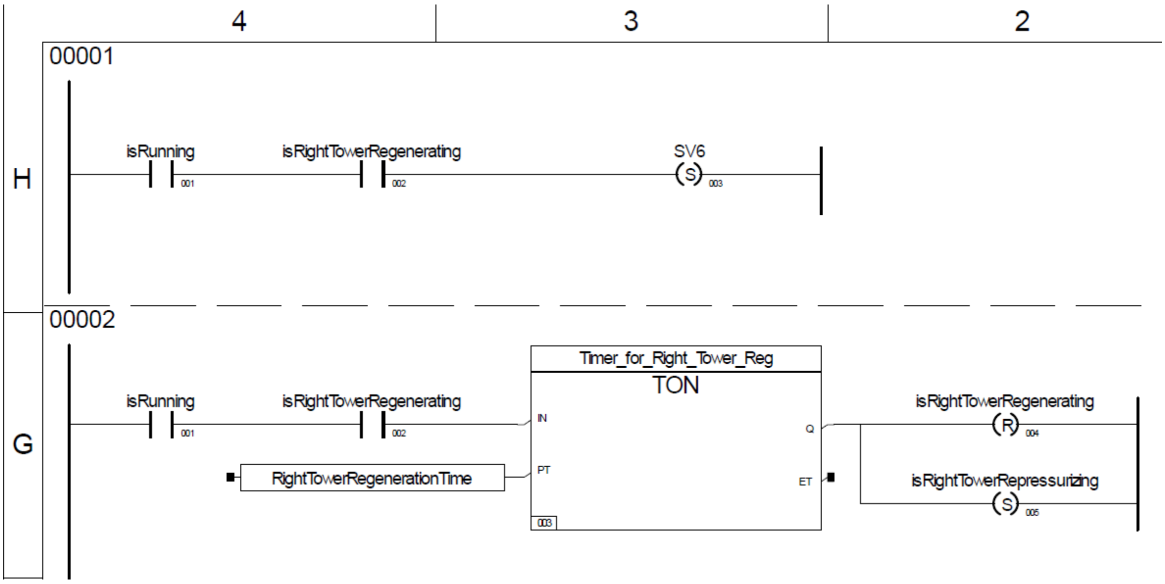

Figure A.7: Right Tower Regeneration

A.8 Right Tower Repressurization

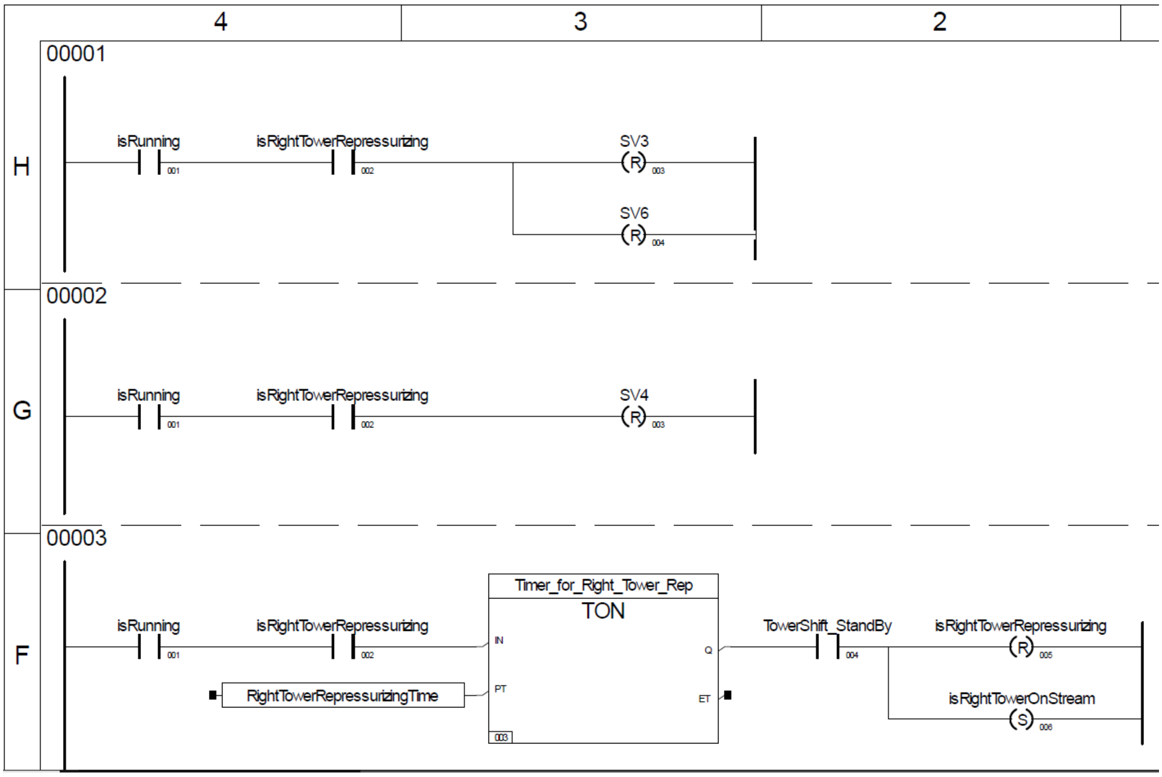

Figure A.8: Right Tower Repressurization

A.9 Limit Switch Status

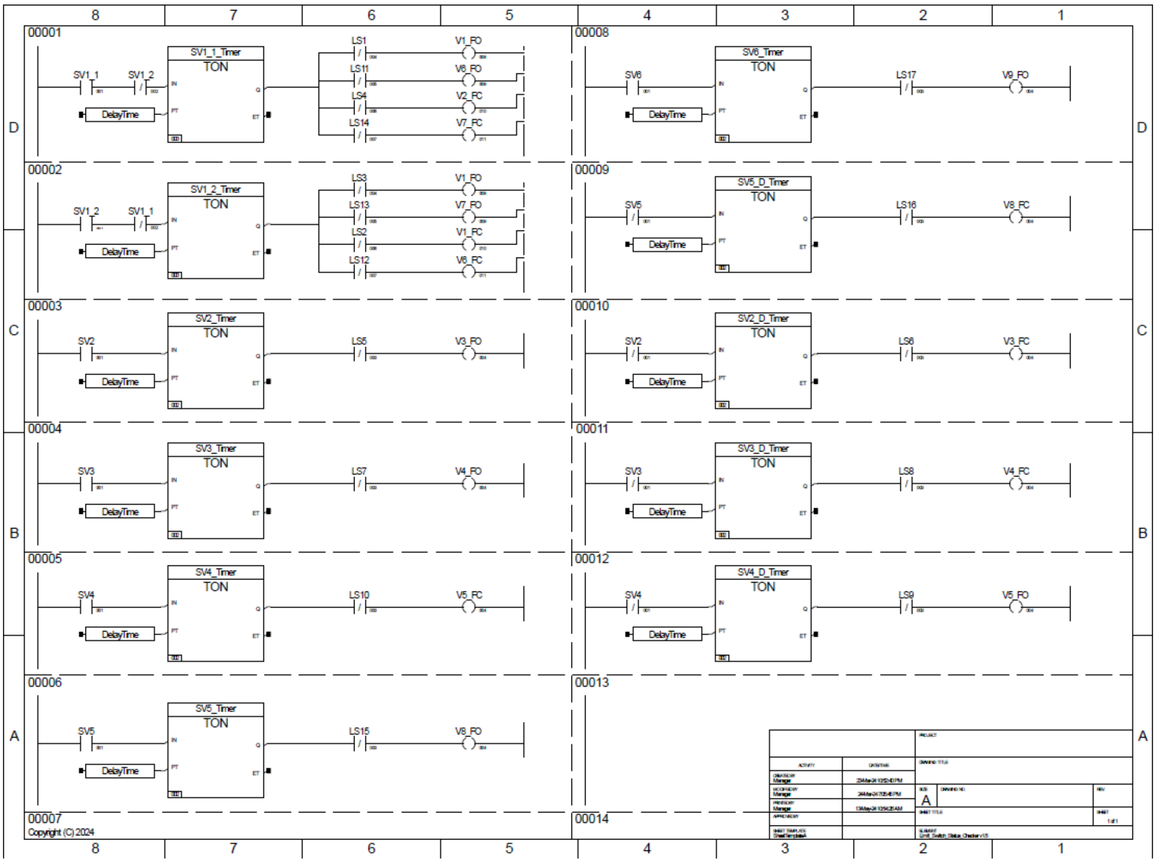

Figure A.9: Limit Switch Status

A.10 Operational Condition

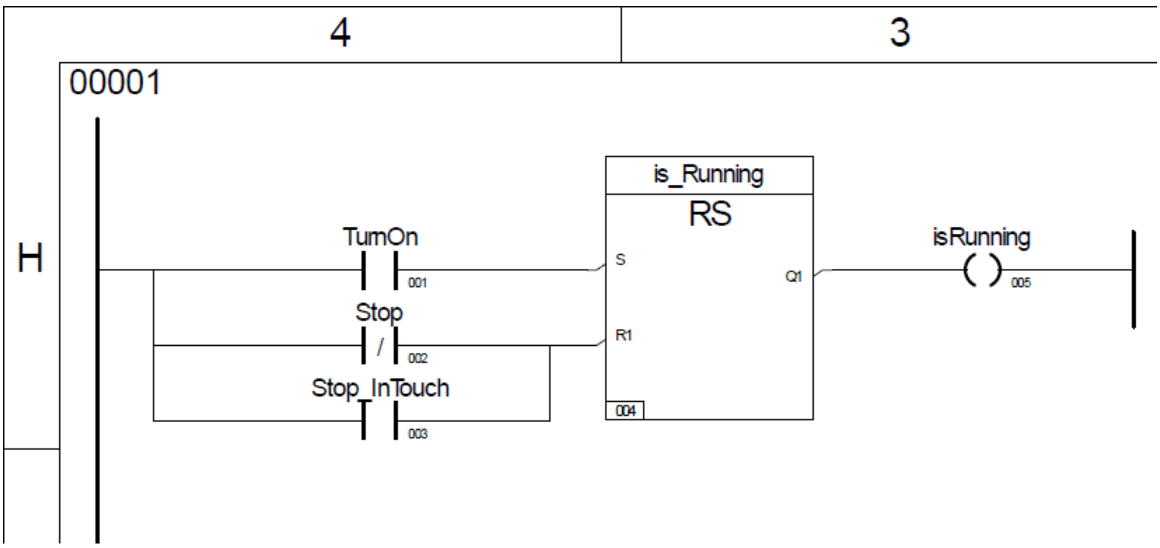

Figure A.10: Operational Condition

A.11 Safety Monitoring Alarms Part 1

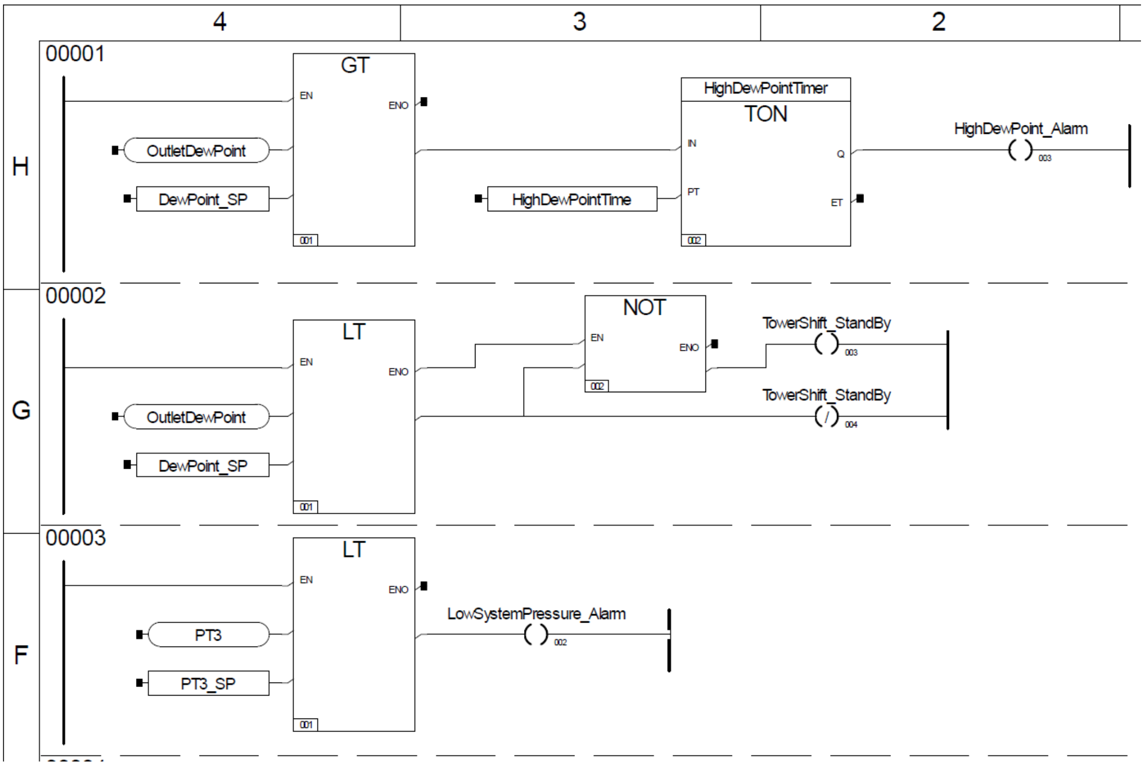

Figure A.11: Safety Monitoring Alarms Part 1

A.12 Safety Monitoring Alarms Part 2

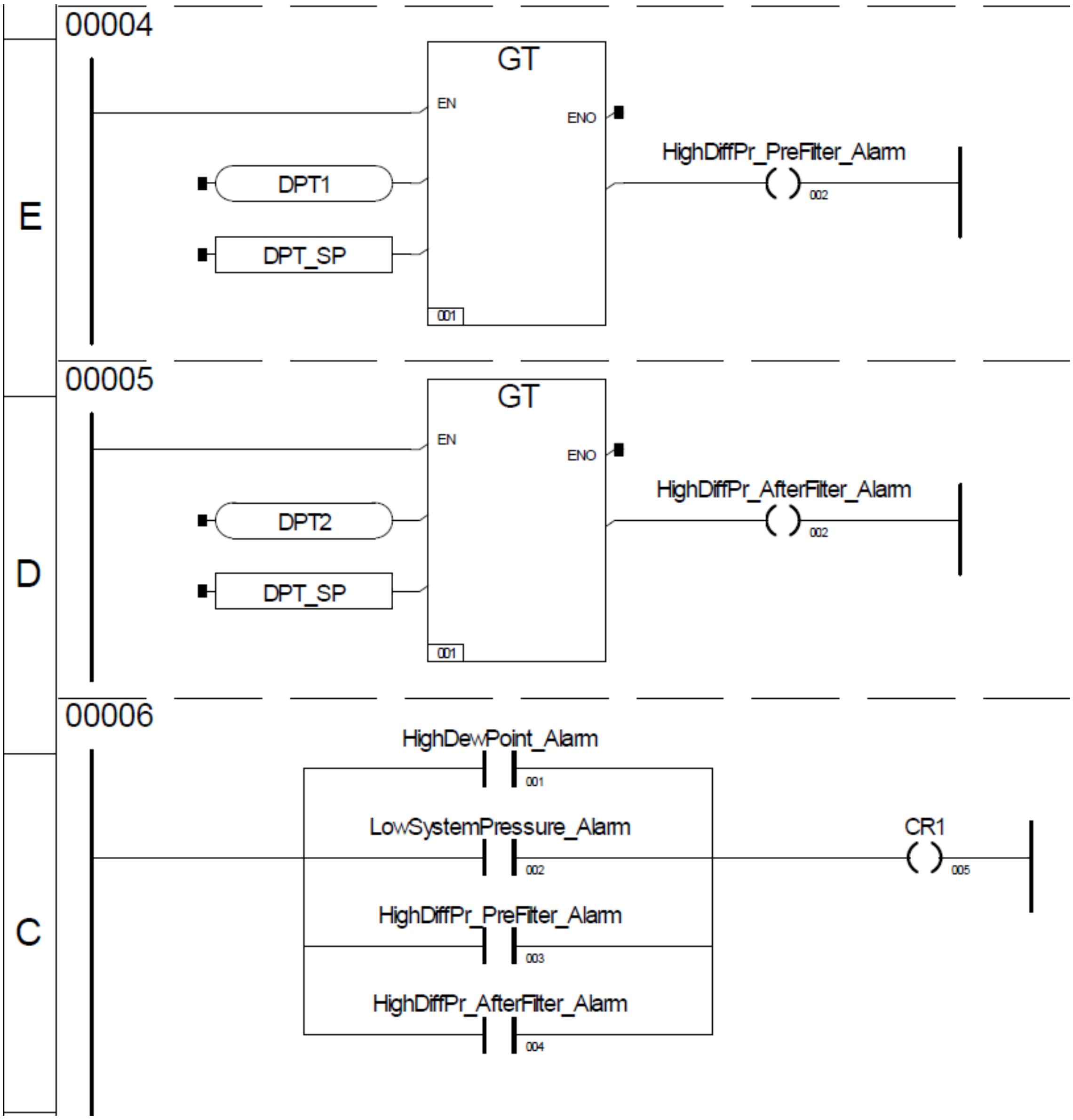

Figure A.12: Safety Monitoring Alarms Part 2