Memoire de master

En automatique

Spécialité : automatique et informatique industrielle

Présenté par

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Automation and supervision of a desalination plant

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ملخص

نظرًا لتناقص وفرة الموارد المائية وتوسع المناطق القاحلة في جميع أنحاء العالم، ظهرت تحلية مياه البحر كوسيلة بديلة لتوفير المياه العذبة في مناطق مختلفة في جميع أنحاء العالم. الهدف من هذا المشروع هو تطوير حل آلي وخاضع للإشراف لمحطة تحلية مياه البحر EL-MARSA في سكيكدة، باستخدام تقنية التناضح العكسي.

لهذا الغرض، استخدمنا وحدة التحكم المنطقية القابلة للبرمجة Modicon M580 واستخدمنا برنامج Unity Pro و Citect SCADA لبرمجة عملية الأتمتة والإشراف على عمليات المحطة.

الكلمات المفتاحية: المياه، تحلية المياه، التناضح العكسي، ألأتمتة، يونيتي برو، سيتكت سكادا.

Résumé

En raison de la diminution de la disponibilité des ressources en eau et de l'expansion des régions arides dans le monde, le dessalement de l'eau de mer est devenu un moyen alternatif de fournir de l'eau douce dans diverses régions du monde.

L'objectif de ce projet est de développer une solution automatisée et supervisée pour l'usine de dessalement d'eau de mer EL-MARSA à SKIKDA, utilisant la technique d'osmose inverse. À cette fin, nous avons utilisé le contrôleur logique programmable Modicon M580 et utilisé les logiciels Unity Pro et Citect SCADA pour programmer le processus d'automatisation et superviser les opérations de la station.

Mots clés : Eau, Dessalement, Osmose Inverse, Station de dessalement d'EL MARSA SKIKDA, Automatisation, Unity Pro, Citect SCADA.

Abstract

Due to the decreasing availability of water resources and the expansion of arid regions worldwide, seawater desalination has emerged as an alternative means of providing fresh water in various regions across the world.

The objective of this project is to develop an automated and supervised solution for the EL-MARSA seawater desalination plant in SKIKDA, utilizing the Reverse Osmosis technique. For this purpose, we employed the Modicon M580 programmable logic controller and utilized Unity Pro and Citect SCADA software to program the automation process and oversee the station's operations.

Keywords: Water, Desalination, Reverse Osmosis, EL MARSA SKIKDA desalination plant, Automation, Unity Pro, Citect SCADA.

Acknowledgement

Dedication

I dedicate this dissertation:

To my dear parents, my brothers and my sister for all their sacrifices, their
love, tenderness, support and prayers throughout my studies,
may this work be the accomplishment of your so alleged wishes, and the flight of
your unfailing support.

To my family, my loved ones and to those who give me love and liveliness.

To all those who stood by me during the ups and downs of completing this work, sharing in both the triumphs and challenges. Your unwavering support and encouragement have been invaluable throughout my journey.

To all my friends with whom I experienced the most memorable moments during my university journey.

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Abbreviation's list

- **ABVC :** Absorption vapor compression ;
- **ADVC :** Adsorption vapor compression ;
- **AGBT :** General low voltage cabinet;
- **AGMD :** Membrane Distillation with air gap;
- **CIP :** Clean In Place ;
- **CPU :** Central processing unit ;
- **CRA :** Communication remote adapter ;
- **CVC :** Chemical vapor compression ;
- **DBNPA :** 2,2-dibromo-3-nitrilopropionamide ;
- **DCMD :** Direct Contact Membrane Distillation ;
- **DFB :** Derived function block ;
- **EC :** Electrical conductivity ;
- **ED :** Electrodialysis ;
- **EF :** Elementary function ;
- **EFB :** Elementary function blocks ;
- **ERD :** Energy recovery device ;
- **FBD :** Function Block Diagram ;
- **FC :** Freezing Concentration ;
- **FM :** Flow measurement ;
- **HDH :** Humidification-dehumidification ;
- **HP :** High pressure ;
- **IL :** Instruction List ;
- **LC :** Level calculator ;
- **LD :** Ladder Diagram ;
- **LS :** Level switch ;
- **MEE :** Multiple effect evaporation ;
- **MF :** Microfiltration ;
- **MSF :** Multi-stage flash ;
- **MVC :** Mechanical vapor compression ;
- **NF :** Nanofiltration ;
- **NTU :** Nephelometric turbidity unit ;
- **ORP :** Redox potential ;
- **P&ID :** Piping & Instrumentation Diagram ;
- **PT :** Pressure transmitter ;
- **RIO :** Remote input output ;
- **RO :** Reverse Osmose ;
- **SCADA :** Supervision and data acquisition ;
- **SDI :** Silt Density Index ;
- **SEE :** Single effect vapor compression ;
- **SFC :** Sequential Function Charts ;
- **SGMD :** Gas Swept Membrane Distillation;
- **SMBS :** Sodium metabisulphite ;
- **ST:** Structured Text ;

▪ **TVC :** Thermal vapor compression ;
▪ **UF :** Ultrafiltration ;
▪ **VDM :** Vacuum Membrane Distillation.

General Introduction

Water is a vital resource for all life on Earth. It is essential for human consumption, agriculture, industry, and numerous other purposes. However, access to clean and safe drinking water can be a challenge in many parts of the world, particularly in arid or drought-prone regions. One solution to this problem is desalination, which is the process of removing salt and other minerals from seawater or brackish water to produce freshwater.[1]

The escalating human populations and expanding economies have resulted in a swift rise in global demand for fresh water. The adverse effects of population growth worldwide, the consequences of climate change, and changes in lifestyle are mounting pressures on our crucial water resources, leading to widespread water stress in numerous countries. This is especially exacerbated by the uneven distribution of wealth worldwide, with some countries, such as Ireland, having an abundance of water while others, such as African countries, do not have enough. Approximately 60% of the world's freshwater reserves are shared among nine countries, namely: Brazil, Russia, China, Canada, Indonesia, the United States, India, Colombia, and the Democratic Republic of Congo. [1]

At present, over 33% of the global population resides in a country facing water stress, and it is projected that this figure will surge to almost 66% by 2025. This has made water scarcity a significant worldwide problem and a potential trigger for conflicts. Consequently, there is a mounting recognition of the pressing need to preserve water. Industrial desalination of seawater is one of the crucial solutions to address the shortage of water resources, and it provides sustainable sources of fresh water to numerous communities globally.

Desalination stations, also known as desalination plants or water treatment plants, are facilities that use various methods to remove salt and minerals from seawater or brackish water. These methods include reverse osmosis, thermal distillation, and electrodialysis, among others. Reverse osmosis is the most commonly used method and involves forcing seawater through a semipermeable membrane that filters out salt and other impurities. Thermal distillation involves boiling seawater to produce steam, which is then condensed to produce freshwater. Electrodialysis uses an electric current to separate salt and other minerals from seawater.

The process of desalination requires a significant amount of energy, typically from electricity or fossil fuels. It also generates waste products, such as brine or saltwater, which must be disposed of properly to avoid environmental harm. Despite these challenges, desalination has become an increasingly popular solution to water scarcity
in many parts of the world. As technology improves and becomes more efficient, desalination is likely to play an even greater role in providing clean and safe drinking water to populations around the globe.

To this end, this thesis is divided into four complementary chapters:

- The first chapter is devoted to the problem of water scarcity in the world and in Algeria, where the process of seawater desalination has become essential as one of the most widespread solutions in the world. In the last thirty years, desalination methods have been developed, and the techniques known as membranes" such as reverse osmosis, with a lower energy cost, have emerged, this technique will be used in our thesis's work;

- In the second chapter, we describe the process of the desalination plant, the various pieces of equipment that make it up, before establishing the energy consumption of these equipment;

- The third chapter contains an overview of the APIs that help to choose the PLC that suits our project. We approach a presentation of the software Unity Pro and Citect SCADA which allow you to program Schneider Electric APIs, and supervise the station;

- Finally, the fourth chapter is devoted to the creation of the automation solution of our desalination plant under Unity Pro, and its supervision with Citect SCADA.

Chapter 1: General information on the seawater treatment.

Introduction:

In this chapter we will present an overview of the situation of water resources in the world, at the end of which we will discuss the low availability of freshwater and drinking water, and in particular the presence of the alternative resource which is sea water. This will be followed by an update on the desalination of seawater in the world, and its different thermal and membrane processes, based on the reverse osmosis technique which presents the body of our thesis

1. Water resources:

Water is a finite resource: Although it covers approximately 70% of the Earth's surface, only a small fraction of it is available for human consumption because most of it exists in the form of saltwater oceans and polar ice caps.

The distribution of global water resources is very uneven. Some regions have abundant water resources while others are under severe water stress, which can lead to social, economic and environmental challenges

Here are some global water resources statistics:

- Water Availability: Only about 2.5% of the world's water is fresh water, and about 70% of it is trapped in ice sheets and glaciers, leaving only about 0.75% of the world's water available as freshwater.
- Water use: Agriculture is the largest user of water in the world, accounting for about 70% of all freshwater withdrawals. Industry and households make up the remaining 30%.
- Water scarcity: Some 1.2 billion people, or nearly one-fifth of the world's population, live in water-scarce areas with per capita water availability of less than 1,000 cubic meters per year.
- Water quality: About 1.8 billion people around the world lack access to safe drinking water, and more than 80% of the world's wastewater is discharged into the environment without treatment.
- Water-related disasters: Over the past two decades, water-related disasters such as floods, droughts, and storms have affected more than 4 billion people, causing an estimated $1.6 trillion in economic losses.
- Transboundary water resources: There are over 300 transboundary river basins worldwide, with about 60% of global freshwater flows originating in one country and flowing into another.

It's important to note that these statistics can vary widely by region and country, and many areas face unique water challenges.[1]

Distribution of fresh and salt water on the planet	km^3	%
fresh water	35 000 000 km^3	2.5 %
salted water	1 365 000 000 km^3	97.5 %
Total volume of water	1 400 000 000 km^3	100 %

Table 1.1: Distribution of water on the planet.[2]

Freshwater reservoirs on land	%
Glaciers	77%
Groundwater	22%
Waters available	1%

Table 1.2: Distribution of fresh water.[1]

Of course, the actual geographical distribution of water on earth shows a very clear reality far from the averages presented in the previous tables. Water availability in the world has been impacted by a number of factors, including population growth, urbanization, climate change, and environmental degradation. Here are some issues: Increasing demand; Depletion of aquifers; Climate change impacts; Water stress; Water governance and management.

The map below shows that between 1950 and 2025 the number of countries with low water availability will increase sharply. Therefore, According to Population Action International, based upon the UN Medium Population Projections of 1998, more than 2.8 billion people in 48 countries will face water stress, or scarcity conditions by 2025. Of these countries, 40 are in West Asia, North Africa or sub-Saharan Africa.[2]
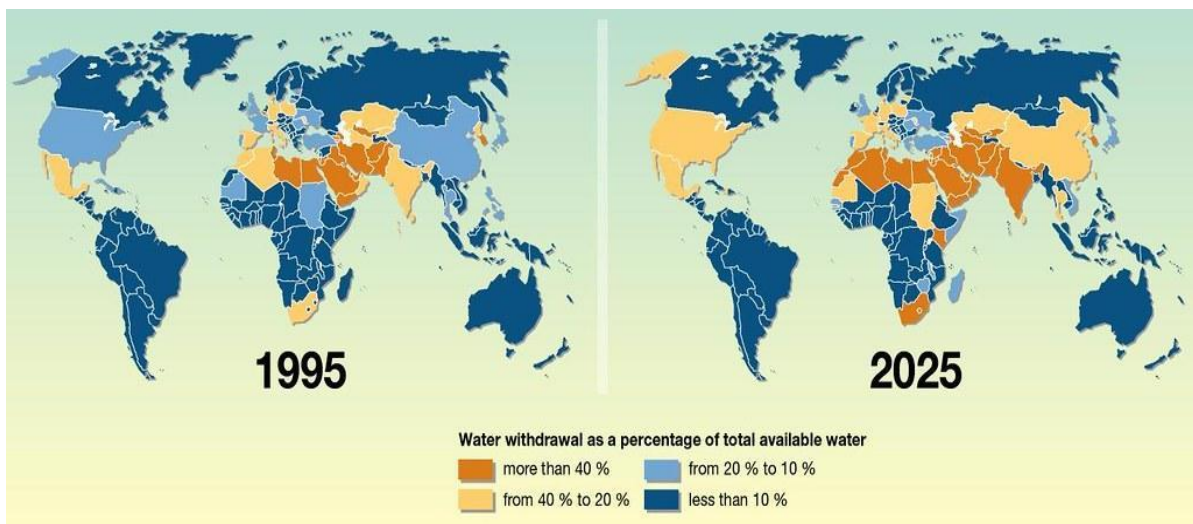
Figure 1. 1: Water availability in the world between 1950 and 2025.[2]

2. Seawater desalination:

Seawater desalination is the process of removing salt and other minerals from this last to make it safe and usable for human consumption and other purposes and uses like agricultural and industrial uses. With growing populations and increasing water scarcity, seawater desalination has become an important source of freshwater in many regions, particularly in arid and coastal areas. This technique does not exert any pressure on the aquifers or even on rivers and makes it possible to be independent of fluctuations in precipitation and even climate change.[4]

2.1. Origin and expansion of desalination technology:

The origins of desalination technology can be traced back to ancient times, where people in arid regions used natural processes such as distillation to produce freshwater from saline water sources. However, it was not until the 20th century that desalination technology began to develop as a modern scientific process.

The first commercial desalination plant was established in 1928 in Aruba, using a process called multi-stage flash distillation. This plant was used to produce freshwater for the local population, as well as for use in the nearby oil refineries. [5]

Over the next few decades, advances in technology and improvements in energy efficiency led to the development of other desalination methods, including reverse osmosis, electrodialysis, and nanofiltration. These technologies enabled desalination to become a more viable and cost-effective solution to water scarcity in many regions, particularly in the Middle East and North Africa.

2.2. Desalination techniques:

Current water desalination technologies are classified into three categories, depending on the principle of separation applied: Thermal processes, membrane processes, and membrane distillation methods. Several techniques have been developed in both types of processes and are presented below.
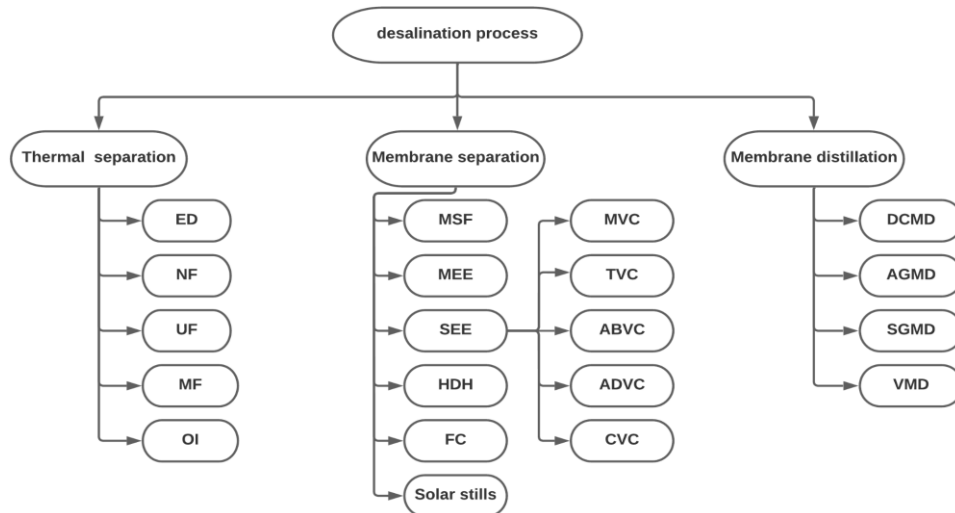
Figure 1. 2: Desalination techniques.

2.2.1. Thermal separation methods:

Thermal separation techniques include two broad categories, the first being evaporation followed by condensation of the water vapor formed, while the second represents freezing followed by melting of the water ice crystal formed. Among the thermal separation processes using the evaporation technique, we find:

A. Multi-stage flash desalination (MSF):

This technique uses a series of chambers, each having a successively lower temperature and pressure, to rapidly vaporize the salt water. The steam is then condensed through inlet water pipes, allowing energy to be recovered. Despite its significant energy needs, MSF is one of the most widely used desalination technologies.[6]

B. Multiple effect evaporation (MEE):

MEE systems can have many possible configurations, basically characterized by the arrangement of heat exchanger tubes. It is increasingly used when thermal evaporation is preferred or necessary due to its consumption lower energy than MSF. [6]

C. Single Effect Vapor Compression (SEE):

Vapor compression is an evaporation process in which the vapor from the evaporator is compressed (mechanically, or using high pressure steam) and its heat is used for the subsequent evaporation of the feed water. The compression units of steam tend to be used when cooling water and low-cost steam are not readily available. [6]

D. Humidification-dehumidification (HDH):

It is described as a new method of volume reduction that uses a carrier gas for the thermal desalination of water. Currently used for small scale desalination ladder. The advantages of this process include its low energy consumption, as well as its simple design and commissioning. [6]

E. Solar stills:

This technique uses solar thermal energy. IT, as well as HDH differ from others evaporation process by the following elements:
- Water evaporates at temperatures below boiling point.
- The main driving force of evaporation is the difference in water vapor concentration in the airflow.
The only thermal separation process employing the freezing technique, so far is the "Freeze Concentration" [6]

F. Freezing Concentration (FC):

This process focuses on the extraction of water from a solution, by crystallization. This is resulting in the freezing of water into high purity ice crystals while pollutants organic and inorganic are concentrated in the rest of the solution. [6]

2.2.2. Membrane separation methods:

In water desalination, a membrane is a thin layer of material that acts as a physical barrier to separate dissolved salts and other impurities from water. The membrane allows water molecules to pass through, while blocking the larger salt ions and other impurities from passing through. The use of a membrane in water desalination is a key component of membrane separation methods such as reverse osmosis, nanofiltration, ultrafiltration, and microfiltration. The membrane is usually made of a polymer material, such as polyamide, cellulose acetate, or polyether sulfone. These materials have properties that make them suitable for use as membranes, including their ability to form a selective barrier and their resistance to fouling and degradation in harsh environments. Membrane technology has become an increasingly important part of water desalination, as it offers a reliable and cost-effective way to produce clean, fresh water from seawater or other sources of brackish water.
The effectiveness of the membrane in water desalination depends on several factors, including the size and shape of the pores or channels, the chemical composition of the membrane material, and the operating conditions of the system. Membrane fouling, which occurs when impurities accumulate on the surface of the membrane, can also affect the performance of the membrane and may require periodic cleaning or replacement of the membrane.[7]
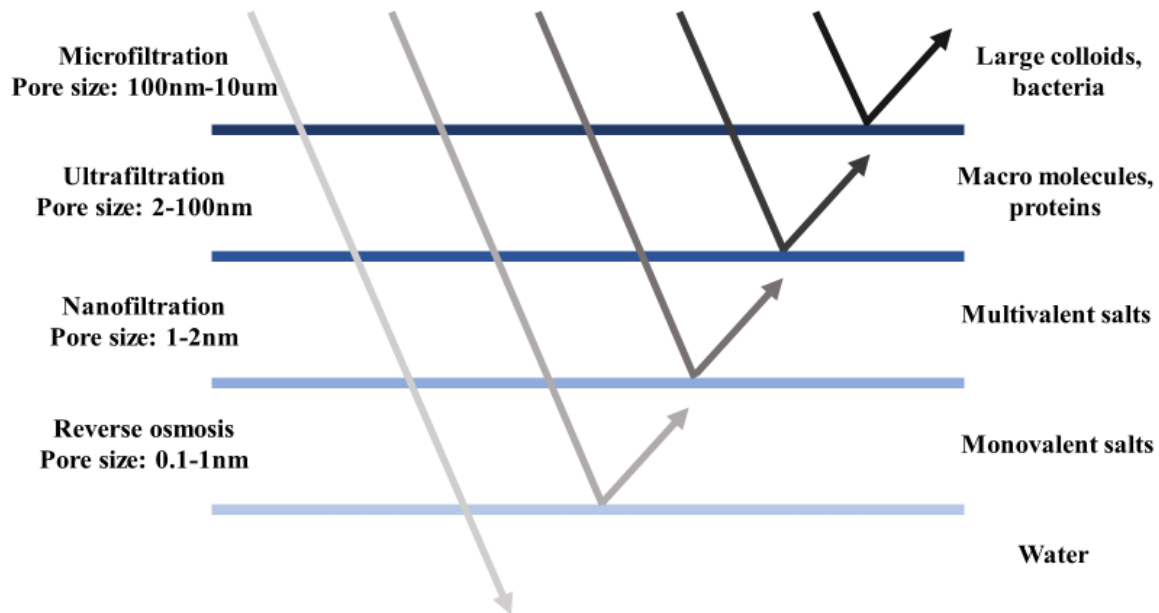
Figure1. 3: Classification of membranes for water purification in terms of pore size and retained species.

A. Electrodialysis (ED):

It is a membrane separation method that can be used in water desalination to remove dissolved salts and other ionic impurities from water. ED operates by applying an electric field across a series of alternating cation and anion exchange membranes, which selectively allow positively or negatively charged ions to pass through while blocking the opposite charge. [7]

B. Nano-filtration membranes (NF):

Nanofiltration operates by using a semi-permeable membrane with pressure differences between 0.5 and 1.5 MPa. In the NF process, seawater or brackish water is fed into a pressure vessel that contains the NF membrane. Water is forced through the membrane under pressure, allowing water molecules and some small ions to pass through the membrane while retaining larger ions and particles such as salt, bacteria, and viruses.NF is an effective desalination technology for removing multivalent ions such as calcium, magnesium, and sulfate. This is because the NF membrane has a pore size that is small enough to remove these ions, but not so small that it removes monovalent ions like sodium and chloride, which are important for water quality and human health. [7]

C. Ultrafiltration membranes (UF):

They are used to remove color, heavier dissolved organic compounds, bacteria and some viruses. UF membranes also operate through a sieving mechanism under a pressure difference between ~50 and 500 kPa. [7]

D. Microfiltration membranes (MF):

They are used to reduce turbidity and remove suspended solids and bacteria. MF membranes use a screening mechanism with a pressure difference between ~50 and 500 kPa. MF membranes have a high flux rate, which means that they can process water quickly and with less energy input. However, MF is not effective at removing dissolved ions such as salt, which limits its use as a standalone desalination technology. [7]

E. Reverse osmosis membranes (RO):

They are used to remove salt in brackish water and seawater applications. RO membranes have also been shown to remove significant amounts of certain molecular organic water contaminants. Reverse osmosis removes contaminants by diffusion of the solution and operates under a difference in membrane pressure between 5 and 8 MPa. [7]

2.2.3. Membrane distillation methods:

Membrane distillation is a relatively new process. The concept of distillation membrane came from the classic distillation process. These two processes are based on vapor-liquid equilibrium. There is a phase change in the process. But the operating temperature in membrane distillation is much lower than the boiling point of the solution to be treated. Membrane distillation is divided into four types configurations, depending on the condensation method used: Membrane Distillation Direct Contact Distillation (DCMD), Air-gap Membrane Distillation (AGMD), Distillation Gas Swept Membrane (SGMD) and Vacuum Membrane Distillation (VMD). [9]

2.3. Comparison between desalination techniques:

2.3.1. Types of energy used in desalination processes:

There are several types of energy that can be used in desalination processes, including:

A. Thermal energy:

Thermal desalination processes, such as MSF, MEE, HDH, MD, use thermal energy to evaporate and condense water, which removes salt and other impurities from the water. Thermal energy can be provided by a variety of sources, including fossil fuels, nuclear energy, and renewable sources such as solar energy. [6]

B. Electrical energy:

Electrical desalination processes, such as reverse osmosis (RO), use electrical energy to pump water through a semipermeable membrane, which removes salt and other impurities from the water. Electrical energy can be provided by a variety of sources, including grid electricity, generators, and renewable sources such as solar and wind energy. [6]

C. Mechanical energy:

Mechanical desalination processes, such as mechanical vapor compression (MVC) and mechanical vapor recompression (MVR), use mechanical energy to compress and expand a vapor stream, which removes salt and other impurities from the water. Mechanical energy can be provided by a variety of sources, including electricity and combustion engines. [6]

D. Solar energy:

Solar desalination processes use solar energy to generate heat, which is used to evaporate and condense water, removing salt and other impurities from the water. Solar energy can be used directly in thermal desalination processes such as solar stills, or indirectly in electrical desalination processes such as RO, where solar panels are used to generate electricity to power the process. [6]

Overall, the choice of energy source for a desalination process depends on a variety of factors, including the availability and cost of energy sources, the local climate and geography, and the specific desalination technology being used.

2.3.2. The advantages and disadvantages of desalination techniques:

The following table (*Table 1.3)* shows the advantages and disadvantages of the different techniques:

	Membrane separation (RO)	Thermal separation (Distillation)	Membrane distillation (MD)
Advantages	• High Efficiency: RO typically removing more than 99% of dissolved salts. • Low Energy Consumption: RO requires less energy compared to other desalination techniques, • Minimal Environmental Impact: RO does not use chemicals, making it a cleaner process.	• Low Operating Costs: Distillation is a relatively simple process that can be operated at low costs compared to other separation techniques.	• Low energy consumption. • Low maintenance: MD systems are relatively simple and require little maintenance.
Disadvantages	• Fouling: Fouling occurs when particles or impurities accumulate on the surface of the RO membrane, reducing its efficiency and increasing operating costs. • Maintenance: RO systems require regular maintenance and replacement of components to ensure their long-term performance.	• Energy-intensive. • Temperature sensitive: Some components may decompose or react at high temperatures, which can limit their use in distillation.	• Low flux rates • Membrane degradation: The hydrophobic membrane used in MD can degrade over time due to exposure to high temperatures and harsh chemicals.

Table 1.3: The advantages and disadvantages of desalination techniques. [8]

2.4. The desalination situation:

Here are some statistics about the desalination situation :

2.4.1. Global situation:

Desalination capacity is growing rapidly: According to the International Desalination Association (IDA), there were over 22,000 desalination plants in operation worldwide; global desalination capacity reached 103.1 million cubic meters per day (m3/day) in 2020, up from 95.1 million m3/day in 2019. This represents a 9% increase in capacity in just one year. [10]

The Middle East is the largest desalination market: The Middle East accounts for a large share of global desalination capacity, with Saudi Arabia, the United Arab Emirates, and Kuwait being among the top desalination users in the world. [10]

Reverse osmosis is the dominant desalination technology: Reverse osmosis (RO) is the most commonly used desalination technology, accounting for around 70% of global desalination capacity. Other technologies used for desalination include thermal distillation, electrodialysis, and nanofiltration. [10]
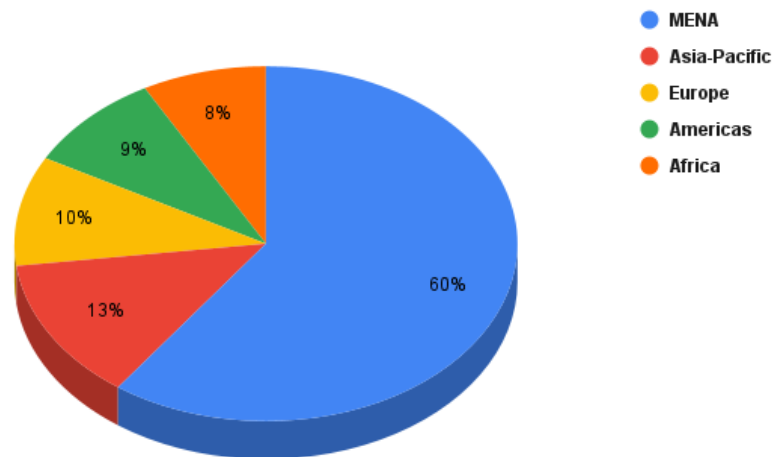
Figure 1. 4: Percentage of Global Capacity by Region

2.4.2.   Situation in the Mediterranean Sea:

In the Mediterranean, the total production of seawater desalination plants in the Mediterranean Sea region was estimated to be over 6 million cubic meters of water per day. This includes desalination plants operating in several countries around the Mediterranean region, including those in the Middle East, North Africa, and Southern Europe.

The largest market for desalination in the region is the Middle East, with countries such as Saudi Arabia and the United Arab Emirates accounting for a significant share of the total production. North African countries such as Algeria, Libya, and Tunisia also have a significant number of desalination plants in operation, while Southern European countries such as Spain and Italy have been increasing their capacity in recent years. [10]

2.4.3.   Situation in Algeria:

Algeria is currently mobilizing 11 billion m3 of water per year, of which 7.2 billion m3/year for agricultural use and 3.8 billion m3/year for domestic and industrial needs. This water comes at a rate of 50% from groundwater, 33% from surface water and 17% seawater desalination. Currently, 11 seawater desalination stations with a production capacity of 660 million m3/year, and 21 small one-piece mobile stations spread over the different willayas. The President of the Republic announced the construction of five large seawater desalination plants, each with a capacity of over 300,000m3/day, whose delivery is scheduled for 2024, which will

be added to the other three stations completed in the suburbs of the capital, with a capacity of 150m3/day. This program will supply 1.4 billion m3/year of desalinated water, i.e., 42% of production of drinking water in 2024, and to reduce the exploitation of surface and groundwater. THE surface water exploitation rate will be reduced from 33 to 20%, and that of exploitation of groundwater from 50 to 20%. [11]

The table below shows some desalination plants located in Algeria:

Desalination Plant	*Location*	*Capacity*	*Technology Used*
Magtaa	Oran province	500,000 m^3/day	Reverse Osmosis
Mostaganem	Mostaganem province	200,000 m^3/day	Reverse Osmosis
Beni Saf	Aïn Temouchent province	200,000 m^3/day	RO and thermal distillation
Algiers	Algiers province	120,000 m^3/day	Reverse Osmosis
Skikda	Skikda province	100,000 m^3/day	Reverse Osmosis

Table 1. 4: desalination plants located in Algeria with their capacity &Technology Used.[11]

2.5. Choice of technique:

The two desalination technologies: Thermal and Membrane require a significant amount of energy. However, the reverse osmosis (RO) membrane technology is considered more advantageous due to its lower energy consumption compared to thermal processes, its ability to treat various types of water (as opposed to only seawater treated by thermal processes), and its high flexibility which allows it to better adapt to production trends
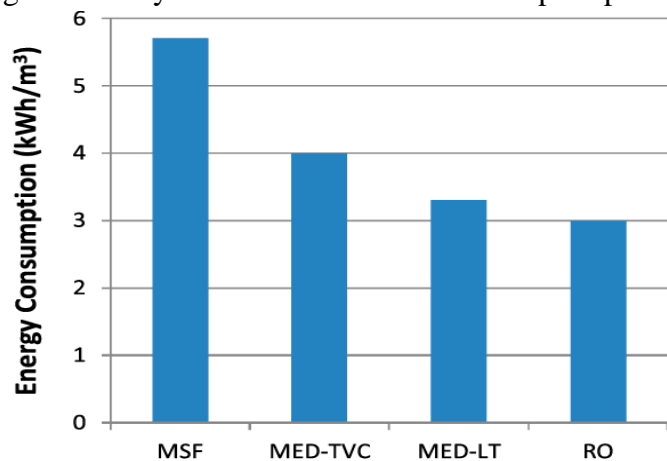
Figure 1. 5: The energy consumption of the different desalination techniques.

Figure 1.5 Given that reverse osmosis is presently the most commonly used process in membrane-based desalination, especially in the specific desalination plant that is the subject of our work, we will focus our attention on this technique going forward.

3.   Desalination by reverse osmosis:

3.1.   Principle of operation:

The Osmosis:

Osmosis is a physical phenomenon where a solvent (such as water) moves across a semipermeable membrane, which allows the passage of solvent molecules but restricts the passage of solute molecules. This movement occurs from a region of lower solute concentration to a region of higher solute concentration until equilibrium is achieved. Osmosis is driven by the concentration gradient between the two regions and does not require the input of external energy. The process of osmosis has important applications in fields such as biology, chemistry, and engineering.[12]

Reverse osmosis:

Reverse osmosis (RO) is a water purification process that utilizes a semi-permeable membrane to remove dissolved solids, organic molecules, and other contaminants from water. In contrast to osmosis, reverse osmosis applies pressure to the side of the membrane with the higher solute concentration, forcing the water molecules through the membrane in the opposite direction. This results in a purified stream of water on one side of the membrane and a concentrated stream of contaminants on the other.[12]
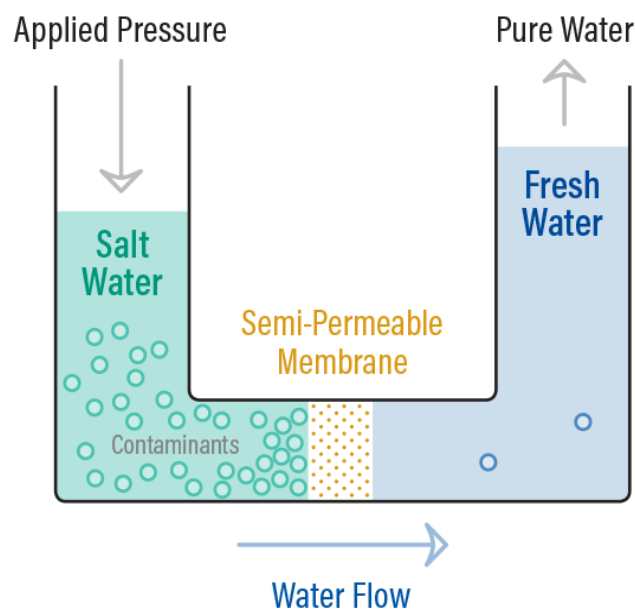
Figure 1. 6: Explanatory diagram of the principle of osmosis and reverse osmosis.[12]

3.2.   Reverse osmosis membranes:

Membranes exhibit a broad range of characteristics, which are determined by their chemical composition and physical structure.

3.2.1.   Chemical natures of membranes:

3.2.1.1.   Cellulose acetate membranes:

The structure of cellulose acetate membranes is asymmetric, featuring a thin surface layer (usually 0.1-0.2 microns thick) responsible for the membrane's salt rejection ability. The remaining portion of the membrane is characterized by a spongy, porous structure that facilitates high water permeability. The performance of cellulose acetate membranes in terms of salt rejection and water flux can be regulated by adjusting the temperature.[13]

3.2.1.2.   Membranes in Polyamide composite:

Polyamide composite membranes consist of a two-layered structure comprising a porous polysulfide support layer and a semi-permeable layer featuring amine chloride and carboxylic acid functional groups. These membranes exhibit a higher specific water flux and lower salt passage compared to cellulose acetate membranes.[6]

3.2.2.   Physical forms of membranes:

Prior to implementation, membranes are typically installed onto support structures known as modules, with two primary configurations used for reverse osmosis applications: hollow fiber and spiral wound modules. Other module configurations, such as tubes, plates, and frames, are utilized in the food and dairy industry. [6]

3.2.2.1.   Hollow fiber modules:

The RO membrane in question is composed of extremely thin tubes, typically ranging in internal diameter from 0.05 mm to 1 mm. These tubes are organized into a cartridge, which may contain anywhere from 50 to over 1000 individual fibers. Water requiring treatment is introduced to one end of the cartridge and dispersed into the fiber cups via a dispenser. The retentate is collected at the opposite end of the cartridge, while the permeate is accumulated within the cartridge itself. [6]
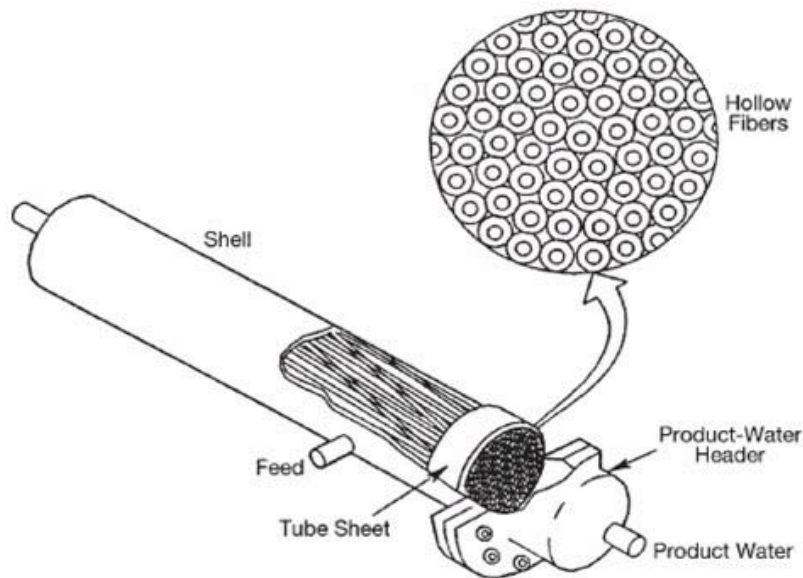
Figure 1.7: Hollow fiber RO membrane module. [6]

3.2.2.2. Spiral modules:

To initiate the spiral construction, two sheets of membrane are sandwiched with a nylon knit spacer, creating a channel for the membranes. The spacer is situated in between the sheets, and the three remaining sides are sealed, allowing the permeate to exit solely from one side. The resulting sheets are combined with a low-density polypropylene spacer that serves as the feed channel for the membranes. Finally, all feed sheets and spacers are wrapped around a permeate collection tube that is punctured to ensure that the open side of the sheet faces the tube.
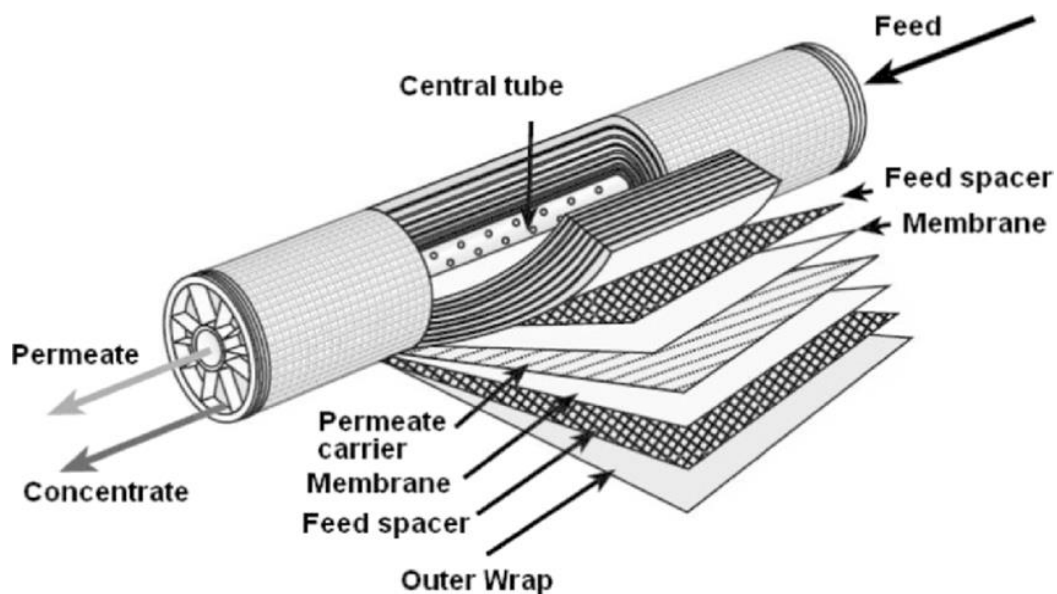
Figure 1.8: Spiral membrane module.

Conclusion:

In this chapter, we have discussed the significance of natural freshwater resources and the limited availability of it in several regions worldwide. This scarcity has led to the necessity of implementing new methods for freshwater supply, particularly through the desalination of seawater.

We have examined various thermal desalination processes and membranes along with their techniques and attributes, with a particular focus on reverse osmosis desalination, which is the topic of our research. This technique is currently the most widely used due to its low energy consumption and high scalability for industrial purposes. However, it cannot be solely relied upon for producing drinkable water since seawater may contain undesirable particles, requiring an additional filtration step.

To ensure the proper functioning of the desalination plant, there should be no inadequacies in terms of measurement instruments and automation actuators. Hence, a comprehensive understanding of the process and adequate instrumentation are necessary, which will be further discussed in the upcoming chapter.

Chapter 2: Description of the station Desalination of EL MARSA in SKIKDA.

Introduction:

Reverse osmosis, which is one of the most widely used desalination processes in the world, involves the use of a partially permeable membrane to eliminate ions and undesirable water molecules from seawater. This is the method employed by modern desalination plants. During this chapter, we will describe the workings of the El-MARSA SKIKDA plant, which is the focus of our study. This plant employs the reverse osmosis technique to produce freshwater from seawater.

In this chapter, we delve into the comprehensive procedure of the desalination plant, starting from the collection of seawater and concluding with the production of potable water. We also explore the sensors that are linked to crucial parameters and the actuators used in desalination systems.

1. The desalination process:

1.1. General description of the desalination process:

The El-MARSA Skikda plant follows a set of fundamental stages to guarantee the production of safe drinking water through seawater desalination. The effectiveness of the reverse osmosis (RO) technique employed in the plant hinges on two primary factors - the efficiency of the membrane and the pretreatment process of the source water. To accomplish this, EL-MARSA utilizes a range of filters and treatments in succession to eliminate a substantial amount of impurities before they can affect the membrane.
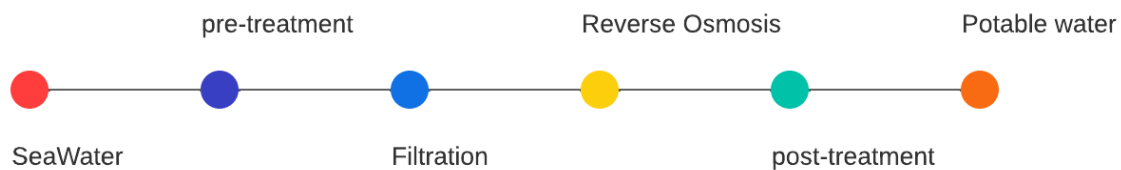
Figure 2. 1: Seawater desalination process

Above, we display a visual representation of how the desalination process operates using reverse osmosis technology at the plant level. Considering the station's "P&ID" (Piping & Instrumentation Diagram - Appendix A), the desalination process progresses through the subsequent stages:
- A seawater pumping station is utilized to extract water from the sea. This station is distinct from our factory.
- A quality control of the pumped seawater is carried out, including the extent of the parameters is as follows:
    - Oxidation-reduction potential (ORP);
    - Electrical conductivity (EC);
    - Measurement of pH and temperature (PH / Temp).

- Then, the water enters the pretreatment stage, which includes the phases and elements following:
    - Coagulation, in a static mixer, with ferric chloride (FeCl3) as a coagulant;
    - Flocculation, in a static mixer, with polymer and hypochlorite sodium (NaClO) as a flocculant;
    - Clarification in a lamellar decanter.
- At the end of the pre-treatment stage, the water is stored in a clarified water tank;
- The clarified water is then injected using feed pumps (3 units) to the sand filters, which represent double layer pressure filters for filtration in depth (8 units). This phase is indeed the first stage of the filtration step.
- In the second stage of filtration and before the water enters the modules of Reverse Osmosis, a treatment of the incoming flow is carried out. This includes:
    - A sodium metabisulphite assay, Na2S2O5 (SMBS);
    - Surface microfiltration in cartridge filters (5 units);
    - A dosage of anti-scaling agent;
    - A dosage of biocide.
- At the end of the filtration phase, a quality control of the arrival flow of RO is carried out, the scope of the parameters of which is as follows:
    - Turbidity;
    - pH/temperature measurement;
    - Electrical conductivity;
    - Concentration of total free chlorine (Cl2);
    - The clogging index (SDI).
- The Reverse Osmosis stage is configured for a single pass, with two (02) units parallel (2 lines or 2 racks);
- Then comes the post-processing step, which includes:
    - A dosage of sulfuric acid (H2SO4);
    - Water treatment using the calcite filter (3 units) to correct the corrosivity (addition of CaCO3);
    - The increase in the pH of the permeate mixed with caustic soda (NaOH), for partial water stabilization;
    - Storing water in a treated water tank;
    - Final disinfection of treated water with NaClO. Although the RO process retains all microorganisms, it is necessary to ensure disinfection at leaving the factory.
- Finally, the resulting drinking water is pumped into the water supply network.

1.2.   **Pre-treatment step:**

The objectives of this stage are to eliminate suspended solids in the seawater, and to supply the clarified water in the quantity required for the sand filters.

The basic preprocessing configuration is as follows:

- A static mixer for coagulation, with FeCl3 as coagulant;
- A static mixer for flocculation, with polymer and NaClO as flocculants;
- A lamellar settling tank;

- A tank for clarified water with three transfer pumps connected (2 for use + 1 backup);
- A sludge tank, connected with a sludge drying bed.
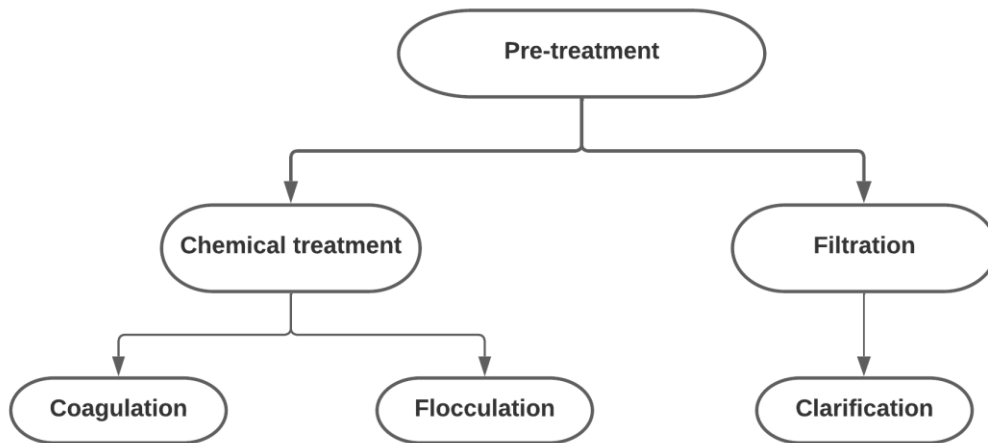
Figure 2. 2: The Pre-treatment phases

As shown in the figure above, the pretreatment is composed of a chemical treatment and sedimentation (filtration). Chemical treatment is usually applied as first step in improving the ability of a treatment process to remove particles.[14]

1.2.1. Coagulation:

The addition of a chemical, such as FeCl3, can result in coagulation, which involves charge neutralization, increased velocity of suspended particles, and intensified collisions between particles. This process ultimately leads to the formation of flocs, a mass of particles large enough to be trapped in the filter.[15]

In principle, any positively charged ion (cation) can serve as a coagulant since most particles in water carry a negative charge.

1.2.2. Flocculation:

Flocculation involves gently agitating particles to encourage their agglomeration into larger macro-flocs that can either settle or be filtered out of a solution. However, the effectiveness of flocculation can be impacted by the ability of flocs to form, which may not always be optimal for settling and filtration. In such cases, different chemical agents like polymers and NaClO may be added to enhance the formation and density of flocs. Nonetheless, there is no guarantee that these agents will improve the ability to deposit or even form a floc.[15]

1.2.3. Clarification:

The process involves allowing the flocs created by the chemical treatment to settle and compact, followed by removing the resulting sludge containing the settled solids.[13] The device responsible for the clarification is the lamellar settling tank schematized in Figure 2.3.
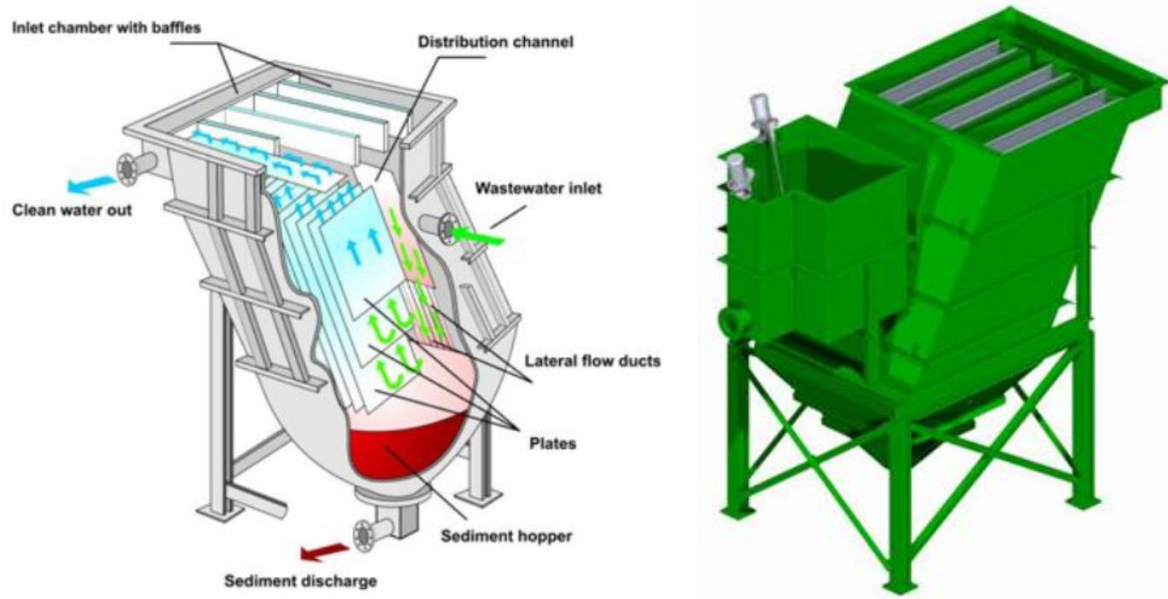
Figure 2. 3: Lamellar settler. [30]

The process of using a Lamellar settler, also known as a lamellar clarifier, separates solids from liquids in the following way:

- Flocculated water enters the settler and flows through the inlet channel, descending to the bottom of the settler before reversing its flow direction and passing upwards through packs of slats.
- Particles settle inside the packs of coverslips and slide down into the sludge funnel.
- Accumulated sludge can be eliminated continuously or discontinuously as needed.
- As the water flows upward through the angled lamellae, the particle's path is determined by the suspension flow and settling rate, resulting in a sedimentation velocity that forces the particle down the slat bundles, causing the sludge to slide downwards.
- Finally, the clean water flows upward and is discharged through the outlet.

1.2.4. Sludge treatment:

Sludge treatment consists of removing the sludge from the pre-treatment, and pumping it into the drying beds to reduce its quantity and ensure easier handling and unloading.

1.3. Filtration step:

One of the primary processes for treating water is filtration, which involves removing suspended solids from a water suspension by passing it through a bed of granular media using primarily physical means. Filtration is particularly effective in removing turbidity, color, micro-organisms, and particles from water, whether they were present in the water or formed as a result of pretreatment.[17]

The basic filtration configuration is as follows:

- Eight sand filters for depth filtration;
- Five cartridge filters for surface filtration;
- Two boosters and two pumps for washing the sand filters (1 for the use + 1 backup) .

1.3.1. Double layer pressurized sand filter:

The double layer filter consists of a layer of anthracite, with a thickness ranging between 1.25 and 2.5 mm, resting on a layer f marbled fine sand that is between 1 and 1.5 mm thick. These two layers are reinforced with gravel, and the filter includes six pneumatic valves, which are depicted in Figure 2.4.

Anthracite is a coarse material that has a greater ability to retain impurities compared to fine sand. In situations where the filter system volume is high, dual filter layers are especially effective in removing particles. To maintain the unit's efficiency, an automated backwash mechanism is used for the dual-layer filters, utilizing a combination of air and water.[18]

Operations		
Stage	Valves Open	Valves Closed
Backwash	V3 & V4	V1, V2, V5 & V6
Rinse	V1 & V5	V2, V3, V4 & V6

Note: Full automation of this process can be provided

V1 - Inlet
V2 - Outlet
V3 - Backwash Inlet
V4 - Backwash Outlet
V5 - Rinse Outlet
V6 - Air Release
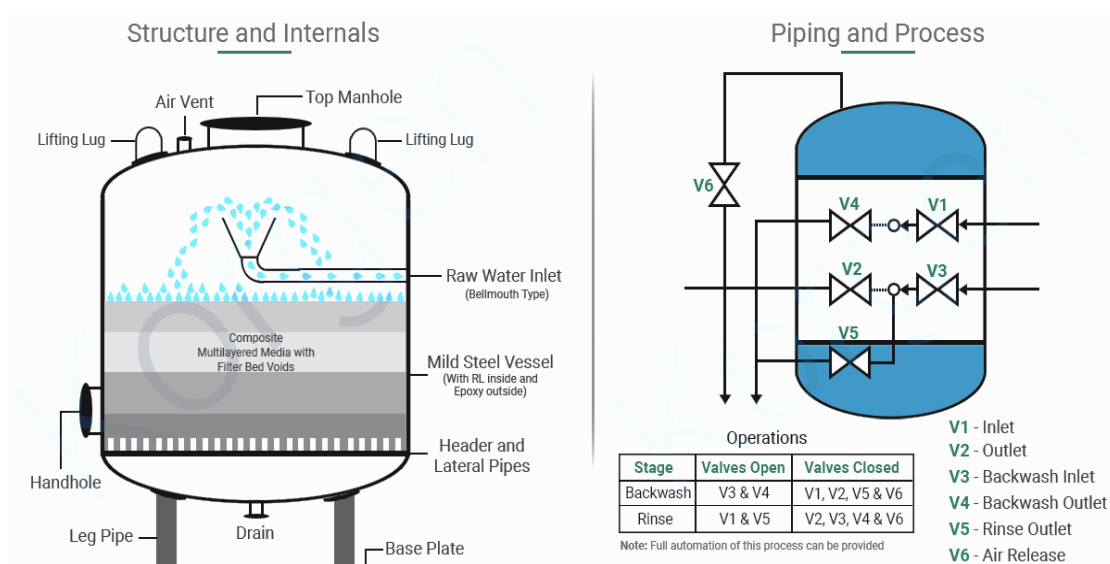
Figure 2. 4: Sand filter

1.3.2. Cartridge filters:

The cartridge filter is cylindrical in shape and contains a filter cartridge. The filter can be easily accessed through a lid on top of the cylinder. The filter cartridges are made of either vegetable fiber or synthetic materials that are pleated in a star pattern to increase the filter surface area without enlarging the cartridge. The quality of the filter is enhanced by making the pleats narrower.[19]

The main objective of the cartridge filter is to use surface filtration to eliminate larger residual particles, which in turn protects RO membranes from mechanical harm.

Figure 2. 5: cartridge filter

1.3.3. Resulting water quality:

After the pre-treatment phase and the filtration phase, the filtrate leaving the cartridge filters must meet strict quality criteria in order to be used for the RO step. The criteria are as follows:

Criteria	Value
PH	Between 7.6 and 7.8
Clogging index (SDI)	≤ 5
Turbidity	≤ 0.5 NTU
Total chlorine concentration Cl2	≥ 0.1 mg/l

Table 2.1: Filtered water quality criteria.

A filtrate that does not meet any of the above criteria is not allowed in step of OI and must be rejected.

1.4. Reverse osmosis step:

The Reverse Osmosis stage involves filtering seawater through a membrane under high pressure (HP), which is the actual desalination process. The purpose of this step is to minimize the amount of dissolved solids in the pre-treated and filtered seawater and to generate permeate at a specific flow rate and quality level as the following:

- RO permeate design flow: 10,000 m³/d;
- Concentration of total dissolved solids required in the final RO permeate: ≤ 450 mg/l.

The high-pressure (HP) pumps feed filtered seawater into the RO membranes for treatment, which produces permeate and a discharge of brine. The high-pressure energy of the brine is recovered by an Energy Recovery Device (ERD). After passing through the ERD, the water is then pumped back into the reverse osmosis system using a booster pump known as the "ERD pump". The basic configuration of the RO is as follows:

- Two (02) RO racks, equipped with an "HP" pump, an "ERD" device, and a "ERD" pump, each.
- The "Clean in Place" (CIP) system for pH regulation and cleaning of RO membranes.
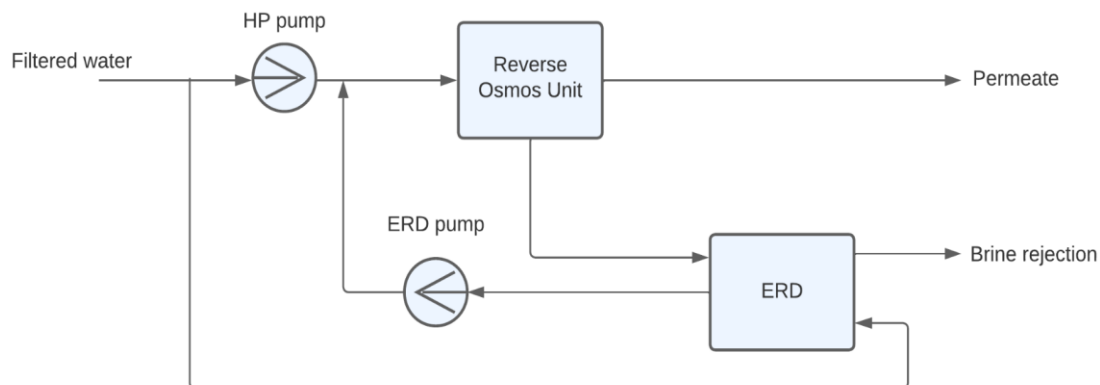
Figure 2. 6: The RO step.

1.4.1. CIP membrane washing system:

When required, the CIP system eliminates biofouling and scaling from the RO membranes. The system for cleaning comprises an 11 m3 tank to prepare the cleaning solution, a heating resistance for the solution if needed, a level detector, a thermometer, a temperature and PH transmitter, along with a CIP pump and a cartridge filter to prevent debris from entering the membranes. This system is used when:

- Normalized salt passage increases by 10%;
- The normalized conductivity of the permeate increases by 10-15%;

- The differential pressure between the RO feed and the brine increases by 10-15%.

The cleaning procedure consists of six steps:

- Replacement of residual liquids (permeate and concentrate) in RO membranes, RO pressure vessels and piping with new permeate;
- Preparation and heating of the cleaning solution;
- Low flow pumping and recycling of cleaning solution through the membranes RO and pressure vessels. This is done at low pressure (≤4 bar) to minimize the production of permeate;
- Soaking with the CIP pump switched off, the cleaning chemical remains in the RO membranes to react effectively with fouling agents and target scales;
- High-speed pumping and recycling of cleaning solution through the membranes RO and pressure vessels. This is also done at low pressure (≤4 bars) to minimize the production of permeate and chase the fallout removed from the surface of the membrane by cleaning;
- Rinse the applied cleaning solution from the RO membranes with new permeate. Continue rinsing until the conductivity and pH of the permeate return to acceptable limits.

1.5. Post-processing step:

The objective of post-treatment is to ensure that the pH is regulated, corrosiveness is addressed, and the treated water is disinfected to make it safe for drinking. The fundamental setup for this process is outlined below:

- Three calcite filters;
- A tank for treated water with two connected water transfer pumps (1+1);
- A motorized valve placed at the end of the production line;
- A suppressor and a pump for washing the calcite filters.

1.5.1. Calcite filters:

The water obtained after the RO phase is distilled water that lacks vital minerals and contains manganese (Mn), which is a newly identified water contaminant. As a result, this water may cause issues like pipeline corrosion, negative health effects, and unpleasant sensory properties. To address these concerns, a calcite contactor is utilized to both remineralize the water and eliminate the manganese content.

The calcite contactor is a pressure filter, in which water passes through a bed of calcite grains while dissolving the carbonate minerals of the grains in the passing water until the pH approaches equilibrium with the calcium carbonate. The dissolution of calcite adds calcium hardness and bicarbonate alkalinity, which are two elements Drinking water essentials needed to minimize water corrosiveness. Furthermore, another interesting advantage of calcite is its ability to absorb metal cations divalent (Me^{2+}) on its surface. Calcite grains must be

periodically added to the bed to replace dissolved media. Figure 2.7 is a schematic illustration of a typical calcite contactor.[20]

Calcite contactors use the same backwash mechanism as dual filters.
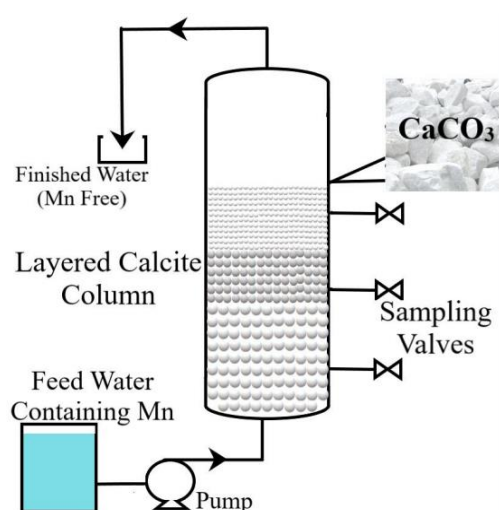
Figure 2. 7: Calcite contactor.

1.5.2. Resulting water quality:

At the end of the reverse osmosis phase, the treated water will have the characteristics represented in the next board:

Criteria	Value
Temperature	Between 13 and 28°C
PH	Between 8,5 and 8,8
Concentration of Total Dissolved Solids (TDS)	≤ 500 mg/l
Alkalinity, CaCO3	≤ 32 mg/l
Conductivity	≤ 900 µS/cm
Turbidity	≤ 0.3 NTU

Table 2.2: Filtered water quality criteria.

1.6. Handling rejects:

The term "rejects" refers to liquids that are disposed of during specific stages of the treatment process. For instance, this may include washing rejects, filtrate that does not meet the criteria outlined in Table 2.1, or the brine generated from the RO process. These liquids are collected in a brine tank and ultimately released into the ocean.

1.7.   dosage:

As previously noted, chemical assays are necessary for treating water. The dosing units used for this purpose typically consist of one or two pumps, as needed, and manual stirrers. The following list provides details on each dosage and its intended purpose:

- Dosage of iron chloride (FeCl3): the injection of FeCl3 allows the destabilization of ionic bonds of water;
- Dosage of polymer: to reinforce the formation of flocs;
- Dosage of sodium hypochlorite (NaClO): in order to eliminate and minimize the formation and growth of bacterial biofilms on the walls of the inlet pipe sea water;
- Dosage of sodium metabisulphite (SMBS): in order to eliminate free chlorine and oxydants ;
- Dosage of antiscalant: to prevent, minimize and control carbon and sulfate scaling in RO membranes;
- Dosage of biocide (DBNPA, empirical formula C3H2Br2N2O): the biocide applied in our station is based on 2,2-dibromo-3-nitrilopropionamide. It works fast with broad-spectrum antimicrobial action, particularly effective when This is to control the growth of algae, bacteria and fungi. The objective of DBNPA is to prevent biofouling in RO membranes;
- Dosage of caustic soda (NaOH): to increase the PH;
- Dosage of sodium hydroxide (H2SO4): the purpose of this dosage is to prepare a low pH acidic solution for cleaning RO membranes.

2.   Instruments and equipment:

In this part, we will discuss the instrumentation used in the EL-MARSA SKIKDA desalination plant.

2.1.   The sensors:

A sensor is an organ for collecting information, which has been developed from a physical quantity, another physical quantity of a different nature representative of the quantity collected can be used for measurement or ordering purposes.

2.1.1. Pressure sensor (PT):

The operator can assess the proper functioning of pumping systems by referring to pressure readings. The underlying principle of pressure measurement involves detecting variations in pressure within a sensing chamber, which in turn triggers movement in a linked mechanism and aligns the indicator element. Moreover, these instruments can serve as primary

sensors for a transmission mechanism, which involves linking a mobile link to a linear and variable differential transformer.[21]

Figure 2.8 illustrates the pressure transmitter.

Its main characteristics are:
Brand : VEGA ;
Reference : VEGABAR 19 ;
Measuring range : 0 to 100 Bar ;
Output : 4-20mA ;
Accuracy : ±0.5% ;
Operating temperature : -40 to 85°C ;
Protection : IP66/IP67.

Figure 2. 8: **Pressure sensor.**

2.1.2. Level sensors:

Level measurement is a technique used to ascertain the amount of fluids in tanks, such as process and storage tanks, silos, or open gutters. The readings obtained from such measurements are translated into electronic signals, which are then integrated into the regulation circuit of process management. This process is further classified into two categories based on the type of measurement method used: continuous and discrete measurement methods[21]

2.1.2.1. Radar level sensor (continuous measurement, LC):

This sensor, also called Micro-pilot, operates by emitting high-frequency radar pulses from an antenna that bounce off the surface of the product due to a shift in the dielectric coefficient. The time it takes for the reflected radar pulse to travel is directly proportional to the distance it has traveled. Its main characteristics are:

Brand: VEGA ;
Reference : VEGAPULS 6X ;
Measuring range : 120m ;
Output : 4-20mA ;
Accuracy : ±1 mm ;
Operating temperature : -196 ... 450 °C ;
Operating pressure : -1 ... 160 bar ;
Frequency : 6GHz, 26GHz, 80GHz ;
Protection : IP66/IP68 (0.2 bar) ,   *Figure 2. 9:* **Radar level sensor.**
          IP66/IP68 (1 bar) .

2.1.2.2. Float level detector (TOR, LS):

The float level switch is a sensor that floats on the liquid to be measured due to its low density. The float is attached to a supported swivel lever and moves according to the level of the product to be measured. Using a permanent magnet, a Reed contact (gas contact inert) is actuated when a predefined switching point is reached.

Its main characteristics are :
Brand : VEGA ;
Reference : VEGAFLO ;
Fluid density : 0.6 to 1.15 ;
Output : 4-20mA ;
Operating temperature : max 85°C ;
Working pressure : max 5 bar ;
Protection : IP68 .

Figure 2. 10: **Float level detector.**

2.1.3. Flow sensor (FM):

Faraday's law of electromagnetic induction is the principle behind the operation of the electromagnetic flowmeter. This law states that when a conductive medium flows through a magnetic field, a voltage is produced, which is directly proportional to the fluid velocity. The magnetic flow meter is best suited for water treatment and other applications that involve pressure drop and conductive liquids.

Its main characteristics are :
Brand : KROHNE ;
Reference : OPTIFLUX 2300 ;
Measuring range : 0…1200 m3/h ;
Output : 4-20mA ;
Accuracy : ±0.2% ;
Operating temperature : max 85°C ;
Operating pressure : 40 bar .

Figure 2. 11: **Electromagnetic flowmeter.**

2.1.4. Process analysis devices:

Due to increasingly stringent water quality requirements, analytical equipment that measures process variables are used more frequently in water systems.

2.1.4.1. PH sensor:

PH sensors are capable of measuring the concentration of hydrogen ions in a given sample and then converting this information into an electrical signal. To make this possible, a PH detection system comprises a reference electrode and a membrane electrode glass. The glass membrane electrode generates a potential that changes based on the PH of the liquid being

measured. By measuring the potential difference between the two electrodes, the resulting signal can be amplified and converted into a PH reading.[22]

Its main characteristics are:
Brand : KROHNE ;
Reference : SMARTPAT PH 1590 ;
Measuring range : 0…14 ;
Output : 4-20mA ;
Operating temperature : 0...+80°C ;
Working Pressure : Max. 5.9 bar at +60°C ;
Protection : IP68 .

Figure 2. 12: **PH sensor.**

2.1.4.2.   Temperature sensor:

Monitoring temperature is crucial in identifying potential installation failures, as an increase in temperature could signal a problem. RTD sensors consist of a metal element that is wrapped precisely within an anti-corrosion sheath. When temperature changes occur, the metallic element's resistance is altered accordingly. This change is then calibrated and transformed into a standard output signal to provide temperature readings.[22]

Its main characteristics are:
Brand : KROHNE ;
Reference : OPTITEMP TRA-P14 ;
RTD element type : 1 x Pt100 ;
Measuring range : -40…+600°C ;
Output : 4-20mA .

Figure 2. 13 : **Temperature sensor.**

2.1.4.3.   Turbidity sensor:

Turbidity in water is caused by the presence of solid particles that are suspended within it. To detect turbidity, sensors are utilized to measure the intensity of light that is scattered by these particles when a light beam passes through the sample. The most commonly used method involves measuring the amount of light that is scattered at a 90° angle from the path of the light beam.

Its main characteristics are :
Brand : KROHNE ;
Reference : OPTISYS TUR 1060 ;
Measuring range : 0…100/1000 NTU ;
Output : 4-20mA ;
Operating temperature : max. +50°C .

Figure 2. 14: **Turbidity sensor.**

2.1.4.4. Electrical conductivity (EC) sensor:

The ionic density of a solution is a determining factor in the level of electrical conductivity exhibited by a liquid. When utilizing inductive conductivity sensors, a minor current is generated within a loop of the solution, after which the sensors gauge the current's magnitude to ascertain the conductivity.

Its main characteristics are:
Brand : KROHNE ;
Reference : OPTISENS IND 1000 ;
Measuring range : 1…2000 mS/cm ;
Output : 4-20mA ;
Operating temperature : max +100°C .

Figure 2. 15: **Electrical conductivity sensor.**

2.1.4.5. Oxidation-reduction potential (ORP) sensor:

The ORP or oxidation-reduction potential is a measure of an aqueous system's ability to either release or accept electrons during chemical reactions. The ORP value is influenced by all oxidizing and reducing agents, not just acids and bases that have an impact on pH measurement. The functioning of the ORP sensor is similar to that of a standard pH sensor, where a two-electrode system is used for potentiometric measurement. In this system, the ORP electrode acts as either an electron donor or acceptor, depending on the test solution. A benchmark electrode provides a stable and constant output for comparison purposes.[23]

Its main characteristics are :
Brand : KROHNE ;
Reference : SMARTPAT ORP 8150 ;
Measuring range : -1500…+1500mV ;
Output : 4-20mA ;
Operating temperature : max +130°C .

Figure 2. 16: **ORP sensor.**

2.1.4.6. Cl2 sensor:

The Cl2 transducer used is a selective electrochemical gas detector which can detect the most common toxic gasses, such as CO, H2S, Cl2, SO2, in many applications. In our case, the detected gas is CL2.

Its main characteristics are :
Brand : KROHNE ;
Reference : SMARTPAT ORP 8150 ;
Measuring range : -1500…+1500mV ;
Output : 4-20mA ;
Operating temperature : max +130°C .

Figure 2. 17: **Cl2 sensor.**

2.1.4.7. Clogging Index Sensor (SDI):

The clogging index serves as a gauge for the density of suspended solids or particles in water. Through the utilization of SDI, one can determine the fouling duration of membranes, the frequency of backwashing, and ultimately, the membrane's lifespan.

Its main characteristics are:
Brand: LOVIBOND;
Reference: ANALYSIS KIT WITH CLOGGING INDEX;
Output : 4-20mA.

Figure 2. 18 : **SDI sensor.**

2.2. The actuators:

The actuators are the components of the operative part which transform the energy received into useful work to carry out the tasks, on command from the control part, often via a pre-actuator. In the various desalination plants, valves, motors and pumps are examples of actuators.

2.2.1. The valves:

A valve is a tool designed for regulating the flow of a fluid within a pipeline, with the ability to either modify or halt the flow altogether. Technologically, a valve can be divided into two parts: the actuator, which provides the force for movement (such as hydraulic, pneumatic, motorized or manual power), and the selector, which either allows or resists the flow of fluid. There are two primary valve categories: On/Off valves, which fully enable or disable the fluid flow, and control valves, which play a crucial role in the control loop by managing fluid flow to maintain a process variable close to a desired set point. The control valve regulates the fluid flow by changing the position of the selector using the actuator's force.
In our research on a desalination plant, various valve types are utilized throughout different stages of the process. The valves are differentiated by their selector form, including the butterfly valve, ball valve, gate valve, valve with valve, and pinch valve. They can be operated manually or automatically using air (pneumatic valves) or motors (motorized valves). The valves employed in the filtration and post-treatment stages are automated on/off valves equipped with two "end of stroke" sensors at either end to indicate valve opening or closing. Conversely, the valves utilized in the metering units are manual control valves.

a. Pneumatically operated butterfly valve.	***b. Manual globe valve***

Figure 2.19: Some type of valve used in the station.

2.2.2. The Motors:

Electromechanical devices called motors transform electrical energy into mechanical energy and find application in different components of desalination systems, such as pumps and agitators. The three-phase asynchronous motor possesses several benefits, including simplicity, durability, and convenient maintenance, which render it highly suitable for use in desalination plants.

Figure 2.20: Three-phase asynchronous motor.

2.2.3. The pumps:

Pumps are employed to transfer fluids by converting energy from kinetics to hydrodynamic energy. The pumps utilized at this facility are single-stage centrifugal pumps featuring an axial suction port. Essentially, a centrifugal pump is a rotating device that propels liquid by pushing it through an impeller. The liquid is drawn into the pump axially via the distributor, then rapidly propelled outward by centrifugal force, and ultimately directed tangentially.

Figure 2.21: Horizontal centrifugal pump.

2.2.3.1. High pressure pumps (HP):

The clarified seawater is typically subjected to pressure ranging from 55 to 85 bars using a high-pressure pump, prior to being fed into the reverse osmosis membranes. The osmotic pressure at this stage is calculated theoretically, providing an insight into the operating pressure of the reverse osmosis system.[22] The osmotic pressure can be calculated with the following formula:

$$P = i \times \varphi \times R \times C \times T$$
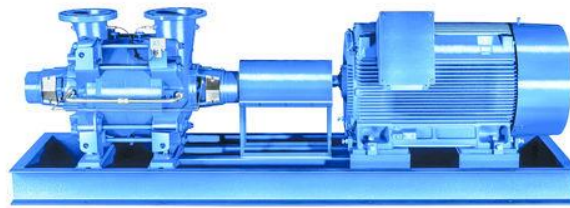
Such as:

i: Number of ions produced during solute dissociation

φ: Osmotic coefficient

R: Concentration of all solutes, (mol/L)

C: Universal gas constant, 0.083145 (L.bar/mol.K)

T: Absolute temperature (K)

Figure 2.22: High Pressure Pump (HP).

2.2.3.2. Energy Recovery Device Pumps (ERD):

The booster pump serves the purpose of amplifying water pressure and flow, which tend to be insufficient at the entrance of the RO membrane, by providing the additional thrust required to attain the desired level of water pressure.[24]

Figure 2.23: ERD Pump (HP).

2.2.3.3. The air compressor:

A compressor is a mechanical organ intended to increase by a process only mechanics the pressure of a gas. The compressor gives pressures of 5 to 15 bars.

2.2.3.4. The air booster:

A suppressor functions as a compressor that elevates the pressure of gasses or liquids within pipes, resulting in added pressure. Specifically, air suppressors are engineered to generate substantial airflow and pressure levels that do not surpass 1 bar.

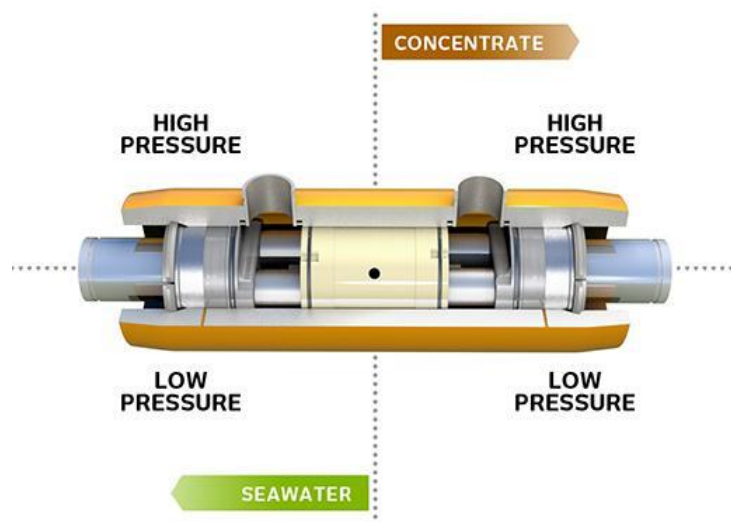## 2.3. Equipment:

2.3.1. The static mixer:

Static mixers are devised to facilitate quick blending of liquids during chemical treatment processes. Their application in continuous operations ensures the production of a homogeneous solution upon exiting.
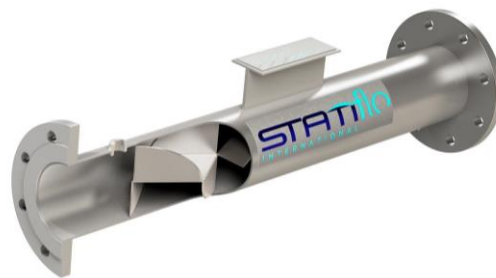
Figure 2.24: **static mixer.**

2.3.2. Isobaric energy recovery device:

The pressure exchanger, also known as a work exchanger, functions by transferring energy from the discharged membrane flux directly to the incoming membrane feed flux. The reverse osmosis membrane's brine discharge is directed towards this device, where it transmits its energy to a portion of the feed water. This energy recovery mechanism allows for the reuse of energy from the rejection process.[24]

Figure 2.25: **Isobaric energy recovery device.**

2.4. The main equipment of the cabinet:

2.4.1. Speed variator:

A variable speed drive is a device designed to control the speed of an electric motor that runs on alternating current, by modifying the frequency, voltage, or current that is supplied to it.[21]

The variable speed drive is essentially composed of:

- A rectifier which, connected to a three-phase power supply, generates a DC voltage residual ripple. The rectifier can be of controlled type or not;
- An intermediate circuit acting mainly on the "smoothing" of the output voltage of the rectifier. The intermediate circuit can also serve as an energy dissipator when the motor becomes a generator;
- An inverter which generates the power signal at variable voltage and/or frequency;
- Control electronics controlling the rectifier, the intermediate circuit and the inverter (signal transmission and reception).

CFW11 from Schneider Electric is the variable frequency drive used for all pumps requiring regulation.
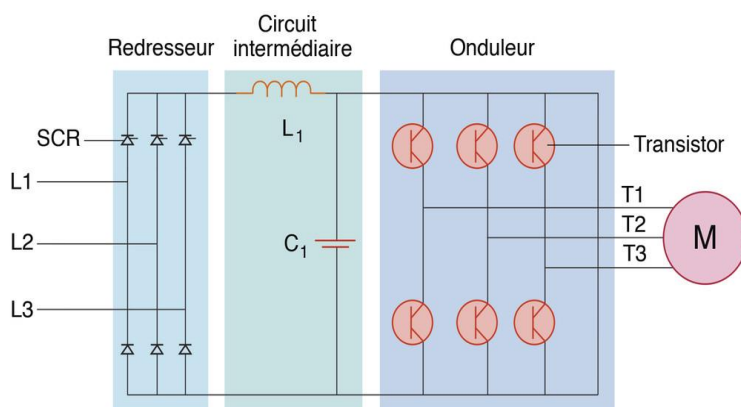
a. main parts of a variable speed drive   *b. The CFW11 variable speed drive*

Figure 2.26: variable speed drive.

2.4.2. Preventa module:

The Preventa is a safety module employed for overseeing emergency stops. It ceases to provide power to the contactor coils when a stop is either activated or has malfunctioned. This module heightens the safety of the installation by employing redundancy, which involves duplicating the components that could be accountable for a breakdown.

Figure 2.27: Preventa module XPSAC.

2.5. Instrumentation report:

The following table presents the results of the instruments used in the station.

Equipment/instrument		Pretreatment	Filtration	RO	Post-treatment	Dosage
Sensor	FM	1	5	7	4	–
	PT	–	4	6	1	–
	LC	1	1	1	1	9
	LS	7	3	–	3	–
	PH	1	1	3	2	–
	Temperature	1	1	1	2	–
	EC	1	1	2	–	–
	Turbidity	–	1	–	1	–
	SDI	–	–	1	–	–
	ORP	2	–	–	–	–
	Cl2	–	1	–	1	–
actuator	Pneumatic valve	–	50	–	15	–
	Motorized valve	–	–	–	1	–
	Pump with variator	3	4	5	3	–
	Pump without variator	2	–	–	1	13
	engine	1	–	–	–	4

Table 2.3: Instrumentation balance sheet.

3. Energy consumption of the station:

The power balance analysis revealed that the correct operation of the station requires a total power of 1411.31 kVA. To meet this requirement, it has been recommended to use two transformers in conjunction with two emergency generators, each having a capacity of 800 kVA.

Phases and Elements	Power (kVA)
Seawater pumping station	423.31
Pretreatment	58.50
Filtration	1.56
RO	614.61
Post treatment	57.72
Dosage	1.71
Control room	5.20
Air compressor	0.35
Accessories (lighting, inverter, fan)	13.14
Total	1176.09 * 1.2
Total power to be backed up (kVA)	1411.31

Table 2. 4: Energy consumption of the different phases of the station.

Conclusion:

Through this chapter, we have gained a comprehensive understanding of the production cycle of seawater desalination and its essential requirements. As a result, we have developed an energy balance and an instrumentation balance, which will prove highly beneficial for automating the station. In the subsequent chapter, we will delve into the programming and hardware configuration aspects, building upon the knowledge gained from this chapter.

Chapter 3: Programmable Controllers and Associated Software

introduction:

When a system can transition from its initial state to an event without any human intervention and this behavior is repeated whenever the initial conditions are met, it is considered automated. Programmable logic controllers are primarily used for automation, which results in faster processing, more consistent outcomes, and eliminates tedious and repetitive tasks.

This chapter provides a brief overview of programmable logic controllers, explains the selection of the automation system for our desalination plant, and offers a brief tutorial on the software used to develop our program.

1.   Industrial Programmable Logic Controllers (PLC):

Programmable Logic Controllers (PLCs) are electronic devices designed for use in industrial settings, which utilize computer programs to process input data from sensors and send commands to actuators. Their primary function is to automatically manage control systems for industrial electrical installations.[25]

1.1.   Internal structure of an PLC:

The internal structure of a Programmable Logic Controller (PLC) can include several components, depending on the specific model and application requirements. Here are some of the most common components[25]:

- Central Processing Unit (CPU): This is the core component of the PLC, responsible for executing the program logic and communicating with other devices. The CPU may have one or more processing cores, cache memory, and other features to enhance performance and reliability.
- Input/output (I/O) Modules: These modules provide the interface between the PLC and the external world, allowing it to read input signals from sensors and provide output signals to control actuators. The I/O modules may include analog-to-digital converters, digital-to-analog converters, and other circuitry to handle different types of signals.
- Memory: The PLC uses memory to store the program logic, data, and configuration settings. There may be several types of memory, including read-only memory (ROM) for storing the firmware, random-access memory (RAM) for storing program variables and other data, and non-volatile memory (NVM) for retaining data even when power is off.
- Communication Interfaces: Many modern PLCs include one or more communication ports, such as Ethernet, serial, USB, or wireless, to connect to other devices in the system. These interfaces allow the PLC to exchange data with other devices, such as HMIs, SCADA systems, or other PLCs.

- Power Supply: The PLC requires a power supply to operate, which may be integrated into the device or provided separately. The power supply may include features such as overvoltage protection, surge suppression, and other safety features.
- Diagnostic and Monitoring Tools: PLCs may include various tools to monitor the system performance, diagnose errors, and troubleshoot problems. These tools may include LEDs, diagnostic software, or built-in self-testing features.
- Programming and Configuration Tools: To create, edit, and download program logic and configuration settings, the PLC may include programming and configuration tools. These tools may include software applications, programming languages, or other tools for designing, testing, and deploying PLC applications.

1.2. PLC programming languages:

There are several programming languages commonly used for Programmable Logic Controllers (PLCs).[26] Here are some of the most popular ones:

- Ladder Logic (LD): This is the most widely used language for programming PLCs. It is based on the traditional relay ladder logic used in electrical control systems, with graphical symbols representing logic functions and input/output devices.
- Function Block Diagram (FBD): FBD is a graphical programming language that uses blocks to represent functions and connections to show the flow of data between the blocks. It is based on the IEC 61131-3 standard and is widely used in Europe.
- Structured Text (ST): ST is a high-level programming language based on Pascal, used for complex programming tasks. It allows the programmer to write code in a structured format using keywords, operators, and functions.
- Instruction List (IL): IL is a low-level programming language that uses a list of instructions to control the PLC. It is similar to assembly language and requires a good understanding of the PLC's internal structure.
- Sequential Function Chart (SFC): SFC is a graphical language that shows the control sequence of a process as a series of steps. It is often used for complex systems that require a structured approach to programming.
- Continuous Function Chart (CFC): CFC is a graphical language that shows the continuous flow of data through a process. It is used for continuous control applications, such as in the chemical and petrochemical industries.

Programmers can choose the most appropriate language based on the complexity of the control system and their familiarity with each language.

2. Choice of PLC to use:

Selecting the right Programmable Logic Controller (PLC) is a crucial step in any project, especially when dealing with sensitive tasks. The choice of PLC is determined by various

factors, including cost, cycle time, availability of spare parts and communication interfaces, as well as the project's technical specifications and requirements. The more critical the tasks to be performed, the more important it is to carefully consider these criteria in the selection process. During the course of this project, we evaluated and examined the required functionalities for our desalination plant. Considering the process's sensitivity and compatibility constraints, we chose the Modicon M580 PLC manufactured by Schneider Electric due to its sturdiness. The programming for this project will be accomplished through the Unity Pro software, and the system's operation will be monitored in real-time using the Citect SCADA.
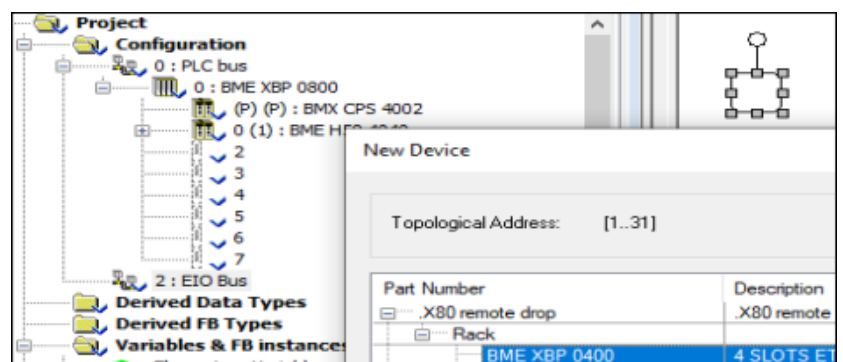
3.   Unity Pro:

Unity Pro is a software workshop that enables programming of Telemecanique PLCs such as Modicon M340, Modicon M580, Quantum, Momentum, Premium or Atrium. It supports multiple programming languages including LD, FBD, SFC, IL, and ST. The following section outlines the fundamental steps involved in creating a project using Unity Pro software.

3.1.   Creating a project:

After opening the software, you must click on the "New" button to choose the API major. To create the "RIO" remote stations, we press "EIO BUS", then we choose the appropriate rack, input/output (I/O) and power supply modules for the project to be completed by double-tapping its slots. Figure 3.1 shows the steps mentioned.
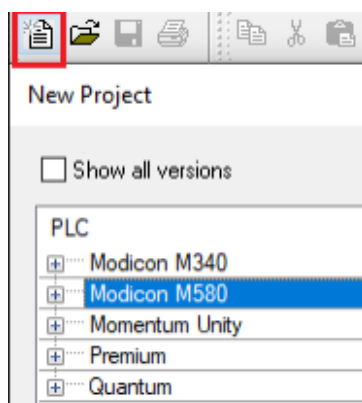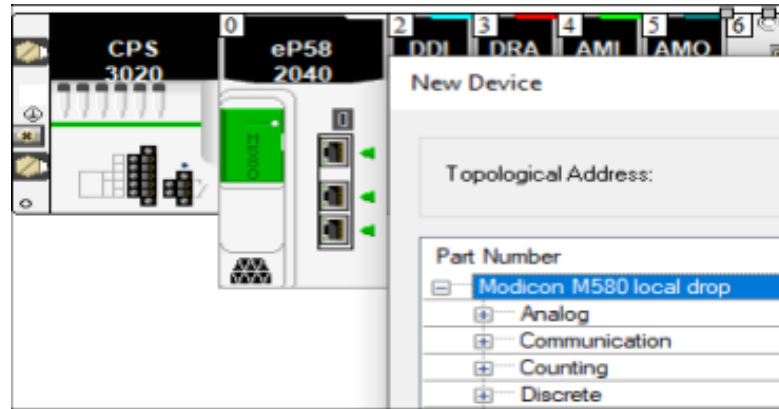

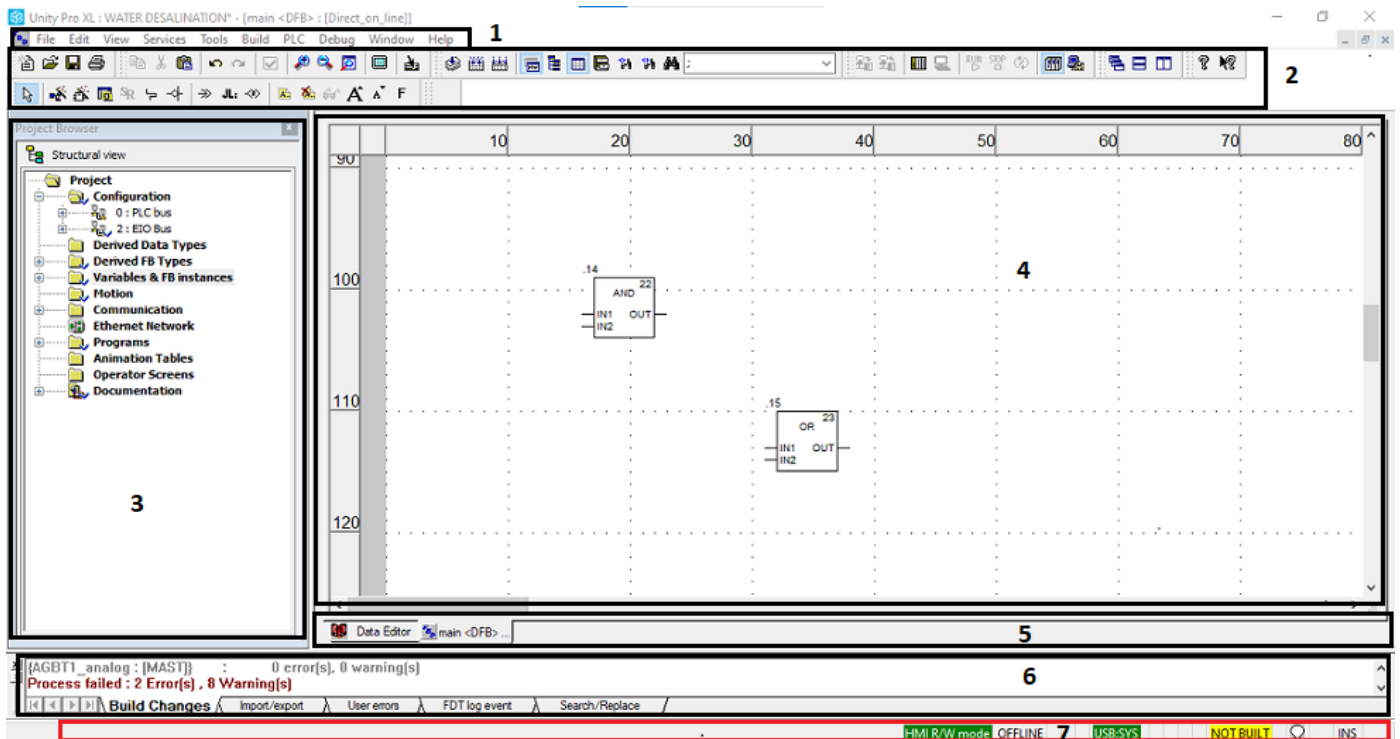*a.   Choice of API*   *b. Choice of rack*

c . Choice of input / output modules

Figure 3. 1: Creating a project in Unity Pro.

At the end of the creation, a user interface is displayed. It consists of several windows and freely positionable toolbars.

Legend:

1: Menu bar, **2:** Toolbar, **3:** Project browser, **4:** Editor window,
5: tabs for direct access to editor windows, **6:** Information window, **7:** Status line.

Figure 3. 2: User interface.

3.2. Variable declaration:

A variable is a memory entity, the content of which can be modified by the program at course of execution. There are different types of variables:

- a variable assigned to an I/O module, which is therefore associated with a memory reference;
- an unassigned variable, whose position in memory is impossible to determine;
- a public or private variable unique to the FBD, where the public variable can be used in SCADA.

To declare an assigned or unassigned variable, just press "Elementary variables" located in the project navigator under "Variables & FB instances". A table appears, which will allow us to edit the data (Data Editor). We enter the name and the type for unassigned variables, while we enter the name, type and address for variables assigned, the following table explains the syntax of a physical I/O address.

Field	Specification
I/Q	Type
	I = Input Q = Output
X/W/D	Format
	X = boolean W = Word D = Double
r	Number of rack
m	Location of modulus on the rack
c	Number of Lane
j	Number of bit

Table 3. 1: Physical addressing of inputs / outputs.

Using mnemonics is a more efficient method of accessing variables that have an assigned memory reference. Symbolic addressing is preferable over absolute addressing, as it greatly enhances the readability and comprehensibility of a program. To declare variables using this approach, one simply needs to enable "Device DDT" (Derived Data Type) in the "Data Editor", specify the name of the I/O module, and then assign "Aliases" (names) to the various data (variables).

Figure 3. 3: Interface for entering variables (Data Editor).

3.3. Elementary functions, Elementary function blocks and derived function blocks (EF - EFB - DFB):

The PLC programming software comes with pre-existing libraries containing models for elementary functions and elementary function blocks. Meanwhile, when a program involves a repetitive logic, a derived function block can be utilized to simplify the process. These user-programmable functions can be written in ST, IL, LD, or FBD and are stored in a library as a set of instructions.

3.3.1. Elementary functions:

The basic elementary functions are as follows:

- Logic functions: this family includes the blocks used to perform logical links, such as: the link AND, OR, NOT and exclusive OR;
- Comparison functions: this family includes the blocks used to compare two input quantities of the same type ($=, \leq, <, \geq, >, \neq$);
- Functions for converting data types;
- Arithmetic functions, such as: addition, subtraction, multiplication, division, and the "Move" function which transfers the value entered at the input at the exit.

3.3.2. Elementary function blocks:

The basic elementary function blocks existing in the "Unity Pro" software are as follows:
- Three types of time delay: the "TOF" time delay (used to perform a time delay on tripping), the "TON" time delay (used for the switch-on delay), and the "TP" timer (used to generate a pulse of defined duration);
- Three types of counters: CTU (used for upcounting), CTD (used for downcounting) and CTUD (used for counting down and up counting).

3.3.3. Derived function blocks:

To create this function, simply press "Derived FB type" located on the browser of the project. The window presented in Figure 3. 4 is displayed in order to create the block and its sections by using the desired language. The program is elaborated in these sections. We add the variables to the DFB according to our needs.
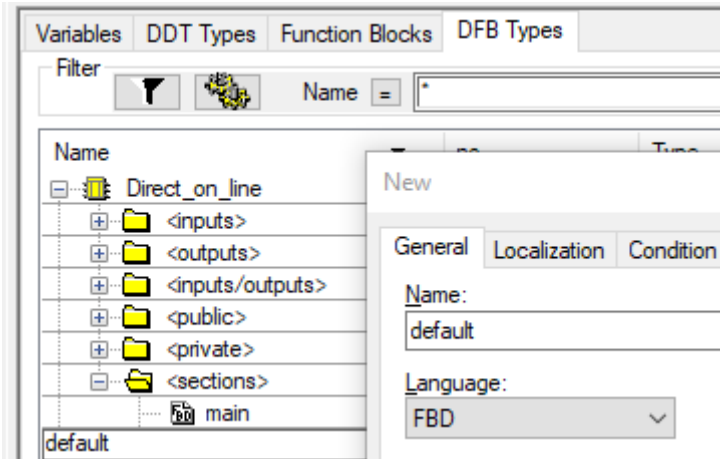

Figure 3. 4: DFB interface.

EFs, EFBs and DFBs are used in the program using the "Data" tool. Selection", located in the toolbar.

3.4. Program development:

In the project browser's structure view, the program sequence to be executed is written in the "logic" subsection of the "MAST" under the "Programs" section. To improve organization and structure, "functional modules" are created for each phase of a project using the "functional view". These functional modules contain sections of logic, written in any programming language available in the software, which are found in the "logic" subsection. This allows for better organization and structuring of the program, particularly when dealing with multiple phases.
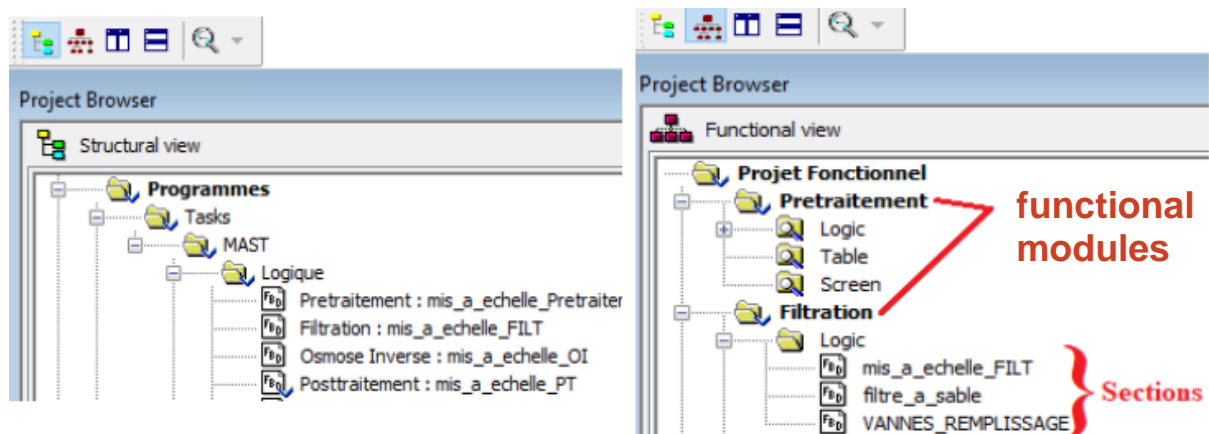

Figure 3.5: The different sections of a program.

3.5. Simulation:

Unity Pro comes with a built-in simulator that enables step-by-step testing of program operations on a simulated CPU. Prior to simulation, the program must be compiled to transform it into an executable file and detect any errors. Compilation is initiated by clicking the "Build" button on the toolbar. To commence the simulation, the "Simulation mode" must first be selected from the toolbar. Next, the virtual API is connected by clicking the "connect" button, and the program is transferred to the virtual API using the "transfer project" button.

Figure 3. 6: The tools used for carrying out a simulation.

4. The SCADA system:

Citect SCADA is the software we will employ for our monitoring solution. Typically, a SCADA system is provided as a combination of software and hardware components, including APIs. These components facilitate communication with equipment within a production center, such as machinery and sensors in a factory, enabling data acquisition. Subsequently, the gathered data is transmitted to the next level, such as a control room. In the control room, operators can oversee PLC controls through human-machine interfaces (HMIs), generate real-time reports based on the data, and archive it for further processing and evaluation.[27]

5. Citect SCADA:

The software consists of two interfaces: the Citect Studio interface and the editor interface for charts. The Citect Studio interface is divided into various activities, including Project, Topology, System Modules, and Visualization. These activities grant access to different functions of the installation through a unified interface. On the other hand, the editor interface for charts enables users to create and edit chart pages.

5.1. Creating a project in Citect SCADA:

To create a project, simply press the "ADD" button located in the interface of Citect studio and enter its name.
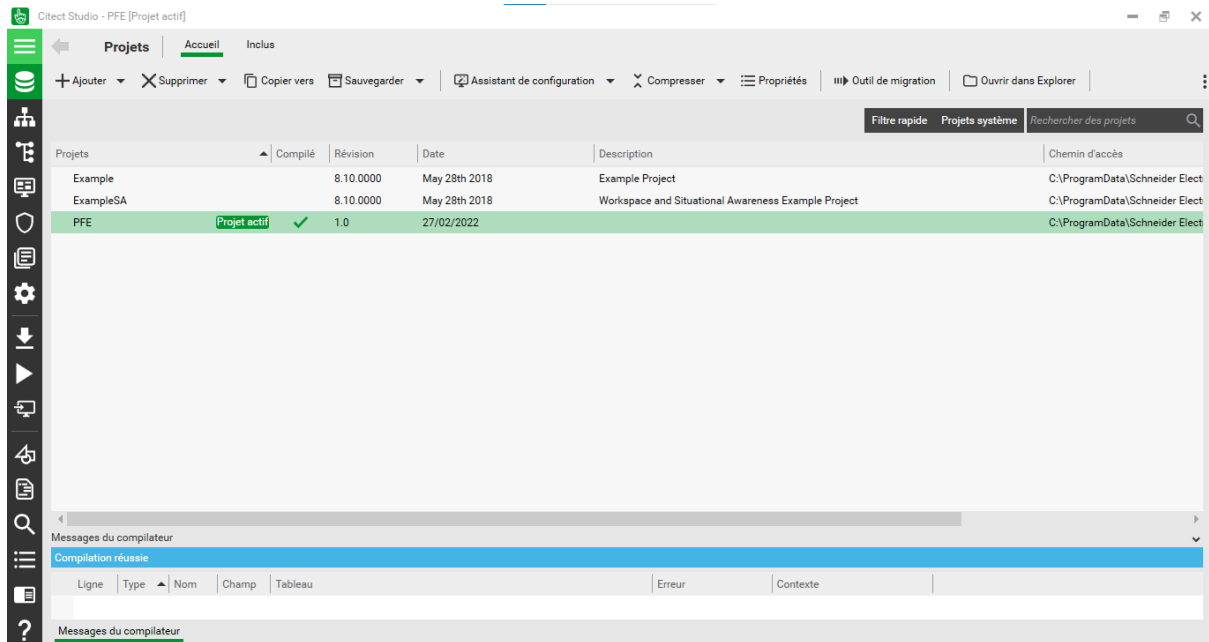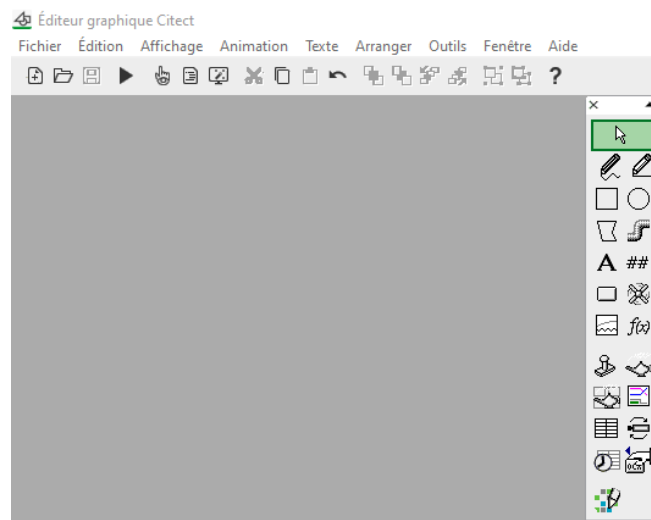
Figure 3. 7: Citect studio user interface.

Figure 3. 8: Graphical editor user interface.

5.2.   Configuring communication between Citect SCADA and the PLC:
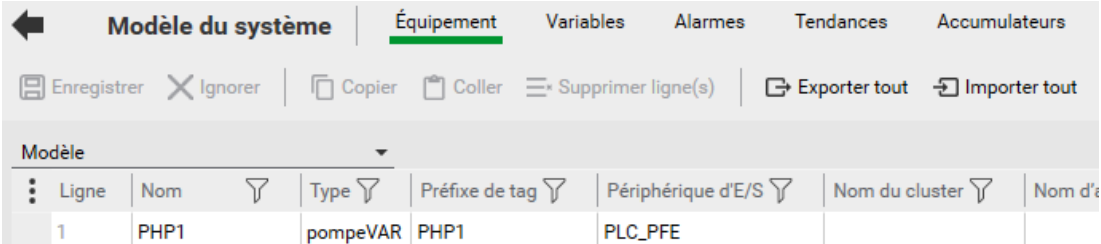
To establish communication between the supervision platform and the PLCs, we utilized the OFS server product. This versatile data server supports communication with various Schneider PLC families, including the M580 series. The OFS server acts as an intermediary between Schneider Electric programmable logic controllers and one or more client applications. These applications enable users to view and potentially modify the data values of the targeted devices. OFS functions as a data access server, allowing reading and writing of data to equipment. To function as the server, it requires knowledge of the network to be used and the specific address of the equipment on that network.[28]
The configuration of the link is carried out by following the steps below:

- Create a new device by selecting the "New Device" icon;
- Define a name that will be used in Citect SCADA for communication;
- Define the IP address of the PAC (real or virtual) in "device address" for a single communication channel.

5.3.   Entering variables:

To enable supervision, it is crucial to have data regarding the status of instruments. To achieve this, the creation of variables for this data is necessary. There are two approaches to accomplish this. The first approach involves directly creating a variable. The second approach entails creating an equipment type that groups variables from a functional block that requires control or monitoring. When needed, equipment of this type can be created. In the Citect SCADA system, variables are addressed using their respective names in the Unity software Pro. However, devices are addressed using the functional block addresses. The "System model" tool within Citect Studio is utilized for configuring equipment and variables. The creation of equipment types takes place in the equipment editor, where variable names, types, and addresses (Tag prefix) are introduced.

Figure 3. 9: Configuration of equipment and variables.

5.4.   The graphics:

We will now show how to create the graphics that make up a screen of supervision, using a small application that will allow us to illustrate all aspects in connection with the creation of graphics.

5.4.1.   Creating a page in the graphic editor:

In order to elaborate the supervision solution, views, geniuses and pop-ups are created. These require a specific type of page for their creation. For this purpose, it suffices press the "New" button on the toolbar of the graphic editor, then choose the type "page_base" for views, the type "Genie" for creating a genie, and the type "page blank" for pop-ups.
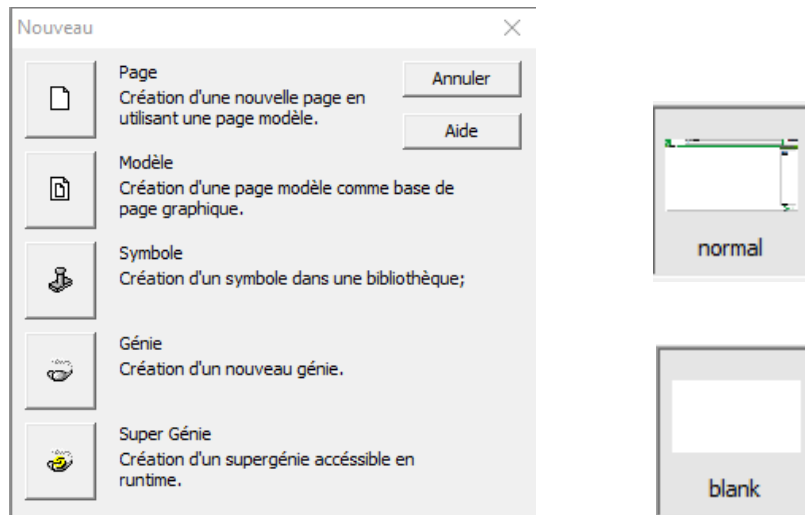
Figure 3.10: Important Citect SCADA page types.

The type of view pages is specifically chosen because of the possibility of switching from one view to another. To declare the views, simply press "Configuration Menu" under "Visualization" located in the Citect studio interface, enter a name and use the function "PageDisplay(name of the view created)" in the "Menu Command" section whose purpose is to display the view created when pressing the name located at the top of the view during simulation.

Figure 3.11: Declaring Views for Visualization.

5.4.2. Creation of geniuses and pop-ups:

A genie is a graphic element allowing to combine several elements between them, to associate with tags, and then add the whole thing (the genie) to the library in order to use it in the views. In the following we will talk about the different tools used for our application which consists in creating the supervision of a pump with variable speed drive. First, we need to draw the symbol by combining elements from the toolbar of the graphic editor (rectangle, ellipse, line, etc.).
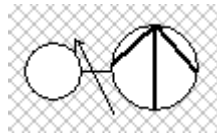
Figure 3. 12: Symbol identifying a pump with variator.

We have employed three circles to enhance the visualization of the pump's operating states. The top circle, depicted in white, remains unseen when the pump is functioning properly or experiencing a malfunction. The second circle, displayed in green, remains hidden only when the pump is faulty. Lastly, the bottom circle, represented in red, remains unseen when the pump is in operation. Figure 3.13 illustrates the characteristic that facilitated this visualization technique.
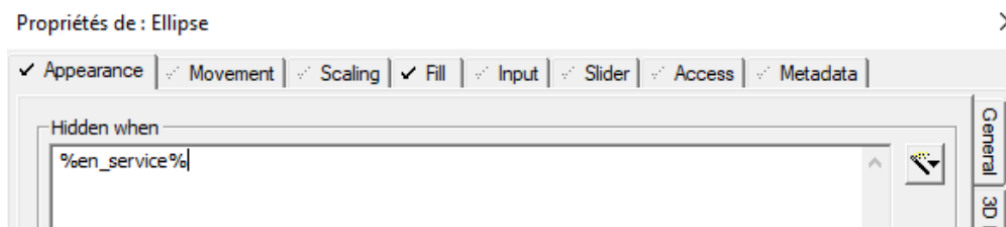
Figure 3. 13: Editing the appearance of an element.

Given the multitude of elements involved in controlling and visualizing a pump, it becomes necessary to employ a highly advanced tool (referred to as a "pop-up" in our system) that comprises buttons and displays. This tool allows for the creation of buttons that can modify process variables by simply selecting the "button" option from the toolbar and entering the corresponding command. Two commands are utilized: "pulse" generates a momentary pulse to the variable, while "toggle" enables or disables the variable upon each click. As it is not feasible to alter the color of a button directly, we have incorporated a rectangular background behind the button that turns green when the variable is activated.
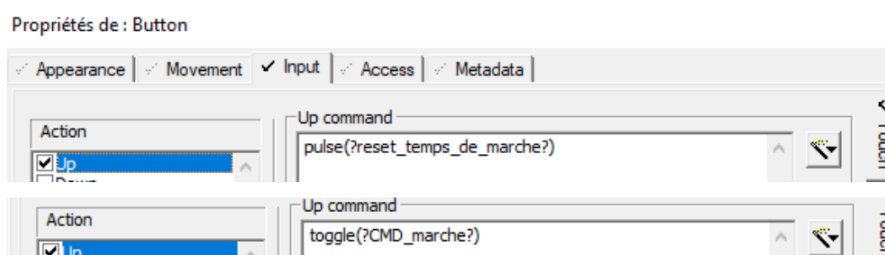
Figure 3. 14: The different commands of a button.
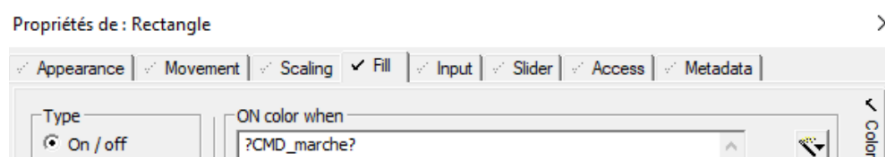
Figure 3. 15: Editing the color of an element.

To create a display, just press "Number" in the toolbar, then enter the variable name to display.

In the case where an entry of a value of a variable and its display are carried out in SCADA, the command shown in the figure below is used to enter the value. The display is done by following the same previous steps.
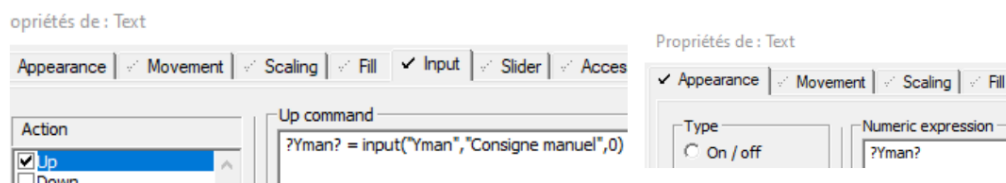
Figure 3. 16: Entering and displaying a variable.

In order to link the pop-up to its genie, we call the pop-up using the function "assmetadatapopup" in an invisible square positioned behind the genius. The "Metadata" tool is used to link the different variables used in the pop-up to those of the equipment.
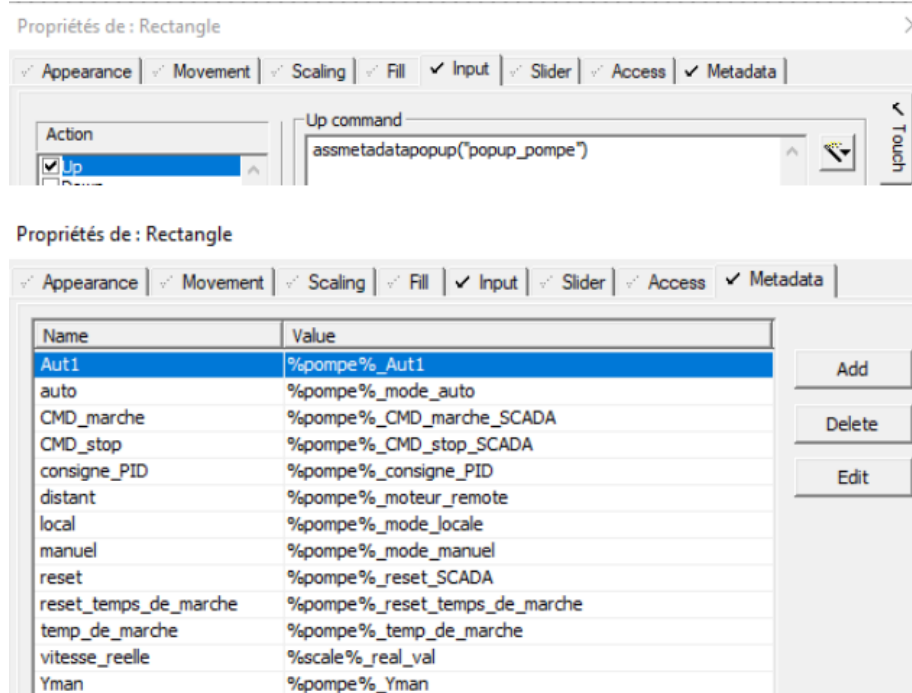
Figure 3.17: Link between pop-up and genie.

Conclusion:

This chapter primarily focused on acquiring knowledge about the usage of Unity Pro software and Citect SCADA. This knowledge will be beneficial for us as we proceed with the development of the automation solution and the subsequent chapter, which will delve into the implementation of supervision.

Chapter 4: Automation Solution and supervision.

Introduction:

To gain control over the station, our approach involves developing a program and integrating it into the M580 automaton. This will be done using the program design software for Unity automation systems, specifically the Pro version from Schneider Electric.

Within this chapter, we will elaborate on the automation program created based on the seawater desalination process discussed in the second chapter. Additionally, we will outline the procedures for system commissioning and the setup of the supervision system within our station.

1. Hardware configuration:

Due to the intricate nature of the station's process and the extensive mechanisms outlined in the specifications, it became essential to distribute the command station accordingly to fulfill the expected specifications and requirements. To accomplish this, the command station will be divided into a primary station (referred to as the master station) and six RIO stations (Remote Input/Output stations). As a result, a rack extension will be implemented to facilitate the organization of the I/O (Input/Output) modules.

1.1. The main station:

This command station consists of a single Rack having a power supply, a CPU and I/O modules.
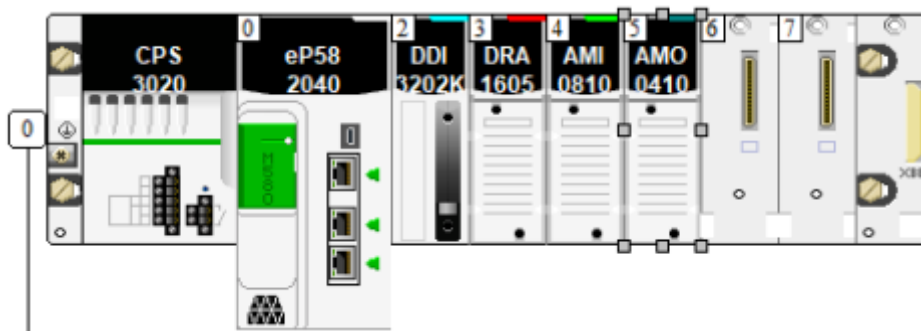
Figure 4. 1: Main station configuration diagram on Unity Pro.

1.1.1. The CPU:

The central element of the command station is the processor board, which plays a crucial role in executing the program stored in memory and interpreting the I/O signals. In a modular command station setup, a dedicated processor card is necessary to enable the configuration of extensions through an Ethernet bus. For our particular case, we will utilize the BME P58xx40 model (with the suffix "40") as the CPU to fulfill this requirement.

The main Features of this CPU are:
- Product range: Modicon M580;
- Reference: BME P58 2040;
- Environmental characteristic: Class I hazardous area Division 2, gas, dust, salt, and sand resistant;
- ATEX equipment;
- This CPU is suitable for harsh and polluted environments.

Figure 4.2: CPU. [29]

1.1.2. I/O modules:

Based on the I/O report, we have established the list of modules in the station rack principal represented in the table below. These modules contain the variables related to HP and ERD pumps.

Module	Number	Signal characteristics	References
32 discrete input modules	1	24V DC	BMX DDI 3202K
16 discrete output modules	1	24VDC/24…240 VAC 2A	BMX DRA 1605
8 analog input modules	1	1…5V / 4…20 mA	BMX AMI 0810
4 analog output modules	1	4…20 mA	BMX AMO 0410

Table4. 1: Main station I/O modules and their main characteristics.

DDI 3202K   DRA 1605   AMI 0810   AMO 0410

Figure4. 3: I/O modules used. [29]

1.1.3. Power supply:

The choice of power supply modules was made after a consumption study based on the current consumed by each module using the "Power Supply and IO Budget" of Unity Pro, as well as the Catalog listing the electrical consumption of the brand mods. The result of this study is shown in the following table:

Module	Current absorbed by the output 3V3 BAC (A)	Current absorbed by the output 24 BAC (A)
CPU	-	0.27
DDI 3202K	0.14	0.11
DRA 1605	0.1	0.095
AMI 0810	0.096	0.034
AMO 0410	0.145	0.137
Total	0.481	0.646

Table 4. 2: Current consumption of the main station modules.

According to the provided table, the 3.3V output draws a total current of 0.481A, while the 24V output draws 0.646A. The selected power module offers a capacity of 4.5A for the 3.3V output and 1.3A for the 24V output, which significantly exceeds the combined current consumption of both outputs. To accommodate this, a Modicon X80 power supply module is installed. Whose main features are:

- Reference: BMX CPS 3020;
- Nominal voltage: 24-48 VDC;
- ATEX equipment;
- Adapted to polluted environments.

Figure 4. 4: Power module. [29]

1.2. RIO remote stations:

Our system comprises six (06) remote RIO stations, with each station consisting of its own power supply module, a BMX CRA 31210 adapter module, and Modicon X80 I/O modules. The stations are specifically categorized as follows: AGBT pre-treatment, AGBT filtration, AGBT OI (Operations and Monitoring), AGBT post-treatment, AGBT dosing, and AGBT valves.

1.2.1. The CRA module:

This module ensures the link and the communication between the extension and the Rack main; it therefore allows the exchange of information between the I/O modules and the CPU to which it is directly connected. Its main characteristics are as follows:

- Reference: BMX CRA 31210;
- Resistant to gas, dust and salt;
- Number of ports: 3;
- ATEX equipment.

Figure4. 5: CRA module. [29]

1.2.2. I/O modules:

For the AGBT valve station, the selection of I/O modules is based on the number of variables associated with the valves (such as valve open or closed). On the other hand, the I/O modules for the remaining RIO stations are chosen based on the number of variables associated with the elements utilized in those respective phases.

Module	DDI	DRA	AMI	AMO
AGBT pretreatment	1 (6402K)	1	1	-
AGBT filtration	1 (6402K)	2	3	2
AGBT RO	1 (6402K)	1	3	1
AGBT post-treatment	1 (6402K) + 1(1602)	1	2	1
AGBT dosage	1 (6402K)	2	2	-
AGBT valves	2 (6402K)	4	-	-

Table4. 3: RIO drop I/O modules.

1.2.3. Power supply:

Following the same approach used in section 0 for the choice of power supply, we deduce that the BMX CPS 3020 module can be used in all remote stations.

1.3. Communication:

The connection between the six (06) RIO remote stations and the main station is made using the Ethernet TCP/IP communication protocol. The PLC and the six CRA modules are connected by a network switch module named "Ethernet switch" through cables Ethernet (RJ45).
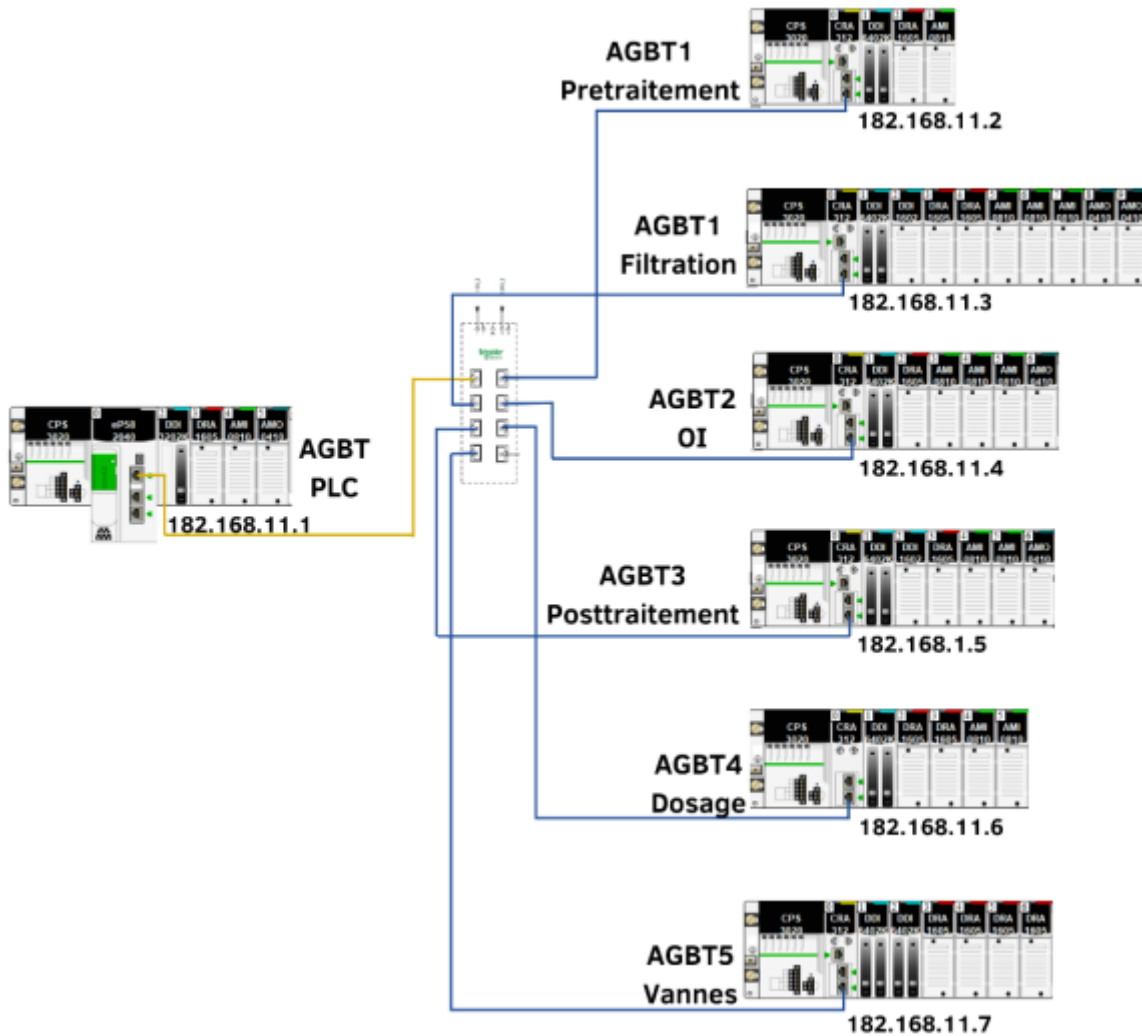
Figure4. 6: Communication between the different stations.

1.3.1. The Ethernet TCP/IP communication protocol:

Ethernet is a local area network (LAN) protocol that relies on switching technology and twisted pair cables to facilitate the connection of multiple machines. It enables these machines to communicate with each other. The TCP (Transmission Control Protocol) ensures the reliable transmission of data in the form of a byte stream, guaranteeing that the data arrives intact and in the correct order. In the event of data loss, TCP employs retransmission mechanisms. Additionally, IP (Internet Protocol) handles the routing of packets from a source to a destination, regardless of their geographical location in the world.

1.3.2. Twisted cables and RJ45 connectors:

An RJ45 connector is used as the physical connector for twisted cables.

Figure4. 7: RJ45 connectors.

1.3.3. The Ethernet switch:

An Ethernet switch is a networking device utilized to establish connections between various devices such as PCs, servers, PLCs, or any other devices equipped with an Ethernet network card within a local network. Its primary purpose is to enable communication between the connected devices, allowing them to interact with one another.

Its main features are as follows:

- Reference: 499NES18100;
- Communication protocol: Ethernet TCP/IP, SSH, http, HTTPS, etc.;
- Ethernet port: 10BASE-T/100BASE-TX - 8 cable port(s) copper ;
- Maximum number of cascaded switches: unlimited.

Figure 4.8: Ethernet switch.[29]

1.3.4. The connection base:

DDI6402K input modules do not have the correct interface to support connection directly with the instrumentation. They are predisposed to receive a slip coming from what one calls a passive connection base.

The Characteristics of the selected connection base are as follows:

- Product range: Modicon ABE7H16R11;
- Type of product or equipment: I/O base all or nothing passive;
- Number of channels: 16;
- Current per channel: 0.5A.

Figure 4. 9: Connection base. [29]

1.4. The input-output balance sheet:

Based on the instrumentation budget, we have established the following I/O budget:

The AGBTs	Inputs		Outputs	
	Discrete	**Analog**	**Discrete**	**Analog**
Main station	22	2	4	2
Pre-treatment	20	5	3	-
Filtration	61	23	18	7
RO	32	24	6	4
Post-treatment	65	15	9	3
Dosage	61	10	27	-
Valve	100	-	50	-

Table4. 4: The entry-exit balance sheet.

2. Station automation program:

2.1. DFB functions:

In order to build the station program, the following functions are created to facilitate the tasks.

2.1.1. The «Scale» function:

The function consists of two sections, namely scaling and default overshoot, which are programmed using the Structured Text (ST) language. Scaling involves processing a signal, such as a process variable, voltage, or current emitted by a sensor (in integer value), and performing calculations to present the signal in engineering units for practical use (actual value). If the incoming signal value exceeds a certain range, a variable called "def_out_of_range" is activated.

For flowmeters, a specific scaling function is required, incorporating the aforementioned sections and an additional section for calculating the total flow. The flowmeter generates a pulse for every 1m3 of water passing through it. The total flow is determined by employing a counter (CTU) that increments with each pulse. A reset button is provided for resetting the counter.

```
real val:= (max - min)/(10000.0)*(int_to_real(int val))+min;
```

a. the section: scaling.
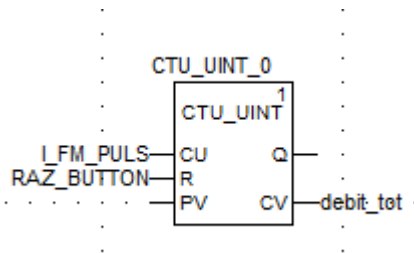

```
if(int val<= -800)OR(int val>=10800)then
def hors plage := true;
end_if;
```

b. the section: overshoot fault

c. the section: calculates the total flow

Figure 4. 10: Program of the "Scale" function.

2.1.2. The «Unscale» function:

This function is practically the inverse of the previous function. It consists of transforming the actual value to an integer value from 0 to 10000.

2.1.3. The "Motor" function:

This is the function that manipulates the operation of all motors used in the station.
It contains the following 5 sections:

- **Default management:** This consists of signaling faults and allowing operators to to pay them after processing.

  - Signaling of defaults: the default is set to 1, if the circuit breaker is open, OR the emergency stop is pressed, OR the drive is default, OR the preventa is in default, OR a mismatch default is present.
  - Acknowledgment of defaults: If the motor is challenging, the operator can press the local OR SCADA "Reset" button to acknowledge the default after having do what is necessary to deal with his case.
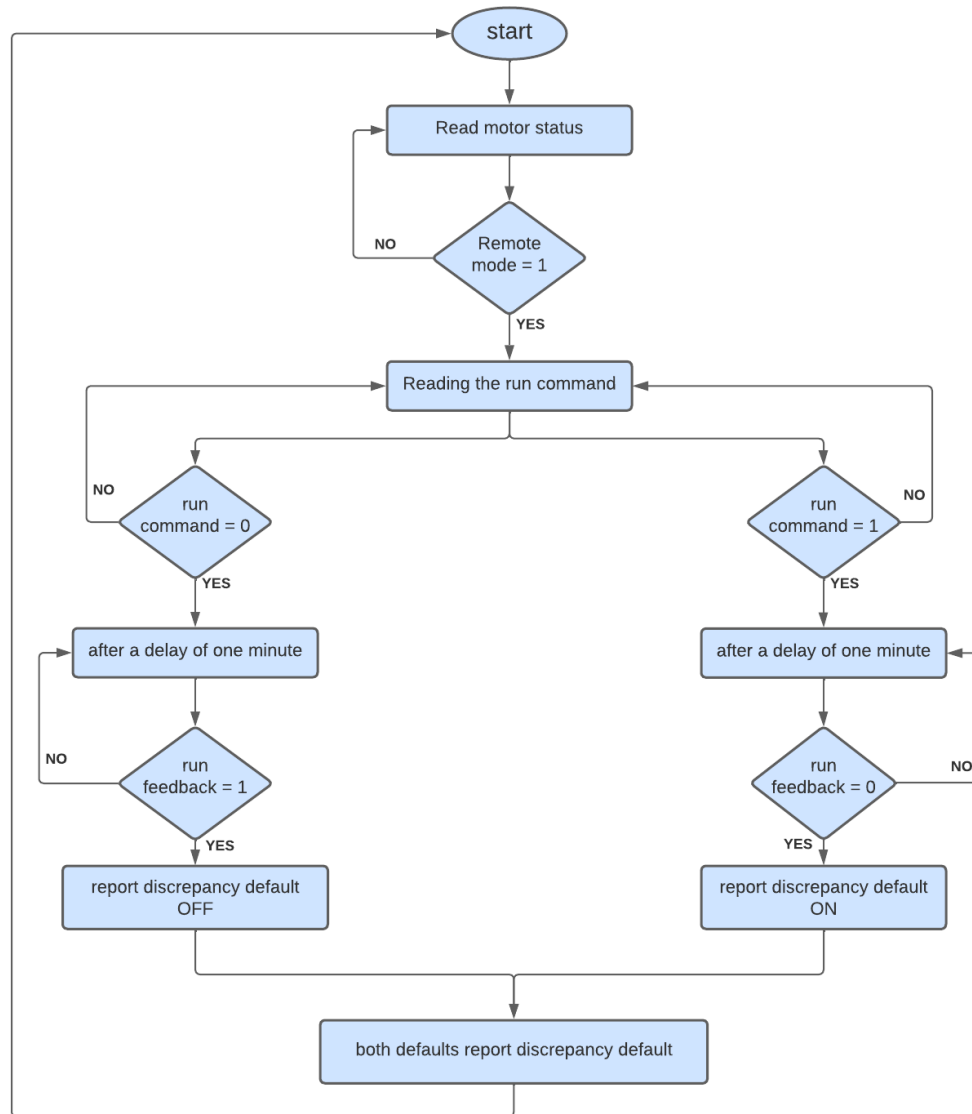
Figure 4. 11: Discrepancy fault detection and signaling flowchart.

o **Calculation of Run time:** It is important to know the period of time during which the motor operated continuously. Using the "%S7" variable specific to the Unity Pro software, which provides a pulse every minute, and using a counter (CTU), the running time is calculated. A reset button is used to the reset.
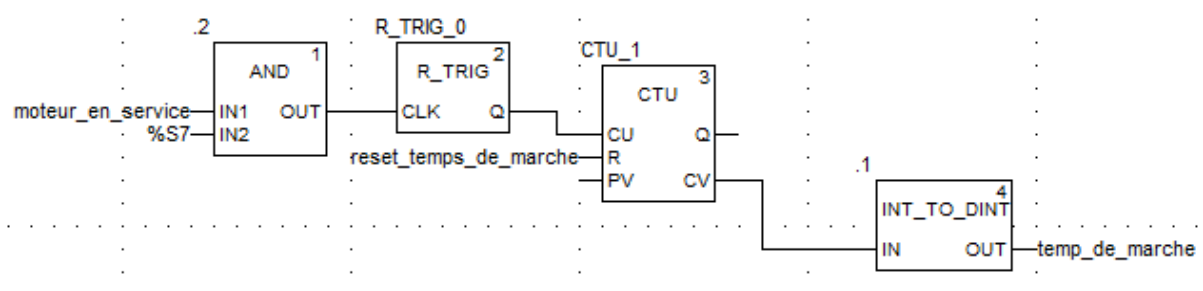
Figure 4.12: Run time calculation section program.

o **Authorization:** Authorization is required for the engine to be put into service. The figure below shows how this section works.
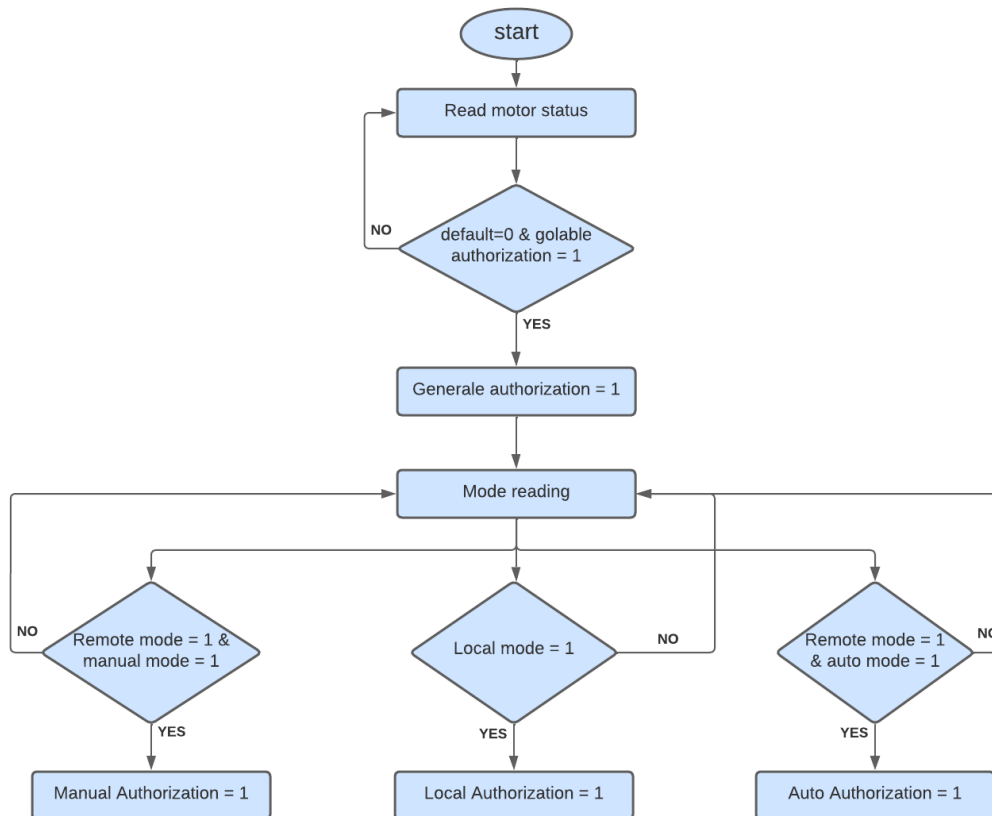
Figure 4. 13: Authorization flowchart.

o **The run command:** This section is responsible for the run command of the motor. If "automatic authorization" = 1 AND "automatic command" = 1, OR "manual authorization" = 1 AND the "marche_scada command" = 1, the command motor run is activated. If "manual authorization" = 1 AND "command stop_scada" = 1, motor run command is disabled. If all permissions are 0 the engine cannot run.

o **The PID regulator:** This section is used only in the presence of the drive of speed. It is used to regulate the speed to reach the desired value. By using the PID module that exists in Unity Pro, the program developed is as follows:
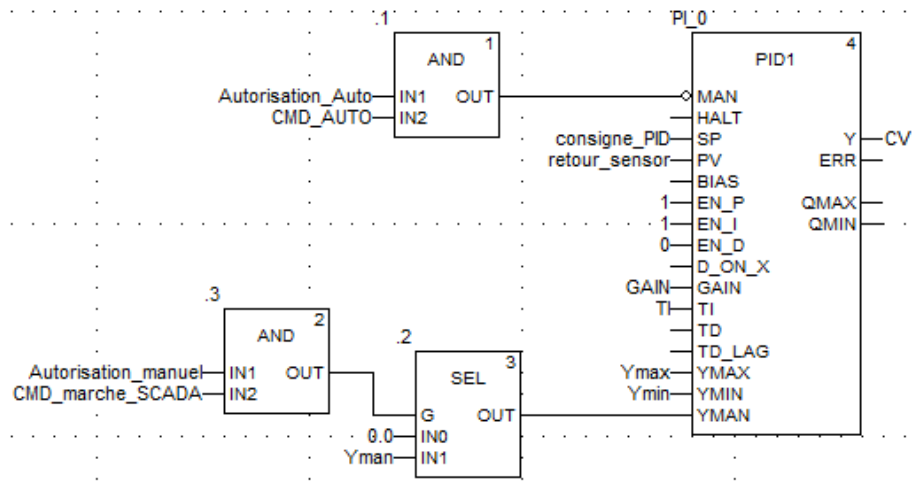
Figure 4. 14: Program of the PID regulation section.

The operation of the PID block is explained in the following figure:
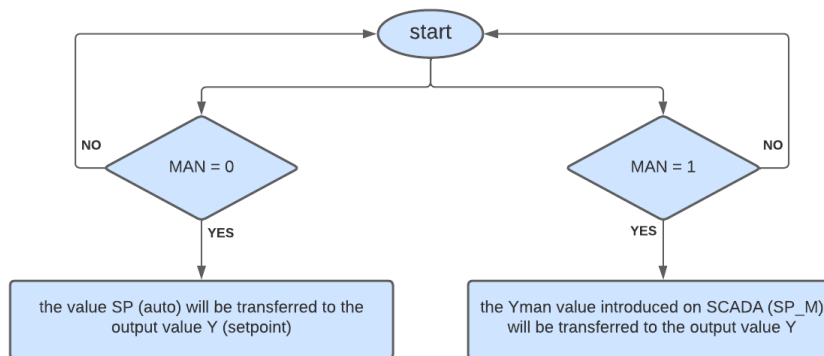
Figure 4. 15: Flowchart of PID block operation.

2.1.4. Choice of pumps:

In order to operate the station, there are instances where we need to select which pump to activate. To achieve this, we have created two functions with the goal of utilizing the pump that has the least amount of running time.

2.1.4.1. The "Choice between two pumps" function:

This function is used for the selection of booster pumps, washing pumps and pumps of treated water. If the "auto authorization" of the first pump (P1) is activated, AND both pumps are in rest, AND the "auto authorization" of the second pump (P2) is deactivated OR the on of P1 and less than or equal to that of P2, the auto control of P1 will be activated. The same principle is applied for the activation of the auto command of P2, except that the time of rate of P2 must be strictly less than that of P1.
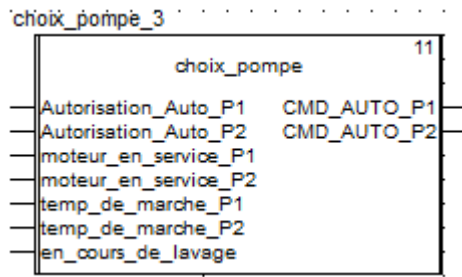
Figure 4. 16 : Bloc de la fonction choix entre deux pompes.

2.1.4.2. The "Choice between three pumps" function:

This function is used for the selection of pumps supplying clarified water to the filters. It contains two sections, the selection of the mode and the choice of the pump to be put into service.

- **Mode Selection:** There are two modes. The "one pump (1P)" mode is activated when one of the pumps is authorized AND there is a request for a pump. The mode "two pumps (2P)" is activated when two pumps at a time are authorized AND there is a request for two pumps.
- **The choice of the pump:** the following flowchart explains the program developed for command "P1" according to the selected mode. The same principle is used to order the two remaining pumps. Except that for "P2", its running time must be strictly lower than that of "P1" to be put into service, so the time of rate of "P3" must be strictly less than that of "P1" and "P2".

Figure 4. 17: P1 pump control flowchart.

2.1.5. The "Valves" function:

This function is used to control the pneumatic valves of the station and to detect faults and signal their presence. It contains the following two sections:

- **Default management:** The default is set to 1, if after a time delay of one minute (TON):
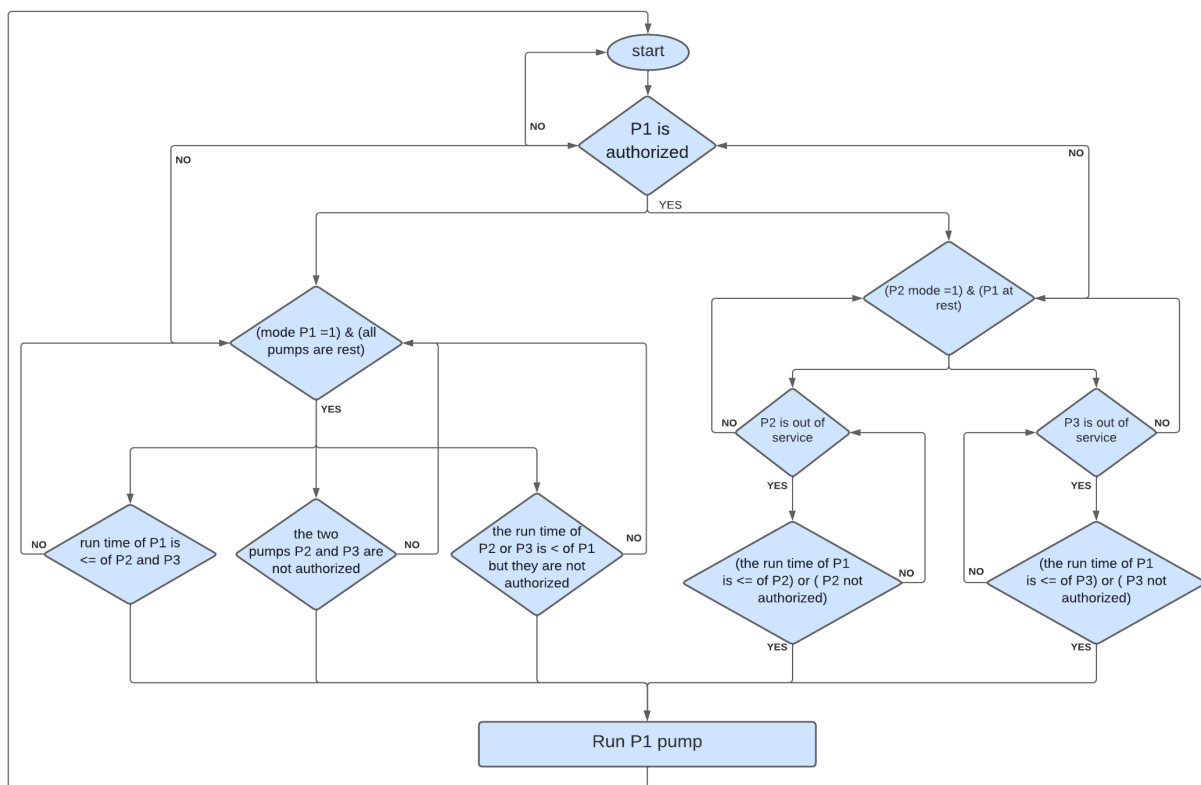 - o both limit switches are activated at the same time, OR deactivated at the same time,
  - o The opening command is activated but the opening limit switch is disabled;
  - o The opening command is deactivated but the closing limit switch is activated;

The default is acknowledged by pressing the "reset" button.

- **The command:** If "default" = 0, AND "automatic mode" = 1 AND "automatic command" = 1, OR the "manual mode" = 1 and "marche_scada command" = 1, the command valve opening is activated.

2.1.6. The "Sand filter" function:

This function has three sections; one for the production sequence, one for the wash condition, and one for the wash sequence. If the filter is in "automatic mode" all the valves necessary for its operation are set to automatic mode, the same principle is applied for the "manual mode".

- **The production sequence:** In our process, filters go into production one by one. For this purpose, a variable called "step_of_filter_succesivement" is created to introduce a time delay (TON).

When one of the feed pumps is in operation, production starts and the raw water valve (EB) AND the 1st filtrate valve by checking that the filter is allowed to be in on AND the variable "on_filter_successively" is set to 1 as well as the button "stop filter" is not supported. After a time, delay of 3 min, the valve of the 1st filtrate and the production valve is opened.

- **The washing condition:** Before entering the washing sequence, the following safety conditions must be met checked: the filter must not be in "manual mode", AND at least one washing pump must be available, AND at least one suppressor must be available, AND the tank level of washing water must be ≥ 85% (the "GE" comparison function is used).
- **The washing sequence:** The washing sequence is presented in the GRAFCET of Figure 4. 18 With the condition Only one sand filter can be washed at a time.
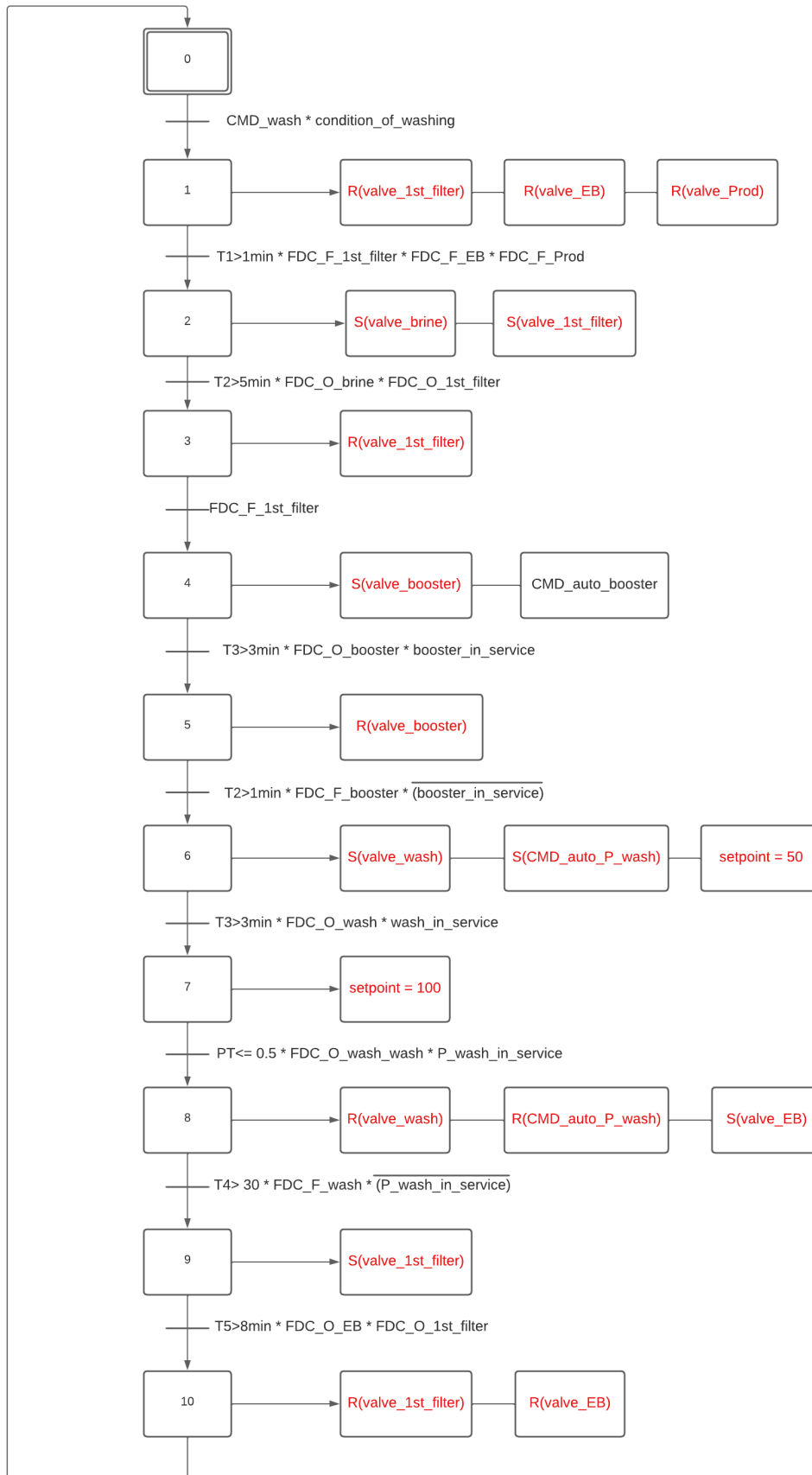
Figure 4.18: GRAFCET of the sand filter washing sequence.

2.1.7. The "RO" function:

This function is responsible for controlling the HP and ERD pumps. The function program is as follows: We check that "OI authorization" is activated, AND that the "request OI" is pressed, AND if the flow rate at the rack inlet is ≥ 200m3/h, to be able to start a 1-minute delay. At the end of the time delay, the ERD pump starts. When the flow at the outlet of the ERD pump reaches 120m3/h the HP pump starts. The HP pump stops immediately when the ERD stops OR by pressing the "stop" button in SCADA. The ERD stops when the inlet pressure becomes ≤ 26 bar or by pressing the button "stop". Figure 4.19 shows the OI function block.
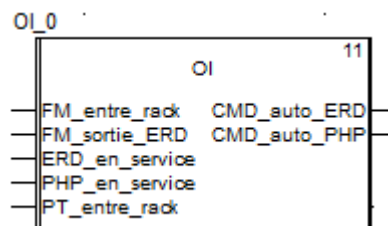

Figure 4. 19: RO function block

2.1.8. The "Calcite" function:

This function contains the same sections as the sand filter function:

- **The production sequence:** When one of the HP pumps is in service, production starts and the "valve" is opened. inlet" AND the "brine valve" of the calcite contactor verifying that it is allowed to be on the move. After a time, delay of 2 min, the "brine valve" is closed and the "outlet valve" of the contactor. If the turbidity value ≥ 0.6 NTU, we close "the outlet", and opens "the brine valve" by repeating the same previous steps.

- **The washing condition:** Before entering the washing sequence, the following safety conditions must be met checked: the filter must not be in "manual mode", AND the washing pump must be available, AND the suppressor must be available, AND the level of the treated water tank must be ≥ 85% (the "GE" comparison function is used).

- **The washing sequence:** The program for this sequence is illustrated in the GRAFCETs of Figure 4. 20. With the provided that only one calcite contactor enters the wash at a time.
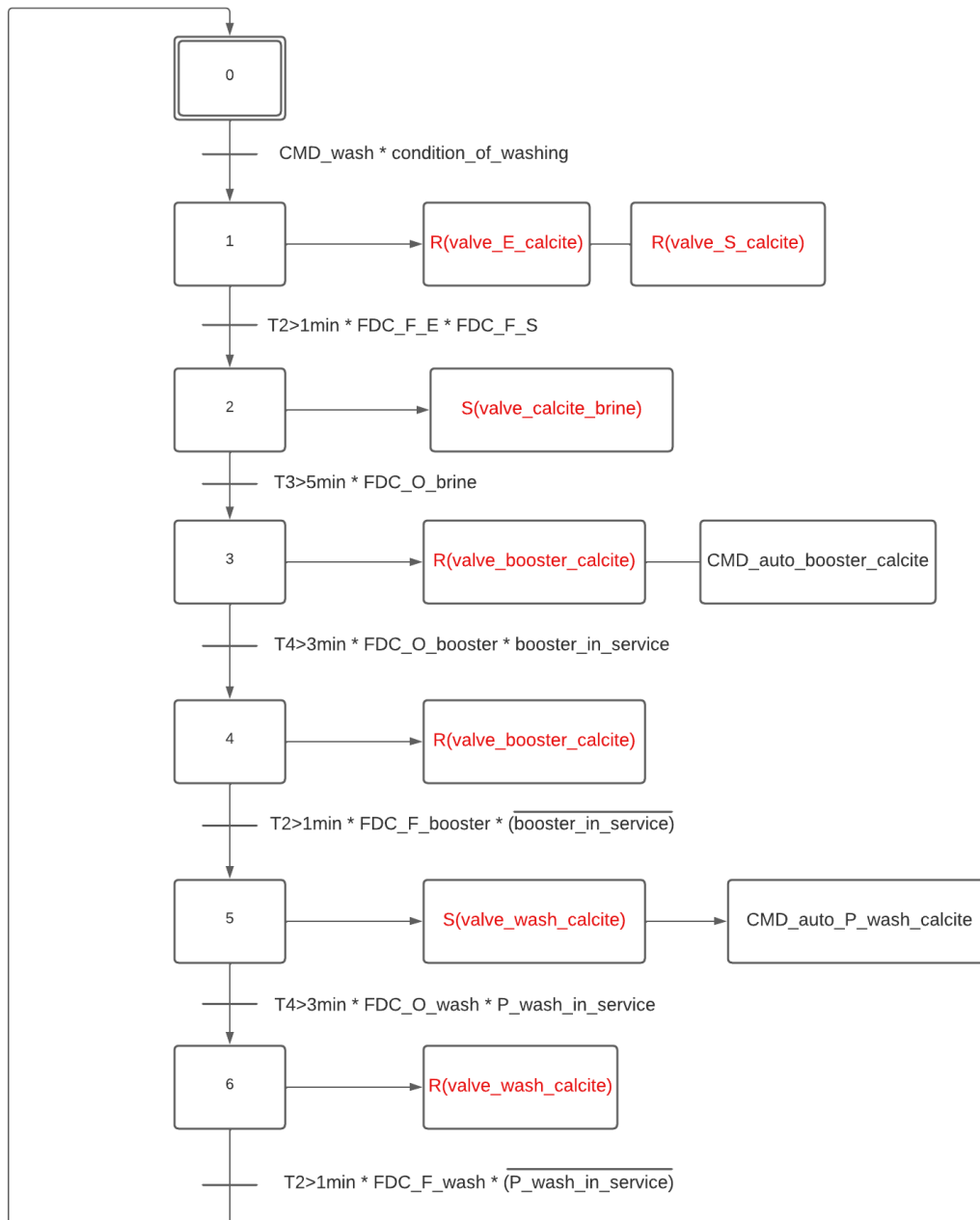
Figure 4.20: GRAFCET of Calcite Contactor Wash Sequence.

2.1.9. The "Motorized valve" function:

This function is specifically designed to control the motorized valve located at the end of the station, as well as detecting faults and signaling them if present. It contains the three following sections:

- **Default management:** This section contains mainly the same program elaborated in the valve function, by adding the case where the opening of the circuit breaker implies the activation of the default.

- **The opening command:** If "default" = 0 AND "automatic mode" = 1 AND "the open command" = 1, OR "manual mode" = 1 AND "command_ouverture_scada" = 1, the valve opening command is activated.

- **The closing command:** If "fault" = 0 AND "automatic mode" = 1 AND the "close command" = 1, OR "manual mode" = 1 AND "command_de_fermeture_scada" = 1, the valve closing command is activated.

2.2.   Station automation program:

Considering the complexity of the station process, we have subdivided the program into five (5) distinct phases or functional modules. Each module consists of its own sections. Notably, these modules include a section called "scaling," which employs the "Scale" function to adjust the value scale of all the sensors within that particular phase. The accompanying figure illustrates the arrangement of these functional modules and sections:
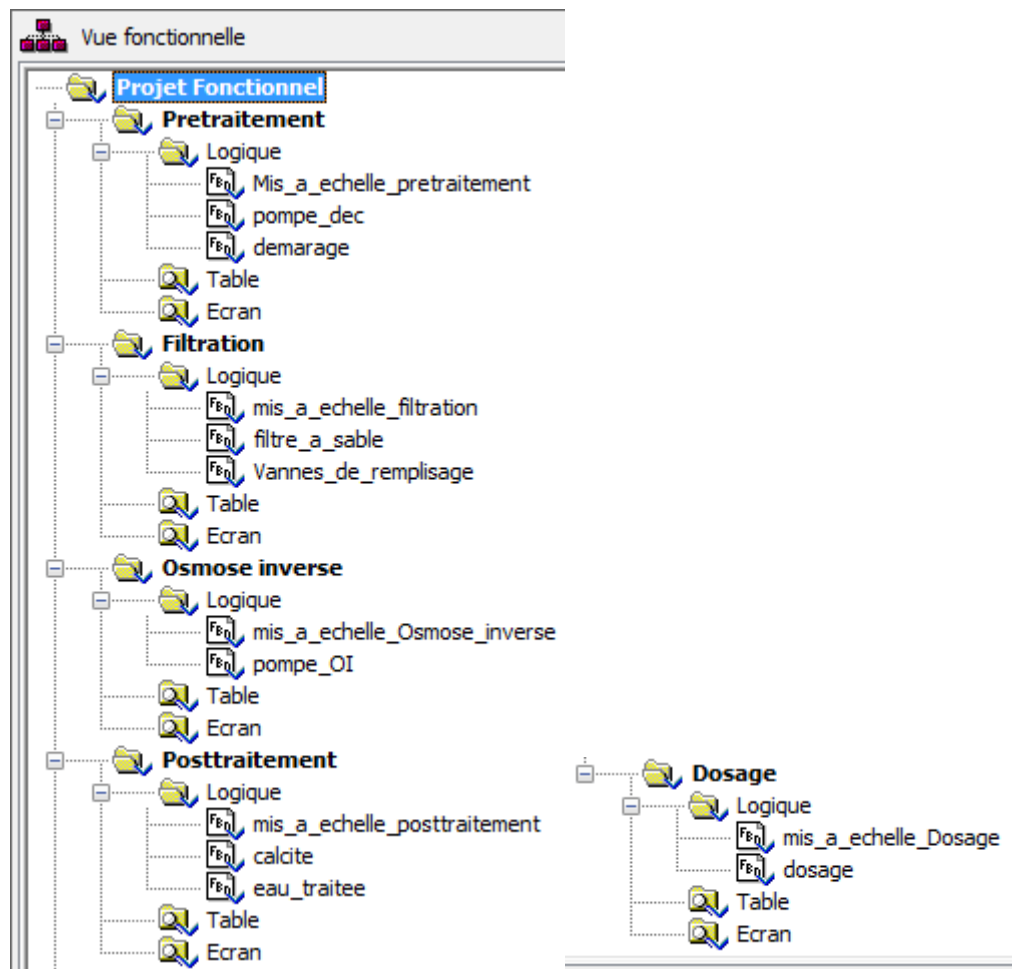

Figure 4.21: The different phases and sections of the program.

2.2.1. Pretreatment:

- **The "RUN" section:** When ordering the start of pre-treatment, AND if no sand filter is in service (EB valves closed), the demand for a pump is activated. When at least one filter fits in production, the request for two pumps is activated. By introducing these two requests in the "choice between three pumps" function block, it allows you to choose the feed pumps of clarified water to be put into service, by activating their automatic control.
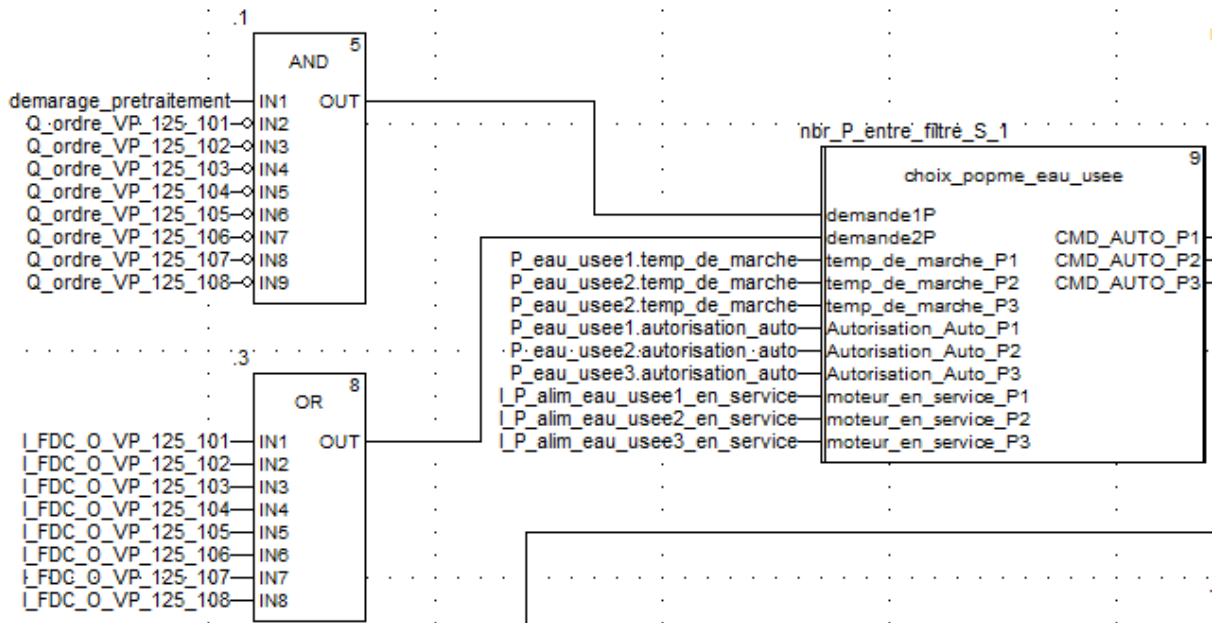

Figure 4. 22: Selection program for clarified water supply pumps.

To engage the three feed pumps, the "motor" block is utilized, causing the pumps to activate when their command is received. Activation of the general approvals for these pumps occurs under the condition that both the clarified water tank and the dosing tank are not empty, and the "general authorization" button is pressed. The provided figure displays the program specifically developed for one of the pumps, and the same program structure is replicated for the other two pumps.
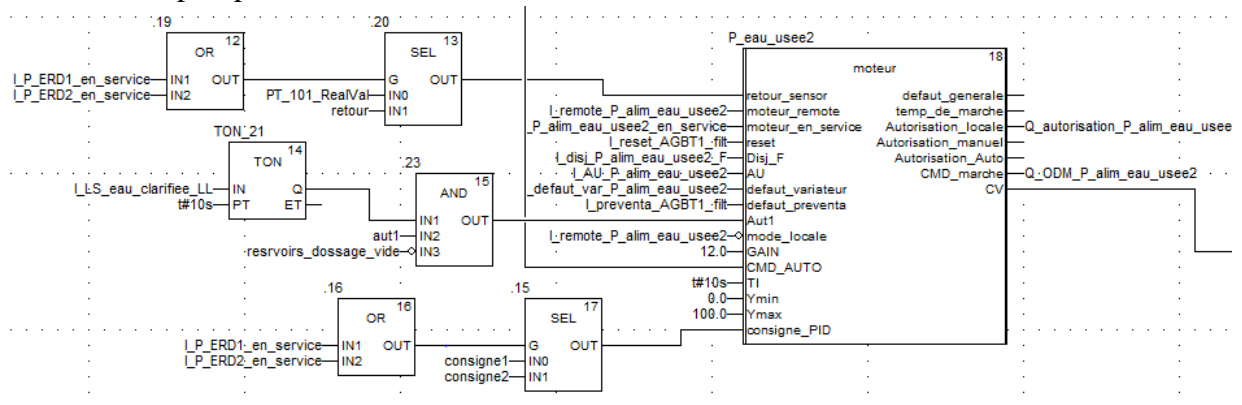

Figure 4. 23: Clarified water feed pump schedule.

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- **The "DEC_pump" section:** This section contains three "engine" blocks, one for the lamellar settler agitator, and two for the sludge drying pumps. These blocks are controlled manually (locally), or remotely (SCADA).

2.2.2. Filtration:

- **The "sand filters" section:** Upon activation of one of the feed pumps, the eight sand filters are sequentially brought into operation with a one-minute delay between each. To regulate all the filter valves, the "filters" functional block is employed, utilizing a combination of the "sand filters" block and six "valve" blocks for each filter. In the case of the first filter, the variable "step_of_filter_succesivement" is consistently set to 1. The accompanying figure depicts the program for a single filter, which is identical for the remaining filters.
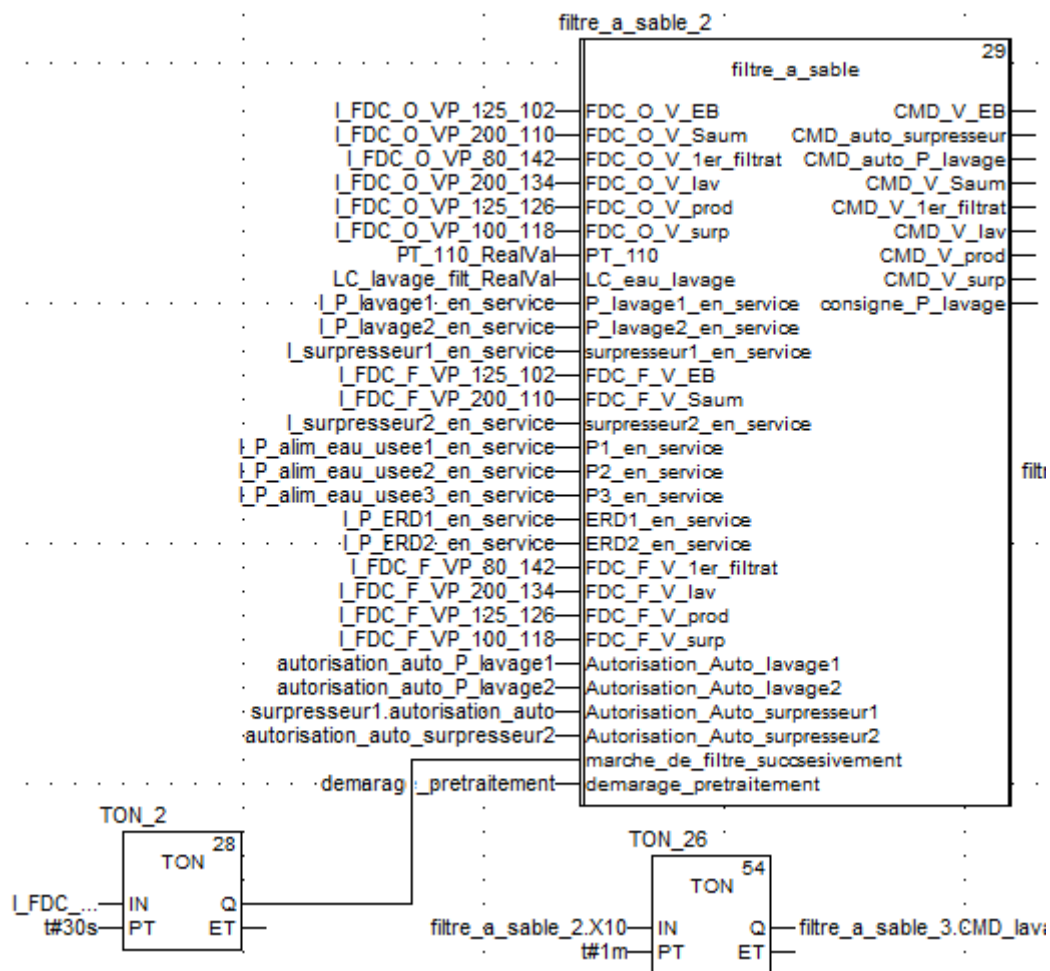
a. The sand filter block (2nd filter)
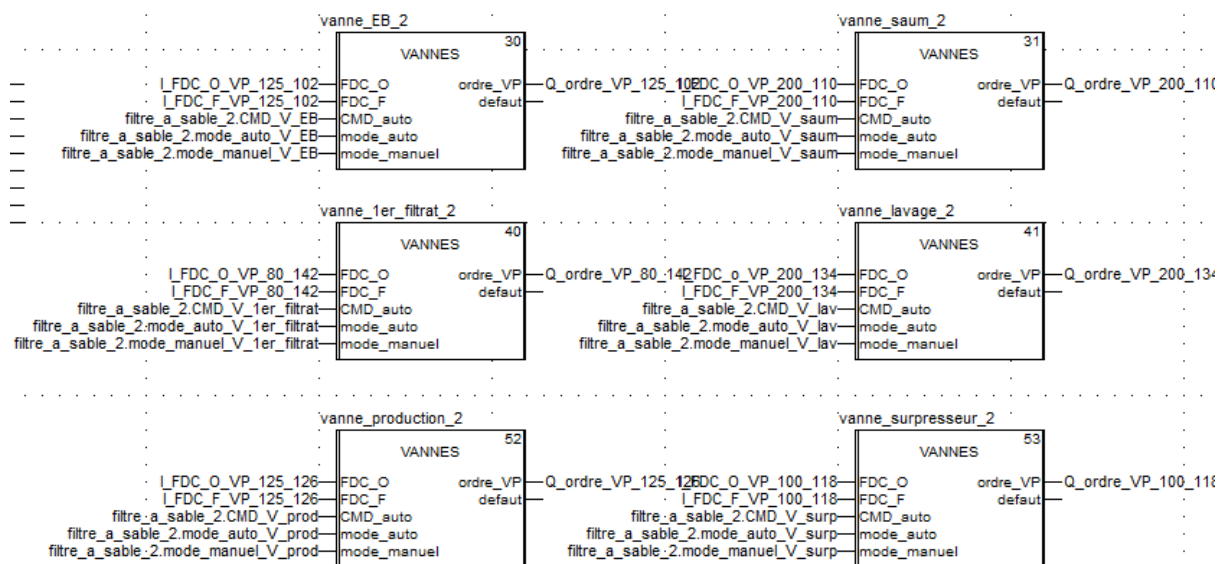
b. **The valve blocks (2nd filter)**
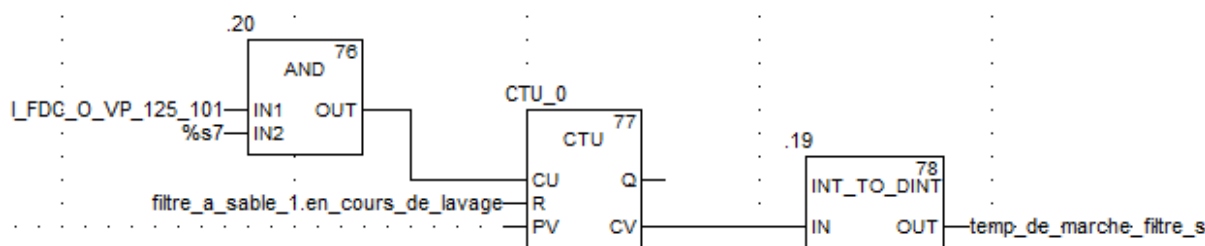
c. **First sand filter running time calculation**

Figure 4.24: Part of the program in the "sand filters" section.

If the operational duration of the first sand filter exceeds a period of three (3) months, an alarm is triggered, alerting the need to initiate a washing process for that specific filter using SCADA (Supervisory Control and Data Acquisition). The sand filters are washed one by one, with the running time calculated by a counter that increments every minute when the "EB" valve is open (refer to Figure 4.24). When a filter enters the washing phase, one booster and one washing pump are activated. To accomplish this, the "choosing between two pumps" block is employed as the controlling mechanism. The sequencing of blowers and washing pumps is determined by the filter blocks, and their automatic control is activated only when both the outgoing command from the filters and the outgoing command from the choices are enabled.
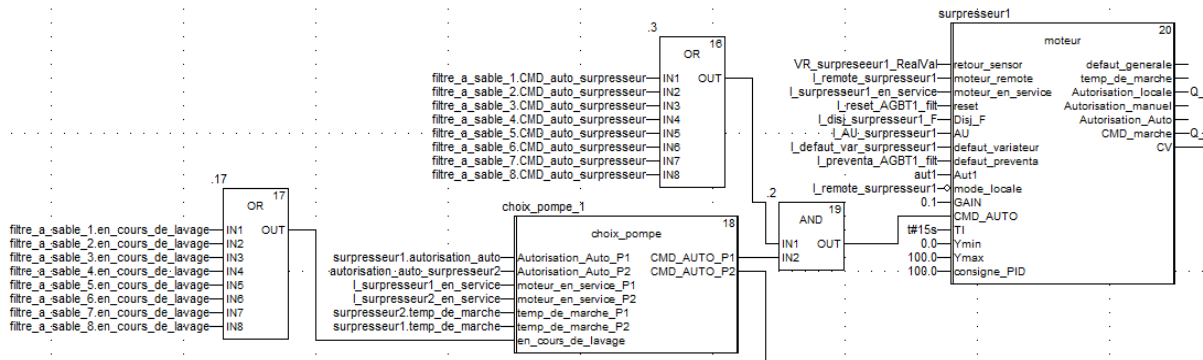
Figure 4. 25: Program of a booster.

- **The "fill valve" section:** A filling of the sand filter washing tank is carried out by two valves of filling located at the outlet of four filters each. The following flowchart illustrates the principle of operation of these valves:
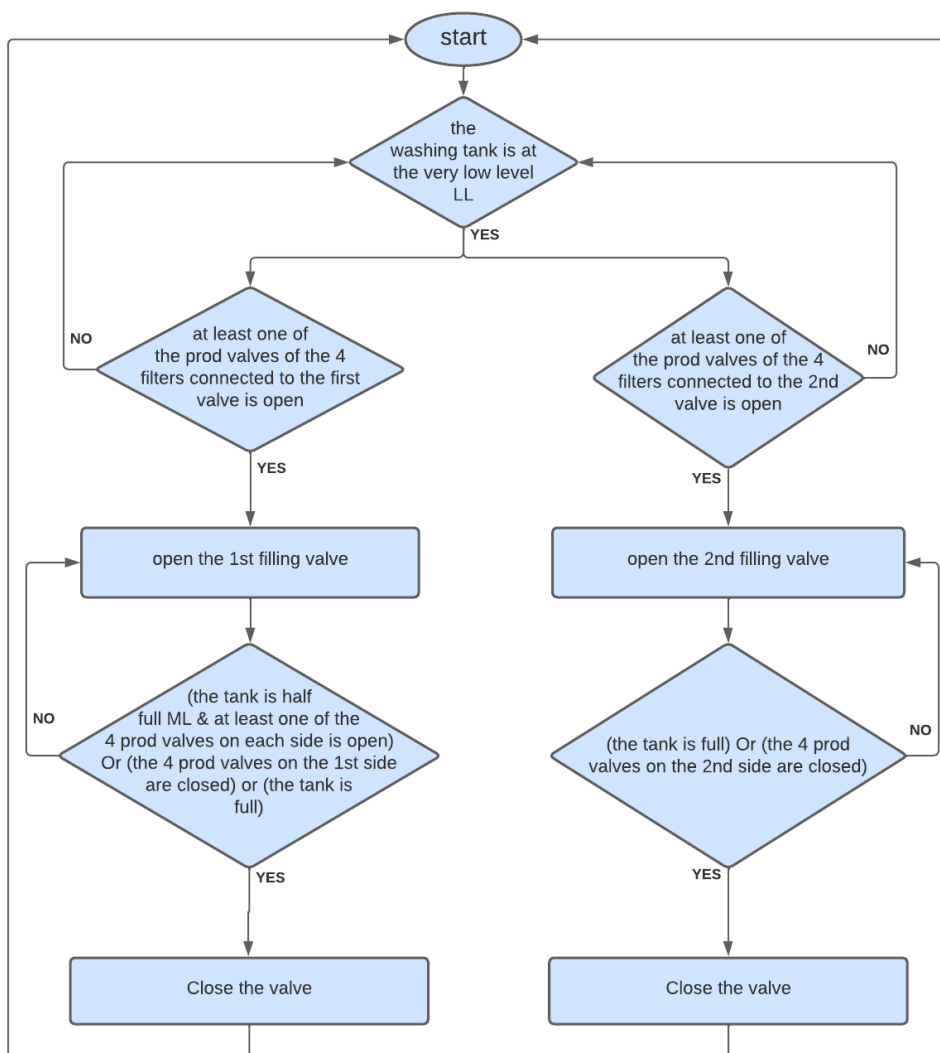

Figure 4.26: Fill valve control flowchart.

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2.2.3. The "RO Pump" section in the "Reverse Osmosis" module:

After the filtration stage, the filtered water enters the reverse osmosis stage. To do this, we used the OI block responsible for controlling the PH and ERD pumps. The orders outgoing from this block enter dedicated "motor" blocks for the two pumps.
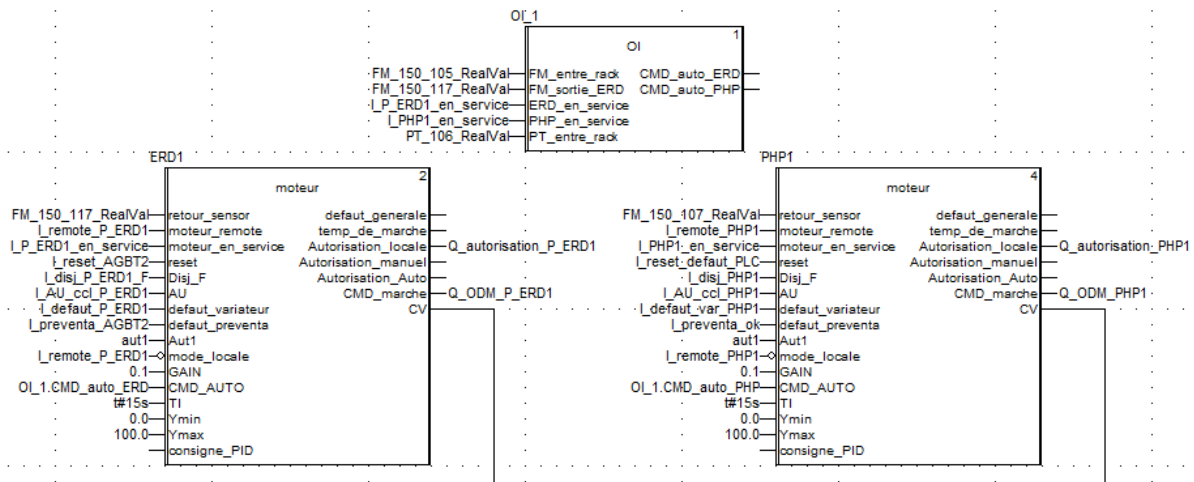

Figure 4. 27: Program of an RO rack

2.2.4. Post treatment:

- **The "calcite" section:** After the water is processed by the Reverse Osmosis (RO) system, it flows into the three calcite filters. To manage the production sequence, the program incorporates three "calcite" functional blocks, along with five "valve" blocks for each filter and two "motor" blocks. The "calcite" block takes charge of controlling the necessary valves for filter operation, as well as managing the booster and washing pump. When the operational duration of the first calcite filter surpasses three months, an alarm is triggered to initiate the washing process for that particular filter via SCADA. The running time is calculated using a counter that increments with each passing minute when the inlet valve of the filter is open. The calcite filters are washed individually, one at a time. The developed program for this functionality is illustrated in Figure 4.28.

- **The "treated water" section:** When one of the RO racks is in service, one of the treated water pumps starts, checking that the treated water tank is not empty. Then the motorized valve opens. In this part of the program, we used a "choice between two pumps" block, two blocks "motor", and the "motorized valve" block. Figure 4.29 shows the program developed.
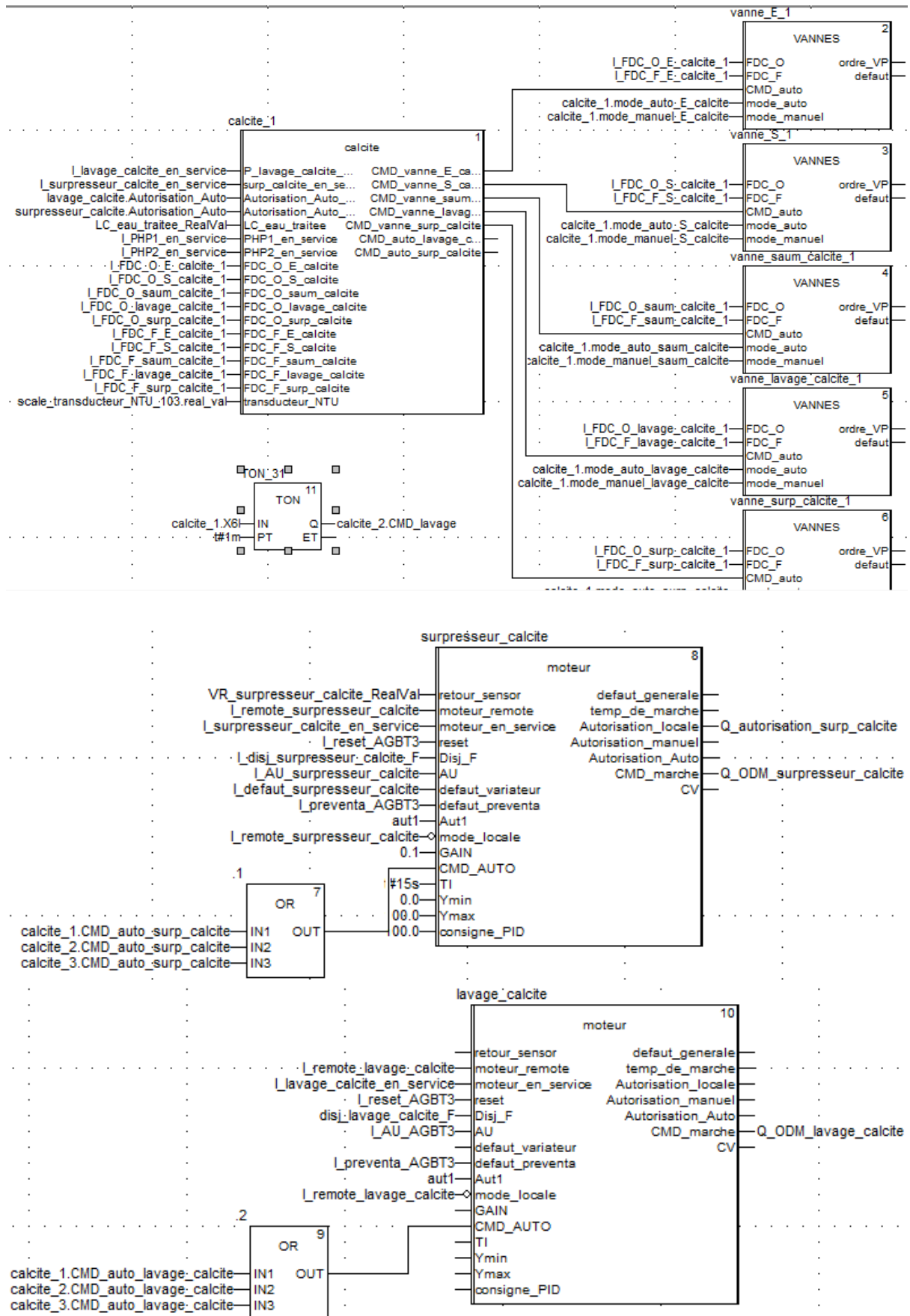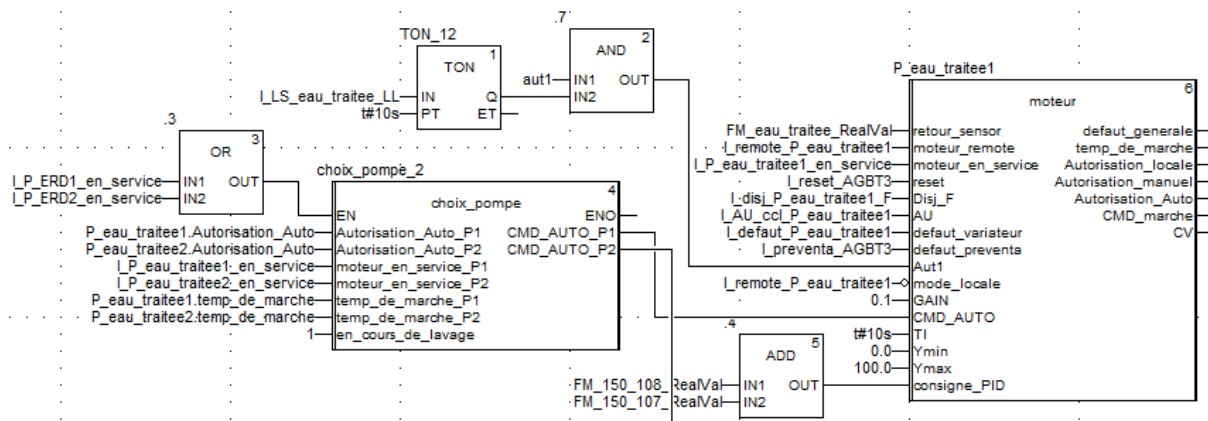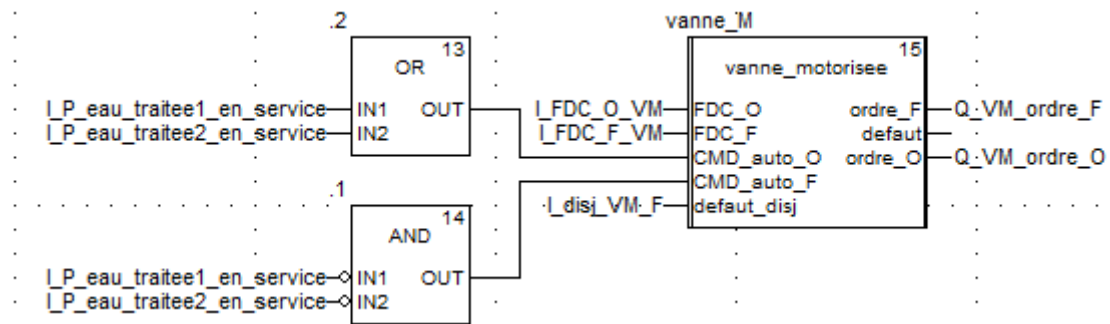
Figure 4. 28: Program of a calcite filter.

a. Program of a treated water pump

b. Motorized valve program

Figure 4.29: Program developed in the "treated water" section.

2.2.5. The "Dosing" section in the "Dosing" module:

Dosages are performed during different stages of the process, with each dosing unit equipped with one or two pumps as required. The pumps are controlled using "Motor" blocks. When the pretreatment start button is pressed, the dosing pumps for FeCl3, polymer, and NaClO are activated. Furthermore, when the HP (High-Pressure) pump is in operation, the dosing pumps for NaClO, NaOH, and biocide start working. Additionally, two pumps for SMBS and two pumps for scale inhibitor are activated, with each pump assigned to one rack. The dosing pumps for citric acid, sulfuric acid, and NaOH CIP are initiated when the CIP (Clean-in-Place) pump is running.

The dosing pumps in service stop when the level of the tank containing the product chemical reaches 10% of the total capacity.

2.3. Regulation:

Regulation is carried out for pumps with a variable speed drive, this regulation is based on feedback from the flow or pressure sensor.

2.3.1. Clarified water supply pumps:

At the commencement of the pretreatment phase, considering the reading from the pressure sensor positioned at the inlet of the sand filters, the pumps are adjusted to achieve setpoint 1 within the range of 1.5 to 1.7 bar. When one of the RO racks begins its operation, the pumps are regulated to reach setpoint 2, ranging from 2 to 2.1 bar, by retrieving the readings from the pressure sensors located at the inlet of the respective RO racks. In the event that both racks are in production, the average of the two sensor values is used as the feedback value for regulation.

2.3.2. HP and ERD pumps:

These pumps are regulated with respect to the flow sensor located at their outlet. The instructions desired for HP and ERD pumps are 104 m3/h and 157 m3/h respectively.

2.3.3. Treated water pumps:

These pumps are regulated in relation to the flow sensor located in the treated water outlet who's the setpoint is equal to the sum of the values of the two flow sensors located at the output of the RO racks.

2.3.4. Boosters and washing pumps:

The boosters are regulated in relation to the speed, to reach the 100% setpoint. Concerning the wash pumps, the regulation is elaborated in the wash sequence programmed in the "sand filter" function.
For this regulation, we used the integral proportional PI regulator, whose values are determined after carrying out tests in the desalination plant. The next board summarizes the values for each pump.

Pump	Gain	Ti (s)
Feed pumps	12	10
HP – ERD	0.1	15
Wash	0.01	1
Booster	0.1	15
Treated water	0.1	10

Table 4. 5: PI regulator parameters.

3. Supervision by Citect SCADA of the station:

In order to supervise our station, equipment, geniuses, pop-ups, alarms as well as graphs have been drawn up.

3.1. Types of equipment created:

Different types of equipment are created for the devices used in the station and require supervision and/or control. These types are based on the function blocks created in Unity Pro. Equipment is created based on these types, the following table indicates the types and amount of equipment of this type created:

Equipment type	Number
Scale	63
Flow meter Scale	17
Pump	36
Valve	65
Motorized valve	1
Sand filter	8
RO	2
Calcite filter	3

Table 4.6: Number of devices used in SCADA views by type.

3.2. Genies and pop-ups created:

To effectively monitor our station, it is essential to create multiple views that encompass various components such as motors, flow meters, and more. These views encompass different elements that necessitate control and supervision of associated variables. In order to streamline the development of the monitoring system, the genies (templates or pre-configured setups) for these elements are utilized, along with pop-ups that provide additional information or functionality. These features greatly facilitate the process of creating and managing the supervision system.

- **Transducers:** This genie is used to display the values retrieved by the PH, temperature, ORP, SDI, EC, turbidity, Cl2 transducers.
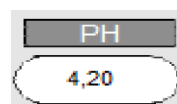

Figure 4.30: Transducer Genie.

- **Flowmeter (named FM):** In addition to the options present in the previous genius, this one contains a field that displays the value of the total flow passed by it, as well as a reset button**.**

Figure 4. 31: Genie of FM.

- **Reservoir:** Reservoirs are positioned along the production line. These tanks differ according to the level sensors they contain (level sensor LC radar, and LS float level detector). For the LS detector, circles that change color (red=0, green=1) are positioned in the different levels (LL, ML, HL). While a display of the volume of water contained in the tank is displayed for the LC sensor.
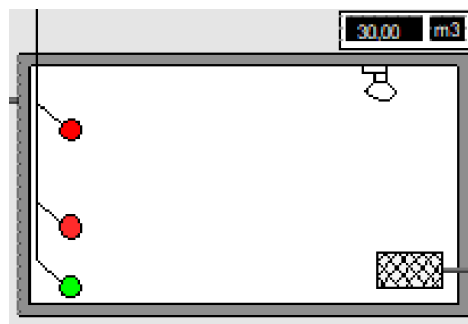

Figure 4.32: Genie of a tank containing the LC and LS sensors.

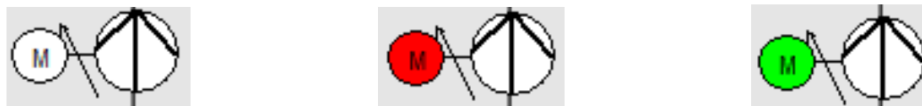- **Pump:** This genie displays the status of the pump, as shown in the figure below.

Figure 4. 33: The different states of the pump (rest, default, in service).

In order to effectively visualize and control the numerous variables associated with pumps, the utilization of pop-ups becomes indispensable. Considering the presence of different types of pumps at the station, namely pumps with a variator, pumps without a variator, and manual pumps, we have developed a distinct pop-up for each type. The pop-up for pumps with a variator enables the display of parameters such as running time, actual speed, and mode (remote/local). It also provides control over the manual setpoint value, operating modes (auto/man), command activation and deactivation, as well as fault acknowledgment. However, the pop-ups for pumps without a variator and manual pumps offer the same options as the first pop-up, excluding those related to the drive and mode selection buttons.
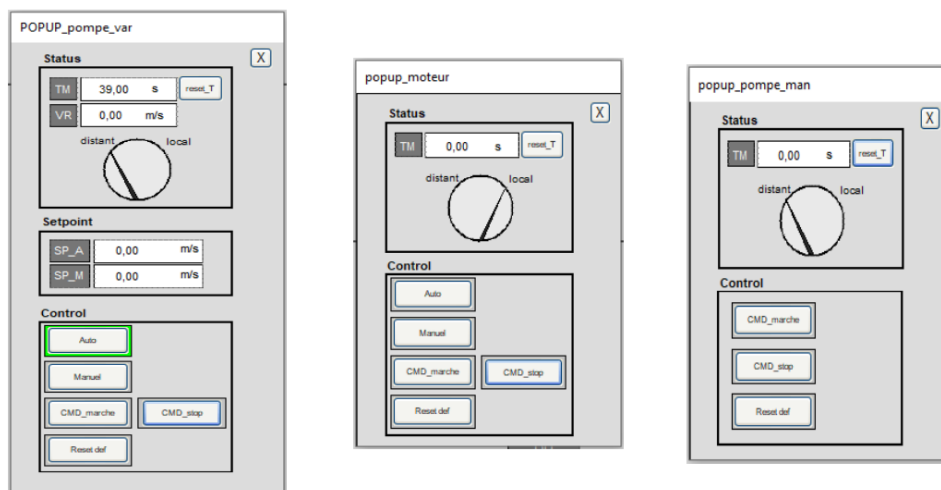
Figure 4. 34: The different pump pop-ups (with var, without var, manual).

- **Valve:** Genius displays the status of the valve, as shown in the figure below. He has a pop-up which allows you to control the opening of the valve (button SCADA control).

Figure 4. 35: The different states of the valve (rest, default, in service).

- **Dosage:** Dosages are carried out in different phases of the process and are therefore present in several views. This genius makes it possible to indicate that the dosing step was well and well done using a circle that turns green.

- **Pressure transmitter (named PT):** This genius displays the real value of the pressure.

Figure 4.36: Genie of PT in normal operation.

- **RO:** This genius has a pop-up responsible for starting, authorizing and stopping the RO rack.

- **Calcite Filter:** This genie has a pop-up responsible for ordering, authorization, shutdown, and choice of filter operating mode.

- **Filtre à sable :** Lorsque le filtre rentre en production, il sera coloré en vert, lorsqu'il rentre en lavage, il sera coloré en bleu.
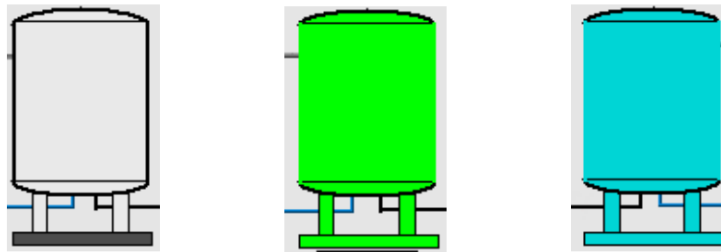
Figure 4. 37: The different states of the sand filter (rest, in production, in washing).

The pop-up shown in Figure 4. 38 allows you to control several sand filter variables with buttons. For the filter to be able to be washed, it is necessary to check that certain pumps manuals are open. By pressing the wash authorization button, a pop-up is displayed with a warning message as shown in the figure below. This pop-up features a button that activates this variable.
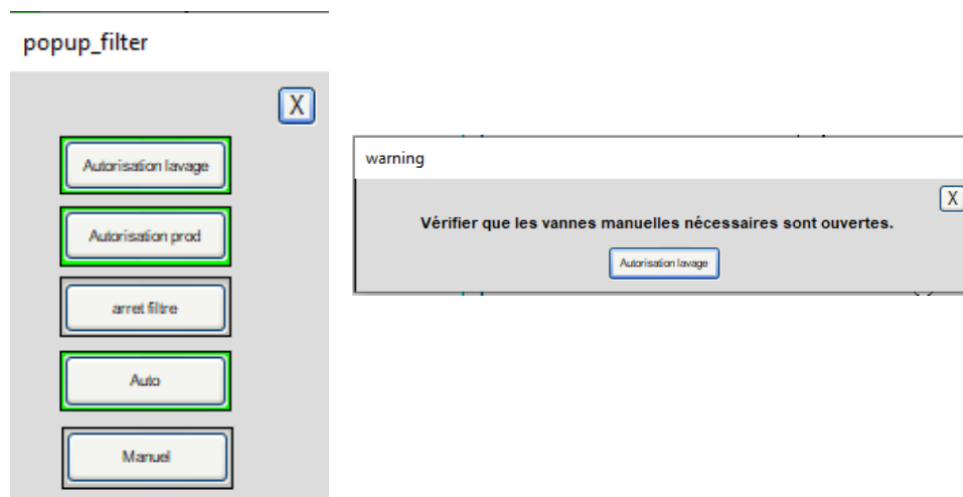

Figure 4. 38: The sand filter and warning pop-up.

3.3. Views created:

To facilitate the comprehensive management of the entire installation, we have created the visual representations depicted in the figure below. Each page corresponds to a specific phase in the process of desalinating seawater at our plant.
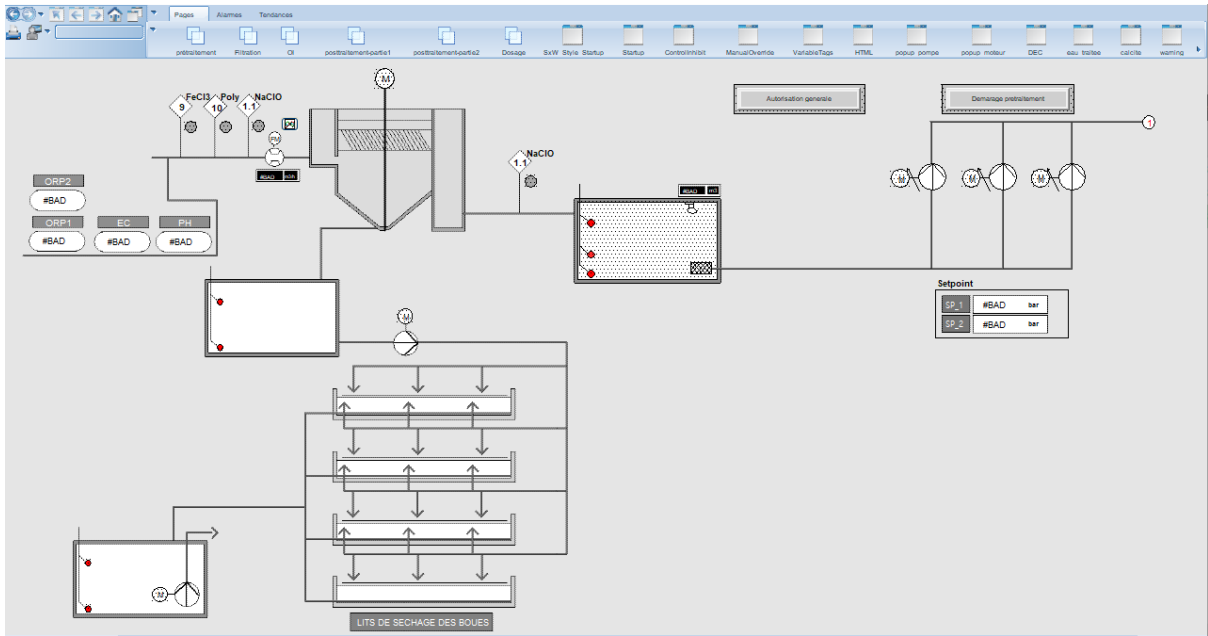
a. The pretreatment view.
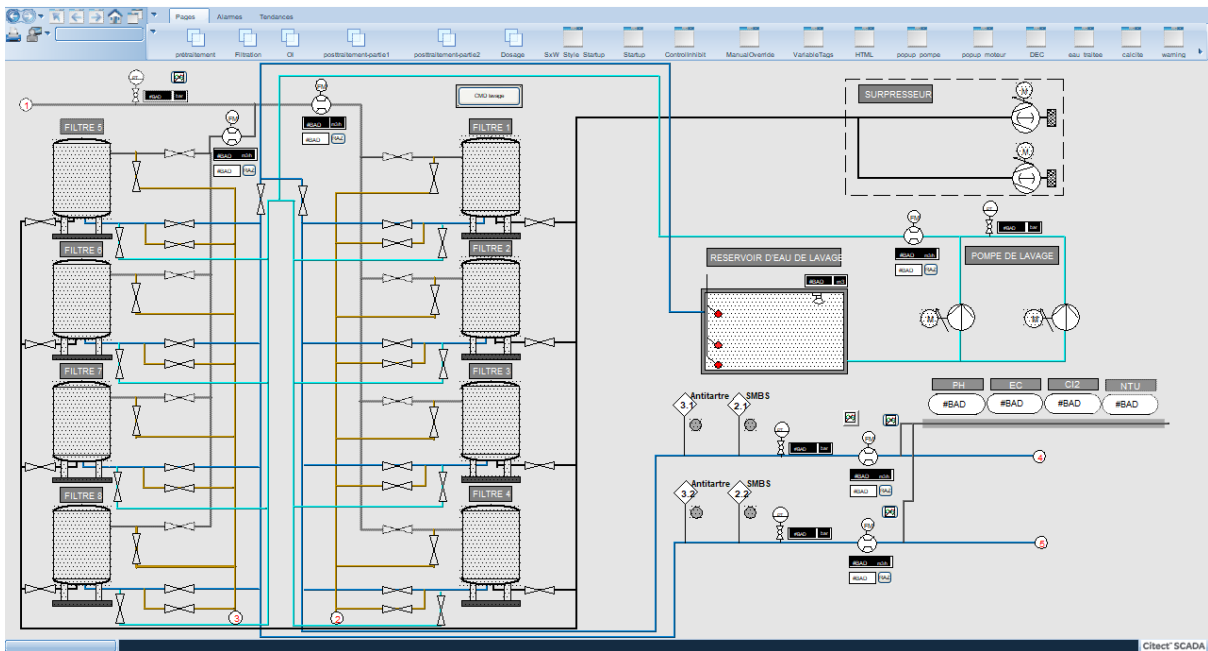
b. The filtration view.

c. The RO view.

d. the first step of post treatment (Calcite filters) view.

e.   the second step of post treatment view.

f.   The dosage view.
Figure 4. 39: The different views of the monitoring solution.

Conclusion:

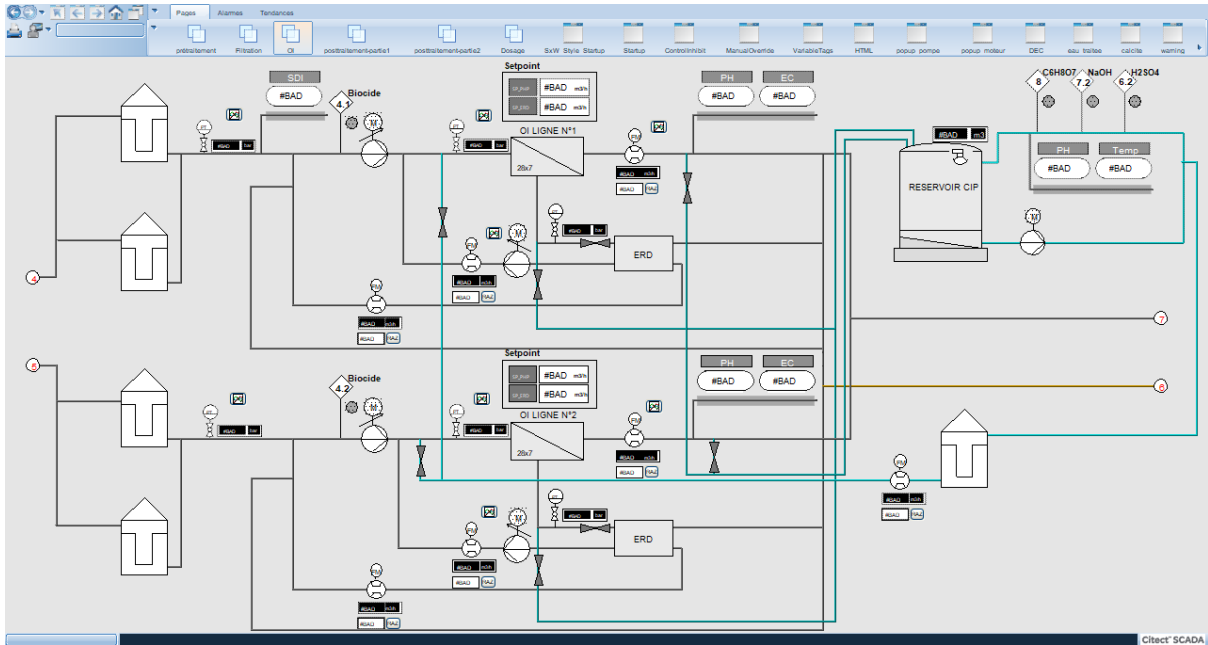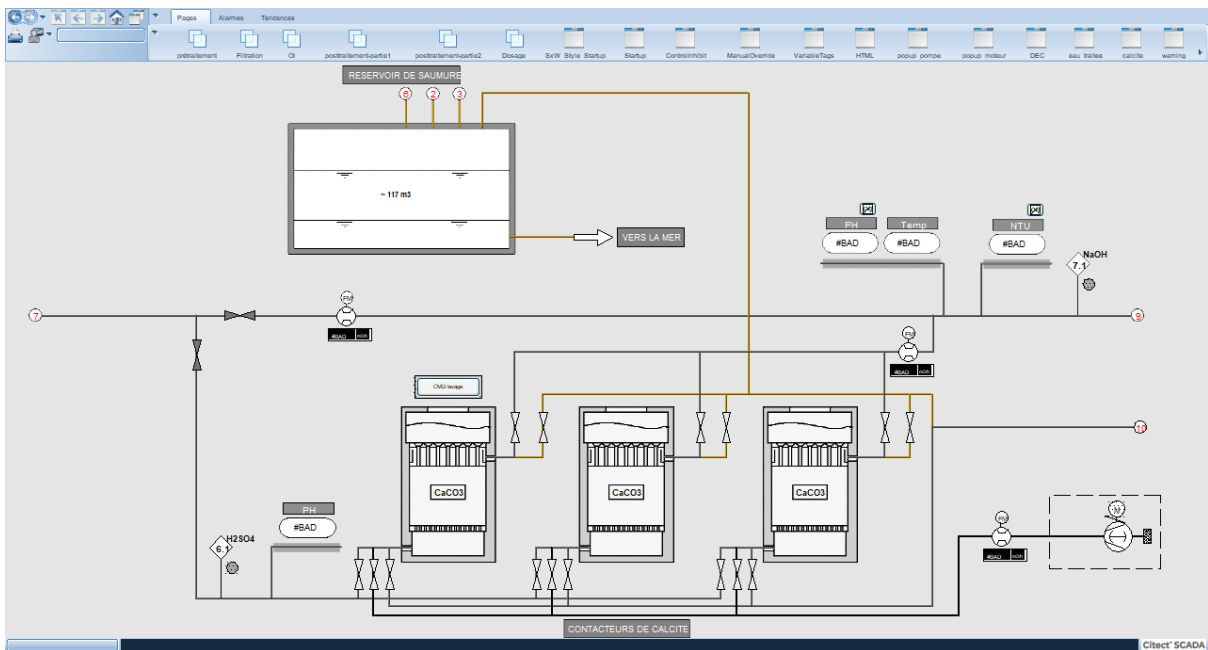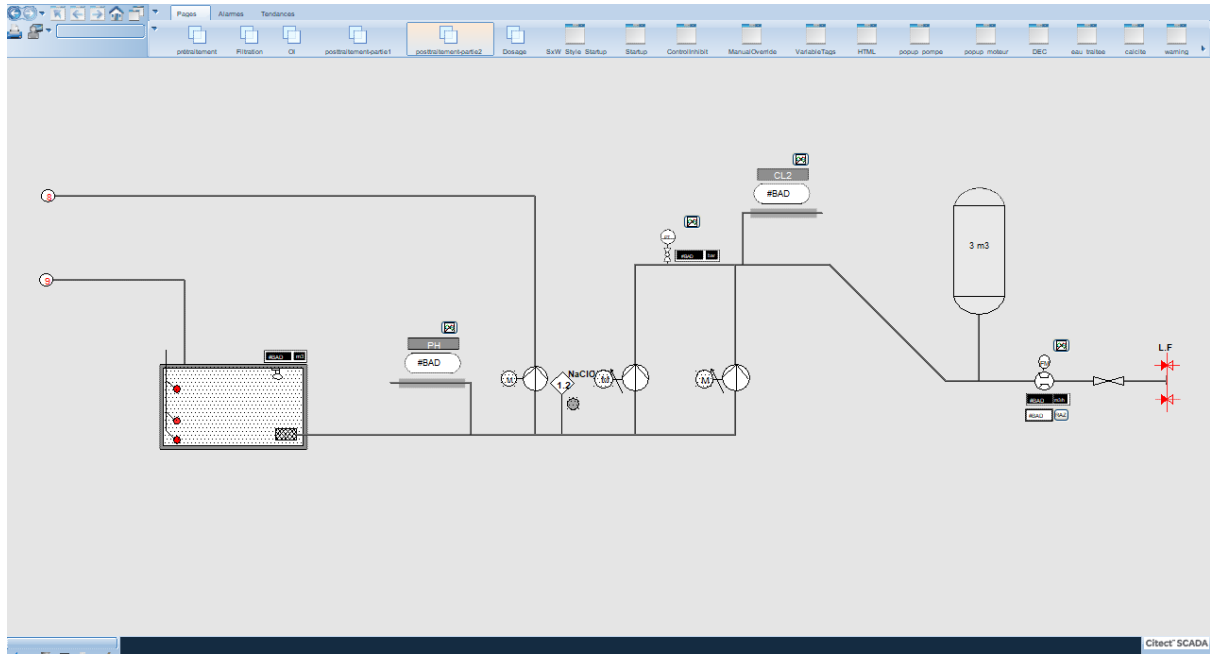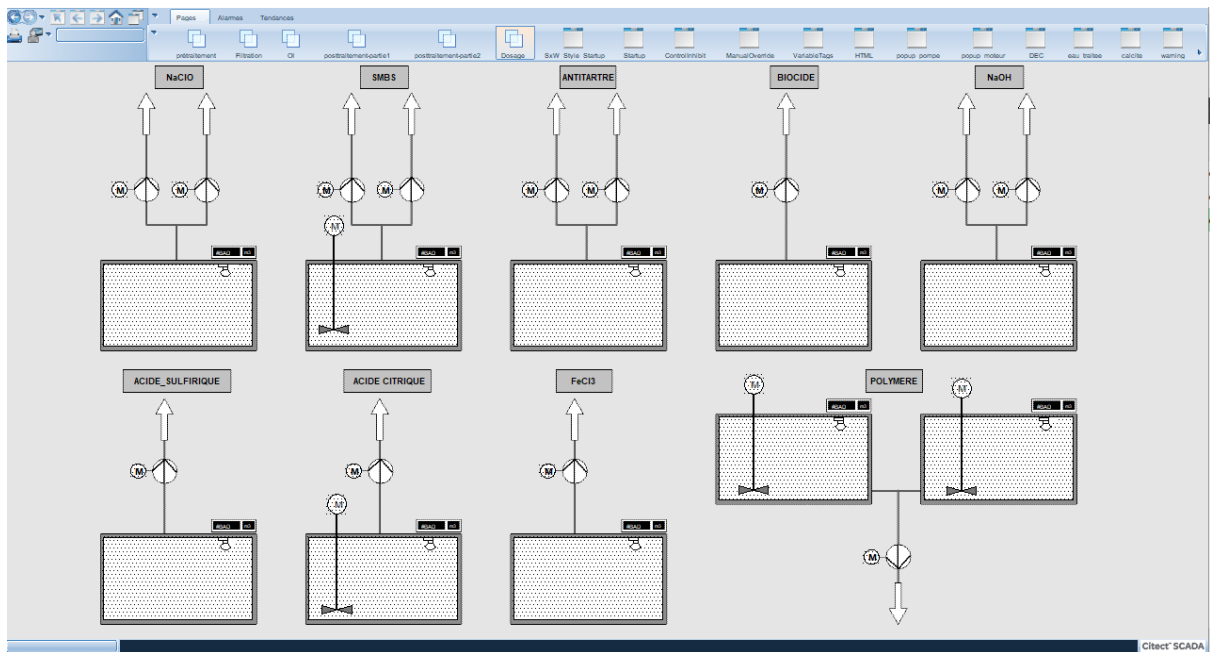In this chapter, we have developed all the essential programs using Unity Pro for the operation of the desalination plant. These programs have been successfully implemented and validated on the simulator. Additionally, we have established an efficient and optimal monitoring solution for the station. This solution encompasses individual views for each processing phase and dosing units. Each view offers specific functionalities, enabling remote management of various tasks within the process. Our supervision solution allows for the display of activated and deactivated alarms, along with additional options. This chapter represents the culmination of our collective efforts throughout this master's project, resulting in the implementation of an automation and comprehensive supervision solution for the EL-MARSA SKIKDA desalination station.

General Conclusion

In our dissertation project, we focused on the automation and supervision of the EL-MARSA seawater desalination plant in SKIKDA. Our goal was to implement the Reverse Osmosis technique for this purpose. To achieve this, we utilized the "Modicon M580" programmable logic controller along with Unity Pro and Citect SCADA software for programming the station's automation process and monitoring. Initially, we provided an overview of various water desalination techniques, followed by a comprehensive explanation of the RO technique employed in our specific plant.

Subsequently, we delved into the various phases involved in the installation process, tailored to the specifications of the EL MARSA desalination station. Additionally, we explored the instrumentation and equipment comprising the station. This section provided a comprehensive understanding of the system's automation requirements, including the distinct phases and components. Furthermore, we prepared an inventory of instrumentation pertaining to the studied production cycle, taking into account the specific requirements outlined in the specifications. This aided us in selecting the appropriate programmable logic controller (PLC) for the project.

By employing the "Modicon M580" PLC, we can enhance the efficiency and overall performance of the installation. To achieve this, we utilized the Unity Pro software to program the station's operations and retrieve variable states. These states are subsequently integrated into the Citect SCADA system for monitoring purposes. This integration of the PLC, Unity Pro, and Citect SCADA enables us to optimize the functionality of the station and closely monitor its performance.

We have successfully designed control stations to cater to all the installations within the factory, including the main station and the six remote stations (RIO). Additionally, we have developed and implemented a comprehensive automation solution for the entire factory. This solution encompasses management programs that control various aspects of the plant, such as valves, motors, fault management, and sensor calibration. These programs were designed using Unity Pro and implemented in the main command stations.

To ensure a complete automation solution, we incorporated monitoring capabilities using Citect SCADA, which allows us to effectively oversee the process and promptly identify any malfunctions. The monitoring solution includes six distinct views, each tailored to specific segments of the plant, namely Pretreatment, Filtration, Reverse Osmosis, Post-treatment, and Dosing. Furthermore, an additional view is dedicated to active alarms, ensuring comprehensive monitoring and facilitating swift response to any issues that may arise.

In summary, the proposed solution facilitates control and supervision of all the factory installations, providing the capability to remotely manage the entire system and monitor it in real time.

This project proved to be highly rewarding due to its intricate nature and our limited prior experience with this specific type of work and facility. Throughout the process, we acquired new knowledge and gained familiarity with Unity Pro, Citect software, and SCHNEIDER ELECTRIC hardware, which were all previously unfamiliar to us.

Looking ahead, we have several perspectives in mind. Firstly, we aim to automate the regulation of various dosages within the process, further enhancing the efficiency of the system. Specifically, we plan to implement our program within the EL-MARSA SKIKDA desalination plant to streamline its operations.

Additionally, we propose to collect and monitor the energy consumption of all the station's equipment. By doing so, we can identify areas where energy usage can be optimized and develop solutions to minimize overall energy consumption. This focus on energy efficiency aligns with our goal of implementing sustainable practices within the plant.

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Annex A

The figures provided below depict the Piping & Instrumentation Diagram (P&ID), which serves as a document enabling comprehension of the EL MARSA station's functioning and identification of its instrumentation. By utilizing this document, we successfully devised the automation solution and formulated various perspectives for the supervisory solution.
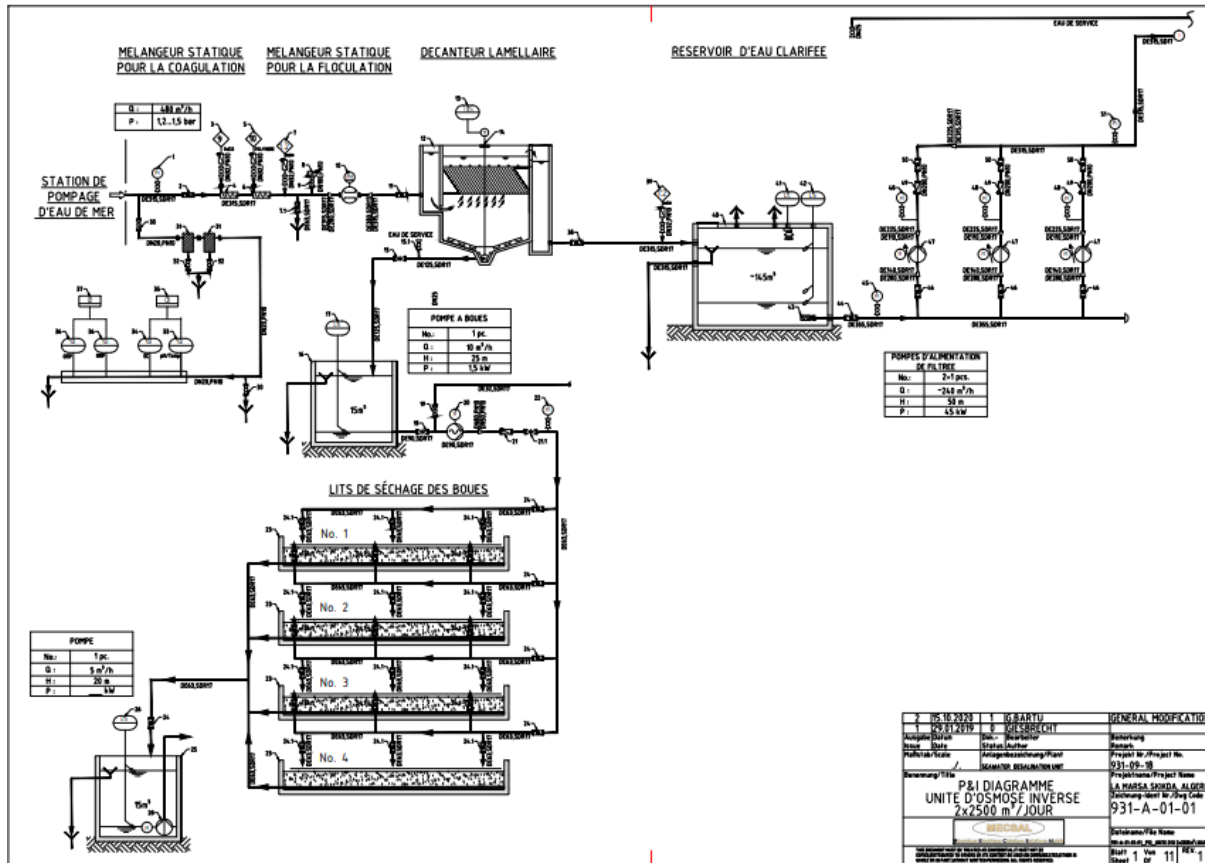

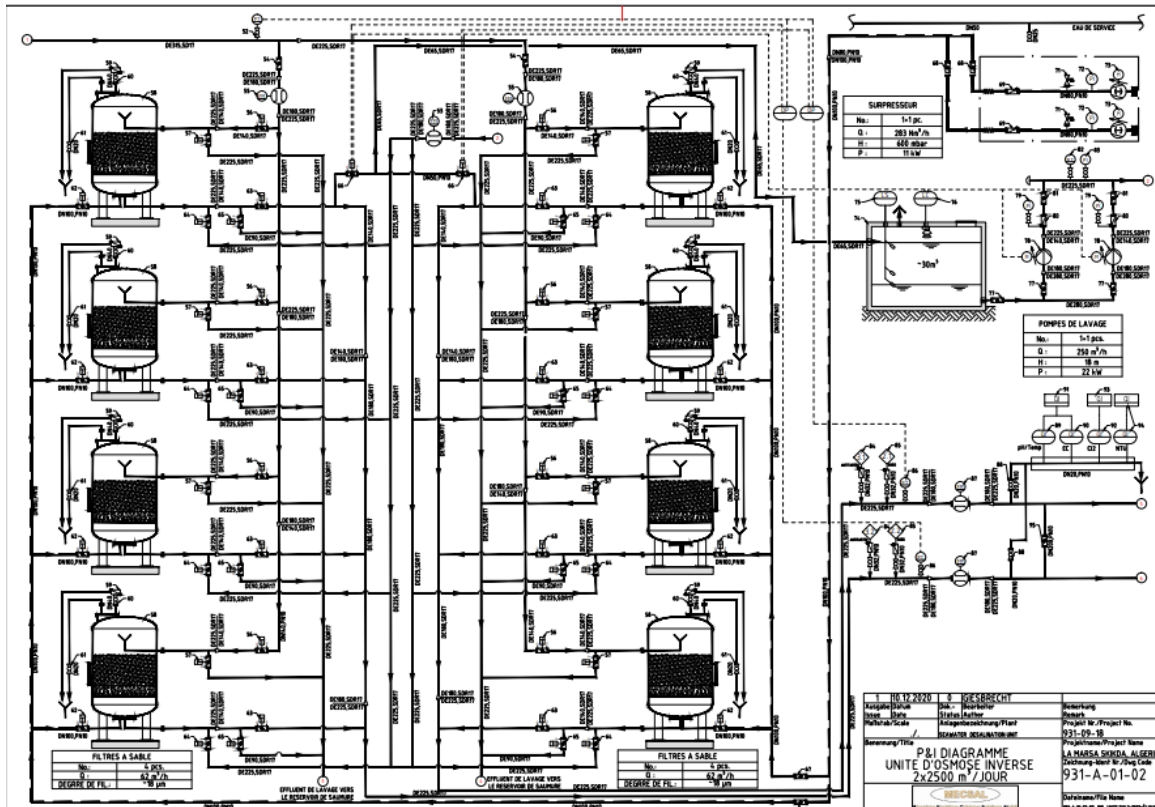
Figure A. 1. Pretreatment phase page.

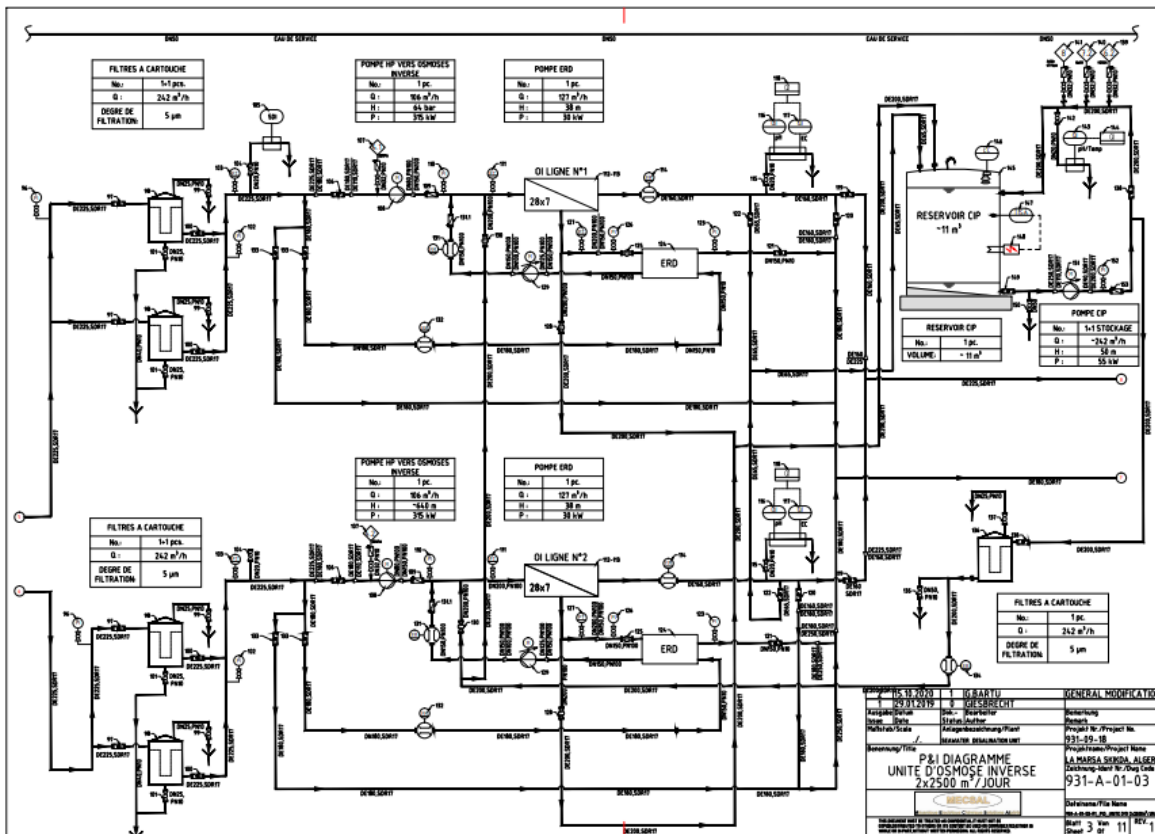*Figure A. 2. Page of the first stage of the filtration phase.*

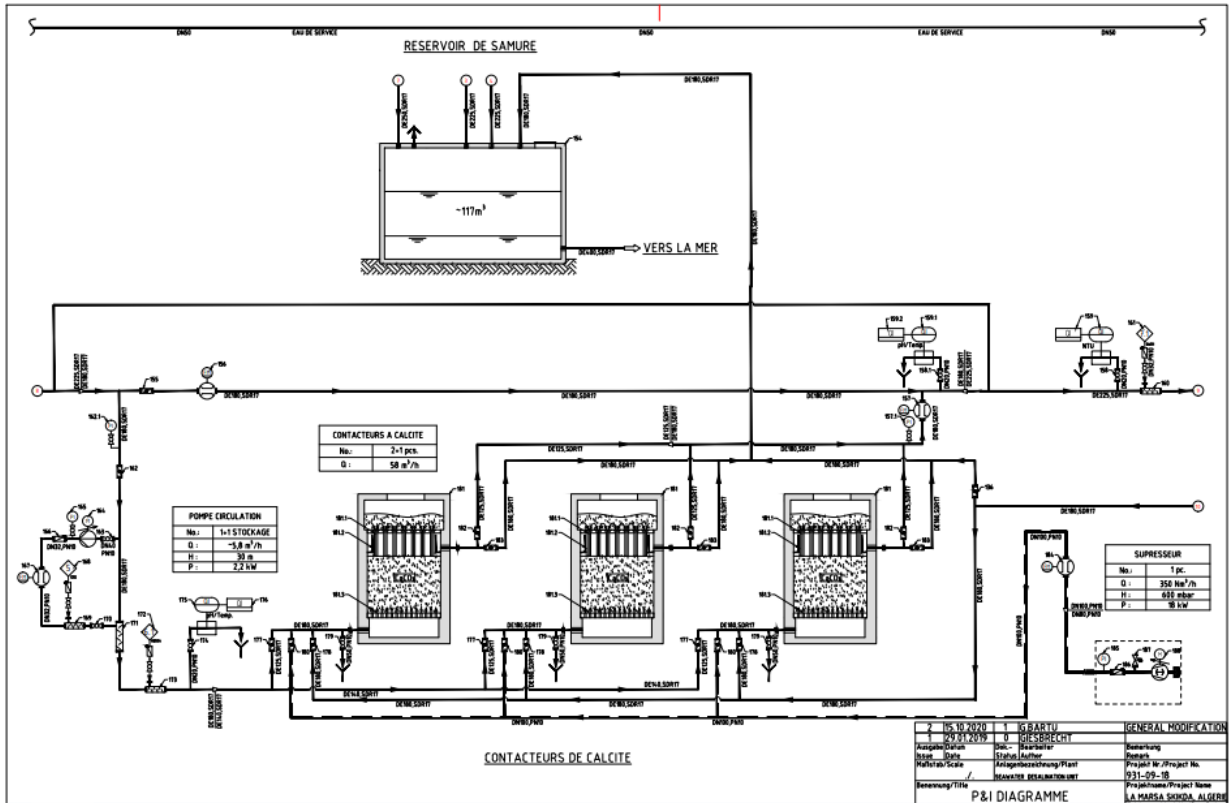*Figure A. 3. Page of the second stage of the filtration phase and the RO phase.*

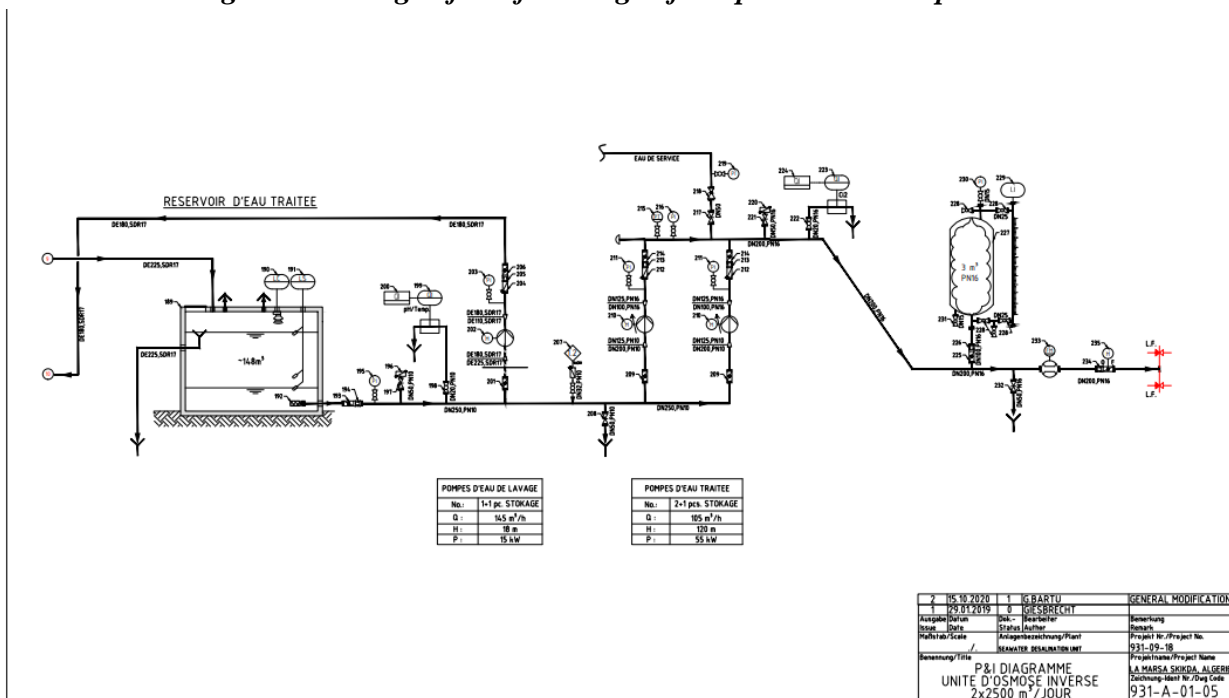**Figure A. 4. Page of the first stage of the post-treatment phase.**

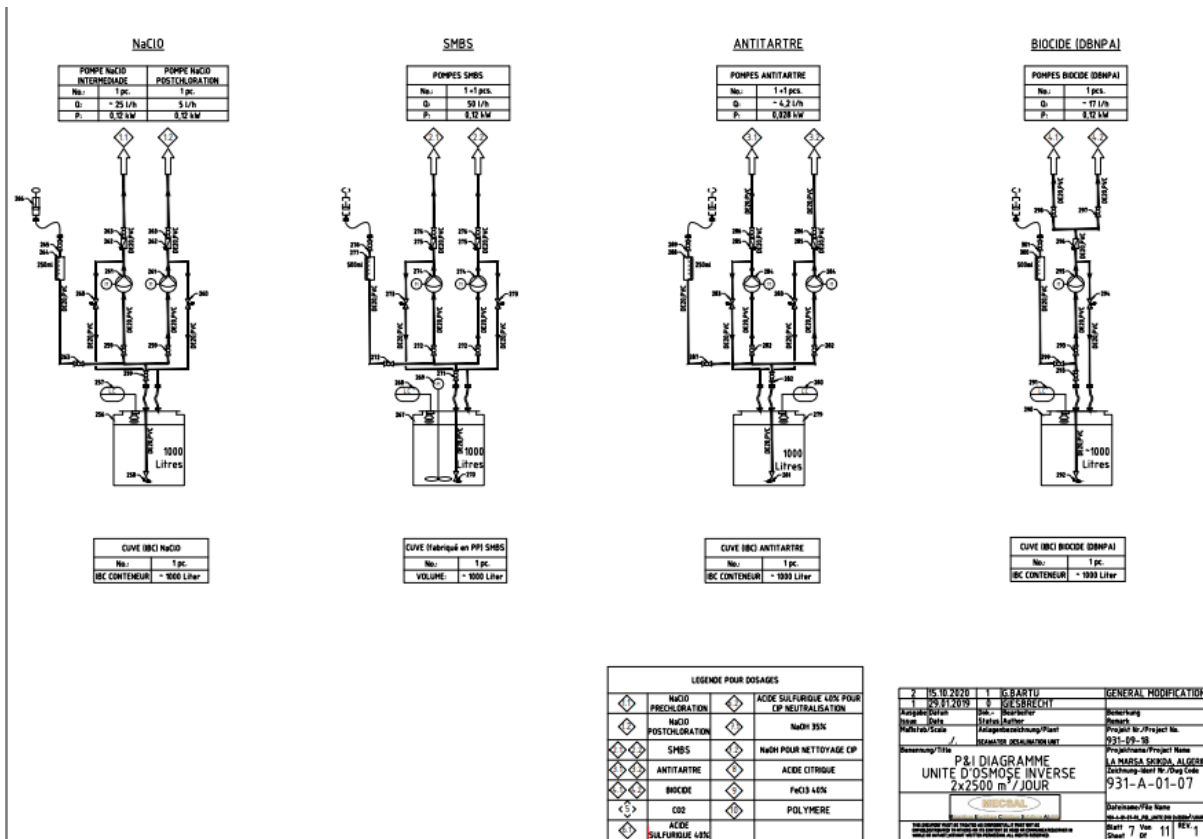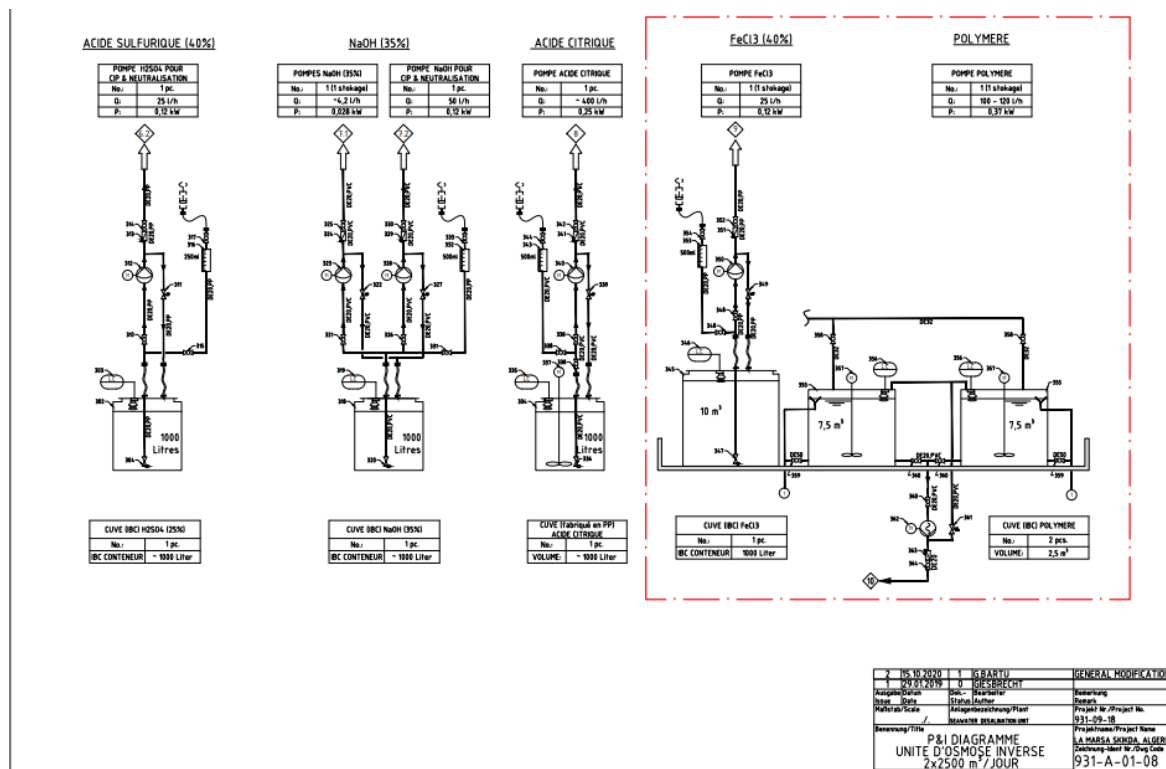**Figure A. 5. Page of the second stage of the post-treatment phase.**

Figure A. 6. First dosage page.

Figure A. 7. Second dosage page.