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THEME

**A Comprehensive Study, Sizing, and Supervisory
System Design of a Reverse Osmosis Desalination Plant**

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Thanks

First, we praise ALLAH and thank Him for His grace and blessings that He has bestowed upon us the ability to reach this station, which is the level of a second-year master's degree, and to submit this work.

Secondly, we thank Mr. **ACHBI Mohammed Said** for helping us, Mr. **TAHRA Hocine**, and we thank Mr. **BENARABI Bilal** for supervising us.

Dedications

*In the name of Allah the most compassionate the most merciful and peace be upon his
Messenger*

*Thanks Almighty God first and foremost for the great blessing bestowed on me,
Then We thank my beloved parents for supporting me from my birth until these
blessed moments.*

To my dear friends,

*You have been my pillars of strength, my confidants, and my
partners in laughter and tears. Your unwavering friendship and
unwavering belief in me have been a constant source of
inspiration and motivation. Thank you for your endless support,
understanding, and for always reminding me to take breaks and
enjoy the journey. This work is dedicated to our shared
memories and the bond we share.*

We dedicate this modest work as a testimony of affection, of admiration

ABSTRACT:

This study presents a detailed examination of the design, sizing, and supervisory system implementation for a reverse osmosis (RO) desalination plant. With increasing global water scarcity, particularly in arid regions and coastal areas, RO technology has become pivotal for converting seawater and brackish water into potable water. The study begins by elucidating the fundamental principles of RO technology, encompassing membrane types, operational processes, and key parameters influencing system efficiency and performance. An integral component of the study is the design and integration of a supervisory system. This system plays a pivotal role in facilitating operational oversight, real-time monitoring, and adaptive control of the RO plant. Through the incorporation of advanced sensors, controllers, and human-machine interfaces (HMIs), the supervisory system enables enhanced operational efficiency, energy optimization, and responsive management of varying feed water quality parameters.

Keywords: Reverse Osmosis (RO), Sizing, Supervisory system, Human-machine interface, SCADA.

ملخص:

هذه الدراسة تقدم فحصاً مفصلاً لتصميم وتحجيم وتنفيذ نظام الإشراف لمحطة تحلية بالتناضح العكسي (RO) مع زيادة ندرة المياه العالمية، خاصة في المناطق الجافة والساحلية، أصبحت تكنولوجيا RO حاسمة لتحويل مياه البحر والمياه المالحة إلى مياه صالحة للشرب. تبدأ الدراسة بتوضيح المبادئ الأساسية لتكنولوجيا RO، بما في ذلك أنواع الأغشية والعمليات التشغيلية والمعلمات الرئيسية التي تؤثر على كفاءة وأداء النظام. ويشكل جزءاً أساسياً من الدراسة تصميم ودمج نظام الإشراف. يلعب هذا النظام دوراً حاسماً في تيسير الإشراف على التشغيل والمراقبة في الوقت الحقيقي والتحكم التكيفي لمحطة RO من خلال دمج أجهزة الاستشعار المتقدمة والمتحكمات وواجهات الإنسان - الآلة (HMIs)، يمكن لنظام الإشراف تحسين كفاءة التشغيل وتحسين الطاقة وإدارة الاستجابة لمعلمات جودة المياه المغذية المتغيرة بشكل فعال.

الكلمات المفتاحية: التناضح العكسي (RO)، التحجيم، TORAY، نظام الإشراف، واجهة الإنسان والآلة، SCADA.

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**Water resources
and desalination plant
presentation**

I. Introduction

In an era of increasing global population and environmental challenges, access to clean and sustainable water resources has become a critical issue. Water scarcity, exacerbated by factors such as climate change and population growth, has heightened the need for innovative solutions to secure reliable freshwater supplies. Among these solutions, desalination technology plays a pivotal role in transforming saline or brackish water into potable water suitable for various uses, from municipal to industrial applications.

This chapter explores the significance of desalination plants in addressing global water scarcity issues. It begins by outlining the increasing demand for freshwater resources due to population growth and climate change impacts. The chapter then delves into the principles and processes of desalination technology, highlighting its role in converting saline water into potable water suitable for various applications. Overall, the chapter aims to contribute insights into the critical role of desalination in sustainable water management practices worldwide.

I.1. World Water Situation

Water is an essential resource that sustains all forms of life on Earth. Despite its abundance, the distribution and accessibility of clean, fresh water present significant challenges globally. The world faces a complex and multifaceted water crisis characterized by scarcity, pollution, and inequitable distribution. Over two billion people lack access to safe drinking water, and climate change exacerbates the situation by altering precipitation patterns and increasing the frequency of extreme weather events. Rapid population growth, industrialization, and agricultural demands further strain limited water resources, leading to conflicts and competition among various users. Addressing the global water situation requires comprehensive strategies that include sustainable management, technological innovations, and international cooperation to ensure that all communities can access this vital resource.

According to global estimates, fresh water represents only 3% of the total volume of water on the planet, but unfortunately 97% of this water is salty and non-drinkable and is not suitable for irrigation [4].

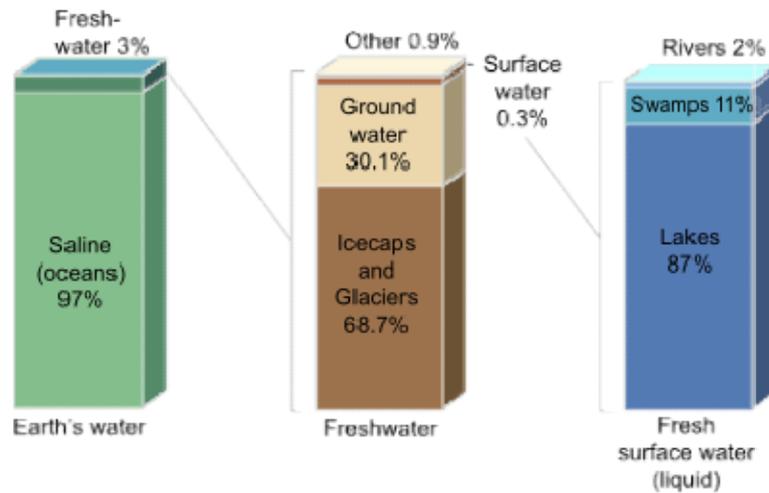


Figure I.1 : Distribution of fresh and salt water on the planet.

The increase in water consumption and the decrease in rainfall have led to a lack of fresh water in several countries. The direct consumption of water (domestic use, bathing, feeding) is about 150-250 L/day per person. However, to produce most of the foodstuffs and daily articles, we consume a huge quantity of potable water. An exponentially growing number of people are tapping into Earth's limited water resources [4].

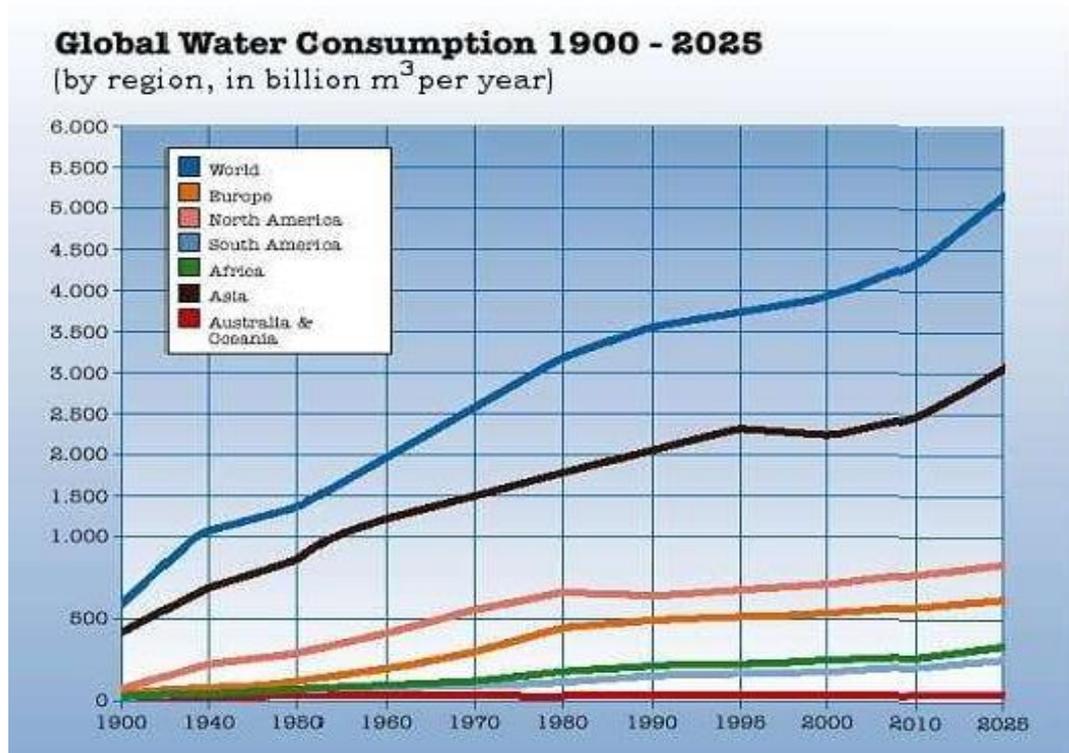


Figure I.2 : Global water consumption.

The global comparison of water availability coefficients with respect to the population highlights the disparities between continents. Regions with less than 1700 m³/year per person are considered to have hydraulic stress, and regions with less than 1000 m³/year per person are considered to have hydraulic scarcity. Figure 1.3 shows the estimation of world water availability [5].

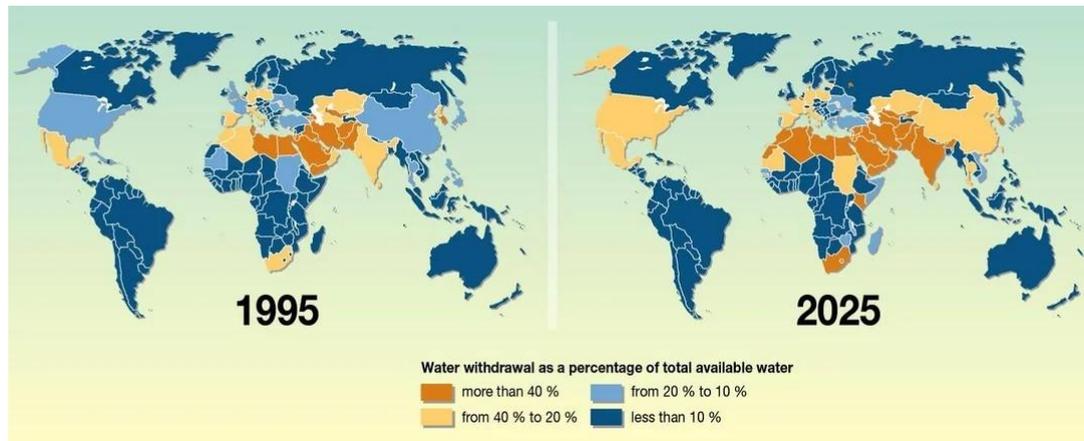


Figure I.3 : The estimation of world water availability.

Worldwide water withdrawals are approximately 4,000 km³ each year. With regard to the quantities of water present in various natural reservoirs, the problem of water is not about the available volume but rather local access to the resource and ensuring it is of sufficient quality. Water withdrawal has three primary uses:

- 70% for agriculture: Mainly to produce food. Agriculture (including crops, livestock, and aquaculture) feeds most humans. While the majority of crops depend on water, 15% of the water used in agriculture is specifically for irrigation.
- 22% for industry: Water is mainly used for cleaning and cooling as part of the manufacturing process. It is increasingly used to cool power stations. Most of the water used for industrial purposes (about 96%) is reused at least once.
- 8% for domestic use: This includes water used for household and municipal purposes, as well as water consumed by businesses and utilities.

Algeria, like other countries, faces the problem of water scarcity. Significant efforts have been made to curb this thorny issue that hinders the socio-economic development of the country. Algeria has very limited water resources, which means it is currently ranked as the 14th country most lacking in water. By 2025, due to demographic pressures, it is projected to be ranked 6th. To combat the lack of drinkable water, desalination has become an effective solution over the last few decades [3].

I.1. Background (problematic)

Water scarcity is a growing global concern, affecting millions of people across diverse regions. Driven by factors such as climate change, population growth, and inefficient water management, the availability of fresh water is diminishing at an alarming rate. This scarcity not only jeopardizes agriculture and food security but also threatens health and sanitation, leading to increased incidences of water-borne diseases. In arid and semi-arid areas, communities are often forced to travel long distances to access potable water, exacerbating social and economic inequalities.

Addressing water scarcity requires a multi-faceted approach, including sustainable water management practices, investment in infrastructure, and the promotion of water conservation and reuse technologies. Without concerted global action, the impacts of water scarcity will continue to escalate, posing significant challenges to development and stability.

Desalination has emerged as a vital solution to address these challenges, particularly in arid regions and coastal areas. Desalination is increasingly recognized as a crucial tool for addressing water scarcity issues, especially in regions where freshwater resources are limited, such as arid areas and coastal regions. By removing salt and other impurities from seawater or brackish water, desalination plants can provide a reliable source of clean drinking water and support agricultural and industrial activities. As technology advances and becomes more efficient, desalination is likely to play an even larger role in securing water supplies for communities around the world facing water stress.

I.2. Desalination

I.2.1. Definition

Desalination has become an increasingly important technology as global water scarcity continues to rise due to population growth, urbanization, and climate change. Regions with limited freshwater resources, such as arid coastal areas, often rely on desalination to meet their water needs. Desalination of water is a process that enables the production of fresh water (drinking water or, less commonly due to cost, water usable for irrigation) from brackish or salt water (particularly seawater) [6].

The feed water is divided into two streams:

1. The desalinated, drinkable water flow,
2. The reject flow (or brine), which contains most of the salt.

I.2.2. Desalination water:

I.2.2.1. Sea waters

The most important characteristic of seawater is its salinity, that is, its overall salt content (sodium and magnesium chloride, sulphates, carbonates). The most important characteristic of seawater is its salinity, that is, its overall salt content (sodium and magnesium chloride, sulphates, carbonates). The salinity of open seas on ocean masses (Atlantic, North Sea, Pacific) is of the order is 35 g/L, this value is considered the standard salinity of seawater.

I.2.2.2. Brackish water:

Brackish water is a non-potable saline water of lower salinity than seawater. Finally most brackish waters have salinity between 1 and 10 g of salts per liter. They occur either as surface water or as ground water [6].

I.2.3. The positive and negative impacts

- Provides a reliable source of freshwater: The main direct positive effect of desalination is increased water availability. Indeed, it provides access to a guaranteed resource independent of climatic hazards and consequently, it contributes to solving a situation of water scarcity and stress for the populations.
- Helps alleviate water scarcity.
- Can be powered by renewable energy sources, such as solar or wind power.

The negative impacts of desalination can be categorized into key aspects which are described in the following paragraphs.

- High energy consumption: Desalination requires a large amount of energy, especially for methods such as reverse osmosis and thermal desalination, which can contribute to greenhouse gas emissions and increase operating costs.
- Environmental Impact: Discharge of salt water and other by-products can harm ecosystems if not managed properly.
- Cost: Desalination plants require significant initial investment and ongoing maintenance, making fresh water produced through desalination more expensive than traditional water sources in many cases.

I.2.4. Desalination Technologies

There are several desalination technologies and several ways to classify them. The desalination techniques can be divided into two important groups:

1. Power-driven processes:
 - Reverse Osmosis (RO).
 - Electrodialysis Reversal (EDR).
 - Mechanical Vapour Compression (MVC).
2. Heat-driven processes:
 - Multi-stage Flash (MSF).
 - Multiple Effect Distillation (MED).
 - Thermal Vapour Compression (TVC).
 - Membrane Distillation (MD).
 - Humidification-Dehumidification (HD).
3. Others:
 - Freezing.
 - Ion Exchange

Each desalination technology has its advantages and limitations in terms of energy consumption, cost, scalability, and environmental impact. The choice of technology often depends on factors such as feedwater quality, energy availability, infrastructure requirements, and economic feasibility.

MSF, MED, MVC, and TVC desalination technologies were widely used in the past. Nowadays, these technologies are still employed in regions with low fuel prices or where a heat source is available. Since the nineties, RO has become the most popular desalination technology, especially for large-scale seawater desalination plants, with the exception of the Middle East.

EDR is very common for medium-scale desalination plants, particularly for treating brackish and surface water with a high concentration of particulates and a low concentration of salt. MD and HD are currently used only for small-scale desalination plants powered by solar radiation.

I.3. Objectives of the Study

This thesis aims to provide a comprehensive framework for sizing a new RO plant, emphasizing the importance of assessing water quality and requirements. The primary objectives of this study are:

1. To evaluate the water quality parameters essential for designing an RO system.
2. To analyze the specific water quality requirements for different applications, including domestic, agricultural, and industrial uses.
3. To develop a methodology for selecting and sizing the appropriate RO plant components based on the assessed water quality.

I.4. Significance of the Study

Accurate assessment of water quality and requirements is fundamental to the success of an RO desalination project. Properly sized and designed RO plants ensure the reliable production of high-quality water, improve system longevity, and reduce operational costs. This study contributes to the existing body of knowledge by providing a structured approach to water quality assessment and its implications for RO plant design, ultimately supporting sustainable water resource management.

In this study, we focused on reverse osmosis (RO) technology. RO has gained prominence due to its efficiency and effectiveness in desalination processes, particularly for large-scale seawater desalination.

I.5. Conclusion

Desalination plants represent a significant advancement in water treatment technology, enabling the conversion of seawater and brackish water into high-quality freshwater suitable for diverse applications. Throughout this chapter, we have discussed the foundational principles of desalination, emphasizing the technological advancements that have enhanced efficiency and reduced costs over time.

In conclusion, while desalination is not a panacea for water scarcity, it remains a vital tool in the toolkit of solutions needed to address the complex challenges of water resource management in the 21st century.

Chapter II

Study and Sizing a Reverse Osmosis Desalination Plant

II. Study and Sizing a Reverse Osmosis Desalination Plant

II.1. Introduction

Desalination, particularly through reverse osmosis (RO), has emerged as a critical technology to address global water scarcity challenges. This thesis chapter focuses on the study and meticulous sizing of RO desalination plants. It begins by exploring the fundamental principles of RO technology, emphasizing membrane filtration and separation processes that enable the conversion of saline water into potable freshwater.

The chapter highlights key factors influencing plant design and sizing, including feedwater characteristics, membrane properties, operational parameters, and sustainability considerations. By integrating theoretical insights with practical applications, the chapter aims to advance understanding desalination technology, promoting its role in sustainable water resource management strategies worldwide.

II.2. Reverse Osmosis (RO)

Reverse Osmosis (RO) is a special type of filtration that uses a semi-permeable membrane to remove ions, molecules, and larger particles from drinking water.

The principle is that when two solutions of different concentrations are placed on either side of a semi-permeable membrane, water naturally moves from the less concentrated solution to the more concentrated one by osmosis until the concentrations balance, or until a difference in height, called osmotic pressure, is established.

By applying a pressure greater than the osmotic pressure, the process is reversed, causing water to move through the reverse osmosis membrane. This reverse effect of natural osmosis purifies the water [7].

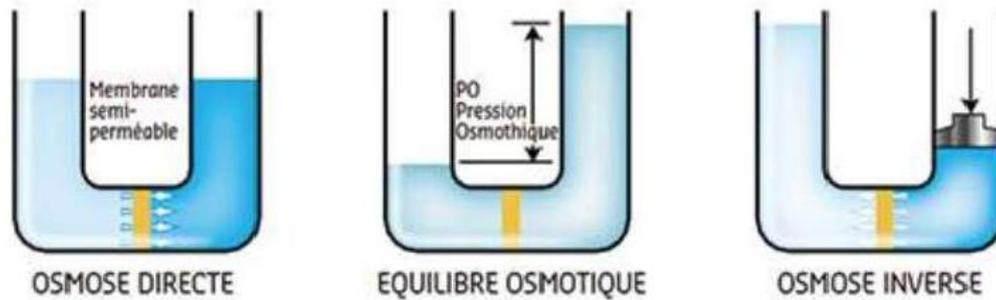


Figure II.1: Osmosis system.

In the field of desalination, reverse osmosis is a process for separating water and dissolved salts using a semi-permeable membrane under the action of pressure: typically operated between 15 to 150 bars.

A semi-permeable membrane is one that allows certain transfers of matter between two environments it separates while prohibiting others, or more generally, favoring some transfers over others. Reverse osmosis membranes are composed of a thin layer (active layer: skin) with a thickness between $0.1\mu\text{m}$ and $1.5\mu\text{m}$, consisting of micropores.

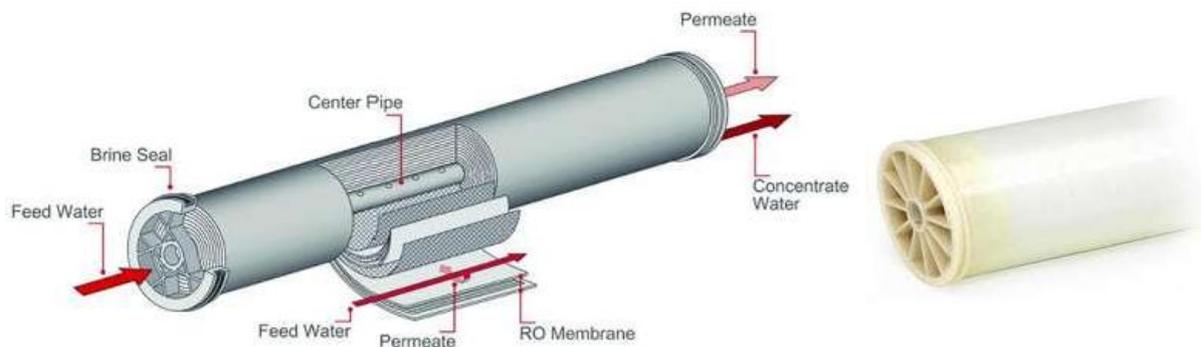


Figure II.2: Reverse Osmosis Membrane.

II.3. Reverse Osmosis Desalination Plants

Reverse Osmosis (RO) Desalination Plants are critical infrastructures that address the increasing global demand for fresh water, particularly in regions facing water scarcity. The proposed equipment for the station implementation is among the most renowned and efficient available. The station's sizing was meticulously conducted to guarantee long-term operational durability [7].

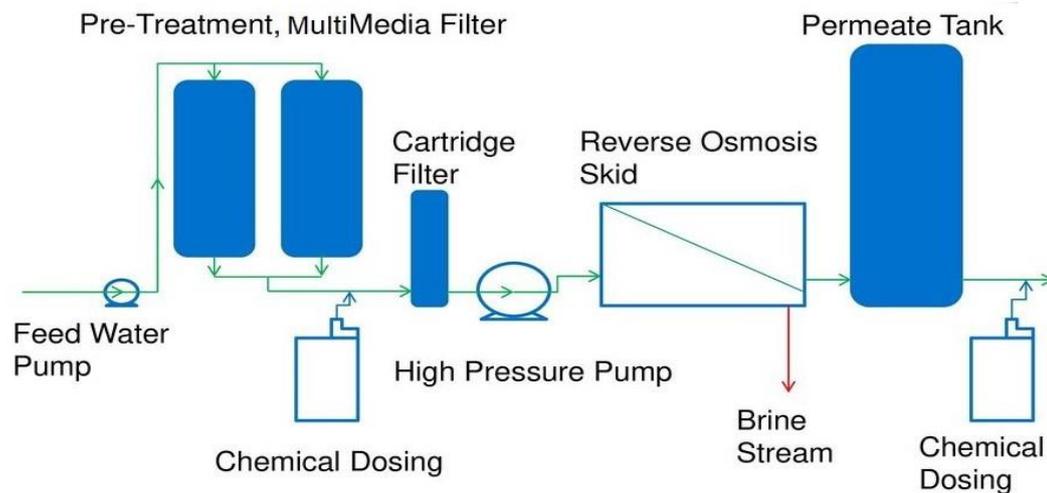


Figure II.3: Schematic diagram of Reverse Osmosis desalination plant.

A Reverse Osmosis desalination plant typically includes the following stages or sections:

1. Water intake:

Depending on the geographic location (surface water, sea, drilling, etc.), this phase must enable the acquisition of the highest quality water feasible, especially with regard to suspended contaminants.

2. Raw Water Storage Tank:

A raw water storage tank is a reservoir used to store untreated water from natural sources like rivers, sea, or wells. The purpose of such a tank is to ensure a steady supply of water for desalination.

3. Pre-treatment:

Because RO membranes have exceedingly fine pores, they are prone to frequent blockages. Additionally, they are highly susceptible to pH variations, acids, and chemical exposure. To prolong membrane lifespan and prevent damage, it is essential to pretreat the feed water before it enters the RO pressure vessels.

3.1 Multi-Media (Sand) Filter: Sand filters are primarily used in water treatment processes for removing suspended solids and turbidity. A sand filter typically comprises a tank, which can be either open or pressurized, containing a bed of sand. Water to be treated passes through this sand bed, where it captures suspended solids larger than 10 μm .

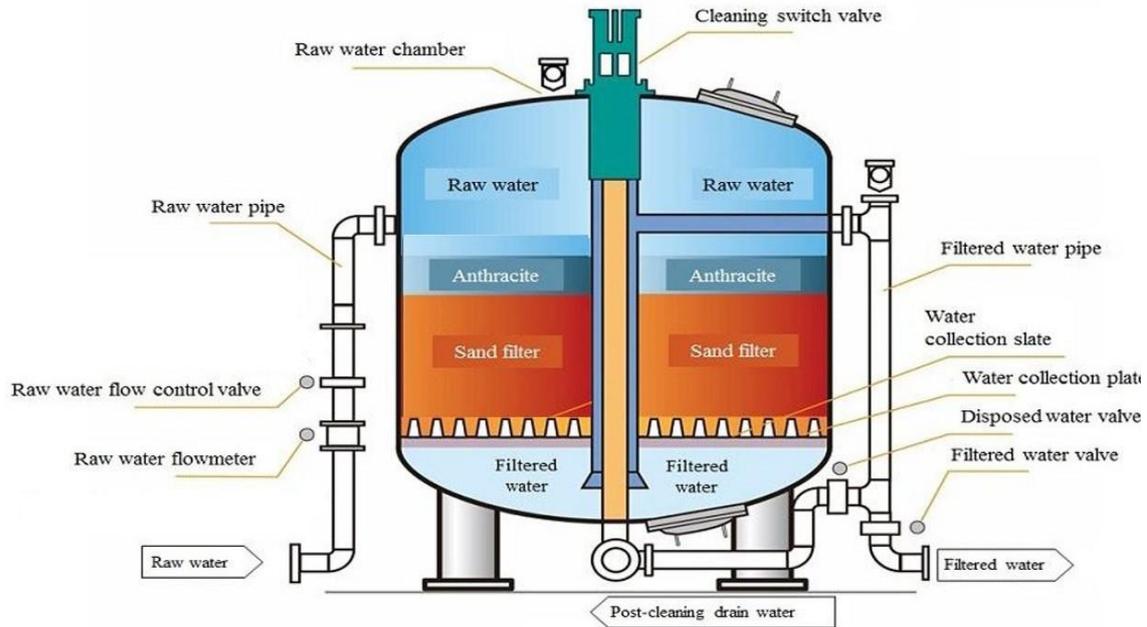


Figure II.4: Multi-Media (Sand) Filter.

3.2 Cartridge filter (microfiltration): Cartridge filtration is implemented to filter out small particles that might evade capture by sand filters, thereby safeguarding the membranes from clogging. Cartridge filters, with the capability to filter particles as small as 5 microns, are installed upstream of osmosis units for this purpose. Cartridge clogging is controlled by the reduction in flow at the outlet, increase in pressure. In this case the filter cartridge must be replaced.



Figure II.5: Multi-Media (Sand) Filter.

- 4. High pressure pumping system:** The heart of the reverse osmosis system is the high-pressure feed pump; it plays a very important role because it is directly related to energy consumption by its efficiency [6].

In order to overcome osmotic pressure and guarantee osmosis water production, a pump draws water from the cartridge filters and brings it to adequate pressure to pass through the membrane train. This increase in pressure will be regulated so as to produce the necessary quantity of water [8].

- 5. Reverse Osmosis System:** A membrane functions as a selective barrier, ranging from a few hundred nanometers to several millimeters thick. It facilitates the separation of dissolved salts, organic substances, viruses, and bacteria from water. This process employs semi-permeable membranes and operates under pressure for water treatment.

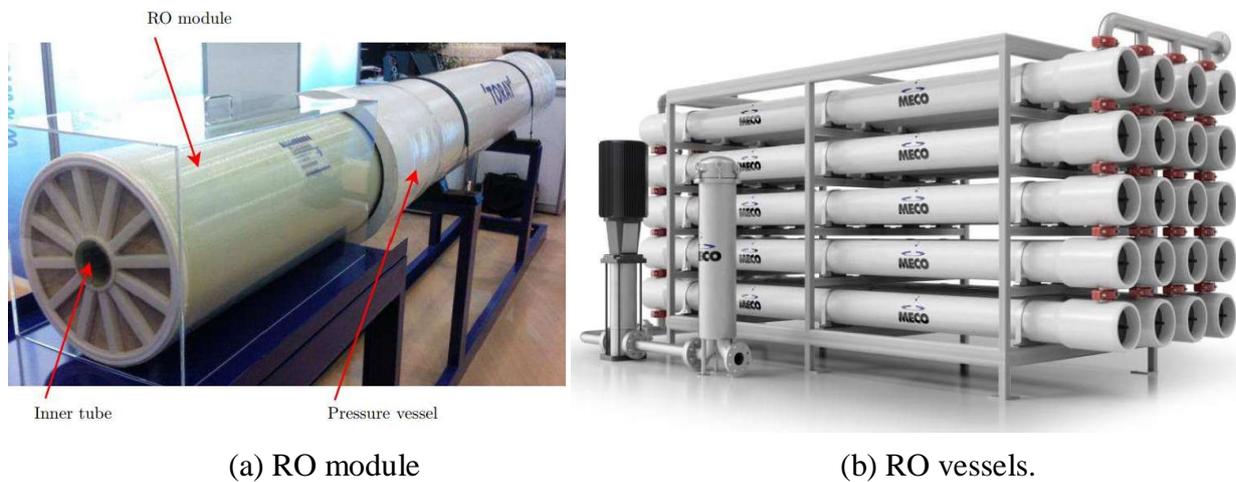


Figure II.6: Reverse Osmosis System.

- 6. Product Water Storage Tank:**

The recommended salt content in drinkable water is typically defined by health organizations and regulatory bodies. For example, the World Health Organization (WHO) sets guidelines for drinking water quality, including parameters like salt content. Since an RO system produces permeate water with salinity lower than 50 ppm, it should be remineralized before being consumed. Treated water tanks play a crucial role in the water distribution system by storing water that has been treated to make it safe for consumption. These tanks help to maintain a steady supply of clean water to homes, businesses, and other facilities.

- 7. Post-treatment:** The purified water may undergo further treatment to adjust its pH, add minerals for taste and health benefits, and ensure it meets drinking water standards.

8. Reject water tank: The concentrated brine solution, which contains the removed salts and impurities, needs to be properly disposed of or treated. The waste water tank is usually used in desalination plants. In these systems, rejected water refers to water that does not pass through the filtration or purification process and is instead discharged as waste. A waste water tank collects this wastewater before it is properly disposed of or subjected to further treatment, depending on specific requirements and regulations. These tanks are essential to effectively manage waste generated during the water treatment process while ensuring environmental compliance and resource conservation.

II.4. Assessing Water Quality and Requirements

The effectiveness and efficiency of an RO plant are significantly influenced by the quality of the feed water. Understanding the chemical, physical, and biological characteristics of the source water is crucial for designing an RO system that meets the desired water quality standards while optimizing operational costs and minimizing environmental impact. Key parameters such as salinity, turbidity, total dissolved solids (TDS), and the presence of specific contaminants must be carefully analyzed to determine the appropriate pretreatment processes and membrane configurations.

II.4.1. Analyzing Feed Water Quality

II.4.1.1. Parameters to Measure

When analyzing feed water quality, especially in contexts such as water treatment plants, industrial processes, or before use in various applications, it's essential to measure several key parameters to ensure water suitability and performance.

- 1. TDS (Total Dissolved Solids):** TDS measures the total concentration of dissolved substances in water, including salts, minerals, and metals. High TDS levels can affect equipment performance and water taste. Measured in mg/L or ppm.
- 2. pH (Potential of Hydrogen):** pH indicates the acidity or alkalinity of water. It's crucial for optimizing chemical treatments and ensuring compatibility with downstream processes. The pH scale ranges from 0 to 14, with 7 being neutral.
- 3. Temperature:** Water temperature affects chemical reactions and process efficiency. It's measured in degrees Celsius (°C) or Fahrenheit (°F).
- 4. Turbidity:** Turbidity measures the clarity of water by quantifying suspended particles. High turbidity can indicate the presence of particulate matter or colloidal solids, affecting

filtration and treatment processes. Measured in NTU (Nephelometric Turbidity Units) or FNU (Formazin Nephelometric Units).

5. **Conductivity:** Conductivity measures the water's ability to conduct electrical current, which correlates with dissolved ion concentrations (e.g., salts). It's crucial for assessing water purity and monitoring for contaminants. Measured in $\mu\text{S}/\text{cm}$ or mS/m .
6. **Dissolved Oxygen (DO):** DO levels indicate the amount of oxygen dissolved in water, crucial for aquatic life and biological processes. Low DO levels can impact water quality and treatment efficiency. Measured in mg/L or ppm.
7. **Chlorine Residual:** Chlorine residual measures the concentration of free chlorine remaining in water after disinfection. It's important for maintaining microbial control and ensuring water safety. Measured in mg/L or ppm.
8. **Heavy Metals:** Testing for specific heavy metals like lead, arsenic, mercury, and cadmium is essential due to their toxicity. Compliance with regulatory limits is crucial for safe water use. Measured in $\mu\text{g}/\text{L}$ or ppb.
9. **Organic Contaminants:** Includes measuring substances like pesticides, volatile organic compounds (VOCs), and disinfection by-products (DBPs). Detection ensures water safety and compliance with health standards. Measured in $\mu\text{g}/\text{L}$ or ppb.
10. **Nutrients (Nitrate, Phosphate):** Nutrient levels can impact water quality, leading to eutrophication and harmful algal blooms. Monitoring ensures balanced nutrient levels suitable for intended use. Measured in mg/L or ppm.

These parameters provide a comprehensive assessment of feed water quality, guiding treatment processes and ensuring the water meets desired standards for its intended application, whether it's for drinking, industrial use, or environmental discharge.

II.4.2. Determining Desired Water Quality

Determining the desired water quality for an RO plant involves identifying the specific parameters and standards that need to be met to ensure the plant operates efficiently and produces water that meets the intended use.

- a) **Regulatory Standards:** Research and identify the regulatory standards and guidelines applicable to your region or industry. Regulatory agencies such as the Environmental Protection Agency (EPA) in the United States or the World Health Organization (WHO) often set standards for various water quality parameters.

b) End-Use Requirements: Consider the intended use of the treated water. Different applications may have varying quality requirements. First, clarify how the water will be used, as this will dictate the relevant quality parameters:

- **Drinking Water:** Must meet stringent health and safety standards.
- **Industrial Use:** May have specific purity requirements to avoid equipment damage or product contamination.
- **Agricultural Use:** Requirements might focus on nutrient content and absence of harmful contaminants.
- **Environmental Discharge:** Compliance with regulatory limits to protect aquatic ecosystems.

c) RO System Design: Consult the manufacturer's specifications and recommendations for the RO system you're using. The desired water quality should align with the system's design parameters to ensure optimal performance and membrane longevity.

d) Water Source Characteristics: Understand the characteristics of the raw water source feeding into the RO plant. Analyze the feed water quality to identify any contaminants or parameters that need to be addressed through treatment.

- **Physical Parameters:**

- Temperature: Ensure within acceptable limits for the application.
- Turbidity: Measure of water clarity; higher clarity may be needed for drinking water.
- Color: Relevant for aesthetic purposes in drinking water.

- **Chemical Parameters:**

- pH: Acidity or alkalinity; typically between 6.5 to 8.5 for most applications.
- Dissolved Oxygen (DO): Crucial for aquatic life; levels vary with temperature and altitude.
- Nutrients: Nitrogen and phosphorus levels; high levels can cause eutrophication.
- Heavy Metals: Lead, arsenic, mercury, etc.; toxic even at low concentrations.

- **Biological Parameters:**

- Microbiological Contaminants: Bacteria, viruses, critical for drinking water safety.

e) Set Quality Objectives

Define specific goals or targets for each parameter based on regulatory requirements and desired outcomes:

- **Numeric Limits:** Specify maximum allowable concentrations or ranges (e.g., pH 6.5-8.5, turbidity <1 NTU for drinking water).

- **Performance Standards:** Ensure effective treatment processes (e.g., chlorine residual >0.2 mg/L after disinfection).
- **Risk-Based Goals:** Consider health risks and environmental impacts when setting goals (e.g., limiting heavy metals to safe levels).

II.5. Calculating System Capacity and Flow Rates

II.5.1. Estimating Daily Water Demand

II.5.1.1. Peak and Average Consumption:

1. Peak Consumption:

Definition: Maximum water usage occurring within a specific timeframe, often daily.

Occurrence: Typically during morning and evening peaks when demand for water is highest.

Importance: Ensures infrastructure can handle maximum demand without shortages.

2. Average Consumption:

Definition: Typical amount of water used over a longer period (day, week, month, year).

Calculation: Total water used divided by the number of days, weeks, months, or years.

Usefulness: Provides insights into overall water demand trends for planning and conservation efforts.

II.5.1.2. Flow Rate Calculations:

3. Feed Flow Rate:

Definition: Rate at which water enters a treatment or filtration system.

Calculation: Typically measured in liters per hour (L/h) or cubic meters per hour (m³/h).

Importance: Determines the volume of water that needs processing.

II.5.1.3. Permeate Flow Rate:

Definition: Rate at which treated or filtered water exits the system as usable product (permeate).

Calculation: Also measured in L/h or m³/h.

Importance: Indicates the efficiency of the treatment process and the amount of usable water produced.

II.5.1.4. Concentrate Flow Rate:

Definition: Rate at which waste or concentrated brine exits the system.

Calculation: Often expressed in L/h or m³/h.

Importance: Helps in managing waste disposal and system efficiency.

These concepts are fundamental in water management and engineering, providing a basis for designing sustainable and effective water supply and treatment systems.

II.6. Sizing and selecting RO plant Components

II.6.1. Sizing RO plant

To size a Reverse Osmosis (RO) plant, you typically need to consider several factors:

- 1. Feed water Quality:** The quality of the water that will be fed into the RO plant is crucial. This includes parameters such as total dissolved solids (TDS), hardness, and other contaminants. The higher the TDS and other contaminants, the more robust the RO system needs to be.
- 2. Recovery Rate:** Recovery rate in the context of reverse osmosis (RO) systems refers to the percentage of feed water that is converted into product water (permeate). Recovery rate is calculated as the ratio of the amount of permeate (product water) produced to the amount of feed water supplied to the RO system, expressed as a percentage.
$$\text{Recovery Rate (\%)} = \left(\frac{\text{Permeate flow rate}}{\text{Feed flow rate}} \right) \times 100$$
This is the percentage of feed water that becomes product water (permeate). Typical recovery rates for RO systems range from 50% to 75%. Higher recovery rates reduce wastewater (brine) but require more advanced pretreatment and post-treatment processes.
- 3. Membrane Selection:** RO systems use membranes that have different pore sizes and configurations. The choice of membrane depends on the feed water quality and desired permeate quality.
- 4. Operating Pressure:** RO operates under pressure. The feed water must be pressurized sufficiently to overcome osmotic pressure and allow water molecules to pass through the membrane.
- 5. Pre-treatment Requirements:** Feed water often requires pre-treatment to remove particles, organic matter, and chlorine, which can damage RO membranes. Pre-treatment includes filters (sand filters, multimedia filters) to remove larger particles and activated carbon filters to remove chlorine and organic matter.
- 6. RO Membrane Modules:** These are the core components where water is separated into permeate (product water) and concentrate (brine).

II.6.1.1. Steps in Sizing

- **Calculate Permeate Flow Rate:** Determine the desired production rate of permeate water. For example, if you want 75% recovery, the permeate flow rate would be 750 m³/h.
- **Select Membrane Configuration:** Based on feed water quality and desired permeate quality, choose appropriate membrane types and sizes (number of membrane elements per vessel).
- **Pressure Requirements:** Determine the operating pressure based on feedwater quality and desired recovery rate. High TDS feedwater requires higher pressure.

- **System Layout:** Design the number of RO trains needed to achieve the desired capacity and redundancy.
- **Energy and Cost Considerations:** Factor in energy costs for pumping and membrane replacement costs over time.
- **Monitoring and Maintenance:** Plan for monitoring systems to ensure performance and regular maintenance schedules.

Designing an RO plant involves detailed engineering considerations to ensure efficiency, reliability, and cost-effectiveness over the plant's lifecycle. Professional engineering consultation and detailed analysis of feed- water quality are crucial to successful design and operation.

II.6.2. Selecting RO plant Components

II.6.2.1. Membrane Selection and Configuration

- **Types of Membranes:**

This involves choosing the appropriate membrane type based on the specific application and water quality. Examples include:

- 1) **Thin-Film Composite (TFC):** Known for high rejection rates and durability.
- 2) **Cellulose Acetate:** Generally used in specific applications where chlorine resistance is required.

- **Membrane Array Design**

- 1) **Single or Multi-Stage:** Determines how many membrane stages are used in the system. Multi-stage systems are used when higher purity levels or specific water quality standards need to be met.

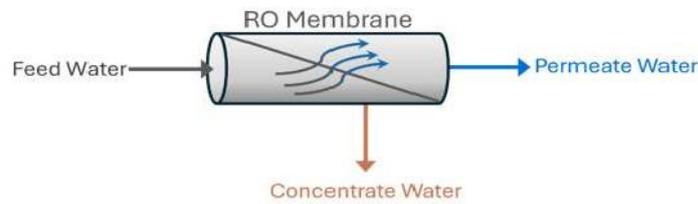
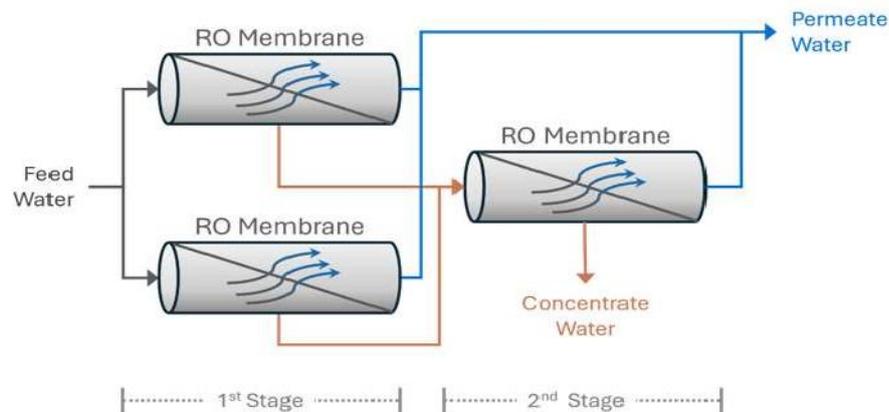
One-Stage RO SystemTwo-Stage RO System

Figure II.7: Single or Multi-Stage membranes system.

II.6.2.2. Pump Sizing and Selection

- 1) **High-Pressure Pump Specifications:** Critical for pushing water through the membranes at the required pressure levels. Factors considered include flow rate, pressure requirements, energy efficiency, and durability.
- 2) **Booster Pumps:** Sometimes needed to increase pressure to specific stages or to compensate for pressure losses in the system.

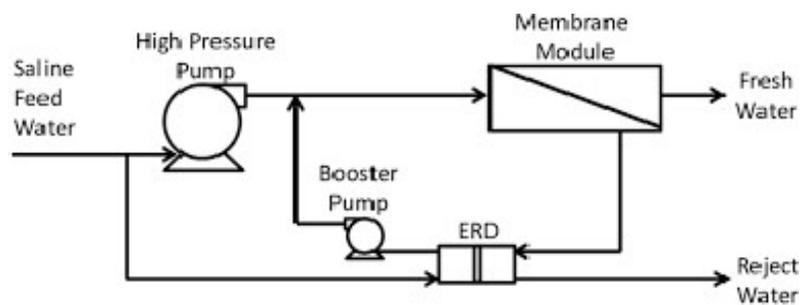


Figure II.8: High-Pressure Pump and Booster Pump.

II.6.2.3. Pre-treatment and Post-treatment Units

- 1) **Pre-filters:** Remove large particles and protect downstream components.
- 2) **Carbon Filters:** Remove chlorine, organic compounds, and some heavy metals.

II.6.2.4. Chemical Dosing Systems

Used for various purposes such as:

- 1) **Antiscalants:** Prevent scaling on membranes.
- 2) **Disinfectants:** Ensure microbial control.
- 3) **pH Adjustment:** Ensure optimal pH for membrane performance.

II.6.2.5. Integration and Considerations

1. **System Integration:** Ensuring all components work together seamlessly to achieve desired water quality standards.
2. **Energy Efficiency:** Selecting components that minimize energy consumption without compromising performance.
3. **Maintenance and Serviceability:** Choosing components that are easy to maintain and have readily available parts and service support.

By following this structured approach, you can design a water treatment system that meets specific water quality requirements efficiently and effectively. Each component plays a crucial role in achieving the desired outcomes, whether it's for potable water production, industrial processes, or wastewater treatment.

Developing Piping and Instrumentation Diagrams (P&ID) is crucial for outlining the design and functionality of engineering systems, particularly complex systems like Reverse Osmosis (RO) systems. Let's delve into the basics, importance, symbols, standards, and drafting considerations specific to an RO system P&ID.

II.7. Developing Piping and Instrumentation Diagrams (P&ID)

II.7.1. P&ID Basics and Importance

1. Basics:

P&IDs are schematic representations that illustrate the interconnection of process equipment and the instrumentation used to control the process. They show the piping, valves, instruments, and other equipment in a system.

2. Importance:

- **Communication:** P&IDs provide a common language for engineers, operators, and other stakeholders to understand how a system operates.
- **Design Basis:** They serve as a basis for design decisions, including safety considerations, operational procedures, and maintenance planning.
- **Regulatory Compliance:** Essential for regulatory approval and compliance with standards such as ANSI/ISA-5.1 and ISO 14617.

Developing a P&ID for an RO system involves meticulous attention to detail, adherence to standards, and clear communication of process elements and instrumentation. Each symbol and component placement plays a critical role in ensuring the system operates efficiently, safely, and meets regulatory requirements. By following established standards and accurately representing system components, P&IDs serve as essential tools in the design, operation, and maintenance of RO systems and other industrial processes.

II.8. Application

II.8.1. Sizing a RO plant with a capacity of 1000 m³/h

II.8.1.1. Presentation of the study area

The lack of drinking water has become the daily concern of Algerians. It is in this context that our study is situated, which aims to contribute to the study of the drinking water supply system in Ouargla city.

Ouargla City, located in southeastern Algeria, faces significant challenges regarding water resources and management due to its arid climate and desert surroundings. It is characterized by low annual precipitation and high evaporation rates. This arid environment poses challenges for securing reliable water sources.

1. **Groundwater Dependence:** The primary source of water for Ouargla City is groundwater extracted from aquifers. However, over-extraction and improper management have led to declining water levels and quality issues.
2. **Desalination and Treatment:** To meet the water demand, especially for municipal and agricultural purposes, Ouargla relies on desalination plants and water treatment facilities. Reverse osmosis (RO) technology is commonly used to treat brackish water and improve its quality for consumption.

II.8.1.2. “TORAYDS” Software for Reverse Osmosis Process design

"TORAYDS" software is specifically designed for the reverse osmosis (RO) process, focusing on the design aspects crucial for efficient operation.

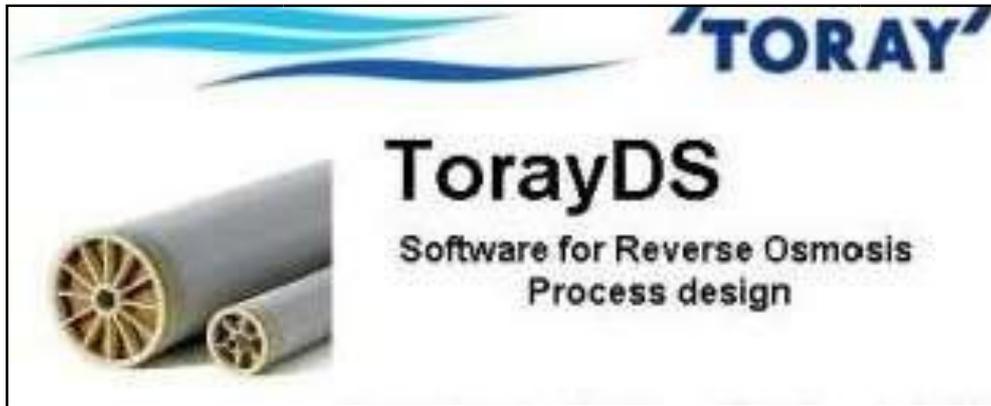


Figure II.9: “TORAYDS” software.

- Project creation:

Creating a project in TORAYDS software would involve designing a comprehensive project creation screen that allows users to input and configure various details related to the project.

The screenshot shows the 'Project creation' screen in TORAYDS software. The interface is light blue and contains several input fields and buttons. The 'Project Name' field is set to 'Treatment 2 stage'. The 'Toray Project ID' is 'DESKTOP-UD9RSMN\Hp 104'. The 'Engineer' field is 'DESKTOP-UD9RSMN\Hp'. The 'Project Notes' field is empty. The 'Case Number' is '1'. The 'Case Description' is 'New Case'. The 'Revision' is '10'. The 'Revision Description' is '1 Pass, Brackish Well, Feed: 10.0 m3/hr, TDS: 1435.3, Perm: 910.0, TDS: 18, Tot Elem: 1230, 1st Elem: TM720D-400'. The 'User Name' is 'DESKTOP-UD9RSMN\Hp'. The 'Run date' is '24-Jun-2024'. The 'Prepared For' field is empty. At the bottom, there are four buttons: 'Open', 'Save', 'Save As New Revision', and 'Start New Project'. There are also 'Delete Current Project', 'Delete Case', and 'Delete Revision' buttons.

Figure II.10: “TORAYDS” software Project creation Screen.

- Plant system Design

The main screen will show “Select Project from Template.” Use the radio button under More Templates to select a water type, then select an available template – eg 50% recovery, Two Pass Sea, etc.

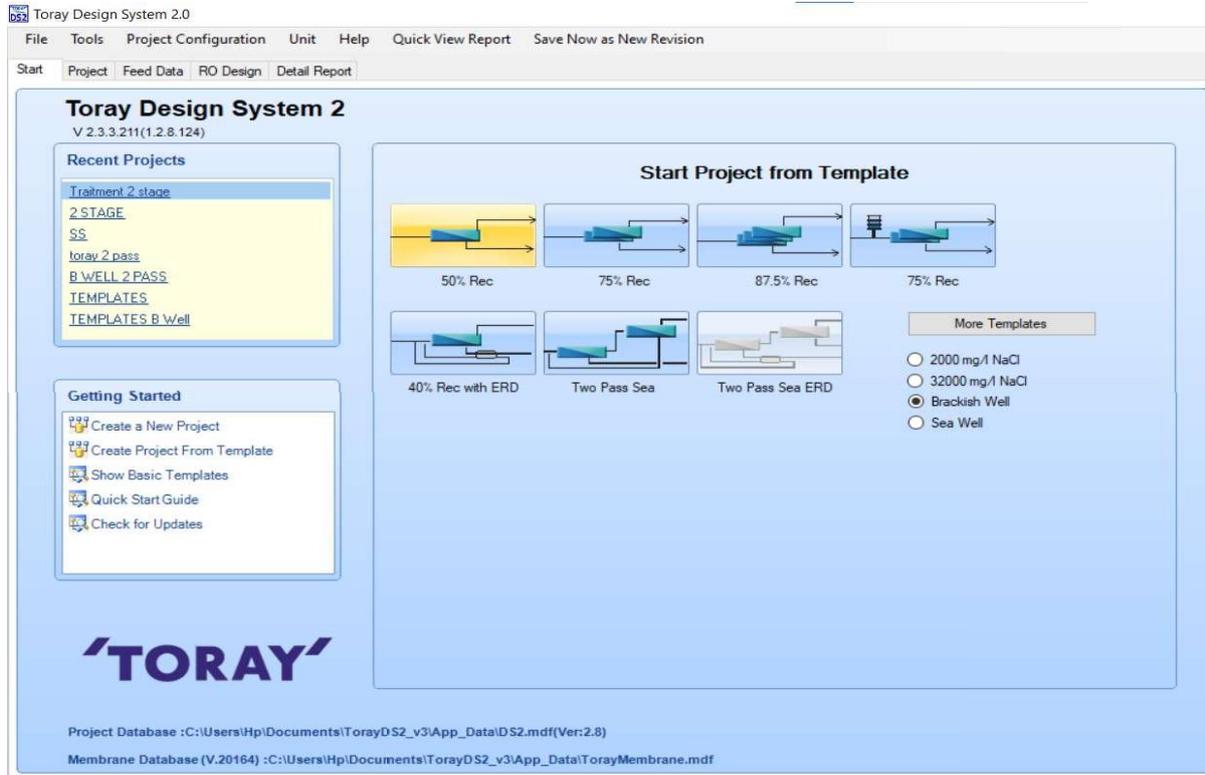


Figure II.11: “TORAYDS” software RO Screen.

II.8.1.3. Feed water Quality (Water analysis)

The template disclaimer will open, accept by saying OK. The database selection screen will open – click Open to start work.

- The Feed Data screen will open. Here you can modify the feedwater analysis or click on the “Load / Review” button to the left and look at all water analyses in your project database (The “Templates” database may take a few seconds to load as it has literally hundreds of projects to choose from. When the dropdown arrow works it is fully loaded). All data is mg/l.
- When satisfied with the analysis and water type. Click the next tab on the tab called RO Design and you will be taken to the main project screen.
- Click the “Calculate Now” button on upper right of the screen to see the results.
- Click the “Report” tab to view and save a detailed printout of the project. The reports may be saved as word docs, pdf files, or as single web pages (*.mht).

Stream Information

Number of Feed Streams: 3
 Current Feed Stream: 1
 Current Feed Stream Percent: 100 %

Feed Parameters

Water Type: Brackish Well
 Temperature: 25 Flow Rate: 10.00 m3/hr
 pH: 7.98 TDS: 1435.263
 Est uS: 2.805

Balance

% Excess Anion: 0.000 %
 AutoBalance

Solubility Data

Species	% Sat'n Feed	Conc
CaSO4	0.00	% of Max Solubility
BaSO4	0.00	% of Max Solubility
SrSO4	0	% of Max Solubility
PO4	0	% of Max Solubility
SiO2	0.0	% of Max Solubility
CaF2	0.0	% of Max Solubility
LSI	-5.66	

Cations

Ions	mg/l	mEq/L	ppm CaCO3
Ca	0.05	0.0025	0.12
Mg			
Na	564.52	24.5553	1228.87
K			
Ba			
Sr			
NH4			
Fe			
Totals	564.5724	24.5578	1228.9970

Anions

Ions	mg/l	mEq/L	ppm CaCO3
HCO3	0.10	0.0016	0.08
Cl	870.59	24.5562	1228.91
SO4			
NO3			
F			
Br			
B			
SiO2			
PO4			
CO3	0.00	0.0000	0.00
CO2	0.00	0.0000	0.00
Totals	870.6908	24.5578	1228.9970

Figure II.12: “TORAYDS” software Feed water Quality Screen.

Let's try a single pass seawater system with an energy recovery device. The seawater you want should have about 40000 mg/l TDS, a pH of 8.2, and a bicarbonate of 137 mg/l. Temperature of seawater should be 27.5 C. Recovery should be 43%. Permeate flow should be 500,000 US gpd.

- Click the “start” tab on left top.
- Select the radio button for “Sea Open” Click the button diagram labeled ”40% rec with ERD”. Click OK, then Click Open.
- You are now at the Feed Data screen.
- Click on the HCO3 / mg/l grid box and change to 137 mg/l.
- Click the “Balance with NaCl” to reset the balance.
- Click on the number in the text box labeled TDS (should default with this project to about 40,945 mg/l after the above changes). Type in 40000 and use the tab key to move away or click somewhere else. The analysis will reset to about 40,000 mg/l.
- Reset the HCO3 one more time to 137.
- Set pH to 8.2, Temperature to 27.5.
- Click the RO Design tab above to go to the design screen.
- Click Calculate Now to run the default design.

Water analysis in Ouargla City involves assessing various parameters to understand water quality and ensure it meets health and environmental standards. The following figure show the Water analysis report of Hai nasr (Algérienne des Eaux-Ouargla).

Zone : Ouargla Unité : Ouargla		Ministre des ressources en eau Algérienne des eaux Laboratoire de contrôle de la qualité des eaux					
Code de l'échantillon : 559 Nature de l'échantillon : EAU POTABLE Lieu de prélèvement : MELANGE ALBEIN EL KHAFDJI Commune : OGX				Bulletin D'analyses Date et Heure de prélèvement : 04/02/2024 Prélèvement effectué par : préleveur ADE OGX Date d'analyse : 04/02/2024 Analyse effectuée par : Laboratoire Central			
Paramètre Organique	Unité	Résultat	N.A (E.I)	Minéralisation Global	Unité	Résultat	N.A (E.I)
Couleur	mg/plaine	03	15	Calcium Ca ²⁺	mg/l	160.32	200
Odeur à 25 C°	Taux dilution	Néant	04	Magnésium Mg ²⁺	mg/l	97.22	150
Saveur à 25 C°	Taux dilution	Néant	04	Dureté Totale (TH)	CaCO3 mg/l	800	500
Chlore résiduel libre	mg/l	/	>0.1	Sodium Na ⁺	mg/l	263	200
Paramètre Physique-Chimique	Unité	Résultat	N.A (E.I)	Potassium K ⁺	mg/l	20	12
Concentration en ions hydrogène	Unité PH	7.98	≥6.5 et ≤ 9	Chlorures Cl ⁻	mg/l	583.2	500
Conductivité à 25C°	µs/cm	2870	2800	Sulfate SO ₄ ²⁻	mg/l	480	400
Température	C°	/	25	Nitrate NO ₃ ⁻	mg/l	7.48	50
Turbidité	NTU	5.91	5	Bicarbonate HCO ₃ ⁻	mg/l	111.54	-
Oxygène dissous	mg/l	/	-	Titre alcalimétrique complet (TAC)	mg/l CaCO3	91.04	-
TDS	mg/l	1435					
Résidu sec 105 C°	mg/l	2190	-				
Paramètres de Pollution	Unité	Résultat	N.A (E.I)	Paramètre Indésirables	Unité	Résultat	N.A (E.I)
Ammonium NH ₄ ⁺	mg/l	0.042	0.5	Fer	mg/l	00	0.3
Nitrite NO ₂	mg/l	<0.005	0.2	Manganèse	mg/l	/	0.05
Phosphore (p)	mg/l	<0.005	5	Aluminium	mg/l	/	0.2
Oxydabilité	mg/l		5				
Paramètre bactériologiques	Unité	Résultat	N.A (E.I)	Paramètre Ioniques	Unité	Résultat	N.A (E.I)
Coliformes totaux	/	00	/	Fluorures(F)	mg/l	/	1.5
Escherichia-coli	n/100ml	00	00	Cyanures (CN)	µg/l	/	70
Entérocoques	n/100ml	00	00	Bromes (Br)	mg/l	/	
Bactéries Sulfito-réductrices	n/20ml	00	00	Sulfure d'hydrogénée (H2S)	mg/l	/	
Observation							
N.A Norme Algérienne relative au décret exécutif N° 14-96							
E.T : Eau Traitée							
Siege Laboratoire :							
Tél :							
Fax :							
Site web : www.ade.dz							
				Visa du Chef Laboratoire  رئيسة المخبر اتيلي حنسة			

Figure II.13: Water analysis report.

Sizing a reverse osmosis (RO) plant for a capacity of 1000 m³/day in Ouargla City involves meticulous planning and consideration of local water conditions. Firstly, the feed water quality in Ouargla City, including parameters like total dissolved solids (TDS), should be thoroughly assessed to determine the appropriate pretreatment processes required to protect RO membranes from fouling and scaling. This typically includes filtration (such as sand and multimedia filters), and potentially softening depending on the water hardness.

The design of the RO system itself will be tailored to achieve the desired production rate of 1000 m³/day, factoring in the recovery rate, membrane selection (considering factors like membrane type, surface area, and configuration), and the overall system efficiency. Additionally, careful calculation of the reject water (brine) output is essential to ensure sustainable operation and compliance with local discharge regulations.

II.8.1.4. Recovery Rate

This is the percentage of feed water that becomes product water (permeate). Typical recovery rates for RO systems range equal 75%. Higher recovery rates reduce wastewater (brine) but require more advanced pretreatment and post-treatment processes.

II.8.1.5. RO Membrane:

Reverse osmosis (RO) systems utilize membranes with varying pore sizes and configurations. The selection of a membrane depends on both the quality of the feed water and the desired quality of the permeate. Selecting a membrane supplier entails evaluating numerous crucial factors to ensure that the chosen membranes align with the specific requirements and performance criteria of the application.

Opting for Toray membranes, a prominent manufacturer in the membrane sector, provides several distinct benefits across a range of applications such as desalination, water purification, and industrial processes.

- **Membrane Selection:** Helps in choosing the appropriate RO membrane type and specifications based on feedwater characteristics and desired output.
- **Process Simulation:** Allows users to simulate the RO process under different operating conditions to optimize performance and efficiency.
- **System Design:** Assists in designing the overall RO system layout, including pumps, pipes, and controls, to ensure smooth operation and maintenance.

- **Performance Prediction:** Provides tools to predict the performance of the RO system in terms of permeate quality, recovery rate, and energy consumption.
- **Data Analysis:** Enables analysis of historical data and trends to improve ongoing operations and troubleshoot issues.

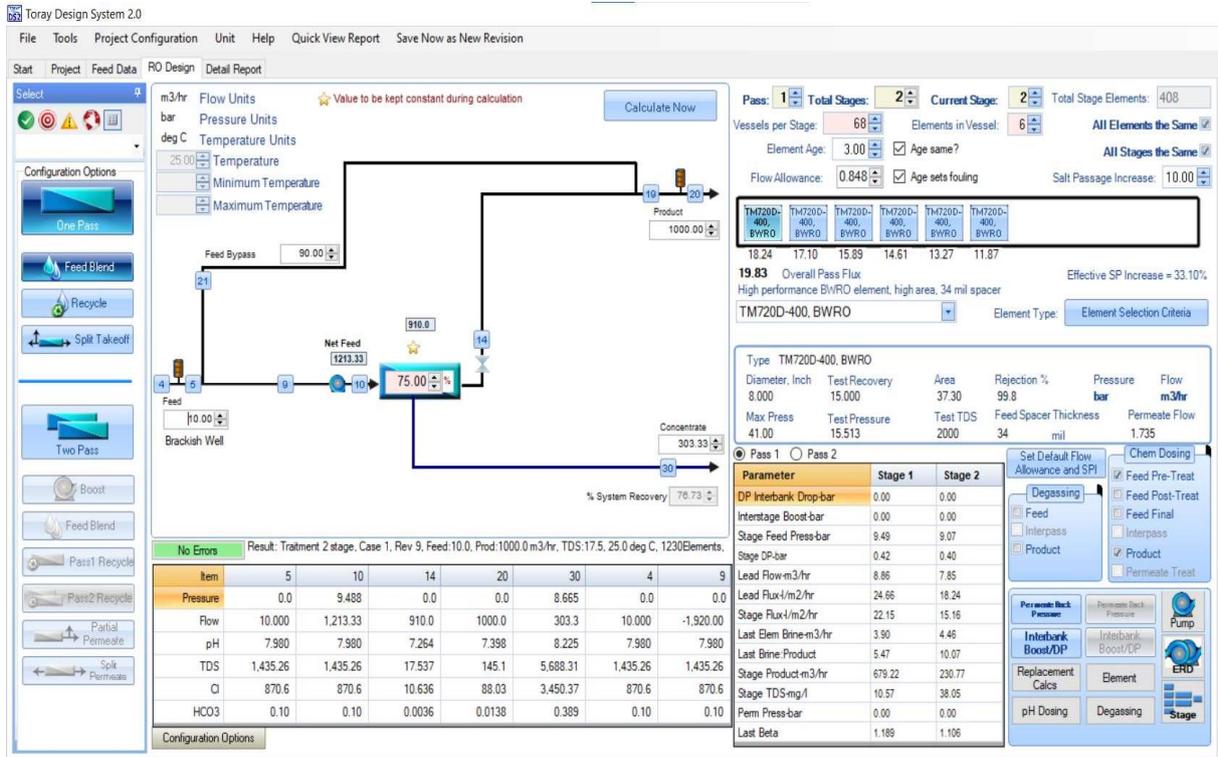


Figure II.14: RO plant design.

Toray DS2 can have different elements in a vessel.



Figure II.15: Membranes selection.

II.8.1.6. Pump Sizing and Selection

Design Data:

Plant Product Flow rate	24000	m ³ /d
	1000	m ³ /hr
Number of streams	3	
Raw Water pH	7.98	
Inlet water temperature to cooling tower	50	
Outlet water temperature to cooling tower	30	
Overall Recovery Ratio	75%	
Operation period	24	hrs
Cooling towers Evaporation loss	4.2%	
Cooling towers feed flow rate	31344	m ³ /d
Total Plant Feed Flow rate after cooling towers	30028	m ³ /d
	1251	m ³ /hr
R.O feed water requirement /stream	8000.0	m ³ /d
	333	m ³ /hr
Feed water quality TDS	2870	mg/l
Reverse Osmosis Quality	Less than 600 mg/L	
TDS Product water pH after pH correction	7.5-8.5	

Pre-treatment Units (Pressure media filter)

Quantity of filters	6	
Filtration rate	3.00	m ³ /m ² /hr
Flow rate	50.00	m ³ /m ² /hr
Filter cross section area	16.67	m ²
Filter type	Horizontal	
Filter Length	4.00	m
Filter diameter	4.17	m
CHOOSE filter diameter	2.50	m

Filter feed water pumps sizing

Quantity of pumps	3	duty
Flow rate	434	m ³ /hr
Pump head	50	m

II.9. Conclusion

In conclusion, the study and sizing of a reverse osmosis desalination plant are complex endeavors that demand a meticulous approach to engineering, environmental stewardship, and economic feasibility. By integrating technical expertise with environmental stewardship and economic foresight, these facilities play a crucial role in ensuring water security and supporting sustainable development worldwide.

Chapter III

Automation and Supervision

of a Reverse Osmosis

Desalination Plant

III. Automation and Supervision of a Reverse Osmosis Desalination Plant

III.1. Introduction

Following the automated, a number of other "ticks" emerged, including computing and robotics. The first industrial automatons, or "programmable controllers," were introduced in the United States in 1968–1969. The evaluation of automata, such as the S7-200 up to S7-1500 models currently in line with new, modern industrial appliances, has made it easier to regulate the activities of various machines, components, and equipment. This is especially true with regard to the digital electronics industry.

In order to achieve a qualitative leap in a short amount of time and in an ideal, modern manner, automated systems eliminate the majority of issues and roadblocks that impede the advancement of industrial technology (high costs, low profitability, very high human monitoring energy, difficult maintenance during breakdowns and occasionally not guaranteed).

Hardware and software are the two components of the automation work; this chapter focuses on enhancing system operating performance, automation, and water quality supervision, has been carried out in our work using a Siemens human-machine interface (HMI) and programmable controller is based on TIAportal software's HMI integration and new PLC programming [9].

III.2. Automated system

An automated or automatic system is one that runs on independently and does not require human intervention outside of system programming and tuning. An automated system's objectives are to ease the pain of repetitive or complex work for humans, increase efficiency and accuracy, and carry out dangerous or unpleasant activities. Combining sensors, actuators, and controls to carry out a task with little or no human involvement is known as an automation system.

III.3. Structure of an automated system

Automated systems are composed of two main parts connected through interfaces, which is illustrated in the following figure.

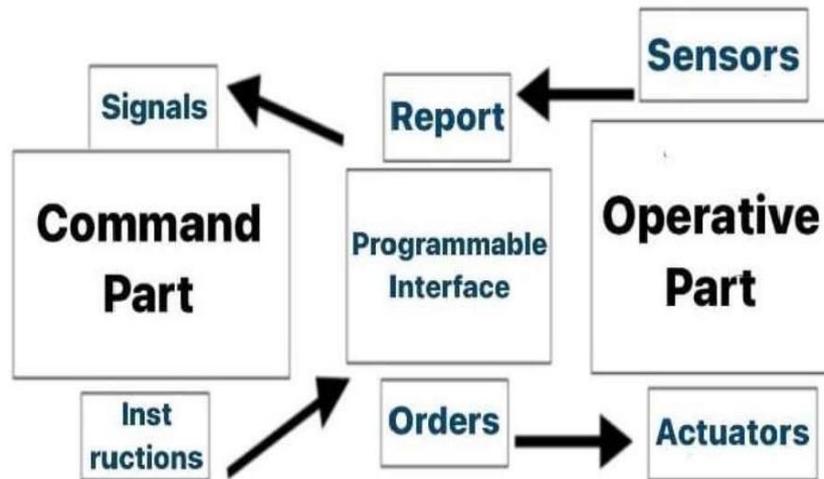


Figure III.1: Structure of an automated system.

1) Control part:

The decision center is the automation's control part, this part which oversees the automated system's operation, frequently consists of up of a computer with a software stored in its memory. It sends signals to the operator. It transmits commands to the operational part's actuators from:

- The software that's included.
- Data obtained by the captures.
- Directions provided by the operator or user.

2) Operative part:

Its actuators carry out orders received and report back to the control section. Its components influence the system or its surroundings, and its sensors respond to changes in the system or the environment. The command part issues commands to the operative part, which carries them out. The main functions provided by the operative part are:

- Transform energy.
- Adapt energy
- Transmit efforts [10].

III.3.1. Definition of industrial programmable logic controller

A programmable logic controller (PLC) is a programmable electronic device that is an industrial computer with various inputs and outputs used to control and monitor industrial equipment based on custom programming. Wherever there is a need to control devices, the PLC provides a flexible way to "software" the components together, adapted to the industrial environment, which performs automation functions to ensure the control of pre-actuators and actuators from logic, analog or digital information. This function consists in linking the various operations necessary for its realization while limiting the intervention of an operator as much as possible [9].



Figure III.2: PLC.

III.3.1.1. Structure of PLC

The main components of a PLC consist of:

- Central processing unit (CPU).
- Programming device (Memory unit).
- Input and output modules.
- Power supply.

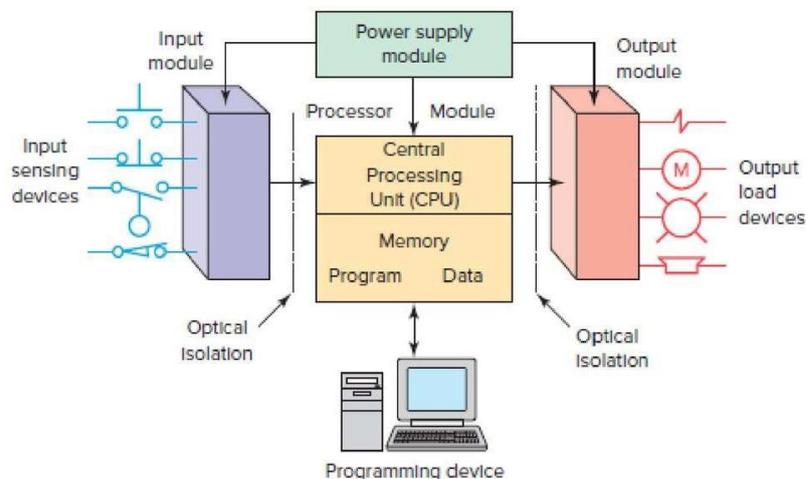


Figure III.3: Structure of PLC.

III.3.1.2. Types of PLC

- 1) **Compact:** They integrate processor, power supply, inputs, and outputs in a single box, performing additional functions like rapid counting and analog I/O, and are simple to operate.
- 2) **Modular:** PLCs, consisting of processor, power supply, and I/O interfaces, are integrated into complex automation systems for power, processing capacity, and flexibility.

III.3.1.3. Information nature processed by PLC

- 1) **TOR:** Information can be either true or false, and can be provided by a detector or a push buttons.
- 2) **Analog:** The information is continuously processed and can be interpreted within a predetermined range, which is then transmitted through a sensor (pressure and temperature).
- 3) **Digital:** The information is encoded in hexadecimal or box codes and is transmitted by a computer or intelligent module).

III.3.1.4. The different models of PLC SIEMENS

The Siemens PLC range contains several types of PLCs:

- ✓ **SIMATIC S7-200:** Simple sequential solution, efficient in terms of real time and communication.
- ✓ **SIMATIC S7-300:** Complex sequential solution. It makes it possible to carry out the majority of automation applications integrating decentralized architectures.
- ✓ **SIMATIC S7-400:** Complex sequential solution, high performance in terms of communication and memory.
- ✓ **SIMATIC S7-1200:** Simple but precise sequential solution.
- ✓ **SIMATIC S7-1500:** This is the latest range of Siemens PLCs. It is programmed under TIA Portal and has a small front screen allowing you to make some basic configurations.



Figure III.4: Different Models of PLC SIEMENS S7.

III.3.1.5. Presentation of the automaton S7-1200:

The development of the industry leads to a constant increase in functions. The S7-1200 provides the versatility and strength to manage an extensive array of devices to fulfill your automation requirements. It is the perfect choice for managing a wide range of applications because of its small size, adaptable setup, and extensive collection of instructions.

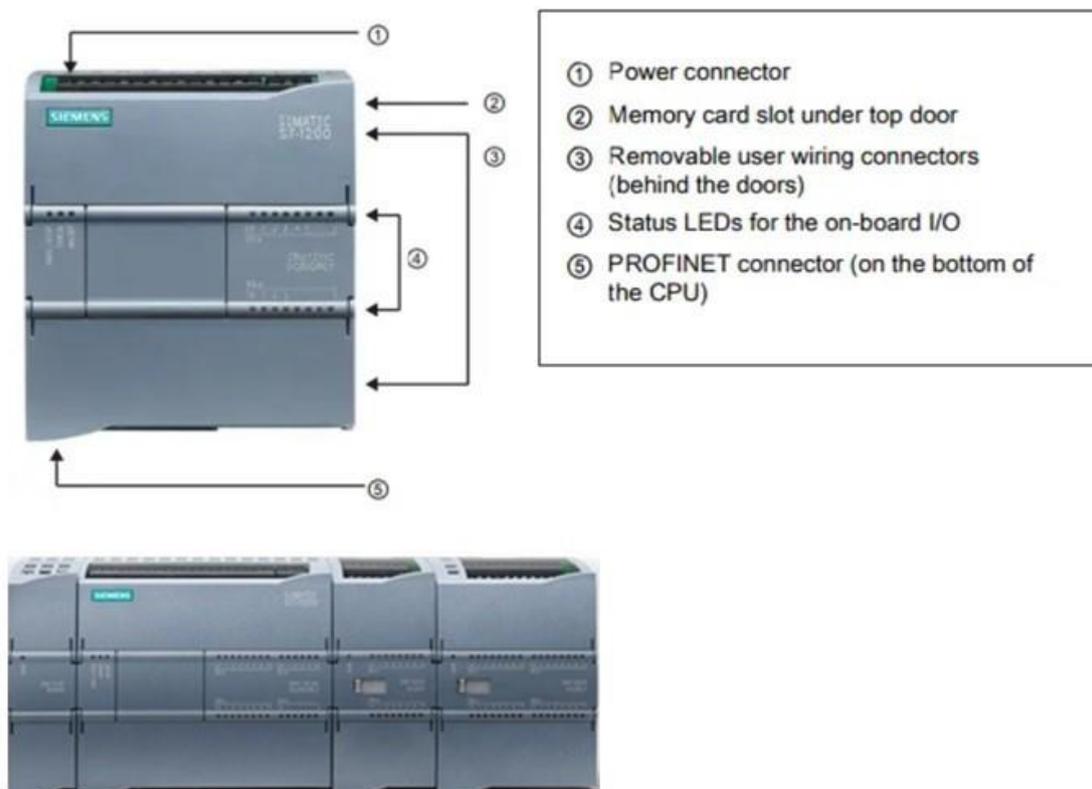


Figure III.5: PLC S7-1200.

In a small package, the CPU integrates a microprocessor, integrated power supply, input and output circuits, integrated PROFINET, quick motion control I/O, and analog inputs to create a potent controller.

Once you have loaded your program, the CPU contains the logic necessary to control and control the devices in your application [12].

III.3.1.6. PLC Programming

A. Programming software

As industrial processes became more complex, there was a growing need for seamless integration of various automation components. Siemens recognized this and, in 2010, introduced the Totally Integrated Automation Portal (TIA Portal).

TIA Portal is a software and tools package developed by Siemens, which aims to integrate multiple development tools for automation devices from the unification and remodeling of preexisting software. Step7 is used to program PLCs of the S7-1200, S7-1500, S7-300, and S7-400 families. The available programming languages are ladder (LD), FBD (Function Block Diagram), IL (Instruction List), ST (Structured Text), and S7 GRAPH.

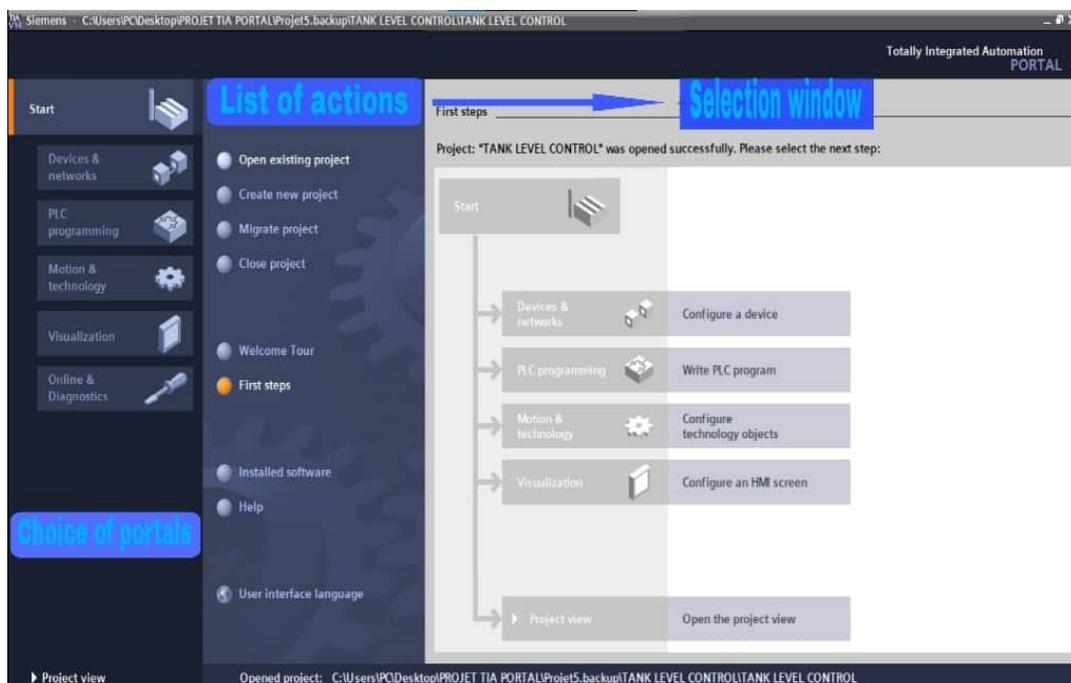


Figure III.6: TIA Portal view.

B. Configuration

The general steps for configuring hardware for a Siemens PLC in TIA Portal:

- a) Add the hardware to the project: Start by adding the type of PLC hardware to the TIA Portal project. This involves selecting the appropriate device type and model.
- b) Add hardware modules: Add the required hardware modules to the system, such as digital and Analogue input/output modules, communication modules, and power supply modules. Configure the parameters for each module, such as the input/output addresses and the module type.

This will enable the PLC to communicate with other devices in the system, such as HMIs, other PLCs, and remote I/O.

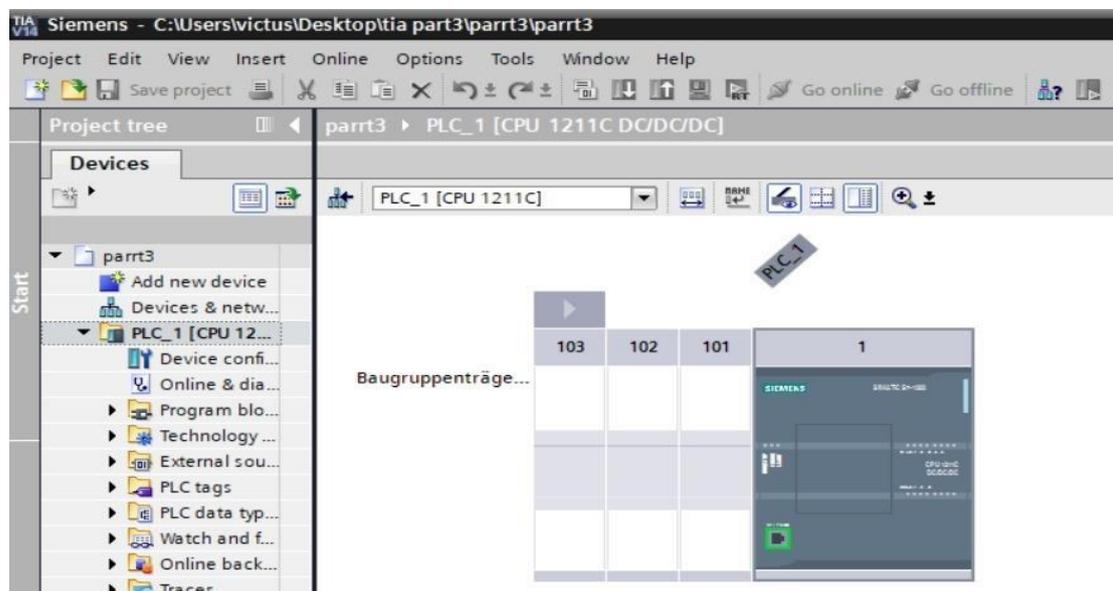


Figure III.7: PLC Configuration Window.

III.4. Automation and supervision of a Reverse Osmosis plant

III.4.1. Plant Automation Programming

III.4.1.1. PLC Programming

- **Select material:**

1. Add a device with the device name: Controle_citerne.
2. Then choose in the catalogue the «CPU 1215C» with the right combination of letters behind.
3. «Add one device > SIMATIC PLC > CPU 1214C > 6ES7 215-1HG40-0XB0»Add.

[10]

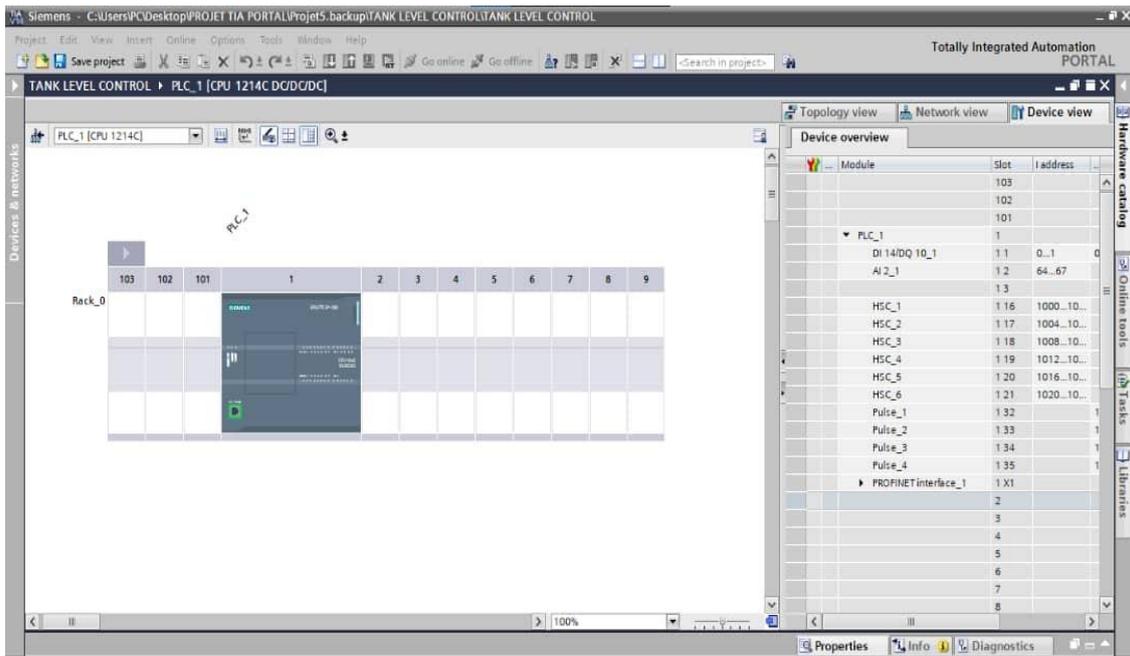


Figure III.8: PLC configuration window.

- **PLC tags table**

In order to facilitate programming, it is interesting to create a table of variables. This is how we will be able to declare all the variables and constants used.

When defining a PLC variable, simply specify:

- Its name: it is the symbolic addressing of the variable.
- Its data type: Bool (1 bit), Word (8 bits), ...
- Its absolute address: indication of operand (for example I0.4, Q1.7, M1.1, etc.).

The project mnemonics table is edited in a way that respects our specifications.

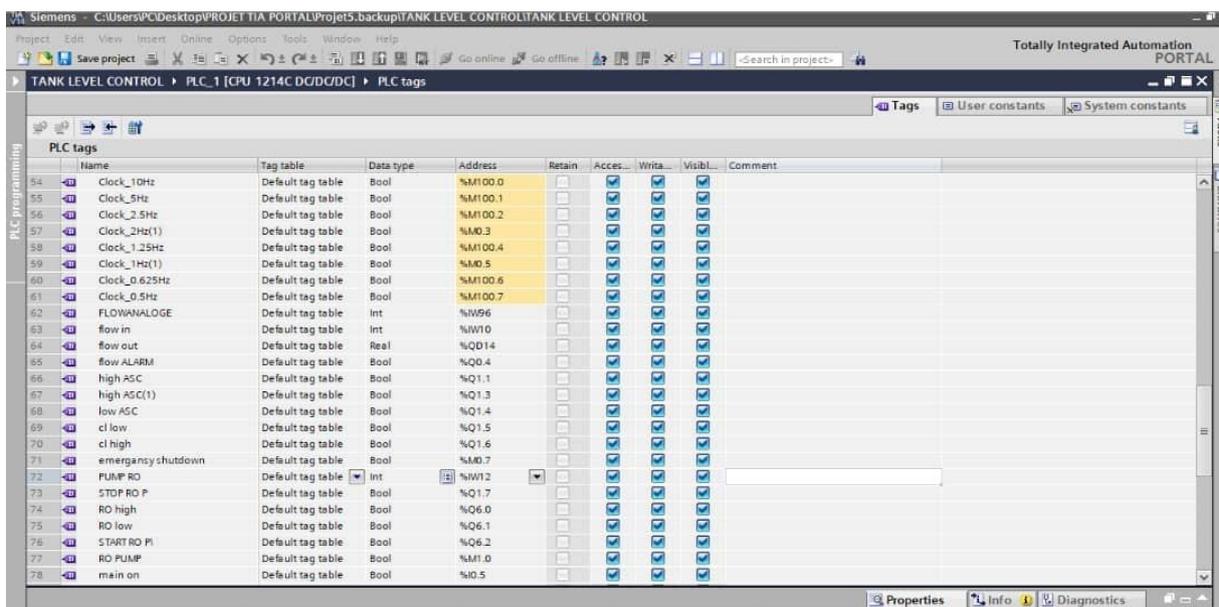


Figure III.9: TIA PLC tags table.

III.4.1.2. Program blocks: Data block

The sequences of the LADDER language program are written in what are called blocks. This block represents the CPU operating system interface. From this OB1 organization block additional blocks can be called to their tower to structure the program as function (on control) and FC2 (pumps) etc.

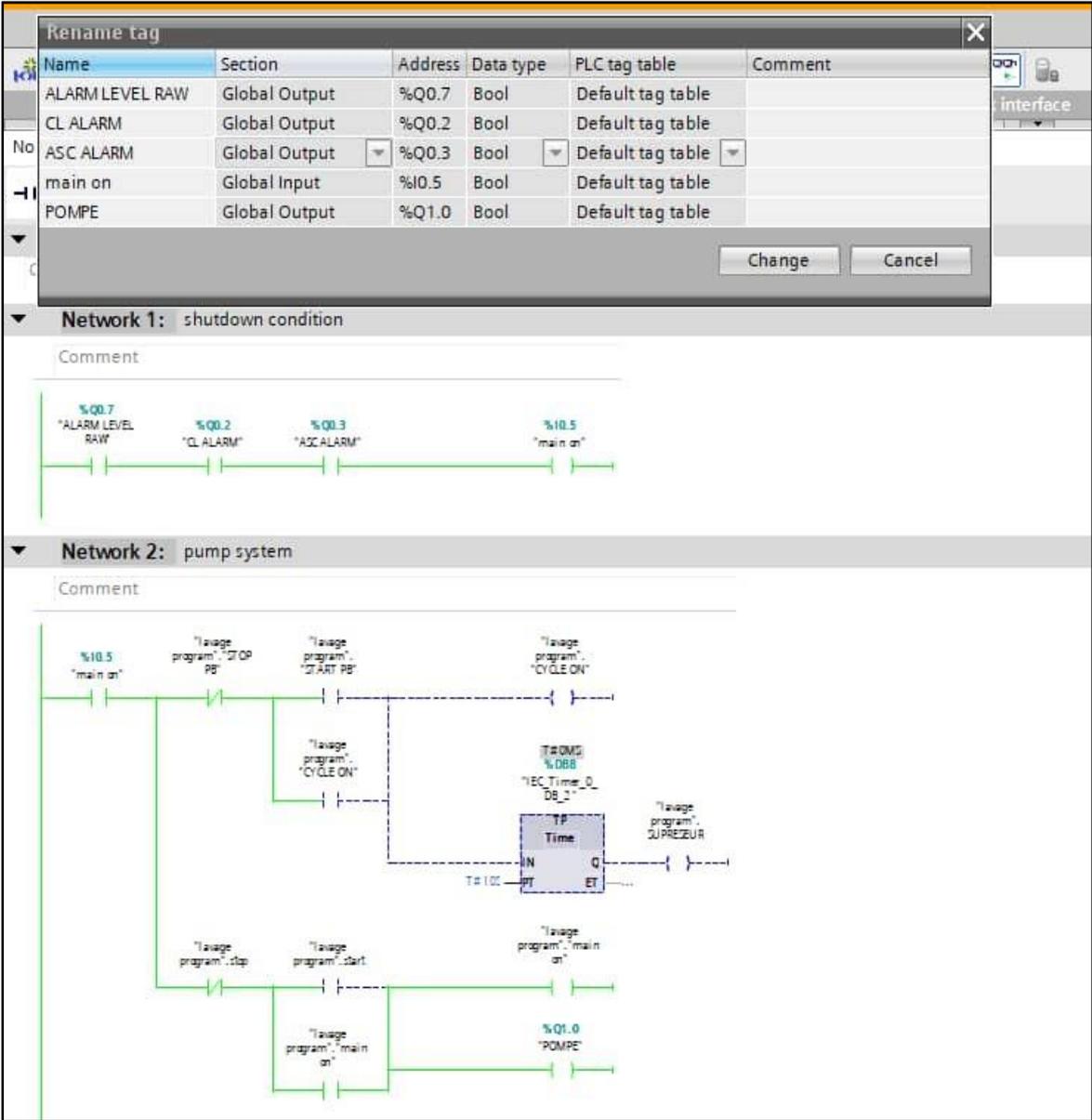


Figure III.10: Pump Fonction (FC2).

FC 4 illustrated in the following figure contains the TIA Portal SCALE function for the scale of analog inputs of both water potable and production tanks of level sensors.

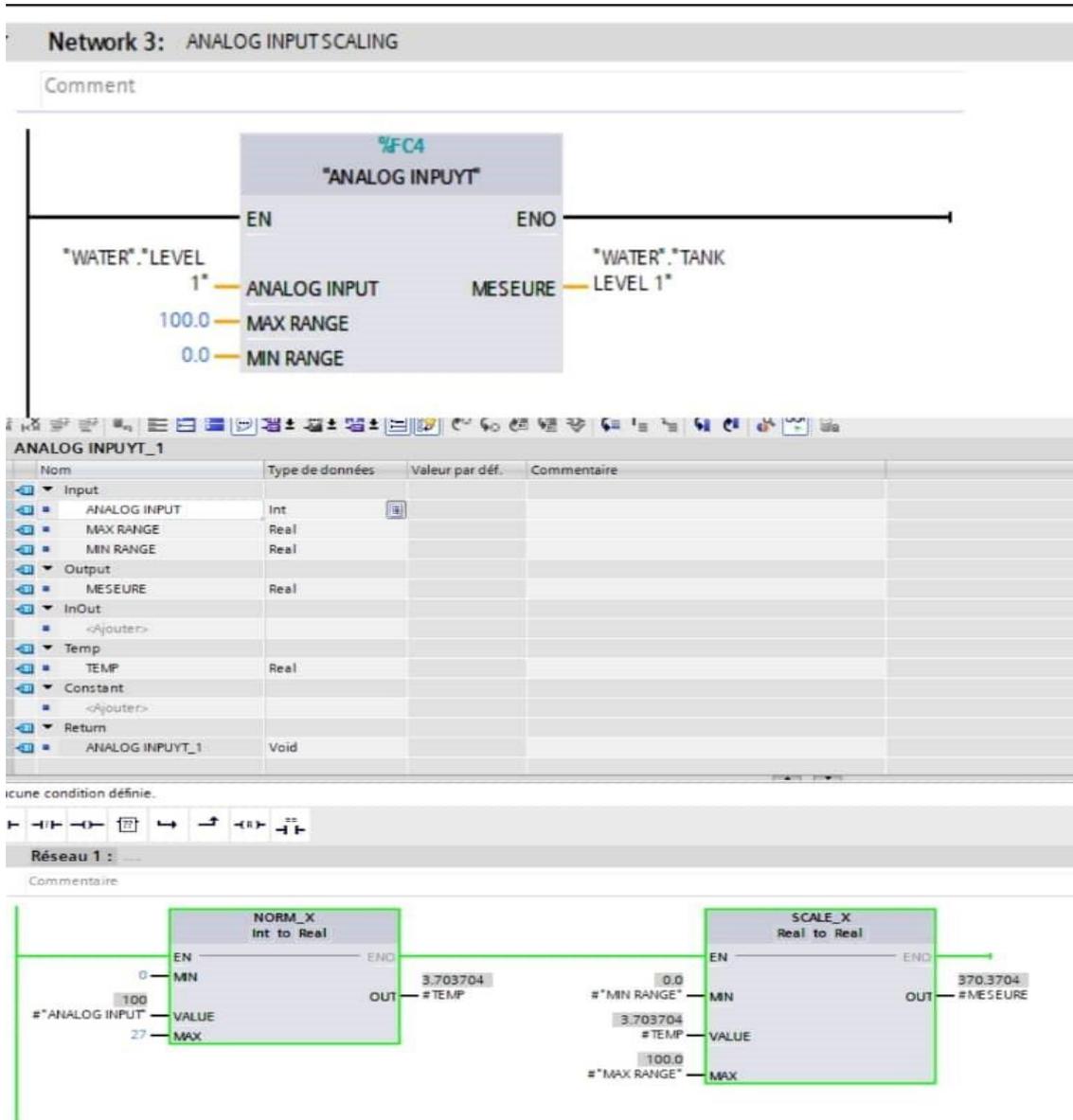


Figure III.11: Function Block

The term "Data Block," or "DB," refers to a particular kind of block that is used to specify a group of data items that can be utilized all throughout the program. Input and output data, as well as intermediate results, are usually stored in data blocks, which other program components can access as needed.

Data blocks can be organized in a variety of ways, depending on the program's requirements.

	Name	Data type	Start value	Retain	Accessible f...	Writa...	Visible in ...	Setpoint	Comment
1	Static			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2	LEVEL 1	Int	0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
3	TANK LEVEL 1	Real	0.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
4	START	Bool	false	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
5	STOP	Bool	false	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
6	MRKER	Bool	false	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
7	PUMP	Bool	false	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
8	VALVE1	Bool	false	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
9	VALVE2	Bool	false	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
10	SET PONTHIGH LEVEL...	Real	0.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
11	SET PONTHIGH LEVEL...	Real	0.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
12	SET POINT LOW LEVE...	Real	0.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
13	SET POINT LOW LEVE...	Real	0.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
14	close valve 1	Bool	false	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
15	close valve 2	Bool	false	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	

Figure III.12: Data block for Tank level control.

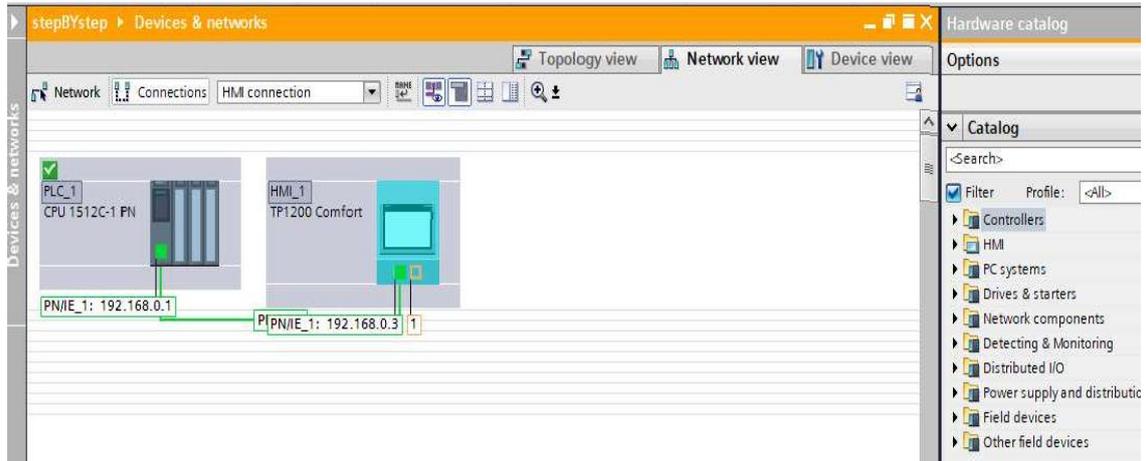
III.4.2. Plant supervision Programming

III.4.2.1. Human machine interface choice

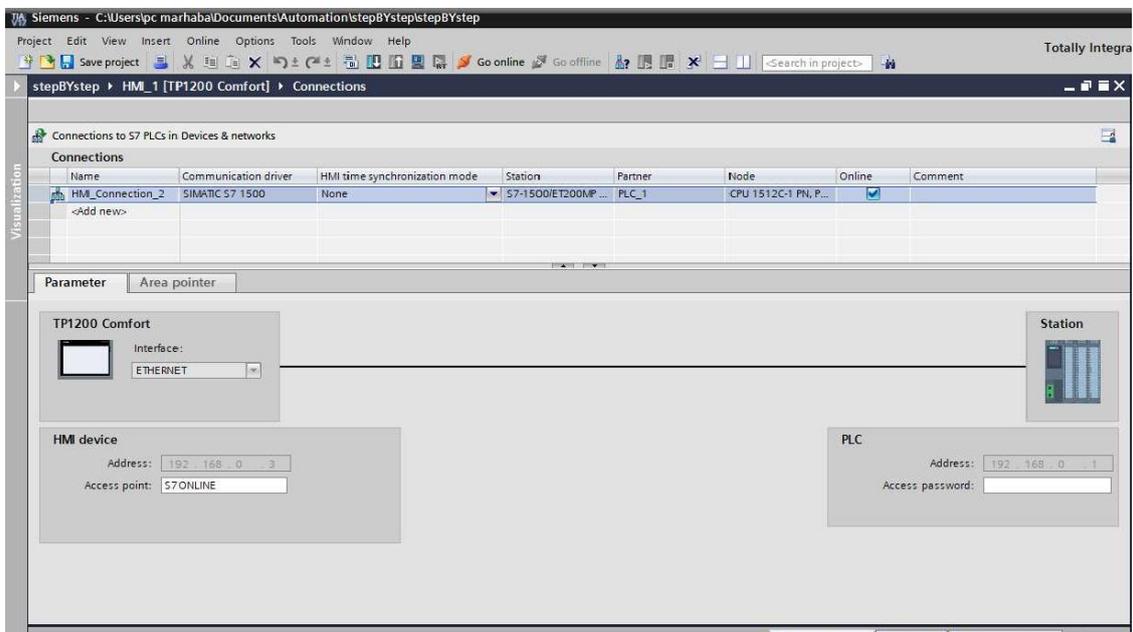
- TP1200 COMFORT:** It is designed for use in industrial automation applications and features a 12-inch touch screen display, high-resolution graphics, and a range of communication options. It can be used to display and control information from a PLC system, such as data from sensors and other input devices, and can provide real-time feedback on system status and performance. The device can be programmed using TIA Portal, allowing engineers to create custom graphics, screens, and user interfaces for the system.
- PC system:** It refers to the software representation of a PC that is connected to a Siemens PLC via an Ethernet network. It allows the PLC to communicate with a PC and exchange data between them. This can be useful in a variety of industrial applications, such as data logging, process monitoring, and control system visualization.

One of the key benefits of using a PC Station in TIA Portal is that it allows you to create powerful HMI applications that can provide operators with a graphical representation of the control system. These applications can display real-time data from the PLC, such as sensor readings, machine status, and alarm notifications.

III.4.2.2. PLC-HMI Connection



(a)



(b)

Figure III.13: Connection between PLC and HMI.

III.4.2.3. HMI tags

HMI tags can be created and configured in TIA Portal's HMI Tag Management tool, which allows engineers to define the data type, address, and other properties of the tags. Once the tags have been defined, they can be linked to input and output signals from the PLC or other automation system, enabling real-time monitoring and control of the system.

III.4.2.4. HMI Screens

An HMI (Human-Machine Interface) screen is a user interface that connects an operator to a machine, system, or device. It allows for the control and monitoring of processes, providing a graphical representation of the machine's operation. HMI displays real-time data from sensors and other inputs, showing the current status of the machine or process. This can include temperature, pressure, speed, and other critical metrics.

HMI screens are a crucial component in modern automation and control systems, providing a vital link between human operators and machines. They enhance efficiency, safety, and productivity across various industries by offering intuitive control and real-time monitoring capabilities. Simulation with HMI and operating status has been completed successfully after launching PLC PLCSIM.

1. Login screen:

A HMI login screen is a crucial part of industrial and automation systems, providing a user interface that allows operators to interact with machinery and processes.

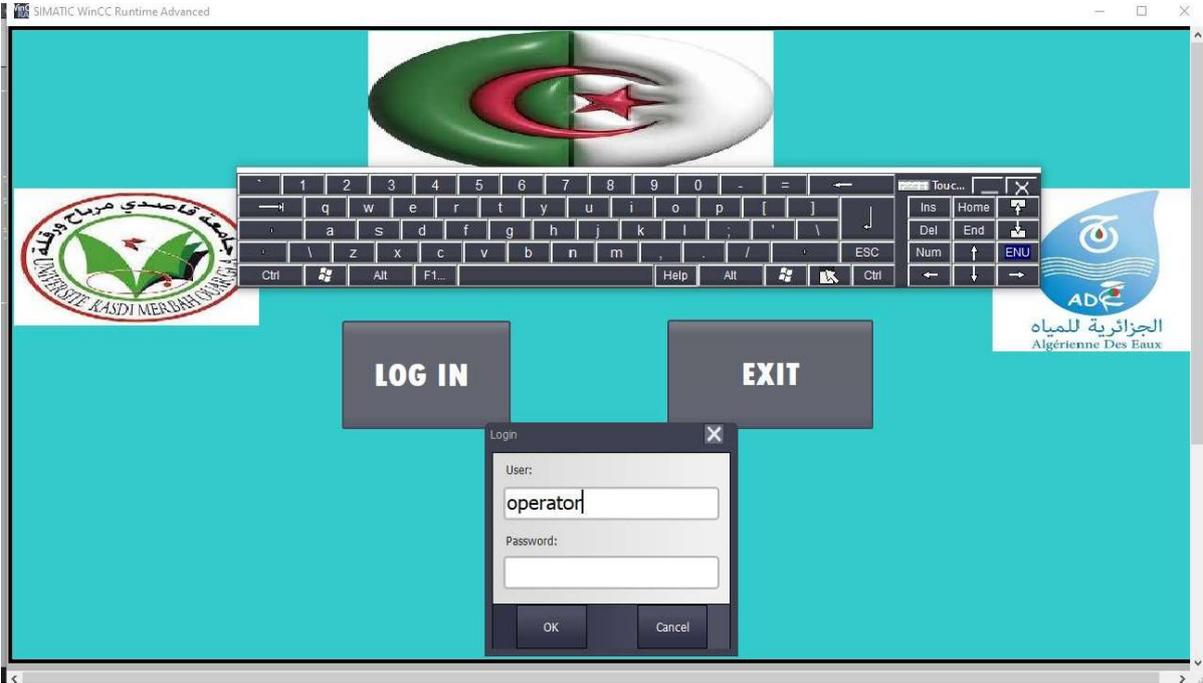


Figure III.14: Login screen.

2. Home screen:

An HMI home screen is the primary interface through which users interact with machines, systems, or devices. It is designed to provide a user-friendly and intuitive way for operators to monitor and control various aspects of the system.

HOME screen is the first screen to appear, and it can be passed from view to others as illustrated in the following figure.

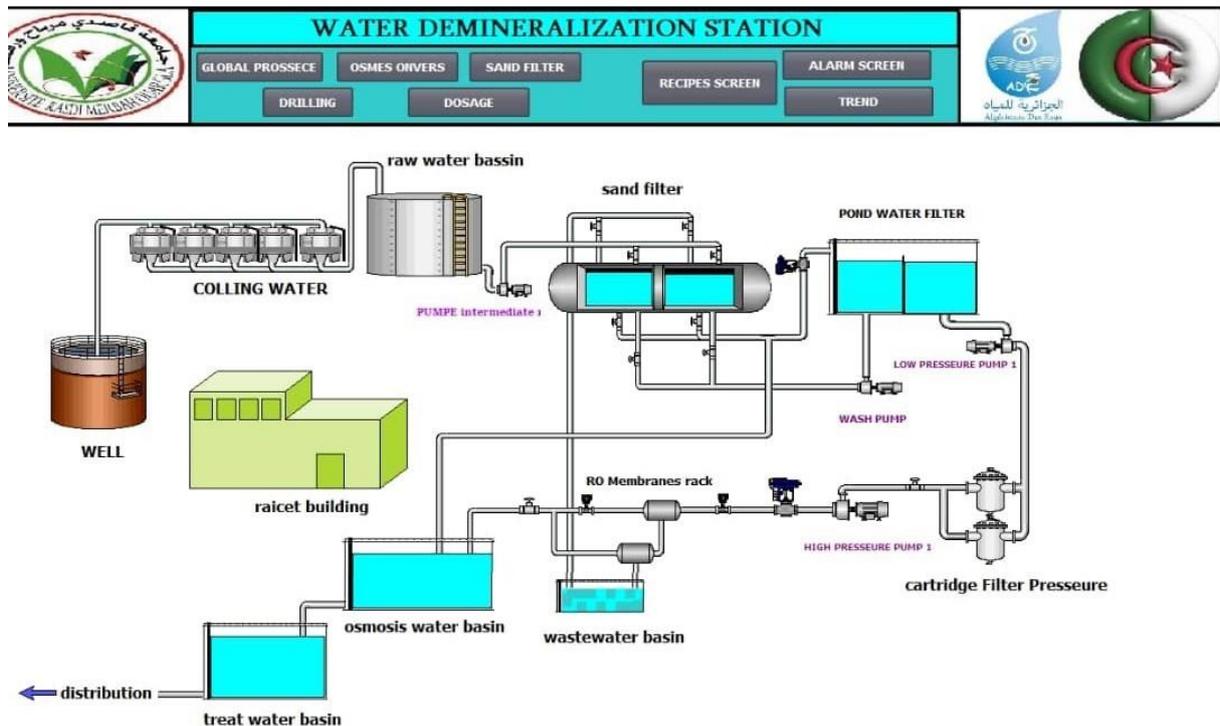


Figure III.15: Main view (HOME).

It allows you to display data in real time, interact intuitively with our equipment and simplify operations.

3. Feed water and cooling screen:

When moved to the feed water screen, it is configured with a cooling system, which allows us to see the flow of the wells and the temperature after the well, which ranges from 37 to 44 °C, and also after the cooling process, which ranges from 28 to 25°C, and the latter is stored in raw water tank to be directed to the next operation.

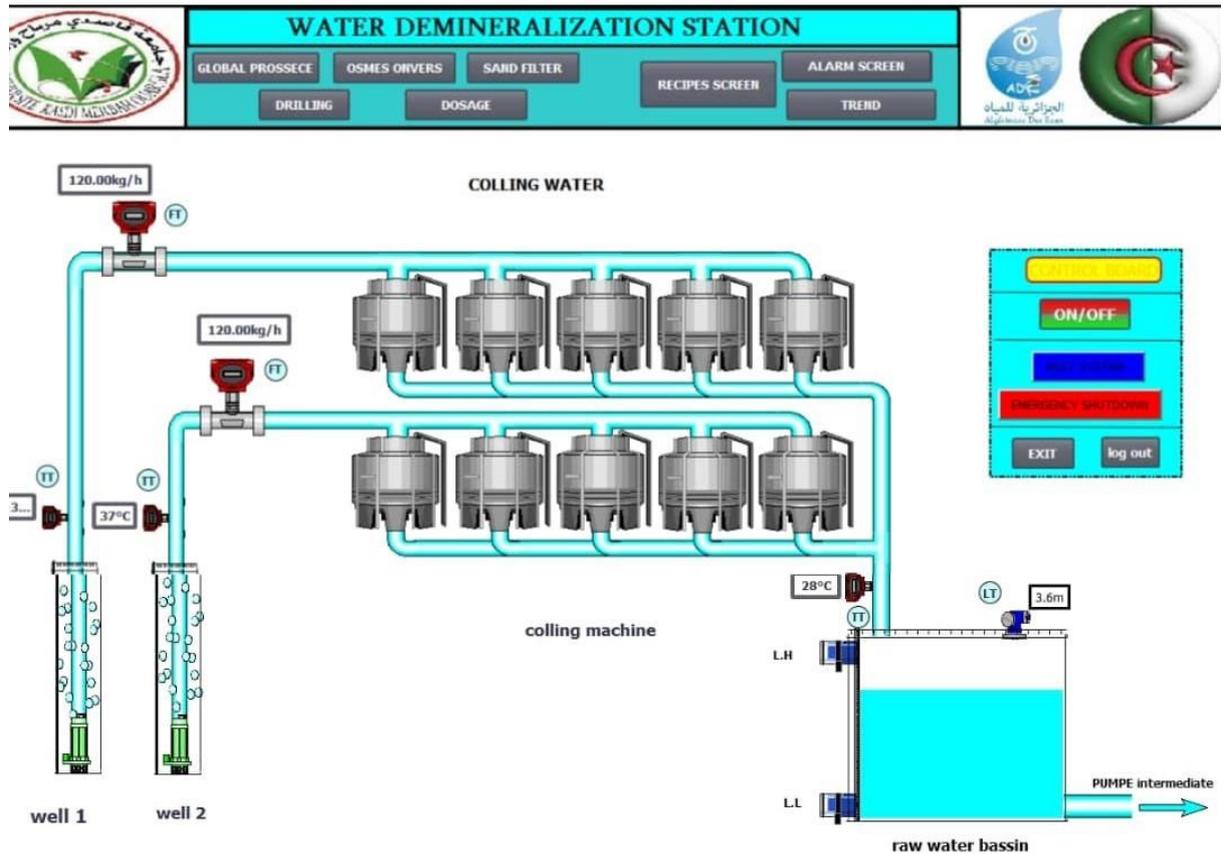


Figure III.16: Feed water and cooling towers screen.

4. Multi-Media (Sand) Filter screen:

When water is collected from its source, it is forced through 2 pump intermediate to a filtration tank fine bed of sand or gravel, where particles are removed through absorption or physical encapsulation Sand filters are used some Instruments that appears there is a difference in the pressure of the couch filtered and go to pond water filter this last have 2 part one of them go to the other process and the other half go to washing process the air blower start first is provided to inject air into the sand bed against current automatically introduced by the API for the network to fluidize the bed and facilitate the detachment of materials retained by the filtered.

Then a water rinse process Alimentation of the water rinse in is connected to the rinse process at the same time alimented by the water tank.

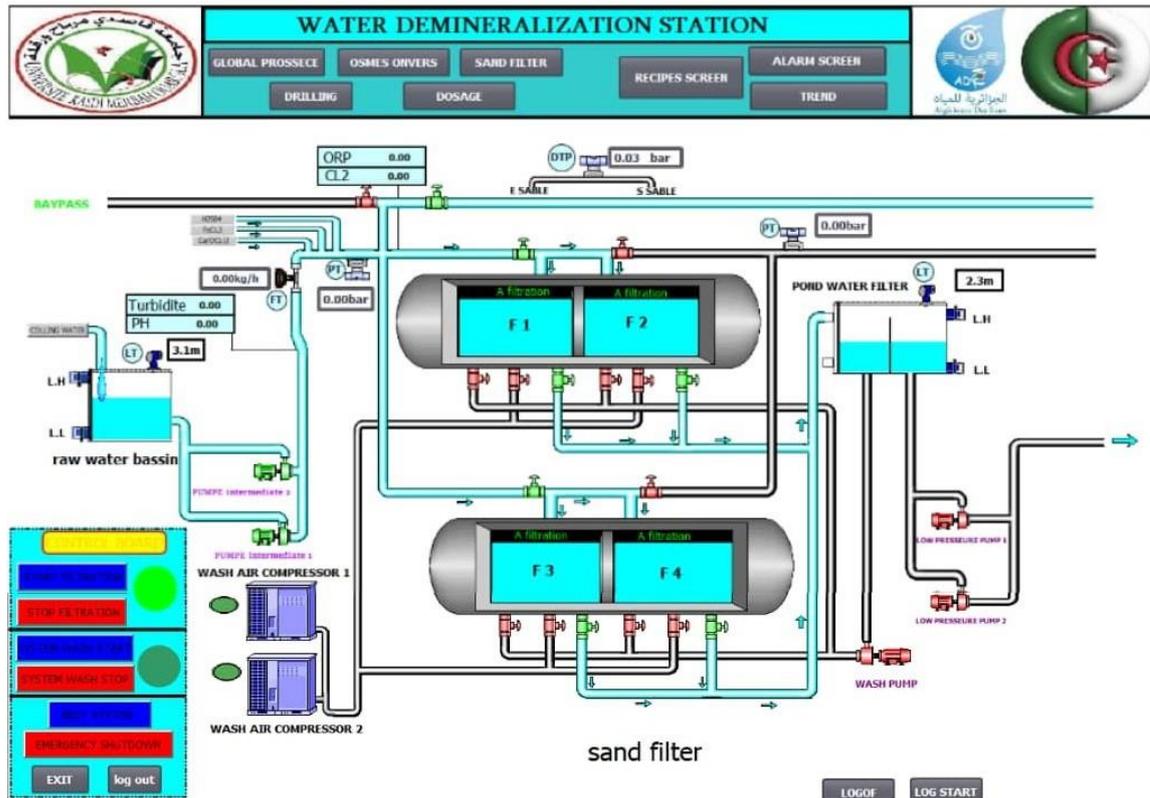


Figure III.17: Multi-Media (Sand) Filter.

5. Reverse osmosis screen:

- Water Inlet: Untreated water enters from the inlet (at the bottom left corner).
- Filtration (Cartridge Filter 1 and Cartridge Filter 2): The water passes through two cartridge filters to remove large particles and impurities. The filter pressure can be measured using the attached gauges.
- High-Pressure Pumps: After filtration, the water is pumped through two high-pressure pumps (High Pressure Pump 1 and High Pressure Pump 2) to push the water through the membranes.
- Reverse Osmosis (RO) Membranes: The water passes through a series of reverse osmosis membranes. The membranes remove salts and minerals from the water.
- Monitoring and Control: There are several measuring devices to monitor water quality, including conductivity; pH level, turbidity, and oxidation-reduction potential (ORP). Water flow and system pressure are measured at multiple points.
- Water Tanks: The treated water is collected in the osmosis water basin. The treated water is transferred to water storage tanks using a treat water pump.
- Drainage: Accumulated waste and impurities are drained into the drain basin via a drain pump.

- Control Panel: There is a control panel to start and stop filtration, start and stop system washing, reset the system, and an emergency shutdown button. The image represents an advanced system for monitoring and treating water using reverse osmosis technology, helping to produce pure water free of minerals and salts

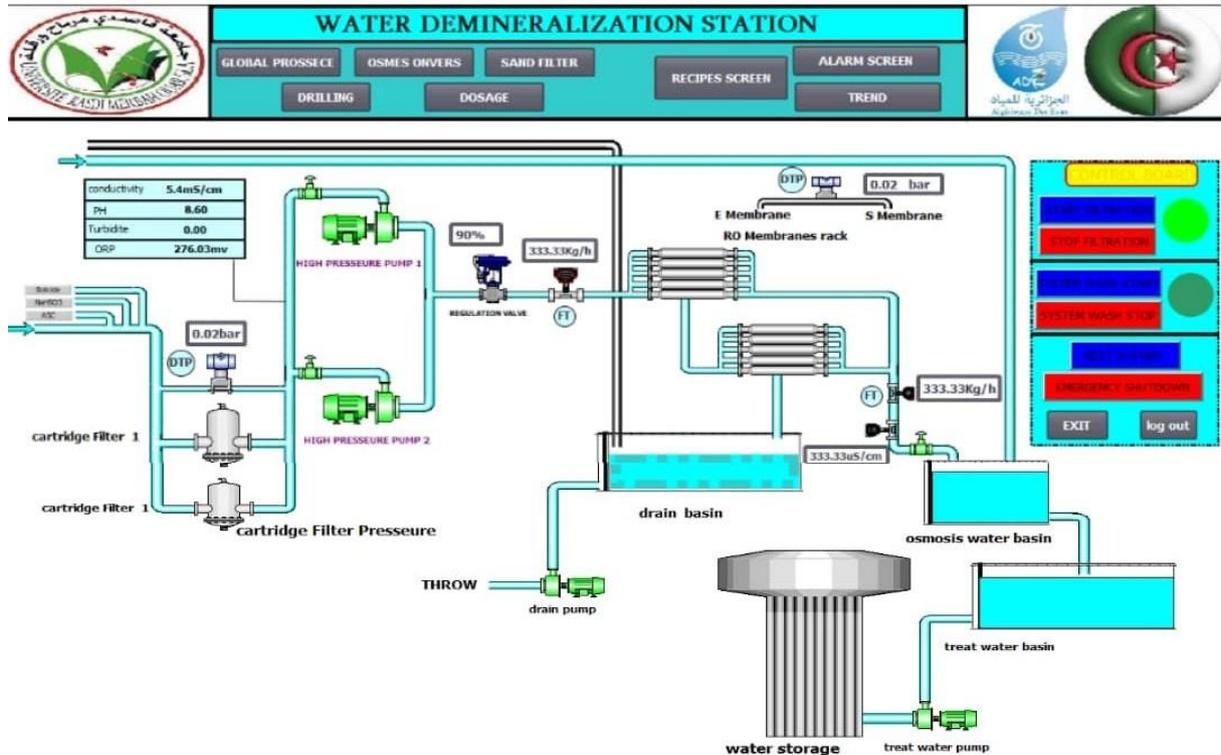


Figure III.18: Reverse Osmosis screen.

6. Alarm screen:

These are alerts that point out anomalies or problems with a PLC system. Alarms are used to notify engineers and operators of possible problems and can be set triggered by a number of different events, including a process deviation, a machine defect, or a sensor failure.

The alarm screen displays a table of active alerts. The table has columns for No., Time, Date, Status, Text, and Acknowledge group. The top navigation bar is identical to the RO screen, including buttons for 'GLOBAL PROSSECT', 'OSMES OIVERS', 'SAIHD FILTER', 'RECIPES SCREEN', 'ALARM SCREEN', 'DRILLING', 'DOSAGE', and 'TREHD'.

No.	Time	Date	Status	Text	Acknowledge group
11	5:28:40:5...	6/5/2024	IO	CHCK YOUR regualtore valve	0
8	5:28:40:5...	6/5/2024	IO	VERY LOW CL STOP THE PROCCESS	0
7	5:28:40:5...	6/5/2024	IO	VERY LOW ASC STOP THE PROCCESS	0
2	5:23:32:1...	6/5/2024	I	LOW LEVEL	0

Figure III.19: Alarm screen.

7. Recipes screen:

Recipes are a way to manage and store sets of parameters and values that can be used to configure a PLC (Programmable Logic Controller) system. Recipes are commonly used in industrial automation applications where different product configurations or process conditions need to be stored and recalled quickly. They can be used to improve efficiency and reduce errors in industrial automation applications. By storing and recalling parameter values automatically, operators can avoid manual entry errors and reduce setup time for new products or processes. Recipes can also be used to ensure consistency and quality across different production runs, reducing the risk of defects or product variations.

This screen allows users to adjust and calibrate the settings of various elements used in the control system, such as pH values, conductivity, chlorine level (CL2), and temperature. These settings are crucial to ensure the system operates correctly and to adjust industrial processes based on specific requirements.

- **Recipes:** The recipes used in the system are defined. In this case, there is one recipe named "Recipe_1" with details related to the creation time and path.
- **Elements and Data Records:** This section shows a list of monitored elements in the system with details such as the display name, tag, data type, data length, default value, minimum and maximum values, and decimal places.

- **Section Details:**

Name: The name used to identify the element in the system.

Display Name: The name displayed to the user.

Tag: The tag or unique code for each element, which is used in programming.

Data Type: The type of data (in this case, all are of type Int)

Data Length: The length of the data.

Default Value: The default value.

Minimum Value and Maximum Value: The minimum and maximum values for the element.

Decimal Places: The number of decimal places.

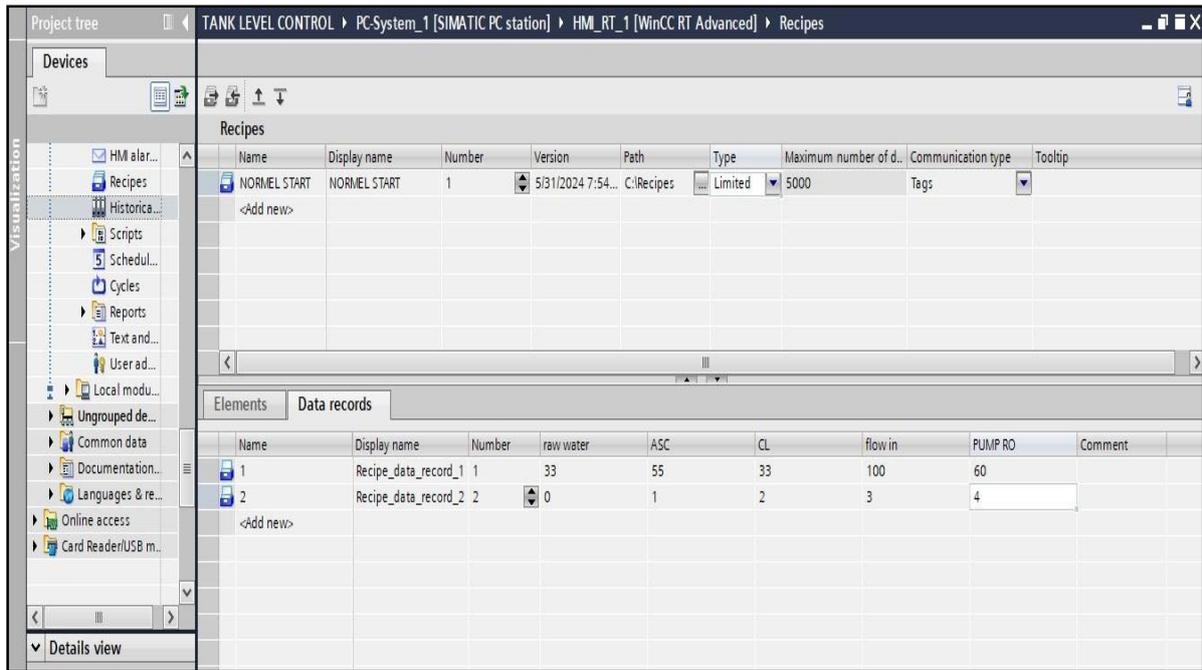


Figure III.20: Recipes screen.

8. Trends screen:

It refers to graphical depictions of data that have been gathered over time from a PLC. Operators and engineers can detect trends and possible problems before they become serious by using trends to visualize changes in process variables and system performance. They can also be used to track production rates, downtime, and other parameters related to system performance.

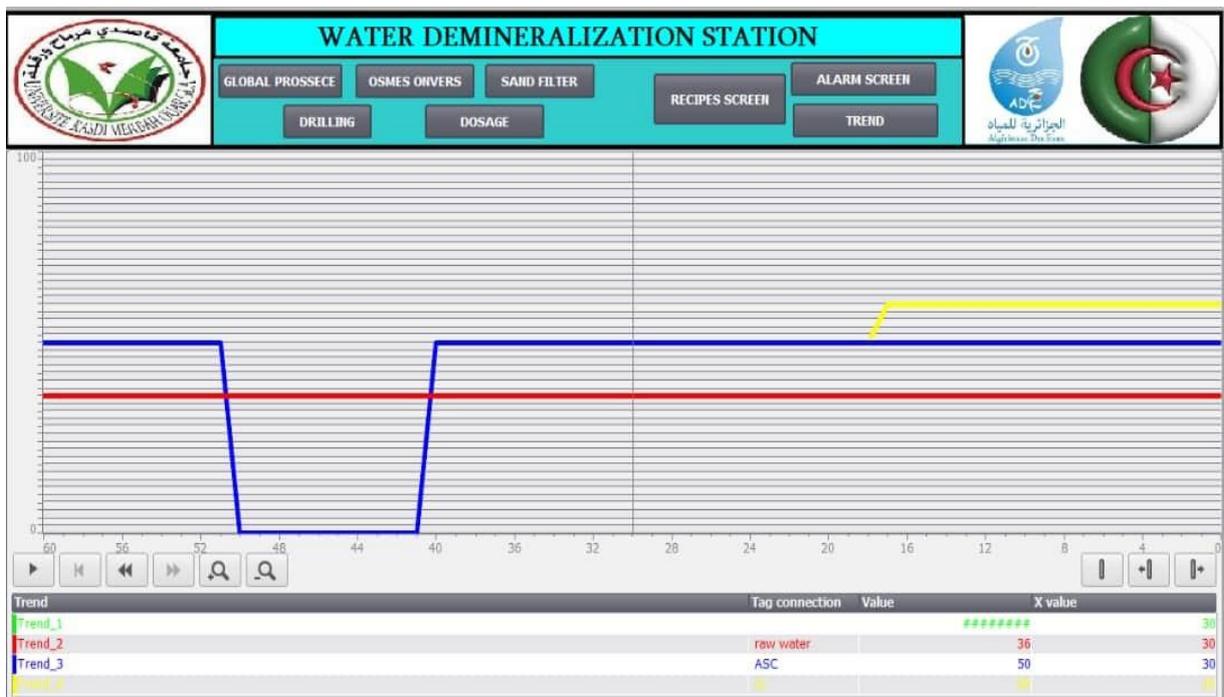


Figure III.21: Trend screen.

9. Historical screen:

Gathered over a given period of time from a PLC (Programmable Logic Controller), historical data can provide important insights into system performance and process variables. Historical data can be used to analyze trends and patterns over longer periods of time and can help identify performance issues and opportunities for optimization. For example, you might use historical data to identify periods of low production and optimize the production process to increase output.

The screenshot shows the 'Historical data' window in SIMATIC Manager. The 'Data logs' table is as follows:

Name	Storage location	Data records	Path	Data source	Name of data source	Logging method	Number of sequences
Data_log_1	CSV file (ASCII)	500	C:\Logs	User-defined		Circular log	10
<Add new>							

The 'Logging tags' table is as follows:

Name	Process tag	Acquisition mode	Logging cycle	High limit	Low limit	Range for logging limits
flow in	flow in	Cyclic	2 s			Within deadband
ASC	ASC	Cyclic	2 s			Within deadband
CL	CL	Cyclic	2 s			Within deadband
PUMP RO	PUMP RO	Cyclic	2 s			Within deadband
raw water	raw water	Cyclic	2 s			Within deadband
Logging_tag_1	z_httrv	Cyclic	2 s			Within deadband
<Add new>						

Figure III.22: Historical Data.

10. Security screen:

The capacity to prevent unwanted access and manipulation of a PLC system and its data. In industrial automation applications, where the integrity of the PLC data and control is crucial to the system's dependability and safety, security is a critical factor to take into account.

Features for security: User administration, password security.

The screenshot shows the 'User administration' window in SIMATIC Manager. The 'Users' table is as follows:

Name	Password	Automatic logoff	Logoff time	Number	Comment
Administrator	*****	<input type="checkbox"/>	5	1	The user 'Administrator' is as...
operator	*****	<input checked="" type="checkbox"/>	5	2	
<Add new>					

The 'Groups' table is as follows:

Member of	Name	Number	Display name	Password aging	Comment
	Administrator group	1	Administrator group	<input type="checkbox"/>	The 'Administrator' group is i...
	Users	2	Users	<input type="checkbox"/>	The 'Users' group is initially g...
<Add new>					

Figure III.23: Security screen.

III.5. Conclusion

The functional analysis allowed us to understand the needs and specifications of the project, which provided a solid foundation for the development of our application, and then we created the program using the appropriate programming tools and languages. Along with the development of the program, we also created a human-machine interface for simulation.

The creation of a human-machine interface requires not only a good knowledge of the procedure and the stages of the creation of the supervision, but also of the language with which the automaton is programmed in order to make a correct communication of the addresses.

General Conclusion

General Conclusion

This comprehensive study explores the design, sizing, and supervisory system implementation of a reverse osmosis (RO) desalination plant. The demand for fresh water has increased significantly in arid regions and coastal areas where traditional freshwater sources are limited or contaminated. RO technology has emerged as a viable solution due to its efficiency in removing salts and contaminants from seawater and brackish water.

The study begins with an overview of the principles behind RO technology, including membrane types, processes, and key parameters influencing system performance. It then delves into the detailed design aspects, covering feed water pretreatment, membrane module selection, and system configuration considerations. Sizing calculations are performed to determine the optimal capacity of the RO plant based on feed water characteristics, anticipated water demand, and environmental conditions.

A critical component of this study is the design of the supervisory system, which ensures efficient operation, monitoring, and control of the RO plant. The supervisory system integrates sensors, controllers, and human-machine interfaces (HMIs) to automate processes, optimize energy consumption, and respond to variations in feed water quality and quantity.

In conclusion, this study provides a comprehensive framework for the design, sizing, and implementation of a reverse osmosis desalination plant. By integrating technical, operational, economic, and environmental aspects, it aims to guide engineers, researchers, and stakeholders in the development of efficient and sustainable water desalination solutions.

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