PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA
MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH
University Mohamed El Bachir El Ibrahimi of Bordj Bou Arreridj

Faculty of Sciences and Technology

Department of Electromechanics

Discuss the graduation thesis in order to obtain the degree of MASTER
In: Automatic

Option :

Automation and Industrial Computing

Design and Realization Of supervision System using TIA Portal Automation Software Application: Water Filtering System

Presented by:

•BOUAFIA WIAM **• BOUNABI SANAE**

Publicly defended on: 28/06/2026 in front jury members:

First Name & Last Name	Grade	Quality	Establishment
Pr. LAYADI Toufik Madani	PROFESSOR	supervisor	Bordj Bou Arreridj University
Dr. MEGHLAOUI Issam	MCA	Co-supervisor	Bordj Bou Arreridj University
Dr. BEN SIDHOUM Tarek	MCA	president	Bordj Bou Arreridj University
Dr. ZAOUI Fares	MCA	Examiner	Bordj Bou Arreridj University

Academic year: 2025-2026


بسم الله الرحمن الرحيم

Acknowledgement

First and foremost, all praise and thanks are due to Almighty God for granting us the strength, patience, and perseverance to successfully complete this Master's dissertation.

We would like to express our deepest gratitude and sincere appreciation to our supervisor, Pr. Laayadi Toufik El Madani, for his invaluable guidance, continuous support, constructive comments, and encouragement throughout the preparation of this work. His expertise, advice, and dedication have greatly contributed to the successful completion of this dissertation. We are truly honored to have benefited from his knowledge and supervision.

We would also like to extend our sincere thanks to the members of the examination committee for accepting to evaluate this work and for the valuable remarks and suggestions they may provide to improve its quality.

A special word of thanks is addressed to our families for their unconditional love, patience, support, and encouragement throughout our academic career. Their confidence in us has been a constant source of motivation and inspiration.We would also like to thank our friends and colleagues for their help, cooperation, and the memorable moments we shared during our years of study.Finally, we would like to express our gratitude to everyone who contributed, directly or indirectly, to the realization of this dissertation.

Thank you all for your support and encouragement.

Dedication

Praise be to Allah, Lord of the worlds, who by His grace perfects all good deeds, brings ease after hardship, and guides hearts after long journeys of effort and patience. I praise Him with praise befitting His Majesty and Greatness. This achievement is nothing but a blessing from Him, His mercy, and His guidance.

To myself…

To the soul that fought silent battles, endured exhaustion and disappointment, fell many times and rose again with stronger faith and greater determination. To the self that believed dreams do not die and that after patience comes relief and reward, I dedicate this accomplishment.

To my parents…

To the purest hearts I have known and my first source of love and prayer in life. To my father, my strength when I weaken, my unwavering support, and my shelter in life's difficulties.

And to my mother, the heart that taught me that love is giving, that prayers make miracles, and that her embrace has always been my safe home.

To both of you, I dedicate this success, a reflection of your endless sacrifices. May Allah protect and bless you both.

I love you beyond words—you are the reason for my existence and success, the light of my path, and a blessing I thank Allah for every moment. May He grant you long life and make me always worthy of your love and prayers.

To my dear brother…

To my support after my father, my friend and companion in every situation. You have been my strength and comfort. I dedicate this success to you and pray that Allah protects you and strengthens our bond.

To my sisters, Leila and Rania…

To my companions in life and one of Allah's greatest blessings to me. You shared my days and dreams, eased my burdens with your laughter, and supported me with your sincere prayers. May Allah grant you endless happiness and success.

To my brother-in-law, Mohamed…

To the elder brother I gained in life, a kind heart and sincere support. Thank you for your encouragement. May Allah grant you health and happiness.

To little Alaa, my niece…

To the innocence of our home and its joy, whose smile removes fatigue. May Allah protect you and grant you a bright future full of success and happiness.

To my partner in this work, Sanae…

Thank you for your patience, effort, and cooperation until we reached this achievement. May Allah bless your path and grant you success.

To everyone who supported me…

To all who believed in me, prayed for me, and stood by me sincerely thank you from the heart.

BOUAFIA WIAM

Dedication

All praise and thanks be to Allah for this precious moment, a moment that can neither be inherited nor bought, but one for which I have paid with years of hard work, sleepless nights, perseverance, and determination.

To my ambitious self, who chose this path and pursued it with unwavering determination; to the one who believed in her dream and succeeded; to the one who faced challenges in silence and answered them with achievement.

With profound gratitude and appreciation, I dedicate this humble work to those to whom no words, however eloquent, could ever fully express my love and gratitude.

To my beloved mother, the source of my happiness and strength,

No dedication could ever convey the depth of my feelings towards you. Your countless sacrifices and endless devotion have been my greatest support. You surrounded me with your love and care, and your prayers and blessings have been my guiding light throughout my academic journey. Thank you for your unwavering support and encouragement over all these years.

I love you, Mum, and I pray that Allah grants you good health, happiness, and a long life.

To my dear father, Allah's precious gift,

I owe you my life, my success, and my deepest respect. Thank you for your love, generosity, understanding, and constant support. You have always been a light that illuminated my path and guided me through every step of my journey. No words can adequately express the love, appreciation, and respect I hold for you. This humble work is a reflection of the sacrifices you made for my upbringing and education.

I love you, Dad, and I pray that Allah grants you good health, wellbeing, and a long and happy life.

To my dear brothers, Abdelrahim and Amir,

For all the wonderful childhood memories we shared and for the love and support you have always given me, I dedicate this work to you as a token of my sincere appreciation. May Allah strengthen the bond between us and keep our relationship filled with love and unity.

I love you both dearly.

To my project partner, my friend and companion on this journey, Wiam,

Your enthusiasm, dedication, and perseverance made you an exceptional partner throughout this work. Thank you from the bottom of my heart for your friendship, support, and the beautiful memories we created together. I wish you a life filled with good health, happiness, success, and fulfilment.

To everyone who supported, encouraged, and believed in me throughout my academic journey, whether near or far,

I dedicate this humble work to you with sincere gratitude and appreciation.

Thank you all.

BOUNABI SANAE

❑ ***Abstract:***

This dissertation deals with the automation of a wastewater treatment plant using a Siemens S7-300 Programmable Logic Controller (PLC). The main objective is to ensure the control and supervision of the different stages of wastewater treatment in order to improve the efficiency and reliability of the process. The control program was developed using TIA Portal and the Ladder Diagram (LAD) programming language. In addition, a Human-Machine Interface (HMI) was designed to monitor and control the process in real time. The results obtained demonstrate the importance of industrial automation in enhancing the performance and reliability of wastewater treatment plants.

Keywords: Wastewater Treatment Plant, Automation, Siemens S7-300, TIA Portal, Ladder Diagram, HMI, Monitoring and Control.

❑ ***Résumé :***

Cette thèse porte sur l'automatisation d'une station d'épuration des eaux usées à l'aide d'un ‘automate programmable Siemens S7-300’. L'objectif principal est d'assurer le contrôle et la supervision des différentes étapes du traitement des eaux usées afin d'améliorer l'efficacité et la fiabilité du procédé. Le programme de contrôle a été développé à l'aide de ‘TIA Portal’ et du langage de programmation‘Ladder Diagram (LAD)’. De plus, une ‘interface homme-machine (IHM)’ a été conçue pour surveiller et contrôler le procédé en temps réel. Les résultats obtenus démontrent l'importance de l'automatisation industrielle pour améliorer les performances et la fiabilité des stations d'épuration.

Mots-clés : Station d'épuration des eaux usées, Automatisation, Siemens S7-300, TIA Portal, Ladder Diagram, IHM, Surveillance et contrôle.

❑ الملخص

تتناول هذه الأطروحة أتمتة محطة معالجة مياه الصرف الصحي باستخدام وحدة التحكم المنطقية القابلة للبرمجة (PLC) من نوع Siemens S7-300. يهدف البحث بشكل أساسي إلى ضمان التحكم والإشراف على مختلف مراحل معالجة مياه الصرف الصحي لتحسين كفاءة العملية وموثوقيتها. تم تطوير برنامج التحكم باستخدام منصة TIA Portal ولغة برمجة Ladder Diagram (LAD). بالإضافة إلى ذلك، تم تصميم واجهة تفاعل بين الإنسان والآلة (HMI) لمراقبة العملية والتحكم بها في الوقت الفعلي. تُظهر النتائج المُتحصل عليها أهمية الأتمتة الصناعية في تعزيز أداء محطات معالجة مياه الصرف الصحي وموثوقيتها.

الكلمات المفتاحية:

محطة معالجة مياه الصرف الصحي، الأتمتة، Siemens S7-300، TIA Portal، Ladder Diagram، HMI، المراقبة والتحكم

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List of Abbreviations:

ADE: Algerian Water Company

BOD : *Biochemical Oxygen Demand*

COD : *Chemical Oxygen Demand*

ATS: Altistart 22

AC: Alternating Current

PLC: Programmable Logic Controller

CPU: Central Processing Unit

I/O: Input/Output

FB: Function Block

GRAFCET: Step-Transition Control Diagram

LD: Ladder Diagram

HMI: Human-Machine Interface

ONA: National Sanitation Office

OB: Organization Block

PC: Control Unit

PO: Operational Unit

PN/IE: Profinet/Industrial Ethernet

PID: Proportional-Integral-Derivative

WWTP: Wastewater Treatment System

TIA Portal: Totally Integrated Automation Portal

TOR: On/Off

V16: Version 16

WinCC: Windows Control Center

General introduction:

Water is one of the most valuable natural resources used for industries, agriculture, and even life itself. The volume of wastewater increases because of rapid urbanization, industrialization, and an increasing population. Unprocessed wastewater may cause negative impacts on both ecosystems and humans, as well as harm water resources when discharged directly to the environment.

Wastewater Treatment Plants (WWTP) should be designed to receive and treat wastewater before its discharge into the environment, providing solutions to the above issues. For the purification of wastewater and improving its quality, physical, chemical, and biological treatment methods are applied by WWTPs.

Industrial automation is one of the most important elements in wastewater treatment facilities nowadays. Reliability, safety, and optimal performance of plants are guaranteed with efficient monitoring and control of treatment processes through PLCs, sensors, actuators, and supervisory systems.

This project aims at designing and implementing an automation control and supervisory system for wastewater treatment plant using a Siemens S7-300 PLC. Contemporary methods of automation are applied to maximize efficiency, ensure process continuity, and provide the possibility of monitoring.

This paper consists of three chapters:

Chapter I: covers the general notions related to wastewater treatment plants and outlines the main features and operation of the **"Ain Taghrout"** wastewater treatment plant and its treatment phases.

In **Chapter II**, the elements of hardware that are applied within the framework of the project, such as the Siemens S7-300 programmable logic controller (PLC), sensors, actuators, and the architecture of the automation system are provided.

The development of automation and supervision systems for the wastewater treatment plant is outlined in **Chapter III**. This includes the implementation of the control strategy, programming the PLC in Ladder language, simulation, and designing the HMI interface in TIA Portal.

The research will end with a summary that will include findings and the discussion of potential future improvements.

We hope that this research will be useful and helpful in terms of enhancing the operations of wastewater treatment plants through the implementation of automation technologies.

Chapter one

Presentation of WWTP

I. Introduction :

Algeria produces about 1.2 billion m3 of wastewater per year from domestic, industrial and agricultural activities. A large part of the wastewater flows directly into the natural environment, which has serious consequences for ecosystems and water resources.Wastewater treatment plants have been established to treat wastewater before being discharged into the environment, knowing the adverse effects of such discharges. Such facilities are very important for the protection of the environment and the safeguard of public health. Generally, wastewater treatment plants are found at the end of collection systems, just before the final discharge point to the natural environment. They ensure that the wastewater is treated through different physical, chemical and biological processes in order to reduce the pollution and improve the quality of the water that is discharged.

I.1.1. challenges:

Algeria has a number of wastewater treatment plants, but the main challenge is to ensure that they are effective in terms of their capacity to treat large volumes of water and meet the required environmental quality standards.

This brings us to the question, how does a wastewater treatment plant work?

What are its different stages and components to ensure effective treatment and improve the quality of the treated water?

I.1.2. objectives :

The aim of this chapter is to:

- ✓ Introduction to SEAAL and its position in the water and sanitation sector
- ✓ General overview of wastewater treatment systems
- ✓ Look at some treatment plants
- ✓ Know the various stages of working of waste water treatment plant
- ✓ Identify the parts and components of a treatment plant
- ✓ Learn the general layout of a treatment plant

I.2. *presentation of SEAAL*:

The Algiers Water and Sanitation Company (SEAAL) is a public limited company, 70% owned by the Algerian Water Company (ADE) and 30% by the National Sanitation Office (ONA).SEAAL was established in 2006 as a result of the Algerian authorities' political will to

rapidly improve the quality of life for citizens, particularly in the capital .SEAAL's primary mission is to produce and distribute drinking water, and to collect and treat wastewater within the provinces of Algiers and Tipasa. It serves 3.8 million inhabitants, representing approximately 10% of the national population.SEAAL also manages the Taksebt Drinking Water Treatment Plant (the largest treatment plant in Algeria), which supplies drinking water to the provinces of Tizi Ouzou, Boumerdes, and Algiers. In total, it therefore provides drinking water, directly or indirectly, to a population of approximately 5 million inhabitants.SEAAL serves 761,824 customers (households, government offices, businesses, industries, and tourist sites) and employs 6,293 people.

SEAAL's challenges were, on the one hand, to rapidly modernize the service (water, sanitation, customer service, infrastructure, etc.) to an international standard, and, on the other hand, to eventually empower the public entity through a transfer of expertise from SUEZ

Environment to local teams. The organizational structure put in place ensures transparent, clear, and reliable communication between stakeholders to achieve lasting trust.

The values that define SEAAL stem from the establishment of a genuine "Corporate Culture" where the concept of belonging takes on its full meaning. The development of this "Corporate Culture" could only be achieved through the sharing of essential references, such as understanding the challenges of modernizing the Public Service, mobilizing to improve its performance, and striving to project an image that meets customer expectations. This has materialized in three Values that summarize SEAAL's identity, in which each of our employees identifies:

- Professionalism, a source of recognition.
- Dynamism, a driver of visibility and therefore pride.
- Mutual Trust.

These values are the result of a collaborative process within the company, the only way to guarantee the buy-in of all employees. Wastewater treatment plants are divided into two parts: drinking water treatment and wastewater treatment:

Drinking Water: Drinking water is water that can be consumed or used for domestic and industrial purposes without risk to health. It can be distributed as bottled water (mineral or spring water, still or sparkling), tap water, or in tanks for industrial use.

Wastewater: Wastewater (or polluted water) is water that has been altered by human activity. This can include polluted water from factories or runoff from parking lots. This water contains hydrocarbons and other polluting chemicals, necessitating treatment to make it clean again. It is most often discharged through sewers, after which it passes through a treatment plant or facility.

These facilities purify the water before releasing it back into the environment, minimizing human impact on water. Our thesis focuses on wastewater.To improve the well-being of citizens in Algiers and Tipasa, SEAAL carries out numerous operations daily. These include:

- Preventive cleaning of the sewer network.
- Maintenance and operation of pumping stations.
- Network and pumping station renewal work.
- Upgrading manholes on roads to allow access to the network.
- Emergency interventions following calls to the dispatch center.
- Diagnosing the condition of the networks using CCTV inspections to anticipate pipe breaks and road subsidence.

This work is particularly critical in urban areas.

SEAAL is responsible for the public sewer network. However, other networks exist under the responsibility of public or private entities, such as internal company networks or stormwater drainage systems. Pollution contained in the collected wastewater must be treated at wastewater treatment plants. Wastewater treatment systems employ physical and biological processes. Therefore, the units must operate 24/7 to treat effluents according to variations in human activity that produce wastewater. . A program for monitoring effluents entering and leaving wastewater treatment plants is implemented to ensure the conformity of water discharged into the natural environment.[1]

I.3. *Presentation of a wastewater treatment system :*

A wastewater treatment plant is a facility designed to treat domestic, industrial, and stormwater wastewater before it is discharged into the natural environment, usually into a waterway. This wastewater contains various impurities, including solid waste, oils, and all dissolved substances. The high concentration of these impurities makes direct discharge into the environment impossible and causes significant pollution. Therefore, the role of wastewater treatment plants is to remove these pollutants in several stages to prevent pollution and enable wastewater recycling. Most of these plants are located at the end of the wastewater collection network.

The plant uses various physical, chemical, and biochemical processes and equipment to analyze and separate organic matter from the water. It also utilizes various electronic and electrical devices to control different aspects of the plant's operations. The result is clean water that is not potable but is of sufficient quality to be absorbed by the environment without causing harm..

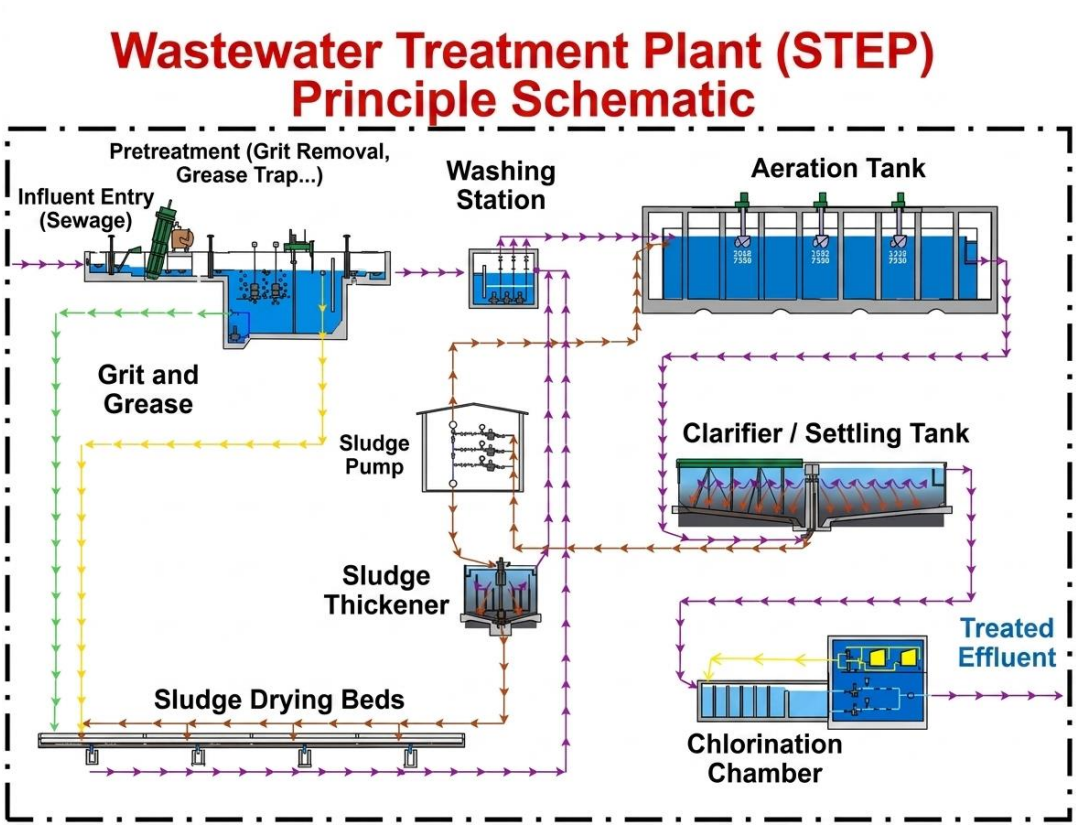


***Figure I.1*:** Diagram of the wastewater treatment plant

I.4 .*Number of wastewater treatment plants in Algeria :*

Algeria has approximately 234 wastewater treatment plants operating at a total capacity of nearly 1.1 billion cubic meters per year, with an additional 75 plants currently under construction. This number is expected to reach 300 by 2030. This development began in 1999 when there were only 12 plants. By 2000, the number had increased to 12 plants with a capacity of 90 million cubic meters per year, and by 2016, it had reached approximately 100 plants with a capacity of 1.8 billion cubic meters per year. This treated water is used in agriculture, industry, and irrigation. Among these plants is the Ain Taghrout plant, considered one of the most important treatment facilities in the province of Bordj Bou Arreridj.

I.4.1. Ain Taghrout Wastewater Treatment Plant:

The Ain Taghrout wastewater treatment plant, located in the Bordj Bou Arreridj province of Algeria, is an urban and domestic wastewater treatment facility commissioned in 2018. It uses the conventional activated sludge process, a biological treatment that includes pretreatment by

screening, grit removal, and grease removal, followed by an aeration basin where oxygenated bacteria break down organic matter, then a clarifier to separate the water from the sludge, and finally disinfection before discharge. The plant was designed in two phases: the first phase to treat the current pollution of Ain Taghrout and Bir Kasd Ali (expected completion by 2025), and a second expansion phase planned for 2035 to increase capacity in line with population growth. The treatment performance recorded during the 2021-2022 period is very satisfactory, with removal efficiencies of 93% for COD, 94% for BOD_5, and 93% for TSS, indicating that over 90% of impurities are removed. However, weaknesses were identified, including very low removal rates of nitrites, nitrates, and phosphates, as well as occasional foaming problems in the aeration basin. A study even tested an advanced oxidation process using photocatalysis with Ag_2MnO_2 to improve treatment. The plant plays a crucial role in the region's sanitation and environmental protection, with treated wastewater reused for agricultural irrigation, thus contributing to the expansion of approximately 500 hectares of irrigated land in the Bordj Bou Arreridj region. Overall, the station is functioning correctly with satisfactory purification performance, despite some temporary foaming problems, and constitutes an essential investment to preserve the natural environment and protect public health in the wilaya.



***Figure I.2*:** location of WWTP ain taghrout (Google maps).

I.5. Station overview:

Wastewater is treated through a series of technologies and stages that purify, filter, reuse, and recycle the water in the natural environment.

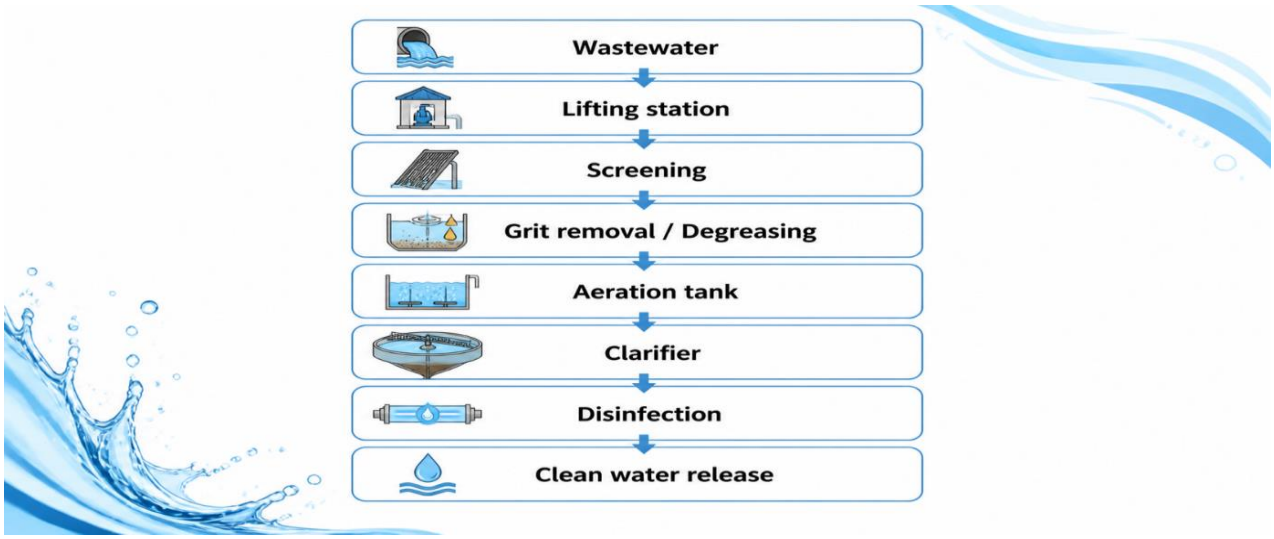


***Figure I.3*:** Functional diagram of the station

I.6. Plant Operation :

The purpose of the Aïn Taghrout wastewater treatment facility is to remove phosphorus, nitrogenous, and carbonaceous pollutants from urban wastewater. The facility receives domestic wastewater via a different sewage system in the manner described below:

1.Submersible pumps are installed at a pumping station that receives the collected wastewater.
2. After that, it is pumped to a settling basin and goes through a fine screen to get rid of big particles.
3. To guarantee the best possible treatment capacity, the raw wastewater is then divided between two parallel treatment lines.
4. Following screening, the wastewater is sent to a grit/oil separation unit, which separates the grit by sedimentation and the grease by flotation.
5. The biological treatment zone, which is made up of two longitudinal aeration basins with floating aerators in each, receives the effluent after that.
6. To ensure that the sludge and treated water are separated, the mixed liquor from the aeration basins is transferred to two secondary clarifiers.
7. After treatment, the water is transported to a storage basin via a pipe with a predetermined diameter before being released or used again.
8. These buildings hold the sludge that has collected in the clarifiers for a predetermined amount of time.

9. A pump is used to remove the sludge.
10. After being removed, the sludge is stored:

either on a platform constructed within the facility for possible reuse, in an external storage area, or in the existing on-site basin.

I.7. Description of WWTP :

The station is equipped with the following facilities:

I.7.1 The pre-treatment section :

I.7.1.a. The pre-screen : The pre-screening stage is the first stage of primary treatment at the plant for disinfecting wastewater coming from homes and factories. It is a process that aims to remove large wastes present in the water such as plastic, wood, paper, and stones.



***Figure I.4*:** The pre-screen

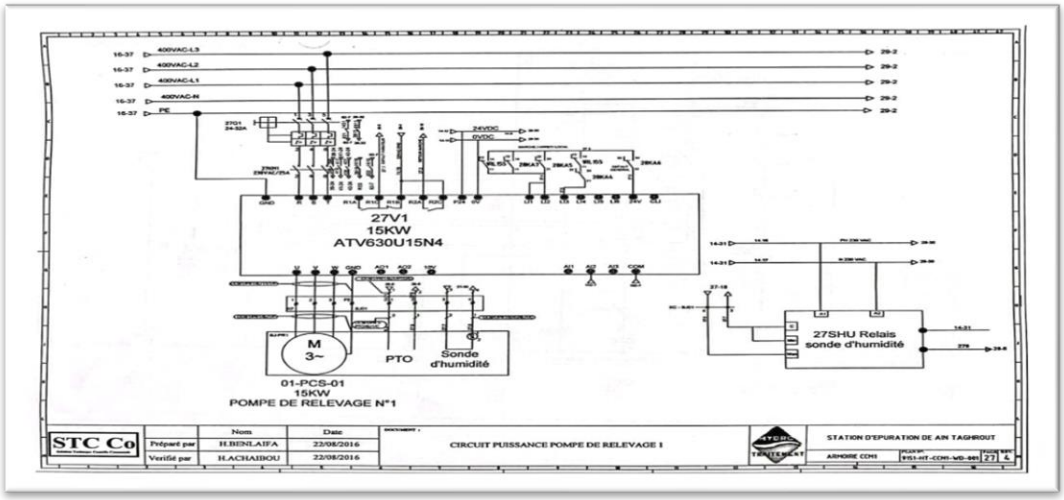
I.7.1.b. The pumping station :

The pumping station is one of the most important facilities in the plant, as it is used to transfer and raise water from a low level to a higher level suitable for the dissipation basin. The inlet station receives water coming from the sewage network into a special basin called the collection basin, and it consists of submersible pumps, water level sensors, valves, and pipes.

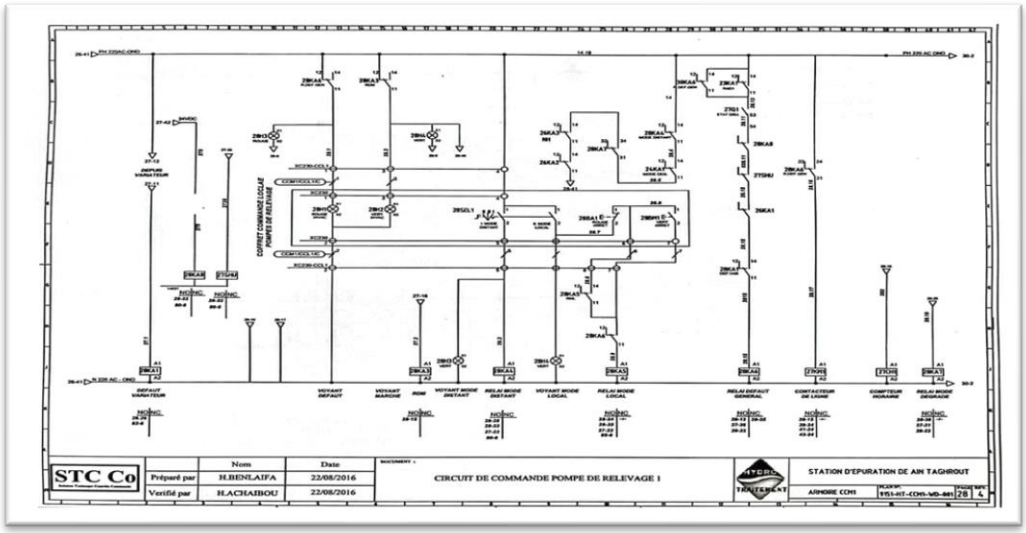




***FigureI.5*:**The pumping station



FigureI.6: **Power diagram of lifting step**[7]



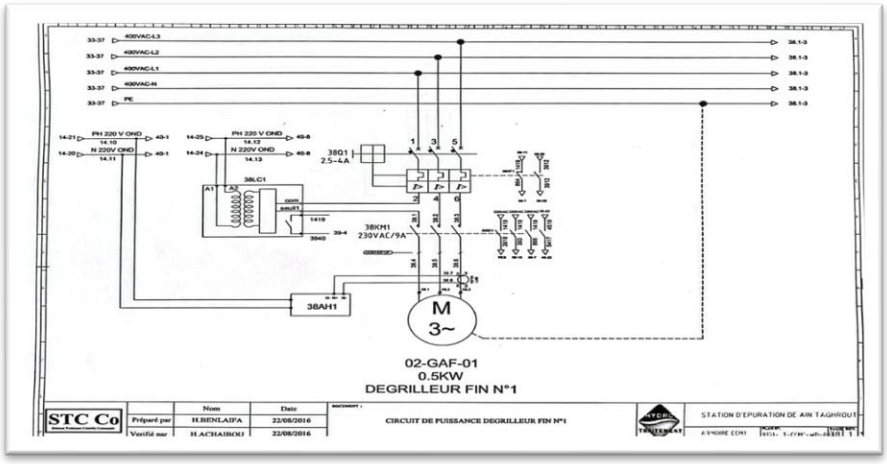
FigureI.7: **Control diagram of lifting step** [7]

I.7.1.c. The screening:

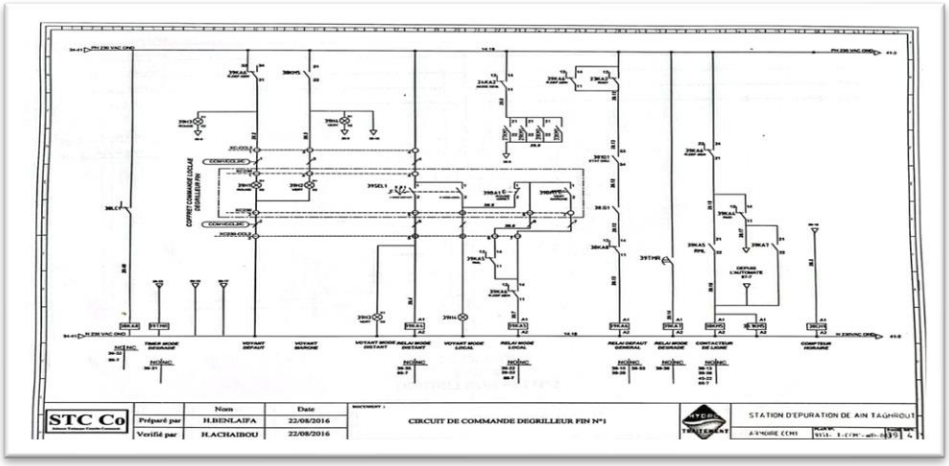
Water enters from the pumping station and flows into two fine screens that are manually cleaned. Each screen consists of two meshes. Cleaning these meshes is very simple. The wastewater then passes through a screen or rotating screw that removes solid materials such as cigarettes, hair, and plastic. The screw conveyor lifts this waste to a container for disposal or incineration.



Figure I.8: The screening



FigureI.9: **Power diagram of screening step** [7]



FigureI.10: **Control diagram of screening step** [7]

I.7.1.d The Sand/Oil Separator :

The sand and oil removal basin is one of the most important components of a wastewater treatment plant. It is designed to remove sand, stones, oil, and grease from the water. Two motors are responsible for this process:

the first, called the SCRAPER : is responsible for sand removal,The SCRAPER separates heavy particles like sand and stones through sedimentation, protecting pumps and equipment from corrosion and wear.

the second is the AEROFLOT, is responsible for oil removal. . The AEROFLOT removes oil and grease using flotation, preventing the accumulation of fats inside the basins and pipes. In this stage, sand and heavy materials settle to the bottom of the basin, while grease and oil rise to the water's surface.These motors operate continuously.



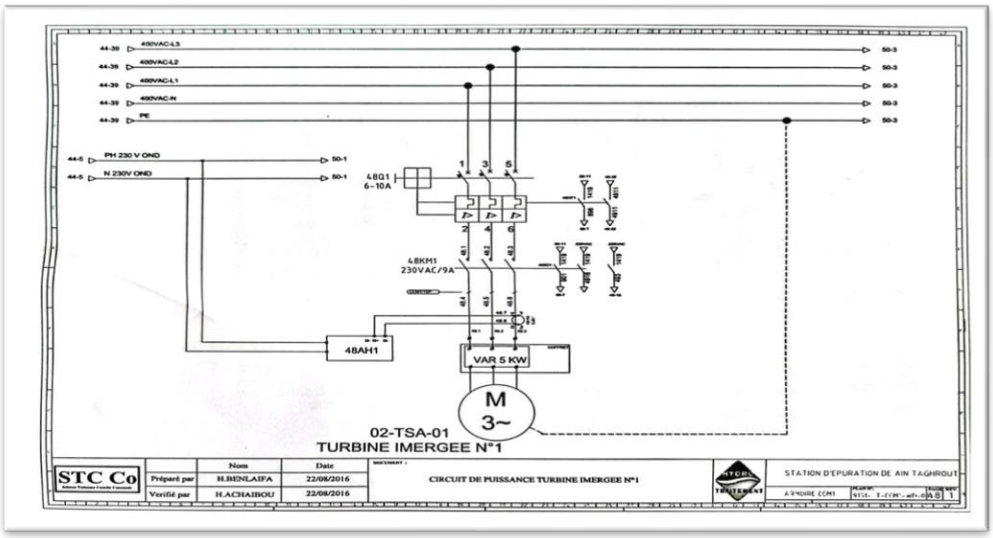
Figure I.11: The Sand Separator (scraper)



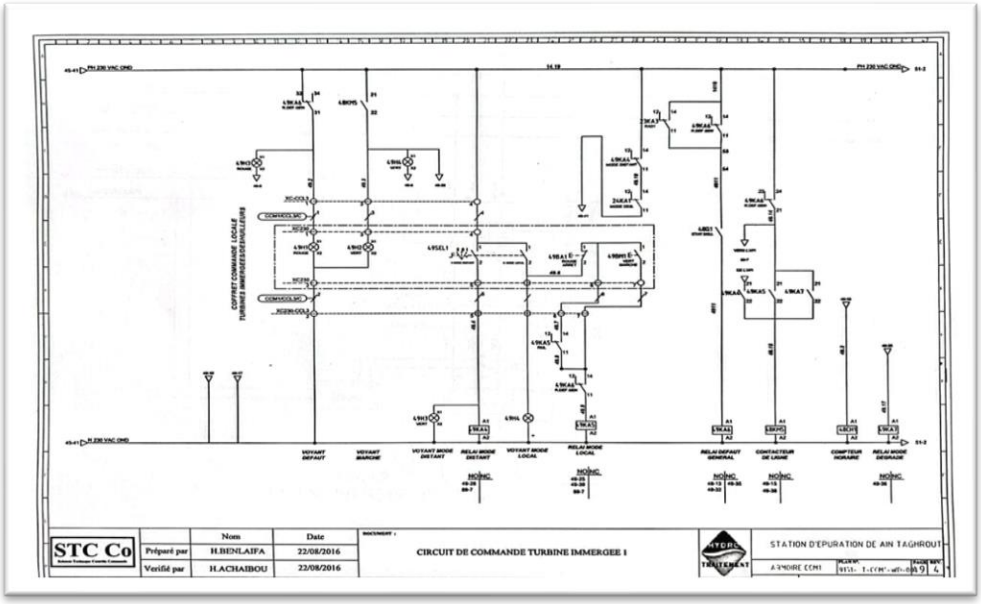
Figure I.12:The Oil Separator(aeroflot)



***Figure I.13*:** The Sand/Oil Separator



FigureI.14: **Power diagram of sand/oil separator** [7]



FigureI.15: **Control diagram of sand/oil separator** [7]

I.7.2 The Biological Section *:*

After pretreatment, it is necessary to remove organic compounds and phosphorus from the water. To do this, we move on to the biological stage, which is based on the activity of microorganisms and constitutes a fundamental stage of water purification. The water is directed to different basins where oxygenated bacteria develop. These bacteria quickly digest and eliminate impurities. The biological stage mainly includes:

Two pools, each with its own function:

I.7.2.a .The anoxic basin: It contributes to the elimination of nitrogen by reducing nitrates. It operates without oxygen supply and involves continuous mixing.

I.7.2.b.The aeration basin: It allows the biological treatment of organic matter. Wastewater is mixed with activated sludge (bacterial cultures). It is also equipped with aerators and air diffusers to provide the necessary oxygen for bacteria and reduce BOD and COD.

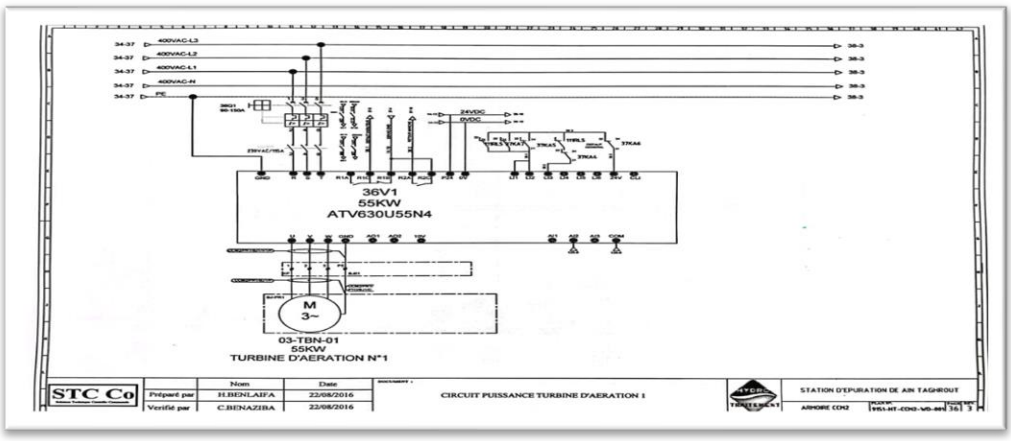
The biological component is automatically controlled using measuring sensors such as:

- Dissolved oxygen
- pH
- flow

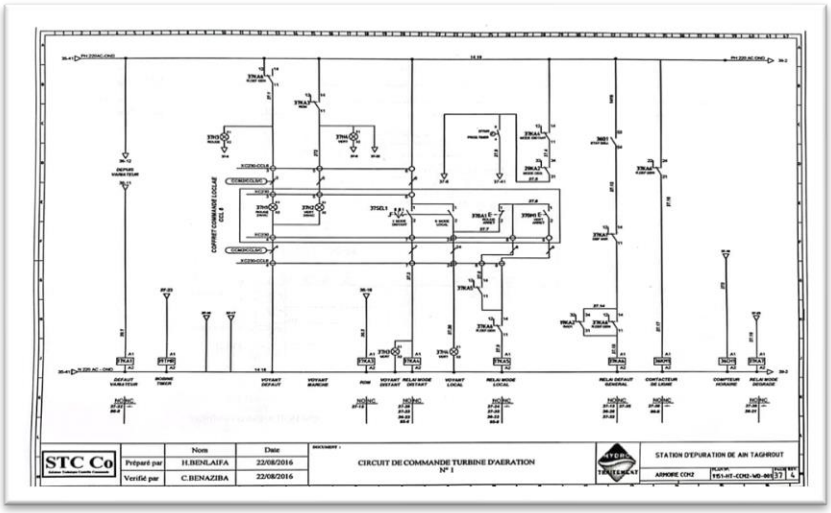
via an industrial monitoring and control system.



***Figure I.16*:**The aeration basin



FigureI.17: **power diagram of aeration basin** [7]



FigureI.18: **Control diagram of aeration basin** [7]

I.7.3 the clarification:

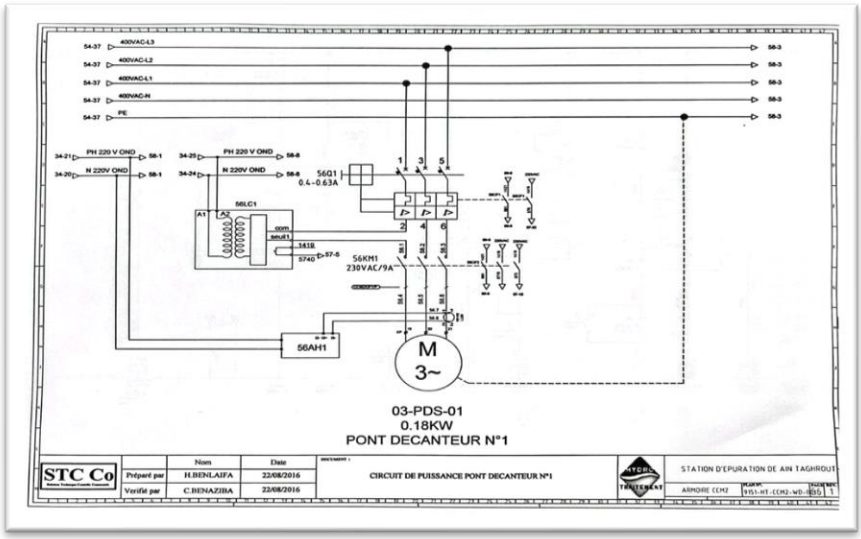
This process involves separating water from the sludge resulting from the decomposition of organic matter. This process takes place in basins called sedimentation basins, which are among the most important facilities in a wastewater treatment plant. At this stage, the mixed effluent from the aeration basin enters the sedimentation basin, where the flow velocity decreases to allow the sludge to settle at the bottom. The sedimentation basin also allows for the separation of sludge from the treated water, the recovery of biological sludge, the improvement of water quality, and the preparation of the water for final discharge. The sludge that settles at the bottom is collected by skimmers and then directed towards the sludge treatment line.

The treated water is discharged into the natural environment or stored in a storage basin.

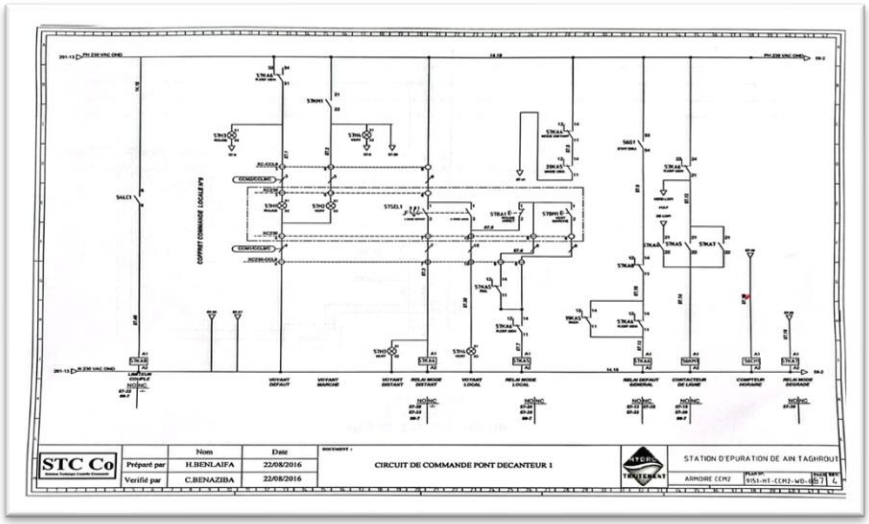




***Figure I.19*:** The clarification



FigureI.20: **Power diagram of clarification** [7]



FigureI.21: **Control diagram of clarification** [7]

I.7.4 The Sludge sector :

Sludge treatment is a crucial stage in wastewater treatment plants. It's a fundamental step aimed at treating the sludge produced during the disinfection process to reduce its volume and hazards, stabilize its components, and utilize it safely and efficiently. This sludge, produced from sedimentation basins and biological tanks, contains organic matter, microorganisms, and other pollutants. Treatment involves several key stages:

1. Condensation: This is achieved through sedimentation, flotation, and centrifugation to reduce the water content in the sludge, resulting in a more concentrated sludge.
2. Dewatering: This is done using pressurized filters and centrifugation to reduce the water volume, facilitating transport and storage. As a result, the solids content decreases by 15-30%.
3. Drying: This aims to obtain a solid sludge and is achieved through thermal and solar drying.
4. Stabilization: This involves methods such as anaerobic digestion (producing biogas), aerobic digestion, oxygen stabilization, and limening (adding lime to disinfect the sludge).

Composting involves mixing organic waste to produce fertilizer. Its purpose is to reduce odors, microbes, and fermentation.

Finally, there is valorization or final disposal.

Agricultural uses: as organic fertilizer.

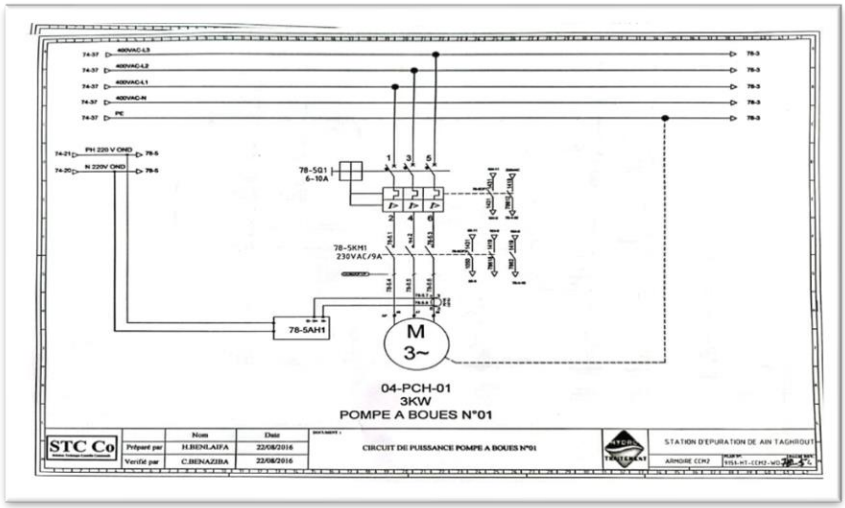
Energy uses: biogas production.

Disposal: incineration or landfilling if the sludge is contaminated with heavy metals or unsuitable for other uses

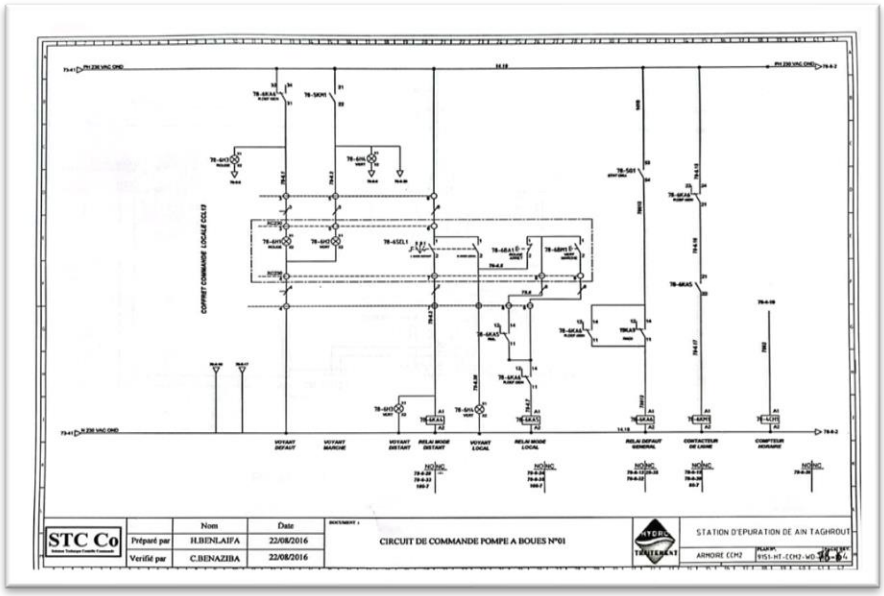




Figure I.22 **:**The sludge sector



FigureI.23 **Power diagram of sludge sector** [7]



FigureI.24 **Control diagram of sludge sector** [7]

I.7.5. The chemical part :

In order to ensure the safety of the water, specific agents are used in the chemical process of any water treatment facility, whether it is for drinking or waste water. Whether or not the water needs to be purified determines the primary steps and agents utilized.

Physico-Chemical Treatment: Used to eliminate various contaminants dissolved in water, including suspended solids (SS).

Coagulation: The process of removing the negative charge of suspended solids by adding metallic salts (such as aluminum sulfate and ferric chloride).

Flocculation: When polymers (also known as "glue") are added, big particle clusters (flocs) are formed.

Precipitation: The precipitation of phosphates and heavy metals or the addition of lime or sodium hydroxide to modify pH.

Disinfection and Oxidation: It's necessary to destroy bacteria, viruses, and other organic molecules as well as to oxidize them.Chlorine (or bleaching powder) and chlorine dioxide are the most often used disinfecting agents. Ozone (O3) and UV light radiation are additional methods.

Water Balance Control and Adjustment

Neutralization: When water is very alkaline, sulfuric or hydrochloric acid is added. Remineralization: Lime (which reacts to generate calcium carbonate) and carbon dioxide (CO2) for drinking water.

I.8. Diagram of the WWTP :

In our project we aim for the stages of STEP (see figure I.12)

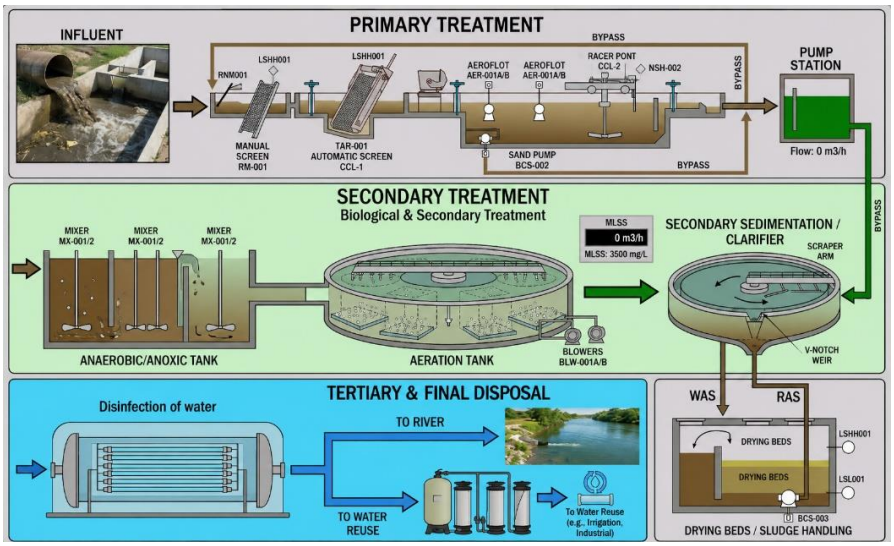


Figure I.25: diagramme of wwtp

Conclusion :

In this chapter, we presented an overview of wastewater treatment plants and their importance in environmental preservation and human health protection. We also introduced the role of the SEAAL company in the field of disinfection and treatment. We focused on the wastewater treatment plant located in Ain Taghrout, explaining its operating principles and the various treatment stages. The next chapter will discuss the plant's electrical equipment.

Chapter two:

Electrical Equipment and Control System

II. introduction:

The efficient operation of a wastewater treatment plant relies on two complementary technical pillars: the electrical equipment and instrumentation responsible for physical treatment operations, and the programmable control system that coordinates and governs these devices. This unified chapter presents both dimensions in an integrated manner, drawing on the practical case of the wastewater treatment plant under study.The first part describes the actuators, sensors and protective devices forming the operative section of the pre-treatment stage. The second part covers the theoretical foundations of industrial automation before presenting the SIMATIC S7-300 programmable logic controller and the TIA Portal development environment adopted for this project.

II.1. Electrical equipment of the plant:

II.1.1. General Architecture of an Automated System:

Every automated system is organised around two functional sub-systems that continuously interact: the Operative Part (OP), which carries out the physical actions on the process, and the Control Part (CP), which processes information and issues the corresponding commands.

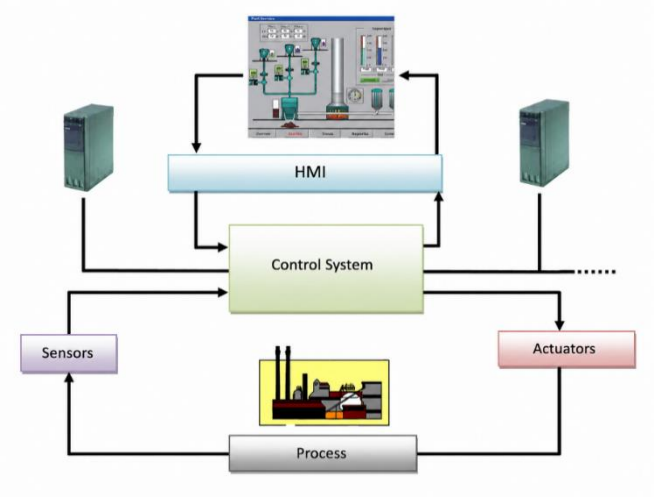


Figure II.1: Structure of an Automated System

II.1.1.a. The Operative Part:

The Operative Part comprises two families of devices:

- **Actuators**: they convert electrical energy into mechanical energy and execute the orders issued by the control part. Electric pumps and motors are the most representative examples in a treatment plant.
- **Sensors**: they continuously monitor the physical variables of the process (liquid level, flow rate, presence of waste…) and transmit an electrical image of these variables to the control part, consuming very little energy.

II.1.1.b. The Control Part*:*

The Control Part constitutes the decision-making centre of the automated system. It collects information from the sensors, processes it according to the programmed logic and sends the appropriate commands to the actuators via pre-actuators such as contactors and soft starters. In modern industrial installations, this function is fulfilled by a programmable logic controller (PLC).

II.1.2. Actuators in the Pre-treatment Stage :

The pre-treatment stage of the plant employs several types of actuators, each assigned to a specific phase of the hydraulic circuit.

II.1.2.a Lifting Pumps:

The pumping station is equipped with four submersible pumps, each rated at 17 kW. Their function is to raise raw wastewater from the collection sump to the fine screen, overcoming the elevation difference between these two structures. The pumps operate alternately to distribute wear evenly and ensure continuous service availability.



Figure II.2*:* Pump Station

II.1.2.b . Screen Drive Motor:

The mechanical screen is driven by a three-phase asynchronous motor rated at 0.9 kW. Its activation mechanically evacuates retained solids from the screens into a collection skip. This command may be triggered manually or linked to predefined operating conditions.

II.1.2.c . Three-Phase Asynchronous Motor: Technology and Operating Principles:

The squirrel-cage three-phase asynchronous motor is by far the most widespread drive technology in industry, accounting for over 80% of the global electric motor fleet. This dominance is due to its inherent qualities: high mechanical robustness, low maintenance costs, near-constant speed over a wide load range and an excellent power-to-size ratio.

Construction: The motor consists of two main elements. The stator (fixed part) is formed by a ferromagnetic frame housing three windings offset by 120° from one another; fed by three-phase current, these windings generate a rotating magnetic field in the air gap. The rotor (rotating part), subjected to this field, develops a torque through electromagnetic induction and begins to rotate.

Operating principle: The speed of the rotating field depends on the supply frequency and the number of pole pairs. The actual rotor speed is always slightly lower than the stator field speed this difference, called slip, sustains the induction phenomenon and maintains the driving torque.

Star/Triangle Connection: Two wiring configurations are possible. In star (Y), each winding is subjected to the phase voltage (~230 V); this arrangement is used during start-up to limit inrush current or when the motor is rated for 230 V on a 400 V network. In delta (Δ), each winding receives the line voltage (400 V) and this configuration is used under normal rated operation.

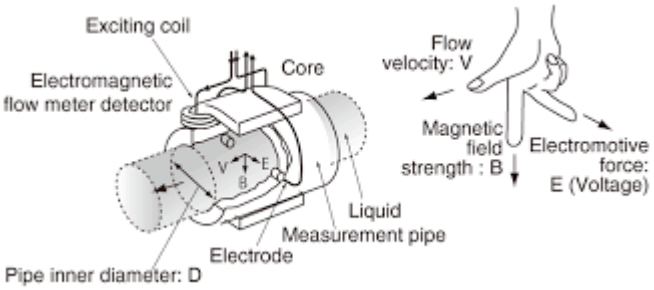


Figure II.3: Three-Phase Asynchronous Motor

II.1.3. Sensors and Measuring Instruments:

II.1.3.a Electromagnetic Flow Meter:

The measurement of wastewater flow is performed by electromagnetic flow meters. These instruments are based on Faraday-Lenz's law: when an electrically conductive medium here the flowing fluid moves through a magnetic field, an electromotive force proportional to its velocity



is induced between two electrodes. The volumetric flow rate is then calculated from this voltage and the pipe cross-section. This technology is particularly suited to loaded fluids such as wastewater, provided their electrical conductivity is sufficient. [2]

Figure II.4: Electromagnetic Flow Meter

II.1.3.b Ultrasonic Level Sensor:

Level measurement in the plant's structures relies on ultrasonic sensors. These devices emit a beam of high-frequency acoustic waves towards the liquid surface; the wave reflects back to the sensor and the round-trip travel time is measured with precision, allowing the distance and therefore the liquid level to be calculated. The key advantage of this technology lies in the absence of contact between the sensor and the fluid, eliminating any risk of clogging or corrosion.

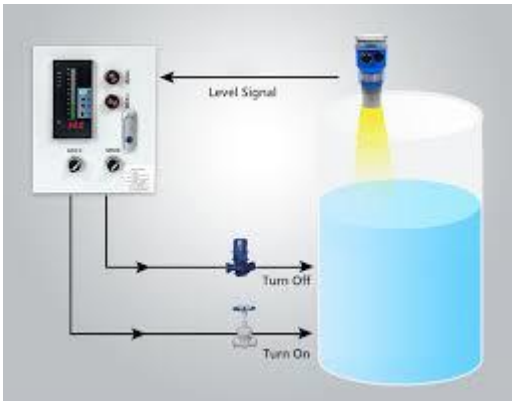


Figure II.5: Ultrasonic Level Sensor

II.1.3.c. Float Switch (Binary Level Sensor):

Complementing the ultrasonic sensor, the float switch detects level thresholds (high or low). It consists of a floating element resting on the liquid surface, linked to a position detector. When the level reaches a preset threshold, the tilting of the float generates a binary (on/off) electrical signal transmitted directly to the control system, enabling the lifting pumps to be started or stopped.



Figure II.6: Float Switch

II.1.4. Control and Protection Devices in Electrical Panels :

The power supply to the motors and their electrical protection are ensured by various devices housed in dedicated electrical panels. The main components are presented below.

II.1.4.a Circuit Breaker :

The circuit breaker is the fundamental protection device of any electrical installation. Its function is to automatically interrupt the circuit in the event of a prolonged overload or a short circuit, protecting the integrity of cables and connected equipment. It comprises a main circuit carrying the service current, a control circuit managing opening and closing conditions, and an auxiliary circuit for signalling and interlocking functions.



Figure II.7 : Circuit Breaker

II.1.4.b. Motor Protection Circuit Breaker (Magneto-thermal) :

Specifically designed for motor protection, the motor circuit breaker combines two protection mechanisms in a compact enclosure. Thermal protection uses a bimetallic strip: prolonged overload heats the strip by the Joule effect, causing it to deform and trigger the trip mechanism; the threshold is adjustable directly on the device. Magnetic protection detects short circuits and causes near-instantaneous tripping (≈ 0.1 s) via an electromagnet; the trip level is expressed as a multiple of the rated current (between 3 and 15 In) and is not adjustable.

II.1.4.c. Contactor :

The contactor is a remotely controlled switch designed to make or break an electrical circuit under the action of a low-energy electrical or pneumatic command. Its amplification factor — the ratio of switched power to control power — can reach 2,000, making it an indispensable component in industrial automation systems. It includes a power circuit, an excitation coil, an auxiliary circuit for interlocking and self-holding, and main and secondary contacts.



Figure II.8 : Contactor

II.1.4.d. Protection Relays:

Protection relays are devices for monitoring the electrical quantities of the network. They detect any anomaly (overcurrent, voltage variation, phase imbalance…) and order the disconnection of the affected circuit before damage occurs.Relays are classified according to the monitored quantity:

- ✓ Overcurrent relay (RMA): trips when the current exceeds a preset threshold.
- ✓ Under/over-voltage relay (RMV): monitors supply voltage variations.
- ✓ Directional power relay (RDW): detects reversals in the direction of energy flow.
- ✓ Minimum reactance relay (RMX): used in certain distance protection configurations.

From a technological standpoint, relays fall into several categories: classical electromagnetic relays, thermal bimetallic relays, time-delay relays (incorporating an adjustable delay between detection and tripping), and digital relays that appeared in the 1980s. The latter use microprocessors to analyse electrical signals numerically, offering high measurement accuracy, the ability to record network disturbances and the integration of multiple protection functions in a single device. [3]



Figure II.9: Protection Relays

II.1.4.e. *S*oft Starter Altistart 22 (ATS 22):

The direct-on-line starting of a high-power asynchronous motor generates an inrush current that can reach five to seven times the rated current, causing mechanical shocks to transmission components and disturbances on the electrical network. To mitigate these effects, the lifting

pumps are equipped with Schneider Electric Altistart 22 soft starters.

This device progressively reduces the voltage applied to the motor during starting, thereby limiting the inrush current and mechanical stresses. It also provides a smooth decelerated stop. The ATS 22 is designed for motors ranging from 4 to 400 kW and natively integrates Class 10 motor protection. For applications requiring minimisation of thermal losses after start-up, a bypass contactor can be integrated to short-circuit the thyristors once nominal speed is reached.

Structurally, the soft starter comprises a power module using thyristors to regulate the motor supply, and a control module managing start-up, operating and stopping parameters. The motor can be connected to the network in star or delta configuration depending on its rated voltage.



Figure II.10 : ATS22 110A 55KW

- **Partial Conclusion*:***

This first part has described all the electrical equipment and instrumentation of the plant's pre-treatment stage. Each component from lifting pumps to protection devices has been studied in terms of its function and operating principle,laying the essential groundwork for understanding the automated control system.

II.2. Control System And Programmable Logic Controller :

II.2.1. Fundamentals of Industrial Programmable Logic Controllers:

II.2.1.a Brief Historical Background:

Industrial programmable logic controllers (PLCs) originated in the United States in the late 1960s at the request of the American automotive industry. General Motors, confronted with the inflexibility of hardwired control systems, sought a solution that could be reconfigured by simply modifying a program without rewiring. The first PLCs quickly demonstrated their economic and technical superiority over wired systems. Today, the product range extends from nano-PLCs for simple low-I/O applications to multifunctional controllers managing thousands of I/O points for complex industrial processes.

II.2.1.b Definition and Key Characteristics:

An industrial PLC is a specialised electronic machine designed to monitor and control industrial processes in real time. It cyclically executes a program stored in memory: reading inputs, processing data according to the programmed logic, and updating outputs.Three essential characteristics distinguish a PLC from a conventional computer:

- Direct field connectivity: the PLC connects directly to sensors and pre-actuators via industrial I/O interfaces without requiring additional interface cards.
- Robustness in harsh environments: PLCs are designed to operate under difficult conditions — extreme temperatures, vibrations, electromagnetic interference and power micro-cuts — without any degradation in performance.
- Dedicated automation languages: standardised by IEC 61131-3, these languages (Ladder, Function Block Diagram, Grafcet…) are specifically designed for automation tasks, facilitating implementation and maintenance.



Figure II.11 : Siemens Programmable Logic Controller (PLC)

II.2.1.c Advantages and Limitations:

- Simple execution kernel and ease of programming, even for complex applications.
- Ability to handle parallel tasks without a heavyweight multitasking operating system.
- Capacity to operate on low-power processors, reducing hardware costs.
- The cyclic execution model may be a limiting factor for applications requiring very short response times.
- PLCs show their limits when faced with highly complex or deeply nested control sequences.

II.2.2. Internal Architecture of a PLC :

The hardware structure of a PLC is inspired by that of a microcomputer, optimised for industrial automation constraints. The following components are invariably present:

- Central Processing Unit (CPU): groups the processor and central memory; reads and executes program instructions sequentially, clocked by an internal oscillator.
- Memories: the program memory (ROM, read-only) holds the executable code; the data memory (RAM, read/write) stores the I/O images and intermediate program variables.
- Input/Output modules: form the interface between the PLC and the physical world; input modules digitise sensor signals; output modules convert logical data into signals driving the pre-actuators.
- Power supply: adapts the network voltage (230 V AC or 24 V DC) to the levels required by the internal electronics.

The PLC scan cycle runs in four successive phases repeated indefinitely: internal processing (diagnostics, system parameter updates), synchronous input reading, instruction-by-instruction program execution, and synchronous update of physical outputs.

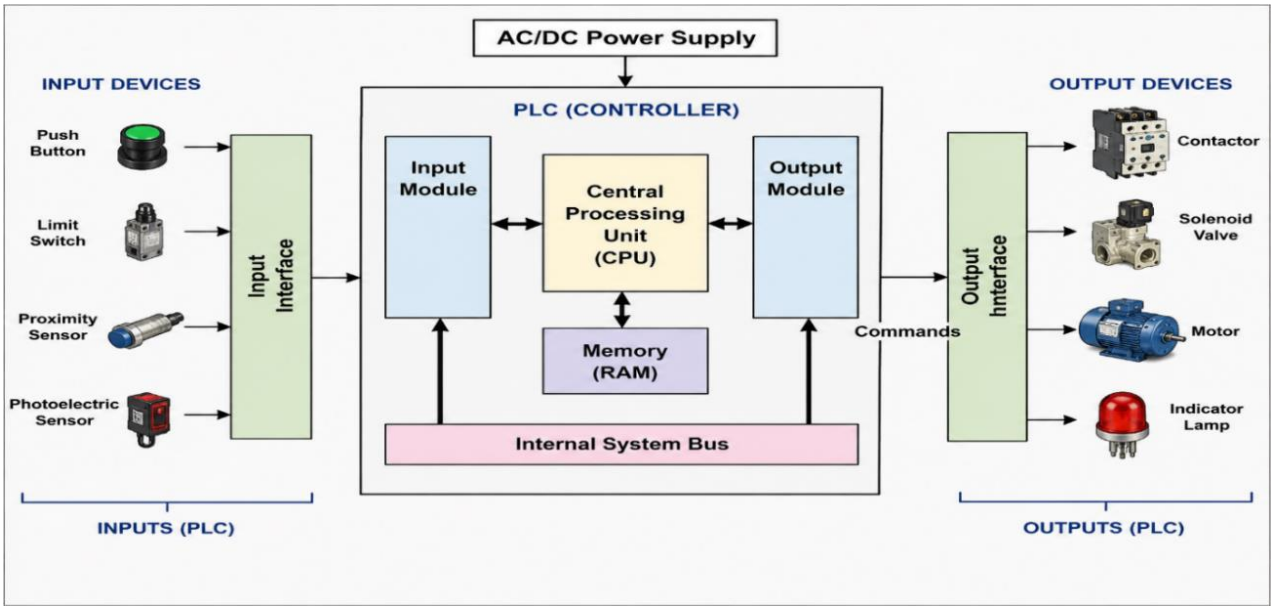


Figure II 12: Architecture of PLC

II.2.3. PLC Selection Criteria:

PLC selection results from a multi-criteria analysis involving technical, economic and organisational considerations:

- Number of I/O points: sizing must anticipate current needs and foreseeable extensions.
- Processor performance: memory size, processing speed and advanced functions (integrated PID regulation, motion control…).
- Communication capabilities: the PLC must integrate into the installation's network architecture (PROFIBUS, PROFINET, Industrial Ethernet…).
- Software environment: the availability of a capable development tool including simulation and diagnostics is a key factor for engineering team productivity.
- Standardisation: limiting the diversity of makes and models on a site simplifies personnel training and reduces spare parts inventory.

II.2.4. Presentation of the Used PLCs:

S7-300 CPU 315-2PN/DP V3.2 PLC: The main PLC (Programmable Logic Controller) used in this project is S7-300 CPU 315-2PN/DP V3.2. It is a modular mini PLC for factory automation that provides a comprehensive automation platform for centralised and decentralised architectures. A broad selection of S7-300 modules is available that are ideally suited for a variety of automation tasks.

CPU 315-2PN/DP V3.2: The SIMATIC S7-300 CPU 315-2PN/DP V3.2 is a central processor with 384 KB of working memory.

The CPU 315-2PN/DP has two interfaces:

- 1st MPI/DP 12 Mbit/s interface
- 2nd Ethernet PROFINET interface with 2-port switch.

A Micro Memory Card is required.



Figure II. 13: CPU 315-2PN/DP

The figures below show the position of the CPU and the various I/O modules on the S7-300 PLC chassis:

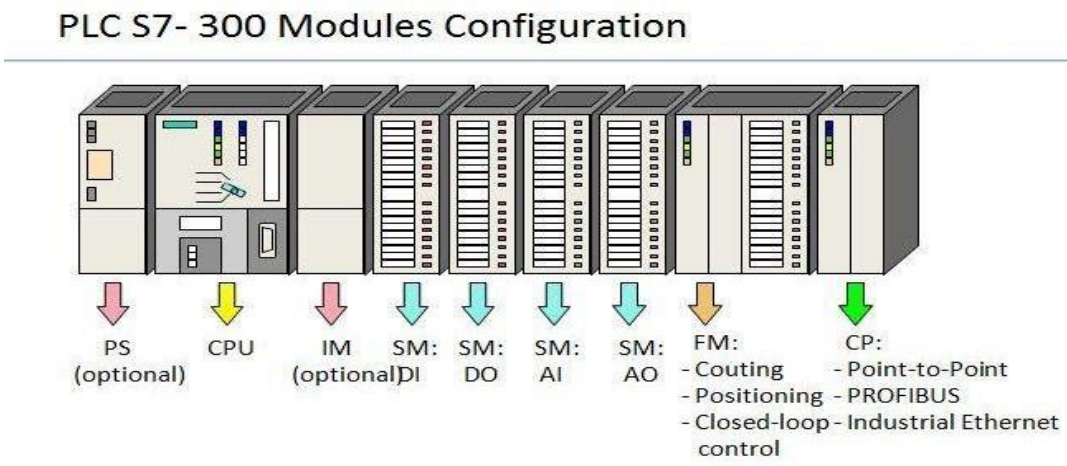


Figure II. 13: S7-300 Configuration Modules.

II.2.4.a General Description:

S7-300 is a modular type mid-range PLC based on DIN rail mounted rack system. It is made up of a number of distinct, yet interrelated parts which are the Power supply module (PS), the Central processing unit (CPU) which holds the processor and memory, the Signal modules (SM) that include a digital and analog I/O, Communication processors (CP) and the Function modules (FM).

Single-rack setups, like the CPU 312 and CPU 313, can hold up to eight I/O modules in a single rack that is DIN rail mounted. Multi-rack systems such as the CPU 314, CPU 315, and CPU 317 can be expanded to up to four racks with the use of IM 360/361 interface modules.

When the user program is downloaded, the CPU operates by continuously scanning the inputs and outputs in real time. It performs Boolean logic operations, timer, counter, floating point calculations, high speed instruction, and minimum time of 4 ns for execution.

Communication is provided through:

- MPI at 187.5 kbps for programming and HMI connectivity;
- PROFIBUS DP for distributed I/O system and drive control, with speeds up to 12 Mbps;
- PROFINET 100 Mbps for Industrial Ethernet.

PROFINET support is only available for CPU models with the "PN" suffix. The S7-300 is now available for motion control application with special function modules, high speed counter modules and position modules for driving servo motors and CNC machines.

Conclusion:

In this chapter, we discussed both of the technical focal points of a WWTP. The operational part covered electrical devices: lift pumps, motors, sensors, protection devices. In the first part we also looked at the different electrical equipment and measuring devices that make up the operational section. The second part was the control system introduction; we discussed the basic principle of industrial automation, and then integrated the SIMATIC S7-300 logic controller. The following chapter will be focused on developing the control for the pretreatment phase in the TIA Portal.

Chapter three:

Automation System Designand Programming With TIA Portal

III.1. Introduction

To identify the Ain Taghrout wastewater treatment plant, you will find that the program will implement automation solutions with an integrated system including STEP7, SIMATIC WINCC, and PLC SIM by designing and automating the SIEMENS TIA PORTAL.

In this chapter, we will reveal, through functional analysis and monitoring of the results of the automation programming of our system and the simulation used in this project..

III.2. TIA PORTAL (Totally Integrated Automation Portal)

III.2.1 Introduction :

TIA Portal software is a programming tool for S7 PLCs and KTP operator panels of the S7 series. It consists of STEP7 Basic and WinCC Basic. It is based on the same programming concept as STEP7 Pro but uses a simplified user interface and includes operator panel design. Siemens wants to bring all of its product lines under a single software umbrella.This facilitates the design, programming, operation, and monitoring processes.

On TIA Portal you can:

• View and open projects.

• Create a new project.

• Transport a current project.

• Connect to an S7 series PLC or KTP operator panel and view diagnostics.[4]

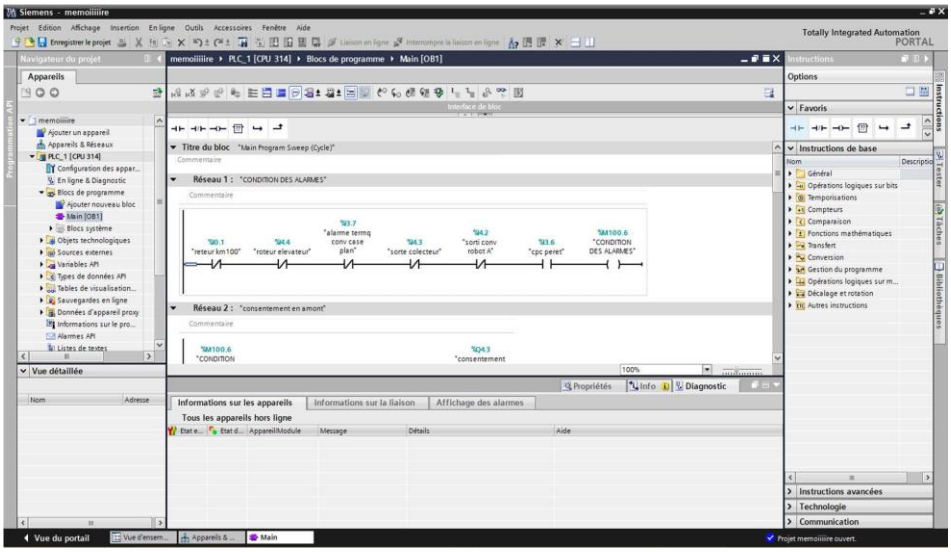


Figure III.1: Overview of TIA Portal

III.2.2 Programming languages:

There are different languages to program programmable logic controller (PLC), which are us standardized according to international standard IEC 61131-3. These controllers are programmed either from a proprietary programming unit or a computer with the development software from the manufacturer.

a. Literary Languages:

- **Instruction List (IL : Instruction List):** Text language, equivalent to assembler (microcontroller programming). I For our automatons, it very seldom use.

```
IF %M0 THEN
    FOR %MW99 := 0 TO $1 DO
        IF %MW100 [%MW99]< > 0 THEN
            %MW10 : =%MW100 [%MW99];
            %MW11 : =%MW99;
            %M1 : = TRUE;
            EXIT;              (*Sortie de la boucle FOR*)
        ELSE
            %M1 : = FALSE;
        END_IF;
    END_FOR;
ELSE
    %M1 : = FALSE;
END_IF;
```

Figure III.2. List language

- **Structured literal language (ST: StructuredText):**

  A computer language of the same nature as Pascal, it uses functions like if ... then ... else … (si ... alors ... sinon ...) Little used by automation engineers.

```
! %L0 :   LD          %I1.0
          ANDN        %M12
          OR (        %TM4.Q
          AND         %M17
          )
          AND         %I1.7
          ST          %Q2.5
! %L5 :   LD          %I1.10
          ANDN        %Q2.3
          ANDN        %M27
          IN          %TM0
          LD          %TM0.Q
          AND         %M25
          AND         %MW0:X5
          [ %MW15 :=  %MW18+500]
```

***Figure III.3**:* Literal language

b. ***Graphic languages:***

- **Contact language (LD: Ladder diagram) :** A graphical language designed for electricians. It utilizes elements such as contacts, relays, and function blocks and is structured in networks (also called labels). It is the most popular.

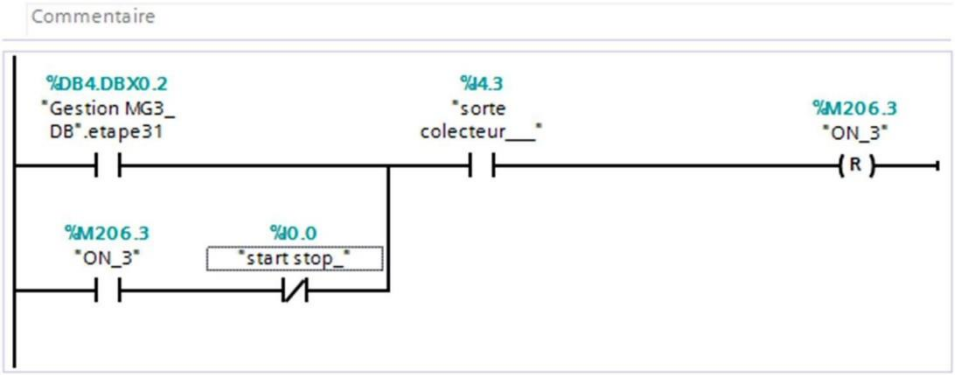


***Figure.III.4* : Ladder language**

- **Blocs Fonctionnels (FBD: Function Block Diagram):**

A graphical language in which functions are shown as rectangles with their inputs on the left and outputs on the right. The blocks are preprogrammed (from a library) or programmable .Used by Automation engineers.

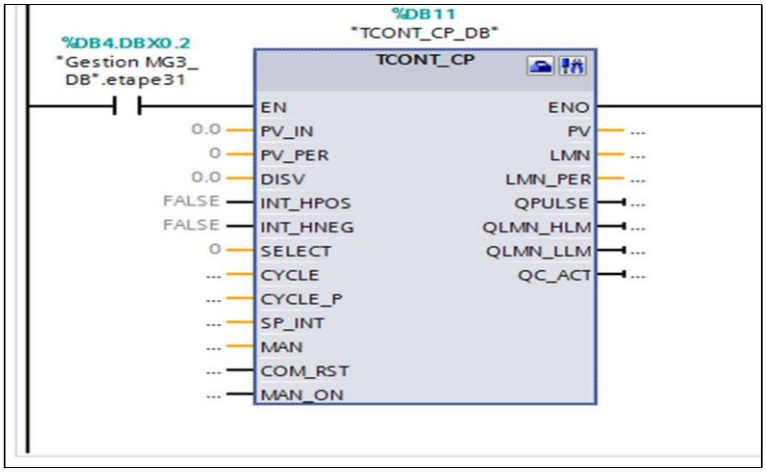


Figure III.5: Function block language

- **Programming using GRAFCET (SFC : Sequential Function Chart) :**

GRAFCET, a specification language, is employed by certain PLC vendors (Schneider, Siemens) for programming. Sometimes used with a programming language,
enables you to program sequential systems with ease and offers you the possibility to develop the program and troubleshoot the system. A GRAFCET chart can be converted to a ladder logic language and be run on any type of PLC.

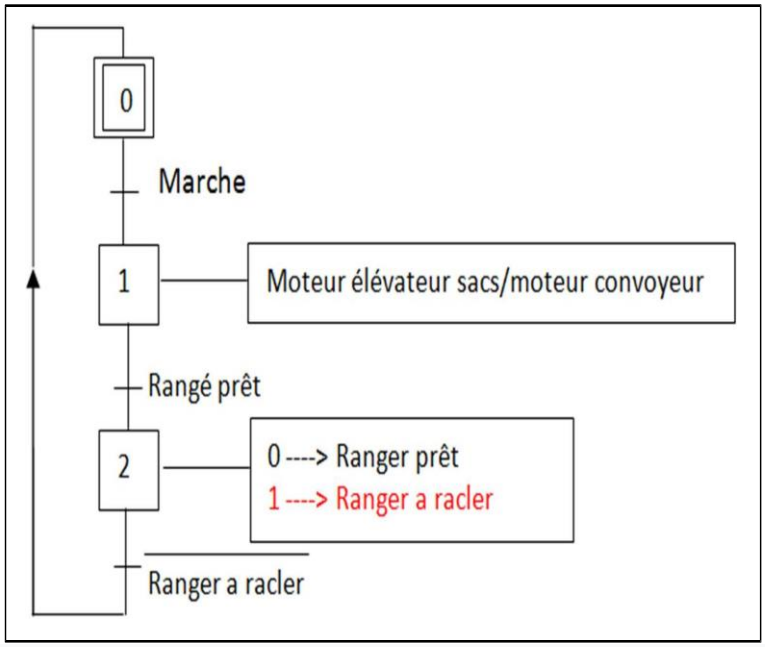


Figure III.6 : GRAFCET Programming

III.3. Human-machine interface (HMI):

Modern automation principles are placing process visualization under constantly increasing pressure. In particular, it is necessary that process control at the machine level is able to adequately meet the requirements of simplicity and performance. We want to transmit the process data rapidly and reliably in its information contents immediate way easily and readily comprehensible for the operator, for example in form of a graph. For this purpose it is most essential to record process data at the machine level, thus the requirement for human-machine interfaces (HMIs).

A human-machine interface (HMI) enables interaction between a person and a device.

Two things are required in a human-machine interface. The First is the Input: the human user must have some means to issue commands to the machine or otherwise manipulate it. Examples of input devices are keyboards, keys, switches, touchscreens, and mice. You can use any of these devices to communicate with a system, or even a suite of systems that rely on each other.

Output is also required from the interface, through which the machine may inform the human user of the status of previously sent commands, and/or perform actions in the physical world. For example, the users have a screen to show the information. Outputs can also be things as simple as status lights to tell people.

Siemens SIMATIC Panels – proven for years through countless applications over many industries! They not only have a revolutionary design but also high performance with amazing engineering efficiency.

SIMATIC panels are clearly structured:

- SIMATIC HMI Basic Panels offer basic functions for simple HMI applications.
- SIMATIC HMI Comfort Panels are suitable for demanding applications.

III.4. Programming software « TIA Portal V16 » :

III.4.1. Software Overview :

The TIA (Totally Integrated Automation) Portal platform is the latest generation of Siemens engineering software. It enables the implementation of automation solutions through an integrated engineering system. Within a single software environment, this platform brings together the programming and configuration of the various devices used in an industrial

installation. In addition to PLC programming, it allows the configuration of HMI devices, drives, and other automation components.

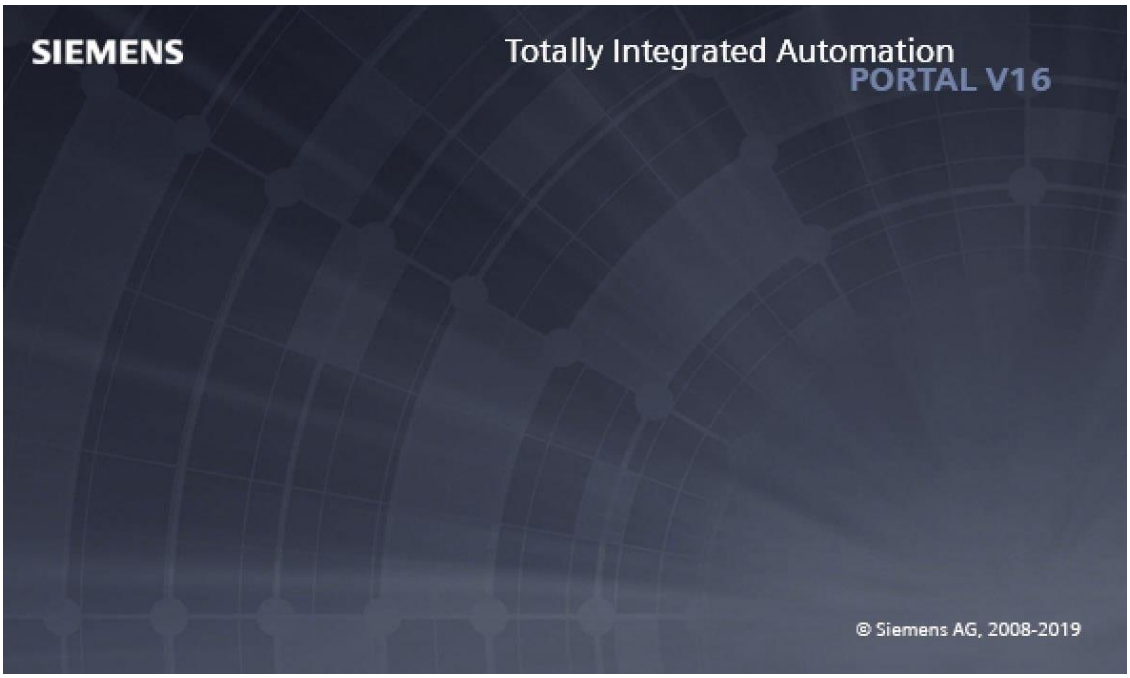


***Figure III.7** : TIA PORTAL logo*

TIA Portal is a single automation tool that enables even complex configuration of production processes on the basis of one computer screen.

This allows for the best possible performance of the planning and manufacturing processes. Because of the clear structure and simple menu navigation, the recognition when learning the programming functions is very high. Divided into a « portal view » which visually guides the user through the different stages of engineering, and a « project view » which offers fast access to the best tools for each engineering stage, TIA Portal maximizes the productivity of both new and experienced users. The development of the TIA Portal software editors is oriented in a consistent user interface and navigation concept. Whether working with hardware configuration, producing logic, configuring a drive or creating an HMI screen, the interface stays consistent across the different environments. The functions, features and the libraries load automatically with the most intuitive view in context of what the user wants to do - valid also for all safety products. The setup of all the hardware and all of its networking is achieved through a single graphical representation of the devices and the network. In fact, networking the controller, HMIs, PC, and drives is as easy as configuring the connections graphically.[5]

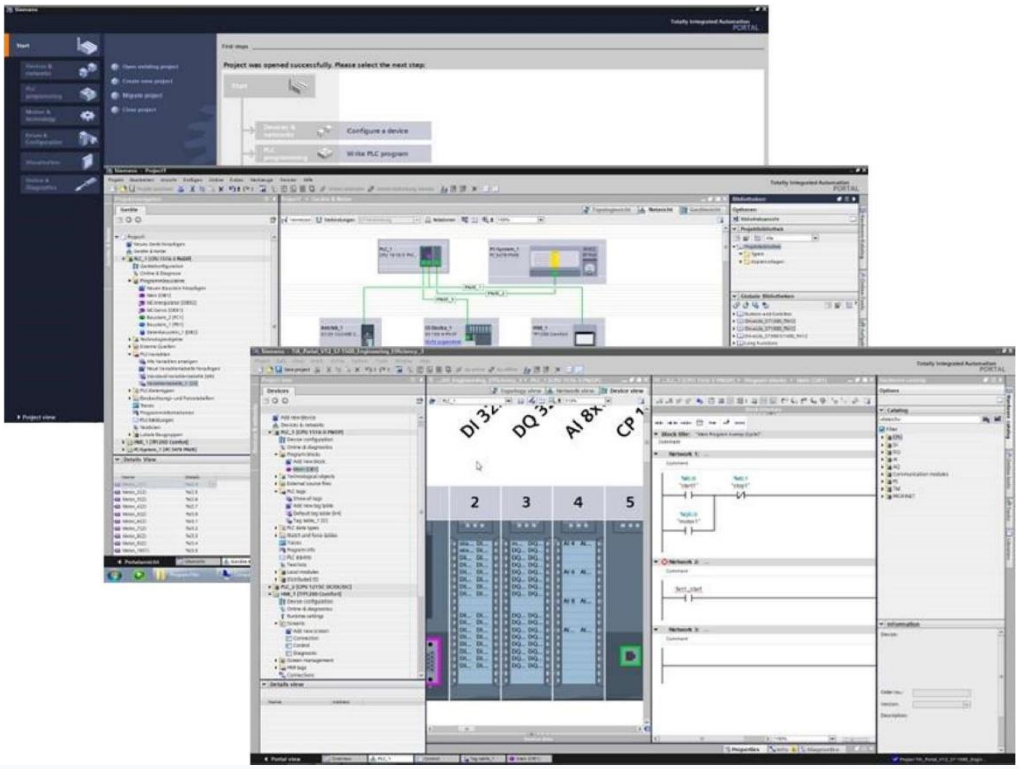


Figure III.8 : Different views of TIA PORTAL

Engineering work in automation systems can be as straightforward as complex. Efficient algorithm design can be time-consuming and the algorithm should be easy to use and to reuse. Interoperability is a must in the ideal engineering software.

The results should be re-usable, so you can save time and also guarantee maximum quality of your projects. For this purpose, the TIA Portal software integrates a number of features that facilitate the work of the engineer, saving time and increasing productivity.These features include:

- PLCs, HMIs, drives and safety integrated in one automation environment
- Libraries for reusing project components
- Integrated system diagnostics
- Trace functions
- Integration of Motion functionalities
- Integrated PID Controller
- Cross-references in the entire project

- Full simulation for PLCs and HMIs

III.4.2.Designing a program with TIA PORTAL V16:

The approach for developing the program with the TIA PORTAL V13 platform as: New project First of all, now consider you start with a new project, you enter the project name and the project path location.

➢**Hardware configuration**

➢**Compiling and downloading the configuration**

➢ **To make mnemonic table**

➢ **program Development**

➢ **Simulating with software**

➢ **Visualising program status(testing)**

When it comes to you design an automation solution, you have two choices, either designing from programming or designing from hardware configuration. In our case, we started with the configuration.

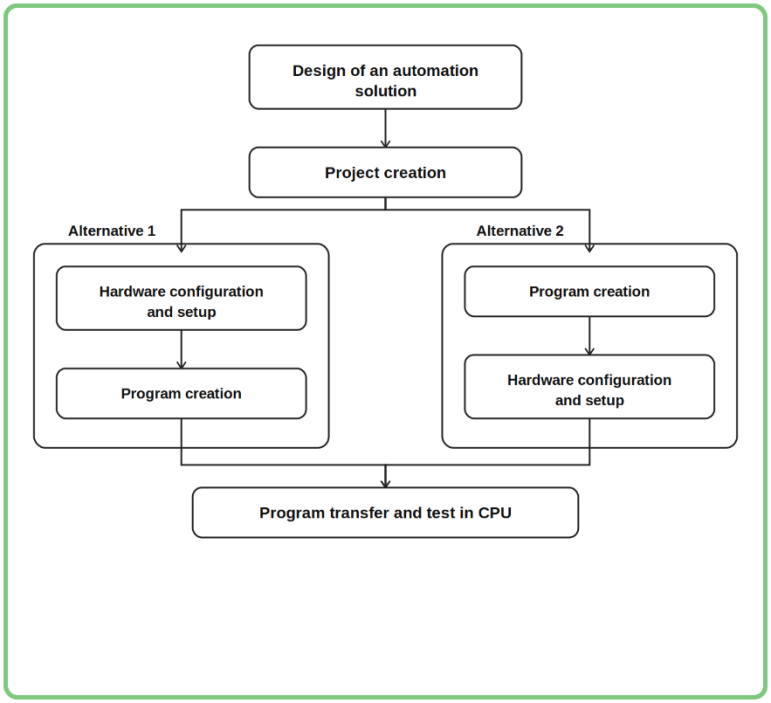


Figure III.9 : Organization for the creation of a project under TIA PORTAL

III.4.3. Portal view:

Each gate enables you to handle a type of operation (actions). The window shows the list of actions available for the task at hand.

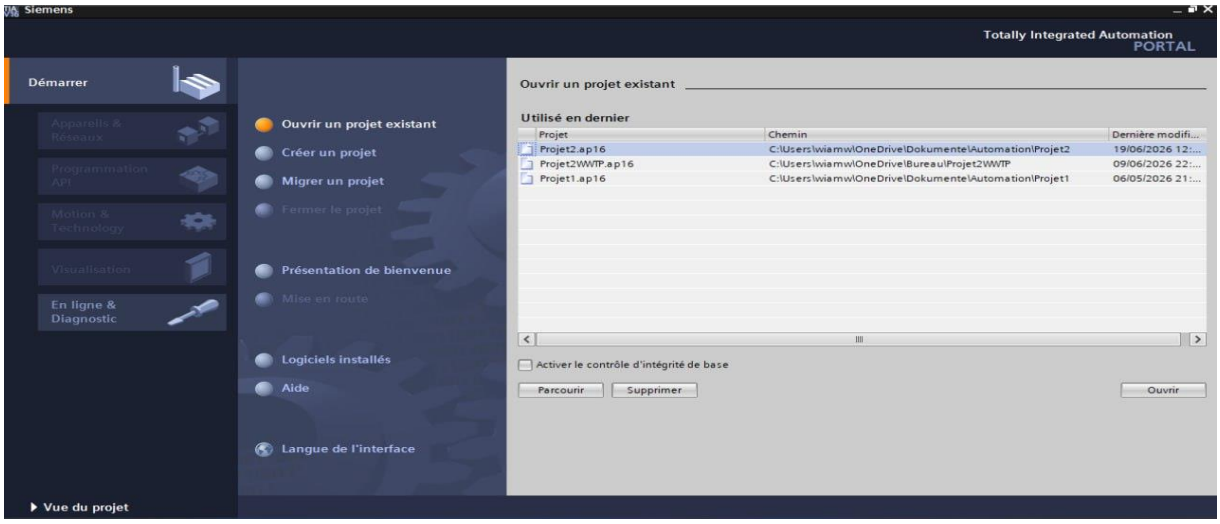


Figure III.10 : Detailed view of the portal

III.4.4. Project overview:

The « Project » element contains all the elements and data necessary to implement the desired automation solution.

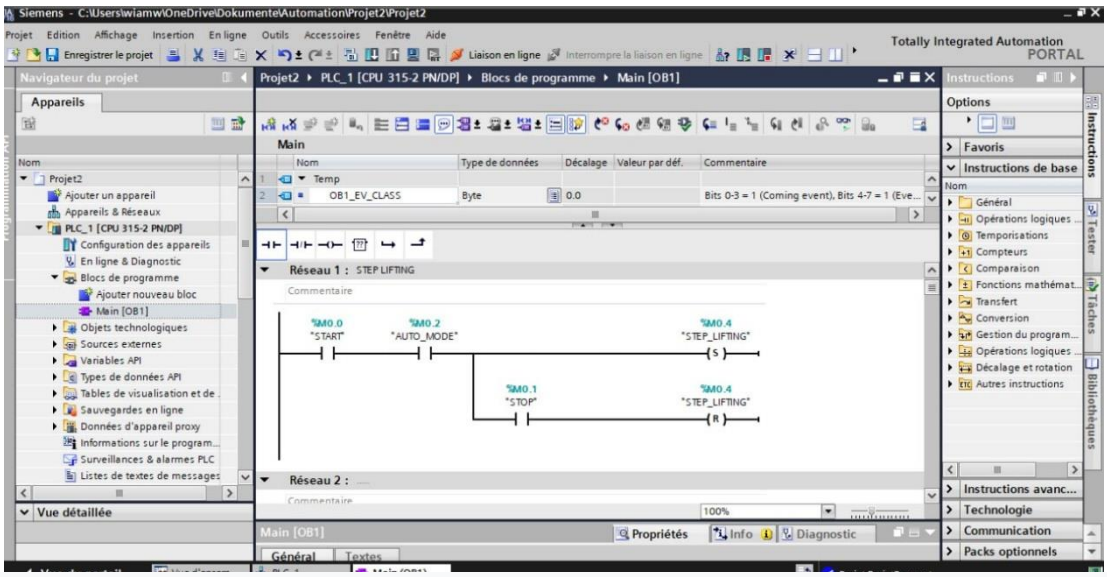


Figure III.11 : Detailed view of the project.

The workspace window shows the objects that are selected in the project for processing. This can be hardware, a program block, a variable table, an HMI, etc.

Additional information about the selected object or the actions being executed is displayed in **the inspection window** (e.g. properties of the selected hardware, error messages when compiling a program block and more).

Bind to which tab to display content from when task is selected This content panel varies depending on the selected item (hardware configuration, component libraries, program block, programming instructions).

This workspace has a lot of information. You can hide or minimize some of these windows when you don't need them. Windows can also be resized, moved, and undocked, allowing for further customization to the user's preferences.

III.4.5. Creating the project in TIA PORTAL V16:

We create a new TIA PORTAL V16 project with the project creation wizard « l'assistant de création de projet» Now we can start the configuration by clicking on create a project « Créer un projet » This way we can handle all our project easily.

The main window appears when we click on the create a project « créer un projet », icon. We complete the blank fields in our window and hit the create « créer » button. The project start is as follows:

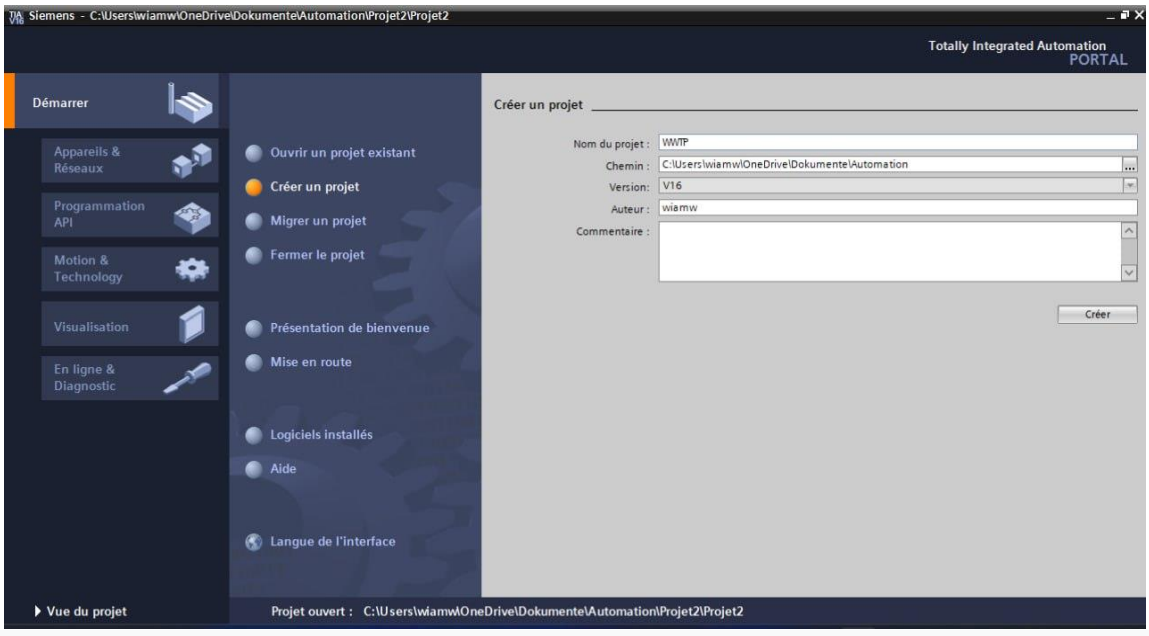


Figure III.12 : Project creation phase.

Step two of our setup is now to tap the Devices and Networks button « appareils et réseaux » , and from there, select the devices that will comprise our system.

We're going to need to select a type of PLC (Programmable Logic Controller) and a HMI (human machine interface).

III.4.6. Hardware configuration and setup:

When creating the project, the workstation can be set up. The hardware is now to be defined. In the project view, select a device and click on add a device « ajouter un appareil » in the project browser.

The list of components which can be added shows (PLC, HMI, PC system). Let's start by choosing our CPU and then add the additional modules (power supply, digital or analog I/O, AS-i communication module, etc.).

Modules for PLC extensions can be purchased from the catalog. If you want to add a monitor or a different PLC, you have to select the add a device « ajouter un appareil » option from the project browser.

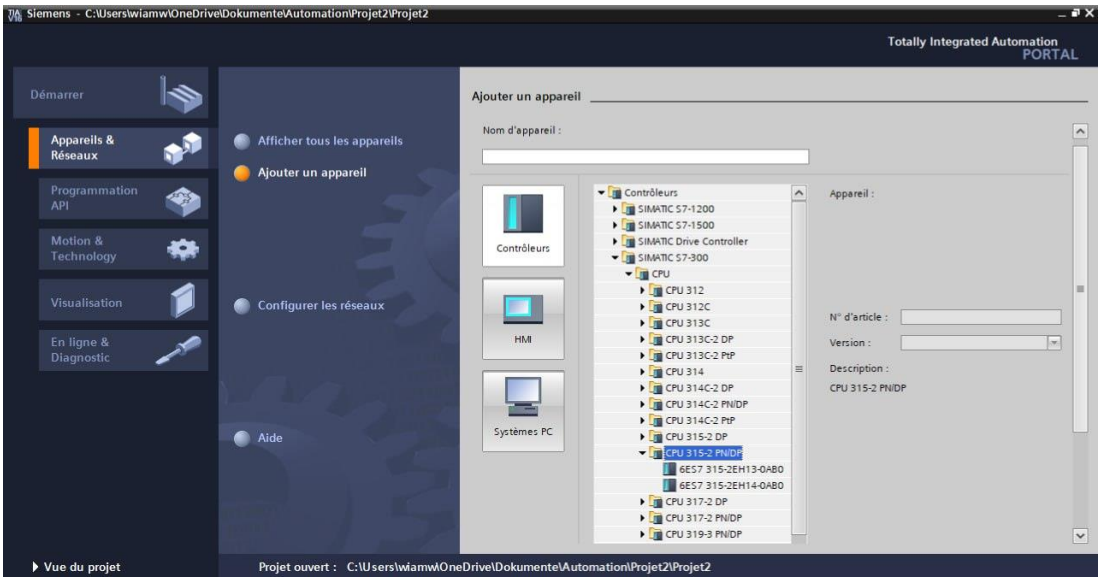


Figure III.13 : PLC Configuration.

III.5. PLC Variables :

III.5.1. Symbolic and Absolute Addressing:

In TIA Portal, all global variables (inputs, outputs, memory bits, etc.) have a symbolic as well as an absolute address.

- **The absolute address** consists of the operand identifier (I, Q, M, etc.) and its address including the bit number.
- **The symbolic address** is the name of the variable that you define (e.g. Start_Button).

The PLC tag table holds the mapping of symbolic to absolute addresses. You can view absolute addresses, symbolic addresses, or both while programming.

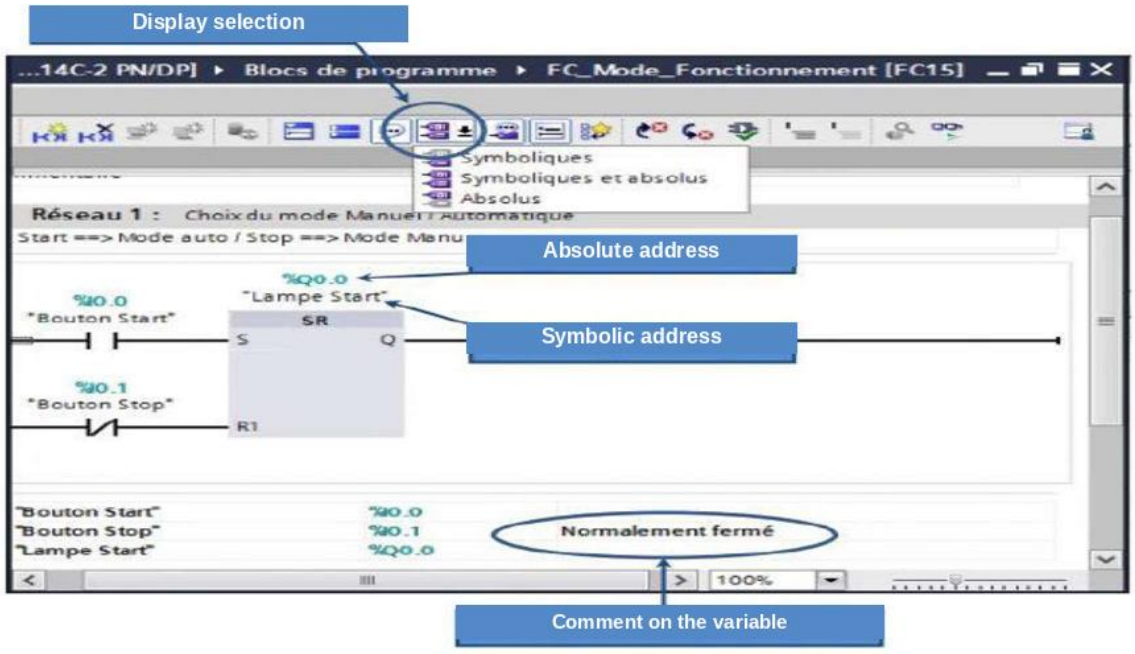


Figure III.14 : Address and comment.

III.5.2. PLC Tag Table :

The PLC Tag Table is where all the variables and constants used within the program are declared.

When declaring a PLC variable, the following information needs to be provided:

A name: It is symbolic address of the variable.

- The data type: e.g. BOOL, INT,...
- The absolute address: e.g. Q1.5.

You can also add a comment with information about the variable. This remark can be shown in each network in which the variable is used.

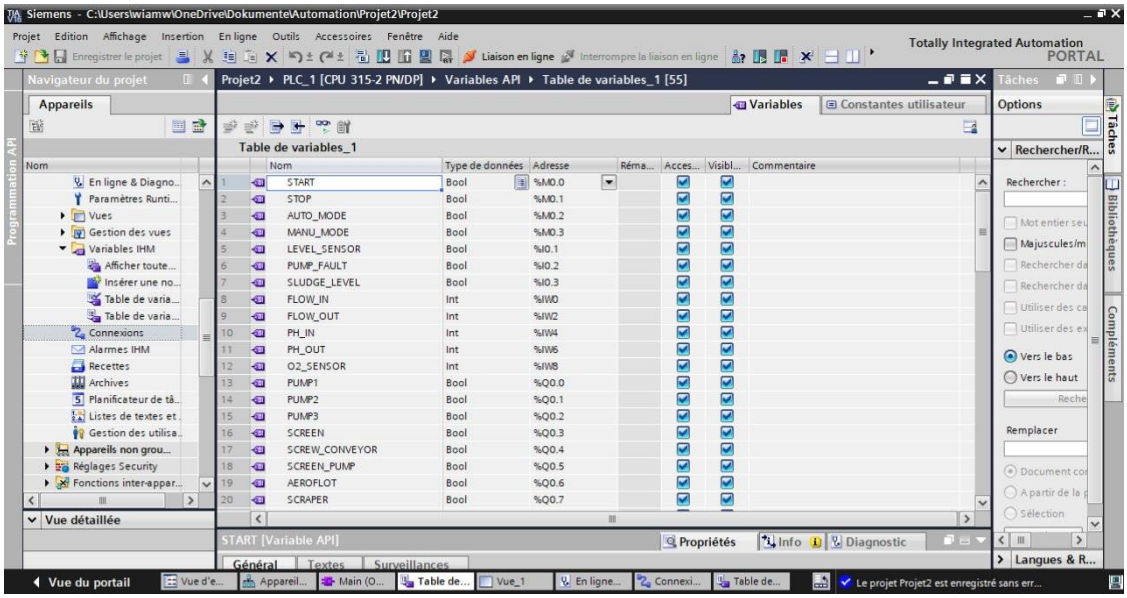


Figure III.15 : PLC Tag Table

III.6. PLC Programming Languages in TIA Portal :

With TIA PORTAL powerful programming editors are available for programming SIMATIC S7 PLCs. Structured text (SCL), instruction list (LIST), ladder diagram (CONT), and logic diagram (LOG) can be used with all PLCs, they provide the user with very intuitive tools to complete all their work.

III.6.1. CONT and LOG – Graphical Programming Languages :

III.6.1.a. LOG :

Logic diagrams (LOG) are a type of graphical programming language which represents logical operations as the application of Boolean algebra through boxes. More complicated functions such as mathematical functions can also be directly represented using these logical boxes.

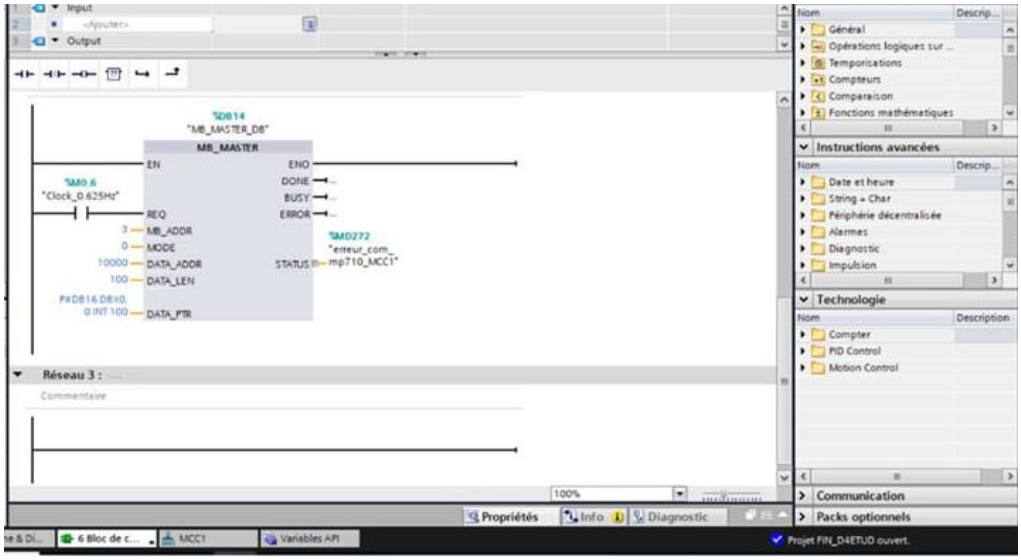


Figure III.16 : Presentation of a logic diagram (LOG).

III.6.1.b. CONT (Ladder Diagram):

Ladder logic is a graphical programming language and is widely used among automation engineers. It looks a bit like electrical schematics and can be interpreted by anyone with common sense in electrical. There are three kinds of language elements:

Inputs (or contacts), which let you read the value of a Boolean variable. Outputs (or coils) that allow you to write the value of a Boolean variable. Function blocks, where you can build complex functions.

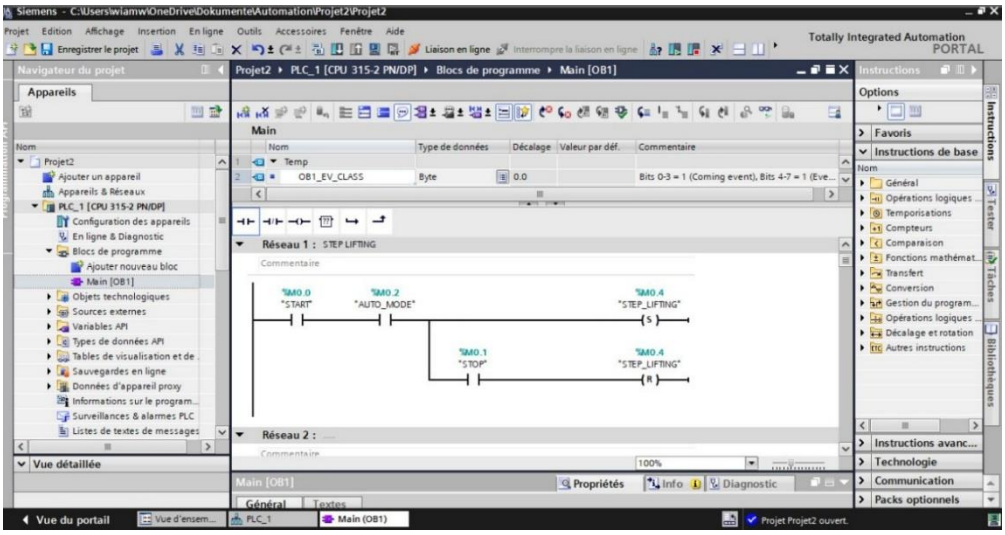


Figure III.17 : Presentation of a Ladder Diagram (CONT).

III.6.2. Program Blocks:

The PLC has classes of blocks, which include the program blocks and the data blocks. Based on the process needs and complexity regress the program at the levels of OB, FB and FC blocks.



Figure III.18 **: The different blocks**

Organizational blocks (OB) are being invoked by the operating system for the following reasons:

Behaviour at Startup. Program execution in cycles.

Program execution caused by alarms (cyclic, process, diagnostic etc.).

Error handling.

In the project a minimum of one cyclic OB (for e.g. OB 1) must exist for the program execution

to get started.

- The functions (FCs) are stateless code entities.

The value stored in temporary variables is lost after the function is executed. Global operands need to be used to store such data. They serve for programming functions that are used more than once, so programming is simplified.

- Functional Blocks (FBs) are code blocks with persistent storage of their input, output, and input/output parameters within instance DBs, and the parameter values can be retained even post block execution.
- Data blocks (DBs) are user program data areas which include the user data._

III.6.3. Memory Bits (Flags) :

Memory bits (mementos) are employed in the internal workings of the PLC without the need for signal output. Mementos are bistable electronic elements that can store the logical states “0” and “1”. Every programmable logic controller (PLC) is equipped with a large number of mementos. They are programmed as outputs.

III.6.4. Mnemonics :

Mnemonics are the names given to PLCs variables. Using mnemonics makes it easier to read and understand a program and can aid in isolating potential faults.

III.7. Configuration of the Visualization Interface (HMI Interface) :

An HMI system is the human interface to the process. The process execution is primarily managed by the PLC, but the user can follow the evolving process on the operator panel, or has a chance to interrupt it.

III.7.1. SIMATIC WinCC:

WinCC, embedded in TIA Portal, is the HMI software for all screens – from Basic Panels for simple control applications up to multi-station PC-based systems for process visualization. (Control and visualization) SIMATIC WinCC in TIA Portal forms part of a new integrated engineering solution, the Common Engineering, which allows for a consistent engineering approach when programming and configuring control, visualization and drive solutions.[4]

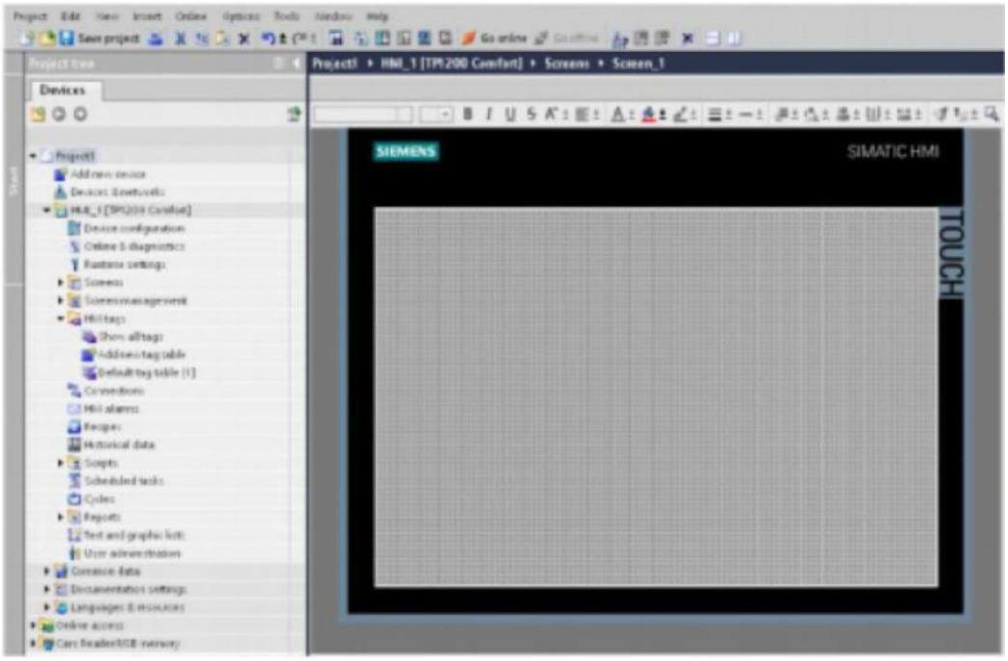


Figure III.19 : WinCC View

III.7.2. Graphical Programming :

Create operating and monitoring screens for machines and plants via the TIA portal. Predefined objects can be used to build such screens. With these elements, you simulate your machine to demonstrate processes and teach process values. The operator panel functions define the visualization of the project on the operator panel (HMI) and the degree of functionality of the graphic objects. These objects constitute all the elements that are used to visualize the project on the HMI. These include, for example, text, buttons, diagrams, and graphs.

III.7.2.a. Graphical Objects :

Objects are visual components that build the project screens. The toolbox window varies with each opened editor and can have several palettes. When "Screens" editor is active the toolbox window has the following palettes:

- **Simple Objects :** Simple objects are lines, circles, text fields and graphic views.
- **Items:** Items are simple control elements like the I/O fields, buttons and gauge instruments.
- **Controls:** Controls have extended functionality. They also enable dynamic representation of process activities, for example trend views and recipe views.
- **Graphics:** Industrial equipment symbols like pumps, agitators, valves and other industrial equipments can be found in this palette.

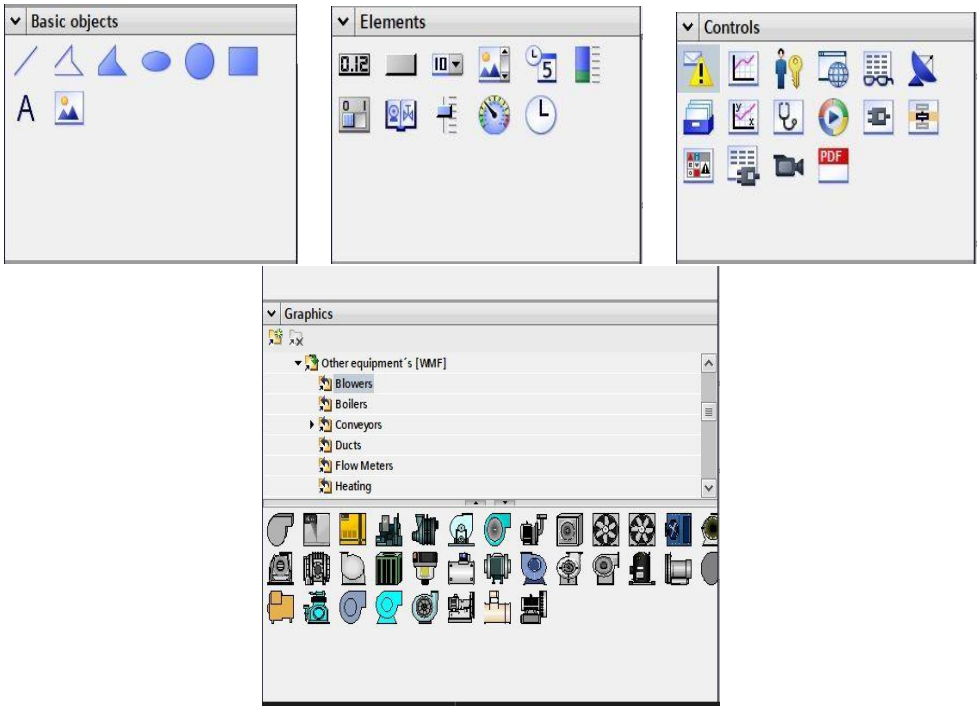


Figure III.20: Graphical Objects

III.8. Creation of the Program for the WWTP Design :

III.8.1. Project Creation:

We started by opening TIA Portal V16 and creating a new project named **WWTP**, dedicated to the wastewater treatment station.

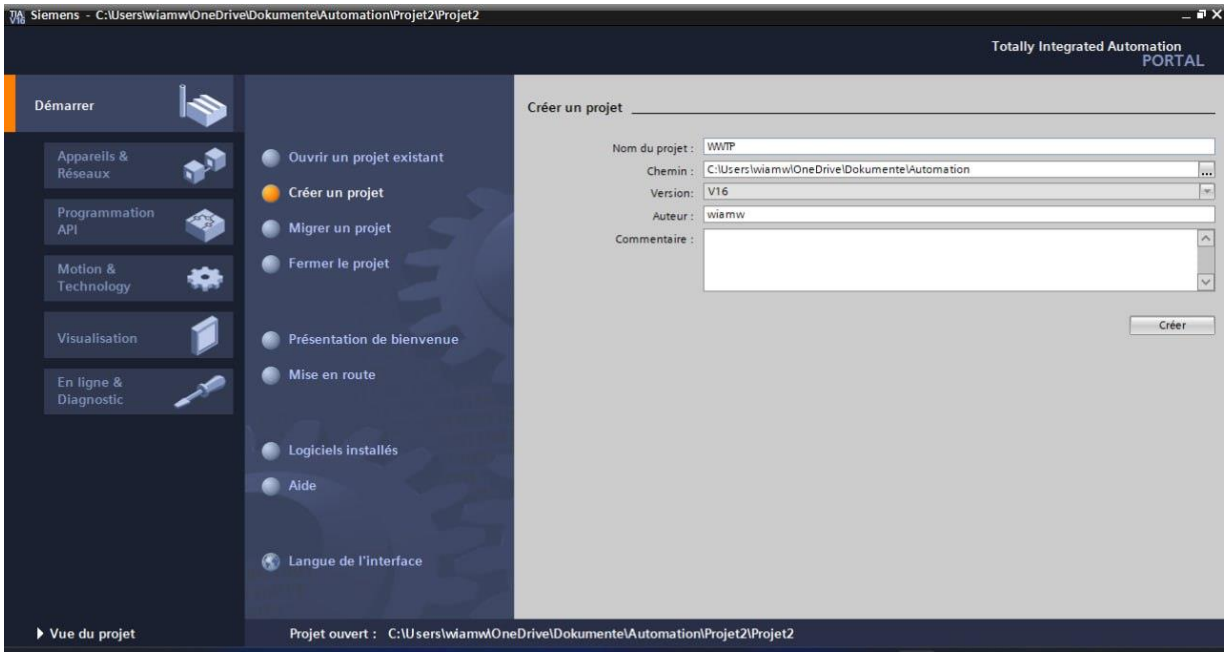


Figure III.21 : Creating the "WWTP" project in TIA Portal V16.

III.8.2. CPU Selection :

We then added a controller and selected the **CPU 315-2 PN/DP** from the SIMATIC S7-300 family.

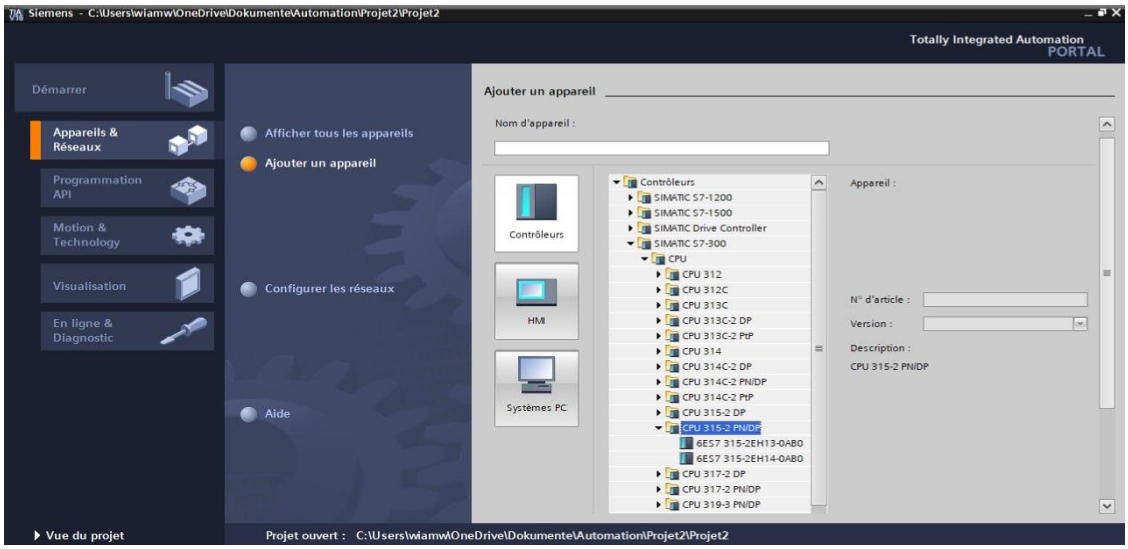


Figure III.22 : Selecting the CPU 315-2 PN/DP from the catalog.

- We chose this CPU because it offers enough memory and processing speed for the station, a native PROFINET (Ethernet) port to communicate with the HMI, and an expandable rack for future modules.

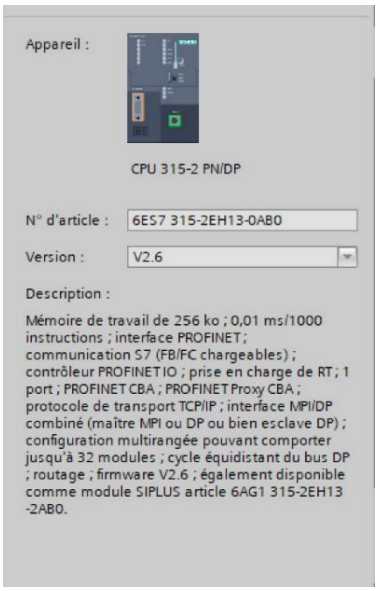


Figure III.23 : Technical description of the CPU 315-2 PN/DP.

III.8. 3. Hardware Configuration :

After placing the CPU in the rack, we added the I/O modules needed to match the station's sensors and actuators.

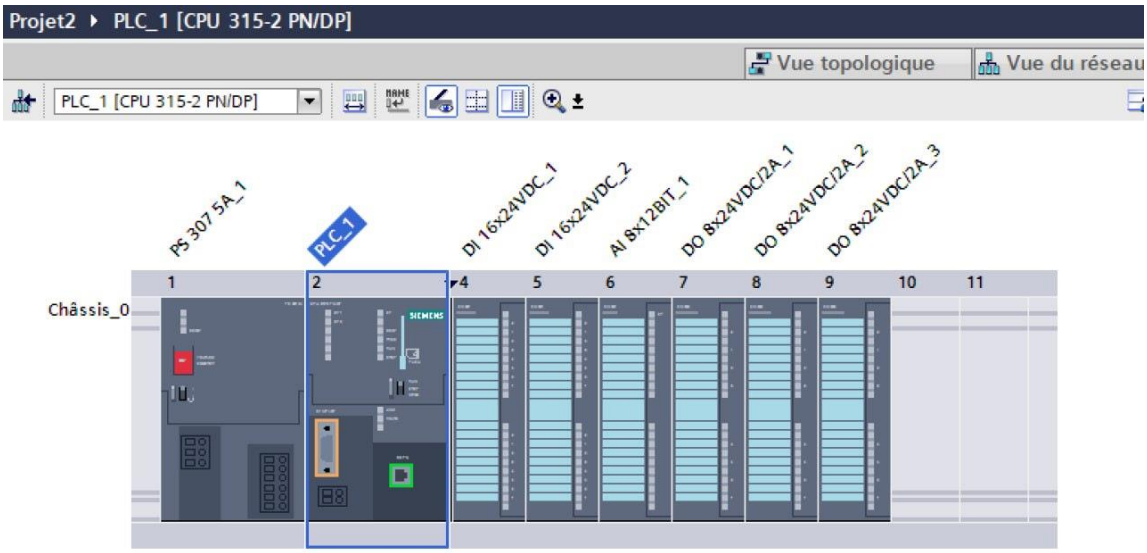


Figure III.24 : Hardware configuration (rack) of PLC_1.

III.8. 4. PLC Variable Table :

Next, we built the PLC variable table, declaring every input, output, and internal bit with a clear name and address.

Table de variables_1

	Nom	Type de données	Adresse	Réma...	Acces...	Visibl...
1	START	Bool	%M0.0		☑	☑
2	STOP	Bool	%M0.1		☑	☑
3	AUTO_MODE	Bool	%M0.2		☑	☑
4	MANU_MODE	Bool	%M0.3		☑	☑
5	LEVEL_SENSOR	Bool	%I0.1		☑	☑
6	PUMP_FAULT	Bool	%I0.2		☑	☑
7	SLUDGE_LEVEL	Bool	%I0.3		☑	☑
8	FLOW_IN	Int	%IW64		☑	☑
9	FLOW_OUT	Int	%IW66		☑	☑
10	PH_IN	Int	%IW68		☑	☑
11	PH_OUT	Int	%IW70		☑	☑
12	O2_SENSOR	Int	%IW72		☑	☑
13	LIFTING_LEVEL_RAW	Int	%IW74		☑	☑
14	FLOW_IN_REAL	Real	%MD30		☑	☑
15	FLOW_OUT_REAL	Real	%MD34		☑	☑
16	PH_IN_REAL	Real	%MD38		☑	☑
17	PH_OUT_REAL	Real	%MD42		☑	☑
18	O2_REAL	Real	%MD46		☑	☑
19	LIFTING_LEVEL_REAL	Real	%MD50		☑	☑
20	RET_FLOW_IN	Word	%MW80		☑	☑
21	RET_FLOW_OUT	Word	%MW82		☑	☑
22	RET_PH_IN	Word	%MW84		☑	☑
23	RET_PH_OUT	Word	%MW86		☑	☑
24	RET_O2	Word	%MW88		☑	☑
25	RET_LEVEL	Word	%MW90		☑	☑

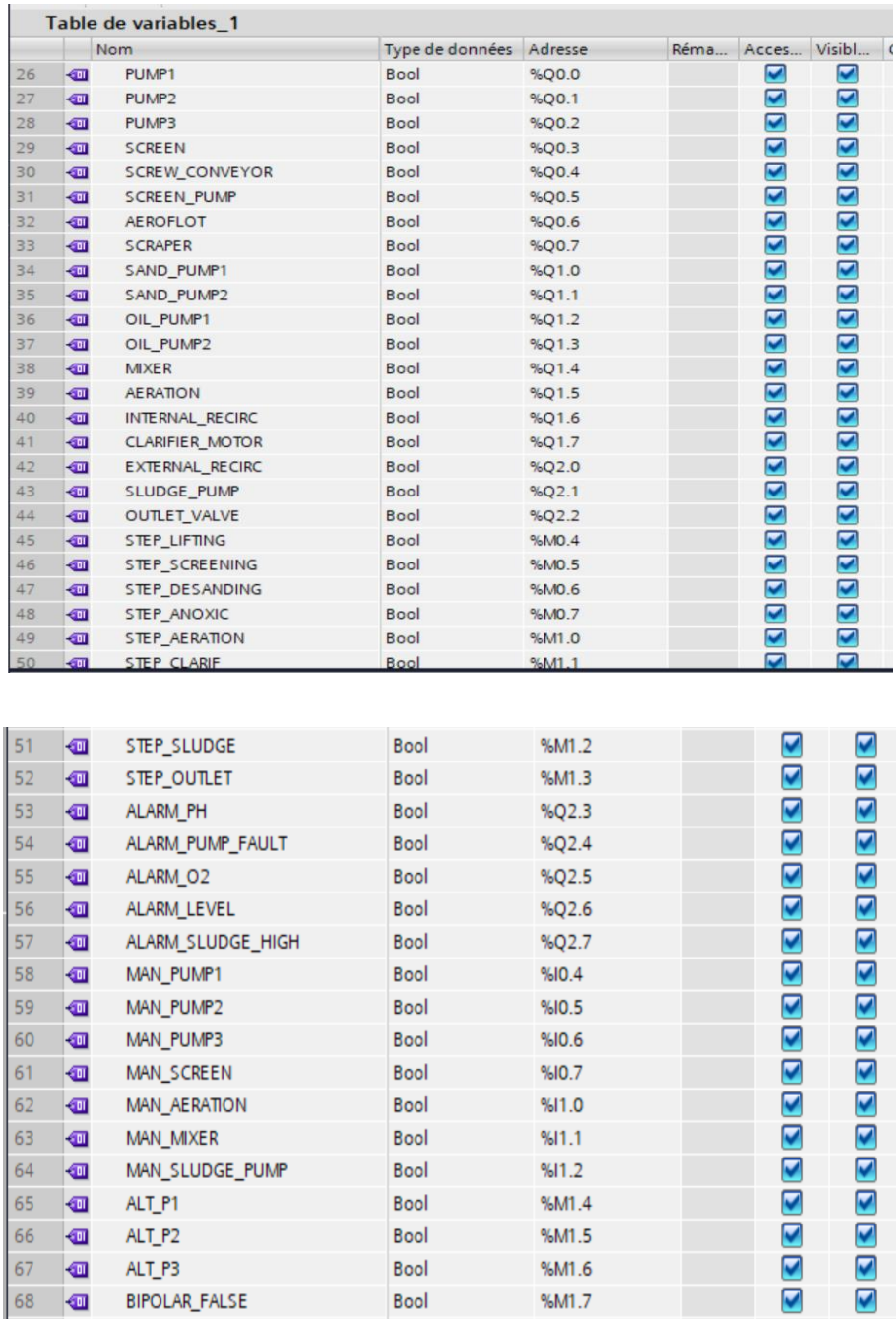


Table de variables_1

	Nom	Type de données	Adresse	Réma...	Acces...	Visibl...
26	PUMP1	Bool	%Q0.0		☑	☑
27	PUMP2	Bool	%Q0.1		☑	☑
28	PUMP3	Bool	%Q0.2		☑	☑
29	SCREEN	Bool	%Q0.3		☑	☑
30	SCREW_CONVEYOR	Bool	%Q0.4		☑	☑
31	SCREEN_PUMP	Bool	%Q0.5		☑	☑
32	AEROFLOT	Bool	%Q0.6		☑	☑
33	SCRAPER	Bool	%Q0.7		☑	☑
34	SAND_PUMP1	Bool	%Q1.0		☑	☑
35	SAND_PUMP2	Bool	%Q1.1		☑	☑
36	OIL_PUMP1	Bool	%Q1.2		☑	☑
37	OIL_PUMP2	Bool	%Q1.3		☑	☑
38	MIXER	Bool	%Q1.4		☑	☑
39	AERATION	Bool	%Q1.5		☑	☑
40	INTERNAL_RECIRC	Bool	%Q1.6		☑	☑
41	CLARIFIER_MOTOR	Bool	%Q1.7		☑	☑
42	EXTERNAL_RECIRC	Bool	%Q2.0		☑	☑
43	SLUDGE_PUMP	Bool	%Q2.1		☑	☑
44	OUTLET_VALVE	Bool	%Q2.2		☑	☑
45	STEP_LIFTING	Bool	%M0.4		☑	☑
46	STEP_SCREENING	Bool	%M0.5		☑	☑
47	STEP_DESANDING	Bool	%M0.6		☑	☑
48	STEP_ANOXIC	Bool	%M0.7		☑	☑
49	STEP_AERATION	Bool	%M1.0		☑	☑
50	STEP_CLARIF	Bool	%M1.1		☑	☑
51	STEP_SLUDGE	Bool	%M1.2		☑	☑
52	STEP_OUTLET	Bool	%M1.3		☑	☑
53	ALARM_PH	Bool	%Q2.3		☑	☑
54	ALARM_PUMP_FAULT	Bool	%Q2.4		☑	☑
55	ALARM_O2	Bool	%Q2.5		☑	☑
56	ALARM_LEVEL	Bool	%Q2.6		☑	☑
57	ALARM_SLUDGE_HIGH	Bool	%Q2.7		☑	☑
58	MAN_PUMP1	Bool	%I0.4		☑	☑
59	MAN_PUMP2	Bool	%I0.5		☑	☑
60	MAN_PUMP3	Bool	%I0.6		☑	☑
61	MAN_SCREEN	Bool	%I0.7		☑	☑
62	MAN_AERATION	Bool	%I1.0		☑	☑
63	MAN_MIXER	Bool	%I1.1		☑	☑
64	MAN_SLUDGE_PUMP	Bool	%I1.2		☑	☑
65	ALT_P1	Bool	%M1.4		☑	☑
66	ALT_P2	Bool	%M1.5		☑	☑
67	ALT_P3	Bool	%M1.6		☑	☑
68	BIPOLAR_FALSE	Bool	%M1.7		☑	☑

Figure III.25 : PLC variable table

III.8. 5. HMI Selection:

We then added an HMI panel and selected the **KTP700 Basic Panel** for its touch display and native PROFINET port.

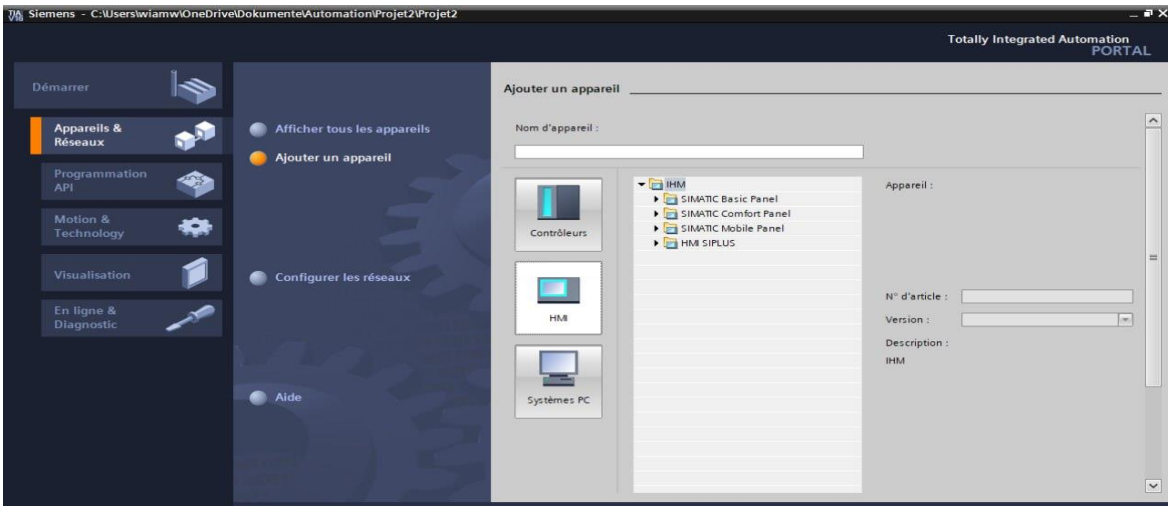


Figure III.26: HMI catalog

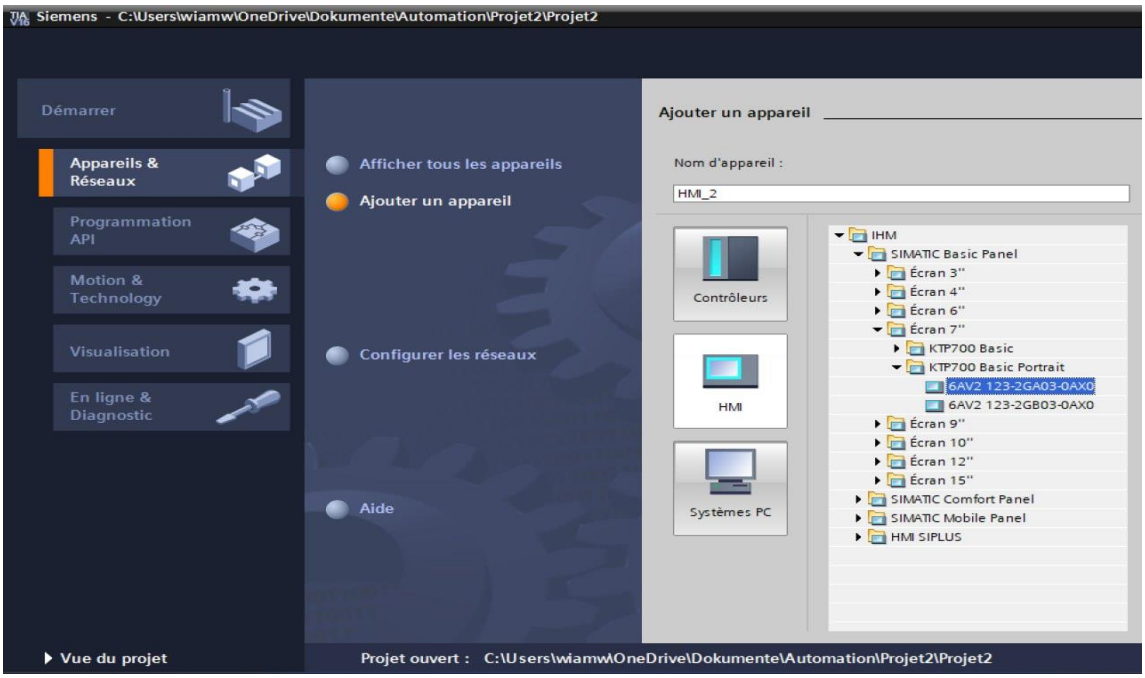


Figure III.27: Selecting the KTP700 Basic Panel



Figure III.28: Technical description of the panel.

III.8. 6. Network Configuration (Ethernet/PROFINET):

We connected the PLC and the HMI through **PROFINET (Industrial Ethernet)**, assigning IP

PLC :192.168.0.1

HMI :192.168.0.2

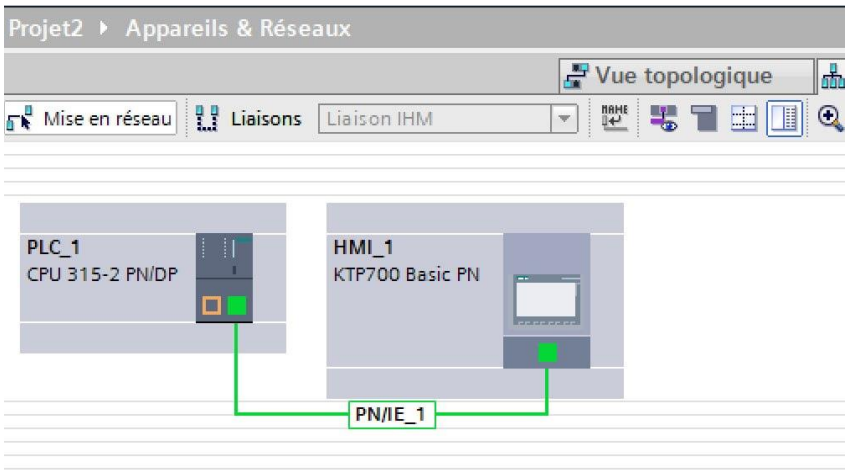


Figure III.29 : PROFINET connection between PLC_1 and HMI_1

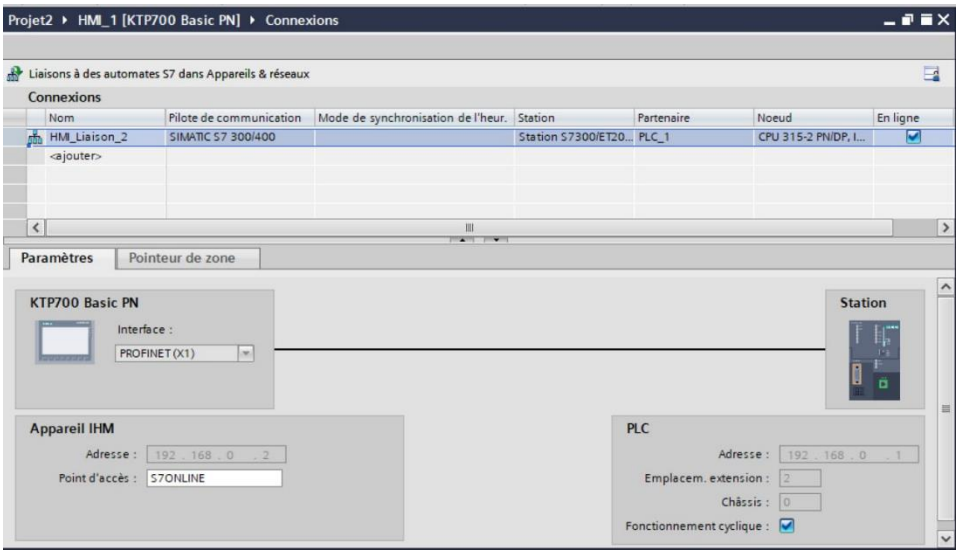
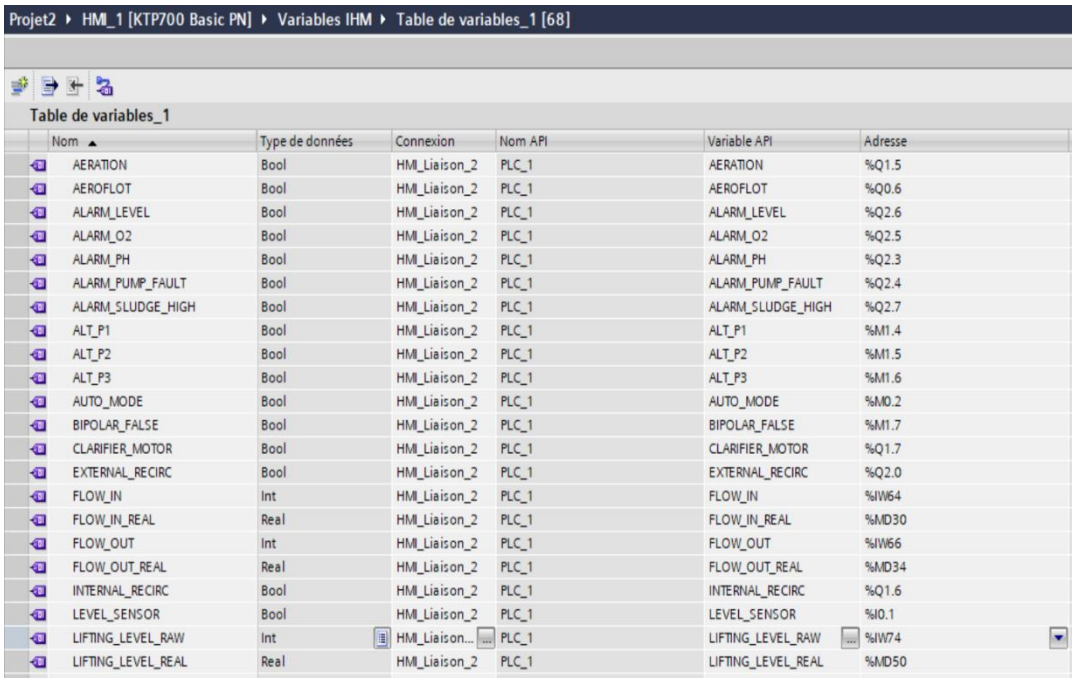


Figure III.30: HMI connection settings

III.8. 7. HMI Variable Table :

we linked the HMI variables to the matching PLC variables, so every value and command shown on the panel corresponds directly to the controller's memory.



Nom	Type de données	Connexion	Nom API	Variable API	Adresse
AERATION	Bool	HMI_Liaison_2	PLC_1	AERATION	%Q1.5
AEROFLOT	Bool	HMI_Liaison_2	PLC_1	AEROFLOT	%Q0.6
ALARM_LEVEL	Bool	HMI_Liaison_2	PLC_1	ALARM_LEVEL	%Q2.6
ALARM_O2	Bool	HMI_Liaison_2	PLC_1	ALARM_O2	%Q2.5
ALARM_PH	Bool	HMI_Liaison_2	PLC_1	ALARM_PH	%Q2.3
ALARM_PUMP_FAULT	Bool	HMI_Liaison_2	PLC_1	ALARM_PUMP_FAULT	%Q2.4
ALARM_SLUDGE_HIGH	Bool	HMI_Liaison_2	PLC_1	ALARM_SLUDGE_HIGH	%Q2.7
ALT_P1	Bool	HMI_Liaison_2	PLC_1	ALT_P1	%M1.4
ALT_P2	Bool	HMI_Liaison_2	PLC_1	ALT_P2	%M1.5
ALT_P3	Bool	HMI_Liaison_2	PLC_1	ALT_P3	%M1.6
AUTO_MODE	Bool	HMI_Liaison_2	PLC_1	AUTO_MODE	%M0.2
BIPOLAR_FALSE	Bool	HMI_Liaison_2	PLC_1	BIPOLAR_FALSE	%M1.7
CLARIFIER_MOTOR	Bool	HMI_Liaison_2	PLC_1	CLARIFIER_MOTOR	%Q1.7
EXTERNAL_RECIRC	Bool	HMI_Liaison_2	PLC_1	EXTERNAL_RECIRC	%Q2.0
FLOW_IN	Int	HMI_Liaison_2	PLC_1	FLOW_IN	%IW64
FLOW_IN_REAL	Real	HMI_Liaison_2	PLC_1	FLOW_IN_REAL	%MD30
FLOW_OUT	Int	HMI_Liaison_2	PLC_1	FLOW_OUT	%IW66
FLOW_OUT_REAL	Real	HMI_Liaison_2	PLC_1	FLOW_OUT_REAL	%MD34
INTERNAL_RECIRC	Bool	HMI_Liaison_2	PLC_1	INTERNAL_RECIRC	%Q1.6
LEVEL_SENSOR	Bool	HMI_Liaison_2	PLC_1	LEVEL_SENSOR	%I0.1
LIFTING_LEVEL_RAW	Int	HMI_Liaison...	PLC_1	LIFTING_LEVEL_RAW	%IW74
LIFTING_LEVEL_REAL	Real	HMI_Liaison_2	PLC_1	LIFTING_LEVEL_REAL	%MD50

Table de variables_1

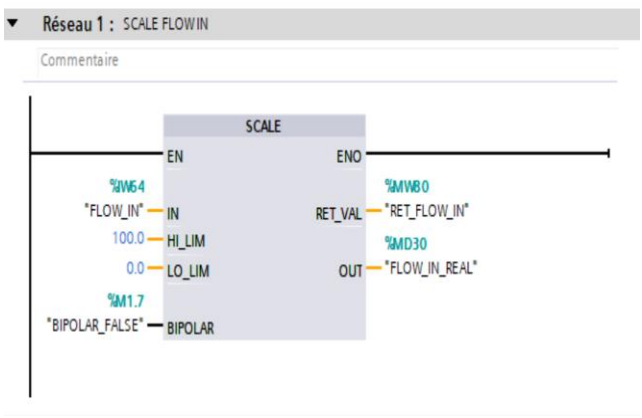
Nom	Type de données	Connexion	Nom API	Variable API	Adresse
MAN_AERATION	Bool	HMI_Liaison_2	PLC_1	MAN_AERATION	%I1.0
MAN_MIXER	Bool	HMI_Liaison_2	PLC_1	MAN_MIXER	%I1.1
MAN_PUMP1	Bool	HMI_Liaison_2	PLC_1	MAN_PUMP1	%I0.4
MAN_PUMP2	Bool	HMI_Liaison_2	PLC_1	MAN_PUMP2	%I0.5
MAN_PUMP3	Bool	HMI_Liaison_2	PLC_1	MAN_PUMP3	%I0.6
MAN_SCREEN	Bool	HMI_Liaison_2	PLC_1	MAN_SCREEN	%I0.7
MAN_SLUDGE_PUMP	Bool	HMI_Liaison_2	PLC_1	MAN_SLUDGE_PUMP	%I1.2
MANU_MODE	Bool	HMI_Liaison_2	PLC_1	MANU_MODE	%M0.3
MIXER	Bool	HMI_Liaison_2	PLC_1	MIXER	%Q1.4
O2_REAL	Real	HMI_Liaison_2	PLC_1	O2_REAL	%MD46
O2_SENSOR	Int	HMI_Liaison_2	PLC_1	O2_SENSOR	%IW72
OIL_PUMP1	Bool	HMI_Liaison_2	PLC_1	OIL_PUMP1	%Q1.2
OIL_PUMP2	Bool	HMI_Liaison_2	PLC_1	OIL_PUMP2	%Q1.3
OUTLET_VALVE	Bool	HMI_Liaison_2	PLC_1	OUTLET_VALVE	%Q2.2
PH_IN	Int	HMI_Liaison_2	PLC_1	PH_IN	%IW68
PH_IN_REAL	Real	HMI_Liaison_2	PLC_1	PH_IN_REAL	%MD38
PH_OUT	Int	HMI_Liaison_2	PLC_1	PH_OUT	%IW70
PH_OUT_REAL	Real	HMI_Liaison_2	PLC_1	PH_OUT_REAL	%MD42
PUMP_FAULT	Bool	HMI_Liaison_2	PLC_1	PUMP_FAULT	%I0.2
PUMP1	Bool	HMI_Liaison_2	PLC_1	PUMP1	%Q0.0
PUMP2	Bool	HMI_Liaison_2	PLC_1	PUMP2	%Q0.1
PUMP3	Bool	HMI_Liaison_2	PLC_1	PUMP3	%Q0.2

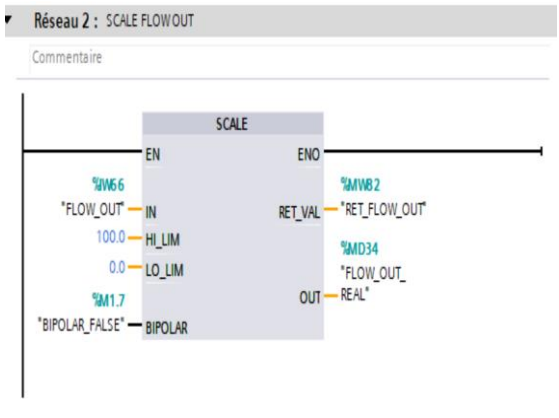
Table de variables_1

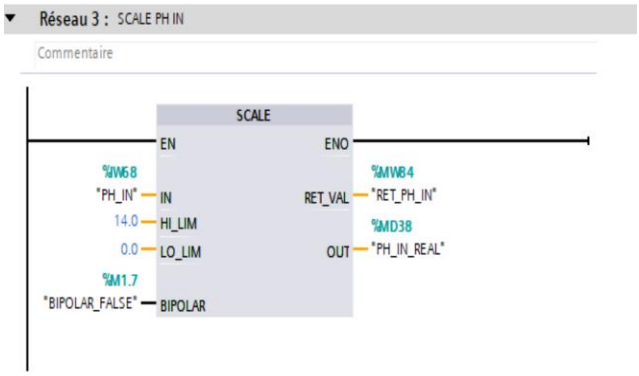
Nom	Type de données	Connexion	Nom API	Variable API	Adresse
RET_FLOW_IN	Word	HMI_Liaison_2	PLC_1	RET_FLOW_IN	%MW80
RET_FLOW_OUT	Word	HMI_Liaison_2	PLC_1	RET_FLOW_OUT	%MW82
RET_LEVEL	Word	HMI_Liaison_2	PLC_1	RET_LEVEL	%MW90
RET_O2	Word	HMI_Liaison_2	PLC_1	RET_O2	%MW88
RET_PH_IN	Word	HMI_Liaison_2	PLC_1	RET_PH_IN	%MW84
RET_PH_OUT	Word	HMI_Liaison_2	PLC_1	RET_PH_OUT	%MW86
SAND_PUMP1	Bool	HMI_Liaison_2	PLC_1	SAND_PUMP1	%Q1.0
SAND_PUMP2	Bool	HMI_Liaison_2	PLC_1	SAND_PUMP2	%Q1.1
SCRAPER	Bool	HMI_Liaison_2	PLC_1	SCRAPER	%Q0.7
SCREEN	Bool	HMI_Liaison_2	PLC_1	SCREEN	%Q0.3
SCREEN_PUMP	Bool	HMI_Liaison_2	PLC_1	SCREEN_PUMP	%Q0.5
SCREW_CONVEYOR	Bool	HMI_Liaison_2	PLC_1	SCREW_CONVEYOR	%Q0.4
SLUDGE_LEVEL	Bool	HMI_Liaison_2	PLC_1	SLUDGE_LEVEL	%I0.3
SLUDGE_PUMP	Bool	HMI_Liaison_2	PLC_1	SLUDGE_PUMP	%Q2.1
START	Bool	HMI_Liaison_2	PLC_1	START	%M0.0
STEP_AERATION	Bool	HMI_Liaison_2	PLC_1	STEP_AERATION	%M1.0
STEP_ANOXIC	Bool	HMI_Liaison_2	PLC_1	STEP_ANOXIC	%M0.7
STEP_CLARIF	Bool	HMI_Liaison_2	PLC_1	STEP_CLARIF	%M1.1
STEP_DESANDING	Bool	HMI_Liaison_2	PLC_1	STEP_DESANDING	%M0.6
STEP_LIFTING	Bool	HMI_Liaison_2	PLC_1	STEP_LIFTING	%M0.4
STEP_OUTLET	Bool	HMI_Liaison_2	PLC_1	STEP_OUTLET	%M1.3
STEP_SCREENING	Bool	HMI_Liaison_2	PLC_1	STEP_SCREENING	%M0.5

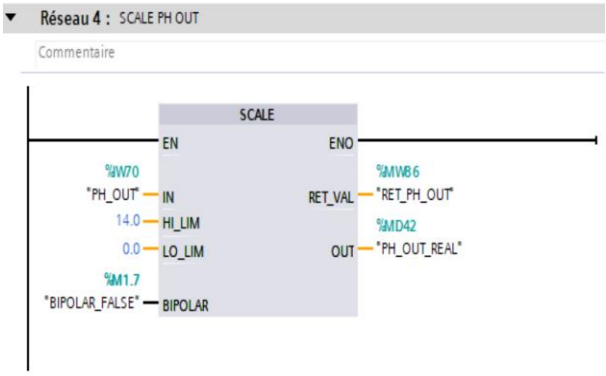
Figure III.31: HMI variable table.

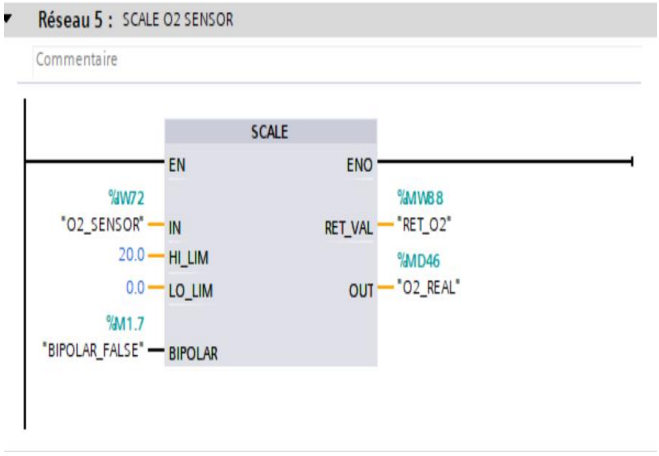
III.9. Supervision Views Architecture(Main OB1) :

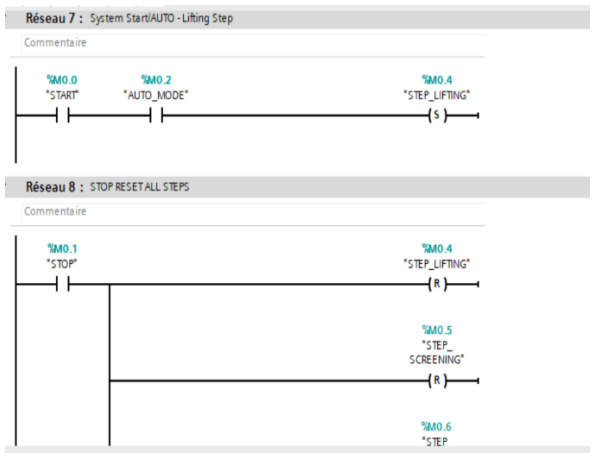


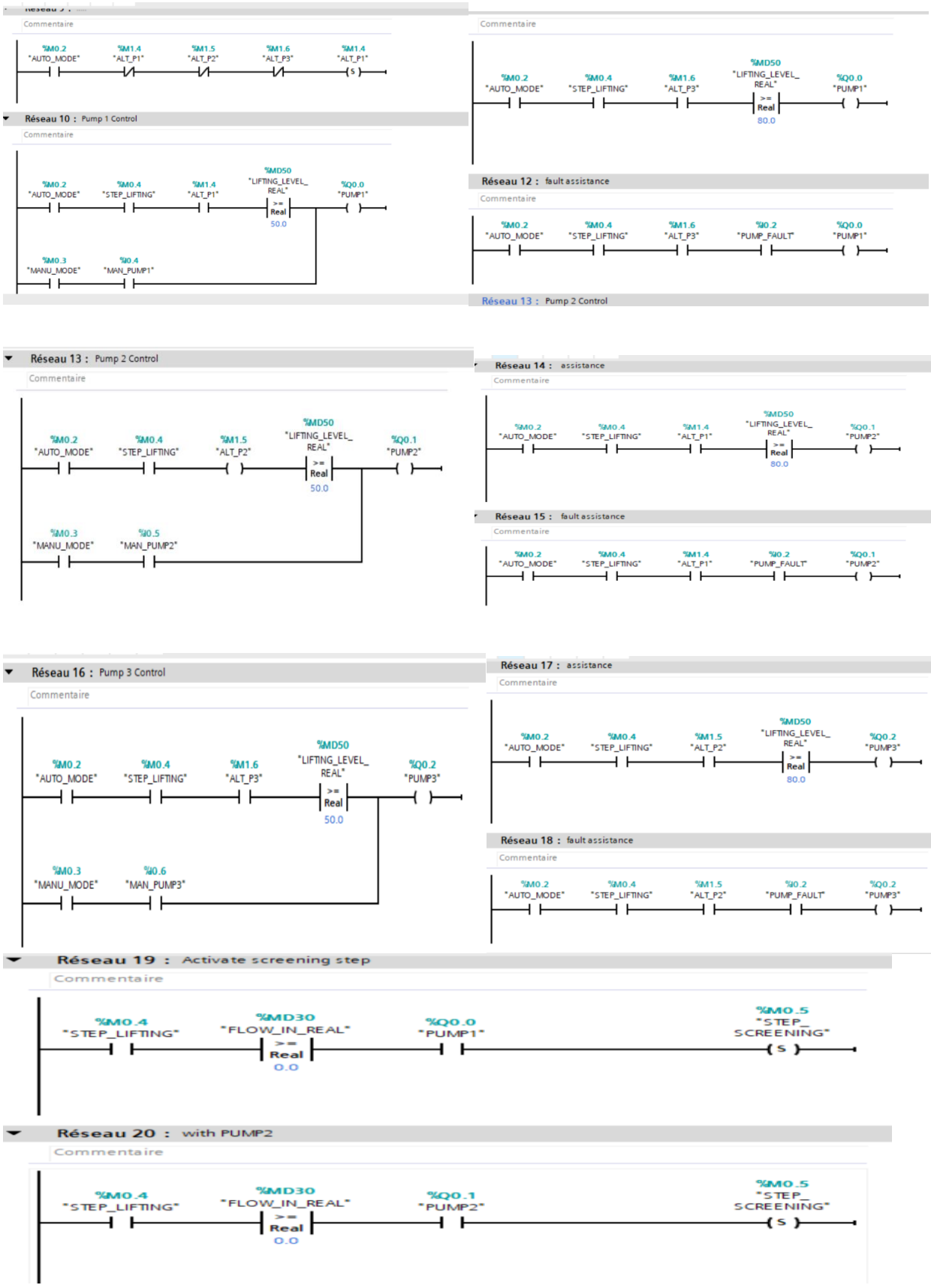











Commentaire
%M0.2 "AUTO_MODE"
%M1.4 "ALT_P1"
%M1.5 "ALT_P2"
%M1.6 "ALT_P3"
%M1.4 "ALT_P1"
S
Réseau 10 : Pump 1 Control
Commentaire
%M0.2 "AUTO_MODE"
%M0.4 "STEP_LIFTING"
%M1.4 "ALT_P1"
%MD50 "LIFTING_LEVEL_ REAL"
>= Real
50.0
%Q0.0 "PUMP1"
%M0.3 "MANU_MODE"
%0.4 "MAN_PUMP1"
%M0.2 "AUTO_MODE"
%M0.4 "STEP_LIFTING"
%M1.6 "ALT_P3"
%MD50 "LIFTING_LEVEL_ REAL"
>= Real
80.0
%Q0.0 "PUMP1"
Réseau 12 : fault assistance
Commentaire
%M0.2 "AUTO_MODE"
%M0.4 "STEP_LIFTING"
%M1.6 "ALT_P3"
%0.2 "PUMP_FAULT"
%Q0.0 "PUMP1"
Réseau 13 : Pump 2 Control
Réseau 13 : Pump 2 Control
Commentaire
%M0.2 "AUTO_MODE"
%M0.4 "STEP_LIFTING"
%M1.5 "ALT_P2"
%MD50 "LIFTING_LEVEL_ REAL"
>= Real
50.0
%Q0.1 "PUMP2"
%M0.3 "MANU_MODE"
%0.5 "MAN_PUMP2"
Réseau 14 : assistance
Commentaire
%M0.2 "AUTO_MODE"
%M0.4 "STEP_LIFTING"
%M1.4 "ALT_P1"
%MD50 "LIFTING_LEVEL_ REAL"
>= Real
80.0
%Q0.1 "PUMP2"
Réseau 15 : fault assistance
Commentaire
%M0.2 "AUTO_MODE"
%M0.4 "STEP_LIFTING"
%M1.4 "ALT_P1"
%0.2 "PUMP_FAULT"
%Q0.1 "PUMP2"
Réseau 16 : Pump 3 Control
Commentaire
%M0.2 "AUTO_MODE"
%M0.4 "STEP_LIFTING"
%M1.6 "ALT_P3"
%MD50 "LIFTING_LEVEL_ REAL"
>= Real
50.0
%Q0.2 "PUMP3"
%M0.3 "MANU_MODE"
%0.6 "MAN_PUMP3"
Réseau 17 : assistance
Commentaire
%M0.2 "AUTO_MODE"
%M0.4 "STEP_LIFTING"
%M1.5 "ALT_P2"
%MD50 "LIFTING_LEVEL_ REAL"
>= Real
80.0
%Q0.2 "PUMP3"
Réseau 18 : fault assistance
Commentaire
%M0.2 "AUTO_MODE"
%M0.4 "STEP_LIFTING"
%M1.5 "ALT_P2"
%0.2 "PUMP_FAULT"
%Q0.2 "PUMP3"
Réseau 19 : Activate screening step
Commentaire
%M0.4 "STEP_LIFTING"
%MD30 "FLOW_IN_REAL"
>= Real
0.0
%Q0.0 "PUMP1"
%M0.5 "STEP_ SCREENING"
S
Réseau 20 : with PUMP2
Commentaire
%M0.4 "STEP_LIFTING"
%MD30 "FLOW_IN_REAL"
>= Real
0.0
%Q0.1 "PUMP2"
%M0.5 "STEP_ SCREENING"
S

III.9.1.HMI of WWTP

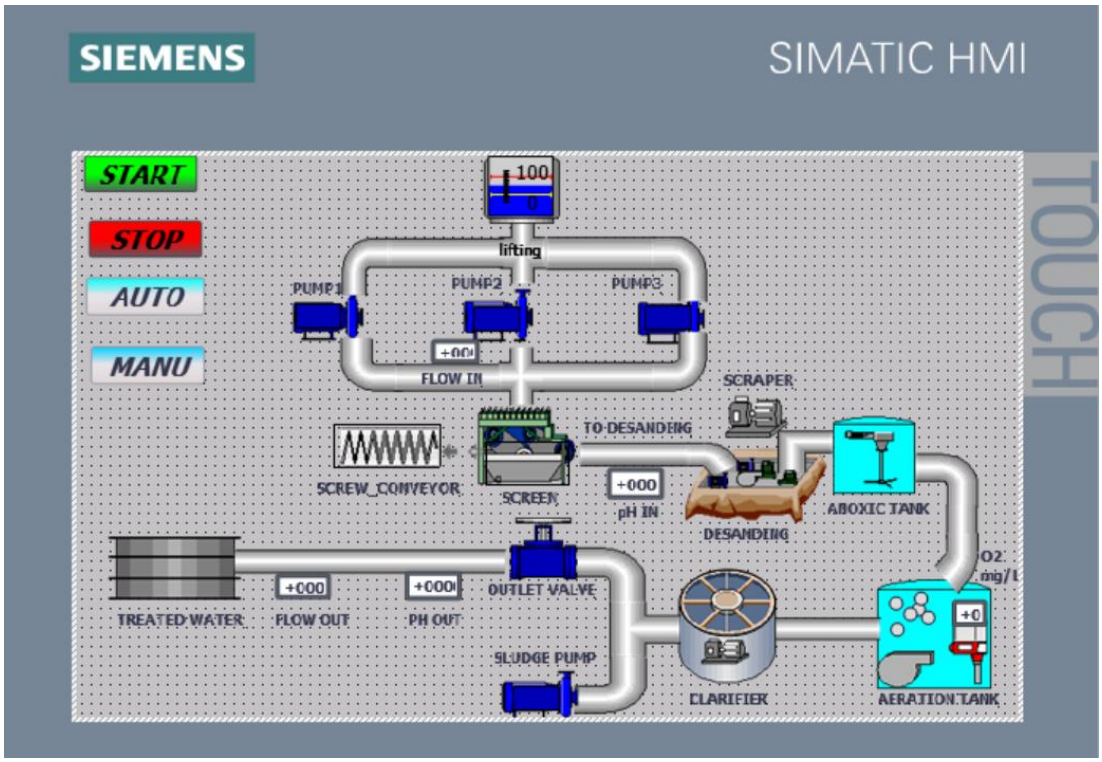


Figure III.32.SIMATIC HMI

III.10. Conclusion :

In this chapter, we presented the TIA Portal software and reviewed the different stages involved in creating a project using TIA Portal V16. We also discussed the programming language used for the Programmable Logic Controller (PLC) to ensure proper communication and correct addressing of variables. Finally, we concluded this work by presenting and designing the pre-treatment control program for the wastewater treatment station of Ain Taghrout

General Conclusion :

The increasing advancement of automation technology has allowed for the substitution of hardwired control systems by automated production systems with better product quality, enhanced safety, and diversified processes. Traditional hardwired systems, however, have become too massive and rigid to meet the increasing complex industrial needs. As a result, industries have turned more and more towards programmable, information-processing technology-based solutions, chiefly Programmable Logic Controllers (PLCs), which are indispensable in the automation of present-day industry.

This work aims to emphasize the significance of and advantages in utilizing the PLCs in industry by showing up the evolution from a hardwired logic to a programmable logic. In addition, this methodology has been used for the management of a wastewater treatment plant.

There we were introduced to the importance and vastness of urban domestic wastewater treatment plant (WWTP) in Ain Taghrout during our internship.

During this internship period, we had the honor and opportunity to:

- Become familiar with and observe equipment that does not exist at the university, as well as various devices and materials within the electrical control cabinet.
- Apply theoretical knowledge in a real working environment.

The aim of this internship was to highlight the value of practical training as a link between theoretical studies and real-world practice

Bibliography

[1] LOUATI Abdelghai and AMAR Fouzi, "Automatisation d'une station d'épuration des eaux usées de HADJOUT," Master's Thesis, Université SAAD DAHLAB de BLIDA, Algeria, 2019/2020.

[2] LOUATI Abdelghai and AMAR Fouzi, "Automatisation d'une station d'épuration des eaux usées de HADJOUT," Master's Thesis, Université SAAD DAHLAB de BLIDA, Algeria, 2019/2020.

[3] LOUATI Abdelghai and AMAR Fouzi, "Automatisation d'une station d'épuration des eaux usées de HADJOUT," Master's Thesis, Université SAAD DAHLAB de BLIDA, Algeria, 2019/2020

[4] Documentation SIEMENS, aide STEP7 CD ROM Siemens. (CD STEP7)

[5] Documentation logiciel TIA Portal.

[6] SIMATIC-HMI-WinCC, 'Gettingstarted', A5E00279568-03, 04/

[7] Ain Taghrout WWPT.

Annexes"A":

Alarm Management in the HMI Supervision System

This annex presents the alarm management used for the supervision of the wastewater treatment plant. The alarms are defined to help the operator detect abnormal operating conditions, protect equipment, and ensure safe operation of the process. The alarm system is connected to the PLC program and displayed on the HMI interface through TIA Portal and WinCC.

The proposed alarms are grouped into digital alarms, analog process alarms, and communication or system alarms. The thresholds presented in this annex can be adjusted according to the real operating limits of the plant.

A.1 Alarm Classification

The alarms are classified according to their importance and their effect on the operation of the plant.

Priority	Meaning	Example	Operator action
Critical	Immediate risk for equipment or process safety.	Emergency stop, very high level, motor overload.	Stop the concerned equipment and intervene immediately.
High	Important fault that can interrupt the treatment process.	Pump fault, blower fault, communication loss.	Check the equipment and restart only after solving the cause.
Medium	Process value outside normal range.	Low oxygen, high pH, low flow.	Adjust the process or verify the sensor value.
Low	Information or warning that does not stop the process immediately.	Maintenance reminder, manual mode active.	Monitor the system and plan maintenance if required.

Table A.1: Alarm priority classification

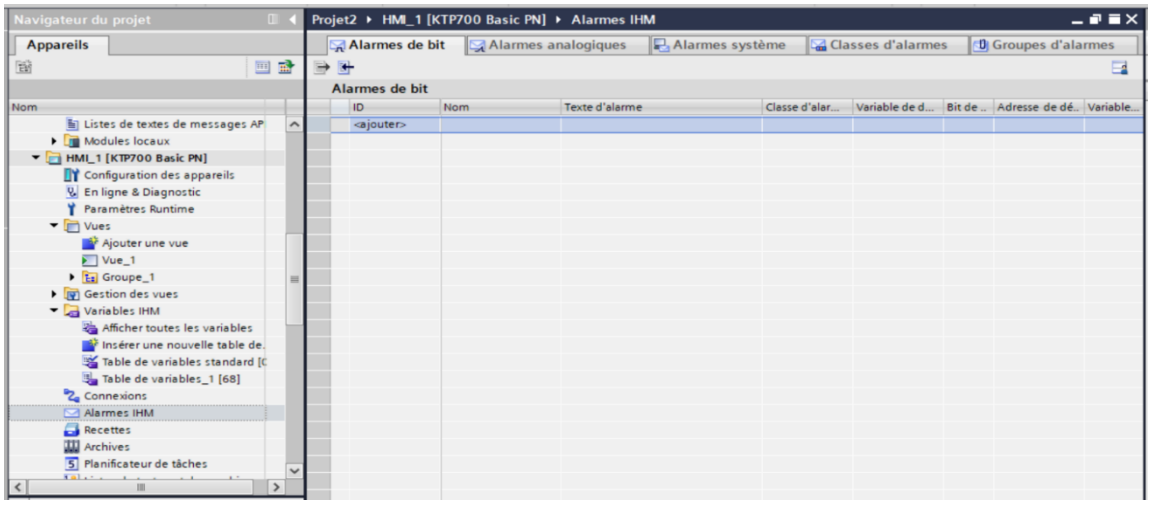


Figure.A.1: view alarme in tia portal