PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA
KASDI MERBAH UNIVERSITY - OUARGLA
FACULTY OF NEW INFORMATION TECHNOLOGIES AND COMMUNICATION
DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATIONS

End of studies dissertation
With a view to obtaining the Professional Master's Diploma

Domain: Science and Technology
Sector: Electronics
Specialty: Instrumentations and systems

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THEME

Automation, Supervision and Simulation of an industrial Process using Tia Portal and Factory I/O

In front of the jury composed of:

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Academic year: 2023/2024

Thanks

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

We would like to thank in the first place and very warmly our supervisor:Mr. **ACHBI Mohammed Said** for agreeing to lead our work, for his valuable advice,For his spirit and for his Availability.

Our thanks also go to the **jury** members who do us the honor of judging our work.

Finaly, wethank Pr. **SEGNI**, Mr. **TEDJANI Zakaria**, and our colleague **Hussein *Al*-Hussein**, **Zatout Ahmed Aymane** Those who gave us their intellectual and moral supportthroughout our approach.

Dedications

To the best of fathers

To our dearest mom

To our friends

ABSTRACT:

After visiting Professor Signi's laboratory and observing the oil extraction process, we decided to adopt this process and conducted a general study of it. Then, it was converted into an automated process divided into three stations: (the main process – steam distillation, the production line, and storage). To control these stations in real time, we used the S7-1200 controller, including ladder programming and an HMI (Human-Machine Interface) to supervise the main process and the production line. As for the storage process, it was supervised using Factory I/O for 3D designs.

Keywords: Factory I/O, PLC, essential oil extraction, production line, storage, Siemens, SCADA, HMI.

ملخص:

بعد زيارة مخبر الأستاذ سيقني ومشاهدة عملية استخلاص الزيوت، قررنا تبني هذه العملية وقمنا بدراسة عامة لها. ثم تم تحويلها إلى عملية أوتوماتيكية مقسمة إلى ثلاث محطات: (العملية الرئيسية – التقطير بالبخار، خط الإنتاج، التخزين). للتحكم في هذه المحطات في الوقت الفعلي، استخدمنا وحدة التحكم S7-1200 متضمنة برنامج ladder وواجهة الإنسان والآلة HMI للإشراف على العمليتين (الرئيسية وخط الإنتاج). أما عملية التخزين، فقد تم الإشراف عليها ببرنامج Factory I/O للتصاميم ثلاثية الأبعاد.

الكلمات المفتاحية: Factory I/O، PLC استخلاص الزيوت العطرية، خط الإنتاج، التخزين، Siemens، SCADA، HMI.

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Symbols and shortcuts

EOs: essential oils**.**

PLC: Programmable Logic Controller.

HMI: Human Machine Interface**.**

CPU: Central processing unit**.**

RAM: Random access memory.

ROM: Read Only Memory**.**

DI: digital input module.

DO: digital output module.

AO: analog output module.

AI:analog input module**.**

TIA Portal: Totally Integrated Automation Portal.

LD:ladder.

FBD: Function Block Diagram.

IL: Instruction List.

ST: Structured Text.

OB: Organization block.

FBs: Function Blocks.

SFBs: System Function Blocks**.**

FB: Functional blocks.

DB:data block**.**

GUIs: Graphical User Interface.

SCADA: Supervisory Control and Data Acquisition system.

OT: OperationalTechnology **.**

MTU: Master Station Computer Systems.

RTUs: Remote Terminal Units.

SQL: Structured Query Language**.**

RTD: Resistance Temperature Detector.

Pt: platinum.

AIT: Analyzer, Indicator, Transmitter**.**

P&ID: Piping and Instrumentation Diagram.

General Introduction

General Introduction

The history of essential oils extends back thousands of years, as they were used in various cultures and civilizations for multiple purposes, including medical treatment, religious and cosmetic uses. It was used in ancient times in Egypt, India, and China for the purposes of healing, purification, and getting rid of diseases, and it continued to the Greek and Roman civilizations, where it was used in perfumes, therapeutic oils, and even in mineral baths. Now the aromatic oil industry has witnessed a great development in technology and science, which led to the expansion of... Its uses are increasing in diversity, and it has become an integral part of multiple industries, including perfumery, cosmetics, body care, alternative medical treatment, food and beverage, and many other industries.

Although handcrafting essential oils may have some positive aspects, it may also face some negatives, including limited productivity in handcrafting, as production is limited due to constraints imposed by available resources, such as raw materials, available techniques, and time. This can make it difficult to meet growing demand and expand the business.

Also, the quality and uniformity of hand-made essential oil products may not be as guaranteed as in machine-made ones. The chemical composition and smell vary between different batches, which may affect customer confidence. Also increasing labor costs and safety risks, as due to the lack of safety systems, this makes labor exposed to greater risk and thus increases its costs.

The proposal proposes a solution to the negatives of manual industry by converting all manual tasks to automation, implementing safety systems for potential dangers., use Monitoring systems remotely monitor data changes within a process. and Remote-control systems to minimize human intervention in the operation of devices.

Chapter I

Introduction to Essential Oil Extraction

I. Introduction to Essential Oil Extraction

I.1. Introduction

Essential oils are the aromatic, volatile compounds derived from plants, capturing the essence and beneficial properties of their source. These oils have been cherished for centuries, utilized in everything from ancient medicinal practices to modern-day aromatherapy and cosmetics. The process of extracting essential oils is both an art and a science, requiring precise methods to preserve the delicate compounds that give each oil its unique character and therapeutic potential.

In this chapter, we will explore the interesting world of essential oil extraction. Understanding the various extraction methods is crucial for anyone interested in the production, quality, and application of essential oils. Each technique has its own advantages and challenges, and the choice of method can significantly impact the purity, potency, and aroma of the final product. We will delve into the most commonly used extraction methods.

I.2. Background and Context of Essential Oils and Their Significance

Essential oils are natural aromatic compounds extracted from plants through various methods such as distillation, expression, or solvent extraction. They have been used for centuries in traditional medicine, perfumery, aromatherapy, and culinary practices due to their therapeutic, aromatic, and flavoring properties.

Historically, essential oils have played a vital role in cultural rituals, religious ceremonies, and holistic healing practices across different civilizations worldwide. Ancient civilizations like Egypt, Greece, China, and India utilized essential oils for medicinal purposes, perfumes, cosmetics, and spiritual rituals.

In modern times, the significance of essential oils has expanded beyond traditional uses. They are widely incorporated into various industries including pharmaceuticals, cosmetics, food and beverage, household products, and alternative medicine.

Essential oils are valued for their diverse range of properties such as antimicrobial, anti-inflammatory, analgesic, and antioxidant effects. The growing interest in natural and holistic approaches to health and wellness has led to an increased demand for high-quality essential oils. However, the traditional methods of essential oil extraction, while effective, can be labor-intensive, time-consuming, and may result in variable product quality.

This context underscores the importance of developing efficient and reliable extraction methods to meet the rising demand for essential oils while ensuring consistent quality and sustainability. Automation presents a promising solution to address these challenges by streamlining the extraction process, optimizing parameters, and enhancing productivity, thereby making essential oils more accessible and economically viable for various applications.

- **Problem Statement: Limitations of Traditional Extraction Methods and Need for Automation and Monitoring**

Traditional methods of essential oil extraction, including distillation, expression, and solvent extraction, have been the cornerstone of production for centuries. However, these methods present several inherent limitations that hinder efficiency, consistency, and sustainability in essential oil production.

1. **Labor Intensity:** Traditional extraction methods often require significant manual labor, leading to high operational costs, resource inefficiency, and potential inconsistencies in product quality due to human error.
2. **Variable Yield and Quality:** Variability in raw material quality, extraction parameters, and environmental conditions can result in inconsistent yields and fluctuations in product quality, impacting the reliability and marketability of essential oils.
3. **Environmental Impact:** Certain traditional extraction techniques, such as solvent extraction, may involve the use of chemicals that pose environmental and health risks, necessitating stringent safety measures and regulatory compliance.
4. **Limited Process Monitoring:** Traditional extraction processes often lack real-time monitoring and control capabilities, making it challenging to optimize parameters such as temperature, pressure, and extraction time to maximize yield and quality while minimizing energy consumption and waste.

Addressing these limitations requires a paradigm shift towards automation and monitoring technologies in essential oil extraction. Automated systems equipped with sensors, actuators, and advanced control algorithms offer several advantages:

1. Increased Efficiency: Automation streamlines the extraction process, reducing manual intervention and improving throughput, thereby enhancing productivity and reducing production costs.
2. Consistent Quality: Automated systems enable precise control over extraction parameters, ensuring consistent product quality batch-to-batch and minimizing variations due to human factors or environmental fluctuations.
3. Environmental Sustainability: By optimizing resource utilization and reducing waste, automated extraction systems can mitigate the environmental impact of essential oil production, aligning with sustainability goals and regulatory requirements.
4. Real-time Monitoring and Control: Integration of sensors and monitoring devices allows for real-time data collection and analysis, enabling proactive adjustments to extraction parameters and ensuring optimal performance and product quality.

In light of these challenges and opportunities, there is a clear imperative to develop and implement automated extraction systems with robust monitoring capabilities to address the limitations of traditional methods and meet the evolving needs of the essential oil industry.

I.3. Overview of Essential Oil Extraction Plants

I.3.1. Definition of essential oils

Essential oils are concentrated compounds extracted from various plant parts, containing the plant's natural essence, providing unique aromas, flavors, and healing properties through processes like distillation, cold pressing, solvent extraction, or CO_2 extraction. Essential oils are unique blends of aromatic compounds, including phenols, alcohols, esters, and other volatile organic compounds, characterized by their distinct chemical composition and sensory properties [1].

I.3.2. Types of essential oil extraction methods

Essential oil extraction involves separating aromatic compounds from plant materials using various manual methods, each suited to specific types of plants and desired oil qualities. Some common extraction processes include [2]:

I.3.2.1. Essential Oil Extraction by Distillation:

- **Steam Distillation**: This is one of the most common methods for extracting essential oils. In steam distillation, plant material is placed in a still and steam is passed through it.
- **Water distillation:** This method of extracting essential oils from plant material uses water rather than steam. This technique is frequently applied to plants that are heat-sensitive.

I.3.2.2. Essential Oil Extraction by Expression:

- **Cold Press Extraction**: Citrus fruits are the main product of this process. The essential oil is extracted from the fruit by mechanically pressing its skin.

I.3.2.3. Essential Oil Extraction by Hydrolytic Maceration Distillation:

Certain plant materials require maceration in warm water before they release their essential oils, as their volatile components are glycosidically bound.

- **Solvent Extraction:** With this technique, essential oils are extracted from plant material using a solvent (such as ethanol or hexane). The aromatic compounds are dissolved by the solvent, and the plant material is then removed from the solvent-oil combination. After that, the solvent evaporates, revealing the essential oil.

It's important to note that while manual extraction methods can yield high-quality essential oils, they are often labor-intensive and may not be suitable for large-scale production. Additionally, some methods (such as solvent extraction) may require special safety precautions due to the use of flammable or toxic solvents.

I.3.3. Explanation of essential oil manual extraction process

I.3.3.1. Steam distillation:

This method is usually used to extract light oils such as rose, mint, and rosemary...etc. These are the steps of this process:

a) **Preparing the plant material:** The plant material, such as flowers, leaves, or seeds, is prepared first by washing it well from dust and placing it in a distillation flask.
b) **Place the solvent (water) in the distillation flask.**
c) **Heating:** The distillation flask is heated, causing the water to boil and produce steam. As the steam passes through the plant material, it causes the essential oil glands within the plant cells to burst, releasing their aromatic contents. The steam helps to volatilize these aromatic compounds.
d) **Steam and Essential Oil Mixture:** The steam, along with the essential oil vapors, rises through the still and enters the condenser.

e) **Condensation:** In the condenser, the steam is cooled down, causing it to condense back into liquid form. The essential oils, which are insoluble in water, also condense and form a mixture with the condensed steam.

f) **Separation:** The condensed mixture of water and essential oil is collected in a receiver. Since essential oils are lighter than water, they float on top of the collected liquid and can be separated easily.

g) **Collection of Essential Oil:** The essential oil is then separated from the water. This can be done by decantation, where the oil is skimmed off the top of the water, or by using a separating funnel.

h) **Storage:** The collected essential oil is usually stored in dark, airtight containers to protect it from degradation due to light and oxygen.

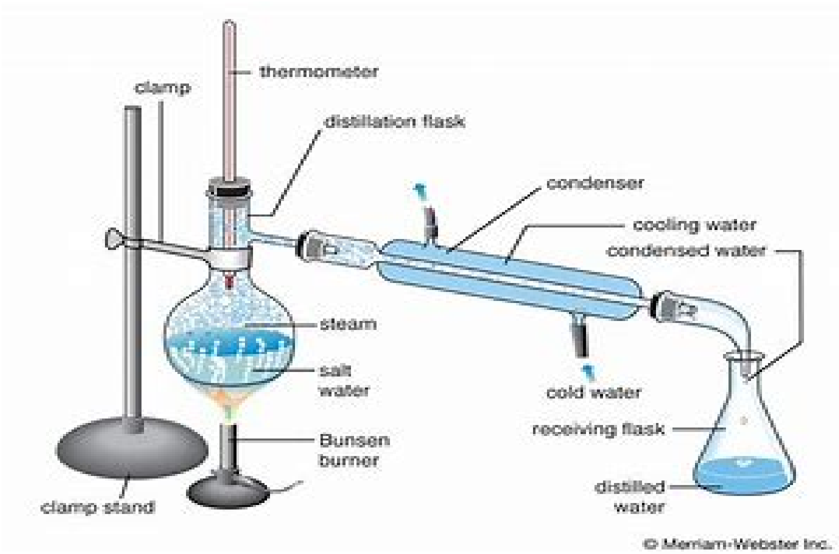


Figure I.1 :Illustration of the steam distillation process.

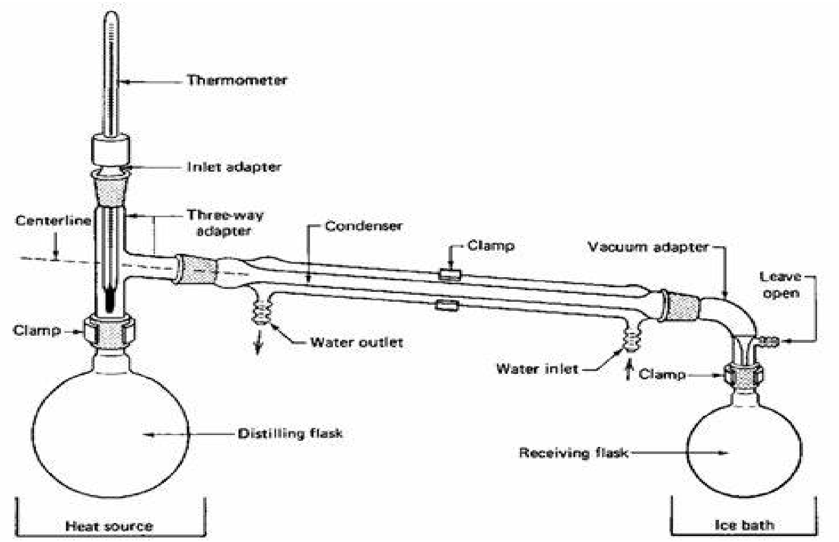


Figure I.2 :Tools used in the steam distillation process.

I.3.4. Application areas and industries utilizing essential oils

a) Personal Care Products: They are common ingredients in skincare, hair care, and bath products due to their fragrance and beneficial properties.
b) Healthcare: Essential oils are used in natural remedies for various health issues like headaches, stress relief, and respiratory congestion.
c) Food and Beverage: Some essential oils are used as natural flavoring agents in food and beverages, adding aroma and taste to culinary creations.
d) Household Cleaning: Essential oils with antimicrobial properties are used in eco-friendly household cleaning products.
e) Perfumery: They are essential components in perfumes and fragrances, providing unique scents and notes.

I.4. Presentation of the Existing Oil Extraction Plant

I.4.1. Introduction to the University Laboratory

The Laboratory at KasdiMerbahUniversityof Ouargla in Algeria is a vital academic and research facility that serves as a cornerstone of scientific exploration and innovation. Situated within the university campus 3, this laboratory is dedicated to conducting advanced research, fostering academic excellence, and addressing key challenges facing society.

I.4.2. Overview of the current processes and methodologies used

In this laboratory, we learned about three methods for extracting essential oils:
The first, as we mentioned previously, is **steamdistillation.**

Figure I.3 :Steam distillation process in Professor Signi's laboratory.

The second is the Cold pressing by using a milling machine, also known as cold pressing is a method used to extract oils from seeds or nuts without the use of heat. Here's how it generally works:

- Clean and prepare seeds or nuts, and possibly remove debris, Place seeds or nuts in a machine to crush them into a coarse powder or paste, Then the oil is dropped into a bowl and the solid residue and peels come out of the top.

Cold pressing is preferred for its ability to retain more of the natural flavor, color and nutritional quality of the oil compared to hot pressing methods, which involve heating the seeds/nuts before pressing. This method is commonly used to produce high-quality cooking oils such as olive oil, coconut oil, and certain types of nut oils.

Figure I.4 : Grinding machine in Professor Signi's laboratory.

The third is by using the **Soxhlet device**. A Soxhlet extractor is a piece of laboratory equipment used for the extraction of compounds from a solid sample. While it's not commonly used for oil extraction due to the availability of more efficient methods in industrial settings, it can still be used for small-scale experiments or research purposes. Here's how oil extraction using a Soxhlet extractor generally works:

- Grind the solid sample into a fine powder for extraction. Then place them in heat-resistant paper and add solvent to a round-bottomed flask. The solvent is then heated, causing it to evaporate and rise through the Soxhlet arm. The solvent dissolves the oil components from the solid, allowing for effective extraction. The extracted mixture of oil and solvent accumulates in the beaker, then the solvent evaporates and the oil remains.

Figure I.5 : Soxley device in Professor Signi's laboratory.

I.5. Why choosing Oilessential oil extraction plant?

Choosing an essential oil extraction plant involves several considerations due to the unique properties and commercial potential of essential oils. Here are some key reasons and factors to consider:

- **Growing Demand:** Increased demand for essential oils due to growing awareness of natural remedies and aromatherapy. The growing demand for natural products due to their health benefits has prompted manufacturers to invest in essential oils (EOs) for commercial products like cosmetics, pharmaceuticals, and food, indicating expected market growth [14].
- **Trends towards Natural and Organic Products:** Consumers are increasingly seeking natural and organic products, driving the growth of the essential oils market.
- **Diverse Applications:** Essential oils find application in various industries including aromatherapy, personal care, cosmetics, food and beverages, pharmaceuticals, and household cleaning products.
- **Value-added Products**: Essential oils are high-value, premium products used by companies in perfumery, cosmetics, and aromatherapy to differentiate their products and enhance market appeal.

I.6. Objective of the study

In an attempt to bridge the gap between automation techniques and traditional methods, the aim of this work is to investigate the implementation of an automated essential oil extraction process.

Our goal is to increase productivity and maintain the integrity of extracted oils while simplifying the extraction process and reducing human involvement through automation and monitoring. In addition to enhancing technological skills, this research endeavor seeks to support the sustainable production of essential oils, ensuring their availability for a range of sectors and uses while minimizing environmental impact.

Choosing an essential oil extraction installation is a significant decision for businesses and individuals involved in the production of essential oils. The following figure shows a P&ID schema of Essential oil extraction process with basic instrumentation.

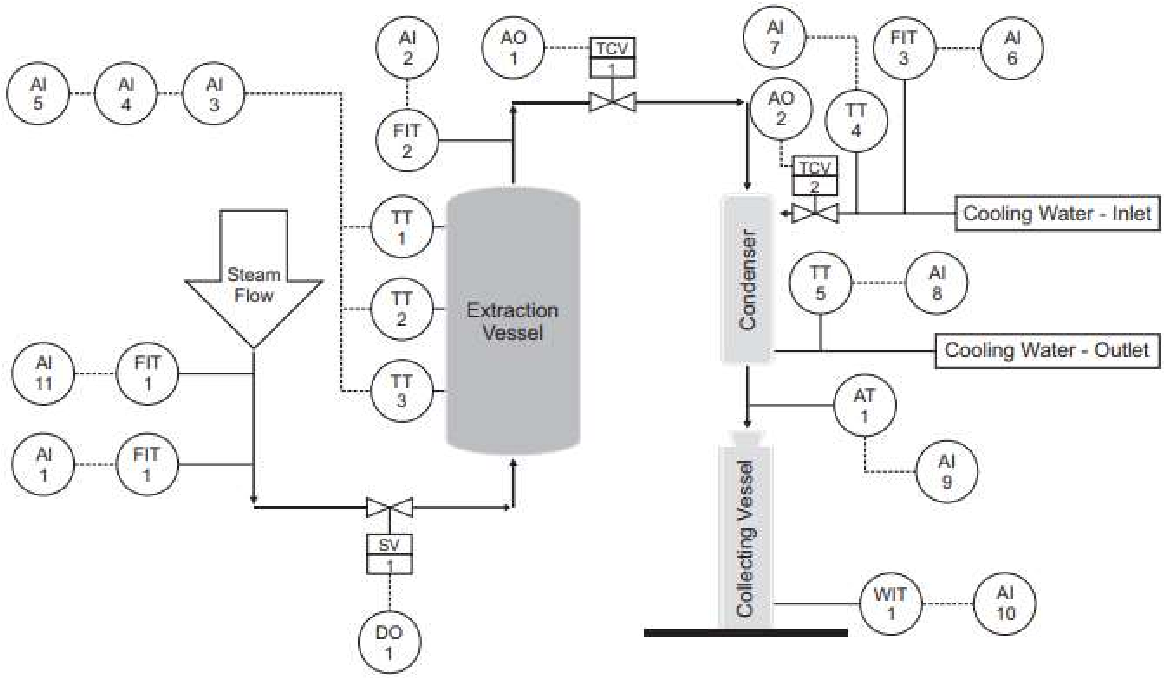


Figure I.6 : Schema P&ID of essential oil process.

I.7. Importance of Automation and Real-time Monitoring

Automation is important in essential oil extraction plants. It makes the process more efficient, improves quality and makes it safer. Here are some reasons why automation is important in essential oil extraction plants:

a) **Precision (accuracy):** Automated systems can control variables such as temperature, and processing time with high precision.

b) **Optimized Process Control:** Automation optimizes extraction parameters, maximizing essential oil yield while minimizing energy consumption and material waste, by real-time monitoring and adjustment of solvent flow rate, temperature, and duration**.**

c) **Reduced Costs and Safety Risks:** Automation reduces manual laboring hazardous tasks, lowering costs and lowering workplace accident risks.

d) **24/7 Operation:** Automated extraction plants enable continuous, efficient operation, maximizing production throughput and capacity, enabling higher volumes of essential oil production to meet market demand without compromising product quality.

e) **Data Monitoring and Analysis:** Automated systems collect and analyze real-time data on process parameters, providing insights into extraction performance and product quality, enabling operators to optimize processes, identify issues, and implement corrective actions.

I.8. Examples of successful automation implementations in similar industries

a) **Cosmetics Manufacturing:** Precise filling and dosing: The cosmetics production process relies on precise and continuous product filling, but mechanical filling and dosing components can be costly and unreliable, leading to process interruptions [7].

b) **Food and Beverage Industry:** Automated Packaging Systems its equipped with robotics and conveyor belts to streamline packaging processes, reduce labor costs, and improve packaging consistency [8].

c) **Chemical Processing Industry[9]:** Automation in the Chemical industry can be grouped as follows:

- Automation Technology to replace existing manufacturing/process lines
    - Automation technology to improve operational control
    - Automation technology to assist in decision-making, planning, and management

I.9. Conclusion

The automated system designed for Essential Oil Extraction from aromatic and medicinal plants is a comprehensive solution with use of Tia portal, WinCC, and Factory I/O software, the programming and simulation aspects of the system will be elaborated in the next chapter, demonstrating its potential for efficient operation and improvement. By simulating the system's functions, potential issues can be identified and resolved before actual implementation, ensuring smoother integration and enhancing overall performance

Chapter II

Industrial Automation and Supervision

II. Industrial Automation and Supervision

II.1. Introduction

In the field of industry, automation is used to control the means of production. The objective of automation equipment is to produce while ensuring the integrity of the production chain and the safety of people. Implementation platforms are often made up of Programmable Logic Controller (PLC), particularly for their ease of integration and their operational robustness. The use of these PLCs requires programming methods based on the standardization of programming languages.

This chapter consists of describing the PLC and programming software & SCADA system, its role and its operating principle.

II.2. General information about automated systems

II.2.1. Definition

An automated system is a process that operates without human intervention, utilizing technology to execute predefined instructions or tasks based on predefined conditions or inputs. Automated systems are utilized in various industries like manufacturing and transportation to improve efficiency, reduce human error, and minimize labor costs and manual intervention [20].

II.2.2. Objectives of automated systems

Automation enhances the system's value by adding additional elements, which can be expressed in terms of objectives [21].

- Increase the productivity (profitability, competitiveness) of the system.
- Improve production flexibility.
- Improve product quality.
- Adaptation to particular contexts such as hostile environments for Man (toxic, dangerous environment. Nuclear, etc.),
- Adaptation to physical tasks or intellectual tasks that are difficult for humans.
- Increase security, etc.

II.2.3. Structure of automated system

An automated system is typically divided into three main components, as shown in Figure: the control part, the operational part, and the interface [22].

- The industrial process (called the operative part)
- The control or command system (called the command part)
- The Interface

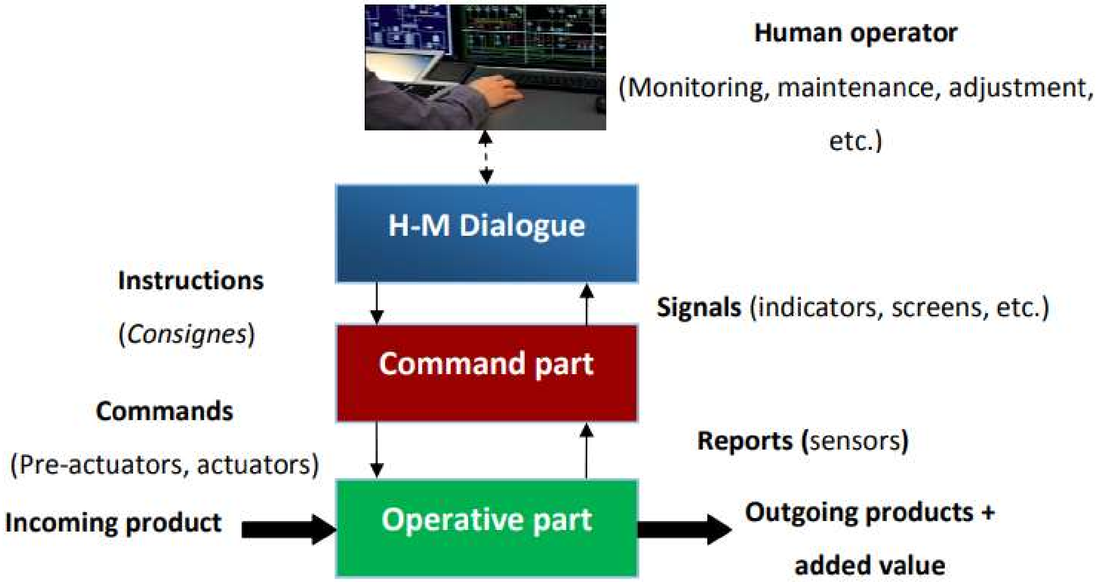


Figure II.1: Structure of automated system.

1) The operative part:

The operative part is made up of three sets: sensors, actuators and the production unit. Using actuators, this part executes orders sent by the control part and communicates to it the information collected (reports) from sensors.

- It receives orders from the command part.
- It sends reports to the command part.

2) The command part:

It plays the role of the "brain" of the system, it controls the operational part and receives information from the sensors and It sends orders to the operative part and signals to the operator. The control part consists of the following sets:

- Input interfaces: which transform information from sensors placed on the operational part or in the dialogue part into information

- Output interfaces: which transform the information produced by the processing unit into information of compatible nature and amplitude.
- Processing unit: (PLC industrial programmable controllers, computer, microprocessors) which develops the orders intended for the actuators based on the information received from the various sensors and the operation to be carried out.
  - It receives its instructions from the operator and reports from the operative part.
  - It sends orders to the operative part and signals to the operator.
  - It is the command part's program that manages all these exchanges of information.

3) The interface:

IT enables the exchange of information between the two parts of the production system: the control part and the operational part. These exchanges are highlighted by the commands (actions) and the feedback (sensors).

II.3. Industrial automation

Industrial automation is a set of technologies that uses control systems and devices, such as computer software and robotics, to enable automatic operation of industrial processes and machinery without the need for human operators. Industrial automation eliminates the possibility of human error, reduces costs, saves time, and achieves higher performance.

A wide range of tools are required for industrial automation. They include various control systems that incorporate different devices and systems impacting aspects of the manufacturing process. The elements of automation typically include:

- Sensors: These devices detect environmental changes like temperature, pressure, or motion and transmit this data to the control system.
- Actuators: Actuators are devices that convert automation system control signals into physical actions, such as valve movement, door opening, or motor speed adjustment.
- Controllers: Controllers, ranging from simple PLCs to advanced computer-based systems, are the central hubs of automation systems, processing sensor data and sending commands to actuators.
- Human Machine Interface (HMI): HMIs enable operators to interact with automation systems through a graphical interface, allowing monitoring of system status, access to control functions, and setting configuration.
- Communication Networks: enable data exchange between automation system components like sensors, controllers, and HMIs using protocols like Ethernet, Modbus, and Profibus.

- Software: is essential for programming controllers, configuring system parameters, and analyzing sensor data, playing a crucial role in defining the behavior and functionality of an automation system.
- Safety Systems: such as emergency stop buttons, safety interlocks, and alarm systems, are crucial in safeguarding personnel, equipment, and the environment from potential hazards in automated processes.
- Power Supply: A reliable power supply is crucial for automation systems' continuous operation, and backup power sources like uninterruptible power supplies (UPS) can prevent system downtime during power outages.

II.3.1. Programmable Logic Controller (PLC)

II.3.1.1. PLC definition

We call Industrial Programmable Logic Controller, PLC (in French, Automate Programmable Industrial, API) is an industrial computer, with various inputs and outputs, used to control and monitor industrial equipment based on custom programming. Where ever there is a need to control devices the PLC provides a flexible way to "software" the components together.

Figure II.2: PLC.

II.3.1.2. Structure of PLC

The main components of a PLC consist of [23]:

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

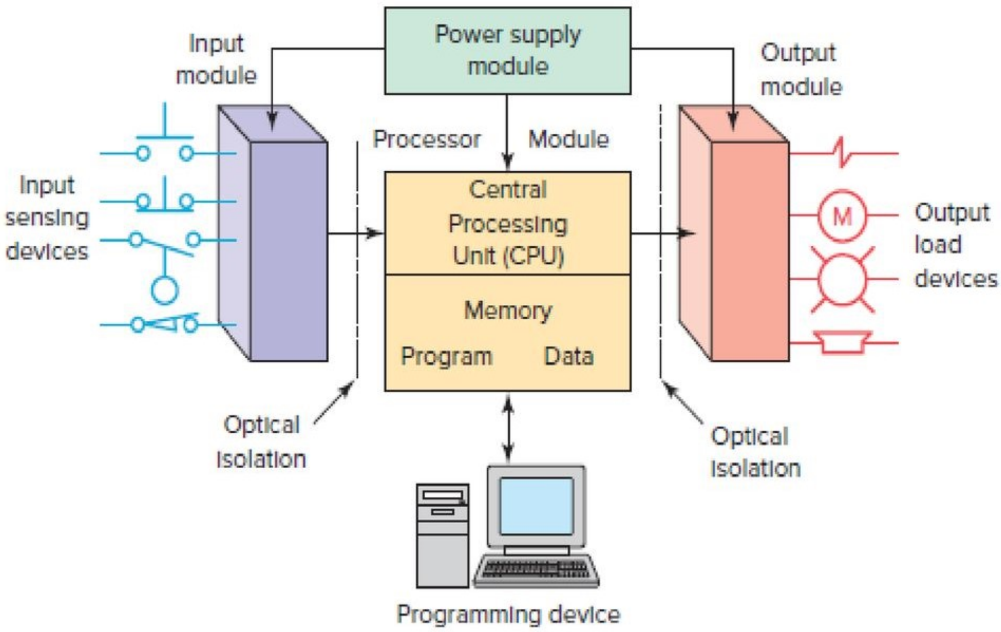


Figure II.3: Structure of PLC.

1) Central Processing Unit (CPU):

The CPU is the central unit of a PLC, responsible for processing and executing the control program stored in memory. PLCs have various types of memory, including program, data, and system. Each CPU features a mode switch, a removable key switch, allowing for the change between RUN and STOP operating modes.

2) Memory unit:

Memory stores information, programs, and data in a PLC, with putting new information into a memory location (called writing) and retrieving information from a memory location (called reading), containing two types of memory:

- **RAM** (Random access memory): RAM is a read/write memory that stores all users programs, allowing easy programming and repair. It can be easily backed up with a battery to prevent data loss if the power source is removed.
- **ROM** (Read Only Memory): ROM is a read-only memory type, storing information for internal use and operation of the PLC. Manufacturers place system programs in ROM, which cannot be changed and can only be deleted using special equipment.

3) The Input / Output modules (Signal modules):

A computer system's input and output interfaces have addresses, connecting sensors and actuators. Input devices send signals to the CPU, while output devices receive signals. A Programmable Logic Controller (PLC) allows operating modes and functions.

PLCs have two types of inputs and outputs: digital and analog. Digital devices are ON/OFF and connected to digital channels, while analog devices use variable voltage or current signals. Analog input signals are converted by an input signal module to binary values for CPU processing.

a) The digital input module (DI): The digital input board will allow us to monitor all the logic inputs of the following types: Valve end-of-travel, Pushbutton, Motor operating feedback, Pressure switch, Thermostat, Level detector etc.
b) The analog input module (AI): The analog input board will allow us to have all the measurements of the following types in the PLC: Pressure, Flow rate, Temperature, Level, Etc.
c) The digital output module (DO): Output modules interface with external actuators and devices, such as motors, valves, and relays
d) The analog output module (AO): The analog output board will allow us to regulate all the following actuators: Regulation valve, Speed variator, Etc.

4) Power supply:

The power supply board powers all PLC boards in the base, typically 24 VDC, using a stabilized filtered 230VAC/24VDC power supply. Always use a 230VAC power outlet from the uninterruptible power supply for PLC power.

II.3.1.3. Types of PLC

1) **Compact**: They integrate processor, power supply, inputs, and outputs in a single box, performing additional functions like rapid counting and analog I/O, and are simple to operate.
2) **Modular**: PLCs, consisting of processor, power supply, and I/O interfaces, are integrated into complex automation systems for power, processing capacity, and flexibility [24].

II.3.1.4. Operation of PLC

Programmable controllers control pre-actuators based on a program written in memory, operating cyclically. The microprocessor performs all AND, OR logic functions, timing, counting, and calculation functions, connected to memory and I/O interface through 'BUS' links. Synchronous operations consider frozen inputs for the entire cycle.

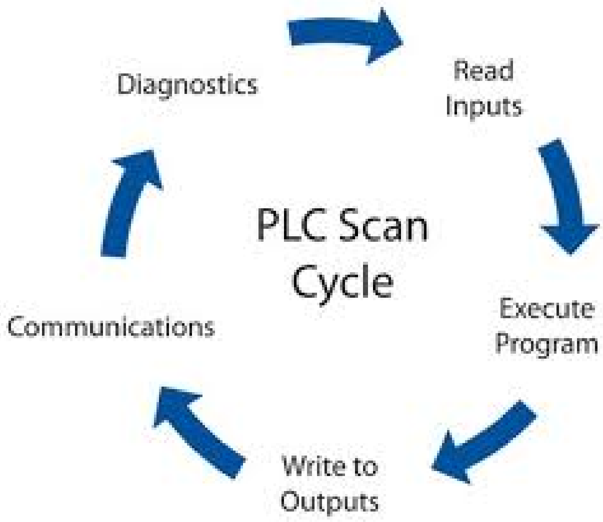


Figure II.4: Cyclic Operations Of PLC.

II.3.1.5. Information nature processed by PLC [25]

a) **TOR**: Information can be either true or false, and can be provided by a detector ora push buttons.

b) **Analog**: The information is continuously processed and can be interpreted within a predetermined range, which is then transmitted through a sensor (pressure and temperature).

c) **Digital**: The information is encoded in hexadecimal or box codes and is transmitted by a computer or intelligent module).

II.3.1.6. The different models of PLC SIEMENS

The Siemens PLC range contains several types of PLCs [25]:

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

Figure II.5: Different Models of PLC SIEMENS S7.

II.3.1.7. PLC Programming

A. Programming software

As industrial processes became more complex, there was a growing need for seamless integration of various automation components. Siemens recognized this and, in 2010, introduced the Totally Integrated Automation Portal (TIA Portal) [26].

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

B. Configuration

The general steps for configuring hardware for a S7-(1500, 1200, 400, 300) PLC in TIA Portal:

a) Add the hardware to the project: Start by adding the type of PLC hardware to the TIA Portal project. This involves selecting the appropriate device type and model.

b) Add hardware modules: Add the required hardware modules to the system, such as digital and Analogue input/output modules, communication modules, and power supply modules. Configure the parameters for each module, such as the input/output addresses and the module type.

This will enable the PLC to communicate with other devices in the system, such as HMIs, other PLCs, and remote I/O [25].

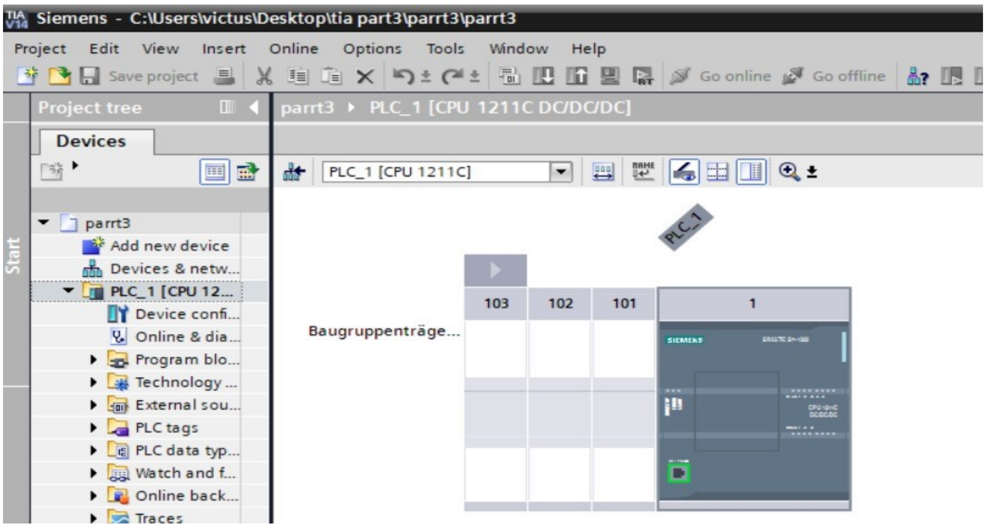


Figure II.6: PLC Configuration Window.

C. Program blocks

a) Organization block (OB): Organizational blocks are closely related to program execution cycles and interrupts because their execution is linked to pre-defined triggers, such as time interval or hardware failure detection.

b) Main OB1: OB1 refers to the main organization block, which is essential for initializing and sequentially scanning the calls of the blocks corresponding to the implemented code, and ensuring that the system operates as intended. At the end of the main, the CPU resumes execution of the code from the beginning, and this process repeats indefinitely.

The OB1 may also contain calls to other organization blocks, such as Function Blocks (FBs) and System Function Blocks (SFBs) and System Function Blocks (SFBs).

c) Function Block (FB): Functional blocks (FB) have their own memory area and can be assigned a data block (DB) for access. They can call other FBs and FCs in a function block via call instructions.

d) Function (FC): A Function (FC) is a memory less algorithm that compresses routines, returns values to output variables, and can use global data blocks. It saves temporary variables in local data stacks. The local variables declared in FC and their characteristics can be of type in (input), Out (output), In Out (input and output), Temp (temporary), or Constant (Constant).

e) Data Block (DB): DBs provide memory for variables and define data elements for programs. Data blocks store input and output data, with global DBs allowing all OBs, FBs, and FCs to read or write data.

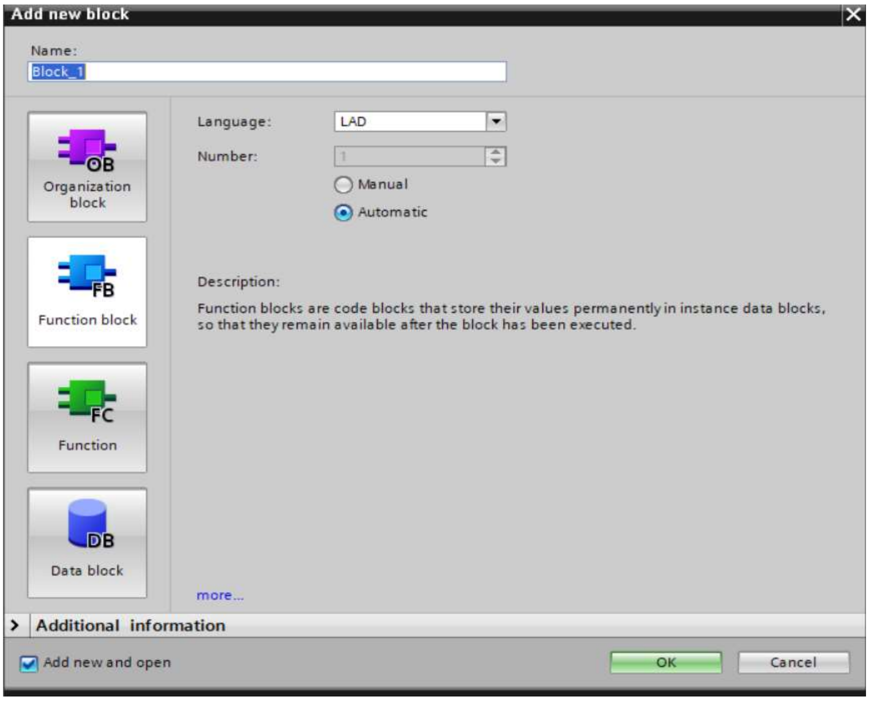


Figure II.7: Program Blocks.

II.4. Industrial supervision

Industrial supervision is a fundamental component of modern industrial operations, facilitating efficient management and control of complex systems. Industrial supervision involves overseeing and managing various processes, machinery, and systems within industrial settings. It encompasses monitoring, analyzing, and directing operations to ensure optimal performance, safety, and productivity. Supervision in industries often involves real-time monitoring, data collection, and decision-making to maintain smooth and efficient operations while addressing any anomalies or issues that arise.

The concept of supervision operates within a hierarchical framework with at least two levels. At a very local level, supervision may be minimal (when everything is planned and fixed in advance, and monitoring is integrated into the control). Conversely, at more abstract levels, supervision becomes more significant compared to control and monitoring.

- In classic industrial supervision, the focus is often on top-down decision-making, where supervisors dictate tasks and monitor their execution. It relies heavily on standardized procedures and clear chains of command. Safety protocols and adherence to regulations are emphasized, alongside maintaining productivity and efficiency.

- Modern approaches to industrial supervision may integrate more collaborative and participative methods, incorporating technological advancements, employee involvement, and a stronger emphasis on continuous improvement and adaptability.

II.4.1. Human Machine Interface (HMI)

II.4.1.1. Definition

Human-Machine Interface (HMI) is a user interface used in industrial settings to enable human operators to interact with machines or processes, enabling monitoring and control. HMI can take a variety of forms, including Batch Interface (1945-1968), Command-Line User Interface (1969-Present), and Graphical User Interface (GUIs) (1981-Present) is used to present process data, input commands, set points, and display alarms to operators [26].

In industrial settings, HMIs can be used to:

- Visually display data
- Track production time, trends, and tags
- Monitor machine inputs and outputs, and more… etc.

Figure II.8: Human Machine Interface (HMI).

II.4.1.2. Uses of HMI

HMI is a digital tool that communicates with Programmable Logic Controllers (PLCs) and sensors to display information for users. They optimize industrial processes by digitizing and centralizing data, enabling operators to view important information, manage alarms, and connect with SCADA system all through one console. This eliminates the need for manual record-keeping and reduces costs [30].

HMI technology is utilized by numerous industrial companies to enhance machines interaction and optimize their industrial processes. Industries using HMI include: Energy, Food and beverage, Manufacturing, Oil and gas, Transportation and Water plants.

II.4.1.3. Types of HMI

Common types of Human-Machine Interfaces (HMI) include:

- Graphical User Interfaces (GUIs): Computer-based HMIs, GUIs can be created using software like Microsoft Windows, which use a graphical interface to present process data and allow operator to input commands.
- Touch screens: Touch screen HMIs display process data and allow the operator input commands; they are often used in applications where a physical control panel is not practical.
- Physical Control Panels: Physical HMIs, consisting of buttons, switches, and displays to present process data and allow the operator to input commands are commonly used in industrial settings where a GUI or touch screen may not be practical.
- Web-based HMI: Web-based HMIs, accessible from any device with a web browser, enable operators to remotely monitor and control processes by presenting process data and inputting commands.

II.4.2. Supervisory Control and Data Acquisition system

II.4.2.1. Definition

Supervisory Control and Data Acquisition system (SCADA) is a technology that allows users to collect data from distant facilities and send limited control instructions to those facilities.

SCADA systems combine hardware and software to automate industrial processes by capturing Operational Technology (OT) real-time data from sensors monitoring equipment like motors, pumps, and valves, connecting them to onsite or remote servers.

II.4.2.2. SCADA system elements

SCADA is a centralized system that monitors controls, and alarms plant and regional facilities' operating systems; the system consists of the following elements:

1) Master Station Computer Systems (MTU): The SCADA system's data repository is standard computer hardware equipment, typically used by remote terminal units to collects data in real-time or near real-time reported, with few suppliers producing their own equipment.
2) Human-Machine Interface: The host station uses HMIs to present stored values to human operators. These may provide trending, diagnostic or management information and detailed schematics and animations of machines under its control.
3) Remote Terminal Units (RTUs): (RTUs) are transducers or sensors that interface with process instrumentation and control equipment. They measure physical parameters like pressure and temperature through changes in electrical properties. the Input/output circuitry of a RTU can be analog or digital, with analog measuring continuous values and digital having limited states for flagging which are later converted using an ADC.
4) Programmable Logic Controllers: Microprocessors on RTUs enhance functionality and automation and helped to become smarter with increased functionality. PLC-based RTUs support multiple polling, exception reporting, and time-tagging, executing simple logical processes, allowing for debugging and fixing on the field.
5) SCADA Communication: SCADA systems require a communication system for data transmission from RTU to master station and commands from host to RTU. The network's vastness, speed, accuracy, security, and performance must be considered. Prior to computer networking, voice communication systems had similar bandwidth limitations.

II.4.2.3. SCADA programming requirements

1. **Understanding the Process:** Before programming, it's crucial to have a deep understanding of the industrial process that the SCADA system will monitor and control. This includes knowledge of sensors, actuators, control loops, and the overall system architecture.
2. **Logic Programming and Scripting languages:** Choose a suitable SCADA software platform based on the specific requirements of the project. SCADA systems use logic programming to define the control strategies and behaviors of the system. This often involves using languages such as ladder logic, function block diagrams, or structured text, depending on the SCADA software and the underlying control devices (PLCs or RTUs).

3. **Tags define and configuration:** Tags are variables that represent data points from field devices, sensors, and other components in the industrial process. Programmers configure tags to collect and display real-time data**.**
4. **Graphical Interface Design:** SCADA programming involves designing the graphical interface or HMI. This includes creating screens, displays, and visual representations of the industrial processes for operators to monitor and control.Graphical interfaces are a crucial tool for the smooth operation of the decision support procedure. They are the only point of interaction between the operator and decision support algorithms, helping the operator in the interpretation and decision-making tasks by offering excellent visibility of the installation's state and evolution, displaying residues, alarms, and suggestions for action in different colors.
5. **Communication Protocols:** SCADA programming includes configuring communication protocols to establish connections between the SCADA server and field devices such as PLCs, RTUs, and sensors.
6. **Alarm Configuration:** The configuration of alarms has evolved dramatically over the past decades. The primary role of alarms is to maximize the productivity of the production system and provide more security to both the facilities and operators. Alarm management is not only about reducing anomalies but also about making operators more efficient by obtaining the right information at the right time.
7. **Real-Time Operation:** The concept of real-time has become very important and essential in the monitoring and supervision procedure in general. It allows for signal refreshing at every moment, enabling continuous monitoring of the system's state.
8. **Trend and Historical Data Configuration:** SCADA programming includes configuring trends and historical data logging. This involves setting up parameters for data logging and defining how historical data will be stored and presented for analysis. Some SCADA systems involve the integration of databases for storing and retrieving historical data, configuration settings, and other relevant information. SQL (Structured Query Language) may be used for database-related programming tasks.
9. **Data Archiving:** Data archiving is one of the key elements of a SCADA system. It allows for archiving data from various system installations.
10. **User Authentication and Access Control:** SCADA systems often require programming to implement user authentication and access control mechanisms. This ensures that only authorized personnel can access specific features or perform certain actions within the SCADA system.

II.4.3. Factory I/O

II.4.3.1. Introduction

Factory I/O is an advanced software platform designed for simulating industrial automation and control systems. It offers an interactive 3D environment that replicates real-world factory operations, providing an invaluable tool for both educational and professional purposes.

Figure II.9: Factory I/O.

The software can be used to create virtual 3D views of production lines and systems using predefined work-pieces and system components. You can choose from sensors such as scanners, actuators such as switches and displays, transport technology such as conveyors, and complex machines such as water tanks.

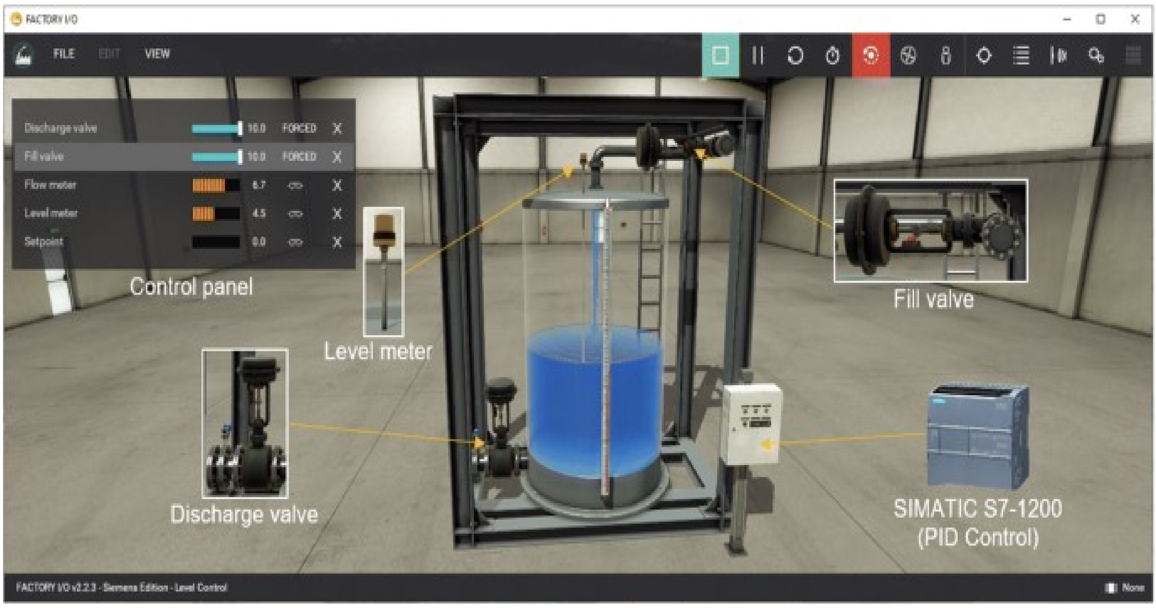


Figure II.10: Functions of factory I/O.

II.4.3.2. Configuration

The factory components can be linked to various PLC modules with a choice a number of input/output points.

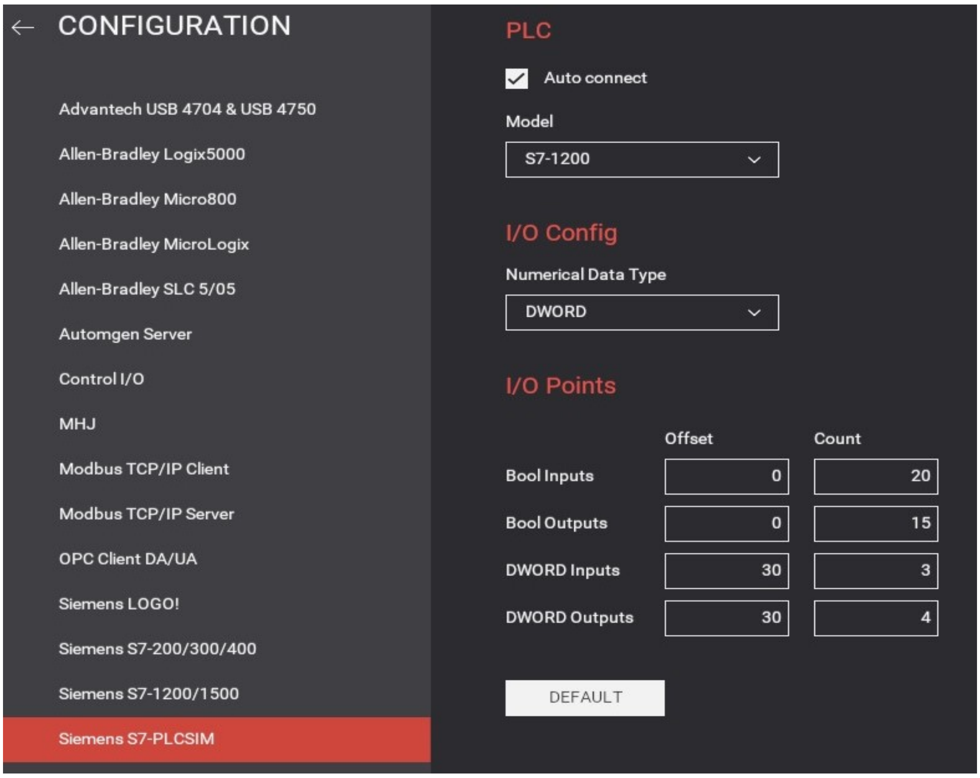


Figure II.11: Configuration of factory I/O.

II.4.3.3. Applications of Factory I/O

1) **Real-time Simulation:** Factory I/O provides a realistic 3D simulation environment where users can design and interact with virtual industrial factories. The software includes a variety of components such as conveyors, machines, robots, and sensors, enabling users to create comprehensive industrial processes. Factory I/O offers real-time simulation, enabling users to see the immediate effects of their control logic and adjustments. This real-time feedback is crucial for testing and validating automation solutions.
2) **PLC Integration:** One of the standout features of Factory I/O is its ability to connect with real PLC hardware or software-based PLCs. This integration allows users to develop and test their control logic in a virtual environment before implementing it in actual industrial settings. The software supports multiple PLC brands and programming environments, making it versatile and widely applicable.

3) **Training:** For professionals, Factory I/O provides a safe and controlled environment for hands-on training. It allows trainees to experiment with different automation scenarios and solutions without the risk of damaging real equipment or causing accidents.
4) **Testing:** Factory I/O is an effective tool for testing and validating PLC programs and industrial automation solutions. By simulating the factory environment, users can identify and resolve issues before deploying their solutions in real-world settings.
5) **Skill Development:** Engineers and technicians can use Factory I/O to enhance their skills by experimenting with various industrial automation scenarios. This continuous learning process helps them stay updated with the latest technologies and practices in the industry.[30]

II.4.3.4. Advantages/ Disadvantages of Factory I/O

- **Advantages**

- Cost-effective: Factory I/O reduces the need for expensive physical equipment for training and testing. By providing a virtual simulation environment, it minimizes costs associated with purchasing and maintaining industrial equipment.
- Safety**:** The virtual environment of Factory I/O allows users to experiment with automation solutions without the risk of causing accidents or damaging real equipment. This safety aspect is crucial for both educational and professional training.
- Flexibility**:** Factory I/O offers flexibility in designing and customizing the simulation environment. Users can easily modify scenarios to meet specific learning or testing needs, making it a versatile tool for various applications.

- **Disadvantages**

- Limited and paid software.

II.5. Conclusion

This chapter underscores the pivotal role of automation in modern industries, enhancing efficiency and productivity. Through advanced control systems and real-time monitoring, automation ensures streamlined processes and improved decision-making.

Factory I/O software holds expanded features, increased integration, and continued dominance in industrial automation training and simulation. The incorporation of Factory I/O enhances automation training, providing realistic simulations for industrial processes and fostering learning and skill development in various educational and professional environments."

Chapter 3

Automation and Supervision of an Essential Oil Extraction System

III. Automation and Supervision of an Essential Oil Extraction System

III.1. Introduction

The system under study is an automated system designed to extract water and oil from aromatic and medicinal plants, such as rose, mint, rosemary, and nutmeg, with the primary purpose of extracting oil. The system is divided into two parts: the first part involves the automated distillation process for extracting oil and water, while the second part involves the automatic filling and capping of bottles.

The system under study is an automated solution designed for the extraction of water and oil from aromatic and medicinal plants, such as rose, mint, rosemary, and nutmeg, with a primary focus on oil extraction.

This chapter details the programming and simulation of the system using TIA Portal and Factory I/O software. The system is divided into two main components: an automated distillation process for extracting oil and water, and an automatic filling and capping process for bottling the extracted products.

III.2. Automated Essential Oil Extraction plant Components

The automated distillation process is the first step in the extraction system. It involves the following steps:

1. **Feeding Plant Material**: Aromatic and medicinal plant material is fed into the distillation chamber.
2. **Heating and Distillation**: The plant material is heated to release essential oils and water vapor.
3. **Condensation**: The vapor is condensed back into liquid form.
4. **Separation**: The oil and water are separated using a decanter or a separator.

III.2.1. Plant Instruments

A. Temperature measurement

Temperature measurement plays a crucial role in the automated extraction system to ensure optimal conditions for the distillation process.

A.1. Resistance Temperature Detector (RTD): A thermometer Pt100 refers to a type of Resistance Temperature Detector (RTD) that uses platinum (Pt) as the sensing element. This sensitive element is in platinum so it's a metallic conductor. Pt100 specifically denotes that the resistance of the platinum element at 0°C is 100 ohms.

A.2. Thermocouples: A thermocouple is a device for measuring temperature. It comprises two dissimilar metallic wires joined together to form a junction.

Choose sensors compatible with the range of temperatures encountered during the distillation process, typically ranging from ambient temperature to elevated temperatures required for vaporization.

- Pt100 thermometers can measure temperatures over a wide range, from as low as -200°C to over 600°C, depending on the specific construction and design of the sensor.
- Thermocouples are suitable for measuring over a large temperature range, from −270 up to 3000 °C.
- RTDs, which have higher accuracy and repeatability, are slowly replacing thermocouples in industrial applications below 600 °C.
- An RTD will often cost two or three times more than a thermocouple with the same temperature and style.

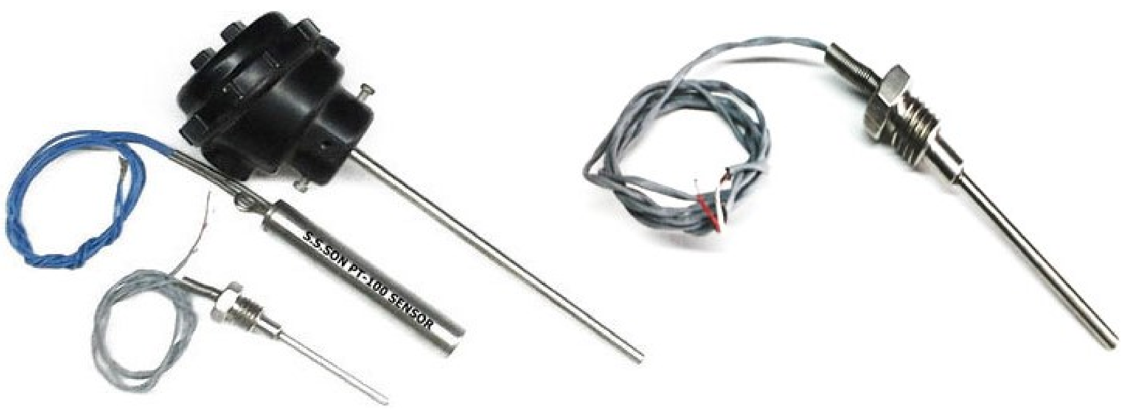


Figure III.1: RTDs and thermocouple.

B. Pressure sensor

In essential oil extraction plants, various types of sensors are employed to monitor and control the extraction process. One crucial parameter to measure is pressure, which can indicate the status of the extraction equipment and the efficiency of the process.

B.1. Pressure Gauges: Mechanical pressure gauges provide a visual indication of pressure levels. Bourdon tube gauges are a common type used in industrial settings.

B.2. Differential Pressure Sensors: These sensors measure the difference in pressure between two points. They are used in systems where pressure differentials are critical for proper operation, such as in filtration processes or across membranes.

B.3. Pressure Transmitters: These sensors convert pressure into an electrical signal and transmit it to control systems or data acquisition systems. Pressure transmitters are essential for continuous monitoring and control of pressure parameters in essential oil extraction plants.

The selection of pressure sensors depends on factors such as the specific requirements of the extraction process, the type of essential oil being extracted, the operating conditions, and budget considerations. [27]

(B.1) (B.2) (B.3)

Figure III.2: Pressure sensors.

C. Level sensors

In essential oil extraction plants, level sensors play a crucial role in monitoring and controlling the levels of various liquids and materials involved in the extraction process.

C.1. Capacitive level transmitter: A capacitive level transmitter gauges liquid or solid levels in containers by measuring capacitance, storing electrical charge. Widely used across industries for its accuracy and adaptability to diverse materials, it's a simple and economical solution, especially suited for smaller tanks.

C.2. UltrasonicLevelSensors: These sensors use ultrasonic waves to measure the distance from the sensor to the surface of the liquid. They are non-contact sensors and are suitable for measuring the level of various liquids, including essential oils.

C.3. RadarLevelSensors: Radar sensors utilize microwave pulses to measure the distance to the liquid surface. They are highly accurate and can work well in challenging conditions such as high temperatures and pressures.

C.4. Level switch: A level switch is a device used to detect the presence or absence of a liquid at a certain level within a container, tank, or vessel. When the liquid reaches a predetermined level, the switch triggers an action, such as turning on a pump, activating an alarm, or shutting off a filling process. Level switches come in various types.

The choice of level sensor depends on factors such as the type of liquid being measured, the environmental conditions, accuracy requirements, and budget constraints. In essential oil extraction plants, where precise control over levels is essential for efficiency and product quality, selecting the appropriate level sensor is critical.

(C.1) (C.2) (C.3) (C.4) (C.4)

Figure III.3: Level sensors.

D. Analyzer, Indicator, Transmitter (AIT)

An AIT typically refers to an Analyzer, Indicator, and Transmitter. It is used in industrial applications for measuring and transmitting analytical data. These devices are often employed in process control systems to monitor parameters like pH, conductivity, and other chemical or physical properties of liquids or gases.

- Analyzer: This part of the AIT is responsible for measuring the desired parameter, such as pH level, conductivity, temperature, pressure, flow rate, etc.
- Indicator: Once the analyzer has measured the parameter, the indicator displays this information in a human-readable format.

- Transmitter: The transmitter takes the analyzed data and converts it into a standardized signal (such as 4-20 mA) that can be easily transmitted over long distances without significant loss or interference.

An AIT indeed plays a crucial role in industrial settings, especially in process control systems where monitoring and maintaining specific parameters are essential for operational efficiency and product quality.

Figure III.4: AIT: Analyzer, Indicator, Transmitter.

E. Valves

A valve can regulate the flow of liquids or gases in an industrial process by opening, closing, or obstructing various passages within a pipe system. This allows it to control both the flow and pressure within the system. Valves are commonly used in industrial piping systems to manage the conveyance of liquids, gases, slurries, and vapors. In many industries, they are essential for controlling the flow, pressure, and direction of fluids. Valves operate by means of a moving part that can open, close, or partially block one or more passageways to regulate fluid flow.

E.1. Gate Valve: Used to start or stop the flow of fluid. It operates by lifting a gate out of the path of the fluid.

E.2. Globe Valve: Used for regulating flow in a pipeline. It involves a movable plug that adjusts the flow by changing the size of the passage.

E.3. Ball Valve: Utilizes a spherical disc to control flow. When the ball's hole is aligned with the flow, it is open; when it is perpendicular, it is closed.

E.4. ButterflyValve: Features a rotating disc to control the flow. It is suitable for quick shutoff.

E.5. CheckValve: Allows fluid to flow in one direction only, preventing backflow.

E.6. Safety & Relief Valve: Safety and relief valves are critical components in various systems to ensure safe operation by preventing overpressure conditions.

Figure III.5: Valves.

F. Pumps

A pump is a mechanical tool used in industries to move fluids like liquids or gases from one place to another. It's vital across various sectors such as manufacturing, oil and gas, and wastewater treatment. These pumps come in different types and sizes to suit specific needs and are crucial for efficient industrial processes.

F.1. Centrifugal Pumps: These pumps use a rotating impeller to create a centrifugal force, pushing the fluid outward. They are versatile and widely used for transferring fluids in various industries.[29]

F.2. Submersible Pumps: Designed to be submerged in the fluid they are pumping, these pumps are commonly used in applications such as sewage pumping, drainage, and underwater mining.

Figure III.6: Centrifugal and Submersible Pump.

III.2.2. Process Equipments

1. Conveyors

A conveyor is a mechanical device or system that was used in several situations in this project: to transport raw material, in the production line, etc.

Figure III.7:Conveyors: straight, diagonal.

2. Tanks

We use several types of tanks, including for storing water, raw materials, and extracted oil.

Figure III.8: Tanks.

3. Separator

A separator is a device used to separate different components from water-oil mixture.Oil-water separators remove oil from water by exploiting density differences.

Figure III.9: Separator.

4. Pipes

Stainless Steel (Inox) and plastic pipes were used to transport water, extracted oil, and steam.

Figure III.10: Stainless Steel (Inox) and Plastic Pipes.

5. Boiler

It is generating steam by heating water above its boiling point.

Figure III.11: Boiler.

6. Condenser

Its primary function is to condense a substance from its gaseous phase to its liquidphase by removing heat.

Figure III.12: Condenser.

III.3. Essential Oil extraction system programming

III.3.1. Steps of System Functions

When we press Start:

1. **Preparing the raw material:**
   a) **Fill the tank to wash the raw material:** The pump starts and the valve opens to fill the tank. When it is filled, the sensor gives a signal to the pump to stop and the valve closes.
   b) **Washing the raw material:** The sensor also gives a signal to the valve, which opens and the raw material comes out. Then, after a period of time, the mixer starts stirring the raw material to wash it and push it to the conveyor.
   c) **Filling the raw material tank:** The conveyor transports the raw material to the standard tank, which contains two sensors, one for the low level and the other for the high level
2. **Filling the water tank:**
   a) **Fill the water tank:** The pump turns on and the fill valve also opens to fill the water tank, which alsocontains a level sensor. When it fills, the pump stops and the filling valve closes
   b) **Washing of the boiler:** The pump starts and the filling valve and the discharge valve are opened for a period of time to wash the boiler. The water enters and all the remains of the raw material or any previous dirt come out with it.
   c) **Mix the ingredients:** When the raw material tank and water tank filled, the discharge valve for the raw material tank and the boiler valve opens, so the material falls through the funnel, then closes when all the quantity is finished. Then the discharge valve for the water tank opens to release an amount of water proportional to the amount of raw material, and finally it closes and closes with the boiler valve to begin the evaporation process.
3. **Vaporization:**
   The gas valve is opened for a period of time, the fire starts under the kettle, and the water begins to boil at 100 degrees Celsius. The kettle is equipped with a sensor to measure the temperature and a sensor to measure the pressure. When water boils, water vapor rises, carrying with it the properties of the raw material. When the temperature reaches 130 degrees Celsius, the gas valve closes automatically. When the pressure reaches a limited value, the safety valve also opens.

3. **Condensation:**

The steam passes through a tube inside a water basin to condense and descend into a mixture of water and essential oil. This water basin is equipped with a temperature sensor. If the temperature increases, the fan turns on to cool the water

4. **Collection of liquid:**

We collect the mixture in a large basin so that we can separate the water from the oil accurately. It is also equipped with a discharge valve and a level sensor for safety.

5. **Separation:**

The mixture flows into the separator, which is equipped with a conductivity sensor and two sensors for low and high levels, and when it is filled, the high-level sensor sends a signal to the mixture discharge valve to close.

After a period of time in which the mixture settles and the oil floats above the water, the unloading valve opens and the water comes out. When the conductivity sensor receives a signal, the water discharge valve closes and the oil discharge valve opens.

When all the mixture is finished, the low-level sensor sends a signal to the mixture discharge valve to open.

III.3.2. Piping and Instrumentation Diagram Design

PID stands for "Piping and Instrumentation Diagram" in the context of engineering and process design. It is a detailed schematic representation of a process system that includes the piping, vessels, equipment, instrumentation, and control elements. PID diagrams are essential in industries such as chemical processing, oil and gas, pharmaceuticals, power generation, and others where complex process systems are involved. They provide a comprehensive overview that integrates the mechanical, electrical, and control aspects of the system into a single document.

III.3.2.1. Components of a PID:

- **Piping:** Shows the interconnected pipes and their arrangement in the process system. It includes information such as pipe sizes, materials, and sometimes flow direction.
- **Process Equipment:** Depicts equipment such as vessels, tanks, pumps, compressors, heaters, and other devices involved in the process.
- **Instruments:** Represents instruments used to monitor and control the process, such as sensors, transmitters, gauges, controllers, and valves.

- **Control Loops:** Illustrates control loops, which include control valves, actuators, and feedback mechanisms that regulate process variables such as flow rate, pressure, temperature, etc.
- **Utilities:** Shows utilities like cooling water, steam, electricity, and other resources required for the operation of the process equipment.
- **Annotations and Data:** Provides labels, tags, and additional data such as equipment specifications, operating conditions, and other pertinent information.

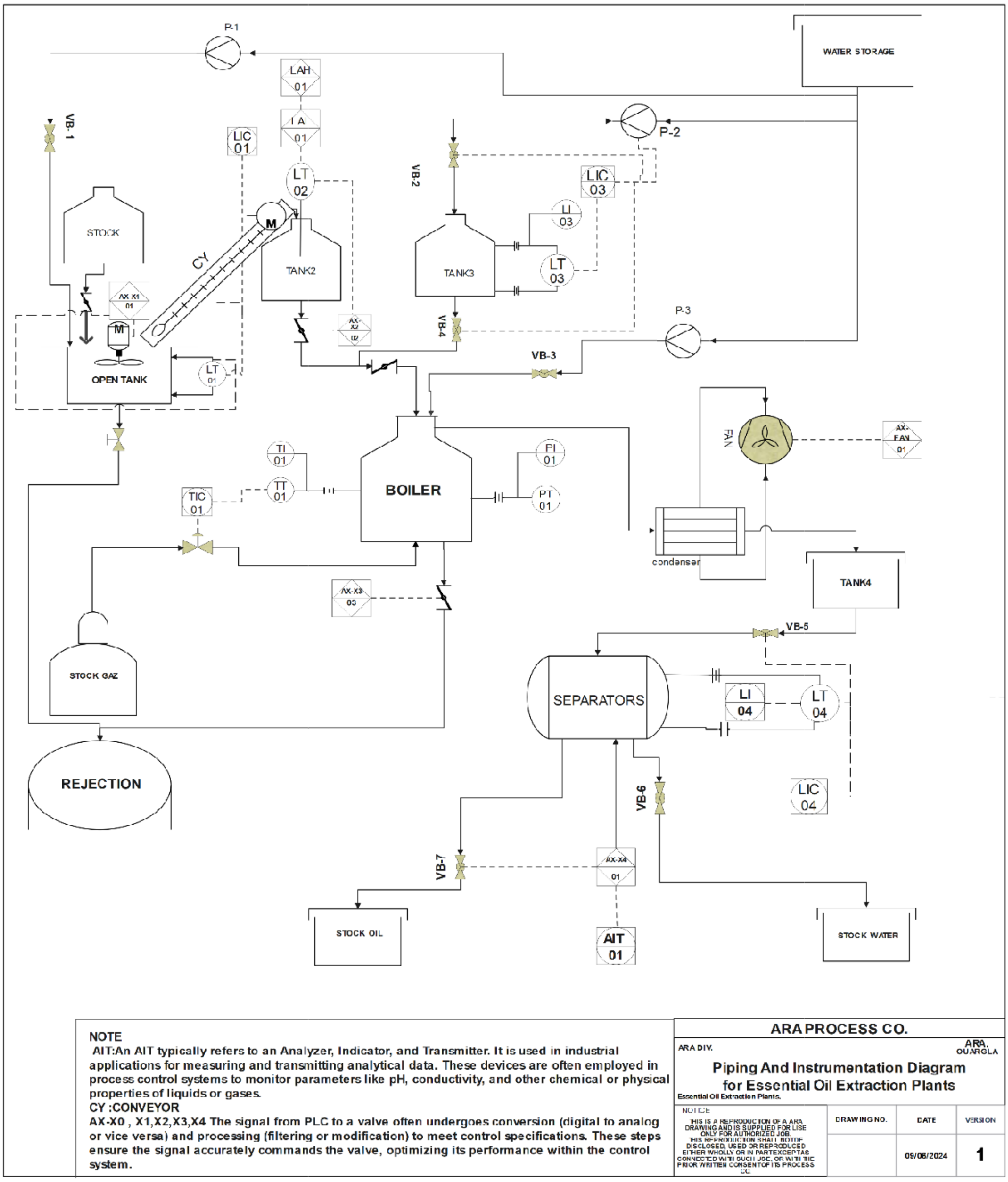


Figure III.13: Piping and Instrumentation Diagram.

III.3.3. Plant Automation Programming

III.3.3.1. Tia Portal v14

TIA Portal V14 is a version of the Totally Integrated Automation (TIA) Portal engineering framework for industrial automation systems.

The TIA Portal is a software solution from Siemens that provides engineers with a single environment for programming and configuring automation systems, including programmable logic controllers (PLCs), human-machine interfaces (HMIs), and other automation components.

It includes several new features and improvements, such as enhanced simulation and testing capabilities, expanded support for multiuser collaboration, and improved security features. It also includes new and updated libraries for programming and configuring Siemens automation components, as well as support for the latest versions of the company's hardware products.

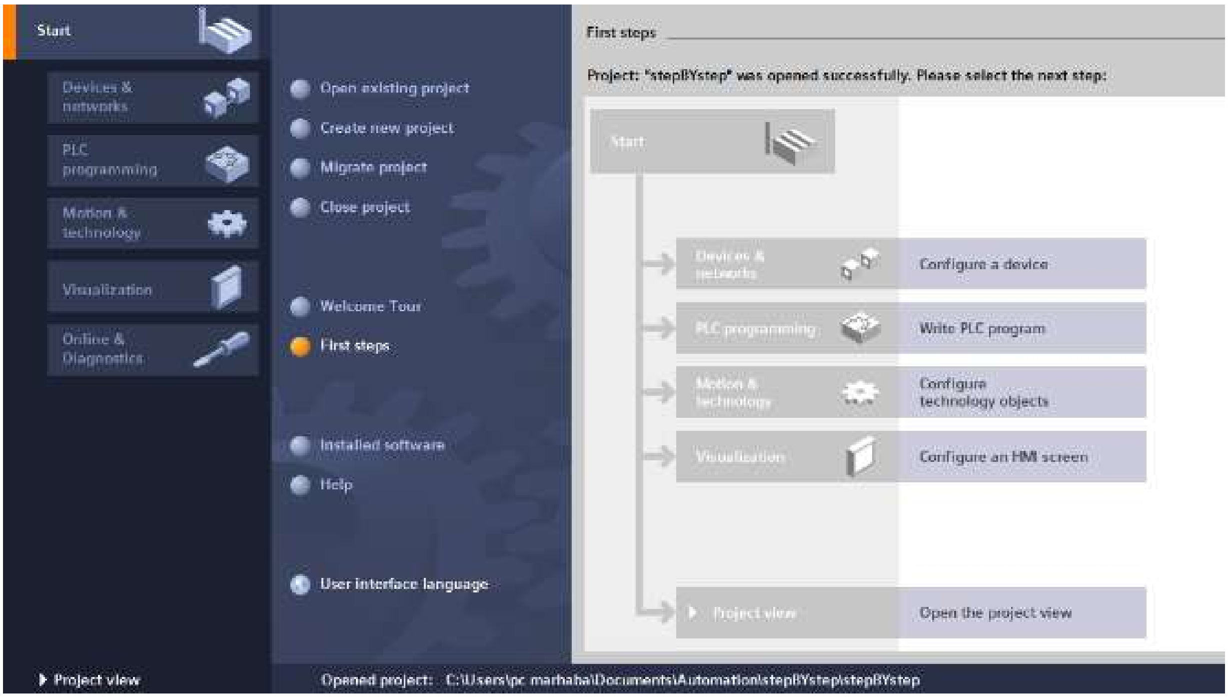


Figure III.14:Tia Portal v14 window.

III.3.3.2. Programmable logic controller

1. Configuration:

Configuring hardware for a Siemens S7-1200 PLC in TIA Portal involves setting up the physical components of the system to enable the PLC to perform its intended functions. Here are the general steps for configuring hardware for a S7-1200 PLC in TIA Portal:

a) Add the hardware to the project: Start by adding the S7-1200 PLC hardware to the TIA Portal project. This involves selecting the appropriate device type and model and adding it to the project.
b) Configure the communication settings: Configure the communication settings for the PLC by specifying the IP address, subnet mask, gateway address, and other network parameters. This will enable the PLC to communicate with other devices in the system, such as HMIs, other PLCs, and remote I/O.
c) Add hardware modules: Add the required hardware modules to the system, such as digital and Analogue input/output modules, communication modules, and power supply modules. Configure the parameters for each module, such as the input/output addresses and the module type.

2. Program blocks:

Main OB1: OB1 refers to the main organization block in a programmable logic controller (PLC) program. OB1 is executed cyclically during normal operation of the PLC and typically contains the main program logic for the system.The OB1 block is responsible for coordinating the execution of other blocks in the program and ensuring that the system operates as intended.
It typically contains the main program logic, which is executed repeatedly during each scan cycle of the PLC. The OB1 may also include calls to other organization blocks, such as function blocks (FBs) and system function blocks (SFBs), as well as to other parts of the program.
Cyclic interrupt OB30: OB30 is a cyclic interrupt organization block that is executed at a specific time interval during the normal operation of PLC. The purpose of OB30 is to perform cyclic tasks that need to be executed at a fixed time interval, which is typically specified in milliseconds. During each execution, the block performs a specific set of tasks, which can include reading inputs, performing calculations, and updating outputs.
For that we are using the PID Compact function block with a cyclic interrupt OB30 can enable precise and efficient control of a system configure the PID Compact function block by setting the appropriate parameters, such as the proportional gain, integral time, derivative time, and filter time. These parameters will depend on the specific requirements of the system and it can be adjusted to optimize the performance of the PID controller.

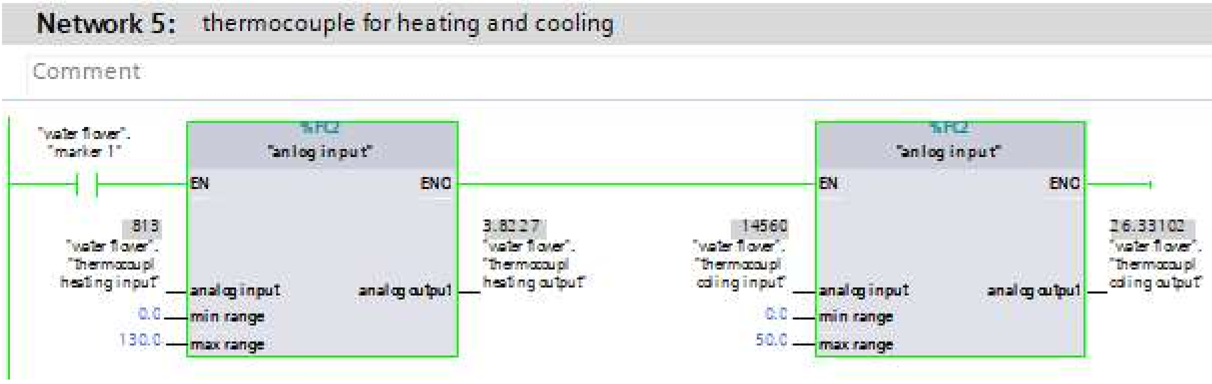


Figure III.15:Program ladder oh heating and cooling.

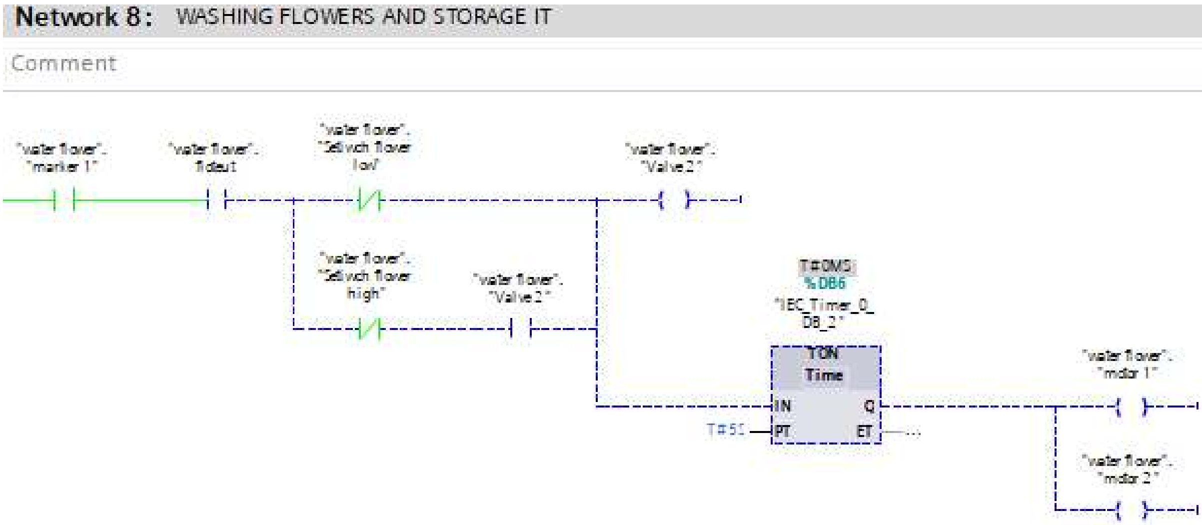


Figure III.16:Program ladder of washing raw material.

Function (FC) & Data block: FC and DB are two types of programming blocks used in Siemens PLCs.

FC stands for "Function Block" and is a type of block used to define a specific function or operation that it can be called from other parts of the program. Function blocks are reusable and can be used in multiple parts of the program, which can help to simplify program logic and improve program organization. The function blocks are typically used for complex operations that require multiple inputs and outputs, such as mathematical calculations or data manipulation.

DB stands for "Data Block" and is a type of block used to define a collection of data elements that can be used throughout the program. Data blocks are typically used to store input and output data, as well as intermediate results, and It can be accessed by other parts of the program as needed. Data blocks can be structured in various ways, depending on the specific requirements of the program.

FCs and DBs can be created and edited in TIA Portal's programming environment, and they can be used together to create complex automation systems. By using function blocks and data blocks, engineers can create modular and reusable code that is easier to develop, test, and maintain. Additionally,

3. PLCsim:

PLCsim is a simulation tool in TIA Portal that allows engineers to test and debug PLC programs in a virtual environment, without the need for physical hardware. PLCSIM can simulate the behavior of a wide range of Siemens PLCs, enabling engineers to test and verify their programs before they are deployed to the actual hardware. One of the key benefits of using PLCSIM is that it allows engineers to test and verify their PLC programs before they are deployed to the actual hardware. This can help to reduce the risk of errors and downtime, while improving the efficiency and reliability of the system.

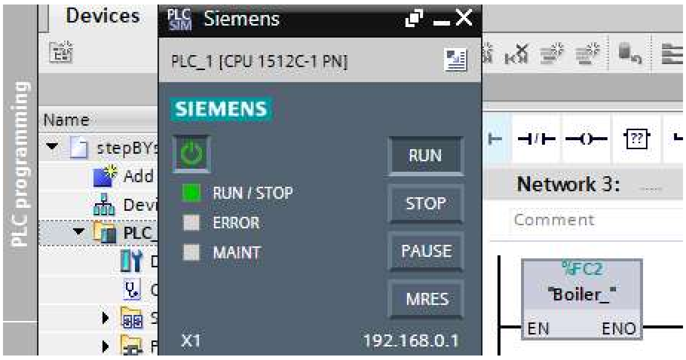


Figure III.17: PLCsim window screen.

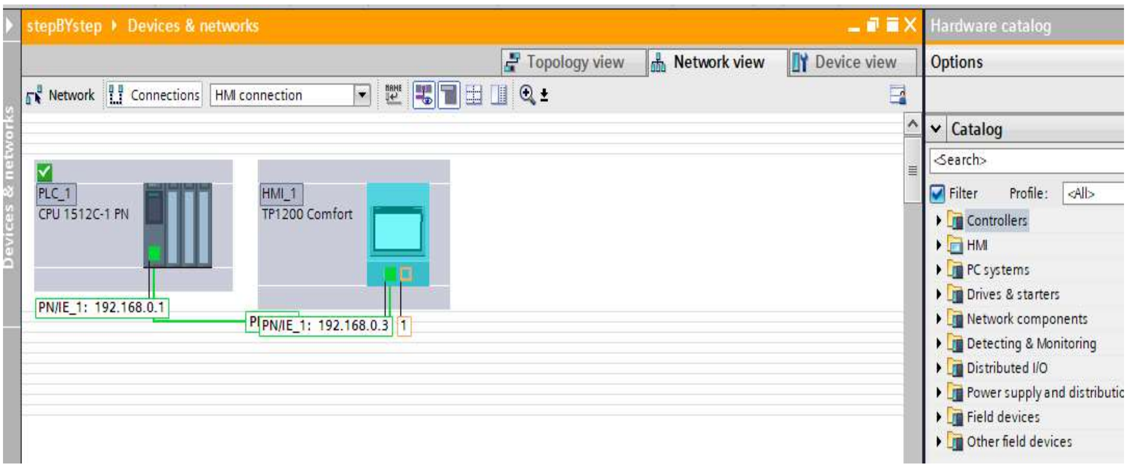
III.3.4. Plant supervision Programming

III.3.4.1. Human machine interface choice

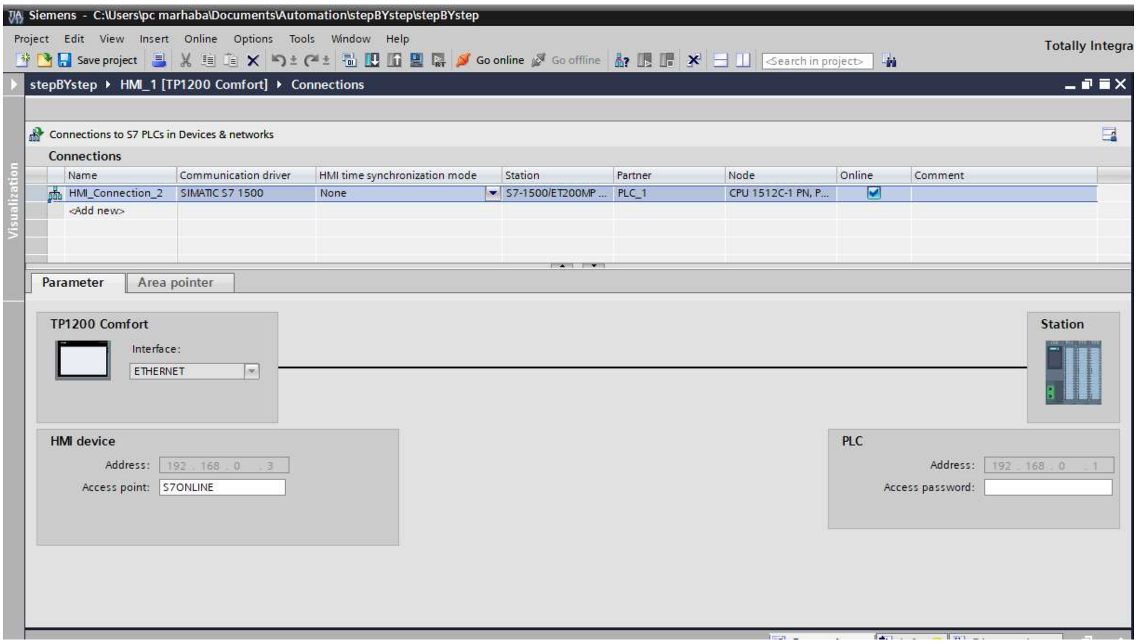
It is designed for use in industrial automation applications and features a 12-inch touch screen display, high-resolution graphics, and a range of communication options.It can be used to display and control information from a PLC system, such as data from sensors and other input devices, and can provide real-time feedback on system status and performance.The device can be programmed using TIA Portal, allowing engineers to create custom graphics, screens, and user interfaces for the system.

The HMI TP1200 Comfort supports a range of communication protocols, including Ethernet, PROFIBUS, and PROFINET, which it can be used to connect to other devices in the system, such as PLCs, sensors, and actuators. The device is also designed to be rugged and durable, with an IP65 rating for protection against dust and water.

III.3.4.2. PLC-HMI Connection



(a)



(b)

Figure III.18: Connection between PLC and HMI.

III.3.4.3. HMI tags

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

1. HMI Screens

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

HMI screens are a crucial component in modern automation and control systems, providing a vital link between human operators and machines. They enhance efficiency, safety, and productivity across various industries by offering intuitive control and real-time monitoring capabilities.

2. Login screen:

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

Figure III.19**:** Login screen.

3. Home screen:

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

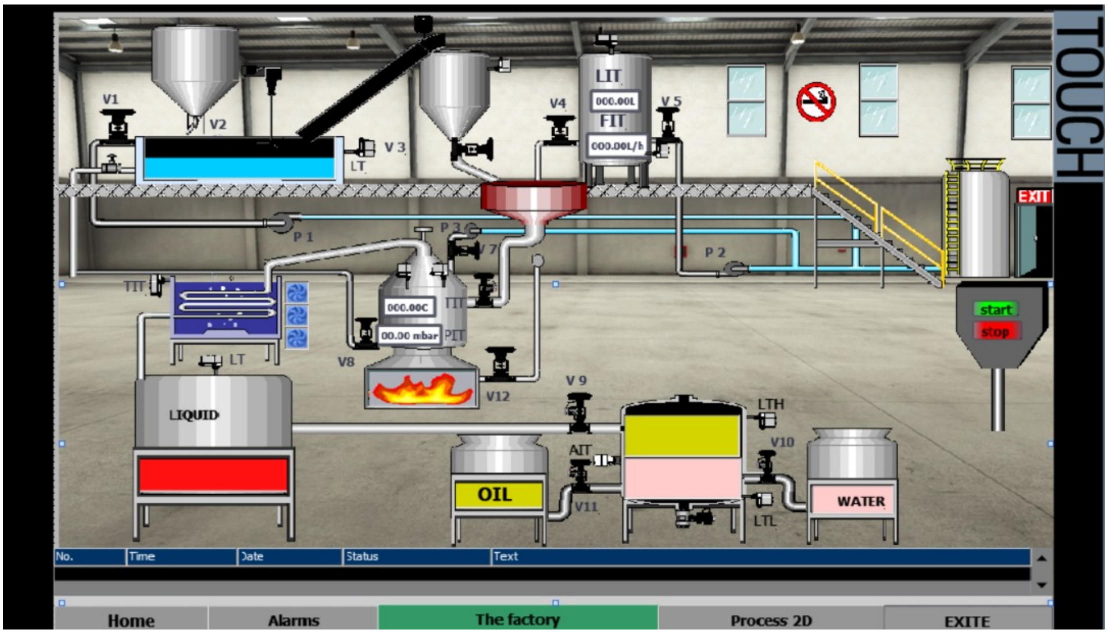


Figure III.20**:** 3D Screen of the factory.

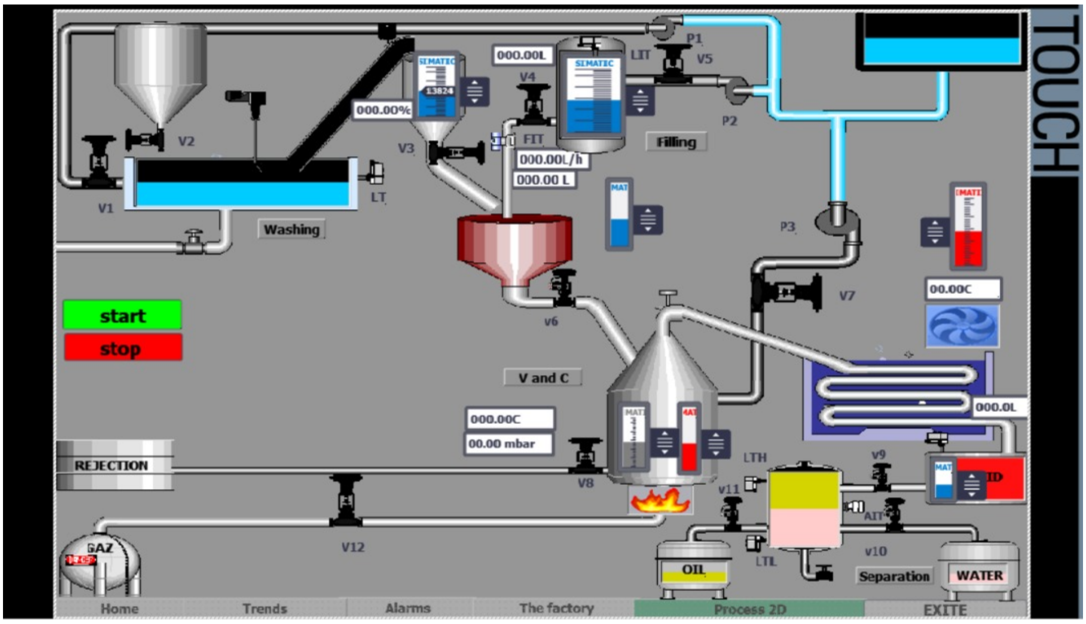


Figure III.21: 2D Screen of the factory.

4. WASHING screen:

In this step:

1. Filling Tank for washing raw material and filling tank raw material of process.
2. The pump fills the tank until a sensor signals it's full, then the pump stops and the valve closes.
3. The sensor opens the valve to release the raw material, and then the mixer starts after a delay to wash and push the material to the conveyor.

4. Open the raw material discharge valve, the conveyor transports the raw material to the standard tank, which is monitored by low and high-level sensors.

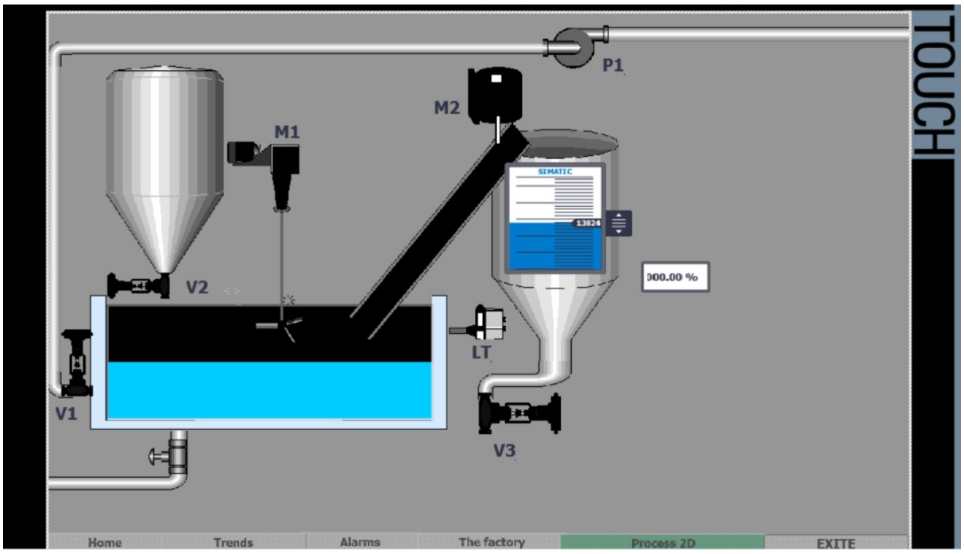


Figure III.22: Filling washing tank.

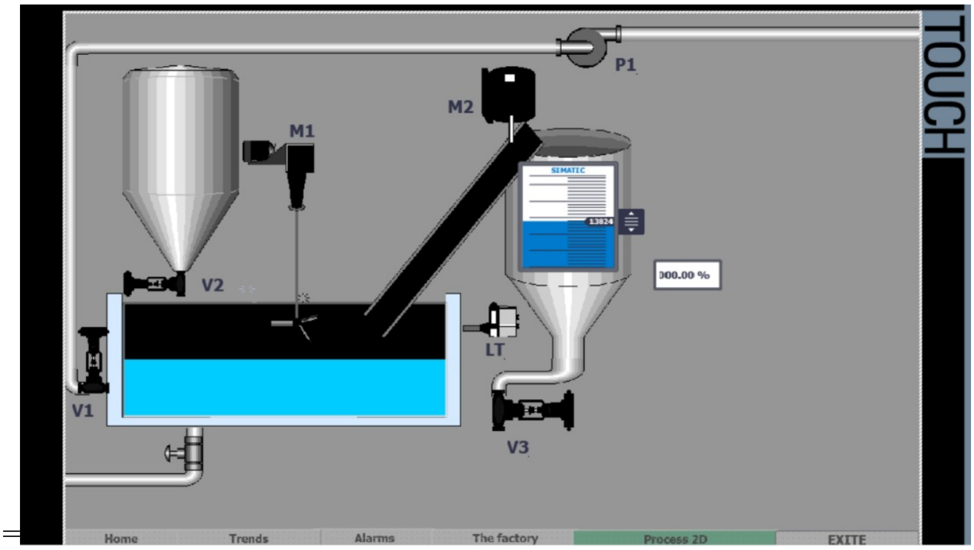


Figure III.23: Filling Raw material tank.

5. WATER TANK screen:

In this step:

1. The pump and fill valve open to fill the water tank, monitored by a level sensor. Once full, the pump stops and the valve close.
2. When opening the water discharge valve, the water discharge valve is now open, allowing water to flow out.

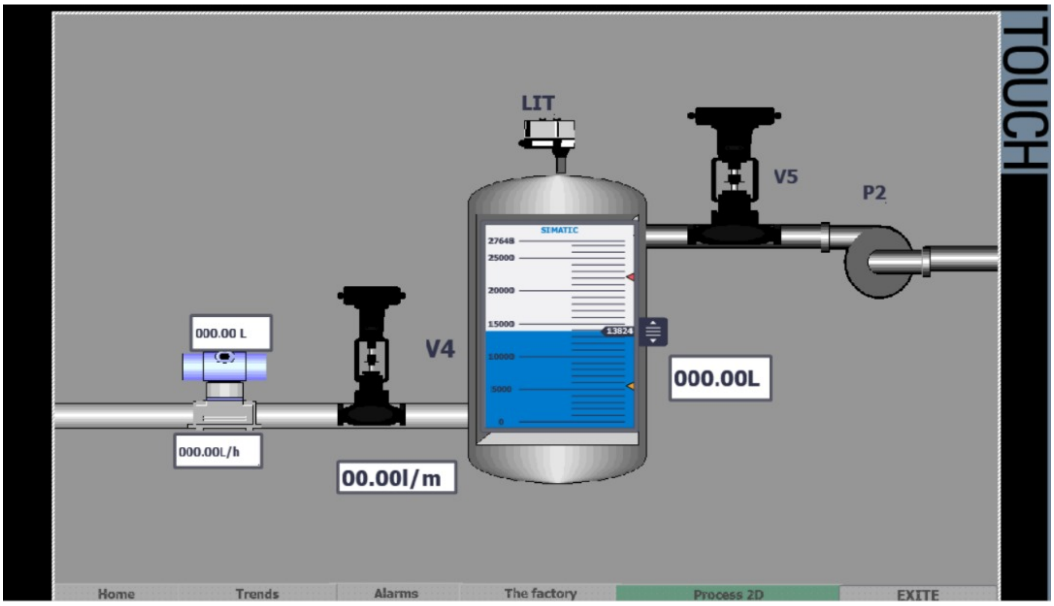


Figure III.24: Filling water tank.

6. VAPORIZATION AND CONDENSATION screen:

In this step:

1. Wash the boiler, once the raw material tank and water tank are filled, the washing process for the boiler begins with the pump starting and valves opening to allow water in and discharge any residue.
2. Discharge the raw material, the raw material valves are currently open, allowing the ingredients to flow through.
3. Discharge the water, the water tank valve opens, releasing water in proportion to the raw material. This ensures the correct balance of ingredients for the process
4. Open gaze valve, the gas valve opens, igniting the fire under the kettle, causing the water to boil at 100 degrees Celsius. At 130 degrees Celsius, the gas valve automatically closes, and when pressure reaches a certain level, the safety valve also opens.

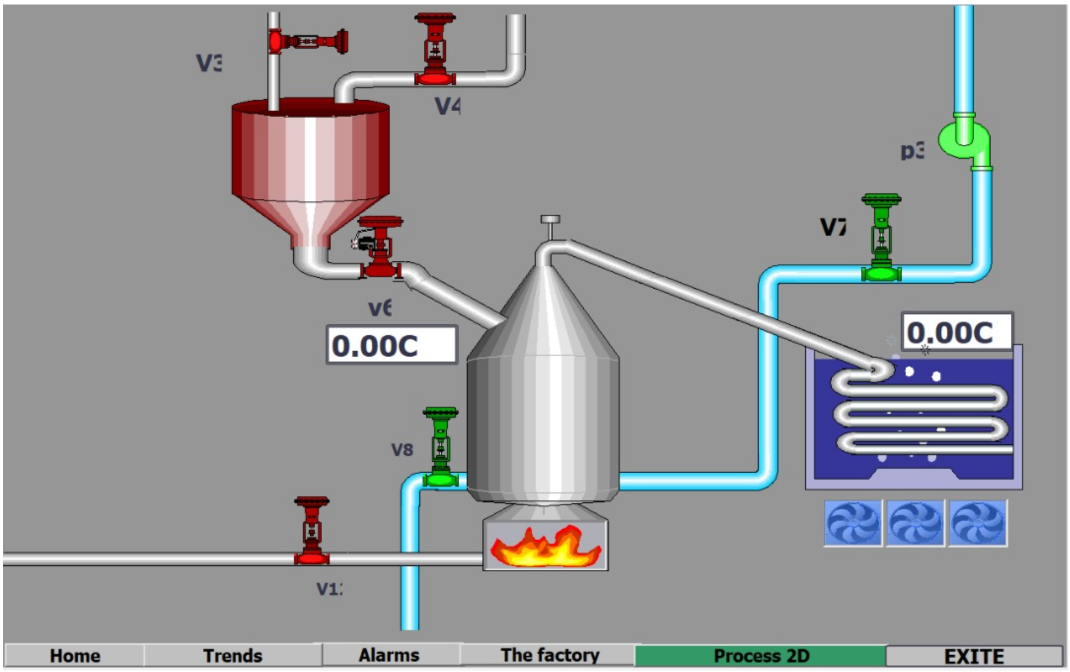


Figure III.25: VAPORIZATION AND CONDENSATION screen.

7. Separation screen:

In this step:

1. Filling separator, the separator fills until the high-level sensor triggers the closure of the mixture discharge valve.
2. Filing tank of water extracted from raw material, the tank fills with water extracted from the raw material until the high-level sensor signals closure.
3. Filing tank of Essential oil, the tank fills with essential oil until the high-level sensor indicates closure.

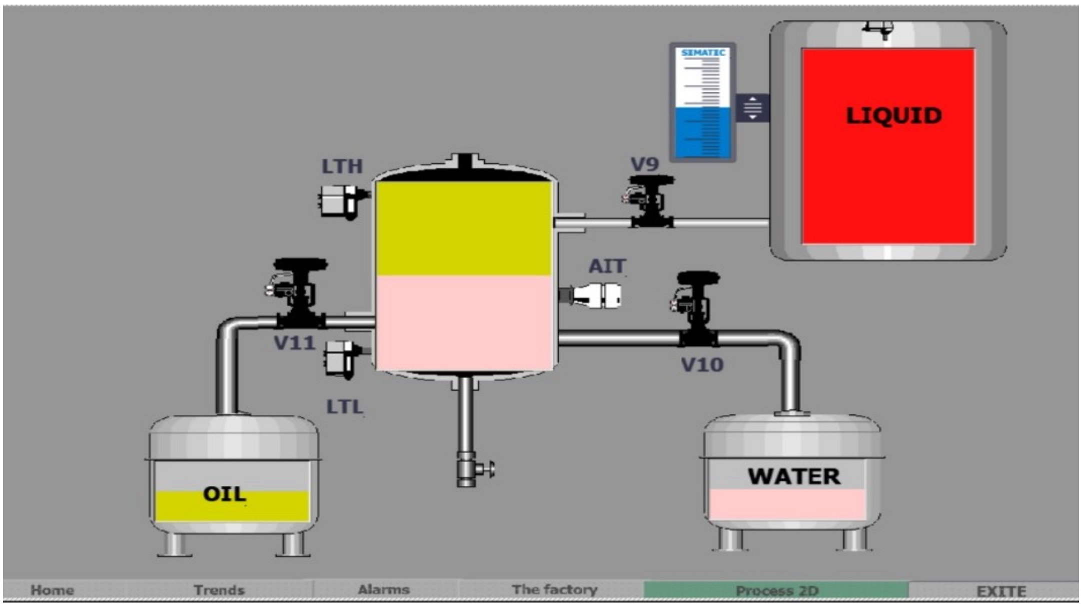


Figure III.26: SEPARAATION screen.

8. ALARMS screen:

They are notifications that indicate a problem or abnormal condition in a PLC system. Alarms can be triggered by a variety of events, such as a sensor failure, a machine fault, or a process deviation, and are used to alert operators and engineers to potential issues.

Alarms in TIA Portal can be customized with various settings, such as priority, severity, and acknowledgement requirements. For example, you might configure a high-priority alarm for a critical machine fault that requires immediate attention, while a lower-priority alarm might be used to indicate a non-critical process deviation. The Alarms window displays alerts for high pressure and high temperature conditions, helping operators monitor critical parameters for system safety and efficiency. Alerts prompt immediate intervention to prevent equipment damage or hazards.


Alarm window

	No.	Time	Date	Status	Text	Acknowled
!	2	11:15:03 PM	6/11/2024	I	H PRESSUER	0
!	4	11:15:03 PM	6/11/2024	IO	LL PRESSUER	0
!	3	11:15:03 PM	6/11/2024	IO	L PRESSUER	0
!	6	11:13:30 PM	6/11/2024	I	H Temperature	0
!	5	11:13:30 PM	6/11/2024	I	HH Temperature	0
!	8	11:12:52 PM	6/11/2024	IO	LL Temperature	0
!	7	11:12:52 PM	6/11/2024	IO	L Temperature	0

Figure III.27: ALARMS screen.

9. Security:

It refers to the ability to protect a PLC system and its data from unauthorized access and manipulation. Security is an important consideration in industrial automation applications, where the reliability and safety of the system rely on the integrity of the PLC data and control. Security features: User management, Password protection, Encryption and Firewall protection.

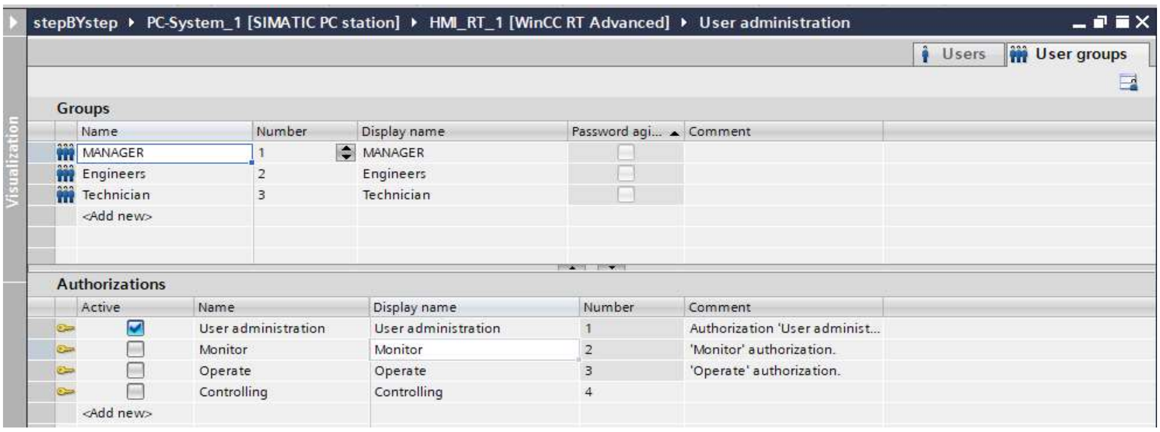


Figure III.28:Security screen.

III.4. Bottling system programming

Bottling line is designed to fill and package different products in order to achieve a finished product. Like many sectors that exist, there are different types and ranges of machines in each area. Thesesystems are often used in the food, cosmetics and pharmaceutical industries to fill bottles of products such as drinks, sauces, lotions and medicines, and today we use them in the manufacture of essential oils.

III.4.1. Steps of System Functions

a) **Conveyor System:** When the “Start” button is pressed, the emitter and motor are activated and the conveyor begins to move forward

b) **Moving the bottle to the First sensor:** When the bottle reaches the first sensor, the sensor engages and then the motor stops

c) **Filling process**: When the first sensor is activated, the filling machine and the level sensor operate. When the bottle is filled, the level sensor sends a signal, so the filling machine stops and the motor starts again

d) **Moving the bottle to the second sensor:** After filling is complete, the motor continues to move the conveyor belt to transport the bottle to the second sensor

e) **Capping process:** When the bottle reaches the second sensor, the closing mechanism is activated, and the lid is lowered onto the sensor to seal the bottle tightly. The system will only restart if the cylinder rises.

f) **Moving the bottle towards the third sensor:** when the cylinder rises, the bottle transport to the third sensor

g) **Labeling Process:** When the bottle reaches the third sensor, the labeling machine is activated and then lowers to place the cap on the bottle, after which the machine rises and the bottle continues moving towards storage.

III.4.2. Bottling system automation programming

An automatic bottling, capping and labeling line is a system used in industry for filling bottles with different liquids and sealing them tightly with caps and label. It is designed to automate the bottling process, allowing to increase the efficiency and productivity of the production line [1]. A bottle machine with filling and capping functions is controlled by a compact Programmable Logic Controller (PLC) and a simple Human Machine Interface (HMI). The HMI displays real-time data and status information, while the PLC monitors machine components and sends signals to motors and actuators for operation.

III.4.2.1. Program ladder in Tia Portal v14

a) Conveyor System

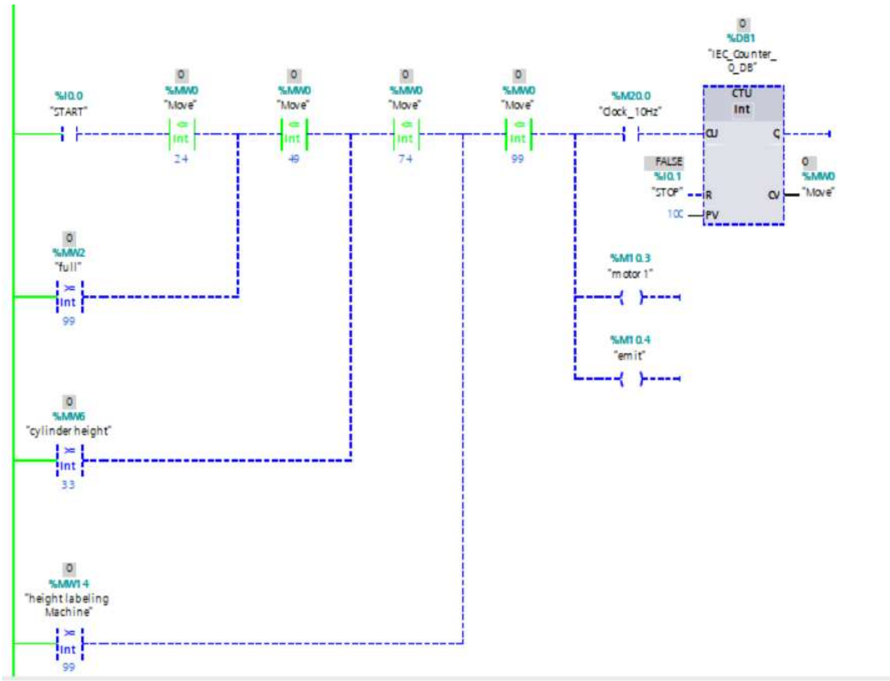


Figure III.29: Ladder basic mobility program.

b) Filling Process

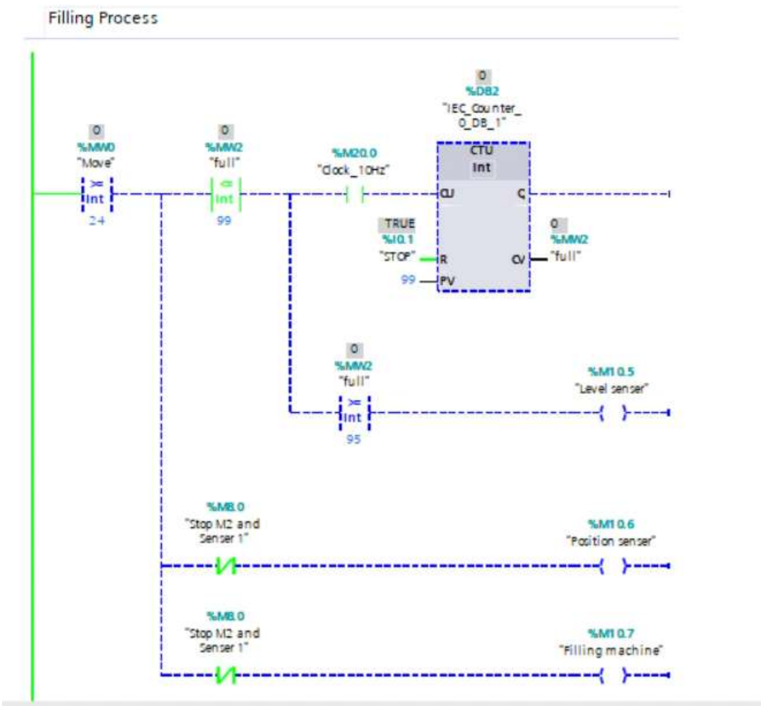


Figure III.30: Ladder basic capping program.

c) Capping process

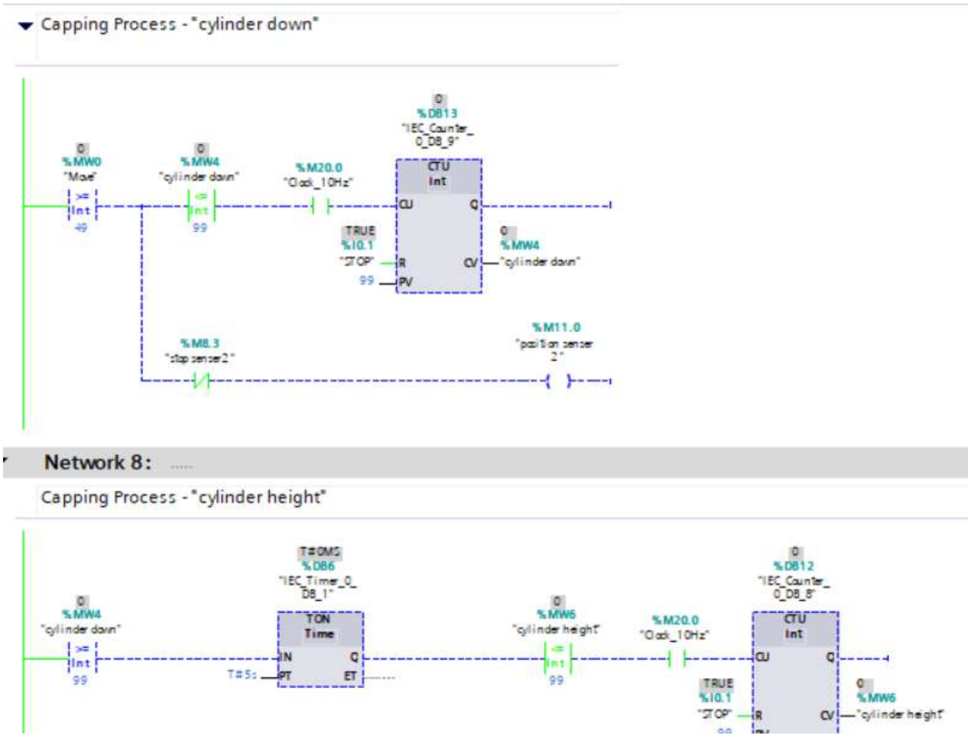


Figure III.31: Capping process.

III.4.3. Bottling system supervision programming

1. BOTTLING LINE Screen:

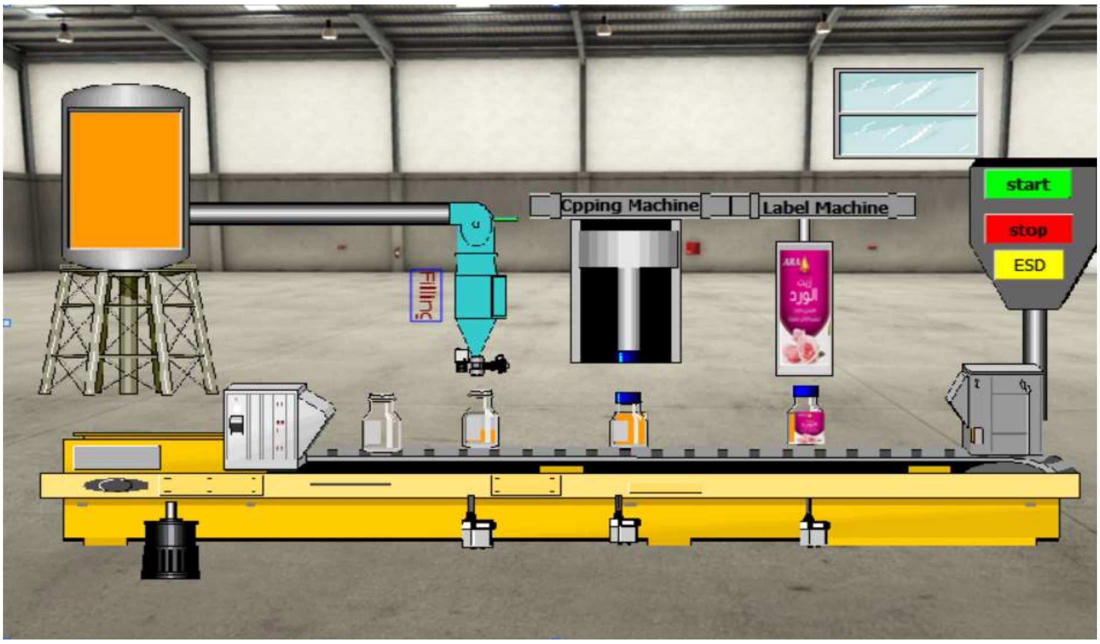


Figure III.32: BOTTLING LINE Screen.

Raising the capping machine, stop second position sensor and the bottle moving to the second Position.

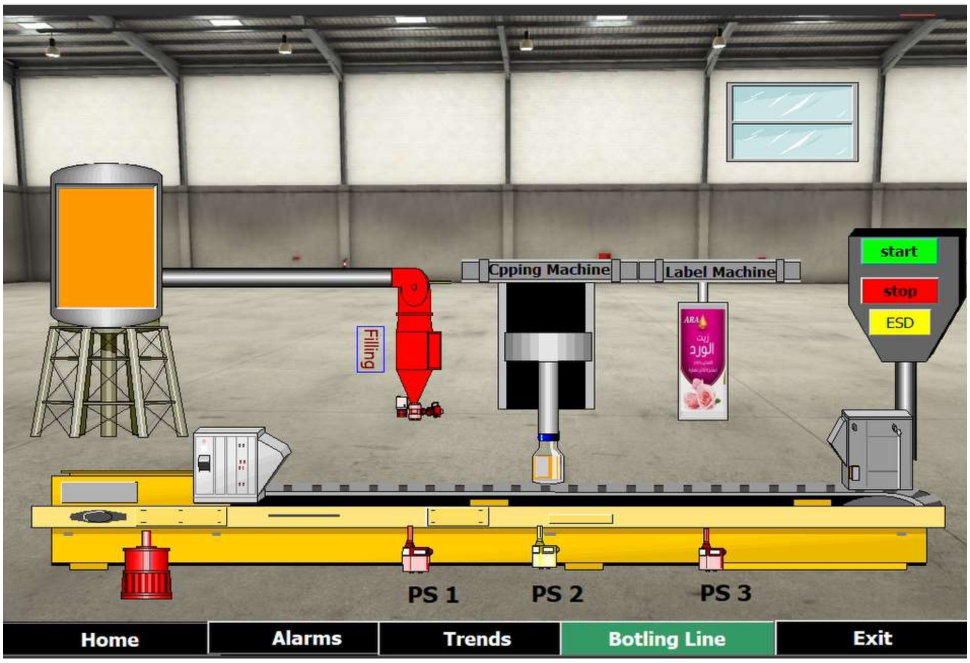


Figure III.33: The capping machine.

The third position sensor activated and the label mechanism descends. Raising the label mechanism and stopping third position sensor. The bottle moves to the storage.

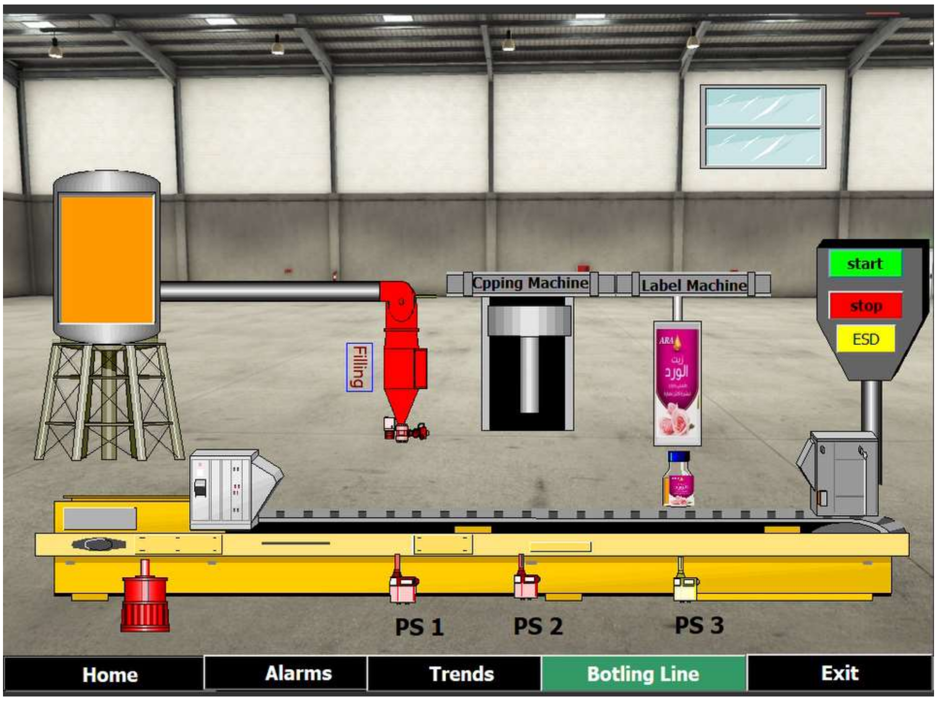


Figure III.34: The labeling machine.

III.5. Bottle storage container system

A bottle storage container system is designed to efficiently store, organize, and transport bottles, often used in industries such as beverage, pharmaceuticals, cosmetics, and household chemicals.

III.5.1. Steps of System Functions:

a) **Initial Dispatch:** The emitter sends the box containing the oil bottles to the first position.

b) **First Position Sensor:** When the box reaches the first position, the conveyor stops and the position sensor sends a signal to the robotic arm, which moves the box from the first position to the second position.

c) **Transfer to the Second Conveyor:** When the robotic arm places the box on the second conveyor, the second position sensor sends a signal to the robotic arm to rise, and the conveyor moves the box to the third position.

d) **Dispatching Boxes:** Another dispatcher sends pallet to carry the boxes when they reach the third position.

e) **Third Position Sensor:** When the box reaches the third position, the position sensor sends a signal to the robotic arm to carry the box and place it into the pallet.

f) **Transporting Boxes to Storage:** The pallet carrying the boxes is transported to the storage area.

g) **Counting the Boxes:** At the end of the conveyor, there is a counter to count how many boxes have passed.

III.5.2. Bottle storage container system automation programming

III.5.2.1. Program ladder in Tia Portal v14

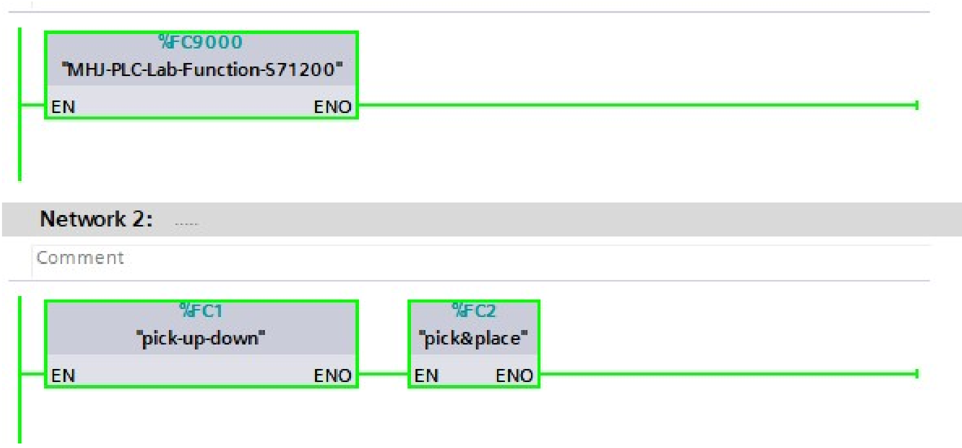


Figure III.35:Program ladder in Tia portal v14.

III.5.3. Simulation and Supervision with Factory I/O

III.5.3.1. Steps of System Functions:

a) **Initial Dispatch:** The process begins with the initial dispatch, where the emitter sends the box containing the oil bottles onto the conveyor belt, directing it towards the first position.

b) **First Position Sensor:** As the box travels along the conveyor, it reaches the first position sensor (S1), which promptly detects its presence. This action triggers the position sensor to send a signal to the robotic arm, indicating that the box is ready for the next step.

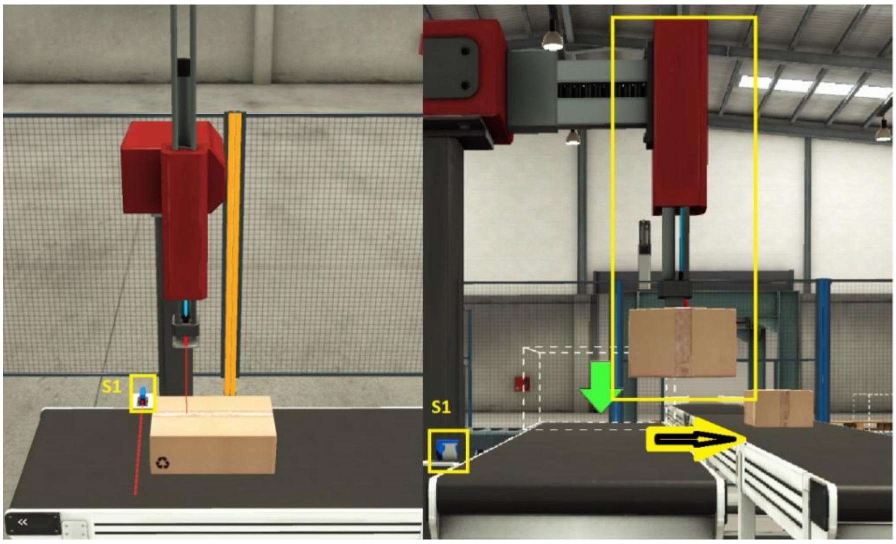


Figure III.36: Initial dispatch, first position and box transfer steps.

c) **Transfer to the Second Conveyor:** The robotic arm then activates, carefully picking up the box from the first position and transferring it to the second position (S2).

d) **Dispatching Boxes:** The process continues with the dispatching of boxes, where another dispatcher sends a pallet to the third position to carry the boxes once they arrive.

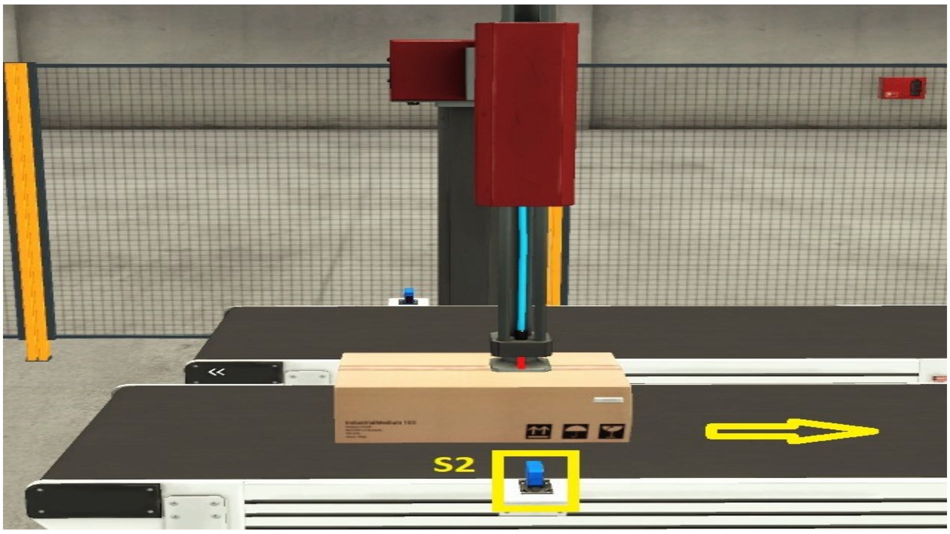


Figure III.37: Second position step and boxes dispatching step.

e) Third Position Sensor: As the box advances through the conveyor system, it eventually reaches the third position sensor (S3). This sensor detects the box's presence and sends a signal to the robotic arm, indicating that the box is now in position. The robotic arm then activates again, lifting the box from the third position and carefully placing it into the pallet provided by the dispatcher. This coordinated effort ensures efficient and accurate handling of the boxes throughout the entire process.

f) Transporting Boxes to Storage: The pallet carrying the boxes is transported to the storage area.

Figure III.38: Third position step and boxes storage step.

h) Counting the Boxes: At the end of the conveyor, there is a counter to count how many boxes have passed.

Figure III.39: Boxes counting step.

Conclusion

This chapter discussed the various processes and systems involved in automation within the industry. It covered the use of different types of sensors, such as thermometers, radar level gauges, and capacitive proximity sensors, and their roles in monitoring and controlling industrial processes. It also elaborated on the operation of automatic bottling, capping, and labeling lines, emphasizing the significance of Programmable Logic Controllers (PLCs) and Human Machine Interfaces (HMIs) in enhancing efficiency and productivity. Furthermore, the chapter described the programming and supervision of these systems using software tools like Tia Portal and Factory i-o and SCADA, demonstrating how automation improves precision and reliability in industrial operations.

The system under study is an automated system designed to extract water and oil from aromatic and medicinal plants, such as rose, mint, rosemary, and nutmeg, with the primary purpose of extracting oil. The system is divided into two parts: the first part involves the automated distillation process for extracting oil and water, while the second part involves the automatic filling and capping of bottles. This chapter presents the programming and simulation of the automated system using Tia portal, Win CC, and Factory I/O software.

General Conclusion

General Conclusion

The main objective of this thesis is to transform a handmade essential oils extraction factory into an automated factory to reduce human effort and increase productivity with high quality through simulation using Siemens programs. This study was carried out with the first step being to convert each manual process into an automated process, and the study was divided into three parts: the first part is related to the general process, which is steam distillation, the second part is bottling, and the third part is storage.

A standards manual was created for each part to facilitate the application of the ladder program on TIA Portal. A control station was created for each part, separate from the others. The first step in applying the ladder program on TIA Portal was hardware configuration, and CPU1200 DC/DC RLY was chosen. Then an FC block was created to apply the subprograms along with a data block to hold all the data. The FC block is called in the main block, and finally, the simulation is performed to verify the program's accuracy. After verifying the program, a SCADA system and HMI were created to design, monitor, and control the automated factory through the program. It was divided into several screens, including Home, Alarm, Trend, Process, etc.

The first and second parts were monitored through the SCADA system with 2D design, but the third part was simulated using Factory I/O, a 3D design program. One of the main objectives was to design a digital twin for this 3D factory. However, due to the limited tools in the program, it was difficult, if not impossible, to create a digital twin for the entire factory, so we designed only the last part with the available tools.

Finally, we state that since creating the digital twin with the Factory program is almost impossible now, and since the program is still under development, we call for the future development of this work if the Factory program is improved. The digital twin allows for the modeling of operations and identifying possible improvements before actual implementation. It can predict potential failures, allowing for proactive maintenance planning and reducing downtime.

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