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FACULTE DE TECHNOLOGIE
DEPARTEMENT D'AUTOMATIQUE DE TELECOMMUNICATION ET D'ELECTRONIQUE

Master's Research Project

For the Attainment of Master's Degree

Field of Study: Automation
Specialty: Industrial Automation and Computing

Topic:

Automation and Supervisory System of the Powdered Chocolate Transfer Process

- CEVITAL Sugar Packaging Unit -

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Dedication

Above all, I dedicate this work to Almighty God, whose grace, direction, and abiding presence have carried me throughout this journey. Without His power, none of it would have been possible.

I also dedicate this work to my wonderful parents and siblings, whose support, prayers and faith in me has really been a solace. I really could not have done it without your love and support, which has sustained me throughout this process.

Lastly, I dedicate this work to myself, for never losing sight of what I wanted, for staying strong through all, and for not giving up even when the road was uncertain. This is a testament to that inner strength.

Thank you so much.
Mwageru Mercy Marura

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Abbreviations

Abbreviation	Long term
PLC	Programmable logic controller
CPU	Central Processing Unit
HMI	Human Machine Interface
TIA	Totally Integrated Portal
RAM	Random Access Memory
ROM	Read Only Memory
IL	Instruction List
ST	Structured Text
FBD	Function Block Diagram
LD	Ladder Diagram
OB	Organization Block
FB	Function Block
DB	Data Block

General Introduction

General Introduction:

Automation in manufacturing industries refers to the use of machines such as PLCs, motors, and sensors to perform tasks with very little or no human intervention. Over the years, technology has drastically evolved, leading to an increased number of manufacturing industries. Automation plays an important role in industries as it boosts productivity and efficiency, reduces human labor, and contributes to the reliability of the overall functioning of industrial processes.

CEVITAL, the largest private agri-food company in Algeria, stands as a leading force in Algeria's agri-food sector, known for its high-quality products. It operates several advanced automated production units. Among its several units is the sugar-packaging unit, which is well-designed for efficiency, reliability, and minimal human intervention. However, some stages in the production chain experience certain inefficiencies, thus requiring improvement.

The food processing industry is crucial, especially in meeting high global demand for quality food products. Food processing involves modifying one or more items into another. An example is sugar and cocoa powder to get powdered chocolate. The final product after food processing will then require transferring, for example, the transfer of powdered chocolate.

As part of my master's research study aiming at improving and automating the powdered chocolate transfer process, I am doing a practical internship at CEVITAL Sugar Packaging Unit. The transfer process is currently manually operated and experiences frequent blockages, which slows operational processes. Following the current situation, an immediate study of the process and development of possible potential solutions is important.

The main objective of this study is to analyze the current powdered chocolate transfer process, highlight its limitations, and develop a robust automated solution that will solve the current inefficiencies and boost the overall functioning of the process.

To attain the main objective of this research project, the methodology of approach adopted, is as follows:

- The first step involves a thorough study of the process through onsite observations and collection of data that will help in the analysis, and understanding of the overall process.
- Suggestion of potential solutions to solve the current inefficiencies of the current powdered chocolate transfer process.

This work is divided into four main sections:

Chapter 1: Overview of CEVITAL – This section gives a general overview of the company.

Chapter 2: Industrial Automation Concepts – This chapter provides an overview of industrial automation principles, with a focus on PLCs

Chapter 3: Study and analysis of the Current Powdered Chocolate Transfer Process – It covers the overall overview of the current powdered chocolate transfer process, experienced challenges, and proposals of potential solutions to solve the current inefficiencies and boost overall operations of the process.

Chapter 4: Programming and Supervision – This chapter covers the main aspects of programming and supervision of the proposed automated solution, to improve the current chocolate transfer process.

Overall, this study aims to improve the operations of the powdered chocolate transfer process at CEVITAL Sugar Packaging Unit by implementing a robust solution that will automate the process and solve the current inefficiencies hence enhancing reliability and overall functioning of the process

Chapter 1: Overview of CEVITAL

1. Overview of CEVITAL

1.1 Introduction

CEVITAL is Algeria's largest private industrial company and a key player in the agri-food sector, ranked both nationally and internationally. It serves a major role in sustaining Algerian economic growth, primarily within the food-processing industry. CEVITAL continues to grow and expand its operational activities, with a commitment to efficiency and meeting its sustainability.

This section gives a detailed overview of CEVITAL group. It explores the company's background and history, geographical location, operations and activities as well as the company's development strategy. Additionally, final touches will be on the CEVITAL Sugar Packaging Unit, where the powdered chocolate transfer Process draws its roots.

1.2 CEVITAL Historical Development

1.2.1 Establishment

- CEVITAL was established in 1998. [1]
- Initially, the company focused on the agri-food sector, with its production lines situated at the Port of BEJAIA, covering approximately 45,000 m². [2]
- Over years, CEVITAL has established itself as a pivotal player in Algeria's economic growth by significantly expanding its financial ventures within various industrial sectors.

1.2.2 Significant Milestones and Growth

- **1998:** Launch of Elio edible oil [1]
- **2001:** Launch of Fleurial and Matina margarine, and Gourmand soft butter [1]
- **2002:** Launch of Skor sugar (1KG) [1]
- **2006:** Launch of Tchina juice drinks [1]
- **2007:** Launch of Lalla Khedidja mineral water [1]
- **2010:** Launch of liquid sugar [1]
- **2013:** Launch of calcium lime [1]
- **2015:** The production of food $C0_2$ gas [1]
- **2016:** Launch of brown sugar [1]
- **2018:** Launch of sauces and condiments [1]
- **2020:** Launch of plastics production [1]
- **2023:** Crushing of oil seeds [1]

Figure 1:1 CEVITAL products

1.3 Geographical Location

CEVITAL is strategically situated at the new quay of the Port of BEJAIA, about 3 kilometers to the southeast of the city, close to the RN 26. This geographical presence offers the company a strong economic advantage due to its closeness to major transport facilities, including the port and the airport. Such facilities enhance efficient export and import operations, crucial for the organization's mass production activities.

The establishment covers an area of 14 hectares and is integrated with a specialized laboratory for carrying out certain analyses and control measures. These analyses contribute to the optimal functioning of the organization's operations by monitoring the quality of raw water, osmosis water, as well as boiler and cogeneration feed water. This rigorous quality control process plays a critical role in maintaining quality standards of streamlined efficiency and product excellence.

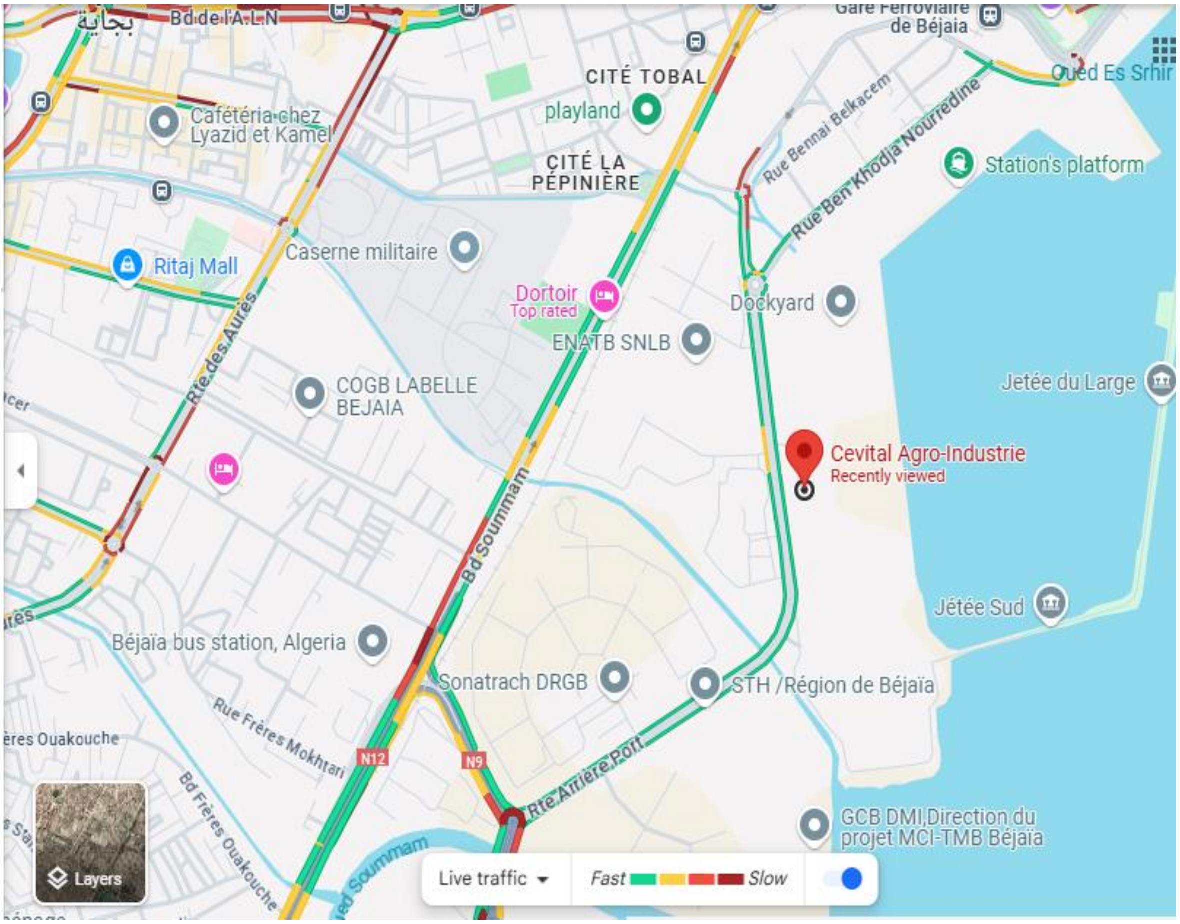


Figure 1:2 CEVITAL on Google maps

1.4 Company Operations & Activities

CEVITAL operates various enhanced production units focused on the production and commercialization of sugar, margarine, vegetable oils and other products. The company's activities include:

- Two sugar refineries – processing 6,000 tons per day
- Liquid Sugar Production unit
- One oil refinery
- Margarine production unit
- One mineral water packaging unit
- One unit for soft drinks manufacturing
- One canning plant/unit
- One unit for quicklime manufacturing
- Cogeneration unit
- Port silos and port unloading terminal - with 2,000 tons/h capacity

The company's expertise, high-performance facilities, rigorous quality control, and supply network enable the company to produce high-quality products at reasonable prices. It meets local demand and has contributed to transforming Algeria from being an importer to an exporter of sugar, oils, and margarine. Its products are distributed across various countries, including Europe, the Maghreb, the Middle East, and West Africa.

The company's customers include some of the world's known establishments in agri-business such as Coca-Cola, Danone, and Kraft Foods.

Key figures:

Nearly 500,000 tons of white sugar refined to EEC No. 2 specifications, were exported in 2015. [3]

1.5 Company Development Strategy

CEVITAL's development strategy is rooted in its founder's grand vision of creating a globally competitive industrial enterprise with a major focus on international exports. The company's strategic roadmap promotes competitiveness through excellence in pricing, quality, automation, production volumes, logistics, and strategic co-location.

Additionally, research and development, innovation, and employee skill set are essential in promoting the company's growth. These assets give CEVITAL a competitive edge and lay a foundation of a robust export industry, which creates job opportunities for Algeria's young generation.

According to Issad REBRAB, CEO of CEVITAL, the foundation of success of the group is built upon seven critical pillars:

1. Continuous Reinvestment – consistent reinvesting profits in emerging sectors with substantial growth value.
2. Technological advancement – Exploring and adopting the most cutting-edge technological solutions.
3. Recruiting the right expertise
4. Entrepreneurial spirit
5. A Sense of innovation
6. The pursuit of excellence
7. Pride and commitment for boosting the nation's economy

1.6 CEVITAL Sugar Packaging Unit

1.6.1 Overview

CEVITAL sugar packaging unit spans an extensive area of 1,131.9m^2, with approximately 430 workers across different departments. The departments include: production, maintenance, and shipping. This packaging unit is developed to guarantee:

- **Product safeguarding and preservation** – Protecting the standard and freshness of product throughout its lifespan.
- **Brand identity** – easy identification of products in stores.
- **Consumer attraction –** grabbing attention of potential buyers through appealing packaging design.

1.6.2 Packaging Process

Various sizes and types of bags are used to package the sugar produced by the machines, which include:

- **Standard 1 kg bag**
  The production of the 1 kg packet is carried out by twenty-eight packaging machines installed on seven independent lines, with a nominal rate of 70 bags per minute.

- **Standard 5 kg bag**
  The 5 kg bag is produced by a single packaging machine with a double filling tube, operating at a nominal rate of 25 bags per tube. It is equipped with an OCS checkweigher, similar to the 1 kg packaging machine.

- **1 kg pourable bag**
  The 1 kg pourable bag is produced by two packaging machines with a nominal rate of 80 pourable bags per minute.

- **750g sugar cubes box**
  The production of 750g boxes of sugar cubes is carried out by two packaging machines with a nominal rate of 23 boxes per minute.

- **300g and 500g powdered chocolate bags**
  The production of powdered chocolate in 300g and 500g bags is ensured by two packaging machines, operating at a nominal rate of 30 bags per minute.

1.7 Conclusion

This section has presented in detail overview of CEVITAL. Some of the insights presented include the company's historical development, geographic position, operational activities, as well as the sugar packaging unit, which forms the basis of the study.

The next chapter will introduce key concepts of industrial automation that support development and implementation of effective automated solution for the transfer process.

Chapter 2: Concepts of Industrial Automation

2. Concepts of Industrial Automation

2.1 Introduction

Industrial automation refers to the use of machines in industries to carry out tasks with very little to no human involvement. The concept "automation" was first used in 1946 by General Motors to describe the automatic handling of parts in manufacturing industries. [4] However, as time passed, automation expanded beyond manufacturing to healthcare, business operations, software development, finance, and other sectors.

This chapter will explore some of the fundamentals of industrial automation, with a major focus on PLCs (Programmable Logic Controllers), as they have become essential in modern industrial automation as a result of their reliability, robustness, and ease of integration.

Some of the objectives of industrial automation include:

- To reduce operational costs
- To enhance human safety
- To enhance efficiency and productivity
- To ensure scalability and flexibility
- To enhance reliability

2.2 Automation with Programmable Logic Controllers (PLCs)

PLC automation is broadly used in many modern industries such as power plants, oil and gas, and manufacturing factories, to monitor machines and processes. PLCs control inputs and outputs to ensure seamless operation.

Allied Market Research shows that the PLCs' global market is projected to reach $15.23 billion by 2027, following a growth rate of 5.3% CAGR (from 2020 to 2027). [4]

A great example of PLC automation is within the oil-refining industry, where PLCs control oil flow and pressure and keep track of temperatures, hence optimizing the overall refining process. This ensures safety, efficiency, and minimal human involvement.

2.3 Programmable Logic Controllers (PLCs)

PLCs, also called programmable Logic Controllers, are computer-type devices with various inputs and outputs used to control equipment in industrial and mechanical automation based on custom programming. Here are some types of equipment PLCs can control:

- Food processing machinery
- Conveyor systems
- Batch control
- Utility plants
- Auto assembly lines

PLCs developed by Dick Morley in 1964, have greatly revolutionized manufacturing and industrial sectors with functions like counting, timing, signal processing, etc. [5] The main advantage of a PLC over traditional computers is that it can be reprogrammed after you've programmed it.

2.3.1 Physical Structure of a PLC

The physical structure of a PLC is closely related to that of a computer:

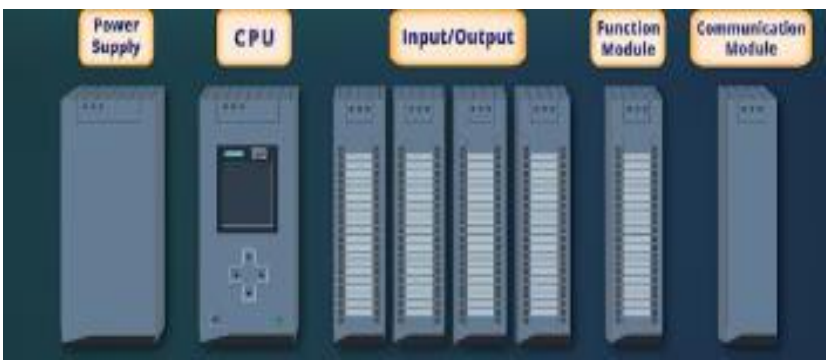


Figure 2:1 structure of a PLC

2.3.2 Components of a PLC

A PLC is made up of various components that work together for consistent and effective control of industrial processes. Each of its components is designed to perform a specific function. Below are some of the basic components of a PLC:

2.3.2.1 Central Processing Unit (CPU)

CPU is also referred to as the brain of a PLC as it is the most important module among other PLC components. It has a central processor, RAM, and ROM. Some of the functions of a CPU include:

- Executing PLC programs
- Reading inputs; it can be from sensors or switches
- Controlling outputs such as industrial equipment or even processes
- Processing data/instructions according to the program
- Communicating with other devices such as SCADA, HMIs, and or other PLCs

2.3.2.2 Input and Output Modules

Input and output (I/O) modules are critical components of a Programmable Logic Controller (PLC). They serve as the interface between the PLC's internal logic circuitry and the external world, allowing the PLC to **receive signals from input devices** (such as sensors, switches, pushbuttons) and **send control signals to output devices** (such as relays, motors, solenoid valves, and alarms). These modules enable the PLC to **monitor and control various industrial processes** by sensing environmental parameters such as pressure, flow, and temperature.

I/O modules are generally categorized into **digital** (discrete) and **analog** types:

- **Digital I/O modules** handle binary signals (e.g., ON/OFF, 1 or 0).
- **Analog I/O modules** handle continuous signals (e.g., 0–10V, 4–20mA) representing physical values like temperature or pressure.

The I/O modules act as a bridge between the **field devices** and the **PLC's microprocessor** (CPU), ensuring safe signal transmission through isolation and conversion circuits.

2.3.2.2.1 Input module:

The input module of a PLC is illustrated below:

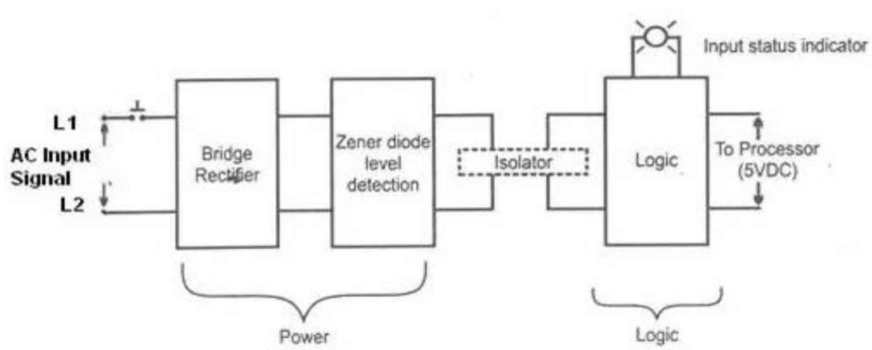


Figure 2:2 Input module of a PLC

The two main sections, the power section, and the logical section are electrically isolated from each other. A bridge rectifier converts the AC signal into a DC signal. Zener diode supplies a low voltage to the LED. The phototransistor works in the conduction zone when illuminated by the light from the LED, and finally, the processor is supplied with 5V DC.

2.3.2.2.2 Output module:

The output module of a PLC is explained below:

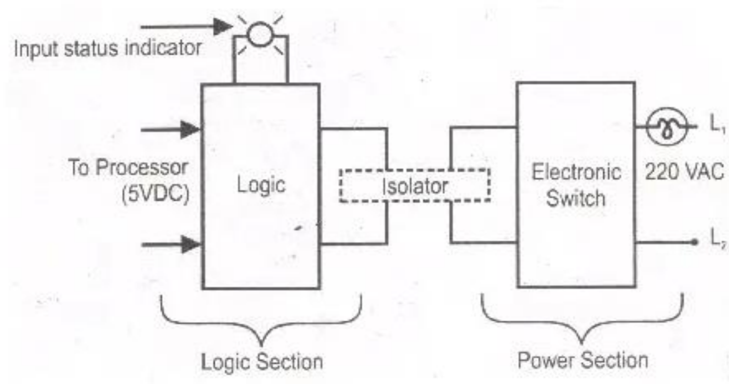


Figure 2:3 Output module of a PLC

Its working principle is similar to that of the Input module but in the reverse way. The logic section comes first, and the power section would be the second.

When the processor generates the program logic high signal the LED turns on, allowing the light on the phototransistor. The transistor generates a pulse to the Triac gate when it goes to the conduction region. The isolator generally separates the logic section and control section.

2.3.2.3 Communication Interface Module

These modules supply extra communication ports that an industrial system may need. They help to connect with other PLCs and computers located in a remote place.

2.3.2.4 Power Supply Module

A PLC power supply module is a device that typically converts the high-voltage AC current from the main source into a low-voltage DC current suitable for the PLC and its components.

It comes in different powers and sizes. The most common input voltage to a power supply is 120V AC or 230V AC. A PLC without a power supply is like a laptop without a battery or a car without fuel. The power of a PLC greatly depends on the strength of the power supply.

2.3.2.5 Programming Device

A PLC (Programmable Logic Controller) is a programmable system, and therefore requires a programming device to create, edit, and upload control programs into the PLC's memory. This device typically consists of a computer (laptop or desktop) equipped with dedicated PLC programming software such as TIA Portal (Siemens), RSLogix (Allen-Bradley), or GX Developer (Mitsubishi).

The programming device allows users to write logic instructions in programming languages such as Ladder Logic, Function Block Diagram, or Structured Text, depending on the PLC manufacturer. These programs can be simple — like turning a motor on when a button is pressed — or complex, involving multiple sensors, timers, and control sequences.

Once the program is developed, it is transferred to the PLC's CPU via communication ports such as USB, Ethernet, or serial connections (RS-232/485). The programming device also allows real-time monitoring, debugging, and modification of the control process without the need for rewiring hardware.

In summary, the programming device acts as the interface between the user and the PLC system, enabling both initial configuration and ongoing system optimization.

2.3.3 Types of PLC

They can either be compact or modular:

2.3.3.1 Compact PLC

Also called fixed PLC. It is an all-in-one device that integrates the power supply, CPU, and input/output modules.

Key Features:

- Are small in size
- Fixed number of inputs and outputs
- Cannot expand the modules
- The manufacturer will decide on every input/output
- Used for small-scale control applications

Use cases:

- Standalone equipment
- HVAC systems
- Simple machines and conveyors

Figure 2:4 A compact type PLC

2.3.3.2 Modular PLC

Also known as a rack-mounted PC. It is a type of PLC that allows multiple extensions of the PLC system through the use of modules, hence the name modular.

Key Features:

- I/O components can be increased or reduced
- Easy to use as each component is independent of each other
- Often used in applications that require a lot of inputs and outputs

Use cases:

- Process control in manufacturing lines
- Large-scale industrial automation systems

Figure 2:5 A modular type PLC

2.3.4 Things to Consider When Choosing a PLC

Choosing the right PLC is a critical step in ensuring the robustness and reliability of automated systems. Below is a list of things to consider when choosing the right PLC:

- **System-specific requirements** – Involves understanding the specific needs of your automation application while considering factors such as what process to control, its complexity, and what you want to achieve.

- **CPU requirements –** Include evaluating the CPU processing speed and capability to handle different types of I/O devices of your application.

- **Memory –** The PLC must have sufficient memory to handle the applications efficiently. The memory requirements depend on how many devices are connected to your PLC.

- **Number of inputs and outputs (I/O) –** It involves determining the number and types of I/O to be connected to the PLC while also considering future expansion of I/O.

- **Communication protocols –** This involves selecting a PLC that supports the required communication protocols. Generally, a PLC has its own communication ports. However, your application may need other communication ports to be added to your PLC to enable it to communicate with other systems/field devices. They may include Ethernet, Profibus, etc.

- **Programming languages and software -** Involves considering programming languages supported by the PLC as well as the accompanying programming software. The goal is to ensure it supports a programming language you're comfortable with. Additionally, the programming software provided by the manufacturer should be user-friendly.

- **Power Supply Requirements -** Verify the power type and voltage input by the PLC. Most commonly: 120/240V AC or 24V DC as application is commonly used.
  Also check if there is a stand-alone power supply module required.

- **Budget and Cost** - The overall cost includes: the PLC hardware, programming software, expansion modules, and maintenance and support.
  A cost effective solution will combine performance, reliability, and future flexibility.

2.4 Conclusion

This chapter presented in detail key concepts of industrial automation, with a main focus on PLCs (Programmable Logic Controllers). Among the details covered include structure of a PLC, PLC components, types of a PLC, and criteria for choosing the right PLC. These fundamentals are essential for developing efficient automated solutions.

The next chapter will focus on the existing powdered chocolate transfer process along with the improvement and automation strategies to make the process more reliable and efficient.

Chapter 3: The Current Powdered Chocolate Transfer Process at CEVITAL

3. Current Powdered Chocolate Transfer Process at CEVITAL

3.1 Introduction

This chapter presents in detail an overview of the existing powdered chocolate transfer process at CEVITAL. It highlights the general process workflow, system instrumentation as well as operational methods used in the handling and transfer of powdered chocolate within the facility. It furthermore covers the limitations of the existing system and explores some possible solutions and improvement strategies to solve the current inefficiencies.

Some key objectives of this section include:

- Analyze and understand the existing workflow
- Identify major challenges faced during the transfer process
- Explore potential solutions for a more reliable automatic process

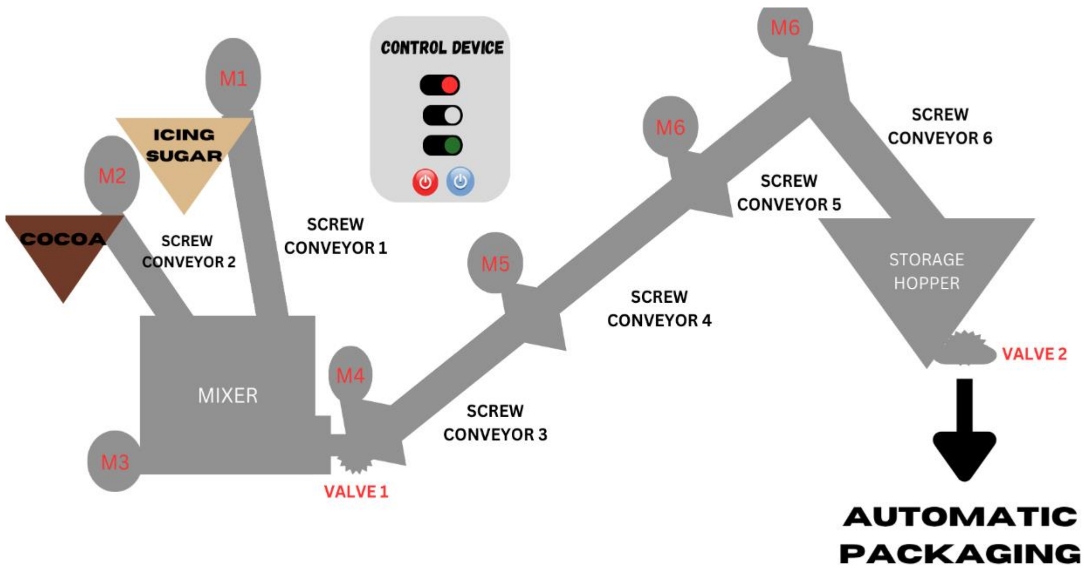


Figure 3:1 *diagram overview of the chocolate transfer process*

3.2 Description of the Transfer Process

It begins with two feeding hoppers, one for cocoa powder and the other for icing sugar. The ingredients are conveyed to the mixer via screw conveyors, driven by asynchronous motors. Other flavoring ingredients (vanilla and caramel) are manually added to the mixer by the operator.

The operator then initiates the heating process of the mixer by pressing the control button, which heats the water inside the mixer, to obtain the optimal mixing conditions of a temperature range of 35°C to 42°C. Once the optimal mixing condition is reached, the next control button is pressed to activate the mixer's motor, initiating the mixing process.

When the final powdered chocolate is ready, the operator manually opens the valve at the bottom of the mixer, allowing the powdered chocolate to exit the mixer and enter screw conveyor.

Finally, the operator presses the next control buttons (4) to power four conveyors that transfer powdered chocolate to the storage hopper. The screw conveyors are driven by asynchronous motors.

From the storage hopper, the product is then packaged automatically by a packaging machine into bags with capacities of 300, 500, and 1kg.

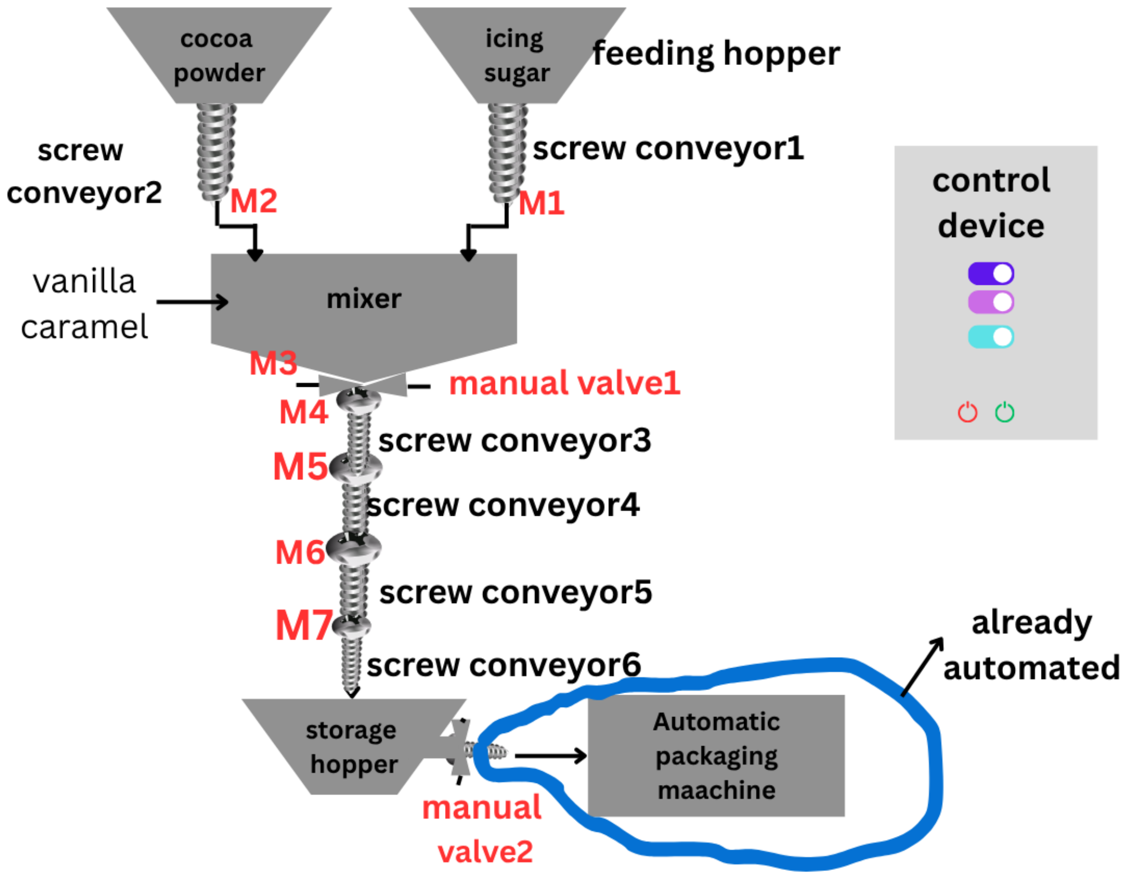


Figure 3:2 flow diagram of the powdered chocolate transfer process

3.3 System Instrumentation

3.3.1 Industrial Mixer

The industrial powder blending machine can be used to mix powders and granules evenly to ensure high quality of the final product.
Some of its features include:

- the industrial powder blending machine is compliant with GMP and CE standards to ensure safe and compliant production processes [6]
- Efficient mixing, hopper design, industrial powder mixing machine can be lifted to different heights for feeding and discharging [6]
- Suitable for a variety of materials, including powders, granules, and liquids with a ratio of no more than 10% [6]
- Automated operation to improve production efficiency and reduce manual intervention [6]

- Compact structure, easy to clean, supports CIP online cleaning system [6]

In the transfer process, it is designed to mix cocoa powder with icing sugar to obtain a uniform final product (powdered chocolate).

Figure 3:3 industrial mixer

3.3.2 Screw Conveyor

Screw conveyor is an industrial equipment meticulously designed to move large quantities of granular materials like grains, powders, and granules. It eliminates the necessity of manual material handling. [7]

It is equipped with a rotating screw shaft placed inside a trough. When the screw shaft rotates, it conveys the material in a straight path. Screw conveyors can be set for material handling along vertical, horizontal, or inclined paths. [7]

It plays a key role in the transfer process by enabling consistent movement of powdered chocolate from the mixing machine (mixer) to the storage hopper.

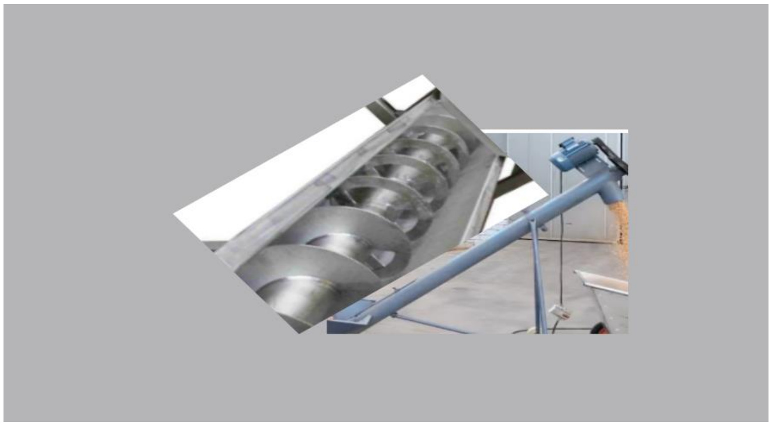


Figure 3:4 Screw conveyor

3.3.3 Hopper

Industrial hoppers are used for the temporary storage of materials. They're designed to allow efficient dumping/feeding of stored materials to a process. Their specifications include weight capacity, volume capacity, depth, diameter, height and material of construction. [8]

Within the transfer process, hoppers serve for both feeding and storage purposes. The feeding hoppers are designed to temporarily hold cocoa and icing sugar fed to the mixer. At the end of the mixing phase, a storage hopper stores the final product, powdered chocolate.

Figure 3:5 industrial hopper

3.3.4 Screw Feeders

They are industrial machines designed to meter and control the flow of material, and are typically located at the beginning of a process. A screw feeder can be mounted directly to a hopper, silo or bin. [9]

Some of the key characteristics of a screw feeder include:

- It is flood loaded or 100 percent full in the inlet area [10]

- It meters material from a hopper, bin or silo [10]
- Screw feeders use varying pitch flighting in the inlet area to pull evenly from storage device past the inlet area [10]
- Feeders are generally shorter than conveyors and will rarely use hanger bearings. [10]

In the transfer process, screw feeders are positioned under storage hopper to ensure precise dosing of the materials into the packaging machine for maintaining product consistency.

Figure 3:6 screw feeder mounted with hopper

3.4 Actuators, Sensors, and Control Device within the Transfer Line

3.4.1 Actuators

Actuators are devices that make something move. Generally, they're devices that accept control commands and cause a change in the physical system by generating motion, force, heat, or flow. They can be used for tilting, lifting, opening, clamping, mixing, turning, metering, and for other operations.[11] Some actuators in the transfer line include:

3.4.1.1 Asynchronous Motor

Also called an induction motor. It is an electric motor that works with AC current. The motor works on the current within the rotor induced by the rotary magnetic field of the stator. Generally, the speed of the rotor is lower than the rotation speed of the magnetic field created from the stator winding, hence the name asynchronous. [12]

Within the transfer line, the asynchronous motor used is three-phase, with a power of 4 kW, operating at a voltage of 380V and a frequency of 50Hz. They are used to drive mixers and screw conveyors for reliable mixing of cocoa and icing sugar and for consistent movement of powdered chocolate.

Figure 3:7 asynchronous motor

3.4.1.2 Valve

A valve is a mechanical device that controls and regulates the flow of substances and pressure within a system. [13] Some functions of valves include:

- To stop/start substance flow [13]
- Throttling the amount of substance flow [13]
- Control the direction of flow of substance [13]
- Piping overpressure [13]

There are different types of valves, such as gate valve, globe valve, ball valve, plug valve, diaphragm valve, reducing valve, butterfly valve, needle valve, swing check valve, lift check valve, relief valve, and safety valve. [13]

Within the transfer process, one valve is at the bottom of the mixer outlet, and it allows the powdered chocolate to exit the mixer and flow into the screw conveyor to be moved/transferred to the storage hopper. The other valve is at the bottom of the storage hopper to allow the powdered chocolate exit the storage hopper and flow into the two screw feeders ready to be packaged into 300g, 500g, and 1kg bags by aid of a packaging machine.

3.4.2 Sensors

A sensor is a device, module, machine, or subsystem that detects events or changes in its environment and relays the information to other electronics, most commonly a computer processor. A sensor converts physical phenomena into a measurable digital signal, which can then be displayed, read, or processed further. [14] Below are some sensors within the transfer process.

3.4.2.1 Conductivity Level Sensor

It's also called a resistance sensor. It uses a probe to read conductivity, which has a pair of electrodes and applies alternating current to them. When a substance covers the probe, its electrodes form a part on an electric circuit, causing current to flow, which signals a high or low level. [15] Some of the advantages of using a conductivity level sensor include:

- No moving parts
- Low cost
- Easy to use

Within the transfer process, there are two level sensors positioned near the storage hopper. They monitor the powdered chocolate level, ensuring that the storage hopper does not overfill or run empty.

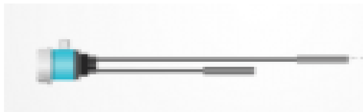


Figure 3:8 conductivity level sensor

3.4.2.2 Control Cabinet

A control cabinet is a structure whose primary task is to power distribution systems and electrical components, and protect automation components from the negative effects of external influences such as dust, humidity or extreme temperatures. As a result, it ensures trouble-free and continuous operation of systems or electrical apparatus. Control cabinets perform many other important functions, including:

- supply power to the equipment
- control the start-up and operation of equipment and systems
- allow complex electronic apparatus to be organized and structured
- protect against unauthorized access to the apparatus

By using a properly designed and constructed control cabinet, it is possible to maintain the correct electrical parameters, such as electrical voltage, and minimize the risk of failure of the equipment being powered. Control cabinets are responsible for distributing the correct current voltage, which is why this type of solution is used very widely, in many industries. [16]

Within the transfer process, the control cabinet ensures coordination of mixer motor, screw conveyors for icing sugar, cocoa, and transfer of powdered chocolate, heating resistance and temperature control. Each switch selector corresponds to a specific motor, providing the operator with full control of the process.

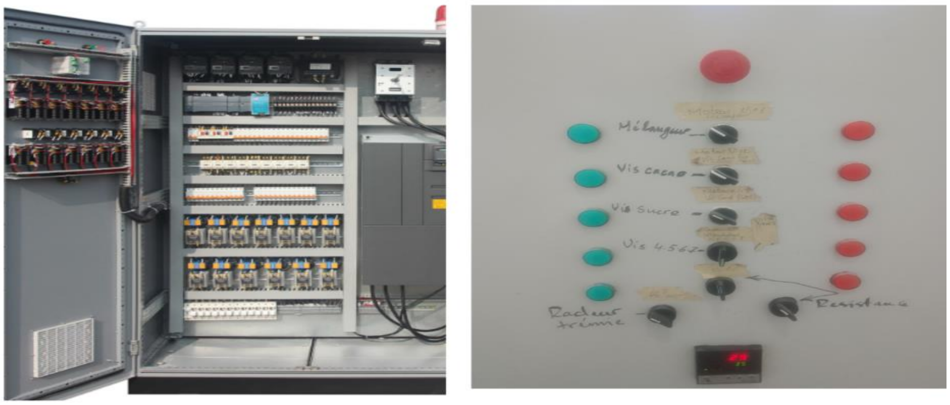


Figure 3:9 Electric control device

3.5 Identified Challenges

The existing transfer process is dependent on manual operations at some key stages of the process. Here are the main challenges in the manual (current) transfer process.

1. **Operation of valves manually**
   - The valve at the bottom of the mixer outlet and the one at the storage hopper are both controlled manually.
   - This manual operation of valves results to the risk of human error, delays, and even inconsistent flow of the powdered chocolate.
2. **Manual activation of motors to power screw conveyors**
   - The four screw conveyors from the mixer outlet to the storage hopper are activated manually using separate control buttons.
   - This manual activation of conveyors through control buttons also results to fatigue of operators as well as lack of synchronization in the process.

3. **Overdependence on Human Operators**
   - The manual nature of the process requires continuous monitoring by operators to open/close valves, start/stop conveyors, and check material flow.
   - This results in an increase in fatigue of operators, labor costs, and even the risk of human errors/accidents

4. **Blockages and Material Build-ups in Screw Conveyors**
    - Powdered chocolate can sometimes accumulate and cause clogging in the screw conveyors because of its fine and sticky nature.
    - This can interrupt the transfer process and requires manual intervention for unblocking/freeing.
5. **Lack of real-time monitoring**
    - There are no sensors to detect powdered chocolate flow and levels in the screw conveyors and storage hopper.
    - This results to not only overflowing and underfilling but also inefficiency of the system.

3.6 Solutions to the identified challenges

1) **Replace manual valves with automated valves**
    - Use actuated valves at the mixer outlet and storage hopper outlet, which will be automatically controlled by the help of PLC based on the sensors' status
2) **Automate Screw Conveyors Operation**
    - This will involve connecting the motors of the four screw conveyors to the PLC. Then program the PLC to run the four motors in a sequence based on the flow and status of sensors in the process line.
3) **Use of Human Machine Interface (HMI)**
    - This involves designing the Interface for operators to interact with the system. The proposed interface (HMI) will display:
        - **i.** Buttons for starting/stopping processes (for example, starting the process)
        - **ii.** Visual indicators to indicate different stages of the transfer process
        - **iii.** Alarm notifications for on-time troubleshooting and real-time monitoring.
4) **Installation of flow and level sensors**
    - Flow sensors are placed at the outlets of four screw conveyors for transferring powdered chocolate. They will detect material movement when screw conveyors are running. If the sensor detects flow, the transfer process continues normally. When the sensor detects no flow, it sends a signal to the PLC. The PLC can, for example, automatically stop motors or trigger an alarm for maintenance.
    - Level sensors (high and low level) will be placed at the storage hopper and mixer to detect chocolate level. Consequently, the PLC will either open or close the valves and other devices based on the sensors' information.

3.7 Piping and Instrumentation Diagram (P&ID) for the Automated Transfer process

This is a diagram that shows the process flow within the piping, as well as the installed equipment and instruments.

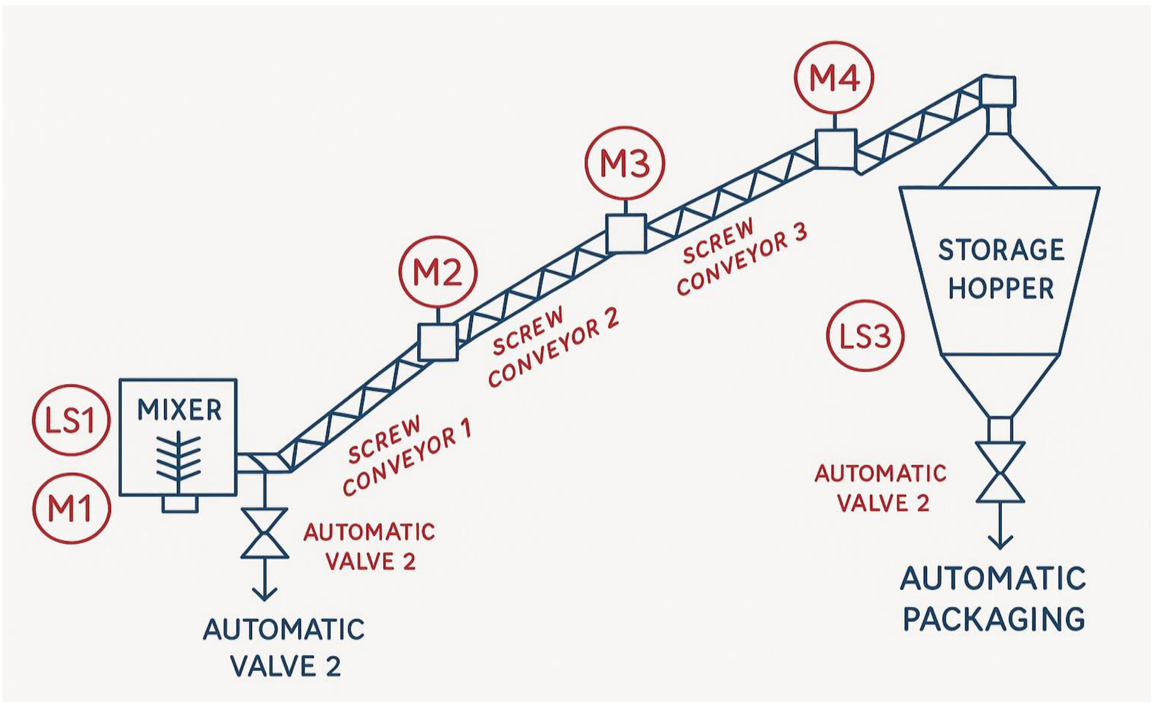


Figure 3:10 P&ID of the Automated System

3.8 System Functional Logic for the Automated system

➢ **System Start Conditions**

- The system can only be initiated when the START button is pressed by the operator and
- Initial conditions must be met:
    - All safety interlocks are active
    - The mixer is empty and ready to receive ingredients

➢ **Ingredient Feeding and Mixing Process**

Upon system start:

- Screw Conveyor 1 (SC1) motor is activated to feed icing sugar into the mixer.

- Once the required amount of icing sugar is fed (confirmed via level sensor or timer), SC1 stops.
- Then, Screw Conveyor 2 (SC2) motor is activated to feed cocoa powder into the mixer.
- After cocoa feeding is complete, SC2 stops.
- The operator is prompted to manually add vanilla and caramel into the mixer.
- Once all ingredients are in, the mixer motor starts and the mixing cycle begins.
- The mixer runs for 20 minutes (controlled by a timer).

➢ **Mixer Discharge Initiation**

- The **mixer motor** starts.
- After a 3-second delay, **valve 1** opens to allow powdered chocolate to flow from the mixer into the first screw conveyor (SC1).

➢ **Sequential Screw Conveyor Activation**

- After a short delay, **SC1 motor** is activated to begin transferring chocolate.
- When chocolate reaches the entry of **SC2** (confirmed via sensor), a 5-second delay is applied, after which the **SC2 motor** starts.
- This sequence continues with:
  - Chocolate reaching SC3 → SC3 motor starts.
  - Chocolate reaching SC4 → SC4 motor starts.
- Each conveyor is equipped with:
  - Input flow detection sensors.
  - Timers to allow enough material accumulation before triggering the next motor.

➢ **Storage Hopper Filling and Valve Control**

- Once chocolate reaches **SC4**, **storage hopper** starts filling
- As the hopper fills:
  - Multiple **level sensors** monitor the powder level inside the hopper.
  - When the hopper reaches a **certain level**, **valve 2** opens to allow chocolate to flow into the **automatic packaging line**.
  - The valve remains open until all chocolate is transferred from the mixer to the packaging

➢ **Process Completion and Shutdown**

- The process automatically stops under any of the following conditions:

    - The mixer becomes empty (detected by low or empty-level sensor) and the storage hopper is also empty, and no chocolate is present in any screw conveyor (verified by absence of flow at each stage).
    - **OR** the operator presses the **STOP** button.
- Upon stopping:
    - All motors and valves are turned off.
    - Memory bits and timers are reset.
    - The system returns to standby until a new START signal is received.

➢ **Safety and Monitoring Features**

- Each stage incorporates **delays, level sensors, and flow detection** to prevent:
    - Overflow or underfilling.
    - Blockages in screw conveyors.
    - Uncoordinated motor activation.

3.9 Conclusion

This section presented in detail an overview of the current powdered transfer process at CEVITAL. Among the details presented include general flow of the process, system instrumentation, and key challenges in the transfer line. Potential solutions to improve and automate the process were also presented. These insights form foundation for the next chapter on programming and supervision, designed to implement the proposed improvements.

Chapter 4: Programming and Supervision

4. Programming and Supervision

4.1 Introduction

Programming and supervision serve as core pillars in the automation of the powdered chocolate transfer process in ensuring system's functionality and efficiency. This chapter presents in detail the development of control logic/program and the design of a user-friendly interface for reliable and real-time monitoring of the transfer process.

Programming part involves converting the functional requirements of the process into a structured and logical sequence using PLC software in this case TIA portal. This entails creation of project, hardware configuration and development of a program that controls the sequence of operations

Supervision provides a visual interface to allow operators to monitor and interact with the system. HMI software in this case WinCC Flexible are used to design process views, monitor alarms and enable user interaction in a user-friendly way.

This chapter is set into two main parts: the first one details the programming steps to implement the control program for the automated transfer process, while the second focuses on the supervisory part to design and oversee transfer process in real time.

4.2 Overview of TIA Portal

TIA Portal, Totally Integrated Automation Portal is Siemens' new engineering environment that enables the implementation of automation solutions using an integrated system. It integrates SIMATIC STEP7 for PLC programming and SIMATIC WinCC software for HMI designs and other tools.

A typical automation solution encompasses:

- A PLC that controls the process with the aid of the program.
- An HMI device with which you operate and visualize the process.

4.2.1 Simatic STEP7 Software

4.2.1.1 Description of Simatic Step7 software

Programming involves a series of activities that enable the writing of computer programs using a programming language through software.

With STEP7 Professional, the following functions can be used to automate a system:

- Project creation and management.
- Hardware and communication configuration and parameterization.

- Mnemonic management.
- Program creation.
- Uploading the program to target systems.
- Automation system testing.
- Diagnostics in case of system malfunctions.

4.2.1.2 Programming languages in Step7

STEP7 dominates the programming language market with the following types:

- **Instruction List (IL):** A textual language similar to assembly, suitable for small applications; rarely used by automation engineers.
- **Structured Text (ST):** A language similar to Pascal; but rarely used by automation professionals.
- **Function Block Diagram (FBD):** A graphical language where functions are represented by rectangles with inputs on the left and outputs on the right. Functions can be library-based or programmable. Widely used in automation.
- **Ladder Diagram (LD):** Designed for electricians. Uses symbols such as contacts, relays, and functional blocks arranged in networks. This is the most commonly used language by automation professionals.

4.2.1.3 Operations available in Step7

- Bitwise combinational operations.
- Timers.
- Counters.
- Jump operations.
- Comparison operations.
- Load and transfer operations.
- Conversion operations.
- Arithmetic and logic operations.
- Block operations.

4.2.1.4 Program Design Principles

During operation, two programs run on a CPU: the operating system and the user program. The latter is organized into blocks:

- **Organization Block (OB):** Used for internal program organization. Defines the execution order of program parts. Higher priority OBs interrupt lower priority ones.
- **Function Block (FB):** Subordinate to OBs. Assigned a data block (DB) during its call to access data. An FB can be linked to different DBs.
- **Data Block (DB):** Used to store data variables. There are two types: global DBs (accessible by OB, FB, FC) and local ones.

4.2.1.5 Portal View and Project View in Simatic STEP7 Software

When launching TIA Portal, the workspace is divided into two views:

- **Portal View**:
  - Task-focused and user-friendly for quick use.
  - This view is task-oriented. You can quickly choose what you want to do and open the required tool. If necessary, it switches automatically to project view.

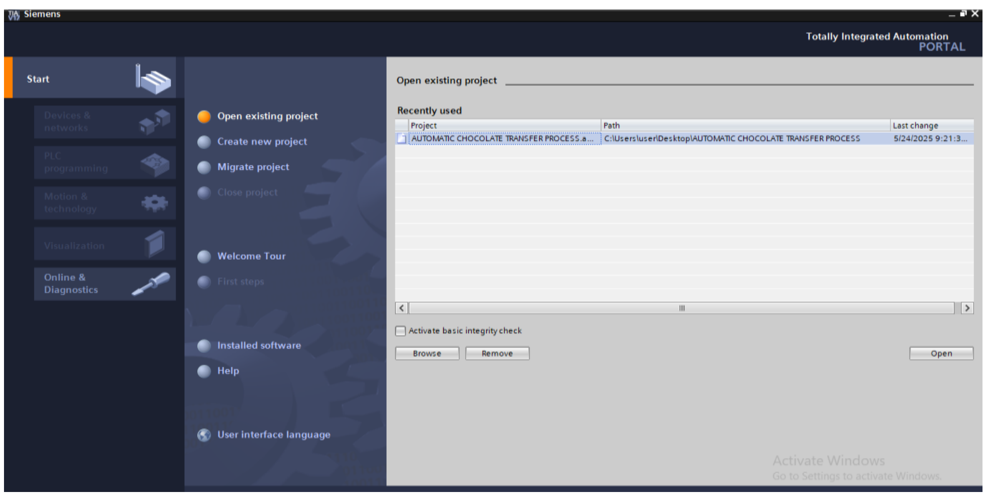


Figure 4:1 detailed portal view

- **Project View:**
  - A tree structure showing all project elements. Relevant editors open based on the task. Data, parameters, and editors can all be viewed in one place.
  - It is a structured view of all project components.

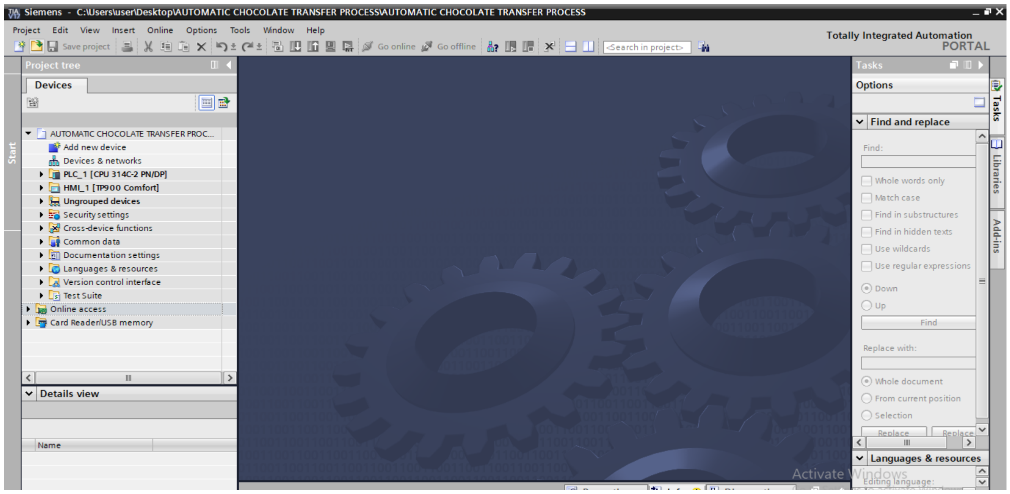


Figure 4:2 detailed project view

4.2.2 SIMATIC WinCC software

WinCC (TIA Portal) is an engineering software for configuring SIMATIC Panels, SIMATIC industrial PCs, and standard PCs using WinCC Runtime Advanced or the SCADA system WinCC Runtime Professional. It is an HMI (Human-Machine Interface) system that enables operators to:

- Visualize and monitor the progress of a process controlled by a PLC,
- Intervene via an operator panel or interface (touchscreen, buttons, etc.),
- Track process data in real time,
- Receive alerts and error messages (alarms),
- Adjust parameters and make manual corrections as needed,
- Archive historical data and analyze system performance.

4.2.2.1 Key Features of WinCC

- **Graphic Design Tools:** Allows the design of user-friendly and intuitive HMI screens, including buttons, indicators, animations, and process diagrams.
- **Alarm Management:** Enables configuration and display of real-time alarms to notify operators of any system malfunctions or critical conditions.
- **Data Logging**: Offers tools for logging and archiving data from sensors, devices, or other control system components.
- **Trend Display**: Real-time and historical trend views help monitor variables over time, aiding in diagnostics and performance evaluation.

- **User Management**: Supports the creation of different user profiles and access levels for security and operational control.
- **Multilingual Interface**: Useful for international projects, allowing interface adaptation to various languages.
- **Integration with STEP7**: Seamless connection with SIMATIC STEP7 for efficient and centralized automation project management.
-

4.2.2.2 Advantages of Using WinCC in Industrial Supervision:

- Improved process visualization for faster decision-making.
- Enhanced operator interaction, reducing the likelihood of human error.
- Remote access capabilities allow monitoring and control from different locations.
- Modular and scalable architecture, adaptable to both small systems and large industrial installations

With WinCC, Siemens offers a comprehensive and integrated solution for supervising automation systems, aligning with Industry 4.0 requirements by supporting digitalization, interoperability, and centralized data handling.

4.3 Implementation of PLC Program for the Powdered Chocolate Transfer in TIA Portal

This section illustrates steps of the development of the PLC program for the automation of the powdered chocolate transfer process in Tia Portal.

4.3.1 Project Creation in TIA Portal

Step 1: Launching TIA Portal

- Open TIA application
- Select create new project and a new window opens

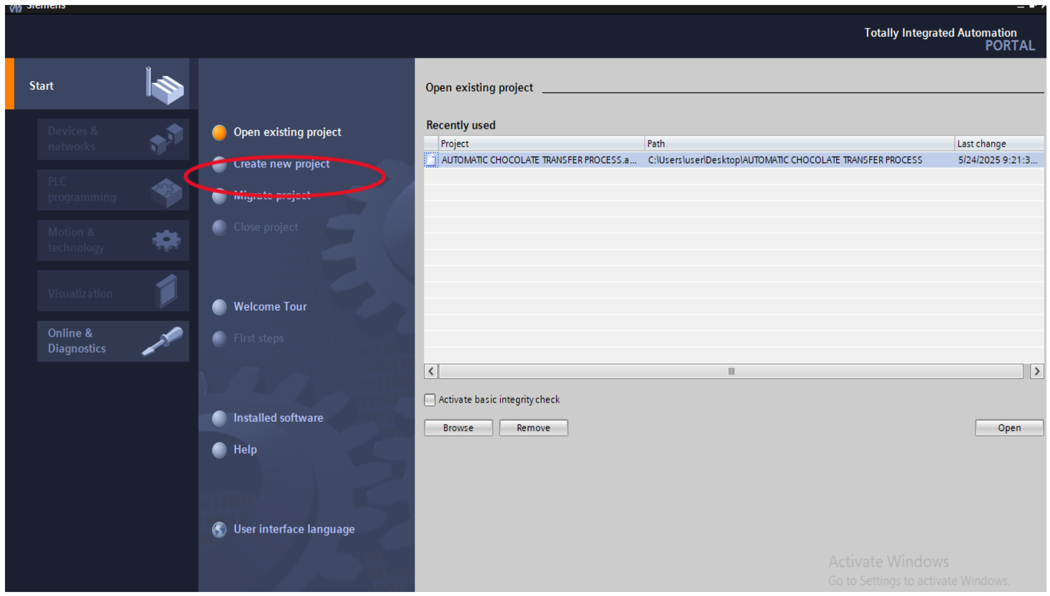


Figure 4:3 TIA Portal home screen

Step 2: Naming and saving the project

- Give a relevant project name e.g. Powdered Chocolate Transfer Process Automation
- Choose location where the project will be saved e.g. Desktop
- Click create

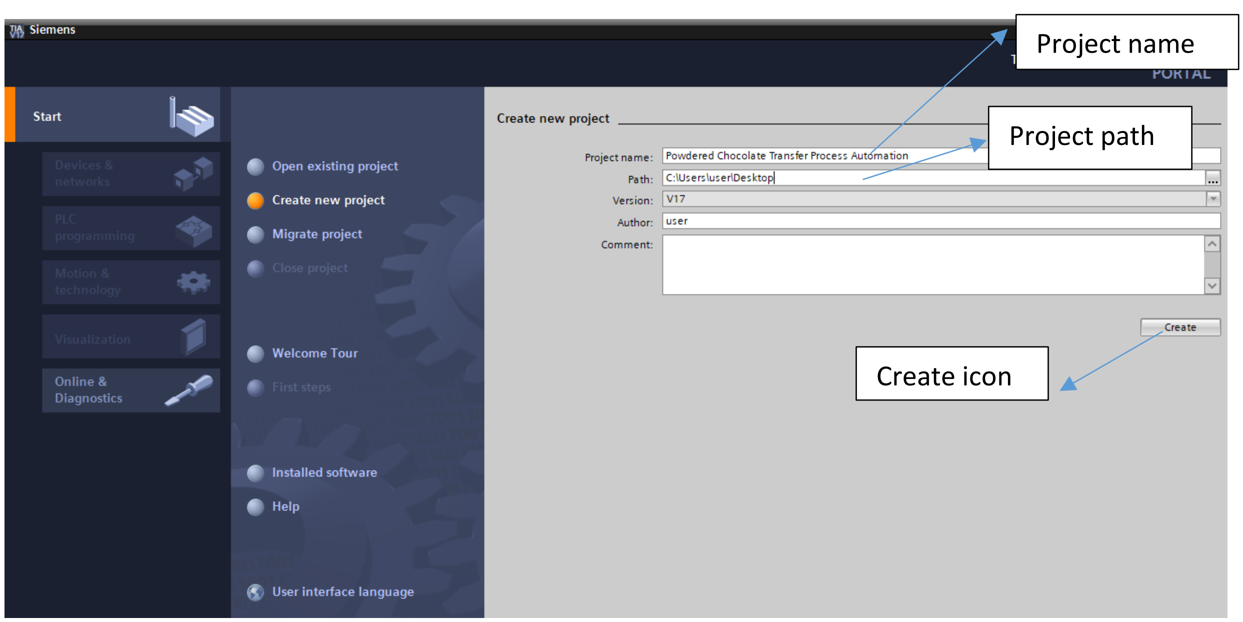


Figure 4:4 new project creation window

- new project window will be open as below;

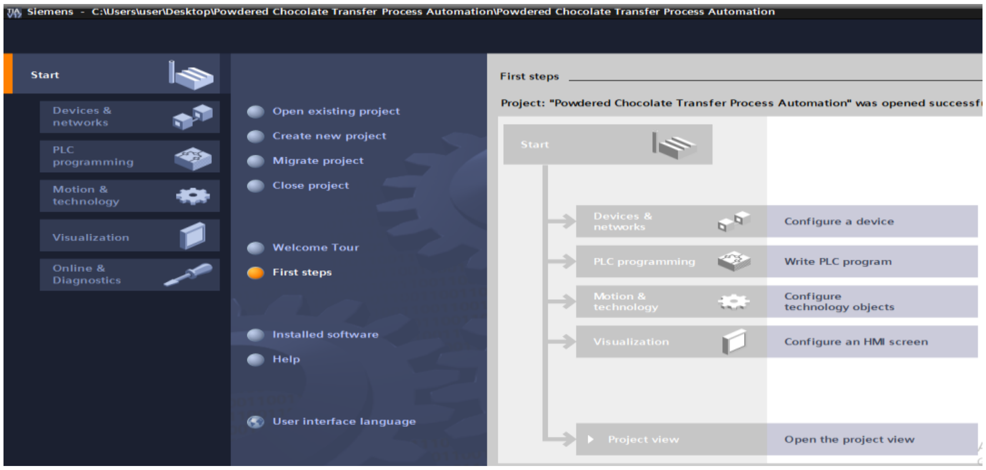


Figure 4:5 Initial Project Configuration Workflow in TIA Portal

4.3.2 Hardware Configuration

After project creation, in the “start” portal, select;

- Configure device
- This window opens

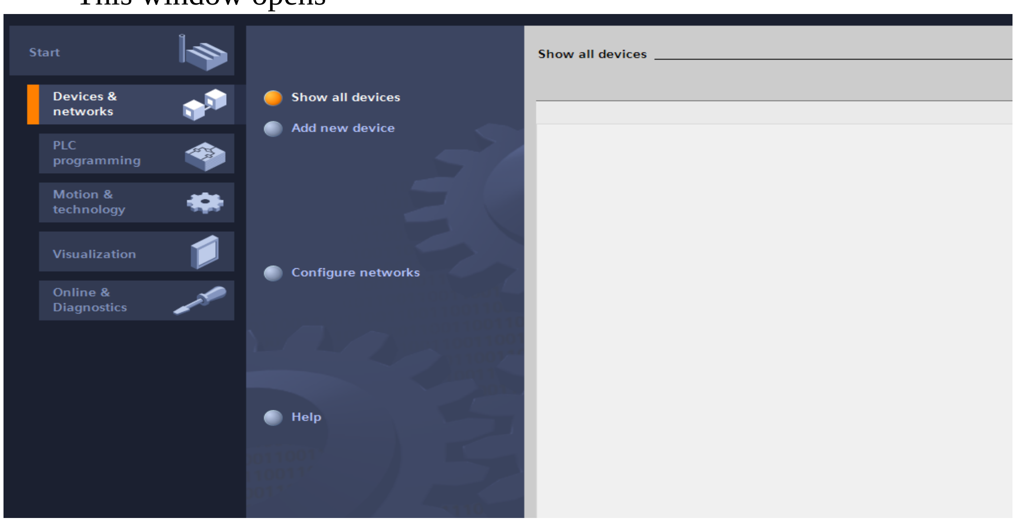


Figure 4:6 configuration steps workflow1

- select and click “add new device”

- this window opens

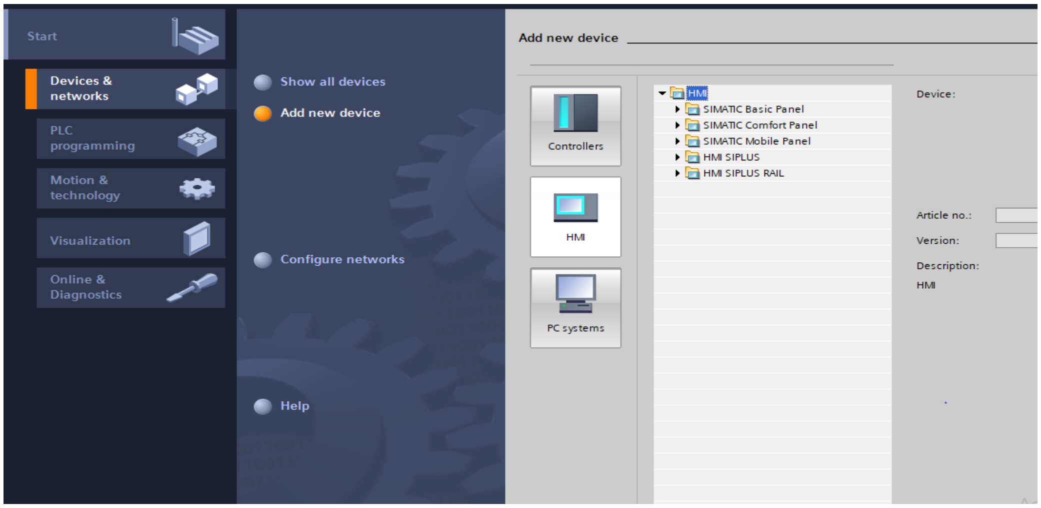


Figure 4:7 configuration steps workflow2

- select: controllers → SIMATICS S7- 300 → CPU → CPU314-2 PN/DP → 6ES7314H04-0AB0

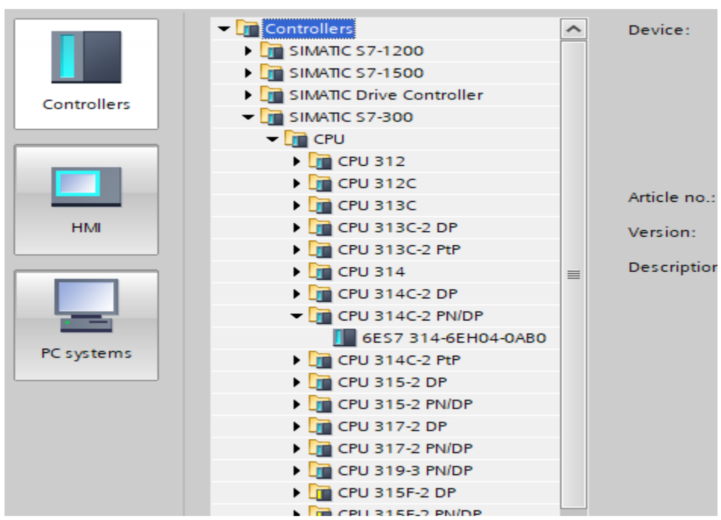


Figure 4:8 configuration steps workflow3

- Click “ADD” and this new window opens (project view)

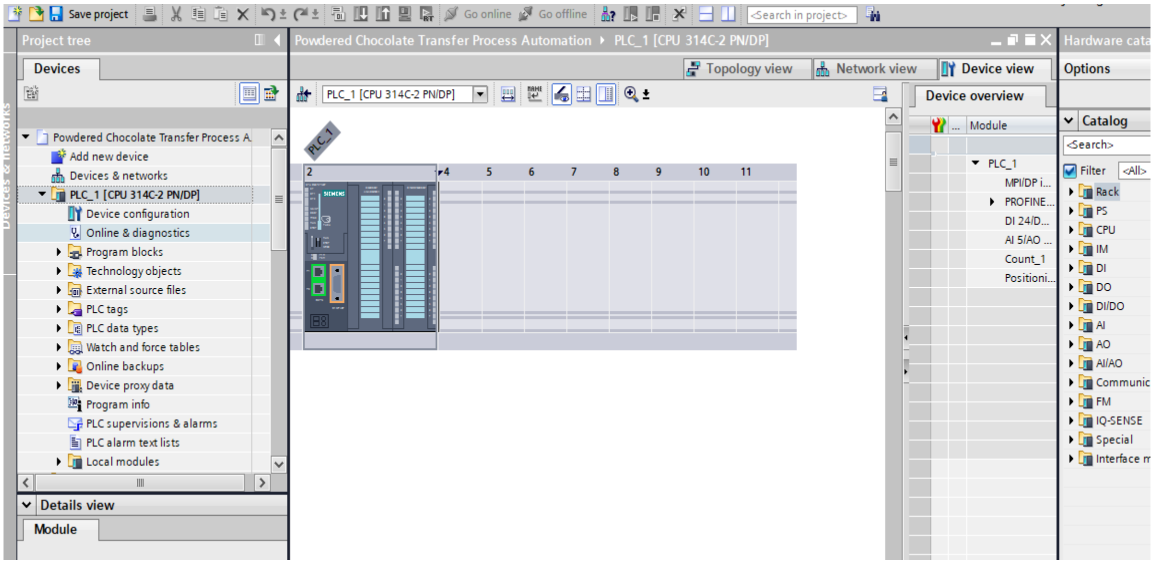


Figure 4:9 project structure view

4.3.3 Project Structure and Navigation in TIA Portal

The TIA Portal interface provides an organized project tree that allows easy navigation and access to key elements of the automation project. The main sections include:

- **Device configuration:** This section shows the hardware setup, such as the CPU and other added modules. Communication parameters and hardware characteristics are configured in this section.
- **Program blocks:** Contains logic blocks; Main Organization Block (OB), Functions (FCs), Function Block (FBs), and Data Blocks (DBs). This is where the user develops and structures PLC program.
- **Tags and variables:** Displays global and local variables, which are used throughout the project. During runtime, tags can be monitored, forced, or changed.

4.3.4 Programming Part

I used Ladder Diagram Language (LD) within TIA Portal and the S7-300 CPU 314-2 PN/DP as choice of the PLC.

The program logic is organized across a collection of networks that reflect the real-time control, timing, sequencing, and interlocking of motors, valves, and level detection sensors.

4.3.4.1 Definition of Global and Local variables (PLC tags)

The first step involves defining variables that will be used throughout the project. They represent interface between the PLC and the physical devices such as motors, valves, and sensors.

Name	Data type	Address		API	API			
START	Bool	%M0.0		True	True	True		
STOP	Bool	%M0.1		True	True	True		
PROCESS RUNNNING	Bool	%M0.2		True	True	True		
MIXER MOTOR CONTROL	Bool	%Q0.0		True	True	True		
SC1 MOTOR CONTROL	Bool	%Q0.1		True	True	True		
SC2 MOTOR CONTROL	Bool	%Q0.2		True	True	True		
SC3 MOTOR CONTROL	Bool	%Q0.3		True	True	True		
SC4 MOTOR CONTROL	Bool	%Q0.4		True	True	True		
VALVE1 CONTROL	Bool	%Q0.5		True	True	True		
VALVE2 CONTROL	Bool	%Q0.6		True	True	True		
CHOCOLATE AT SC1	Bool	%M1.0		True	True	True		
CHOCOLATE AT SC2	Bool	%M1.1		True	True	True		
CHOCOLTE AT SC3	Bool	%M1.2		True	True	True		
CHOCOLATE AT SC4	Bool	%M1.3		True	True	True		
MIXER LEVEL FULL	Bool	%M2.0		True	True	True		
MIXER LEVEL1	Bool	%M2.1		True	True	True		
MIXER LEVEL2	Bool	%M2.2		True	True	True		
MIXER LOW	Bool	%M2.4		True	True	True		
HOPPER LEVEL1	Bool	%M3.0		True	True	True		
HOPPER LEVEL 2	Bool	%M3.1		True	True	True		
HOPPER LEVEL 3	Bool	%M3.2		True	True	True		
HOPPER EMPTY	Bool	%M3.3		True	True	True		
PLC ON	Bool	%M3.4		True	True	True		
MIXER LEVEL3	Bool	%M2.3		True	True	True		
MIXER LEVEL5	Bool	%M2.5		True	True	True		
HOPPER LEVEL 4	Bool	%M3.5		True	True	True		

Figure 4:10 Tag table showing all input/output/memory variables.

4.3.4.2 Creation of Main Organization Block (OB1)

With the PLC, the organization block "Main [OB1]" is automatically created in the project. This is where you create user program.

The powdered chocolate transfer process is split across several networks, of which each is responsible for handling specific stage of the transfer process.

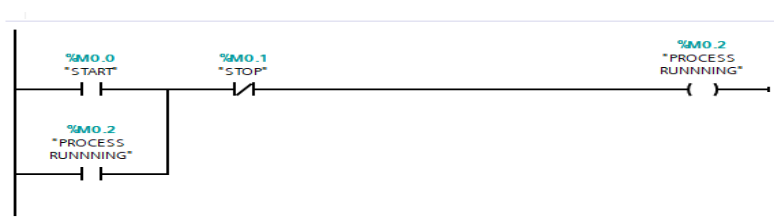


Figure 4:11 example of OBI ladder network structure

4.3.4.3 Network Description and function breakdown

Each network in the main (OB1) represents a logical stage in the transfer process. Below is a summarized logic of main stages:

i. Process Initialization and interlocking Network

- For start, stop and system latch
- When start button is pressed and the stop button is not pressed/active, the rung coil is energized. It then self-latches and the process stays on until stop button is pressed

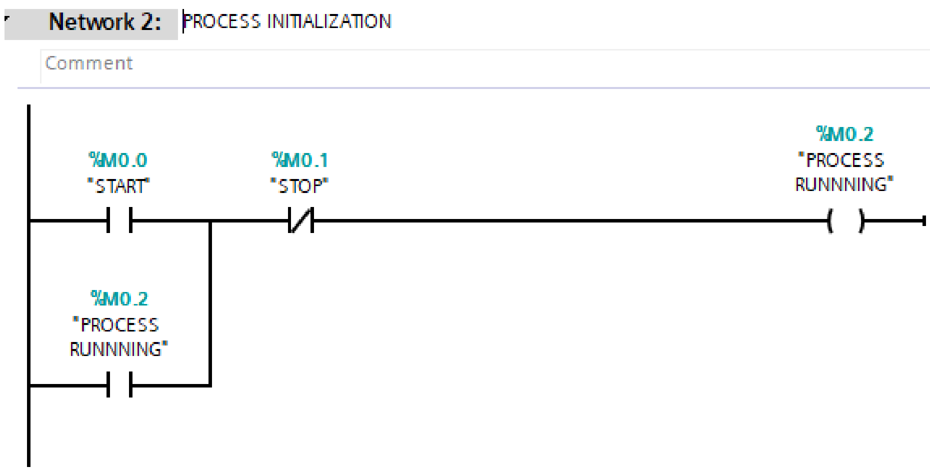


Figure 4:12 Start and System Latch rung

ii. Mixer Motor Control Network

- This network controls mixer motor which aides in pushing powdered chocolate exit the mixer.
- Its input is the process running (memory bit)
- When the process latches on/off the mixer motor turns on/off automatically.

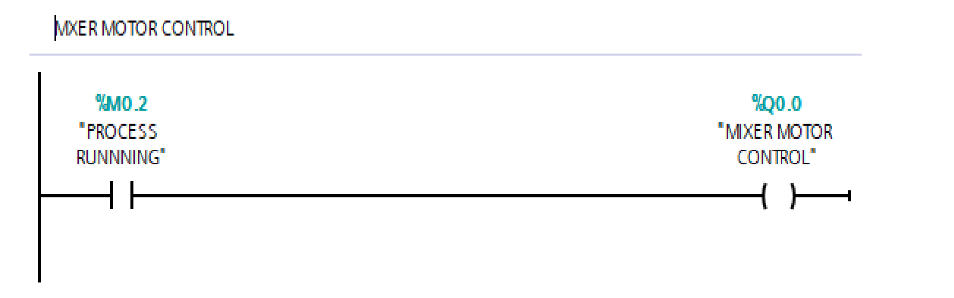


Figure 4:13 mixer motor control rung

iii. Valve1 control Network

- This network controls the opening/closing of automatic valve located at the bottom of the mixer.
- The valve allows exit of powdered chocolate from the mixer into the first screw conveyor.
- The network ensures a delay of 3 seconds after the motor is on before opening valve1
- When the process running bit and mixer motor are active, timer counts up to 3 seconds before opening valve1

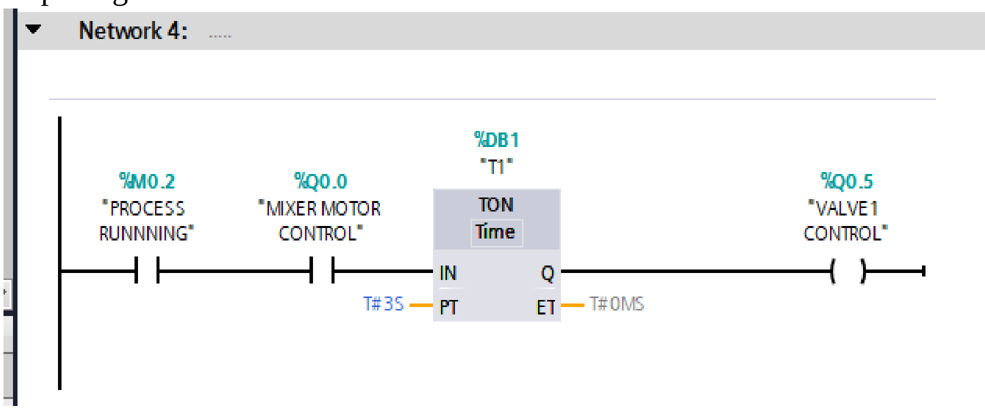


Figure 4:14 Automatic valve1 control rung

iv. Screw conveyors 1 to 4 control networks

- These are for controlling screw conveyors 1, 2, 3, and 4, which transfer powdered chocolate from the mixer to the storage hopper step by step.
- When the chocolate reaches the corresponding screw conveyor, each motor is triggered after a 2 second delay.
- The condition to trigger each motor is determined by presence of powdered chocolate at that specific screw conveyor.

SC#	Condition	Delay	Output
SC1	%M1.0 = "Chocolate at SC1"	2 sec	%Q0.1 = "SC1 MOTOR CONTROL"
SC2	%M1.1 = "Chocolate at SC2"	2 sec	%Q0.2 = "SC2 MOTOR CONTROL"
SC3	%M1.2 = "Chocolate at SC3"	2 sec	%Q0.3 = "SC3 MOTOR CONTROL"
SC4	%M1.3 = "Chocolate at SC4"	2 sec	%Q0.4 = "SC4 MOTOR CONTROL"

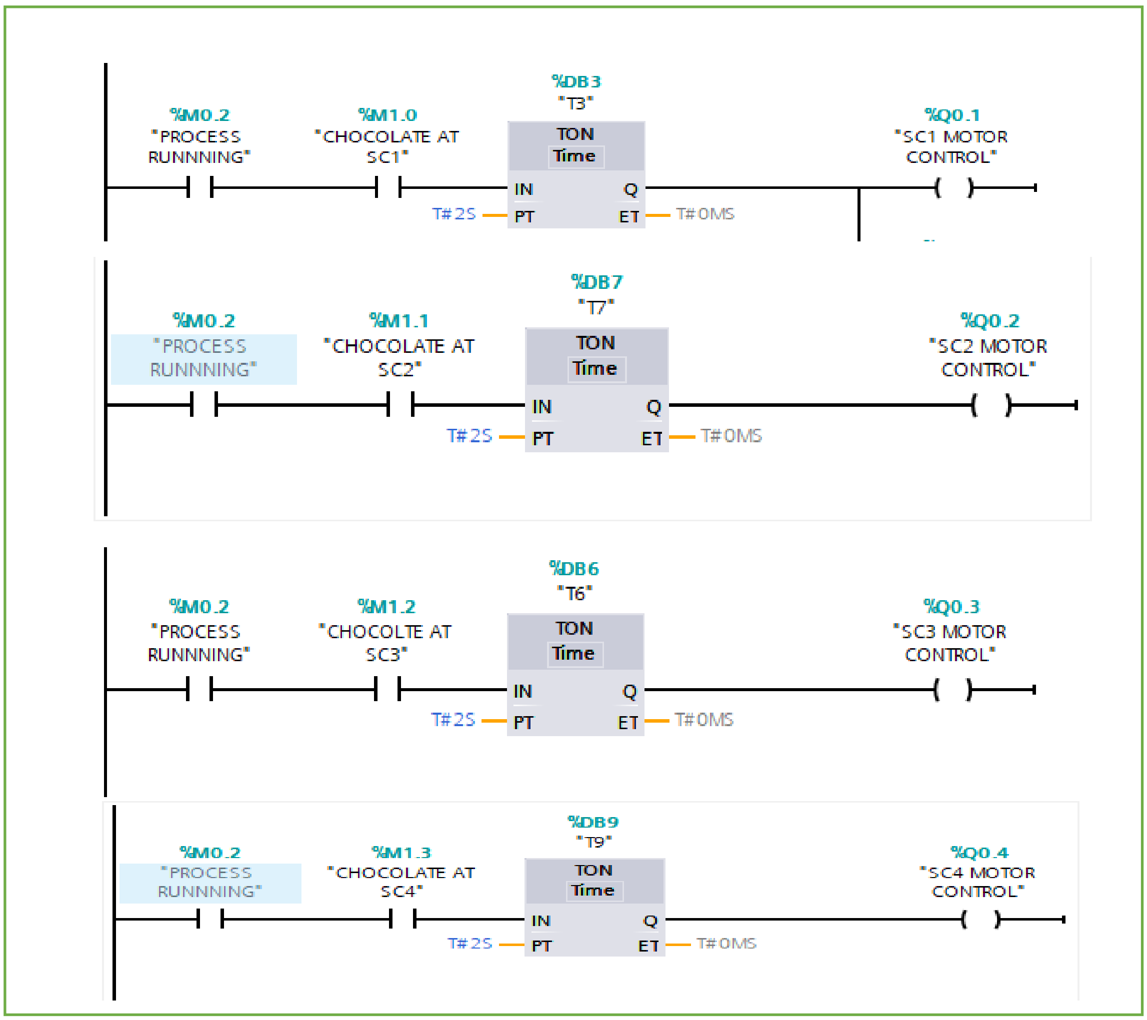


Figure 4:16 screw conveyors 1 to 4 control

v. Automatic valve2 Control Network

- This network allows controlled discharge of powdered chocolate from the storage hopper into the feeder toward the automatic packaging.
- When the storage hopper reaches a certain level, the valve automatically opens and closes automatically when the process completes or when the process is stopped.
- To prevent false triggers, the network has a 3-second timer delay

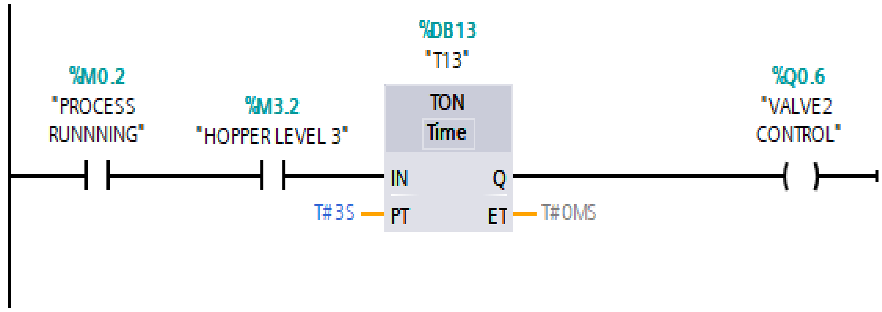


Figure 4:17 automatic valve2 control rung

vi. Process Shutdown and Reset Logic Networks

- They're for ensuring safety and automatic reset of the process when the powdered chocolate is finished in the mixer and storage hopper.
- A 3-second delay timer is triggered when the system is running, and the storage hopper is empty.
- A memory bit that reset/all outputs (motors and valves) is set to true once the timer elapses.

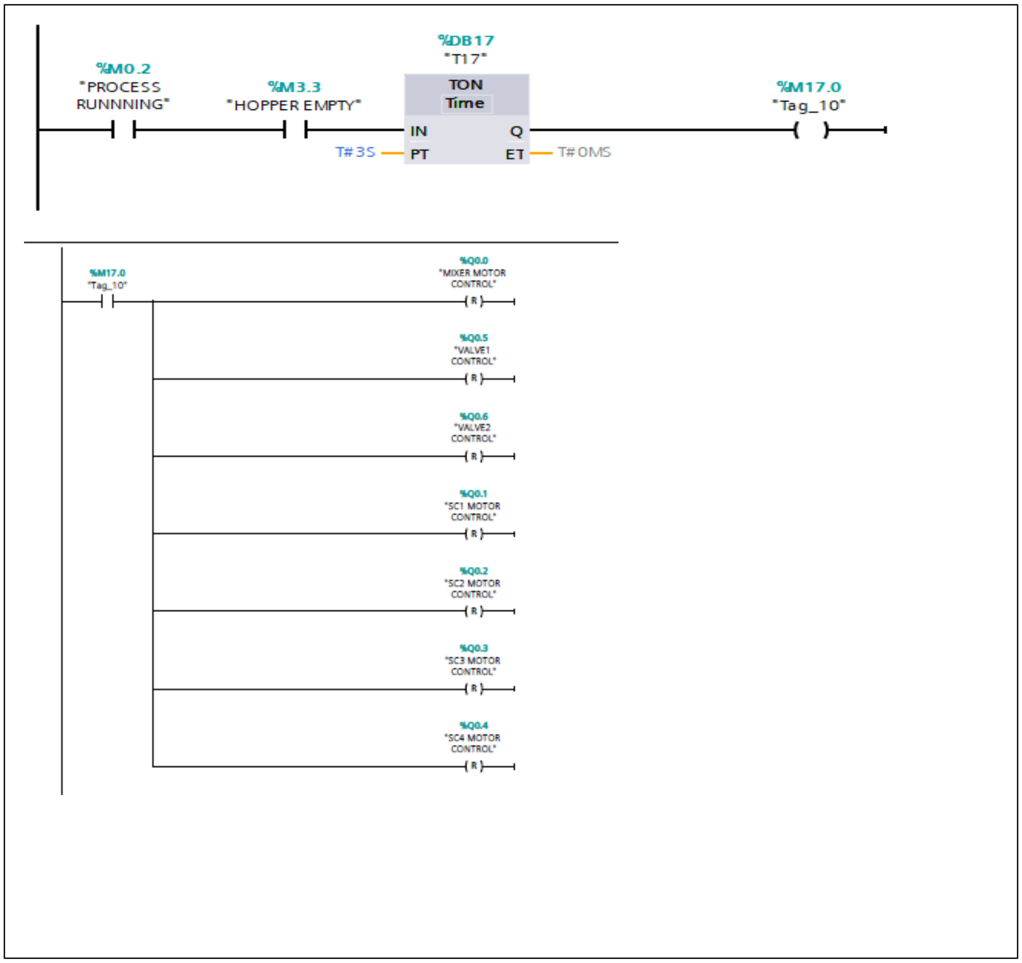


Figure 4:18 Shutdown Trigger and Reset Logic

4.4 HMI Design and Implementation for the Powdered Chocolate Transfer Process

4.4.1 Overview of HMI System

HMIs are visual communication tools that allow human operators to interact with control systems in a user-friendly way. In this project, the HMI enables operator interact with different system elements like motors and valves, and monitor the entire chocolate transfer process.

Platform used: I used WINCC, integrated within TIA Portal compatible with Siemens S7-300.

4.4.2 Step by Step to Designing HMI Screen in TIA Portal

After creating a project and having added a PLC, select: add new device → HMI → SIMATIC Comfort panel → 9" Display → TP900 Comfort → 6AV2 124–0JC01–0AX0 then click 'OK'

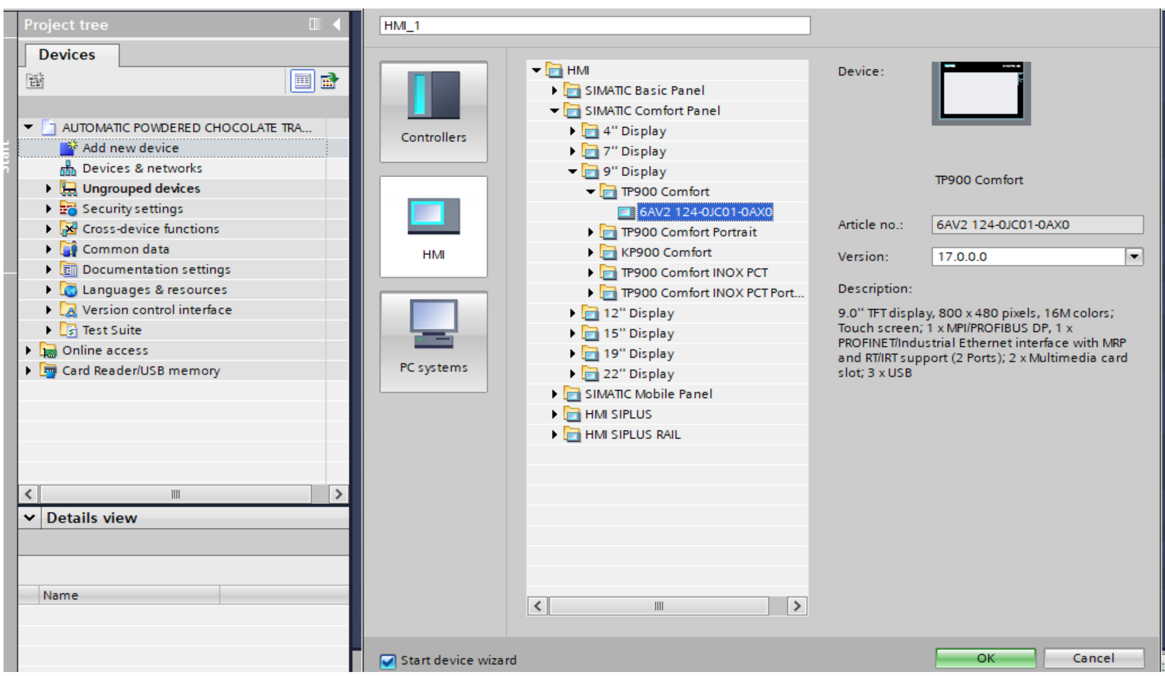


Figure 4:19 first step in creating HMI screen in TIA portal

4.4.3 Configure Communication Between PLC and HMI

- From the devices list on left navigate to "devices and networks"
- Connect the PLC and the HMI using appropriate communication protocol

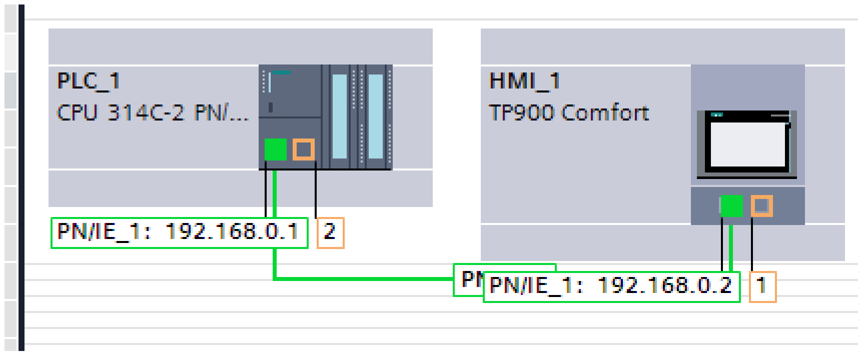


Figure 4:20 HMI and PLC Communication Setup

4.4.4 HMI Variables of the System

In Runtime, process values are transmitted through variables and each HMI element is connected to a specific PLC variable

Name	Data type	Connection	PLC name	PLC tag
HOPPER LEVEL 2	Bool	HMI_Connectio...	PLC_1	"HOPPER LEVEL 2"
HOPPER LEVEL 3	Bool	HMI_Connectio...	PLC_1	"HOPPER LEVEL 3"
HOPPER LEVEL 4	Bool	HMI_Connectio...	PLC_1	"HOPPER LEVEL 4"
HOPPER LEVEL 5	Bool	HMI_Connectio...	PLC_1	"HOPPER LEVEL 5"
HOPPER LEVEL1	Bool	HMI_Connectio...	PLC_1	"HOPPER LEVEL1"
MIXER LEVEL FULL	Bool	HMI_Connectio...	PLC_1	"MIXER LEVEL FULL"
MIXER LEVEL1	Bool	HMI_Connectio...	PLC_1	"MIXER LEVEL1"
MIXER LEVEL2	Bool	HMI_Connectio...	PLC_1	"MIXER LEVEL2"
MIXER LEVEL3	Bool	HMI_Connectio...	PLC_1	"MIXER LEVEL3"
MIXER LEVEL4	Bool	HMI_Connectio...	PLC_1	"MIXER LEVEL5"
MIXER LEVEL4(1)	Bool	HMI_Connectio...	PLC_1	"MIXER LEVEL4"
MIXER LEVEL6	Bool	HMI_Connectio...	PLC_1	"MIXER LEVEL6"
MIXER LOW	Bool	HMI_Connectio...	PLC_1	"MIXER LOW"
MIXER MOTOR CONTROL	Bool	HMI_Connectio...	PLC_1	"MIXER MOTOR CONTR...
SC1 MOTOR CONTROL	Bool	HMI_Connectio...	PLC_1	"SC1 MOTOR CONTROL"
SC2 MOTOR CONTROL	Bool	HMI_Connectio...	PLC_1	"SC2 MOTOR CONTROL"
SC3 MOTOR CONTROL	Bool	HMI_Connectio...	PLC_1	"SC3 MOTOR CONTROL"
SC4 MOTOR CONTROL	Bool	HMI_Connectio...	PLC_1	"SC4 MOTOR CONTROL"
START	Bool	HMI_Connectio...	PLC_1	START
STOP	Bool	HMI_Connectio...	PLC_1	STOP
Tag_ScreenNumber	UInt	<Internal tag>		<Undefined>
VALVE1 CONTROL	Bool	HMI_Connectio...	PLC_1	"VALVE1 CONTROL"
VALVE2 CONTROL	Bool	HMI_Connectio...	PLC_1	"VALVE2 CONTROL"

Figure 4:21 HMI Tags and PLC Connections for Process Control

4.4.5 Process Overview Screen

- This screen represents the overall view of the transfer process of powdered chocolate from the mixer to the packaging (is already automated).
- I used graphical elements motors, valves, etc. to visually represent the process
- Interactive Controls:
  - **Start button (green)** – initiate the entire transfer process
  - **Stop button (red)** – stops all operations
- Status Indicators:
  - Brow arrow for chocolate flow
  - Grey motor symbol for motor ON
  - Green motor symbol for motor OFF
  - Blue valve symbol for valve OPEN
  - Grey valve symbol for valve CLOSED

HMI Element	Function
Start Button	Triggers process via `%M0.0`
Stop Button	Stops all operations via `%M0.1`
Motor Status Icons	Show if SC motors or mixer motor are ON/OFF
Valve Icons	Indicate open/close status dynamically
Sensors Feedback	Level indicators for safety and interlocking
Flow Diagram	Real-time visual feedback of powdered chocolate flow

Figure 4:22 functionality summary of HMI

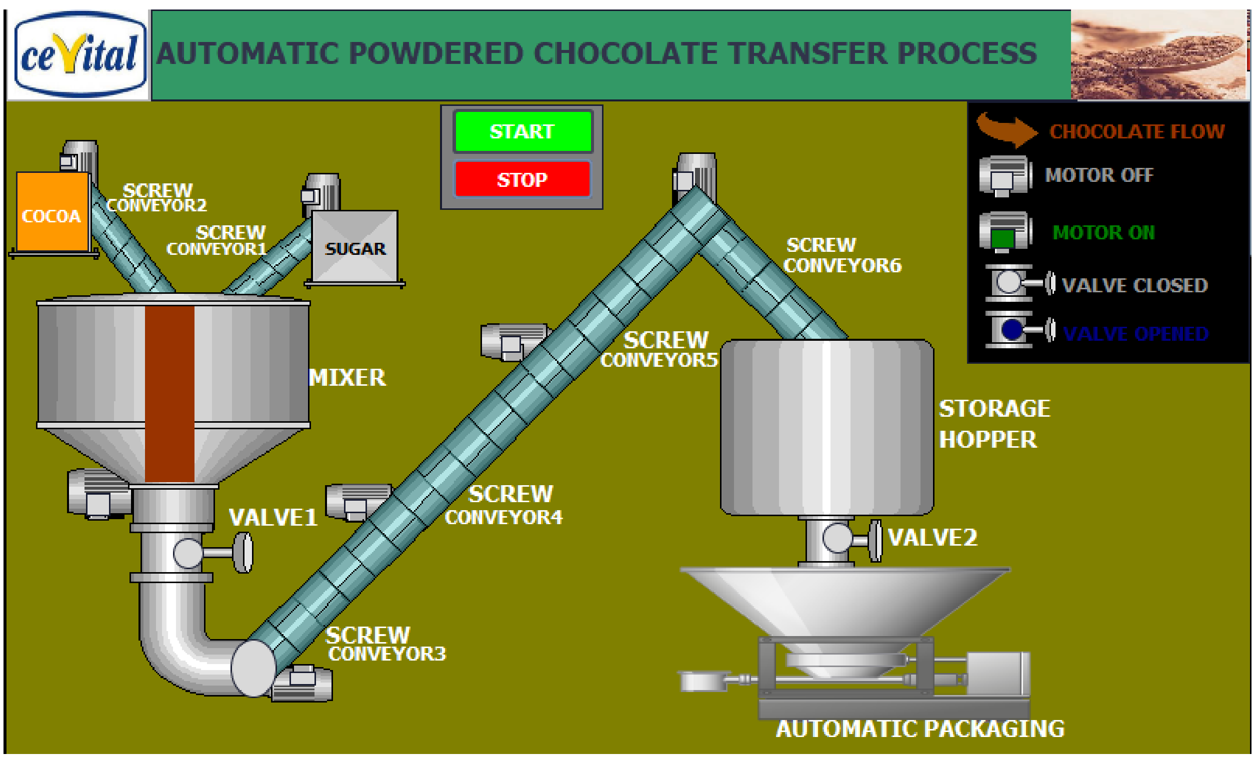


Figure 4:23 HMI Screen for Automatic Powdered Chocolate Transfer

4.5 Conclusion

Programming and supervision form core aspects of industrial automation. In this section they have been implemented to facilitate automatic transfer of powdered chocolate.
Programming part detailed steps for the development of a structured logic using Ladder Diagram programming language, such as program creation, hardware configuration, and declaration of variables. Supervisory part on the other hand focused on the creation of a user-friendly HMI using Simatic WinCC.
The integration of PLC programming with HMI, together form a foundation for a streamlined automated solution. This chapter, therefore, represents a significant step in converting functional needs into a viable industrial automation solution.

General Conclusion

General Conclusion

The aim of this research study was to improve the existing powdered chocolate transfer process, at CEVITAL by proposing and developing automated solution. I was able to able to analyze components and operational workflow of the existing manual system, identify certain inefficiencies of the system, as well as develop a comprehensive automation solution based on industrial automation principles, through a structured approach I followed.

For the first phase of the project, I focused on exploring CEVITAL's operations, particularly the Sugar Packaging Unit, from where I was able to establish contextual foundation for the research. Subsequently, the chapters that followed focused on automation principles with a main focus on PLCs and HMIs, which formed backbone of automating CEVITAL 's powdered chocolate transfer process.

An intensive site-based analysis of the current transfer system exposed numerous inefficiencies, such as manual adjustment of valves, non-synchronized conveyor start-up, regular blockages, operator tiredness and zero in-line visibility. These constraints could be directly correlated to higher labor dependence, delay drift, and lower operational efficiency.

The project proposed a strong automatic approach to tackle these issues, incorporating the following:

- Automatic valves and sequencing of screw conveyors
- Integration of level sensors and flow sensors for real-time monitoring and control
- P LC logic controlled synchronous operation of motors and valves
- Designing of Friendly HMI screen for interoperation control and monitoring

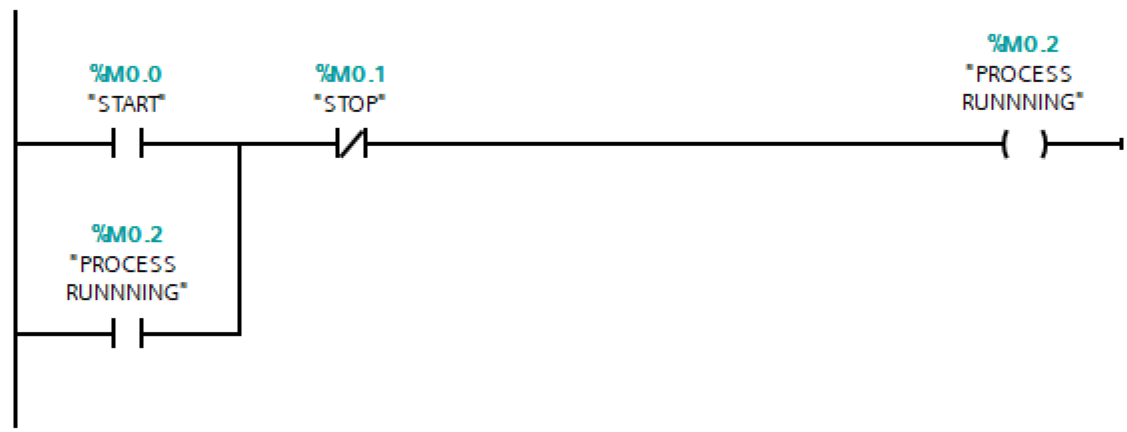
The automation implementation was performed on the TIA Portal engineering system with Siemens S7-300 PLC (Programmable Logic Controller) and WinCC HMI (Human Machine Interface). The system was coded in Ladder Diagram Language (LD) in such a way that all processes executed automatically and were controlled and monitored from a master screen.

Together, this study effectively converted a manual and error-prone transfer to a high-speed, automated and reliable system. The use of PLC and HMI was significantly able to reduce the degree of human intervention, and improve the synchronization process, reducing the time downtime becomes shorter and more safety. The current study fulfils the purposes at the initial part and provides a pilot model to automation in similar food processing work settings. It’s a real strong asset in industrial automation, and in this sense a significant step towards CEVITAL’s wider ambition of smart manufacturing.

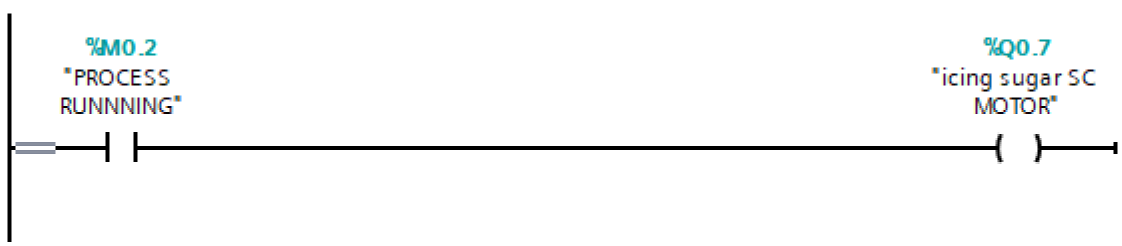
Appendix

Appendix

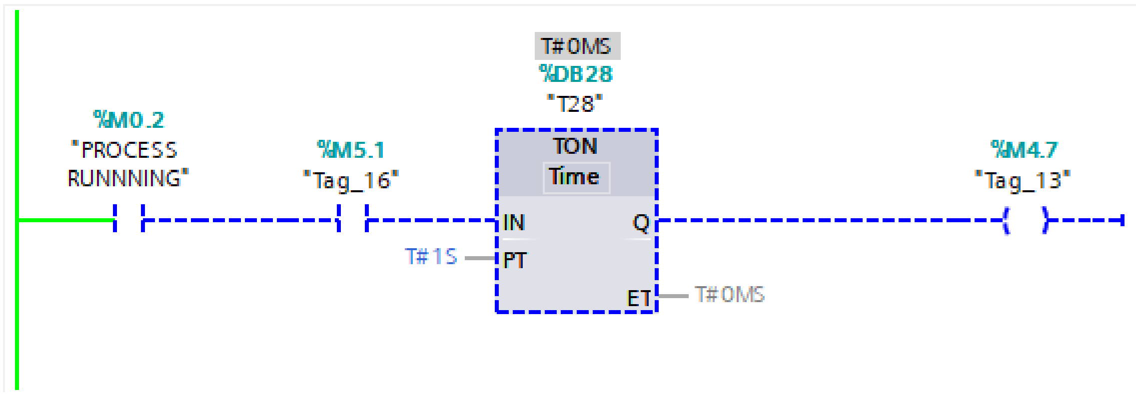
Start/Stop logic and process running latch control



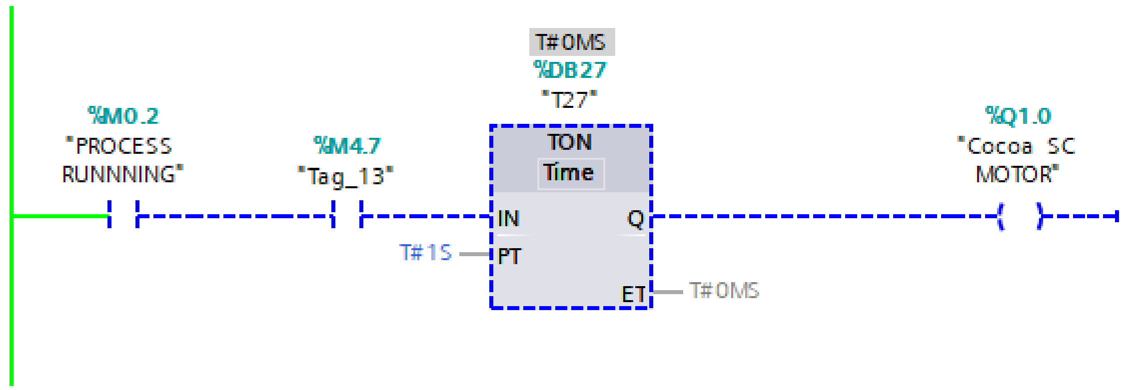
Starts Icing Sugar Screw Conveyor motor when process is running.



Delay before cocoa powder screw conveyor activation.

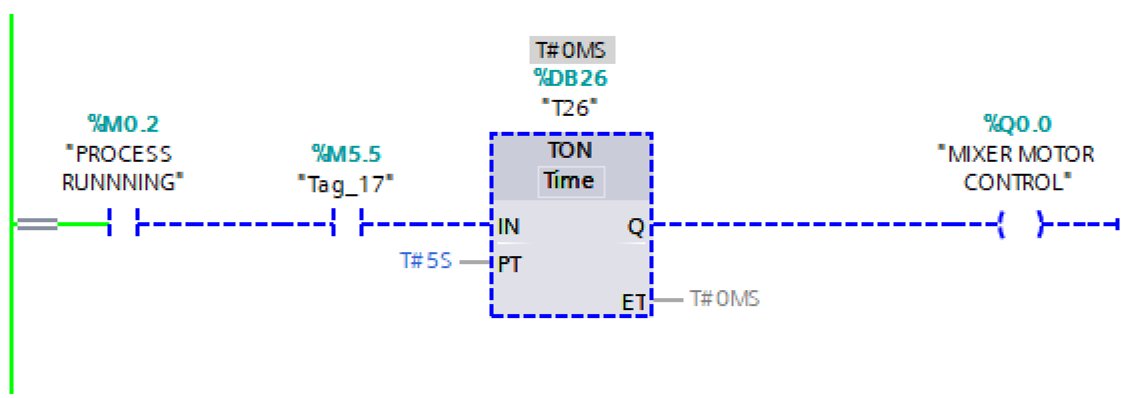


Cocoa powder screw conveyor motor Activation after delay.

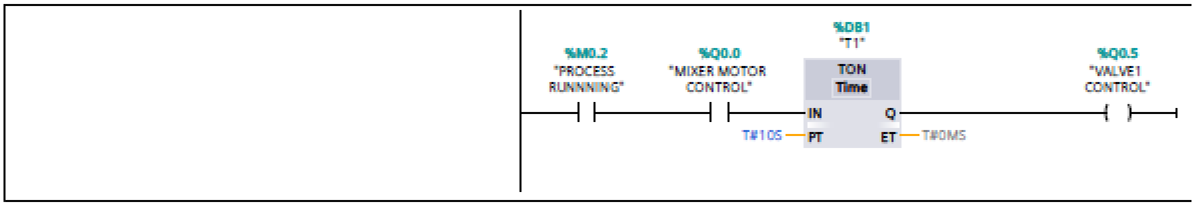


Cocoa SC motor reset logic.

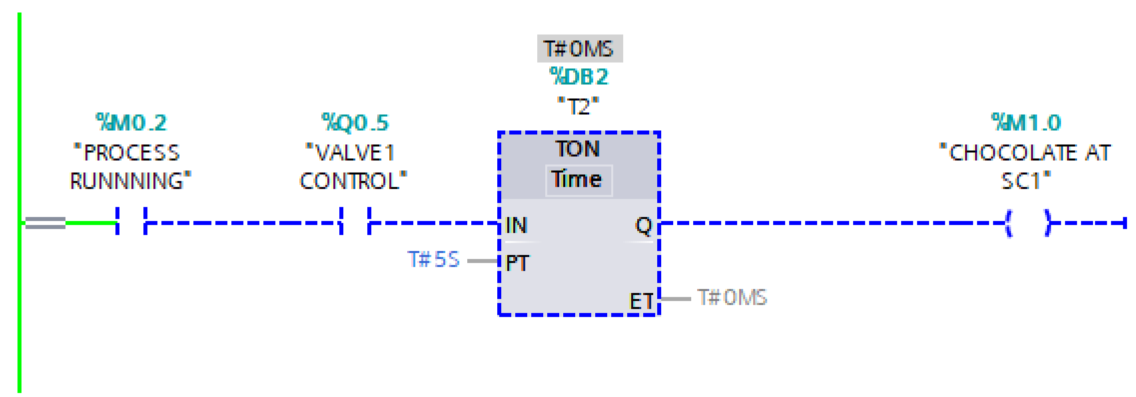
Mixer motor control – starts mixing phase.



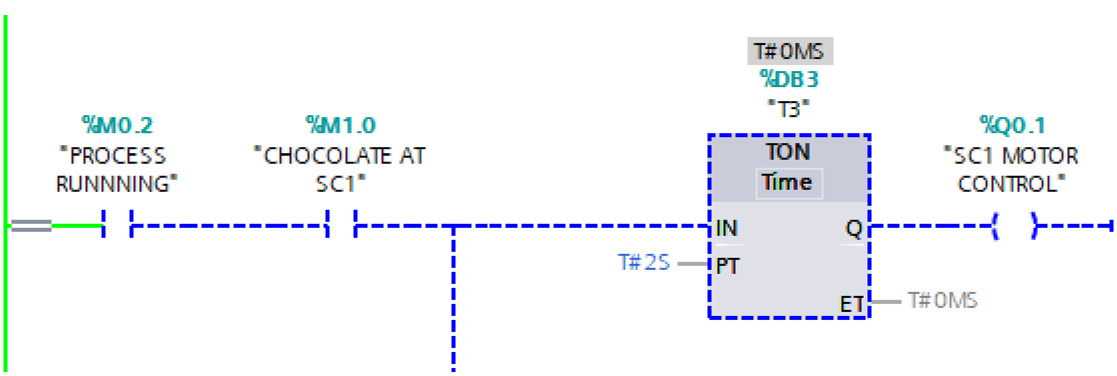
Delay Before Valve1 Opens



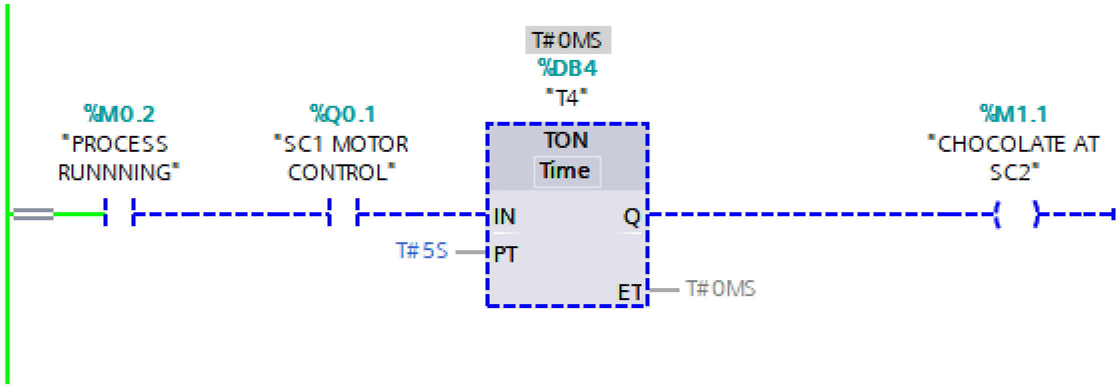
Chocolate Flows Through Valve1 to SC1



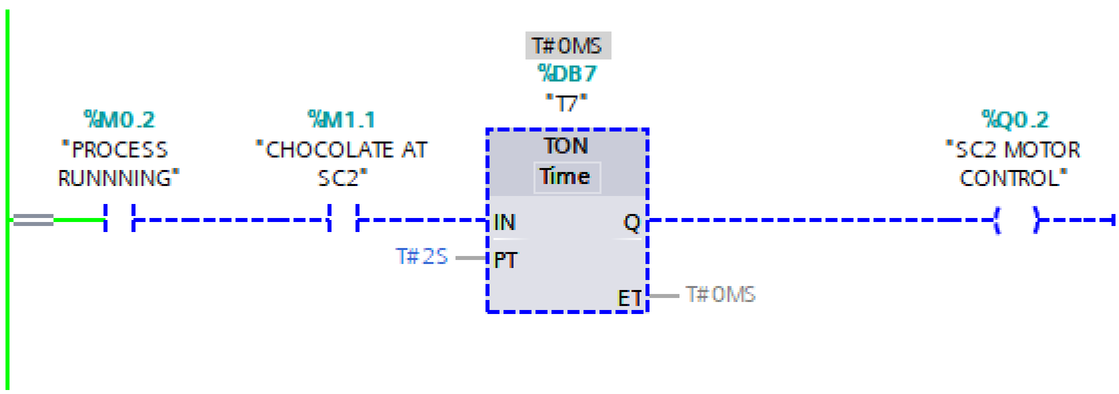
SCREW CONVEYOR1 MOTOR CONTROL



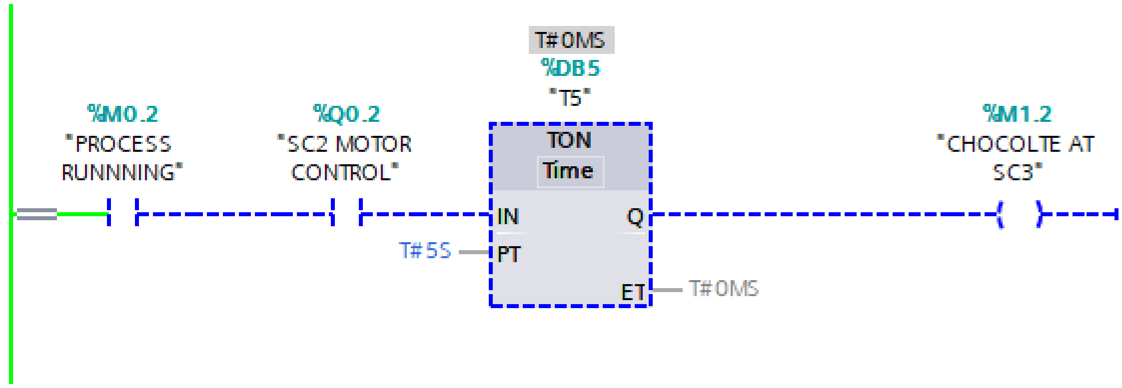
Delay Before Chocolate Reaches SCREW CONVEYOR2



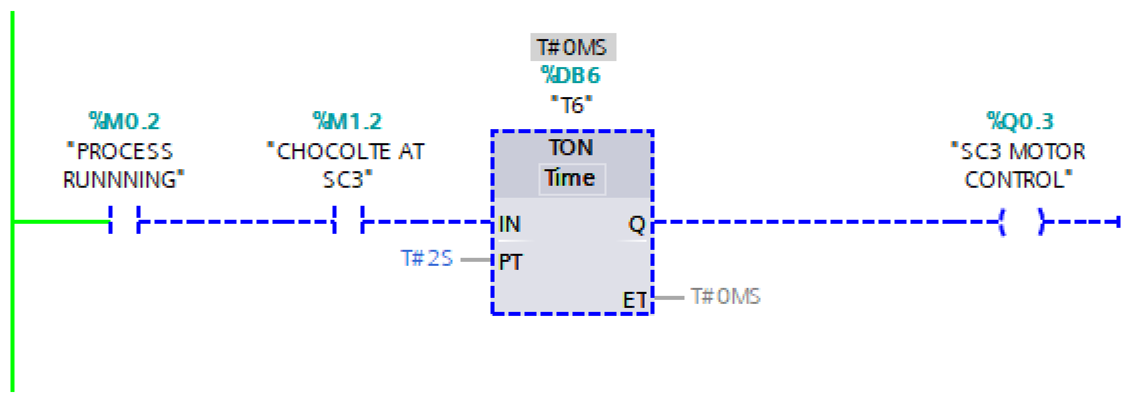
SCREW CONVEYOR2 CONTROL



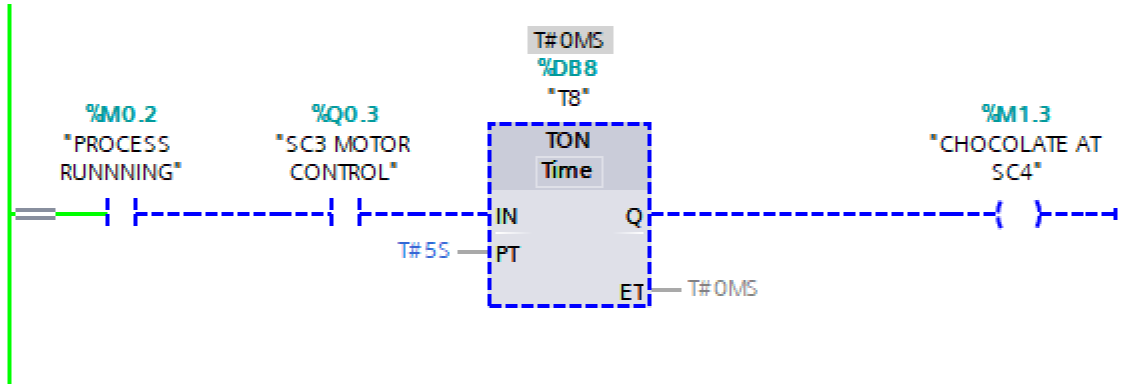
Delay Before Chocolate Reaches SCREW CONVEYOR 3



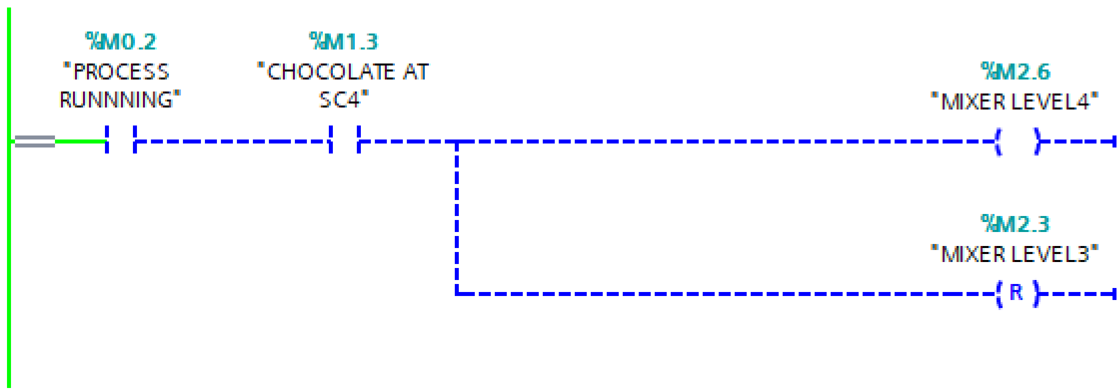
SCREW CONVEYOR3 MOTOR CONTROL



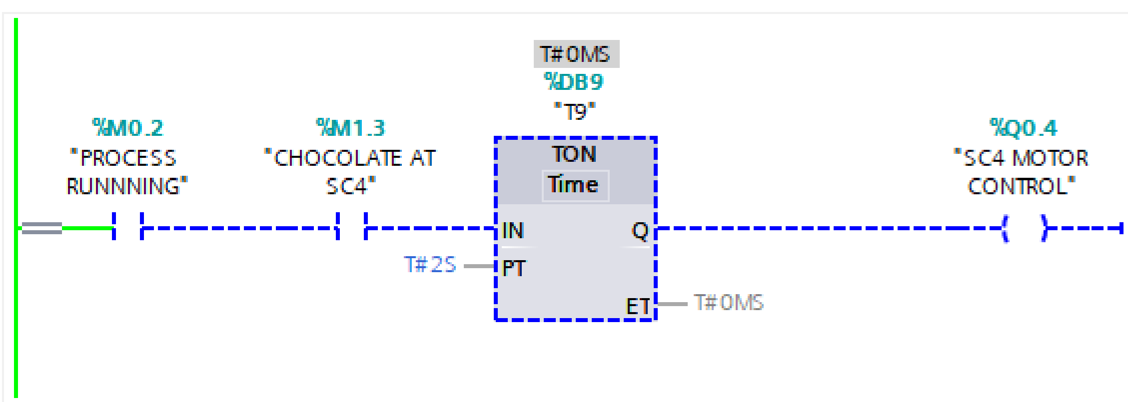
Delay Before Chocolate Reaches SCREW CONVEYOR 4



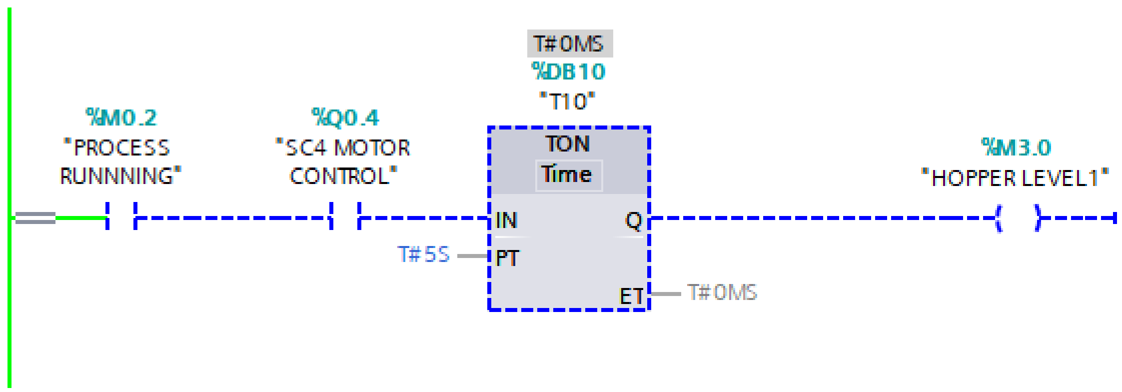
MIXER LEVELS CONTROL



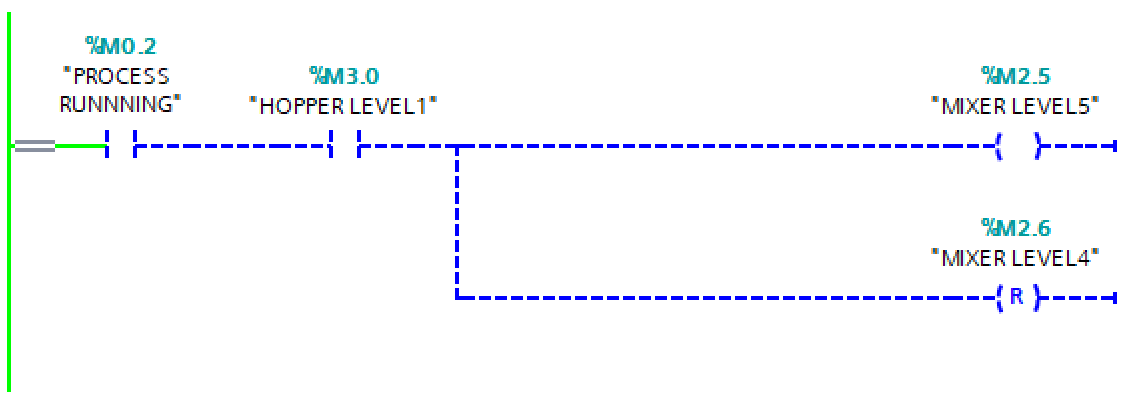
SCREW CONVEYOR 4 MOTOR CONTROL



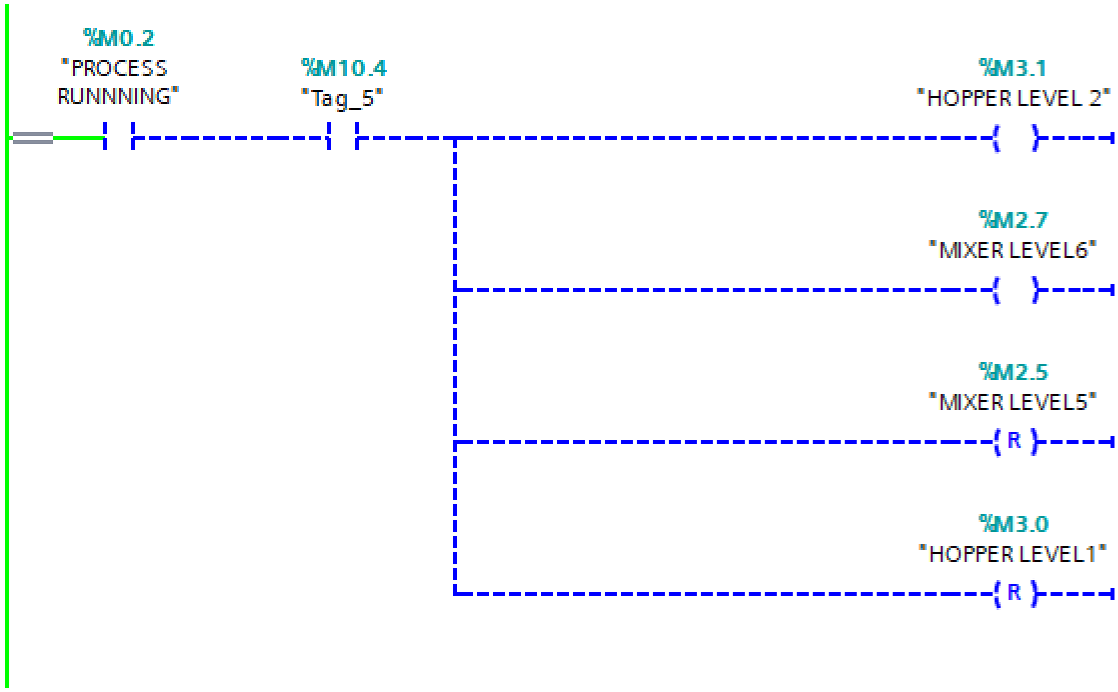
STORAGE HOPPER LEVEL CONTROL



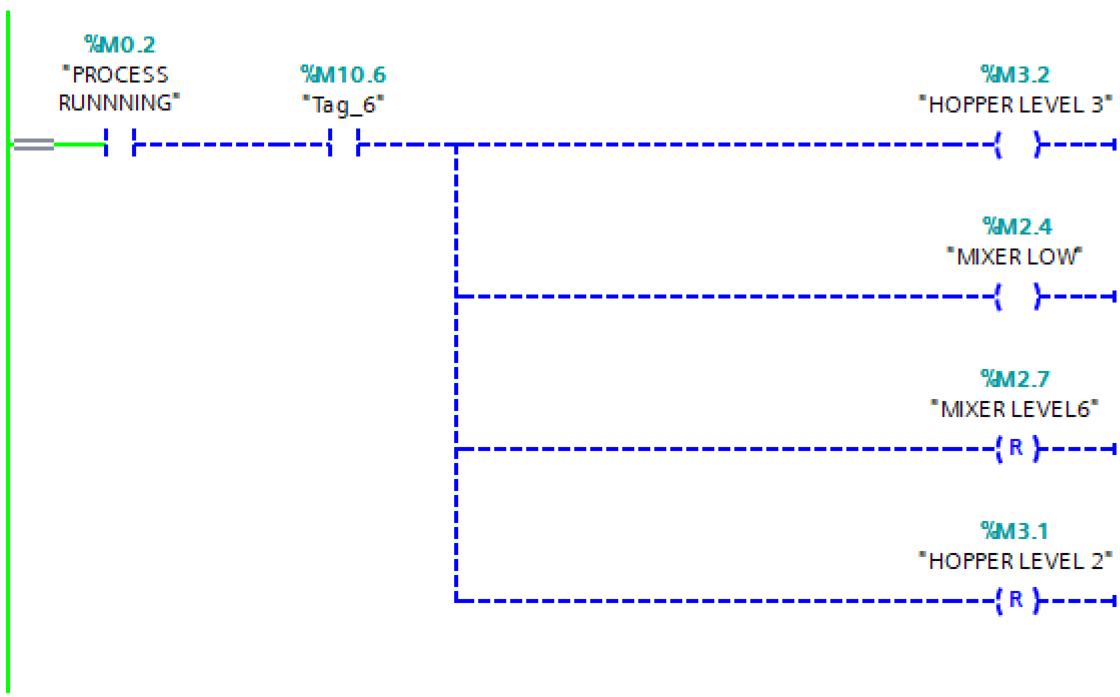
MIXER LEVEL CONTROL



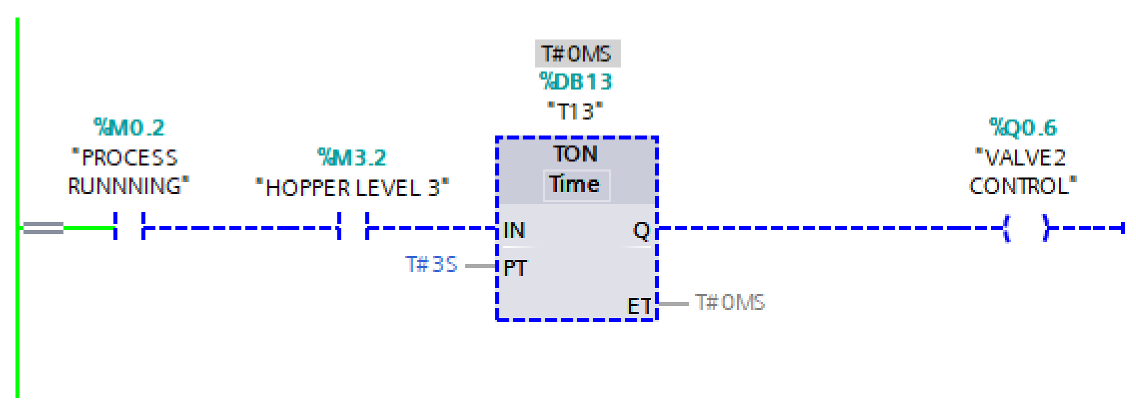
HOPPER AND STORAGE LEVEL CONTROL



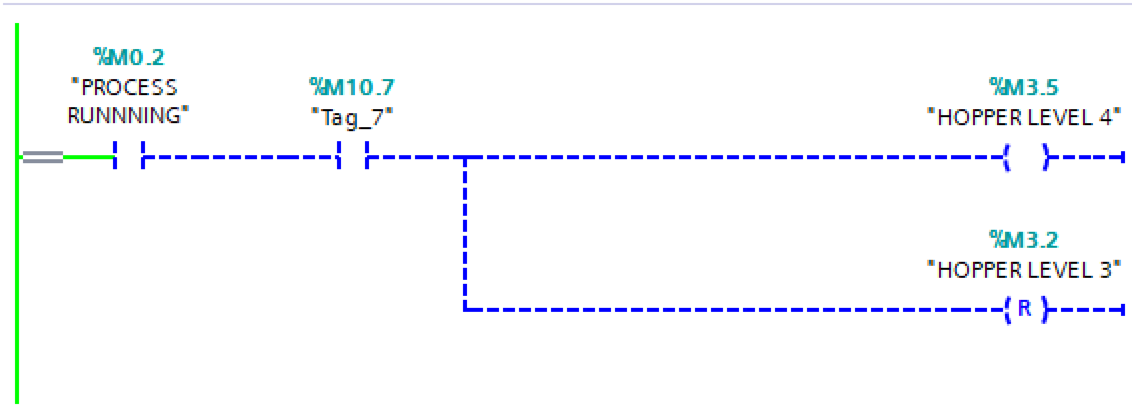
MIXER AND STORAGE HOPPER LEVELS CONTROL

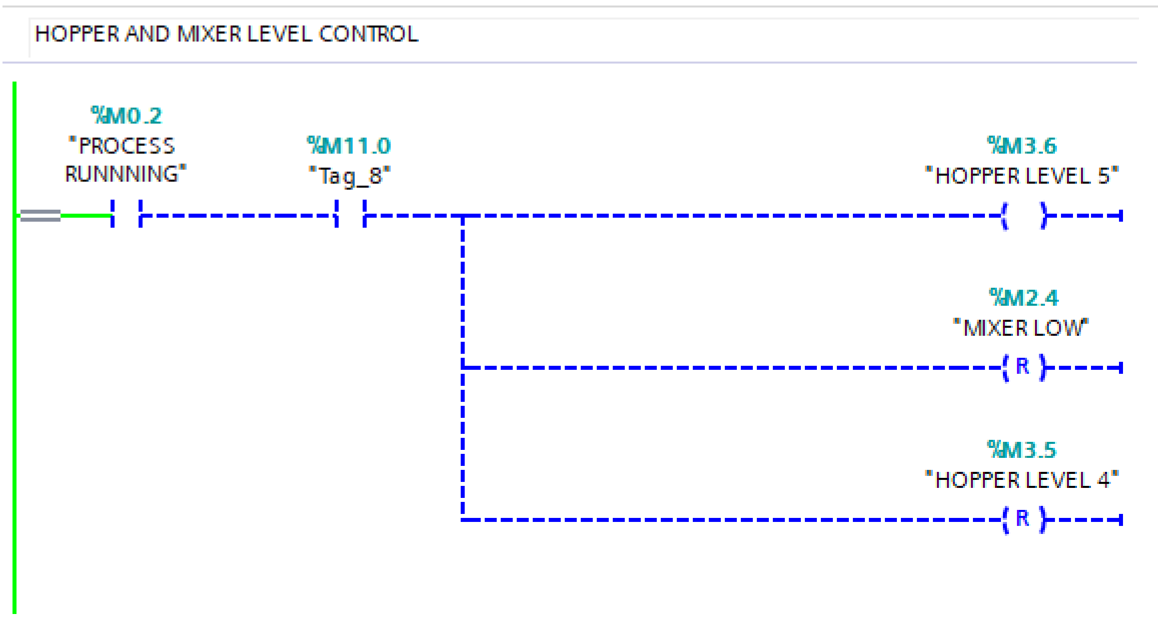


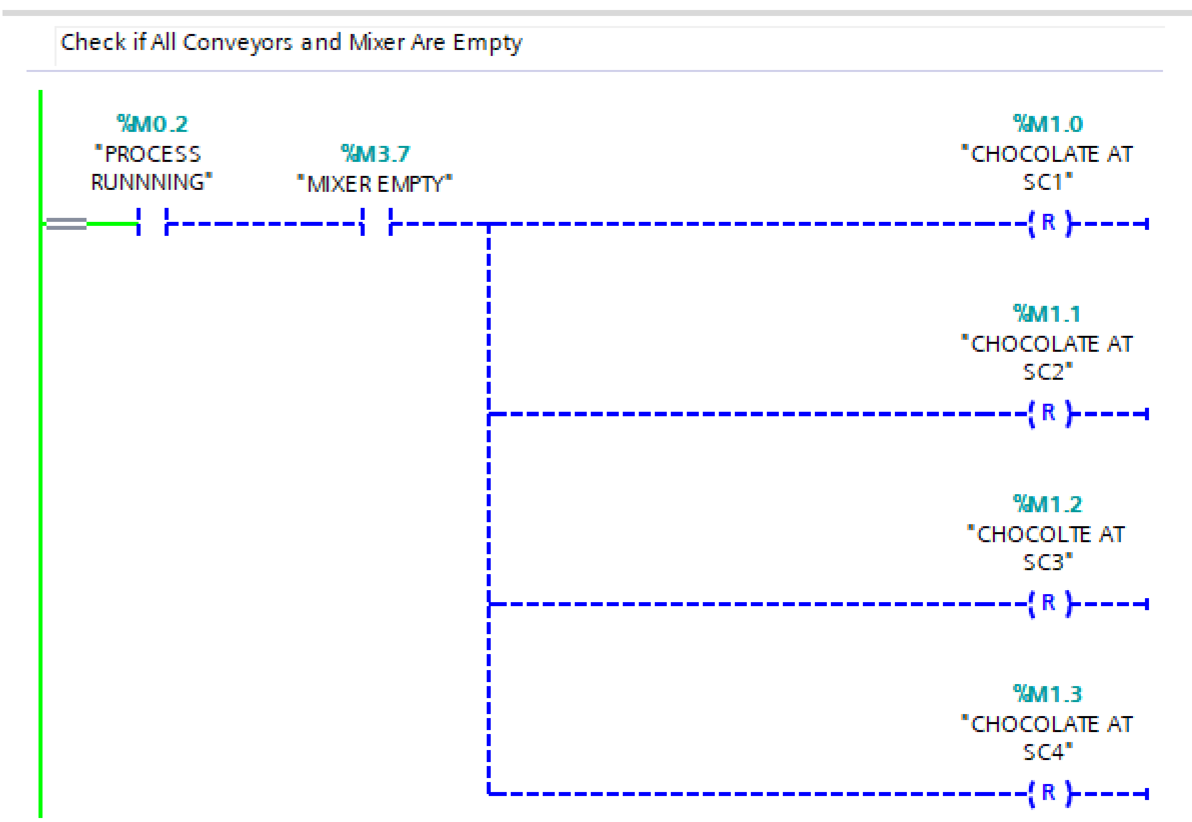
VALVE 2 CONTROL



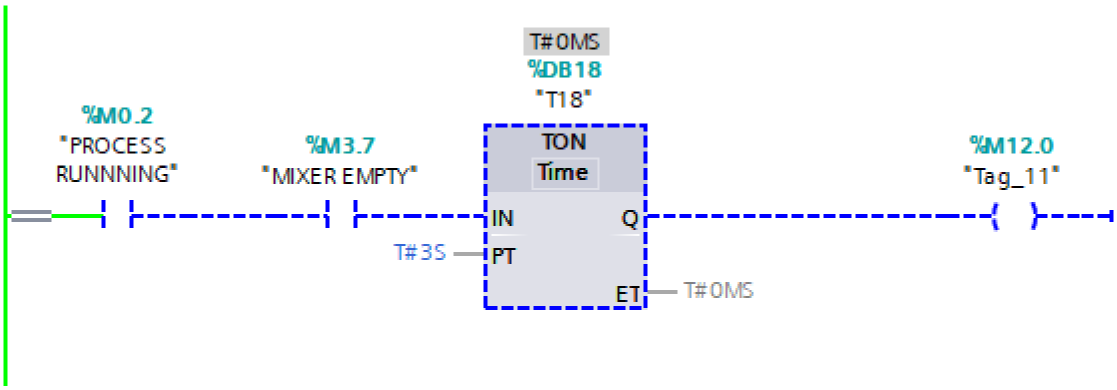
HOPPER LEVELS CONTROL



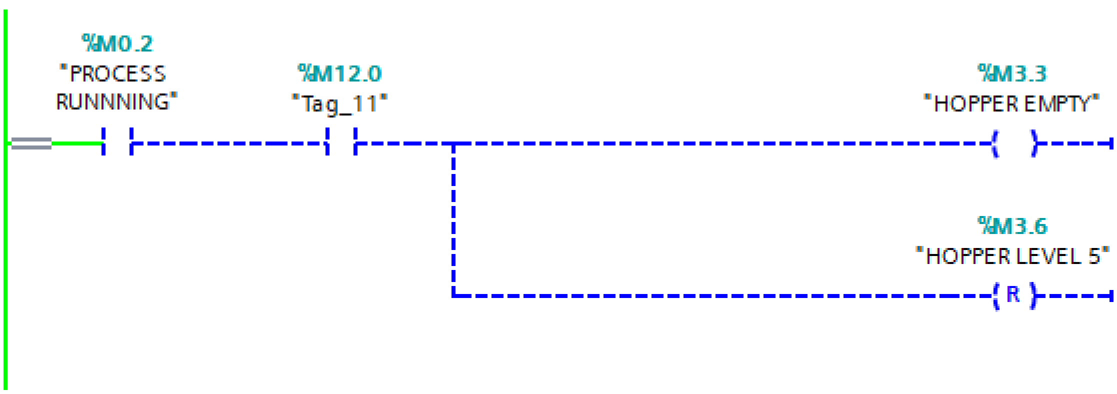

HOPPER AND MIXER LEVEL CONTROL
%M0.2
"PROCESS RUNNNING"
%M11.0
"Tag_8"
%M3.6
"HOPPER LEVEL 5"
%M2.4
"MIXER LOW"
R
%M3.5
"HOPPER LEVEL 4"
R


Check if All Conveyors and Mixer Are Empty
%M0.2
"PROCESS RUNNNING"
%M3.7
"MIXER EMPTY"
%M1.0
"CHOCOLATE AT SC1"
R
%M1.1
"CHOCOLATE AT SC2"
R
%M1.2
"CHOCOLTE AT SC3"
R
%M1.3
"CHOCOLATE AT SC4"
R

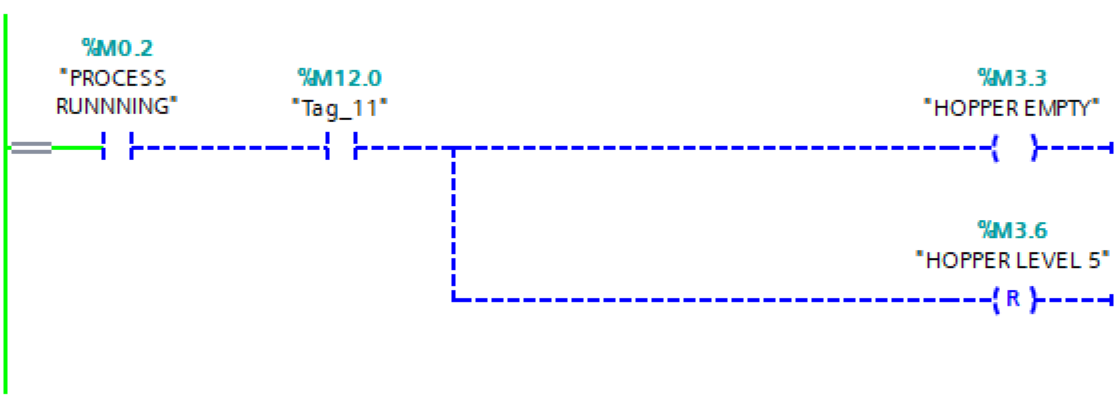
Delay Before Triggering Process Shutdown



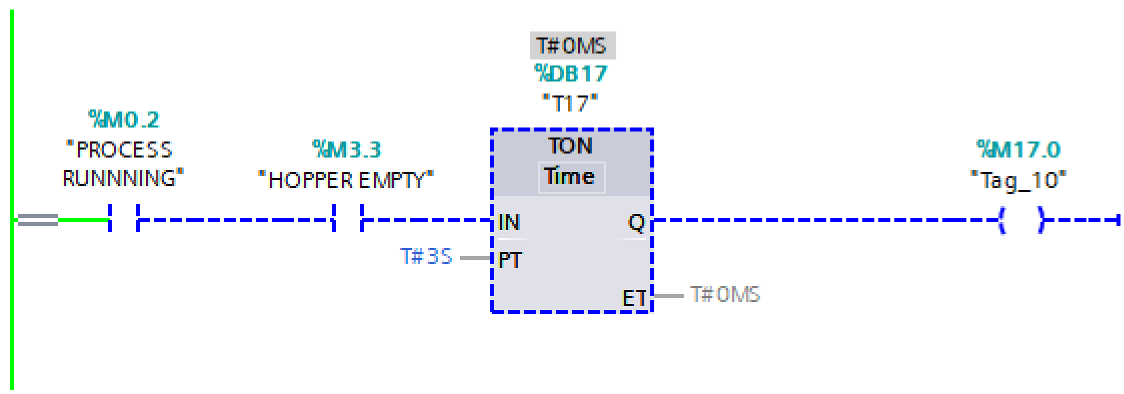
Confirm Hopper is Fully Empty



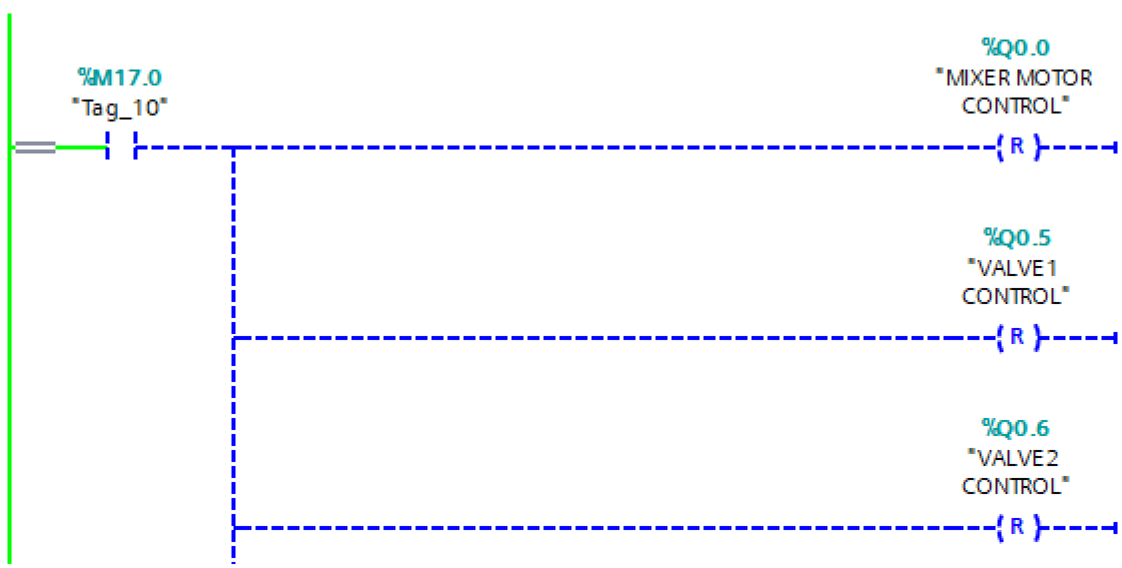
Confirm Hopper is Fully Empty

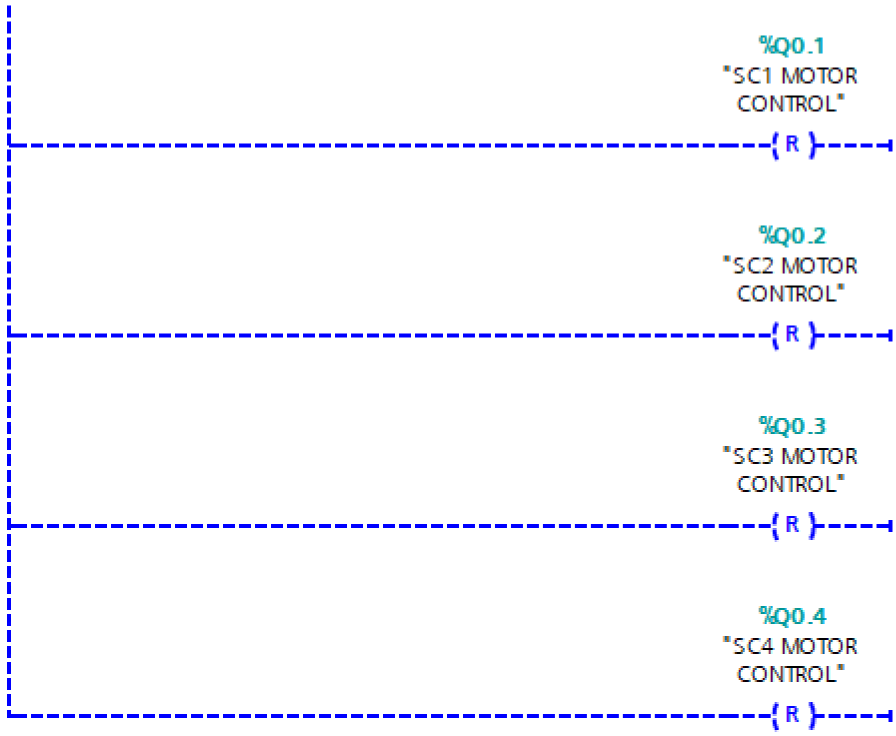


Final Delay Before Resetting Entire ProcesS



Reset All Outputs (Stop Motors, Valves, End Process)




%Q0.1
"SC1 MOTOR CONTROL"
R
%Q0.2
"SC2 MOTOR CONTROL"
R
%Q0.3
"SC3 MOTOR CONTROL"
R
%Q0.4
"SC4 MOTOR CONTROL"
R

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Summary

The aim of this research project was to improve the existing powdered chocolate transfer process, at CEVITAL by proposing and developing an automated solution. The previous process had several inefficient areas, such as manual valve control, manual screw conveyor operation, clogging and unreliable state of control to name a few, and these factors resulted in long lead times and over-manpower requirement for throttling the process.

Based on the detailed analysis of the existing system, the study recommended a stand-alone solution based on industrial automation methodology with PLCs and HMIs. Recommendations of improvement focused on replacing manual valves by automatic valves, automating the screw conveyor, the installation of sensors for monitoring and creating a very user-friendly HMI to assist in the supervision.

The automation implementation was performed on the TIA Portal engineering system with Siemens S7-300 PLC (Programmable Logic Controller) and WinCC HMI (Human Machine Interface), and the programming language used was Ladder Diagram.

Overall, this research illustrates the importance of automation and modernization of the industrial production process, particularly in its application in the food processing industry.

Résumé

L'objectif de ce projet de recherche était d'améliorer le processus existant de transfert de chocolat en poudre au sein de l'entreprise CEVITAL, en proposant et en développant une solution automatisée. L'ancien processus présentait plusieurs points d'inefficacité, tels que le contrôle manuel des vannes, l'activation manuelle des vis sans fin, les problèmes d'engorgement ainsi qu'un système de contrôle peu fiable. Ces facteurs entraînaient des temps de traitement longs et un besoin excessif en main-d'œuvre pour gérer le processus.

Sur la base d'une analyse approfondie du système existant, l'étude a recommandé une solution autonome fondée sur une méthodologie d'automatisation industrielle utilisant des automates programmables (PLC) et une interface homme-machine (HMI). Les améliorations proposées se sont concentrées sur le remplacement des vannes manuelles par des vannes automatiques, l'automatisation des vis sans fin, l'installation de capteurs de surveillance et la conception d'une interface HMI conviviale pour faciliter la supervision du processus.

La mise en œuvre de l'automatisation a été réalisée à l'aide du logiciel TIA Portal, en utilisant un automate Siemens S7-300 (PLC) et une interface homme-machine WinCC (HMI). Le langage de programmation utilisé était le Ladder Diagram (langage à contacts).

Dans l'ensemble, cette recherche met en évidence l'importance de l'automatisation et de la modernisation des processus de production industrielle, en particulier dans leur application dans l'industrie agroalimentaire.