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Faculté des Sciences et de la Technologie
Département de génie électrique

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Le : september 2020

Study And Programming of The RT02(ROTATOR) Machine By The Siemens S7-1200 PLC

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Thème

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Proposé par : MACHIOURI AYMENE
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RESUMES (anglais et Arabe)

Summary

This work, which was carried out in the Biskria cement plant, presents the study of RT02(ROTATOR) machine which allows rotating the package by 180° in order to allow for air-tight packaging. The objective of this work is to automate and supervise. For this, we have using the S7-1200 industrial programmable controller, programmed with TIA Portal software and tested the program by the PLCSIM simulator as well as the WINCC flexible software used for the supervision and configuration of the human machine interface in real time. On the other hand, this work allowed us to familiarize ourselves with the S7-1200 API, to master the language Ladder programming and WINCC explorer which allows you to view and monitor a industry process.

الملخص

يقدم هذا العمل ، الذي تم تنفيذه في مصنع أسمنت بسكرة ، دراسة ماكينة الدوران التي تسمح بتدوير العبوة بزاوية 180 درجة للسماح بتغليف محكم الغلق. الهدف من هذا العمل هو الأتمتة والإشراف. لهذا ، استخدمنا وحدة التحكم القابلة للبرمجة الصناعية S7-1200 ، المبرمجة باستخدام برنامج TIA Portal واختبرنا البرنامج بواسطة محاكي PLCSIM بالإضافة إلى برنامج WINCC المرن المستخدم للإشراف على واجهة الآلة البشرية وتكوينها في الوقت الفعلي. من ناحية أخرى ، سمح لنا هذا العمل بالتعرف على واجهة برمجة التطبيقات S7-1200 ، لإتقان لغة البرمج Ladder ومستكشف WINCC الذي يسمح لك بمشاهدة عملية الصناعة ومراقبتها.

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GENERAL INTRODUCTION

The cement sector has recently experienced great competition between companies leader in the manufacture of cement products. This leadership is measured by the organization work within the company which always seeks to ensure good safety for the staff and equipment, make machines more reliable and available, keep the trust of customers with better quality and above all to have the minimum of breakdowns and the maximum production per day while using the minimum possible manpower.

It is from this that the initiation BISKRIA cement is taking the challenge of improving this performance, by proposing corrective solutions of the state, almost textbook, aimed to double the production capacity of the factory.

Automation is the scientific and technological field that performs control technical tasks, by machines operating without human intervention, or by using a reduced intervention. Automation has become widespread in all production activities, both in industry and in-service activities. Whatever either its field of application and the techniques to which it uses, automation has constantly developed with the sole aim of reducing the drudgery of human labor and improve productivity and product quality.

The objective of the internship is to do a study on the rotating device "**RT02**" that allows rotating the package by 180° in order to allow for air-tight packaging.

To achieve our goal, we used the TIA PORTAL V13 programming software provided by the house siemens. TIA PORTAL V13 contains a SIEMENS PLC simulator such as the S7 1200, while, For the supervision we used the WinCC software.

Following this, the manuscript has three chapters :

➢ The first chapter contains a general description of the biskria cement plant and cement manufacturing stages.

➢ The second chapter consists in the presentation of automated system in a general way.

➢ the third chapter will be devoted the description of the PLCs in a more general way and the S7-1200 PLC in a specific way and the programming tools TIA portal v13, WINCC flexible.

➢ Fourth chapter deals with the description of the rotating device "**RT02**" with these differing components and simulation and supervision of our chosen system with TIA PORTAL V13 software.

We end this work with a general conclusion.

CHAPTER I:

Presentation of the Biskria cement (SPA) plant and cement manufacturing process

CHAPTER I: Presentation of the Biskria cement (SPA) plant and cement manufacturing process

I.1 Introduction

Cement is the most important building material of our time. It is a 'high-tech' product from nature, which has benefited from centuries of development. Cement is more precisely a binder. The actual construction material is concrete, which is based on its composition/quality on cement, the latter is the most expensive component of concrete.

In this this chapter we do general description of the biskria cement plant and the stages of cement manufacturing.

I .2 Description of the Biskria cement (SPA) plant

I.2.1 presentation of the company :

The company BISKRIA CIMENT is a company of manufacture and sales of cements with Share capital: 870,000,000.00 DA.

- - Company name: BISKRIA CIMENT company
- Address: DJAR BELAHRACHE, BRANIS, Wilaya de BISKRA 07000, ALGERIA.
- Tel: +213 (0) 33 62 74 62 mobile: +213 (0) 560 960 470
- Fax: +213 (0) 33 62 73 92.
- E-mail: contact@biskriaciment-dz.com / E-mail: biskria.spa@gmail.com [1]

I.2.2 factory products:

the Biskria cement (SPA) produces high quality cements that are systematically checked by the cement plant's laboratory and periodically by the Center for Studies and Technological Services of the Construction Materials Industry CETIM (according to the ISO 17025 standard). These products are: [1]

1)Portland cement Compound CEM II / A 42.5 NA 442

Composition :

• 80% to 94% clinker (K).

• 100% supplement composed of one or more constituents, such as pozzolan (Z), limestone (L), etc.

• Calcium sulphate in the form of gypsum as a setting regulator.

2) Portland cement Compound CEM II / B 32.5 NA 442 [1]

Composition:

• At least 95% clinker (K).

• Additions: the proportion of secondary constitutions is limited to 05%.

3) Sulfate Resistant Cement (CRS) CEM I 42.5 - ES NA 443 [1]

Composition:

• 65% to 79% clinker (K).

• 100% pozzolan supplement (Z)

• Calcium sulphate in the form of gypsum as a setting regulator.

4) Sulphate Resistant Cement (CRS) CEM IV / A-SR 42.5 NA 443 [1]

Composition:

• 20% to 34% clinker (K).

• 100% dairy supplement (S)

• Calcium sulphate in the form of gypsum as a setting regulator.

I.2.3 SPA Biskria Cement Organization Chart

Here is a general view of the organizational chart of SPA Biskria Cement and it different services (Figure I.1): [2]
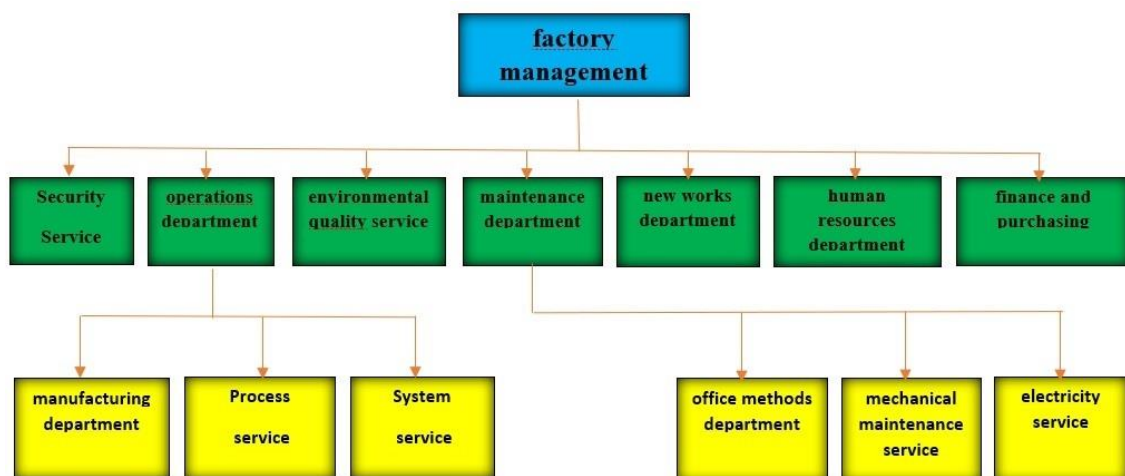
Figure I.1: Organigramme de SPA Biskria Ciment

I.3 Cement manufacturing process

I.3.1 Definition of cement

Cement is an industrial product made by grinding and mixing clinker and additions of other products (gypsum or others) (Figure I.2).

Clinker, which is the main constituent of cements, is a semi-finished product obtained by firing a mixture of raw materials (generally limestone and clay) at high temperature (1450 ° C).

This mixture of raw materials is finely ground before cooking to obtain a "raw flour" which must contain certain components (chemical elements) in well-defined proportions [1].
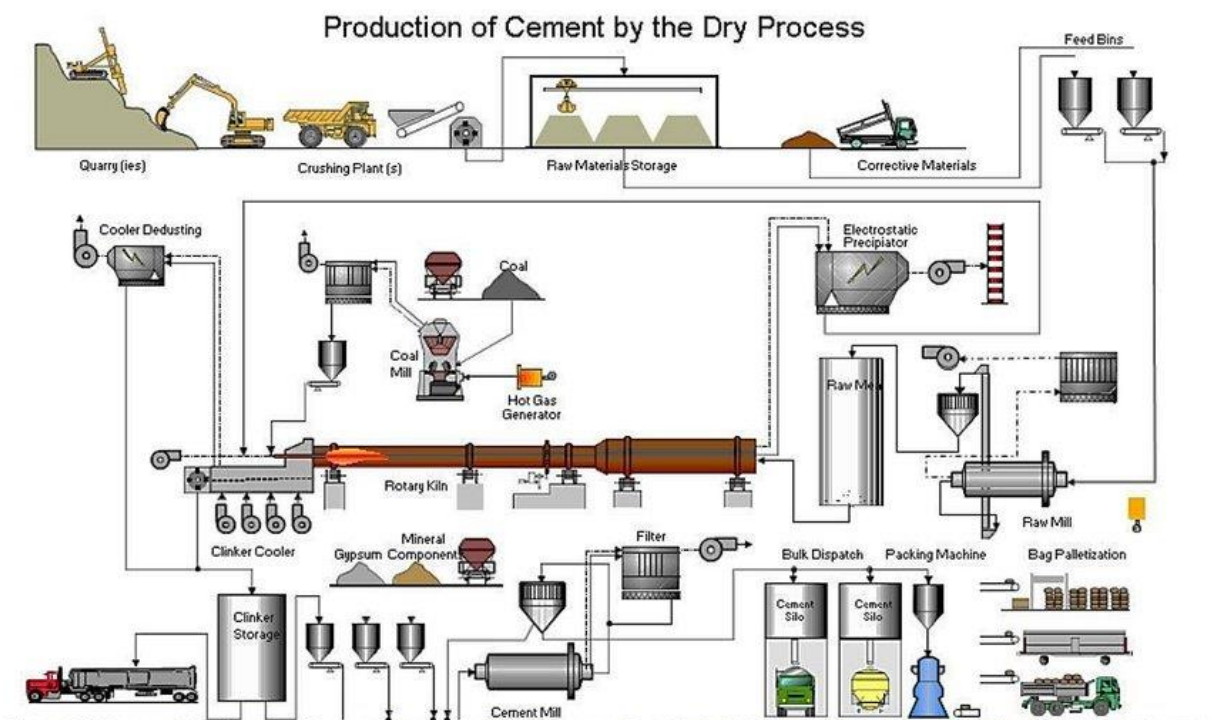
Figure I.2:Cement manufacturing cycle

The manufacture of cement is based on the following main steps:

I.3.2 First Steps: Preparation of raw materials

I.3.2.1 Raw Material Extraction

The limestone is extracted by explosives in quarries near the cement plant (Figure I.3). Clay, sand and iron are extracted by mechanical devices and transported to a cement plant. Crushing, done at the mining site, reduces the grain size of the material to around 50mm (Figure I.4) [2].

Figure I.3: Quarry

Figure I.4: Extraction of raw material for cement making

I.3.2.2 Crushing

The materials are reduced by the crusher to a maximum size of 80mm (Figure I.5). The rock is then continuously sampled to determine the quantity of the various additions required (iron oxide, alumina, silica) and thus arrive at the ideal chemical composition [2].

Figure I.5: Hammer crusher

I.3.2.2 Storage

After these three basic constituents crushing operation a particle size is obtained the component are in chimneys to the plant covered by treadmill and then stored in s two homogenization pre halls: a hall with a circular storage (Figure I.7) for limestone and a linear storage (Figure I.6) hall for clay and sand and iron ore [2].
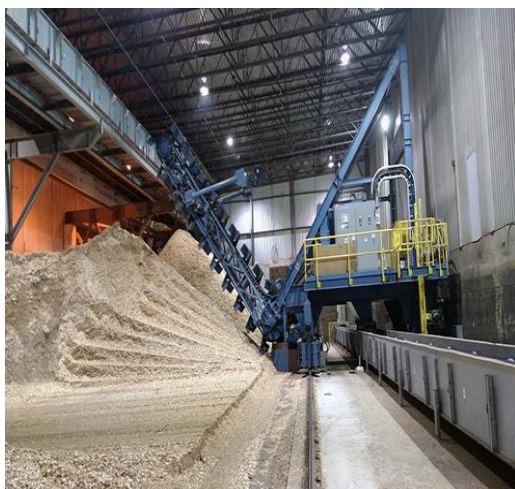
Figure I.6: circular storage

Figure I.7: circular storage

I.3.3 Step 2: raw dosing and grinding

I.3.3.1 Dosage

The raw material consists of a mixture of correction raw materials in proportions which are defined according to the values of the raw chemical moduli, in general the raw material consists of 70% limestone, 20% clay and 10% between the sand and the iron ore, four feeders are installed under the hoppers(Figure I.8), the limestone and clay and the iron ore and the sand are respectively extracted by these feeders, each feeder is systematized automatically, the materials first extracts are loaded onto a single conveyor belt and then transported to the raw crusher [2].

Figure I.8: Dosing Workshop

I.3.3.2 Crushing of raw

Its main component is a cylinder of larger diameter and shorter length which can rotate through the transmission mechanism. The materials are placed in the cylinder through the feed opening and then crushed thoroughly, because during the fall of the iron and raw balls can produce a huge impact of crushing drop (Figure I.9). The raw material is then reduced to powder (flour) and this loaded on a conveyor to then transported to the homogeneous silo [2].

Figure I.9: Raw mill

I.3.4 Step 3: Clinker production

Clinker is a dark grey nodular material made by heating ground limestone and clay at a temperature of about 1400 °C - 1500 °C. The nodules are ground up to a fine powder to produce cement (Figure I.10) with a small amount of gypsum added to control the setting properties [2].
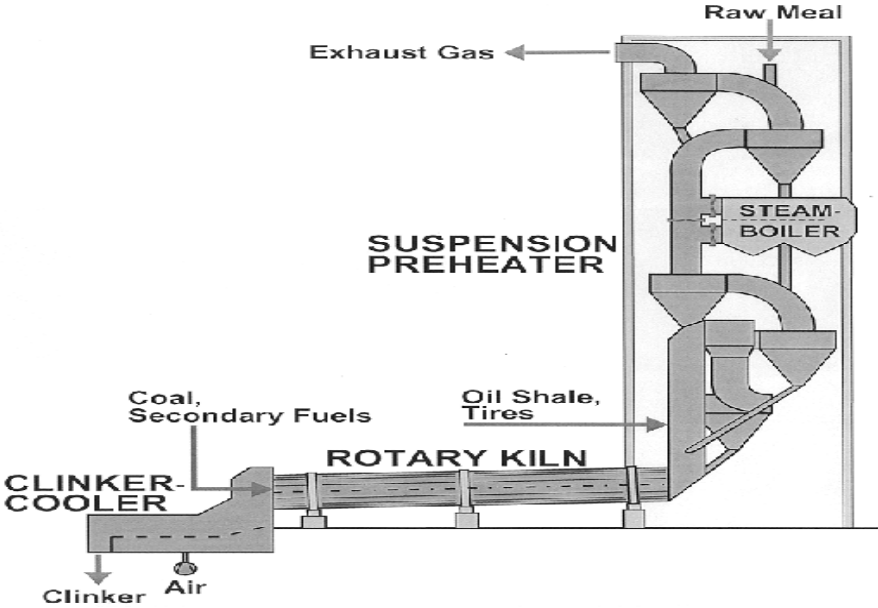
Figure I.10: Production stages of clinker

I.3.4.1 Homogenization and preheating

The gauzes heat the raw powder which circulates in the cyclones in the opposite direction, by gravity (Figure I.11). Raw flour thus heats up to around 800 ° C and therefore loses its carbon dioxide (CO2) and water. It is a counter-current exchanger intended to preheat the flour before it enters the furnace, by recovering the heat of gas leaving the furnace "approximately equal to 100 c", by the fact that the clay and the limestone have the same density (2.70 g / cm3), an exhauster mounted on the cyclones sucks the combustion gases and the quarry mixture, making a tornado guarantee that all the grains of the flood undergo the heat of the gases [2].

Figure I.11: Preheater or cyclones

I.3.4.2 Rotary kiln

The baking of the flour takes place at a temperature of 1450 ° C in a rotary oven.The oven constitutes a cylindrical shell 35m long and 5.6m in diameter protected by refractory brick, inclined at an angle of 1 to 4 degrees from horizontal(Figure I.12)

The oven rotates at rotation speeds between 1.8 and 3.5tr / min, the raw flour will follow different stages of transformation during its slow progression in the oven towards the lower part, to meet the flame.

This heat source is fed with crushed coal. The temperature required for the CLINKER is of the order of 1450 ° C. The energy consumed is between 3,200 and 4,200 MJ per ton of CLINKER, which is the semi-finished product obtained at the end of the cooking cycle.

It is in the form of gray granules, and when it comes out of the oven, the CLINKER must be cooled [2].

Figure I.12: Rotary kiln

I.3.4.3 Cooler

On leaving the rotary kiln, the CLINKER needs cooling to preserve its chemical formula, by a grate cooler it is equipped with a battery of powerful fans supplying the cooling air (Figure I.13).

The role of the cooler is to lower the temperature of the CLINKER falling from the oven to a temperature of about 1135 c up to 80-100 c, the CLINKER will progress inside thanks to the repeated strokes of the grids on which it rests, at the Powerful fans blow under the CLINKER through grids in order to cool it and transport it with a CLINKER silo conveyor [2].

Figure I.13: Grid Cooler

I.3.4.4 Storage of clinker

Once cooled, the clinker is then stored in silos which, on the one hand, confer the cement grinding shop (next step) (Figure I.14) [2].

Figure I.14: clinker silo

I.3.5 Step 4: Cement production

I.3.5.1 Cement grinding

The clinker goes to the cement hoppers and then crushed by adding the gypsum and limestone with different amounts depending on the qualities of the desired cement.

This type of crusher that allows the grinding of clinker by adding additions is called "CEMENT CRUSHER".

I.3.5.2 Storage and shipping of cement

Transported to the storage silos by pneumatic or mechanical transport, the cements leave the factory in bags or in bulk.

The bags generally contain 25 or 50 kg of cement and the bagging frequently reaches 100 tonnes per hour.

The bags are transported to palletizers which constitute 1,500 kg pallets transported by truck.

Cement delivered in bulk constitutes 70% of production. It is transported by tanker, train or boat (Figure I.15) [2].

Figure I.15: The Cement Expedition

I.4 Conclusion

In this chapter we have presented a general description of the Biskria cement (SPA) plant and its different areas and the stages of cement production. And the explanation of how these main areas work.

CHAPTER II :

Automated System

II.1 Introduction

Today's highly increasing competitiveness over the industry demands high quality and most consistent products with a competitive price. To address this challenge number of industries considering various new product designs and integrated manufacturing techniques in parallel with the use of automated devices.

One of the remarkable and influential moves for getting the solutions of above mentioned challenge is the industrial automation. Industrial automation facilitates to increase the product quality, reliability and production rate while reducing production and design cost by adopting new, innovative and integrated technologies and services.

II.2 Definition of an automated system

Automation can generally be defined as the process of following a predetermined sequence of operations with little or no human labor, using specialized equipment and devices that perform and control manufacturing processes.

Automation in its full sense, is achieved through the use of a variety of devices, sensors, actuators, techniques, and equipment that are capable of observing the manufacturing process, making decisions concerning the changes that need to be made in the operation, and controlling all aspects of it [3].

second definition:

Automation is the process in industry where various production operations are converted from a manual process, to an automated or mechanized process [3].

II.3 Advantages of automation

Manufacturing companies in virtually every industry are achieving rapid increases in productivity by taking advantage of automation technologies. When one thinks of automation in manufacturing, robots usually come to mind. The automotive industry was the early adopter of robotics, using these automated machines for material

handling, processing operations, and assembly and inspection. Automation can be applied to manufacturing of all types.

The advantages of automation are:

- Increase in productivity.
- Reduction in production costs.
- Minimization of human fatigue.
- Less floor area required.
- Reduced maintenance requirements.
- Better working conditions for workers.
- Effective control over production process.
- Improvement in quality of products.
- Reduction in accidents and hence safety for workers.
- Uniform components are produced [3].

II.4 Goals of automation

Automation has certain primary goals as listed below:

- Integrate various aspects of manufacturing operations so as to improve the product quality and uniformity, minimize cycle times and effort, and thus reduce labor costs.
- Improve productivity by reducing manufacturing costs through better control of production. Parts are loaded, fed, and unloaded on machines more efficiently. Machines are used more effectively and production is organized more efficiently.
- Improve quality by employing more repeatable processes.
- Reduce human involvement, boredom, and possibility of human error.
- Reduce workpiece damage caused by manual handling of parts.
- Raise the level of safety for personnel, especially under hazardous working conditions.
- Economize on floor space in the manufacturing plant by arranging the machines, material movement, and related equipment more efficiently [3].

II.5 Reasons for automation

1. **Shortage of labor**
2. **High cost of labor**
3. **Increased productivity:** Higher production output per hour of labor input is possible with automation than with manual operations. Productivity is the single most important factor in determining a nation's standard of living. If the valu of output per hour goes up, the overall income levels go up.
4. **Competition:** The ultimate goal of a company is to increase profits. However, there are other goals that are harder to measure. Automation may result in lower prices, superior products, better labor relations, and a better company image.
5. **Safety:** Automation allows the employee to assume a supervisory role instead of being directly involved in the manufacturing task. For example, die casting is hot and dangerous and the work pieces are often very heavy. Welding, spray painting, and other operations can be a health hazard. Machines can do these jobs more precisely and achieve better quality products.
6. **Reducing manufacturing lead-time:** Automation allows the manufacturer to respond quickly to the consumers needs. Second, flexible automation also allows companies to handle frequent design modifications.
7. **Lower costs:** In addition to cutting labor costs, automation may decrease the scrap rate and thus reduce the cost of raw materials. It also enables just-in-time manufacturing which in turn allows the manufacturer to reduce the in-process inventory. It is possible to improve the quality of the product at lower cost [3].

II.6 Reasons for no automation

1. **Labor resistance:** People look at robots and manufacturing automation as a cause of unemployment. In reality, the use of robots increases productivity, makes the firm more competitive, and preserves jobs. But some jobs are lost. For example, Fiat reduced its work force from 138,000 to 72,000 in nine years by investing in robots. GM's highly automated plant built in collaboration with Toyota in Fremont, California employs 3,100 workers in contrast to 5,100 at a comparable older GM plant.

2. **Cost of upgraded labor:** The routine monotonous tasks are the easiest to automate. The tasks that are difficult to automate are ones that require skill. Thus, manufacturing labor must be upgraded.

3. **Initial investment**: Cash flow considerations may make an investment   in automation difficult even if the estimated rate of return is high [3].

II.7 Types of Automation System

Automated manufacturing systems can be classified into three basic types (Figure II.1):

a.   **Fixed automation.**

b.   **ii. Programmable automation**

c.   **Flexible automation.**

II.7.1 Fixed Automation

Fixed automation is a system in which the sequence of processing (or assembly) operations is fixed by the equipment configuration. Each of the operations is the sequence is usually simple, involving perhaps a plain linear or rotational motion or an uncomplicated combination of the two; for example, the feeding of a rotating spindle. It is the integration and coordination of many such operations into one piece of equipment that makes the system complex. Typical features of fixed automation are:

- high initial investment for custom-engineered equipment.
- high production rates.
- relatively inflexible in accommodating product variety [6].

II.7.2 Programmable Automation

In programmable automation, the production equipment is designed with the capability to change the sequence of operations to accommodate different product configuration. The operation sequence is controlled by a program, which is a set of instructions coded so that they can be read and interpreted by the system. New programs can be prepared and entered into the equipment to produce new products. Some of the features that characterize programmable automation include:

- high investment in general purpose equipment
- lower production rates than fixed automation
- flexibility to deal with variations and changes in product configuration
- most suitable for batch production [6].

II.7.3 Flexible Automation

Flexible automation is an extension of programmable automation. A flexible automated system is capable of producing a variety of parts (or products) with virtually no time lost for changeovers from one-part style to the next. There is no lost production time while reprogramming the system and altering the physical setup (tooling, fixtures, machine settings). Consequently, the system can produce various combinations and schedules of parts or products instead of requiring that they be made in batches. What makes flexible automation possible is that the differences between parts processed by the system are not significant. It is a case of soft variety.so that the amount of changeover required between styles is minimal. The features of flexible automation can be summarized as follows:

- high investment for a custom-engineered system
- continuous production of variable mixtures of products
- medium production rate
- flexibility to deal with product design variations [6].
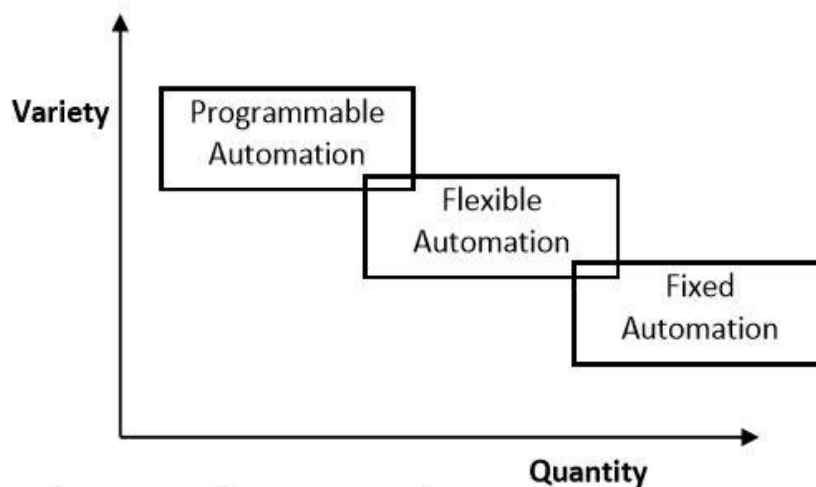
Figure II.1 : Three types of automation relative to production quantity and product variety

II.8 Automation Steps

A process automation system is an arrangement for automatic monitoring and control of the industrial process to obtain the desired results with no manual interventions. As discussed earlier, a typical automation system executes the automation steps

sequentially, cyclically, and continuously, effecting corrections to the process operation and producing the desired results consistently (Figure II.2).

II.8.1 Data Acquisition

The data acquisition step observes the behavior of the process by sensing or measuring the process parameters of interest. These parameters are called process inputs.

II.8.2 Data Analysis, Monitoring, and Decision Making

The data analysis, monitoring, and decision-making step analyzes the behavior of the process by comparing the acquired data from the process with the desired result. Then a decision is made about the new directives or commands that would be required to effect any corrections in the behavior of the process.

II.8.3 Control Execution

The control execution step executes the directives, which are commands decided by the data analysis and decision-making step to effect the corrections, if any [4].
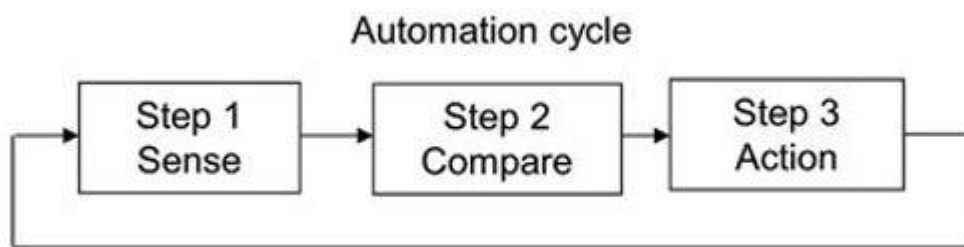
Figure II.2: Typical automation steps and cycle

II.9 Control System

The control element of the automated system executes the program of instructions. The control system causes the process to accomplish its defined function, which for our purpose is to carry out some manufacturing operation. Let us provide a brief introduction to control systems here [6].

The controls in an automated system can be either closed loop or open loop.

II.9.1 closed loop

A closed loop control system, also known as a feedback control system, is one in which the output variable is compared with an input parameter, and any difference between the two is used to drive the output into agreement with the input. As shown in (Figure II.3), a closed loop control system consists of six basic elements: (1) input parameter, (2) process, (3) output variable (4) feedback sensor (5) controller and (6) actuator. The input parameter often referred to as the set point, represents the desired value of the output [6].
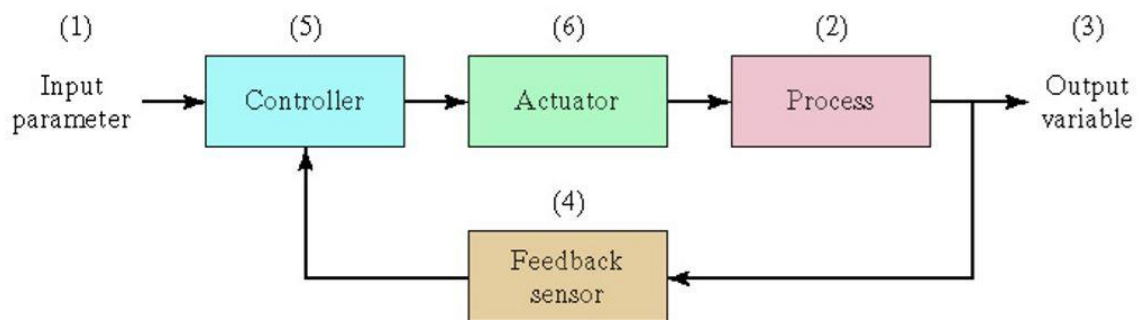
Figure II.3: A feedback control system

II.9.2 open loop

In contrast to the closed loop control system, an open loop control system operates without the feedback loop, as in (Figure II.4). In this case, the controls operate without measuring the output variable.so no comparison is made between the actual values of the output and the desired input parameter. The controller relies on an accurate model of the effect of its actuator for the process variable. With an open loop system, there is always the risk that the actuator will not have the intended effect on the process, and that is the disadvantage of an open loop system. Its advantage is that it is generally simpler and less expensive than a closed loop system. Open loop systems are usually appropriate when the following conditions apply: (1) The actions performed by the control system are simple, (2) the actuating function is very reliable, and (3) any reaction forces opposing the actuation are small enough to have no effect on the actuation. If these characteristics are not applicable, then a closed loop control system may be more appropriate [6].

Figure II.4: An open loop control system

II.10 Automation System Structure (Subsystems)

The automation system is broadly divided into three subsystems: instrumentation, control, and human interface. They are interconnected, as illustrated (Figure II.5) [4].
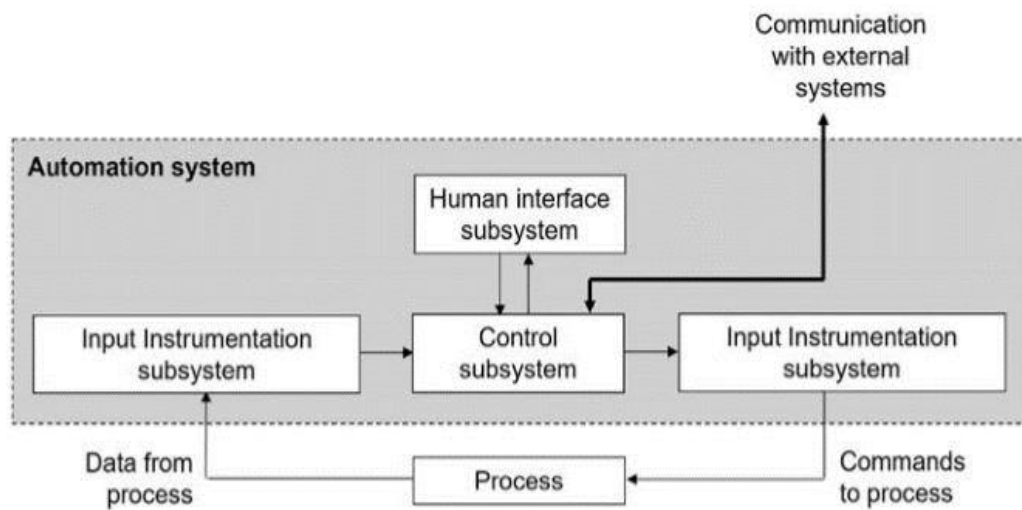
Figure II.5: Basic structure of automation system

II.10.1 Instrumentation

The instrumentation1 is the branch of engineering that deals with the measurement and control of process parameters. An instrumentation device measures the physical variable. and/or manipulates it to produce an output in an acceptable form for further processing in the next stage device. Instrumentation devices are not normally intelligent and are not capable of making decisions (exceptions are discussed later in the book) [4].

The instrumentation subsystem primarily works in two directions: one on the input side of the control subsystem and the other on the output side. Hence the instrumentation subsystem can be further divided into input and output subsystems to explain the flow of data in the order they are received from a process, processed in the control subsystem, and sent to a process for actions:

1. **The input instrumentation subsystem (Sensors):** interfaces with the process to acquire data on the behavior of the process (measurement of process parameters) and sends them to the control subsystem in an acceptable form.

2. **The output instrumentation subsystem (Actuators):** interfaces with the process to send the command received from control subsystem to the process in an acceptable form, to change the behavior of the process (control of process parameters) [4].

II.10.1.1 Actuators

An actuator is a device that uses some type of energy and produces the required force, either providing motion to an object or actuating something. Actuators (independently of their shape, form, and size) produce the mechanical movements required in any physical process in a factory. It should be highlighted that in any industrial production line, if the actuators are removed, what will remain are only the "passive" metallic and plastic components, while the whole automation will lose its ability to alter or produce something meaningful. All actuators are controllable devices for performing the desired manufacturing operations, in order to have a well-controlled and automated production process. In general, there are various kinds of actuators that can be categorized based on the operation principle, such as thermal, electric, hydraulic, pneumatic, and micro-electro-mechanical (MEMS) ones. (Figure II.6) [5].

Figure II.6: Various types of actuators in industrial automation, (a) servo motor, (b) DC motor, (c) stepper motor, (d) linear motor, (e) pneumatic cylinder, (f) solenoid actuator

II.10.1.2 Sensors

Almost any industrial automation system includes sensors for the detection of the various "states" of the controlled manufacturing process and actuators as outputs for real-time acting and achieving the desired behavior of the production procedure. Sensors are devices that, when exposed to a physical phenomenon (temperature, pressure, displacement, force, etc.), produce an output signal capable of being processed by the automation system. In general, sensors transform the variation of a physical quantity into an electrical output signal, which may be an analog or digital one [5].

Different Types of Sensors

The following is a list of different types of sensors that are commonly used in various applications. All these sensors are used for measuring one of the physical properties like Temperature, Resistance, Capacitance, Conduction, Heat Transfer etc (Figure II.7) [5].

- Temperature Sensor
- Proximity Sensor
- Accelerometer
- IR Sensor (Infrared Sensor)
- Pressure Sensor
- Light Sensor
- Ultrasonic Sensor
- Smoke, Gas and Alcohol Sensor
- Touch Sensor
- Color Sensor
- Humidity Sensor
- Tilt Sensor
- Flow and Level Sensor
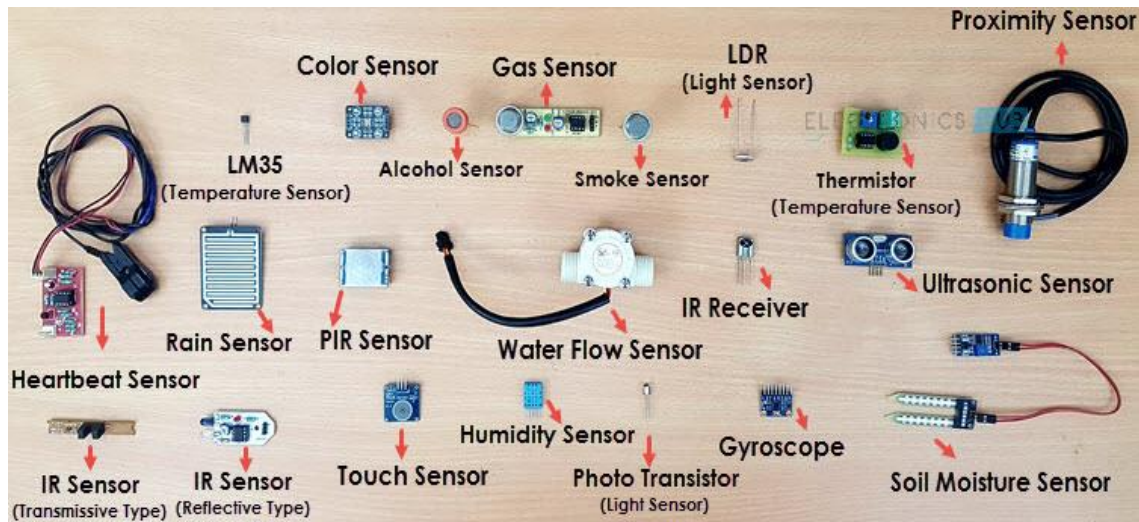
Figure II.7: Different Types of Sensors

II.10.2 Human Interface

The human interface subsystem presents information to the operator or user on the state of the process and facilitates implementing the operator's control instructions to the process. The human interface subsystem is also called the human–machine interface, man–machine interface, human–system interface, and so forth. The human interface subsystem is a facility for the user or operator to interact directly with the process, via the control subsystem, for:

1. Direct monitoring of process parameters to know what is happening inside the process

   (monitoring of process behavior), and

2. Direct control of process parameters by forcing a change, if required, by issuing manual commands (controlling of process behavior) [4].

II.10.2 Control

The control subsystem is a mechanism or device for automatically manipulating the output of a process and for managing, commanding, directing, or regulating the behavior of the process to achieve the desired result. The control subsystem is the heart of the automation system. It is an intelligent device capable of making decisions. The control subsystem manages data flow to/from the instrumentation subsystems for process monitoring and control, and to/from the human interface subsystem for direct interaction with the process; it can exchange data bidirectionally with other external compatible

systems if required. Apart from data analysis and decision making, the control subsystem performs the following functions with respect to other subsystems:

1. Acquires data on process parameters via the input instrumentation subsystem to monitor the behavior of the process continuously.

2. Issues commands to process via the output instrumentation subsystem to correct or change the behavior of the process.

3. Routes process data to the human interface subsystem displays for direct monitoring.

4. Acquires direct commands from the human interface subsystem and routes them to process for the control of process parameters [4].

II.11 Conclusion

In this chapter we presented an overview of the automated systems of production and we discussed the overall structure of automation systems as well as their functional subsystems and interconnections.

the following chapter will be devoted to the description of programmable logic controllers, in general, especially PLCs Siemens S7-1200 with TIA Portal V13 software and monitoring software Win CC.

CHAPTER III :

Programmable Logic Controller

(S7-1200) And TIA Portal V13

Software

CHAPTER III : Programmable Logic Controller (S7-1200) And TIA Portal V13 Software

III.1 Introduction

In this chapter we will talk about the description of the PLCs in a more general way and we will carry out a detailed study on the S7-1200 PLC and its TIA Portal V13 programming software on which to create new projects, as well as the PLCSIM simulator and the flexible Win CC supervision software.

III.2 Generality on the programmable logic controller (plc)

III.2.1 Definition

The first PLC was developed in 1969. PLCs are now widely used and extend from small, self-contained units for use with perhaps 20 digital inputs/outputs to modular systems that can be used for large numbers of inputs/outputs, handle digital or analog inputs/outputs, and carry out proportional-integral-derivative control modes (Figure III.1). They are used in automation tasks for industrial processes in manufacturing such as machining, materials handling, automated assembly and packaging [7].

Figure III.1: Programmable logic controller (Allen Bradley)

A programmable logic controller (PLC) is a special form of microprocessor-based controller that uses programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting, and arithmetic in order to control machines and processes (Figure III.2). It is designed to be operated by engineers with perhaps a limited knowledge of computers and computing languages. They are not designed so that only computer programmers can set up or change the programs. Thus,

the designers of the PLC have preprogrammed it so that the control program can be entered using a simple, rather intuitive form of language [7].
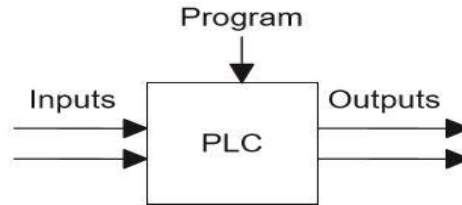
Figure III.2: A programmable logic controller

III.2.2 Types of programmable logic controller

There are two common types of mechanical design for PLC systems: single box (Compact) and the modular/rack types

- ➢ **single box (Compact)**: is commonly used for small programmable controllers and is supplied as an integral compact package complete with power supply, processor, memory, and input/output units. Typically, such a PLC might have 6, 8, 12, or 24 inputs and 4, 8, or 16 outputs and a memory that can store some 300 to 1000 instructions. For example, the Toshiba PLC brick TAR 116-6S has 8 inputs 120V ac, 6 relay outputs, and 2 triac outputs while a bigger brick TDR140-6S has 24 inputs 24V dc, 14 relay outputs and 2 triac outputs. Some compact systems have the capacity to be extended to cope with more inputs and outputs by linking input/output boxes to them (Figure III.3) [7].

Figure III.3: OMRON CP1L(compact PLC)

> ➢ **the modular(rack)**: The modular type consists of separate modules for power supply, processor, etc., which are often mounted on rails within a metal cabinet. The rack type can be used for all sizes of programmable controllers and has the various functional units packaged in individual modules that can be plugged into sockets in a base rack. The mix of modules required for a particular purpose is decided by the user and the appropriate ones then plugged into the rack. Thus, it is comparatively easy to expand the number of input/output (I/O) connections by just adding more input/output modules or to expand the memory by adding more memory units. The power and data interfaces for modules in a rack are provided by copper conductors in the backplane of the rack. When modules are slid into a rack they engage with connectors in the backplane (Figure III.4) [7].


Figure III.4: Mitsubishi Compact PLC

III.3 Structure of an industrial programmable logic controller (Hardware)

Typically a PLC system has the basic functional components of processor unit, memory, power supply unit, input/output interface section, communications interface, and the programming device. (Figure III.5) shows the basic arrangement. The constituent elements are :

- **The processor unit or central processing unit (CPU)** is the unit containing the microprocessor. This unit interprets the input signals and carries out the control actions according to the program stored in its memory, communicating the decisions as action signals to the outputs.

- **The power supply unit** is needed to convert the mains AC voltage to the low DC voltage necessary for the processor and the circuits in the input and output interface modules.
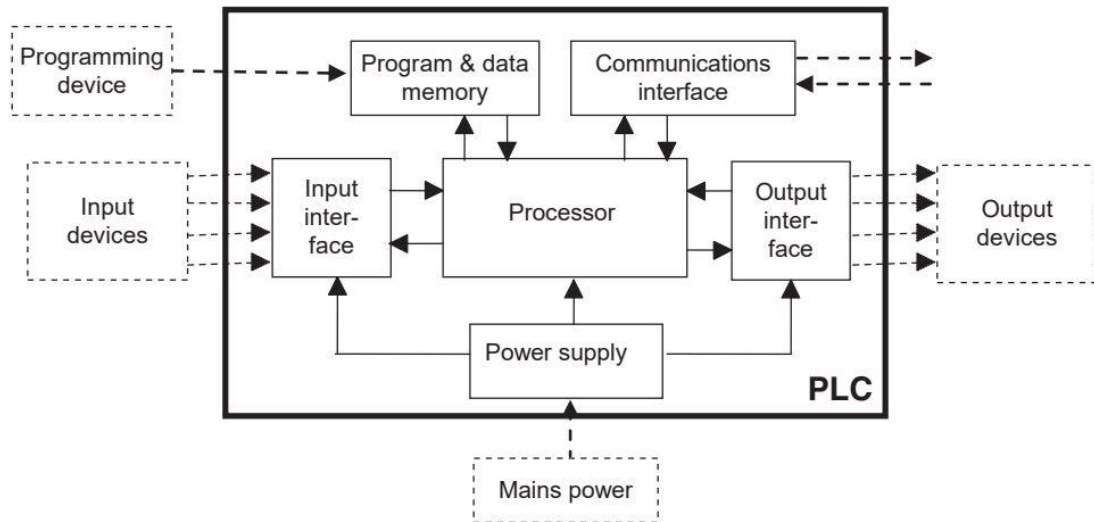
Figure III.5: The PLC system

- **The programming device** is used to enter the required program into the memory of the processor. The program is developed in the device and then transferred to the memory unit of the PLC.

- **The memory unit** is where the program containing the control actions to be exercised by the microprocessor is stored and where the data is stored from the input for processing and for the output.

- **The input and output section**s are where the processor receives information from external devices and communicates information to external devices. The inputs might thus be from switches, as illustrated in (Figure III.6(a)) with the automatic drill, or other sensors such as photoelectric cells, as in the counter mechanism in (Figure III.6(b)), temperature sensors, flow sensors, or the like. The outputs might be to motor starter coils, solenoid valves, or similar things. Input and output devices can be classified as giving signals that are discrete, digital or analog (Figure III.6(c)) [7].
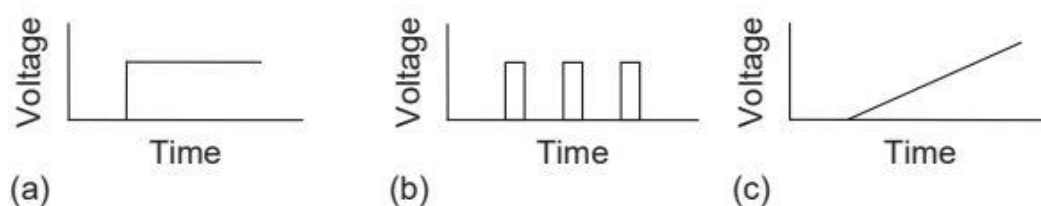
Figure III.6: Signals: (a) discrete, (b) digital, and (c) analog

- **The communications interface** is used to receive and transmit data on communication networks from or to other remote PLCs (Figure III.7). It is concerned with such actions as device verification, data acquisition, synchronization between user applications, and connection management [7].
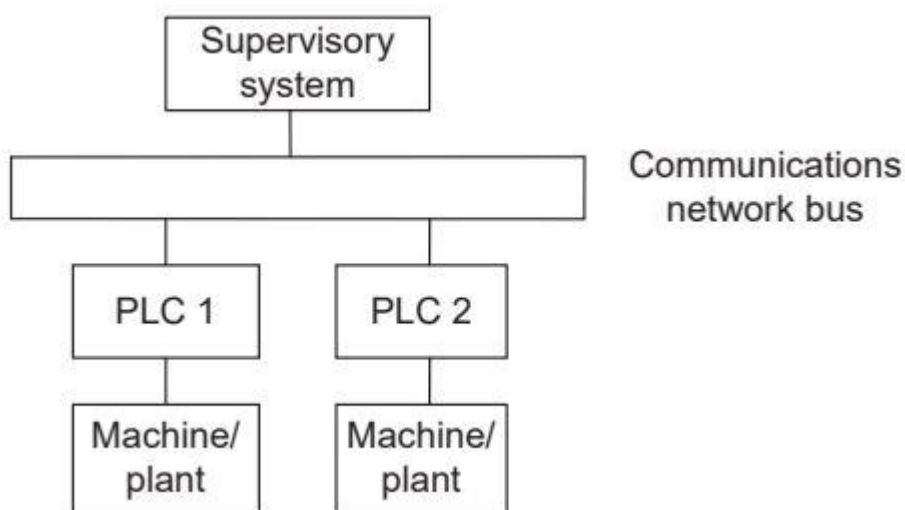

Figure III.7: Basic communications model

III.4 Nature of the information processed by the PLC :

The information can be 3 type:

- **All or nothing (T.O.R.)**: the information can only take two states (true / false, 0 or 1…).

This is the type of information delivered by a detector, a push button, etc.

- **Analogue**: the information is continuous and can take a value included in a

well-defined range. This is the type of information delivered by a sensor (pressure, temperature, etc.)

- **Digital**: the information is contained in coded words in binary form or else hexadecimal. This is the type of information delivered by a computer or a module intelligent [9].

III.5 how to choice industrial programmable controller ?

The essential selection criteria for an industrial programmable logic controller are:

- Number of inputs / outputs: the number of cards can affect the number racks as soon as the number of inputs / outputs required becomes high.

- Processor type: memory size, processing speed and special functions offered by the processor will allow the choice in the often very wide range.

- Special functions or modules: certain cards (axis control, weighing, etc.) will "relieve" the processor and must offer the desired characteristics (resolution, ...).

- Communication functions: the PLC must be able to communicate with other control systems (PLC, supervision, etc.) and offer communication possibilities with standardized standards (PROFIBUS ...) [9].

III.6 Principles of Operation

The CPU controls all PLC activity and is designed so that the user can enter the desired program in relay ladder logic. The PLC program is executed as part of a repetitive process referred to as a scan (Figure III.8). A typical PLC scan starts with the CPU reading the status of inputs. Then, the application program is executed. Once the program execution is completed, the status of all outputs is updated. Next, the CPU performs internal diagnostic and communication tasks. This process is repeated continuously as long as the PLC is in the run mode [10].
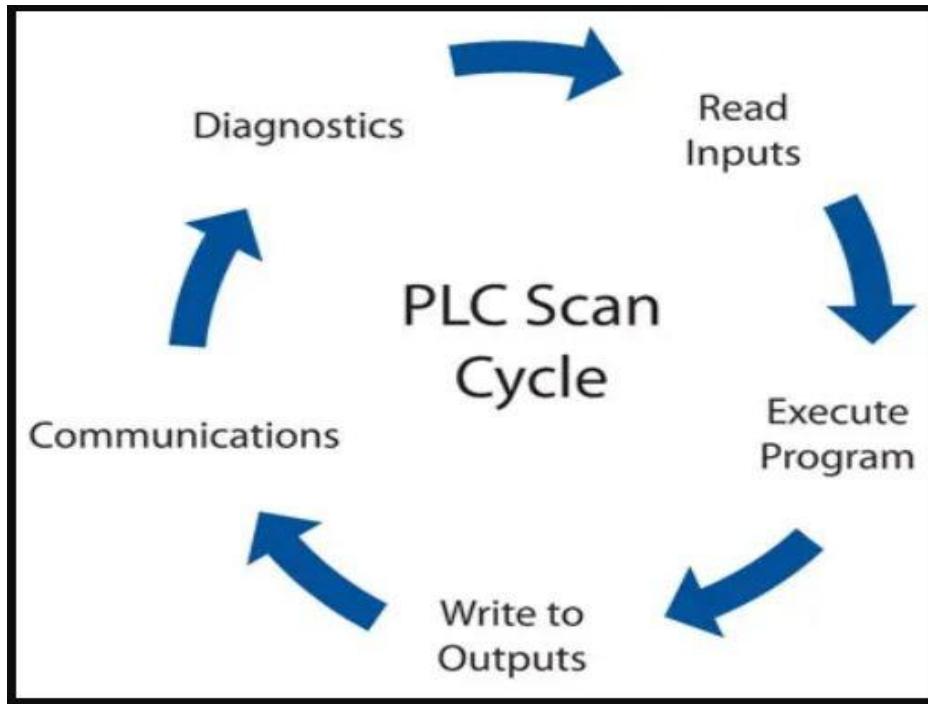
Figure III.8: Typical PLC scan cycle

III.7 Modifying the Operation

One of the important features of a PLC is the ease with which the program can be changed. For example, assume that the original process control circuit for the mixing operation must be modifi ed as shown in the relay ladder diagram of (Figure III.9). The change requires that the manual pushbutton control be permitted to operate at any pressure, but not unless the specifi ed temperature setting has been reached. If a relay system were used, it would require some rewiring of the circuit shown in (Figure III.10) to achieve the desired change. However, if a PLC system were used, no rewiring would be necessary. The inputs and outputs are still the same. All that is required is to change the PLC ladder logic program [10].
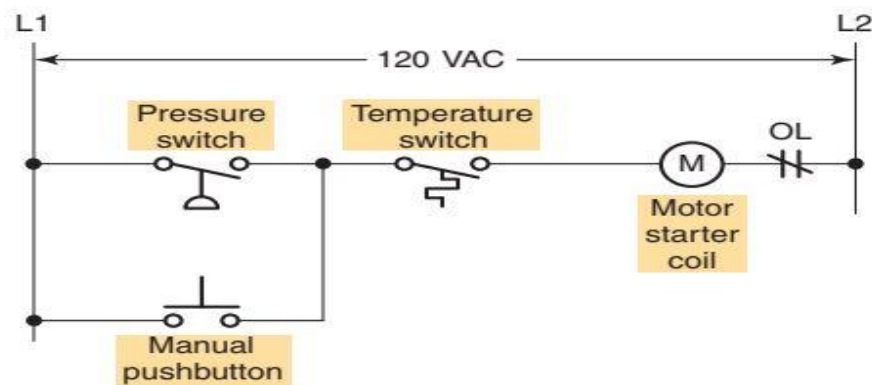

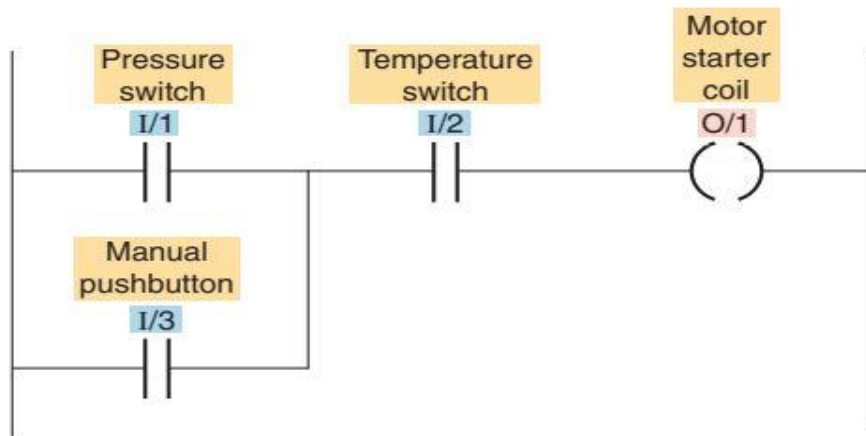**Figure III.9: Relay ladder diagram for the modifi ed process**

Figure III.10: PLC ladder logic program for the modifi ed process

III.8 PLC Programming Languages

The term PLC programming language refers to the method by which the user communicates information to the PLC. The standard IEC 61131 (Figure III.11) was established to standardize the multiple languages associated with PLC programming by defi ning the following fi ve standard languages:

- **Ladder Diagram (LD)**: a graphical depiction of a process with rungs of logic, similar to the relay ladder logic schemes that were replaced by PLCs.
- **Function Block Diagram (FBD)** :a graphical depiction of process fl ow using simple and complex interconnecting blocks.
- **Sequential Function Chart (SFC)** :a graphical depiction of interconnecting steps, actions, and transitions.
- **Instruction List (IL)** :a low-level, text-based language that uses mnemonic instructions.
- **Structured Text (ST)** :a high-level, text-based language such as BASIC, C, or PASCAL specifi cally developed for industrial control applications.

Ladder diagram language is the most commonly used PLC language and is designed to mimic relay logic. The ladder diagram is popular for those who prefer to defi ne control actions in terms of relay contacts and coils, and other functions as

block instructions. (Figure III.12) shows a comparison of ladder diagram programming and instruction list programming [10].
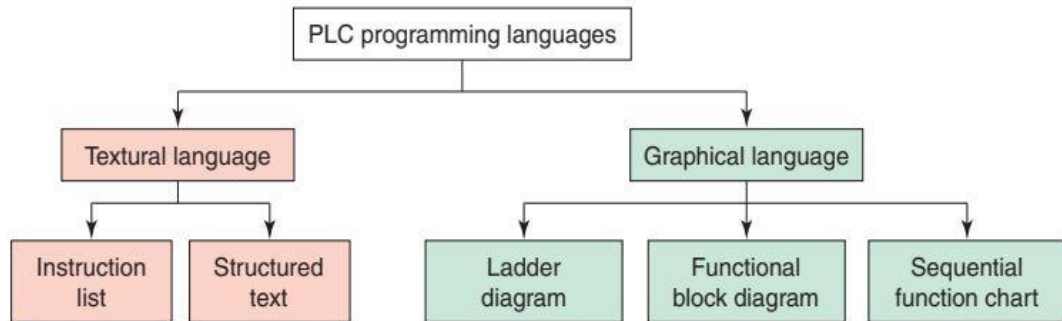

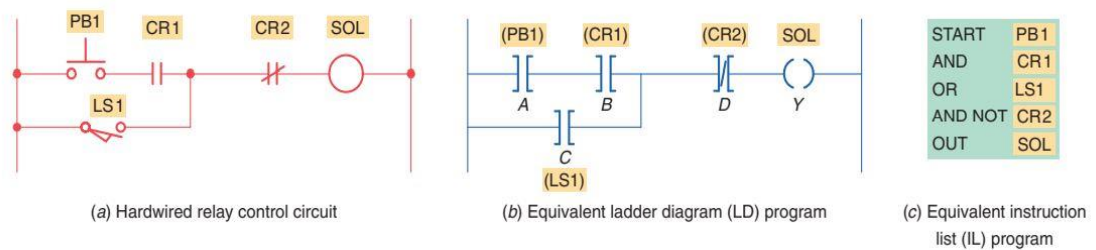**Figure III.11: Standard IEC 61131 languages associated with PLC programming**

Figure III.12: Comparison of ladder diagram and instruction list programming

III.9 GRAFCET

The GRAFCET is a graphical tool that describes the operation of a sequential automation. It can be used to represent automation in all phases of the design : from the definition of the specifications, to the implementation (programming of an industrial PLC, use of sequencers or other technologies) through the study of the modes of marches and stops. The GRAFCET is based on the use of precise instructions, the use of a well-defined vocabulary, the respect of a rigorous syntax and the use of rules of evolution. It allows, among other things, to adopt a progressive approach in the development of automation. It describes the relationships between the outputs and the Boolean inputs of the control system. The GRAFCET is an alternate representation of steps and transitions. Only one transition must separate two steps [11].

III.9.1 Construction rules of a grafcet

A grafcet is graph which is composed of steps and transitions, connected between them by connections or directed arcs see (Figure III.13) [11].
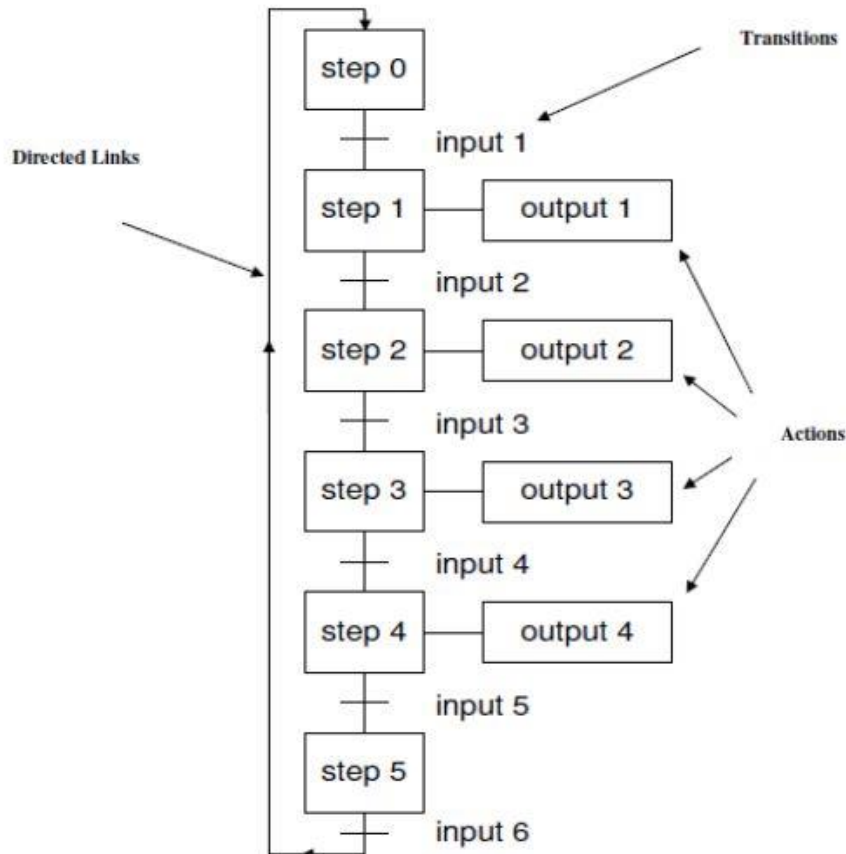

Figure III.13: Typical GRAFCET

III.9.2 Steps :

A Step (Figure III.14) is represented by a square to which a unique number is associated, step can be initial (represented by a double square) and it is either active or inactive. The whole of active steps (called situation) entirely defines the state of the system. We specify for each step, the actions to be executed. These actions are executed only when the corresponding step is active. We can associate a condition to those actions, the action is then executed only if the step is active and the condition is performed [11].
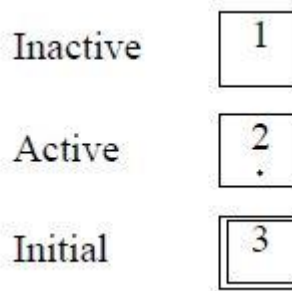
Figure III.14: Type of steps
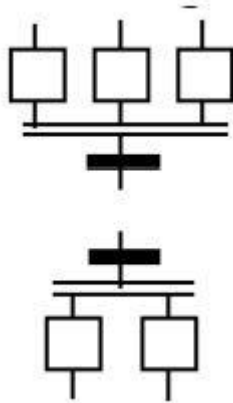
III.9.3 Transitions A transition

is represented by a horizontal line and represents a possibility of change of the comportment of the system. This change of comportment (the passage from one step to the following) corresponds to the crossing of a transition. A transition is validated when all previous steps are active. The logical proposal which conditions the transition calls the receptivity [11].

III.9.4 Directed arcs

Each directed arc links a step to a transition or a transition to a step: there is always strict alternation: step-transition. When this connection is connection is directed upwards, we show the direction by an arrow upwards [11].

III.9.5 Convergences and divergences

When the directed arcs start from several steps (known as steps downstream) and arrive on the same transition or when directed start from the same transition and arrive on several steps (known as steps upstream) then these regrouping are represented by two horizontal parallel lines respectively called convergence and divergence "in and" (Figure III.15) [11].

Figure III.15: In and

When separation is in the direction from several transitions to a common step (respectively from a step to several transitions), we name them convergences (respectively divergence) "in or". Their representation is done by dividing the directed connections (Figure III.16) [11].
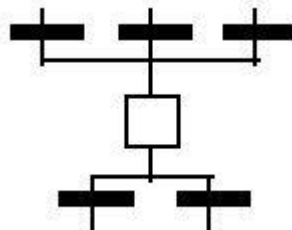
Figure III.16: In or

III.9.6 Rules of evolution of a grafcet

The evolution of a grafcet is subject to five rules:

Rule 1 : Initial situation

The initial situation of a grafcet characterizes the initial behavior of the control part with respect to the operative part, to the operator and/or to the external elements. It corresponds to the active steps at the beginning of operation: those steps are the initial steps.

Rule 2 : Crossing a transition

A transition is validated when all immediately preceding steps connected to this transition are active. The crossing of the transition occurs:

➢ when the transition is validated

➢ AND when the receptivity associated with this transition is true.

Rule 3: Evolution of activated steps

The crossing of a transition involves simultaneously the activation of all immediately following steps and the inactivation of all immediately preceding steps.

Rule 4: Simultaneous evolution

Several simultaneously crossable transitions are simultaneously crossed.

Rule 5: Simultaneous activation and inactivation

If during operation same step is simultaneously activated and inactivated, it remains active [12].

III.10 SIMATIC S7-1200 automation system

The SIMATIC S7-1200 automation system consists of the four controllers S7-1211C, S7-1212C, S7-1214C, and S7-1215C, which can exchange data with each other, with SIMATIC HMI Basic Panels, or with other programmable controllers over SIMATIC NET. STEP 7 (TIA Portal) is used to configure and program the devices (Figure III.17) [13].
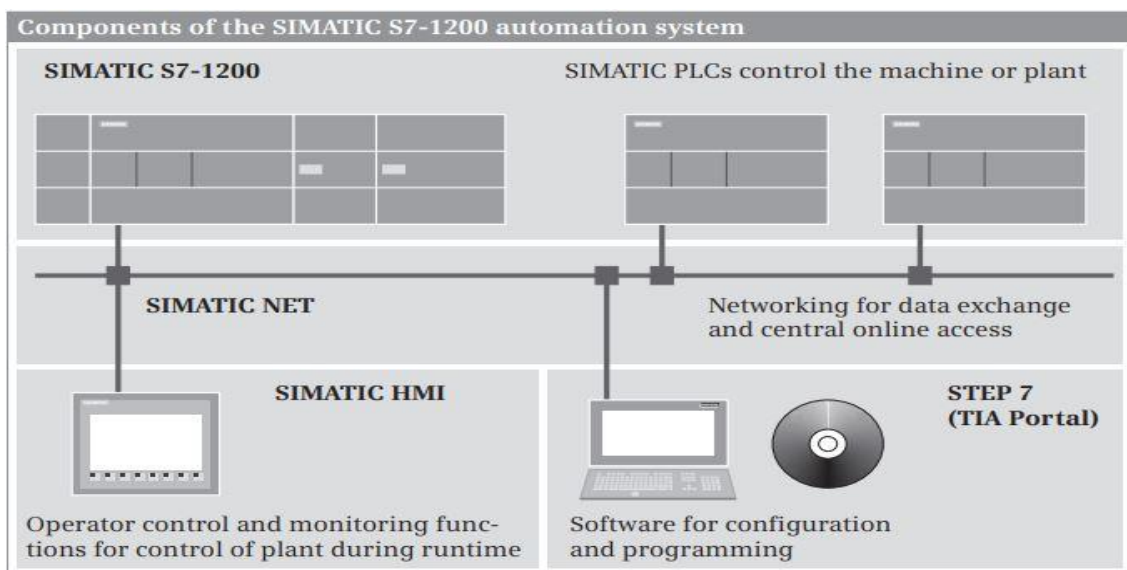

Figure III.17: Components of the SIMATIC S7-1200 automation system

III.10.1 S7-1200 station components

A complete programmable controller including all I/O modules is referred to as a "station". This also includes distributed I/O modules connected to the CPU via a bus system. An S7-1200 station comprise at least the CPU. Depending on the version, it has digital and analog input/output channels and can be fitted with additional input/output channels using a signal board (SB).

Depending on the type of CPU, up to eight signal modules can be plugged in which expand the station by digital and analog input/output channels. A two-tier design is possible using a 2-meter long extension cable.

The programming device is connected over Industrial Ethernet. Industrial Ethernet can also be used to connect further SIMATIC stations or HMI devices to the CPU. Up to three communication modules take over the connection to additional bus systems or to a point-to-point link.

Integral technological functions for measuring and counting tasks, closed-loop control, and motion control allow the CPU 1200 to be used in many complex machine controls.

The SIMATIC Memory Card can be used to download configuration data, as an external load memory, or for a firmware update.

Mounting is on a standard 35 mm DIN rail either horizontally or vertically. Installation without a mounting rail is also possible. An extension cable (2 m long) enables a two-tier design without changing the number of connectable signal modules.

Available accessories include an external power supply module, a connection multiplier (Ethernet switch), a TS Adapter, and two simulator modules. SIMATIC S7-1200 is also available as a SIPLUS version for particularly harsh environmental conditions (Figure III.18) [13].

Figure III.18: S7-1200 station with CPU S7-1214, two SMs (right) and one CM (left)

III.10.1.1 S7-1200 CPU modules

There are four types of CPU (CPU 1211, CPU 1212, CPU 1214, and CPU 1215), available in each case in the versions DC/DC/DC, AC/DC/RLY, DC/DC/RLY. The first item of data refers to the module power supply (DC = 24 V direct current, AC = 120/230 V alternating current). The middle item of data refers to the operating voltage of the onboard digital inputs (DC = 24 V direct current). The last item of data refers to the type of digital outputs (DC = 24 V direct current electronic, RLY = up to 30 V direct current or up to 250 V alternating current with relay) [13].

III.10.1.2 Integrated I/O

The digital inputs (DI) on the CPU module work with an operating voltage of 24 V DC. Different numbers are available depending on the CPU version. The status of the input signals is displayed by means of LEDs.

The digital outputs (DQ or DO) are available in electronic form (24 V DC and 0.5 A output current with a resistive load of 5 W) and as relay outputs (up to 30 V DC and 2 A output current with a resistive load of 30 W or up to 250 V AC and 2 A output current with a resistive load of 200 W). Different numbers of digital outputs are available

depending on the CPU version. The status of the output signals is displayed by means of LEDs.

Each CPU has two analog input channels (AI) for 0 to 10 V. The resolution is 10 bits. The analog value can be processed in the user program in the numerical range from 0 to 27 648. The CPU 1215 has two additional analog output channels (AO) for 0 to 20 mA. The resolution is 10 bits. The analog value can be processed in the user program in the numerical range from 0 to 27 648 [13].

III.10.1.3 PROFINET connection

The CPU is connected to an Ethernet network over the PROFINET interface. The connection (port) takes the form of an RJ45 socket. The protocols Transmission Control Protocol (TCP) in accordance with RFC 793, ISO Transport over TCP (ISO-on-TCP) in accordance with RFC 1006, and User Datagram Protocol (UDP) in accordance with RFC 768 are supported. The connection is able to automatically recognize a transmission rate of 10 or 100 MBit/s (autosensing). Either a standard Ethernet cable or a crossover cable can be used for the network (Figure III.19).

The CPU can be connected, for example, to a programming device, an HMI device, or other SIMATIC stations over the PROFINET connection. The CPU 1215C has two RJ45 sockets, which are connected with a switch. The next device can therefore be connected directly to the Ethernet network from the second connection. The other CPUs have only one RJ45 socket. Here an external switch (connection multiplier) such as the CSM 1277 Compact Switch Module is required when networking several devices [13].

Figure III.19: PROFINET connection

III.10.1.4 Status LEDs

The current operating mode of the CPU is indicated by LEDs on the front of the module :

RUN/STOP	Continuous yellow light in STOP mode
	Continuous green light in RUN mode
	Flashing light in STARTUP mode
ERROR	Flashing red light in event of error
	Continuous red light if hardware is faulty
MAINT	Continuous yellow light with maintenance request

Table III.1: Status LEDs

After switching on, the CPU is in STARTUP mode. It runs through test routines, carries out parameter settings, and executes the startup program. The CPU then changes to the RUN status and executes the user (main) program – this is the "normal" operating status. The CPU returns to the STOP mode if it detects a "serious" error, if it executes a corresponding program statement, or if it is specifically set to this state e.g. by the programming device. The user program is not executed in the STOP mode, but the CPU

is still able to communicate, facilitating downloading of parts of the user program, for example (Figure III.20).

The ERROR LED flashes when an error has been detected. It lights up permanently if the hardware is faulty. The MAINT LED lights up continuously to indicate that a previously configured maintenance request is now present. All LEDs flash if the firmware of the CPU module is faulty [13].

Figure III.20: LED dis-plays on the CPU

III.10.1.5 SIMATIC Memory Card

The SIMATIC Memory Card can be used as a program card, a card for transferring data, or as a data medium for firmware updates. As a program card it is required for runtime operation of the CPU, in the other cases it is not required for operation (Figure III.21).

There are two versions of the SIMATIC Memory Card: with a storage capacity of 2 MB or 24 MB. It has a special ID which is necessary for use in a CPU 1200 [13].

Figure III.21: SIMATIC Memory Card

III.10.1.6 Expansions of the CPU

Signal board (SB) : A signal board (SB) expands the onboard I/O without changing the dimensions of the CPU. The associated slot is located on the front of the CPU (Figure III.22).

Figure III.22: Signal Board 1223

Communication Board (CB) : A Communication Board (CB) expands the communication connections without changing the dimensions of the CPU. The associated slot is located on the front of the CPU.

Battery board (BB) : With the BB 1297 battery board, the buffered runtime of the real-time clock can be extended from a typical 10 days to up to one year, without changing the dimensions of the CPU. The associated slot is located on the front of the CPU.

III.10.1.7 Signal modules (SM)

Signal modules are input/output modules which extend the integrated I/O. Depending on the CPU version, either none, two or eight modules can be plugged onto the right of the CPU.

A two-tier design is possible using a 2-meter long extension cable. But the number of modules which can be used is not changed as a result [13].

III.10.1.8 Digital I/O modules

Digital modules are signal converters for binary process signals. The CPU can use input modules to scan operating modes of the machine or plant, and output modules for intervention (Figure III.23).

Input modules convert external signals of 24 V DC into signals with an internal level. Output modules convert the internal signal level into 24 V DC (electronic outputs) or are designed as relay outputs. Using direct current, a relay can switch maximum 30 W, while with alternating current it can switch 200 W. There are signal modules with one or two bytes corresponding to 8 or 16 signals (Table III.2) [13].

Figure III.23:SM 1221 DI16 signal module

Digital inputs		
SM 1221 DC	6ES7 221-1BF30	DI 8 × 24VDC
SM 1221 DC	6ES7 221-1BH30	DI 16 × 24VDC
Digital outputs		
SM 1222 DC	6ES7 222-1BF30	DO 8 × 24VDC / 0.5 A
SM 1222 DC	6ES7 222-1BH30	DO 16 × 24VDC / 0.5 A
SM 1222 RLY	6ES7 222-1HF30	DO 8 × relay 30 V DC, 250 V AC / 2 A
SM 1222 RLY	6ES7 222-1HH30	DO 16 × relay 30 V DC, 250 V AC / 2 A
SM 1222 RLY	6ES7 222 1XF30	DO 8 × relay 30 V DC, 250 V AC / 2 A (change-over contact)
Digital inputs/outputs		
SM 1223 DC/DC	6ES7 223-1BH30	DI 8 × 24VDC, DO 8 × 24VDC / 0.5 A
SM 1223 DC/DC	6ES7 223-1BL30	DI 16 × 24VDC, DO 16 × 24VDC / 0.5 A
SM 1223 DC/RLY	6ES7 223-1PH30	DI 8 × 24VDC, DO 8 × relay 30VDC, 250 V AC / 2 A
SM 1223 DC/RLY	6ES7 223-1PL30	DI 16 × 24VDC, DO 16 × relay 30VDC, 250 V AC / 2 A
SM 1223 AC/RLY	6ES7 223-1QH30	DI 8 × 125/250 V AC, DO 8 × relay 30 V DC, 250 V AC / 2 A

Table III.2: Selection of digital I/O modules

III.10.1.9 Analog input/output modules

Analog modules are signal transducers for analog process signals. The CPU can use these modules to process analog variables when these have been converted by analog input modules into digital values. The CPU can also continuously supply actuators with

analog setpoints which have been generated from the specified digital values by analog output modules (Figure III.24).

One "channel" is occupied on the module by each analog value (e.g. measured value or setpoint). Analog modules are available with 2, 4 or 8 channels corresponding to 4, 8 or 16 bytes (Table III.3). A digitized analog value is represented internally as a 16-bit fixed-point number (data type INT). Analog modules can output diagnostic data concerning the module status or when limit values are reached (Table III.3) [13].

Figure III.24:SM 1234 AI/AO signal module

Analog inputs		
SM 1231 AI	6ES7 231-4HD30	AI 4 × 13 bit, +10/+5/+2.5 V or 0 to 20 mA
SM 1231 AI	6ES7 231-4HF30	AI 8 × 13 bit, ±10/±5/±2.5 V or 0 to 20 mA
SM 1231 AI	6ES7 231 5ND30	AI 4 × 16 bit, ±10/±5/±2.5/±1.25 V or 0 to 20/4 to 20 mA
SM 1231 RTD	6ES7 231-5PD30	RTD 4 × 16 bit, 0 to 150/300/600 Ω; (Pt, Ni, Cu)
SM 1231 RTD	6ES7 231-5PF30	RTD 8 × 16 bit, 0 to 150/300/600 Ω; (Pt, Ni, Cu)
SM 1231 TC	6ES7 231-5QD30	TC 4 × 16 bit, ± 80 mV; types J, K, T, E, R, S, N, C, TXK/XK(L)
SM 1231 TC	6ES7 231-5QF30	TC 8 × 16 bit, ± 80 mV; types J, K, T, E, R, S, N, C, TXK/XK(L)
Analog outputs		
SM 1232 AO	6ES7 232-4HB30	AO 2 × 14 bit, ±10 V or 0 to 20 mA
SM 1232 AO	6ES7 232-4HD30	AO 4 × 14 bit, ±10 V or 0 to 20 mA
Analog inputs/outputs		
SM 1234 AI/AO	6ES7 234-4HE30	AI 4 × 13 bit, ±10/±5/±2.5 V or 0 to 20 mA, AO 2 × 14 bit, ±10 V or 0 to 20 mA

Table III.3: Selection of analog I/O modules

III.10.1.10 Communication modules (CM)

The communication modules (CM) support the CPU in communication tasks. They establish the physical connection to a communication partner, take over establishment of the connection and data transport on this, and provide the required communications services for the operating system of the CPU and the user program (Figure III.25).

The communication modules are plugged onto the CPU from the left, seen from the front. Operation of up to three communication modules is possible for all CPUs (Table III.4) [13].

Figure III.25:CM 1241 RS485 communication module

CM 1241 RS232	6ES7 241-1AH30	Point-to-point connection via RS 232
CM 1241 RS422/485	6ES7 241-1CH31	Point-to-point connection via RS 422/485
CM 1242 PROFIBUS	6GK7 242-5DX30	PROFIBUS DP slave
CM 1243 PROFIBUS	6GK7 243-5DX30	PROFIBUS DP master
CM 1243 AS-i	3RK7 243-2AA30	AS-Interface master
DCM 1271 AS-i	3RK7 271-1AA30	AS-i data decoupling module
CP 1242 GPRS	6GK7 242-7KX30	Connection to a GSM/GPRS radio network

Table III.4: Communication modules with functions and properties

III.10.2 STEP 7 Basic V13 (TIA Portal V13) programming software

The STEP 7 Basic V13 (TIA Portal V13) software is the programming tool for the following automation systems:

- SIMATIC S7-1200;
- Basic Panels.

STEP 7 Basic V13 provides the following functions for automation of a system:

- Configuration and parameter assignment of the hardware

- Specification of the communication

- Programming

- Testing, commissioning and servicing with operational/diagnostic functions

- Documentation

- Creation of visualizations for SIMATIC Basic Panels using the integrated WinCC Basic software

- Support is provided for all functions through detailed online help [14].

III.10.2.1 Project

To implement a solution for an automation and visualization task, you create a project in the TIA Portal. A project in the TIA Portal contains the configuration data for the configuration and internetworking of devices as well as the programs and the configuration of the visualization [14].

III.10.2.2 Hardware configuration

The hardware configuration includes the configuration of the devices, consisting of the hardware of the automation system, the field devices on the PROFINET bus system and the hardware for visualization. The configuration of the networks specifies the communication between the various hardware components. Individual hardware components are inserted in the hardware configuration from catalogs.

The hardware of SIMATIC S7-1200 automation systems comprises the controller (CPU), the signal modules for input and output signals (SMs), the communication modules (CMs) and other special-purpose modules.

The signal modules and the field devices connect the input and output data of the process to be automated and visualized to the automation system.

The hardware configuration enables the downloading of automation and visualization solutions to the automation system and access to the connected signal modules by the controller [14].

III.10.2.3 Planning the hardware

Before you can configure the hardware, you must plan it (hardware planning). In general, you begin by selecting which controllers are needed and how many. You then

select the communication modules and signal modules. The selection of signal modules is based on the number and type of inputs and outputs needed. As the final step, a power supply that ensures the necessary power supply must be selected for each controller or field device. The functionality required and the ambient conditions are of vital importance for planning the hardware configuration. For example, the temperature range in the application area sometimes limits which devices are available for selection. Fail-safe operation might be another requirement [14].

III.10.2.4 TIA Portal : Portal View and Project View
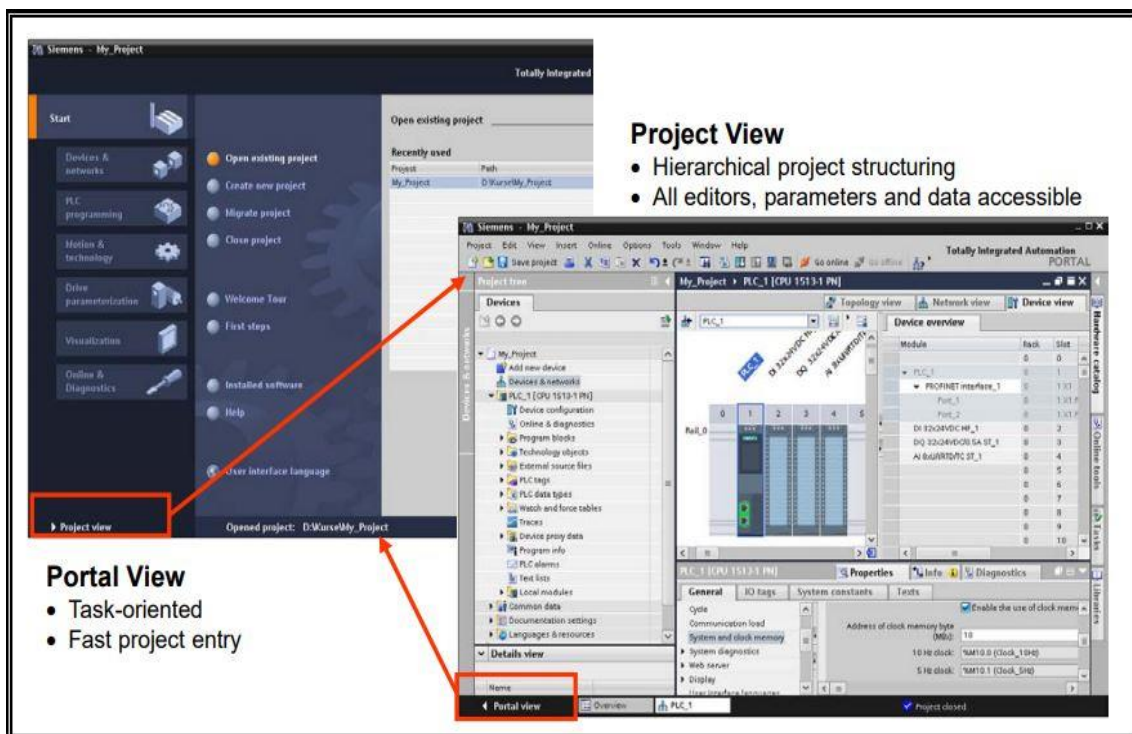
Figure III.26 : Portal View and Project View

Portal View :

- Task-oriented mode of working
- Fast project entry with user guidance

Project View :

- Hierarchical structuring of the project
- The necessary editors open according to the task in hand

- All editors, parameters and data are found in one view

1) Portal View
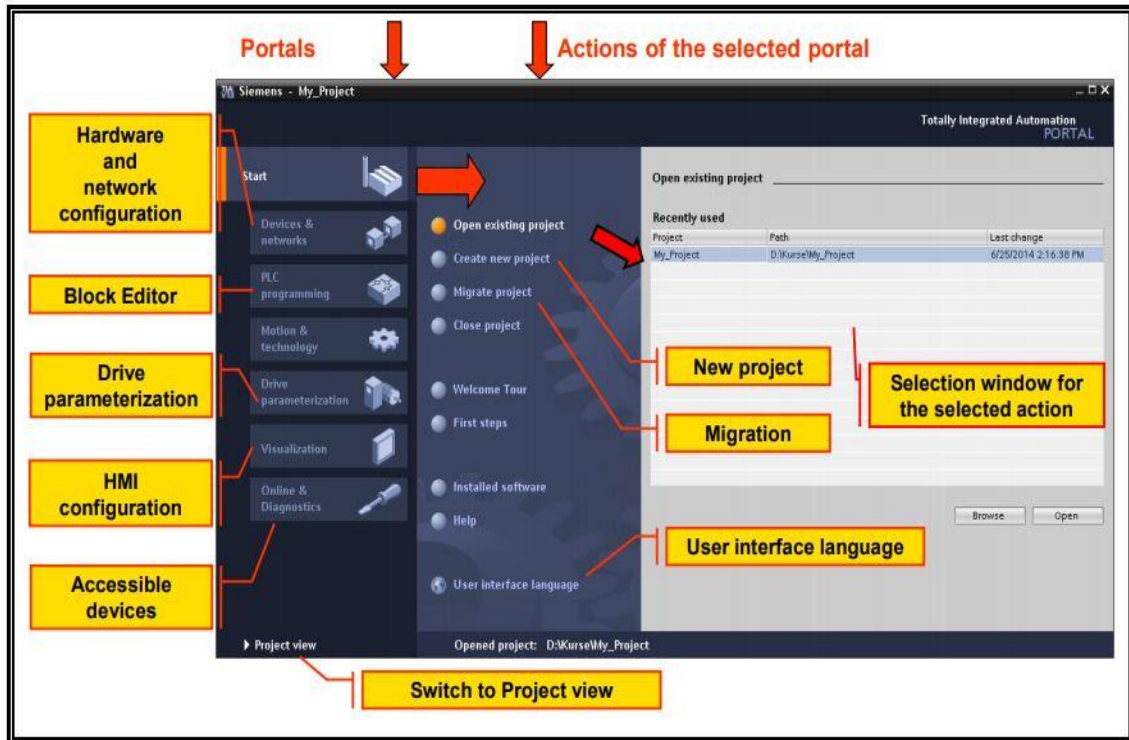
Figure III.27 : Portal View

Layout of the Portal View:

- Portals for the different tasks

- Actions for the selected portal

- Selection window for the selected action

Portals :

- Access to devices, components and their connections.

Actions :

- Depending on the selected portal, actions are available here that can be executed in the selected portal. Context-sensitive help is available in every portal.

Selection Window :

- The selection window is available in all portals. The content of the window adapts to your current selection [15].

2) Project View
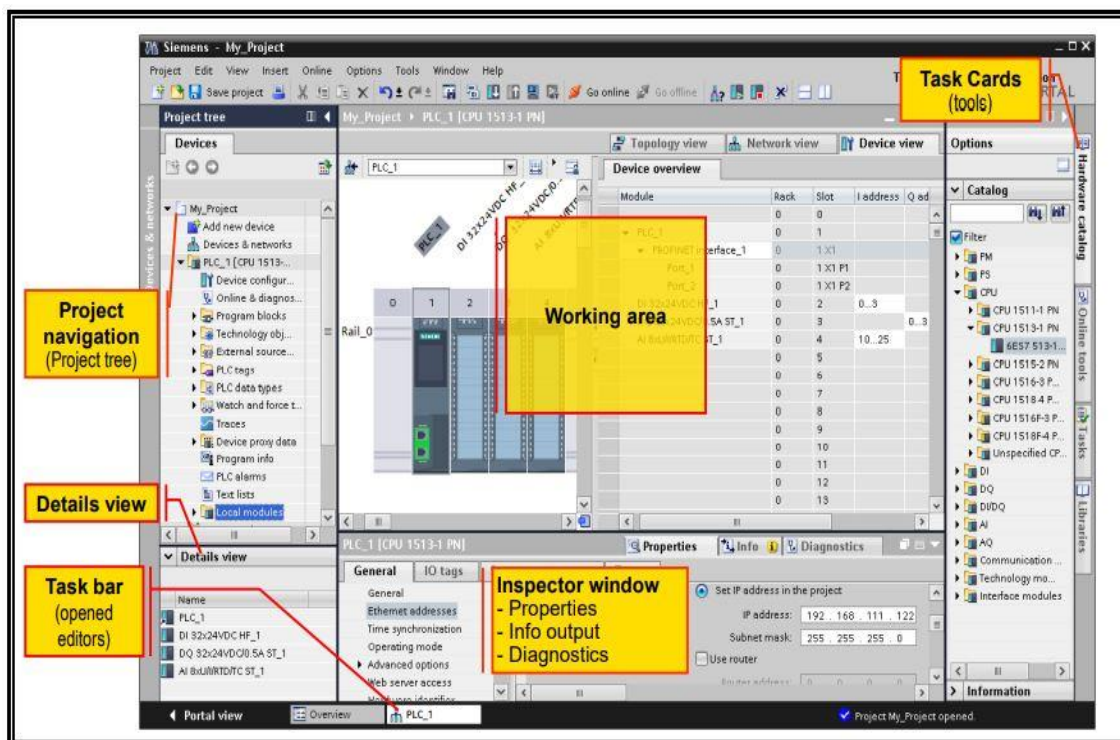
Figure III.28: Project View

Project Navigation (Tree)

- The Project tree contains all components and project data of an automation solution. All components can be opened from there.

Working Area

- The objects opened for editing are displayed in the working area. These objects include, for example hardware components, blocks, PLC tag tables, screens of HMI devices etc. If several objects are open at the same time, they are displayed as tabs in the task bar.

Task Cards

- These provide tools for configuring/programming. The content of the Task cards depends on the object displayed in the working area.
- If a hardware station is open, the Hardware catalog, for example, is available as a Task card. If a program block is open, there is a Task card with Instructions.

Inspector Window

- Additional information on a selected object or on executed actions is displayed in the Inspector window. The available properties of the selected objects can also be edited here (for example, properties of screens, screen objects, tags).
- The Inspector window displays all system messages from the engineering, for example, those resulting from generating a project. This window should always be checked for any errors and warnings after a generation is completed.

Details View

- The Details view is a help window. Here, the elements of the configuration object selected in the Project tree are displayed. These can be used in the active working area (by dragging them to the working area using drag & drop). This enables fast access to the required objects (for example, tags) [15].

III.10.3 Create a new project

The creation of a project always starts with the configuration of the equipment,

Hardware configuration is equivalent to listing all the modules present in the project.

To create a new project, you need follow this step:

- **Step 1**
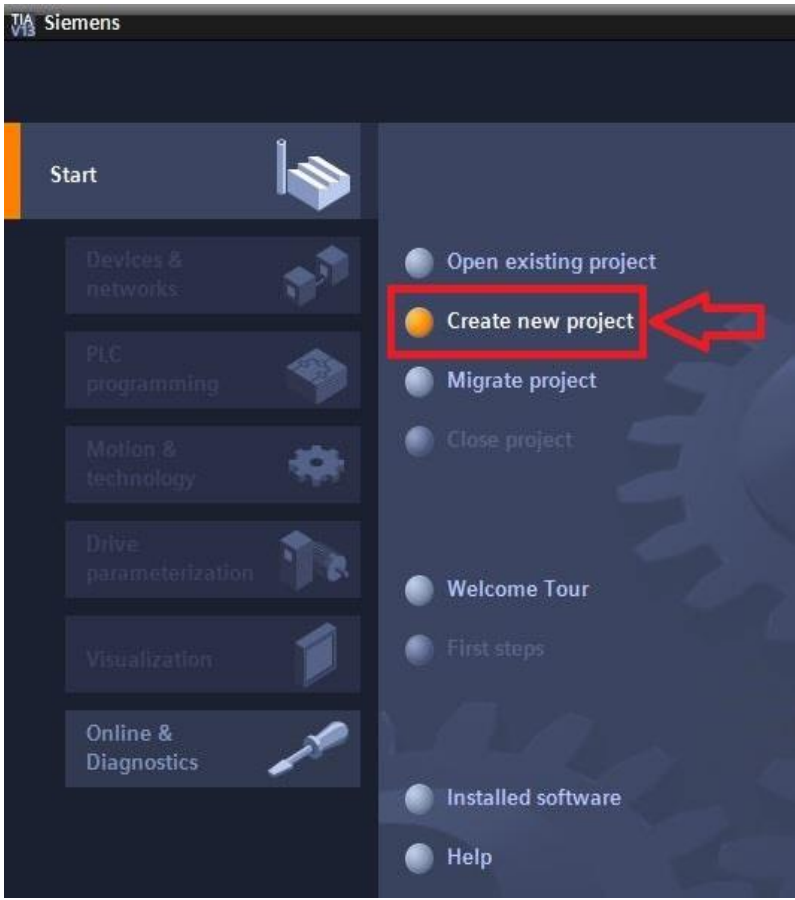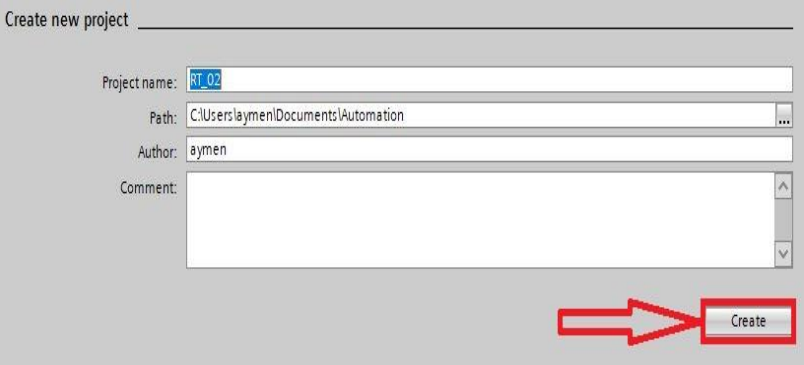
	- Double - click on the TIA portal icon
	- Select: "Create new project "
	- Define the name of the project and the place where it should be saved.

Table III.5: The stage of creating a project

- **Step 2**
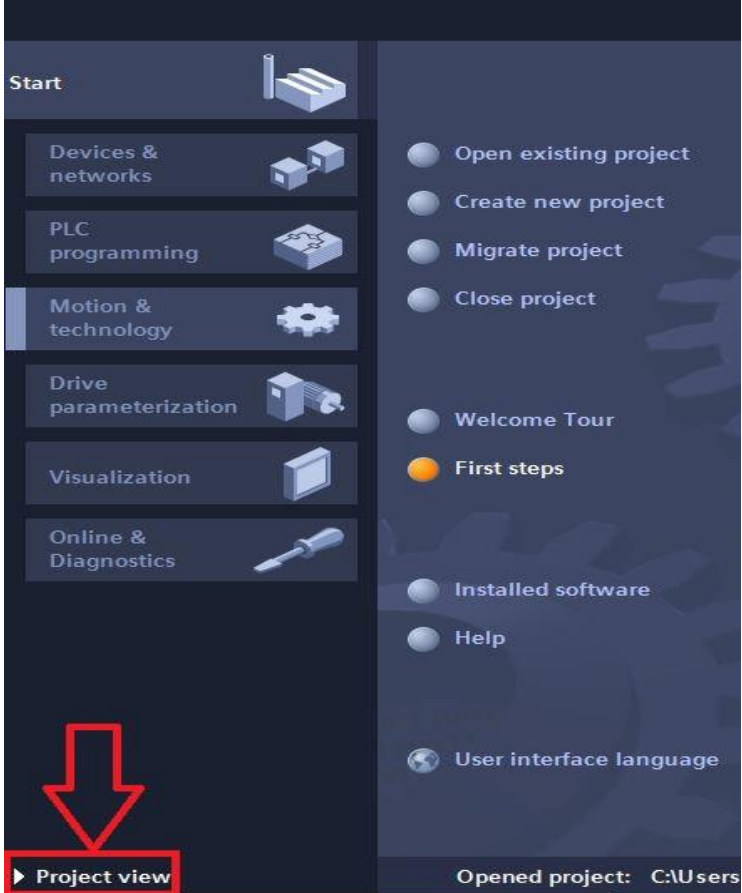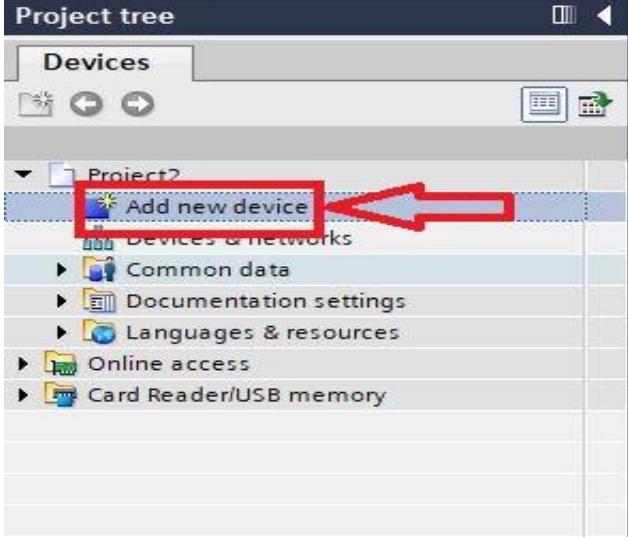
	• When the project is created,click on "Project view".
	• Select "Add new device".
	• Select "Controllers".

Table III.6: The steps to add a device

- **Step 3**
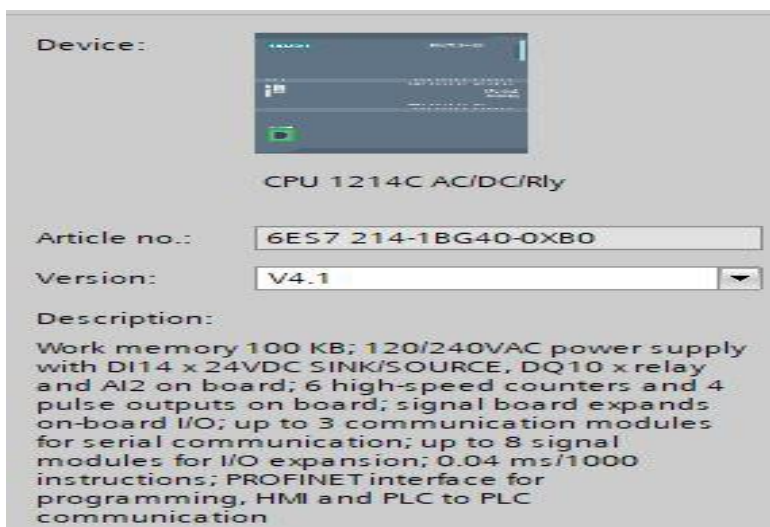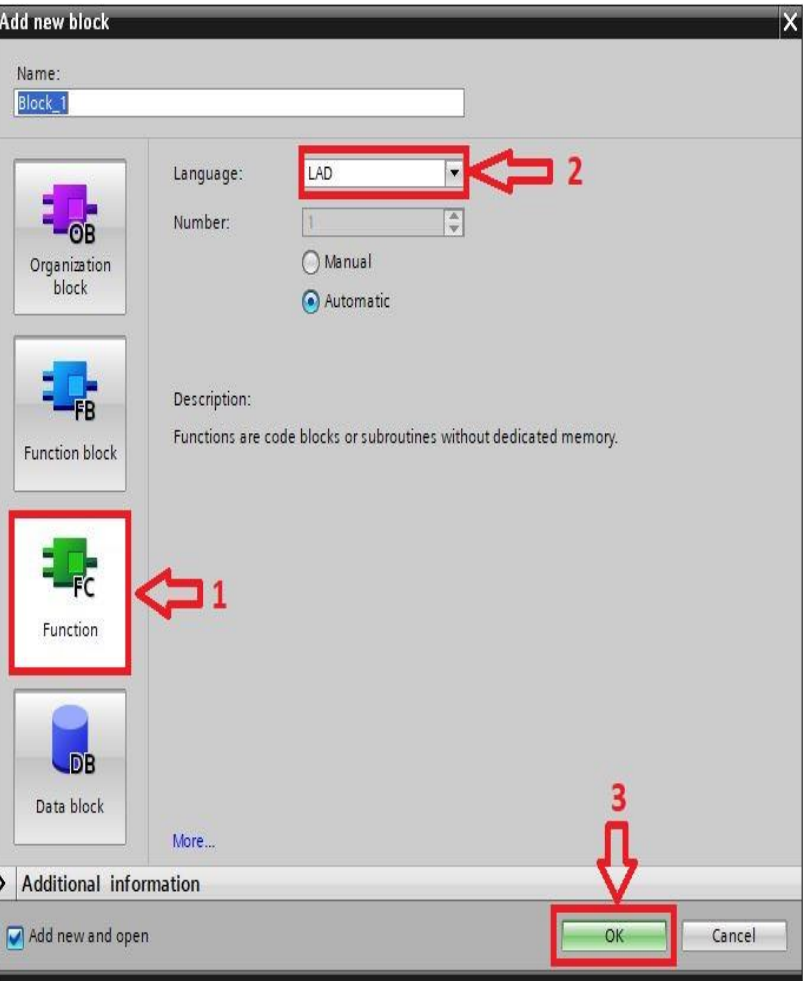
Figure III.29 : Cpu 1214C AC/DC/Rly decription

	• Choose CPU "6ES7 214-1BG40-0XB0"
	• In the catalog of material, choose the card digital input "6ES7 221-1BH32-0XBO"
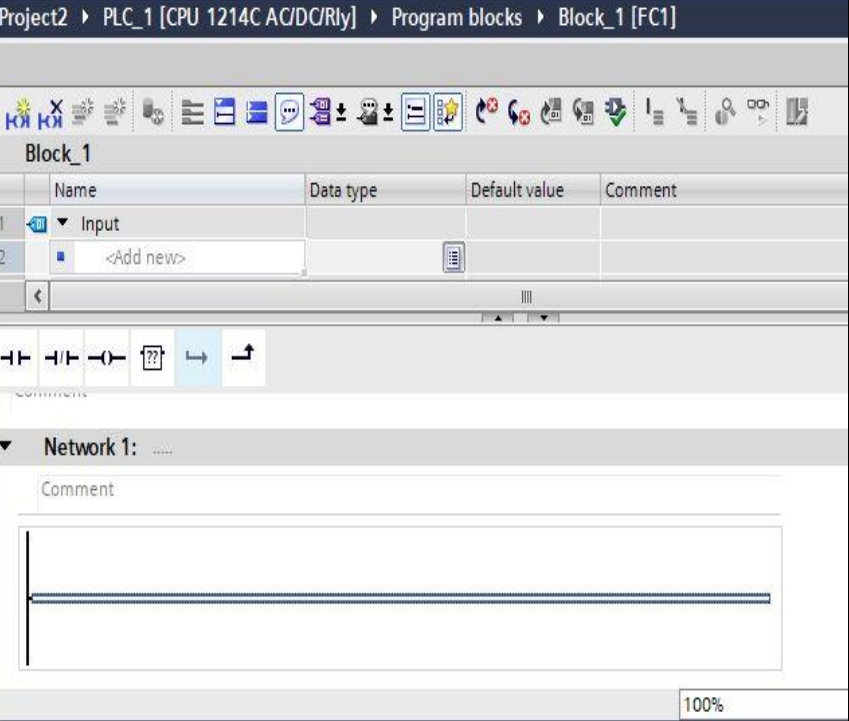
Table III.7: Hardware configuration for the S7-1200

Step 4

This step concerns the insertion of the following blocks: OB – FC - DB.

	• Select "Program bloks" • Double-click on "add new block"
	1. Select one of these blocks for example on choose the block (FC) 2. Choose the LAD language 3. Click on OK
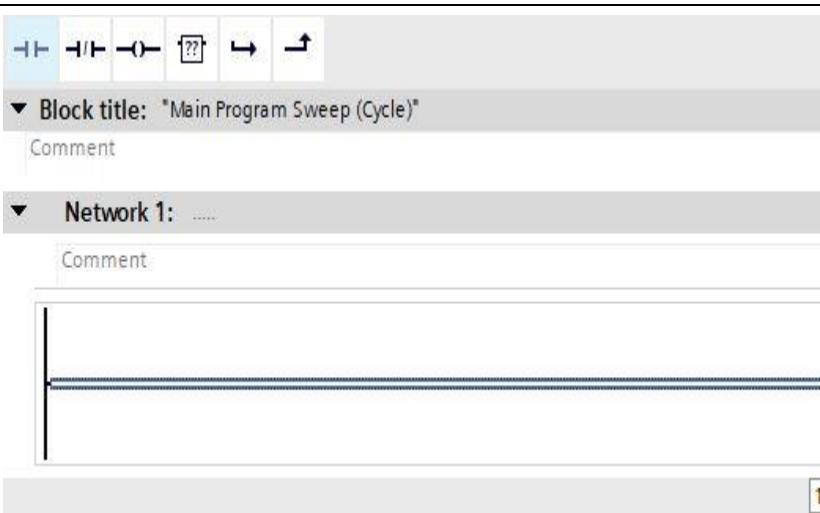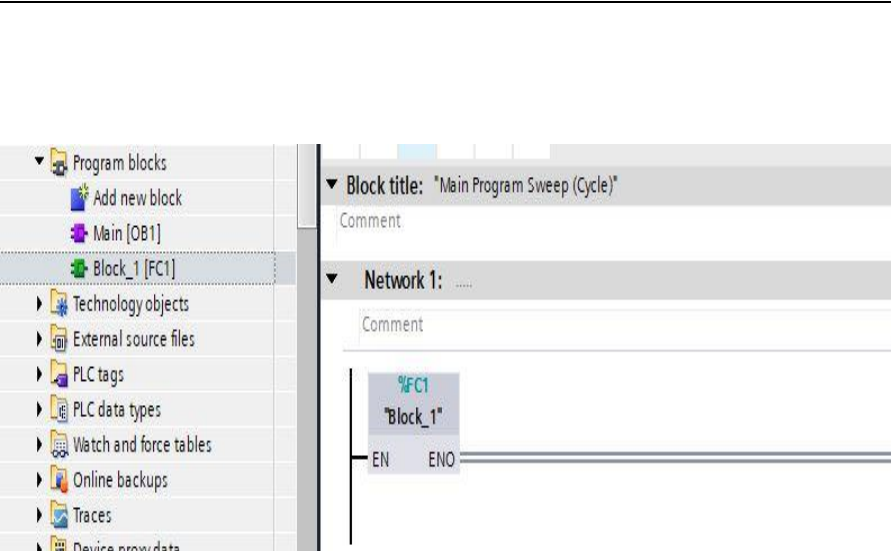
(A)

	• We observe that Block_1 has been added
	• The window of Block_1 is open and ready for programming
	To test the operation, entering: Input: I0.0 Output: Q4.0

(B)

-Call from OB1: The FC type block will be called in OB1.

Note 1: OB1 is automatically called!

	• Double click on OB1 (open in LIST)
	• OB1 opens
	Select Block_1
	• Drag and drop Block_1 onto the line 1, network 1, OB1

Table III.8: (A) and (B): Representation of insertion of a block
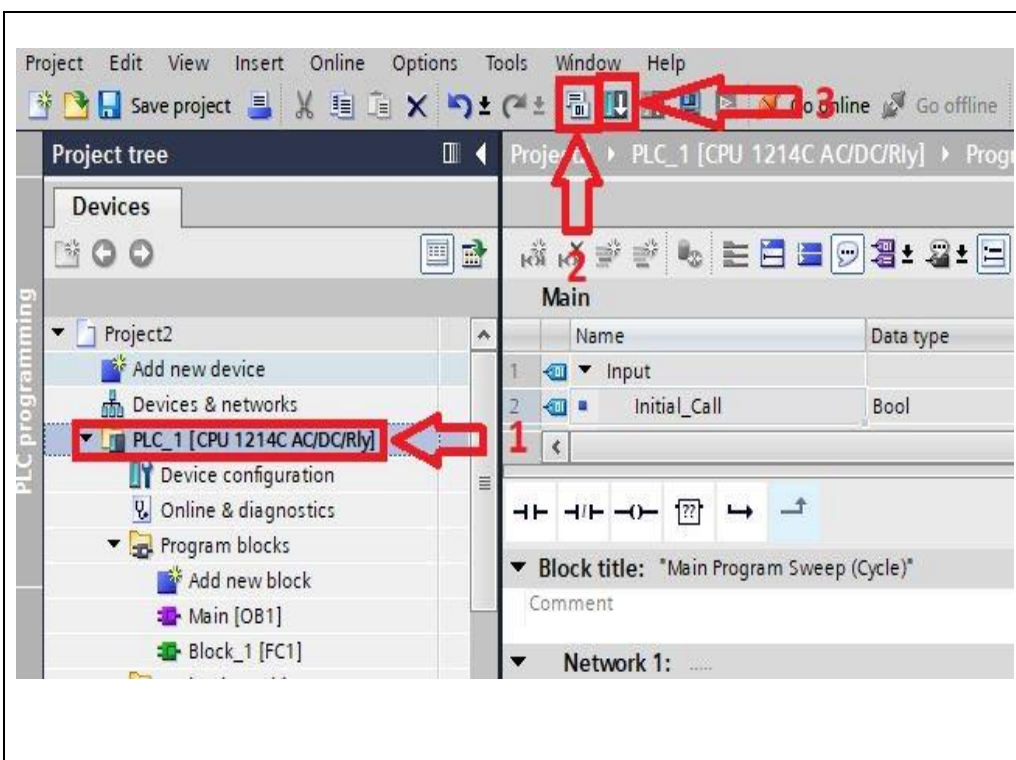
Note : Do the same for the blocks.

Step 5

Compilation is always necessary during the first load. Then the

compilation is only required if the hardware configuration has changed. Examples:

- Add or delete a module.

- Modifying the parameters of a module (decadence flag, remanence,

- cycle, byte address, etc…).

- Save the project
1. Select folder CPU
2. Compile
3. download to device

Table III.9: The procedures followed for compiling and loading the program

Step 6

-Creating HMI Window

We choose an HMI. In the portal view, click on add a device and

selects an HMI among the different choices offered by TIA PORTAL
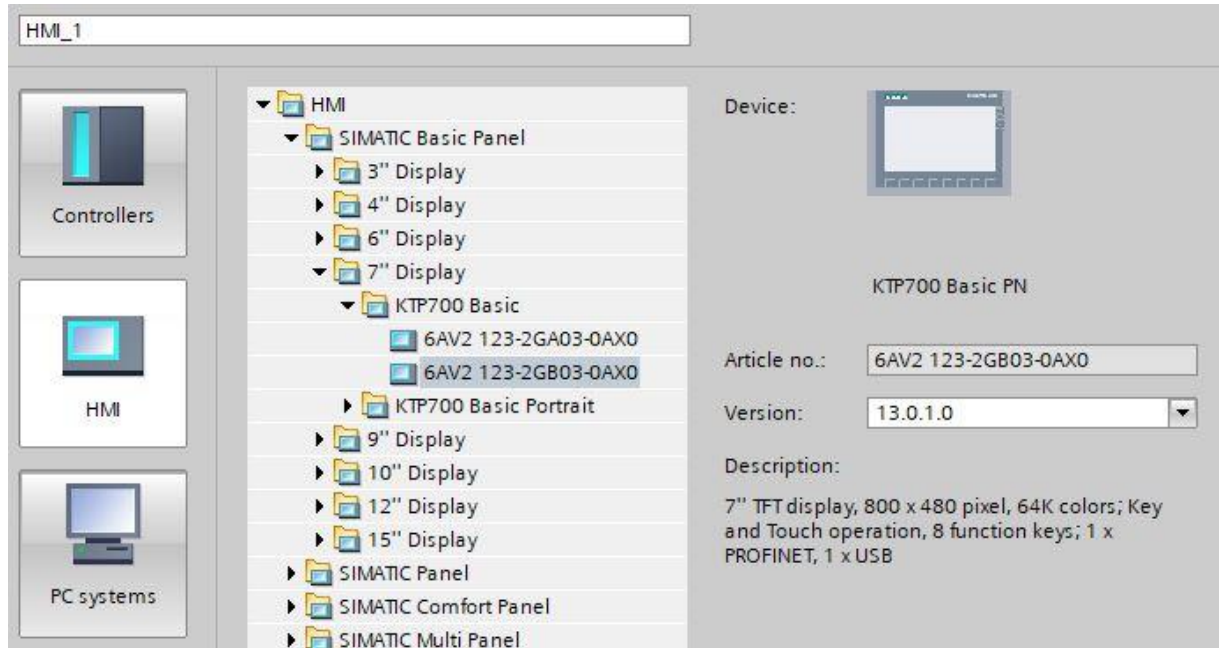
Figure III.30: Configuration of an HMI

A new HMI configuration window representing the network is then displayed to choose the communication interface between the HMI and the PLC (Figure III.31).
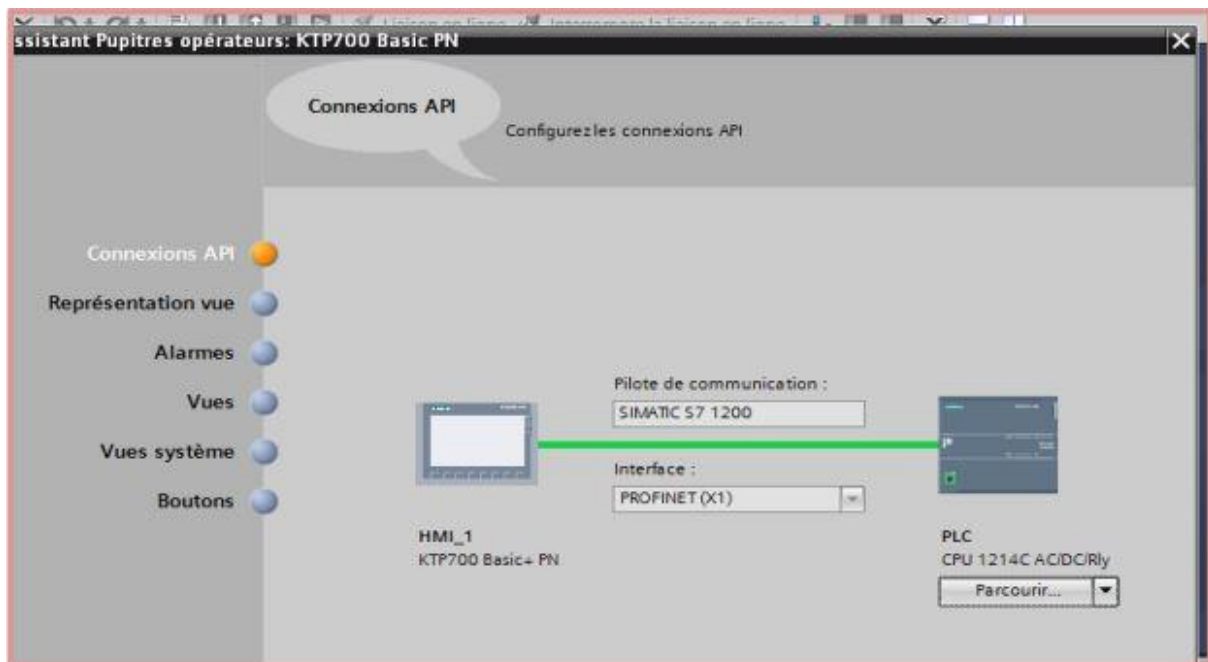
Figure III.31: Connecting the HMI to the plc

- HMI programming

The second part of the programming consists in creating an interface of HMI communication between the user (customer or technician). This interface will consist of a screen for controlling or monitoring the system.

The configuration wizard also allows you to preset the number of views in the HMI and button layout and lots of other useful options (Figure III.32).
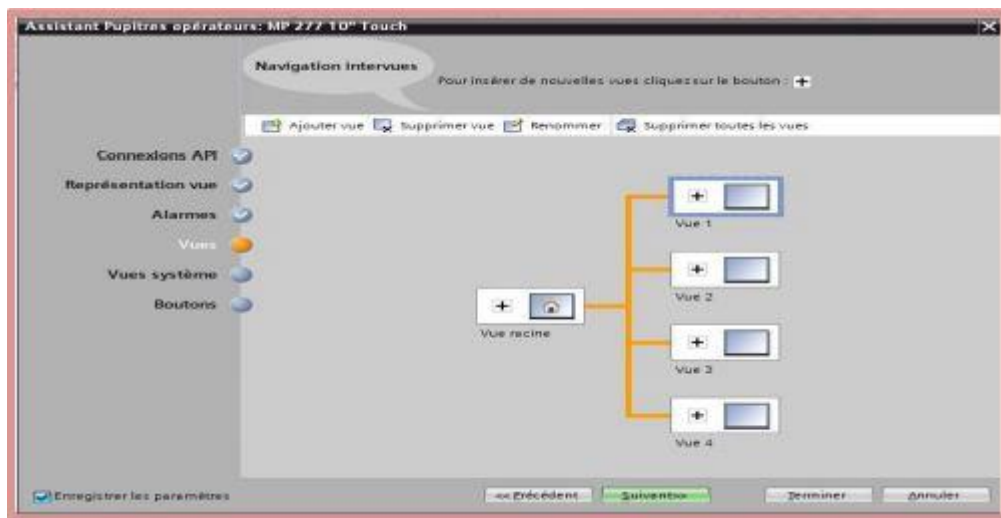
Figure III.32: Configuration of the number of views

Once the HMI is configured, we arrive at the project view which does not differ much from the one allowing to write programs. It is mainly composed of a field workstation representing the HMI screen you want to work on and a library graphic element (Figure III.33).
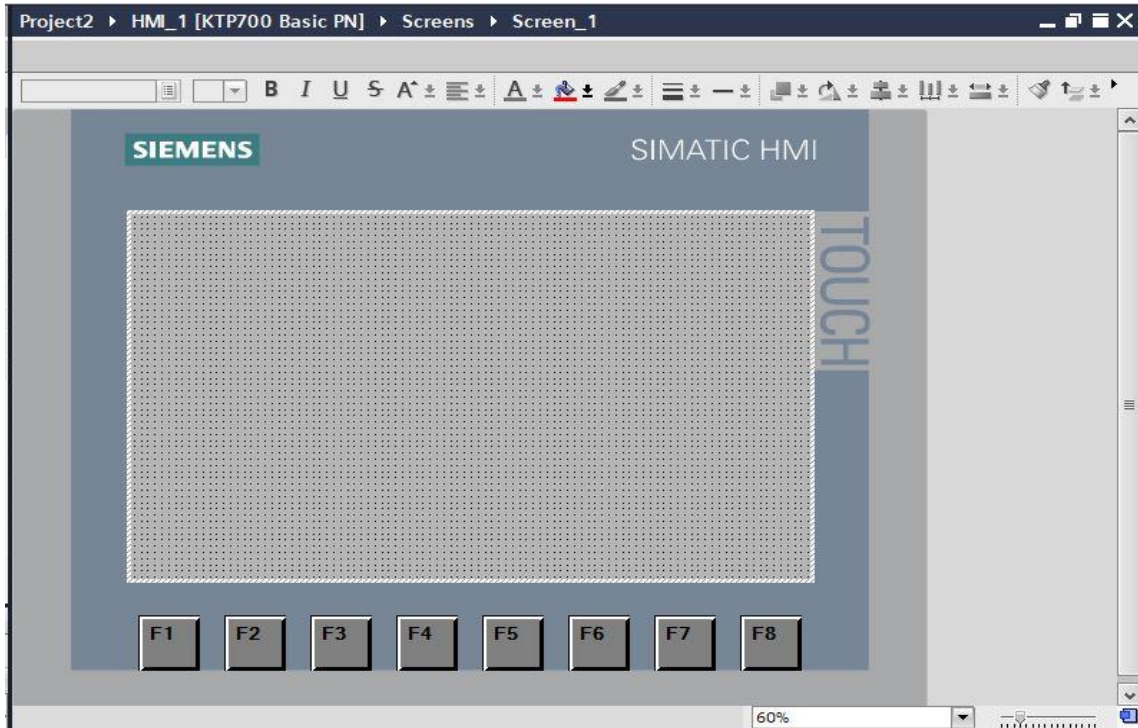
Figure III.33: The project view for working on an HMI

Thanks to the wide choice of objects and graphic elements contained in the menu library on the right of the screen you can start making the HMI screens (Figure III.34).
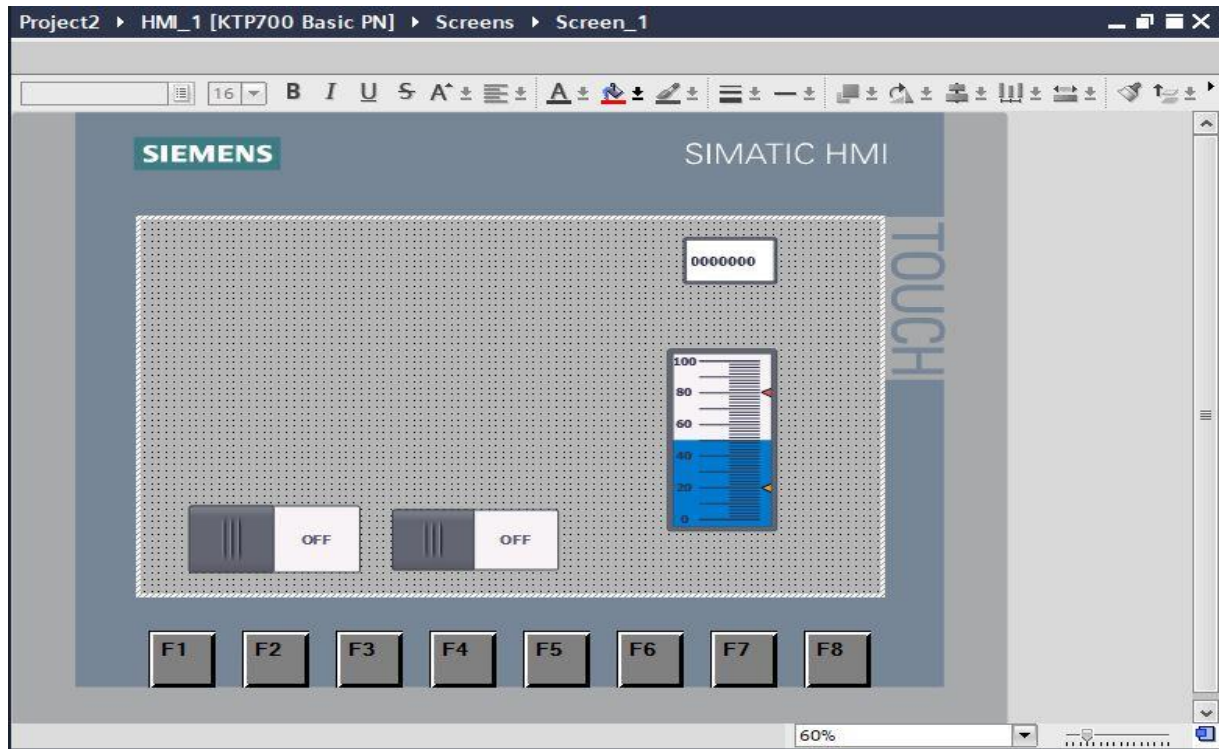
Figure III.34: Library menu of objects and graphic elements

III.10 Conclusion

In this chapter we have seen a description of the S7-1200 programmable logic controller and we talked about how to create a project with steps followed, we ended with the creation of an HMI in detail. All this using software easy and simple called TIA Portal.

CHAPTER IV : Description And Automation Of The RT02 (Rotator) Machine

CHAPTER IV : Description And Automation Of The RT02 (Rotator) Machine

IV.1 Introduction

The simulation part of our work consists in modeling and automating the RT02(ROTATOR) machine, and creating an interface that allows the machine to continue operating steps remotely. We start with a general description of the RT02(ROTATOR) machine. Then, we will detail the specifications of our application by GRAFCET. The specifications will be translated into a program in LADDER language using the TIA Portal V13 programming software. We will finish this chapter by exposing the supervision part with Wincc.

IV.2 Machine description :

The rotating device "RT02" allows rotating the package by 180° in order to allow for air-tight packaging. The machine consists of a center core rotating on ball fifth wheels. The rotation is performed by means of a sprocket wheel transmission, controlled by drive unit, installed on board the static frame where the fifth wheels are installed. The rotating frame contains two belt conveyors that move vertically by means of precision guides and wheels and operated by means of four hydraulic cylinders. The moving belt is required to lift and press the load to be tilted against the antagonist belt . The load is held by the compression exerted by the moving belts. All the power hydraulic equipment (cylinders) are on board the rotating part, whilst the connection to the static section is developed through the appropriate use of a two-way rotating hydraulic joint. The electrical connection between the fixed part and the mobile one is developed by means of a 18-track electrical connector.

IV.3 Working principle :

The rotating device allows rotating a package by 198° in only one workstation. The palletized load enters the rotating device and stops, so that it is centered. The lover and upper belts start a vertical movement in order to press the load. Once the greatest pressing strength is attained, the load can rotate by 180°. Once the load is tilted, the two belts enable the vertical movement to free the load The handling activates the belt in order to free the rotating device from the load.

IV.4 Main components :

The rotator consists of the following main groups :

1) Unit **"Bedplate"**
2) Unit **"Rotation Device Drive"**
3) Unit **"Belt Drive"**
4) Unit **"Rotation Frame"**
5) Unit **"Hydraulic Control Unit"**
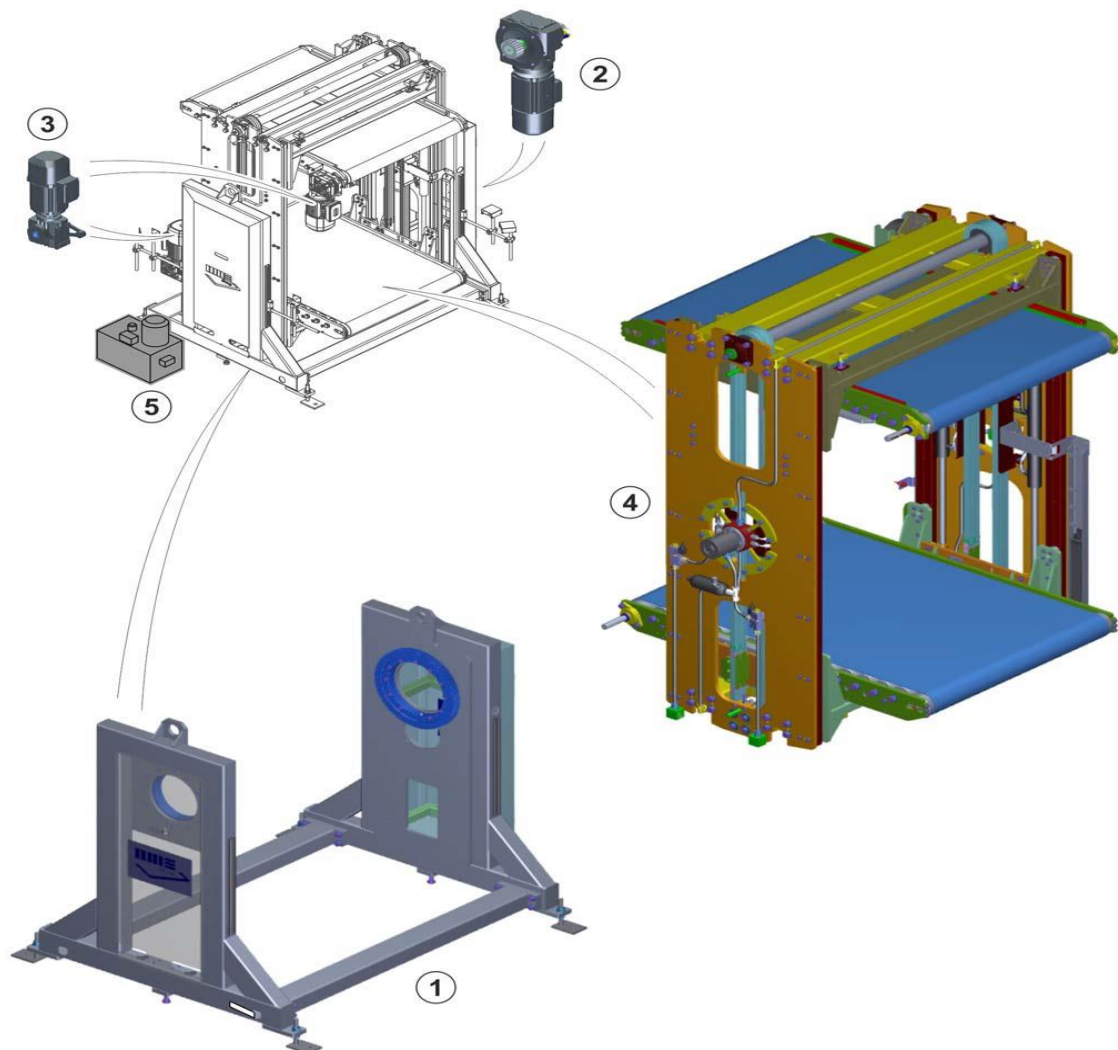
Figure IV.1: Main machine groups

IV.4.1 Bedplate Unit

Bearing frame in painted sheet metal, including the support feet This is the support where the "rotating frame" Unit is applied.

IV.4.2 Rotating Device Drive Unit

The rotation of the frame is developed by a geared motor, with self-braking motor managed by an inverter. The shaft is provided with an incremental encoder.

The motor has separate brake supply; they are directly wired to the control panel, whilst the encoder is wired within a purposely- allocated control box.

IV.4.3 Belt Drive Unit

The handling of the conveyor belts is obtained by two geared motors (one per belt), with self-braking motor managed by inverter.

The motors are provided with separate power supply of the brake. Since the brakes themselves are installed on the rotating part, they need to be wired to the rotating collector.

IV.4.4 Rotating frame

This is a rotating frame that contains the following components :

➢ Two rotating belts with the relevant drive units, which can handle the load .

➢ The hydraulic equipment consists of four cylinders connected to two chains, whose task is to compress the load as appropriate, moving vertically the two belts in order to allow for its rotation.

➢ The rotating frame unit contains the belts and the hydraulic components; the rotation is performed by means of a sprocket wheel transmission connected to a motor.

IV.4.5 Hydraulic Control Unit

The equipment is provided with a separate control unit, which contains the whole power and control circuit (tank, pump, valves, etc.). The control unit must usually be installed on board the machine. The connection between the control unit and the rotating frame is made by hoses with taper fittings. The lengths of these two hosed (delivery and return) may vary depending on the system lay-out A heat exchanger kit is available upon request. Such accessory is used when the machinery is to be installed in areas where the temperature exceeds 40°C. The control unit is hydraulically and electrically arranged for the assembly of such accessory.

IV.5 Work cycle :

The bags are turned by means of the 180° rotation of the mobile structure, while the conveyor belts transport and compress the bags during the rotation.

The rotating device allows rotating the package by 180° in order to obtain air-tight packaging.

The conveyor belts handle and press by means of hydraulic compression ; this in order to allow tilting the load.

The machine's operation phases are detailed in the following chart:

```
┌─────────────────────────────────┐
│        PACKAGE INPUT            │
└─────────────────────────────────┘
              ↓
    ┌───────────────────────┐
    │   package location    │
    └───────────────────────┘
              ↓
    ┌───────────────────────┐
    │     belt loading      │
    └───────────────────────┘
              ↓
    ┌───────────────────────┐
    │  package compression  │
    └───────────────────────┘
              ↓
    ┌───────────────────────┐
    │     180° rotation     │
    └───────────────────────┘
              ↓
    ┌───────────────────────┐
    │     belt opening      │
    └───────────────────────┘
              ↓
    ┌───────────────────────┐
    │   package handling    │
    └───────────────────────┘
              ↓
┌─────────────────────────────────┐
│        PACKAGE OUTPUT           │
└─────────────────────────────────┘
```
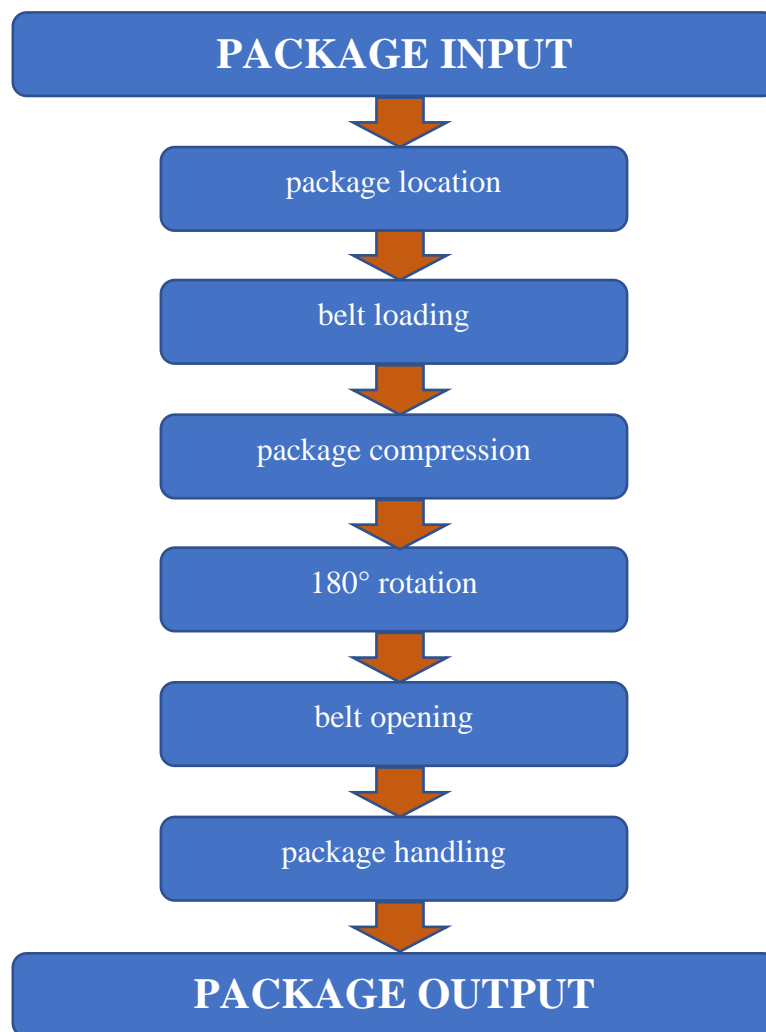
Figure IV.2: The machine's operation phases

IV.5.1 Description of the automatic production cycle

1) The package enters the rotating frame through the handling motion upstream.
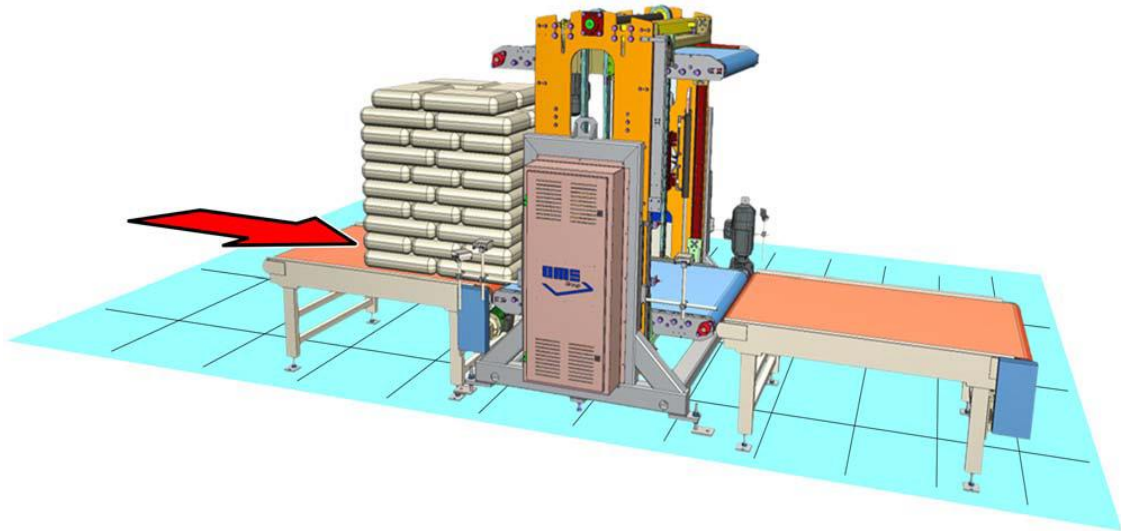
Figure IV.3: (1/7) Work cycle

2) The rotating frame is provided with three photocells that can determine the presence of the package and the centering on the lower belt. (their operation is by-passed during the rotation).

3) Once the package is located on the lower roller bed, the latter stops.
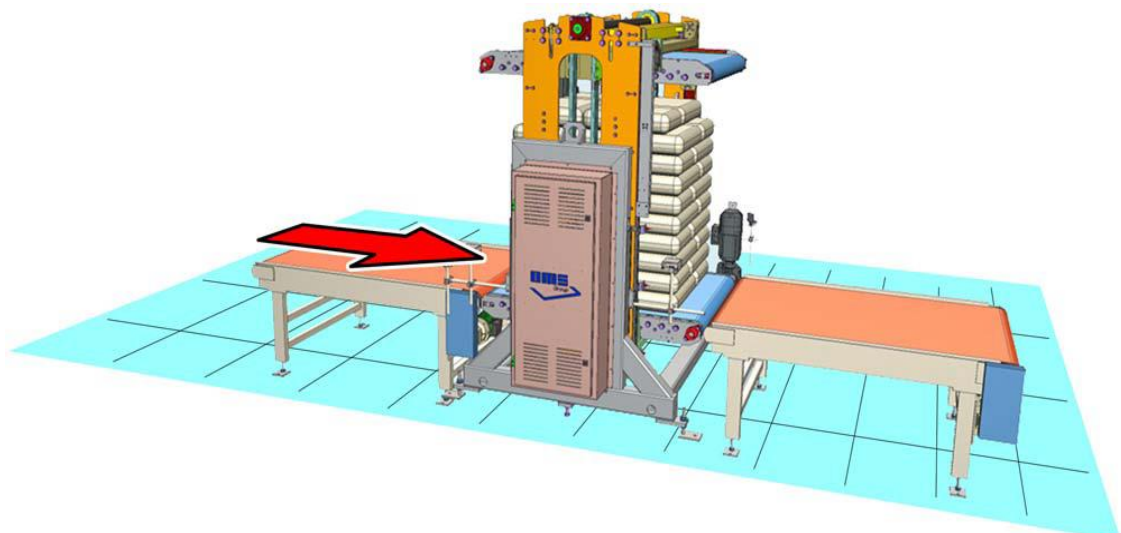
Figure IV.4 (2/7) Work cycle

4) The moving belts cover their vertical stroke, compressing the package between them.
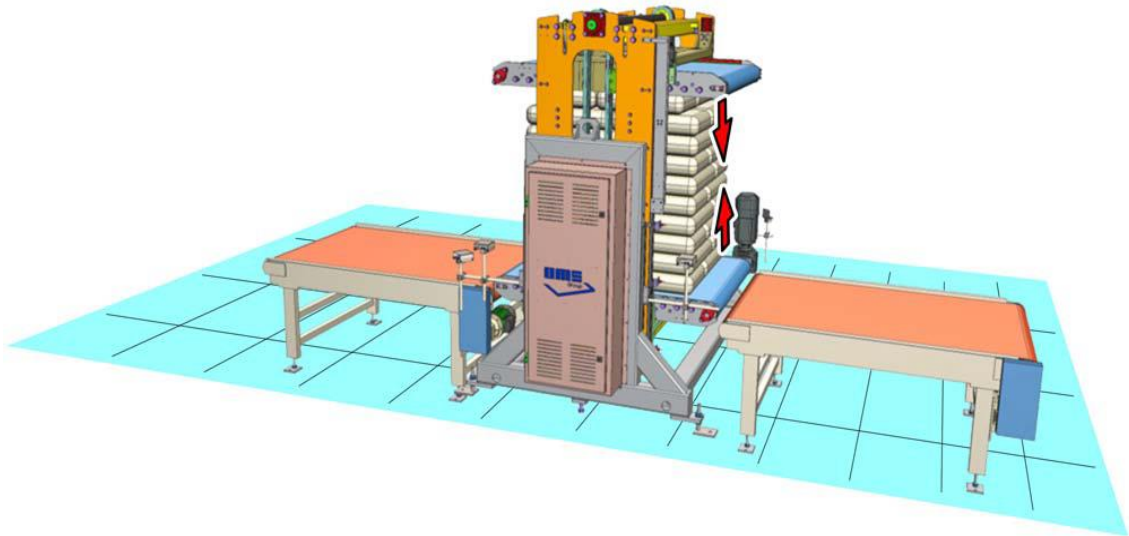
Figure IV.5 (3/7) Work cycle

5) Once the appropriate pressure is reached and the consensus is given by a proximity, the motor allocated to rotation starts.
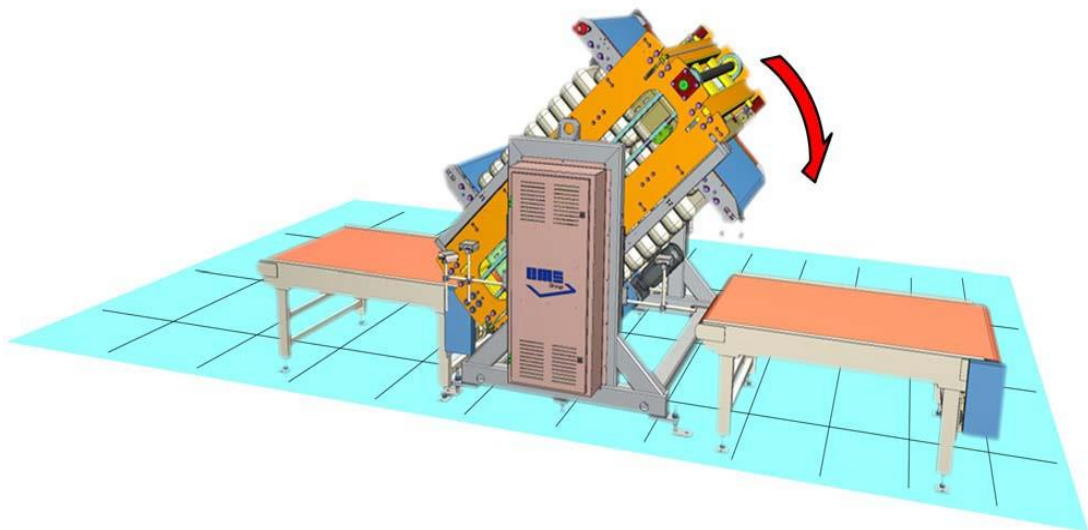
Figure IV.6 (4/7) Work cycle

6) The 180° rotation is performed.
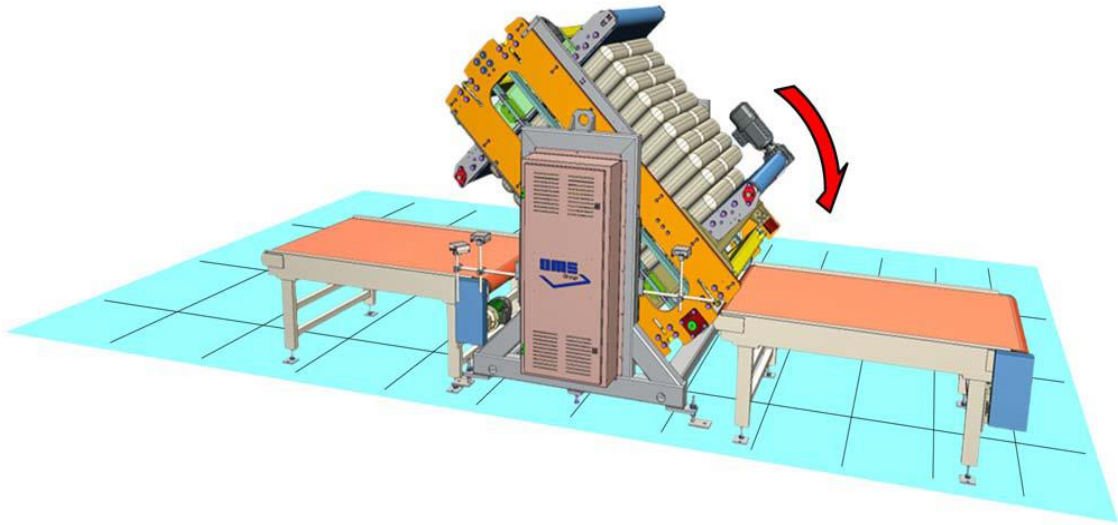
Figure IV.7 (5/7) Work cycle

7) Once the tilting is achieved, the moving belts cover their vertical stroke releasing the package and realigning to the height of the roller beds before and after the rotating frame.
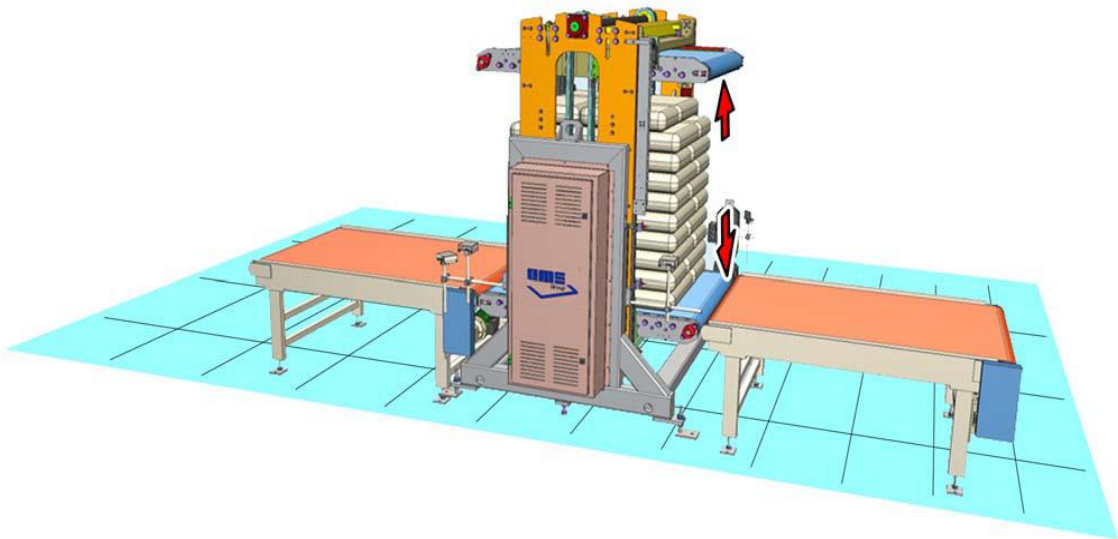
Figure IV.8 (6/7) Work cycle

8) The lower roller bed activates the movement of the belt so that the package leaves the operational position of the machinery.
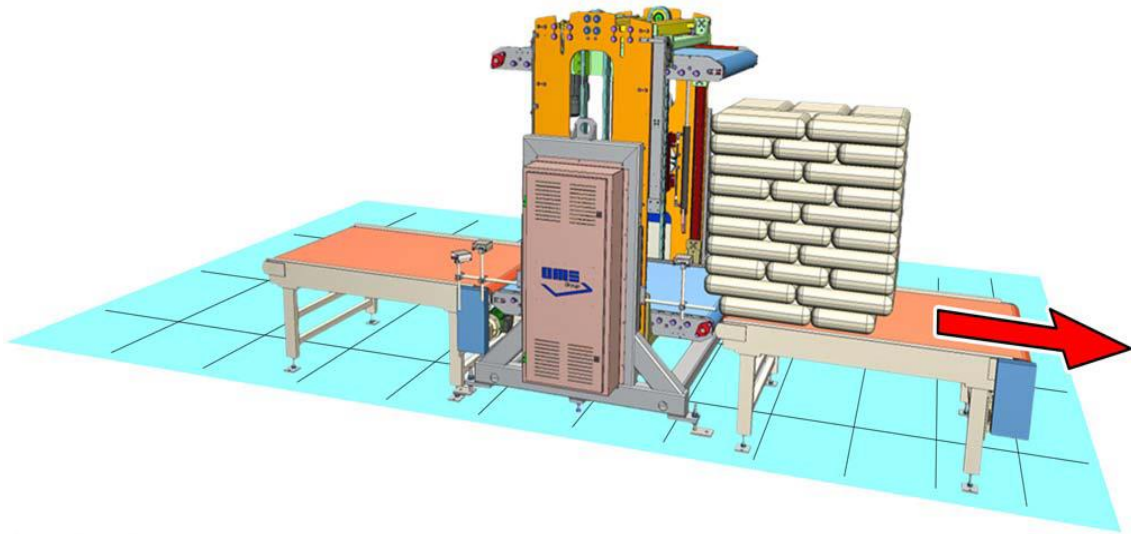
Figure IV.9 (7/7) Work cycle

IV.6 Control panel

IV.6.1 Definition

Electrical control panels are designed and used to control mechanical equipment. Each one is designed for a specific equipment arrangement and includes devices that allow an operator to control specified equipment.

Electrical panel components control every piece of equipment in every industry.

A control panel is also a device, usually wall mounted, in a facility, industrial or other, grouping the various displays (counters, screens, indicators and various indicators ...) for monitoring its operation. It is usually located in a control room, grouped with devices to regulate this operation and control operations. This room also includes the means of communication with the outside.
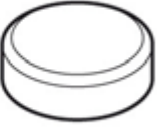
IV.6.2 Control panel structure

The control panel consists of several different buttons and lights shown in (Figure IV.10) and (Table IV.1).
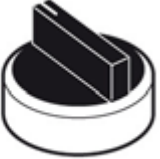
Figure IV.10: Control panel.

GEN_5	**Alarms reset - red light button :** If the light button is lit, it indicates a machine malfunction, the type of fault is indicated on the display. The light turns off when the malfunction is eliminated.
GEN_3	**Off - black button :** To immediately stop the machine's automatic/manual mode.
GEN_1	**Automatic - white light :** Light steadily lit indicates that the machine is enabled to work in the automatic mode. Flashing light : the machine is set to work in the manual mode, but this hasn't been confirmed by pressing the ON button.

GEN_4	**Forward/Backward - Ascent/Descent - Opening/Closing - black multifunction selector :** It can be used with the machine in the manual mode. It enables the movement of the machine group selected with the operator panel function key. The function key and the selector must be actuated contemporaneously.
GEN_4	**Emergency - red mushroom like button :** The red EMERGENCY mushroom-like button is used to stop the machine in case of an emergency. It interrupts the electric power supply to the inverters, it disables the pneumatic circuit and the PLC outputs.
GEN_4	**Manual/Automatic – selector :** Turn the selector to the either the **AUTO** or MANU position to select the desired operation mode.
GEN_9	**White light button :** Button to confirm the machine's MAN_AUTO mode. When pressed with the automatic mode enabled, it makes the machine start.
GEN_1	**Switchboard energized - white light :** When the light is turned on, it indicates that the machine is powered.
GEN_12	**Alarms reset - yellow light button :** If the light button is lit, it indicates a machine malfunction, the type of fault is indicated on the display. Press the button to reset the acoustic alarm. The light turns off when the malfunction is eliminated.

GEN_7	**Safety devices rearming - Blue light button :** Button to enable the system access safety barriers (the light inside the button turns on). It must always be pressed after a safety photocell has been actuated in order to rearm the protection circuits.
GEN_7	**Emergency reset - blu light button :** Press this button to feed the auxiliary circuits, the PLC, the inverters, etc. The light turns off.

Table IV.1: Description of machine operation controls.

IV.7 GRAFCET

Depending upon the position of the rotating frame, from 0° to180°, the moving conveyor belt is always the lower one. The package in input is stopped by photocells (PC1-PC2-PC3).

The belt opening and lowering hydraulic controlled is managed through two fixed pressure thresholds, namely LOW and HIGH pressure (LP and HP).

Two hydraulic valves allow for this difference. They are mechanically adjusted by the supplier of the hydraulic control unit.

For LOW pressure (LP), the valve is adjusted at 90 bar, for HIGH pressure (HP), at 180 bar.

The conveyors close when the rotating device is in the positions 0° or 180°.

High pressure is used to close and press the package : the weight of the package, which may reach 2200 Kg, needs to be won.

The rotation is allowed only when the belts closed on the package engage when the pressure pointed out by the "pressure achieved" pressure switch, which is adjusted as appropriate, and the "close" proximity (CP) switch is reached.

At 0° or 180°, at the end of the rotation, the conveyors open at low pressure until the "open" proximity (OP) switch is reached, with a delay before stopping the control.

The grafcet shown in Figure IV.11:
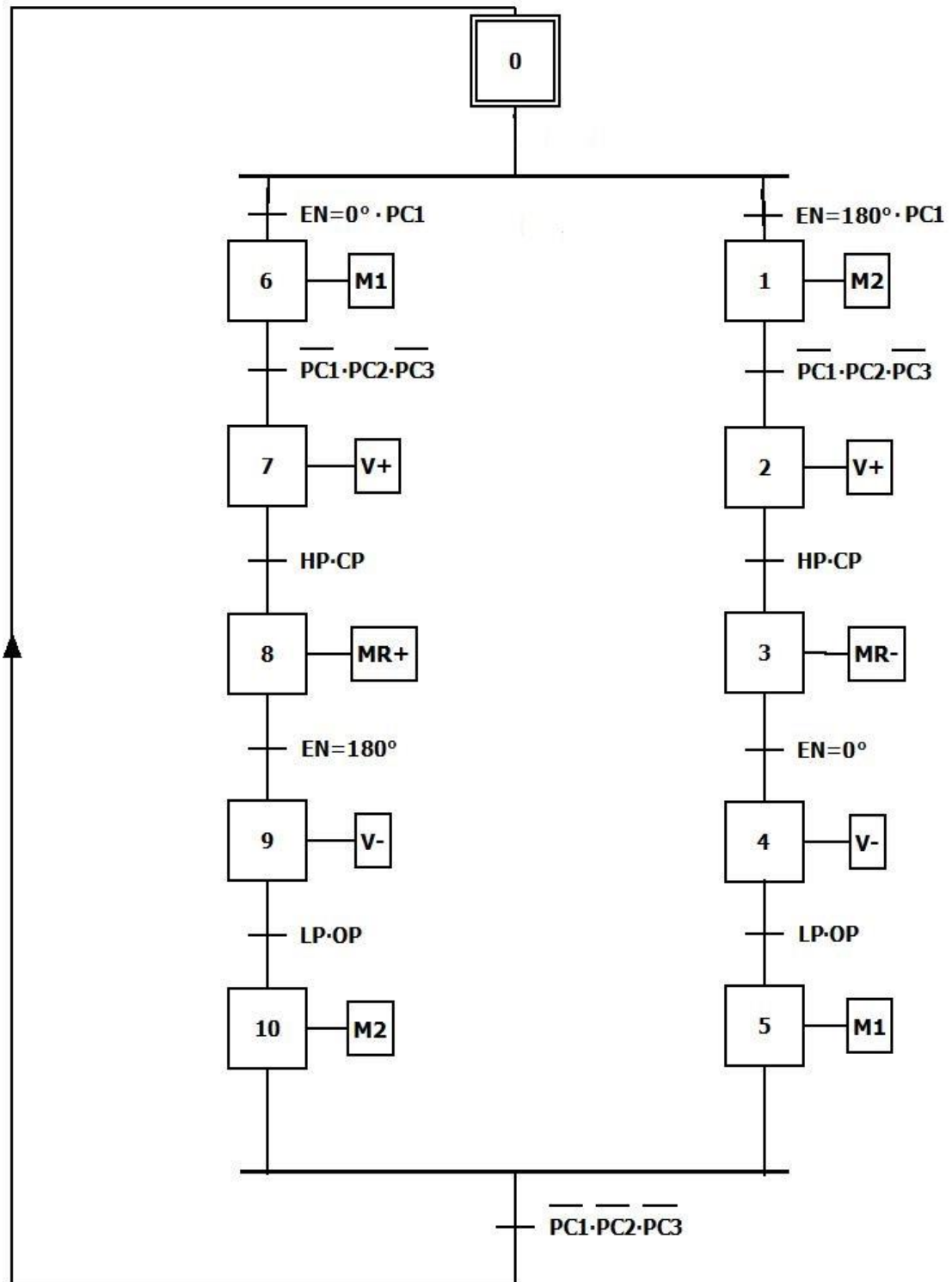
Figure IV.11: Grafcet of the system.

symbols	Description	Type
PC1	The presence of the package at entry	photocells
PC2	The presence of the package at Center of the lower belt	photocells
PC3	The presence of the package at exit	photocells
LP	low pressure	Pressure switch (Pressostat)
HP	HIGH pressure	Pressure switch (Pressostat)
EN=0°	The position of the rotating frame is 0°	encoder
EN=180°	The position of the rotating frame is 180°	encoder
CP	The conveyors is close	Inductive (Proximity)
OP	The conveyors is open	Inductive (Proximity)
M1	moving conveyor belt 1	Motor
M2	moving conveyor belt2	Motor
V+	Close the conveyores	hydraulic cylinders
V-	Open the conveyores	hydraulic cylinders
MR+	rotate by 180°in a positive way	rotary motor with two directions of rotation
MR-	rotate by 180° in a negative way	rotary motor with two directions of rotation

Table IV.2: Meaning of the GRAFCET symbols

IV.8 Programming on TIA Portal V13

IV.8.1 Hardware configuration

The creation of a surTIA Portal V13 project begins by defining a hardware configuration, whose interest is to specify the supply, input and output modules for the project, in order to connect it with the Corresponding CPU at the PLC, hardware shown in (Figure IV.11).

The hardware and software requirements are as follows:

- SIMATIC S7-1200
- CPU : CPU 1214C DC/DC/DC
- DI/DQ : DI 8x24VDC_1
- AI/AQ :AI 4x16BIT_1
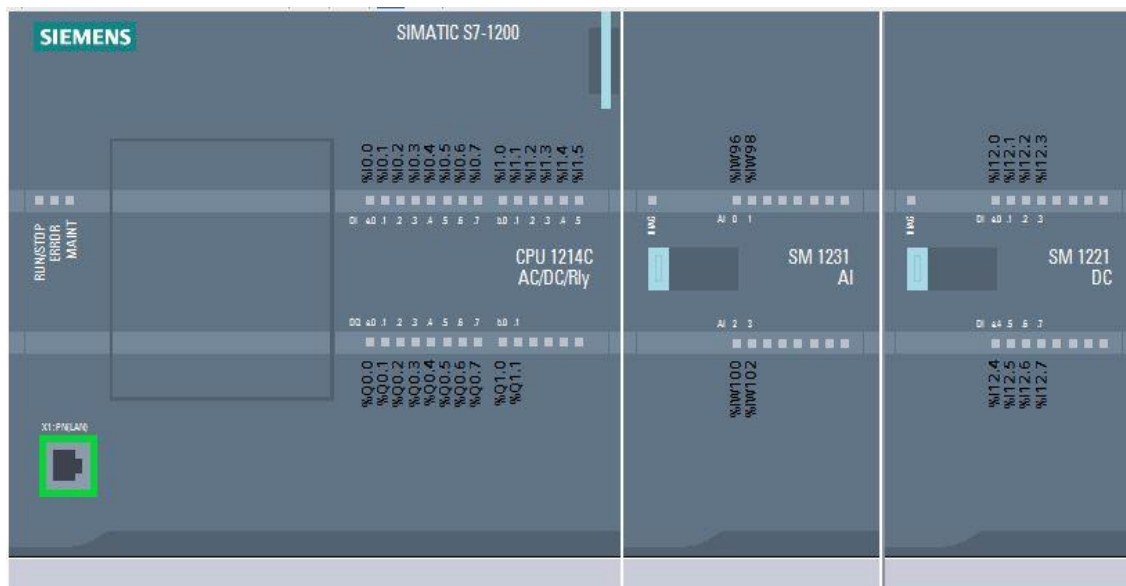
Figure IV.11: Hardware configuration

IV.8.2 PLC tags

The program blocks creation follows the hardware configuration phase where the choice of the language used is made and the definition of the variables at the level of PLC tags table,it's shown in (Figure IV.12).

Figure IV.12: Table of variables.

IV.8.3 Program in contact language

Our work contained 21 contact language networks divided into two parts when of the rotating frame is 0° or 180°:

AI conversion block "FC1":

The following network represents the function "FC105 Scaling values" that read the analog value of encoder.
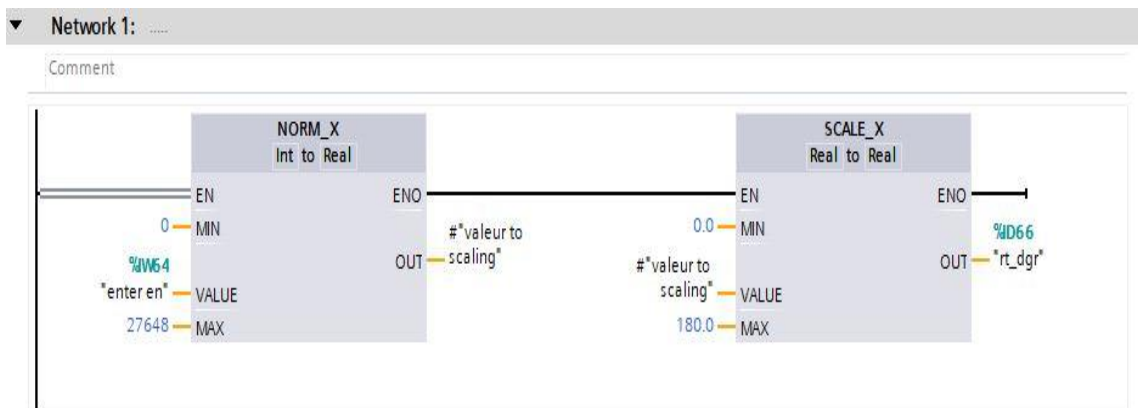
Figure IV.13: Transformation of an analog input to degree of rotation

Network 1: System startup
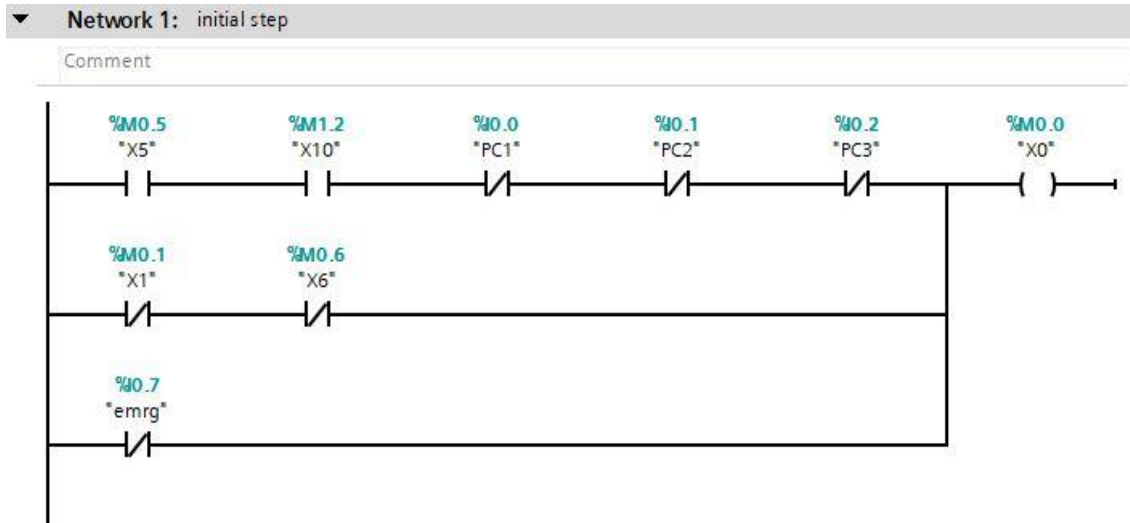
Figure IV.14: Network 1

Network 2: moving conveyor belt 2 (the rotating frame is 180° position)
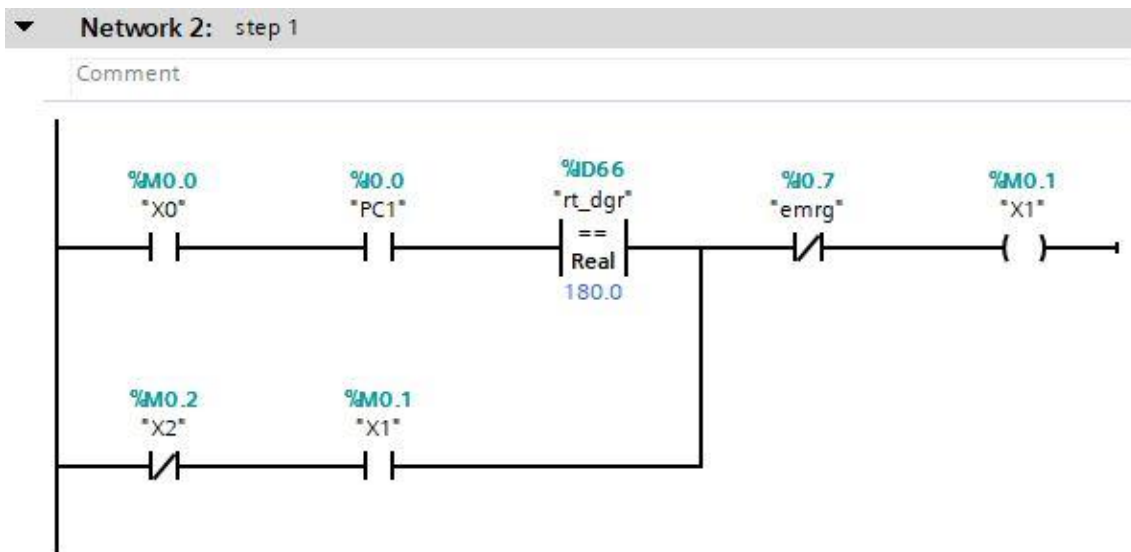
Figure IV.15: Network 2
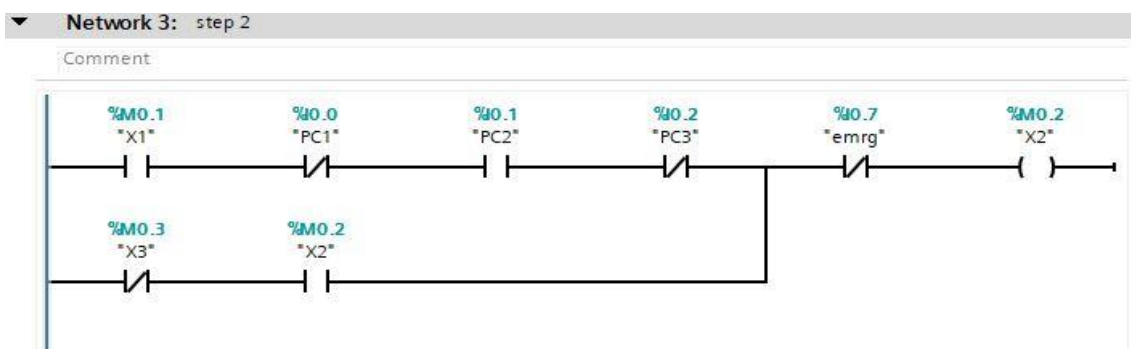
Network 3: Close the conveyors

Figure IV.16: Network 3
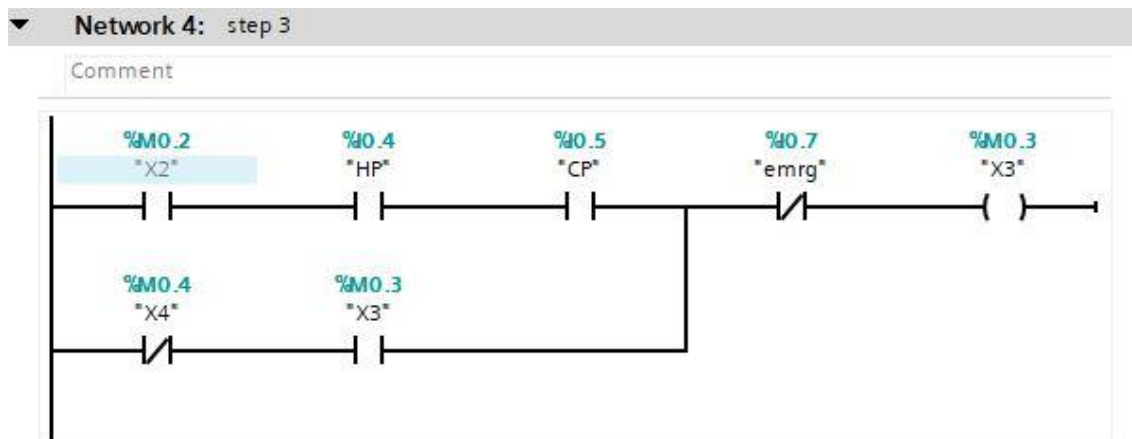
Network 4: rotate by 180°in a negative way

Figure IV.17: Network 4

Network 5: Open the conveyors
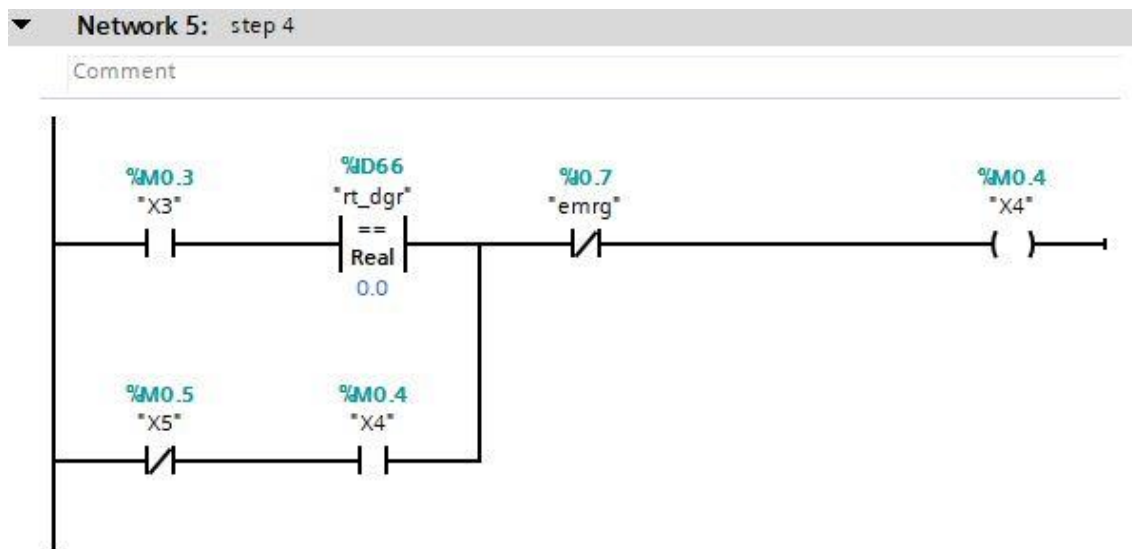
Figure IV.18: Network 5
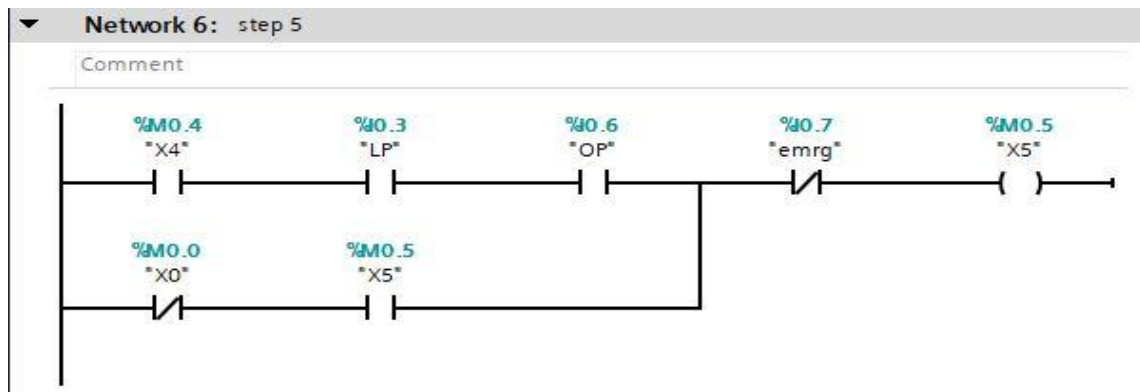
Network 6: moving conveyor belt 1

Figure IV.19: Network 6

Network 7: moving conveyor belt 1 (the rotating frame is 0° position)
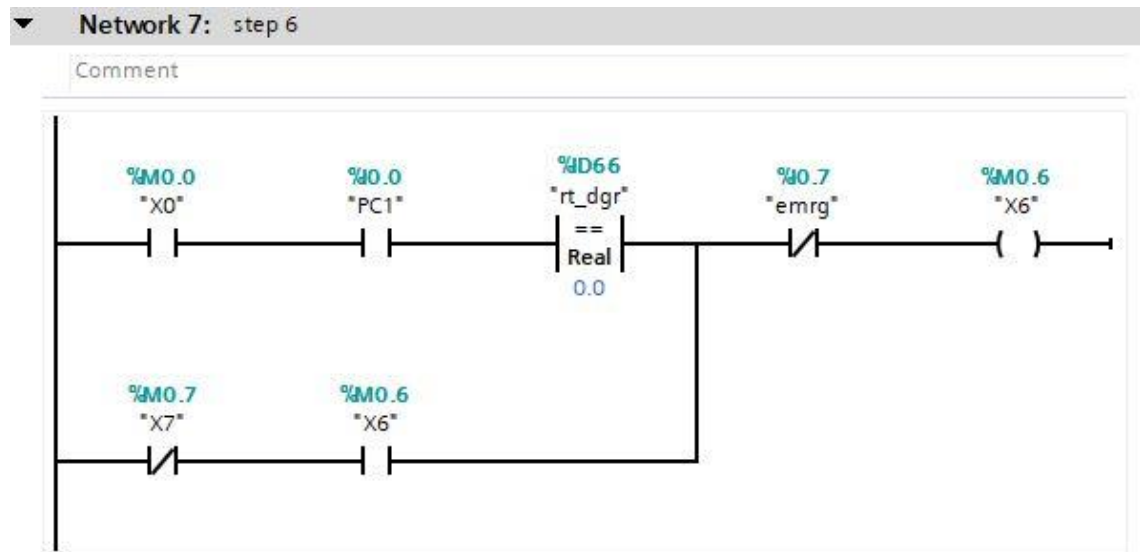

Figure IV.20: Network 7

Network 8: Close the conveyors

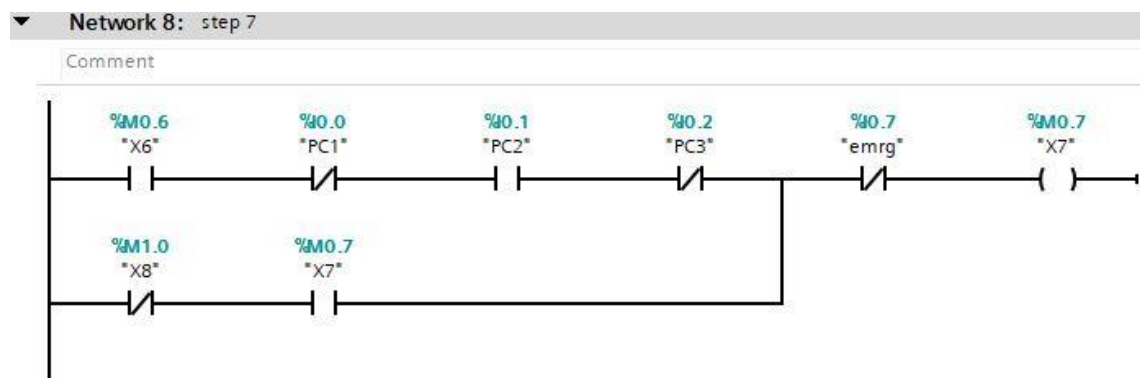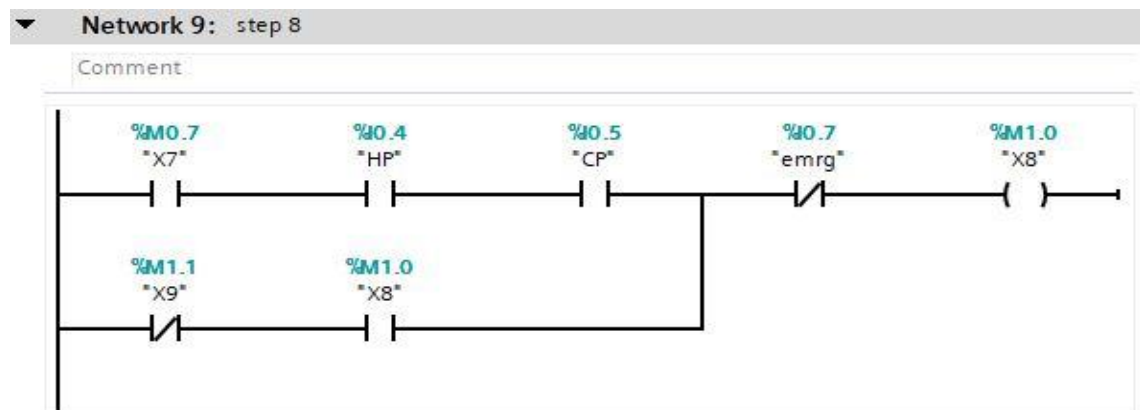**Figure IV.21: Network 8**

Network 9: rotate by 180°in a positive way

Figure IV.22: Network 9
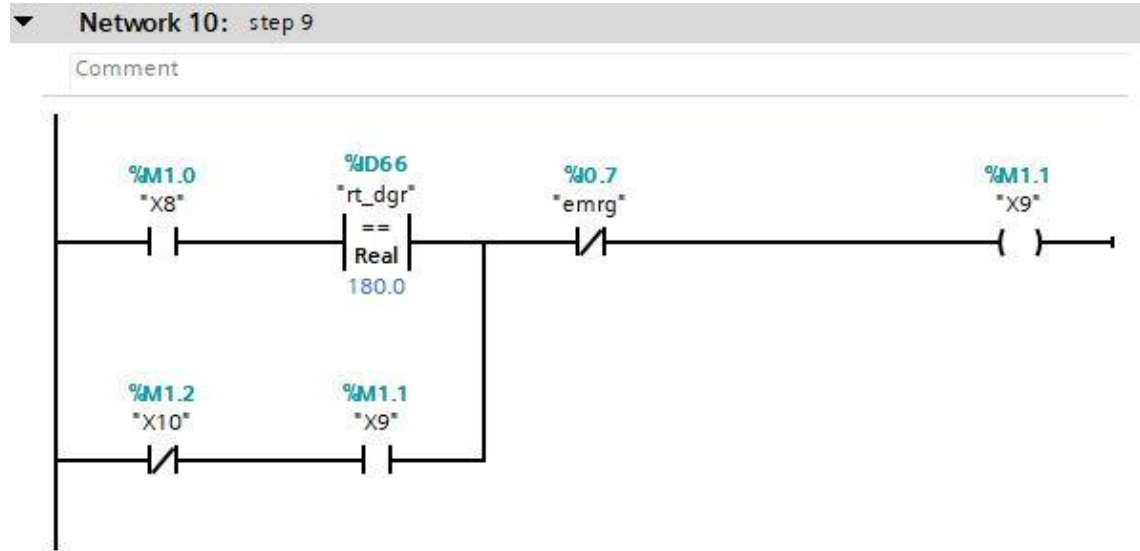
Network 10: Open the conveyors

Figure IV.23: Network 10

Network 10: moving conveyor belt 2
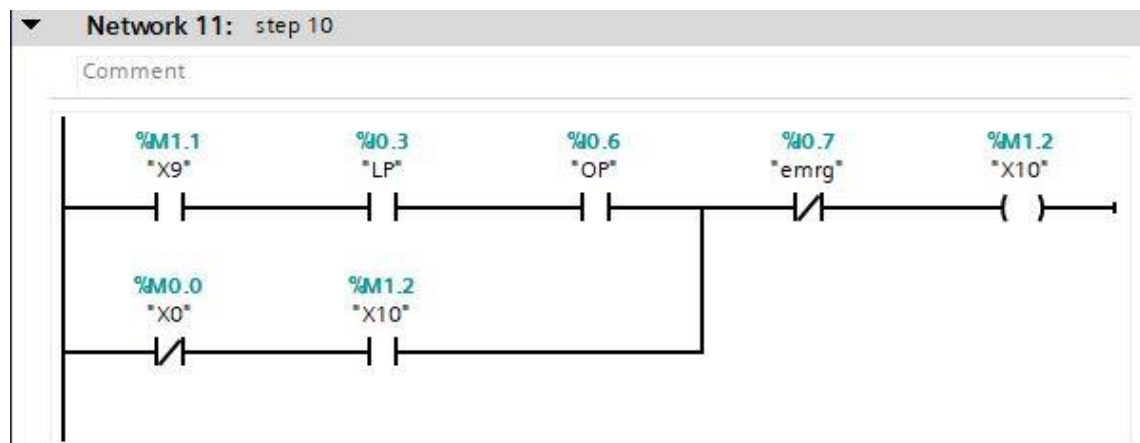
Figure IV.24: Network 11

Action Networks:
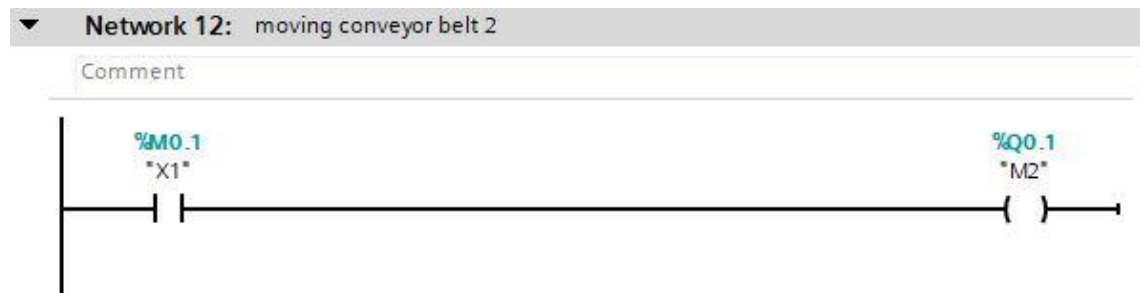
Network 13: Close the conveyors

Comment

```
    %M0.2                                           %Q0.2
    "X2"                                            "V+"
     | |                                            ( )
```
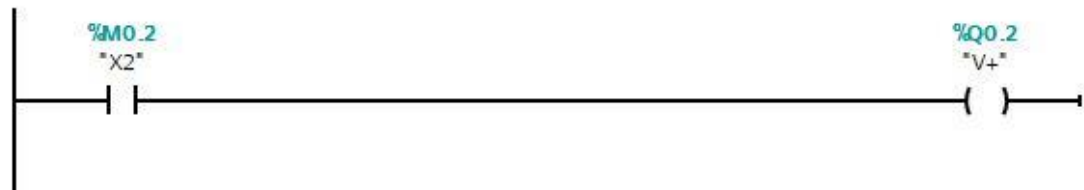
Network 14: rotate by 180°in a negative way

Comment

```
    %M0.3                                           %Q0.5
    "X3"                                            "MR-"
     | |                                            ( )
```

Network 15: Open the conveyors

Comment

```
    %M0.4                                           %Q0.3
    "X4"                                            "V-"
     | |                                            ( )
```

Network 16: moving conveyor belt 1

Comment

```
    %M0.5                                           %Q0.0
    "X5"                                            "M1"
     | | |                                          ( )
```

Network 17: moving conveyor belt 1

Comment

```
    %M0.6                                           %Q0.0
    "X6"                                            "M1"
     | |                                            ( )
```
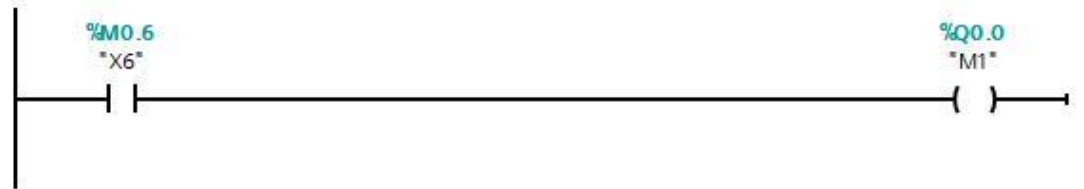
Network 18: Close the conveyors

Comment

```
    %M0.7                                           %Q0.2
    "X7"                                            "V+"
     | |                                            ( )
```
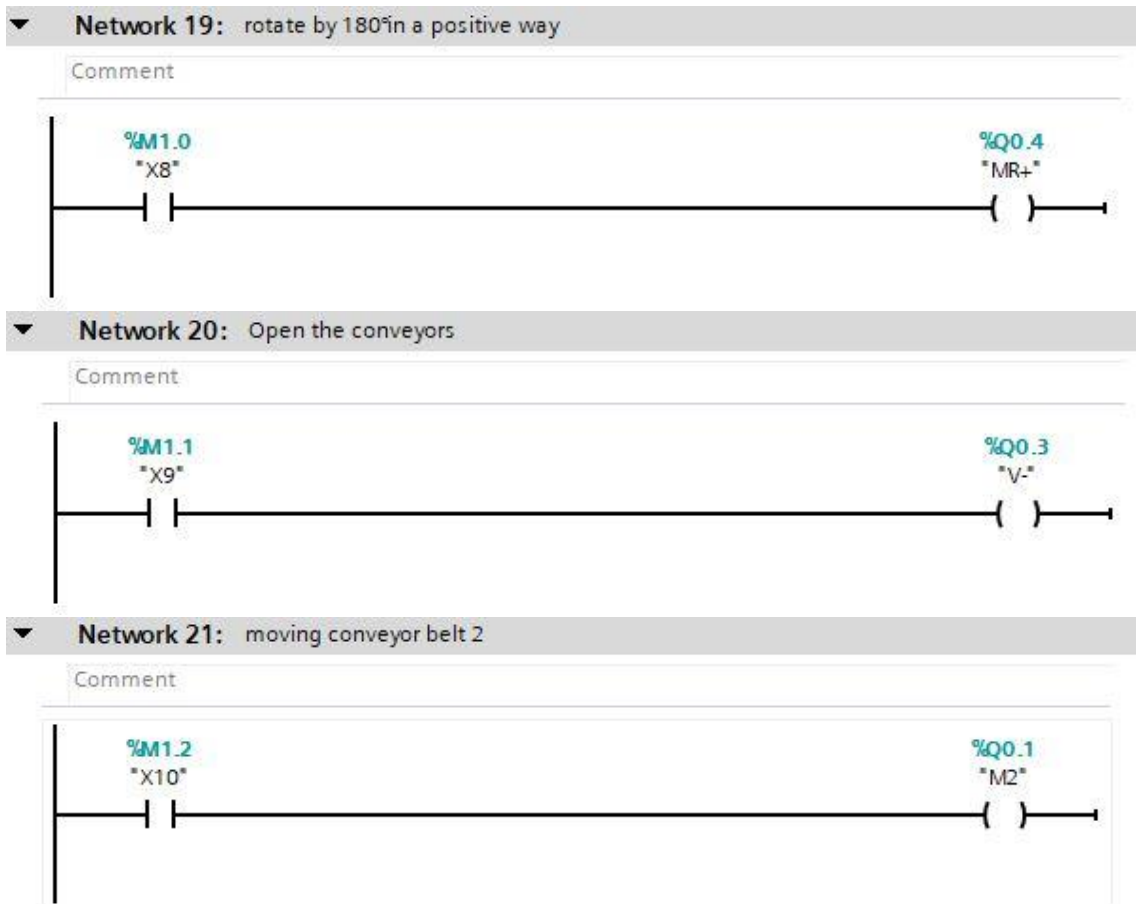
Figure IV.25: Network 12

IV.8.4 Simulating programs using S7-PLCSIM

S7-PLCSIM provides a graphical user interface for viewing and modifying control program variables, to run the simulation CPU in cycle mode single or continuous cycle, as well as to modify the operating state of the simulation.

IV.8.4.1 simulation steps

- Compile the system program (without error).
- Download the program to the device (in the S7-1200 API).
- The online link in PLC_SIM.
- Activate the program display.

IV.8.4.2 PLC_SIM table :

The PLC_SIM table contains the program entries.

Note:

- to activate cleaning in forced DP mode at the DP input.
- To start cleaning in Time canceled mode, DP forcing.

Figure IV.26: The state of the inputs on PLC SIM

IV.8 Creation of HMI station

We choose to complete our project screen with the following property a SIMATIC "KTP700 Basic+ PN "Touch.

For the management of our application we follow the following steps:

- Create a view to create the main interface of our application

- Establishment of the PLC connection - SIMATIC "KTP700 Basic+ PN "Touch.

- The binding is established by choosing the communication protocol which in our case is MPI.
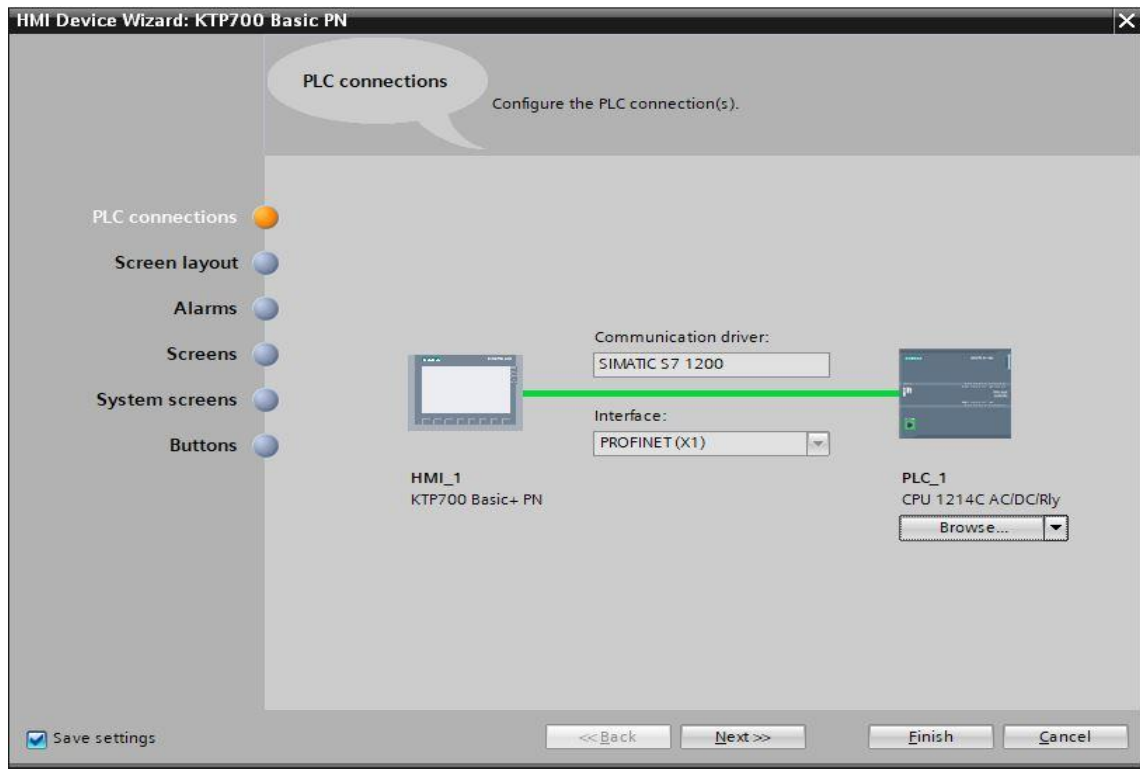
Figure IV.27: The connection between the console and the station

IV.8.1 Project simulation using Win CC flexible

(Figure IV.28) shows the simulation of our project using Win CC flexible.
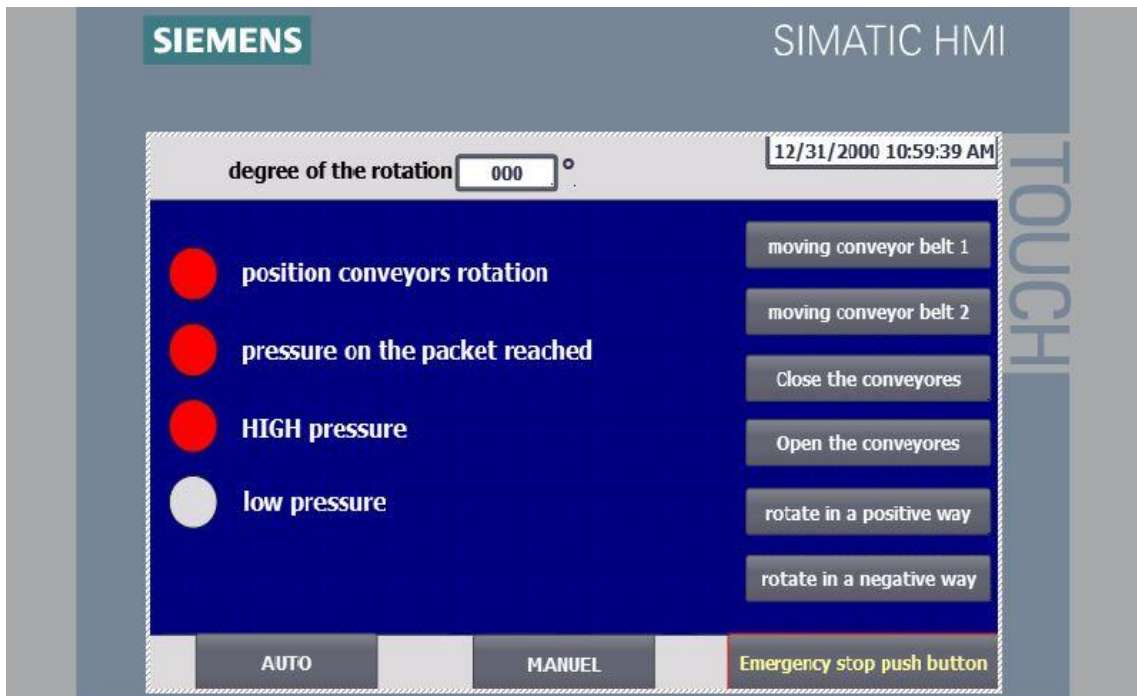
Figure IV.28: Project simulation using Runtime

IV.9 Conclusion

In this last chapter, we have made a general description of the RT02(ROTATOR) machine, then, we have determined the operating principle of this machine, and subsequently, we have enumerated its main components giving them their essential characteristics. A detailed description of the work cycle has been made, we ended our chapter with the creation of different programs that allow us perform the task of automating the RT02(ROTATOR) machine, as well as the HMI views for supervision and communicate it to the PLC.

OVERALL CONCLUSION AND PERSPECTIVEs

Automation is the use of logical programming commands and mechanized equipment to replace the decision making and manual command-response activities of human beings. Historically, mechanization—such as the use of a timing mechanism to trip a lever or ratchet and pawl aided humans in performing the physical requirements of a task. Automation, however, takes mechanization a step further, greatly reducing the need for human sensory and mental requirements while simultaneously optimizing productivity.

This report is the result of an internship carried out within the BISKRIA Cement factory (SPA), as part of this internship, we have detailed the stages of the manufacture of the cement and we have given a very detailed functional study on the system. automated production. On the other hand, we were able to deepen our knowledge of PLCs and in particular Siemens PLCs. Thus, we developed a program for the automation of an industrial process (the rotating machine"**RT02**") using the TIA PORTAL V13 programming software. Finally, an implementation of a computerized tool, which allows local supervision of the machine using the Wincc Flexible software.

The realized project proposes an automated solution using the SIMATIC programming TIA PORTAL V13 and Wincc Flexible and PLCSIM softwares.

In the light of the results obtained, many perspectives are envisaged such:

- ✓ A simulator which allows to give programmable solutions.
- ✓ A supervision system for the Man / Machine interface in order to ensure control and monitoring.
- ✓ Ensuring maximum machine production and minimum breakdowns with reduced waiting time.

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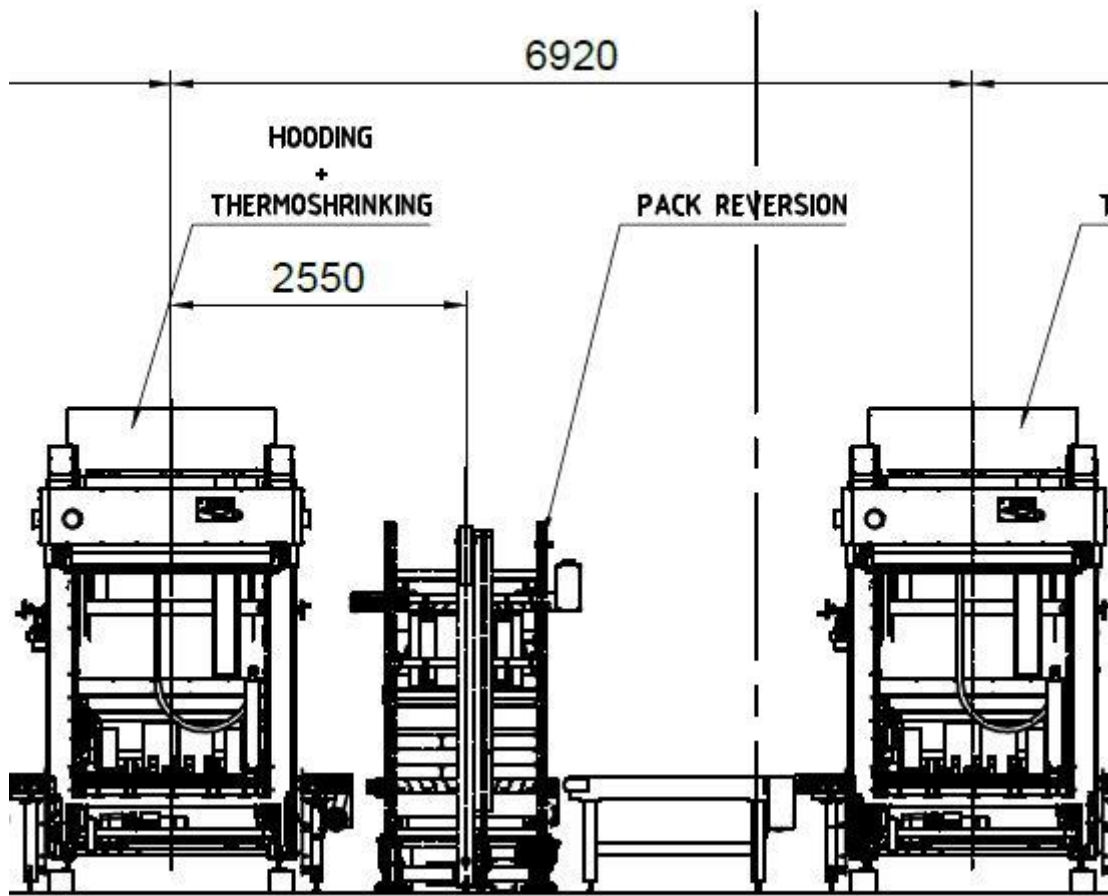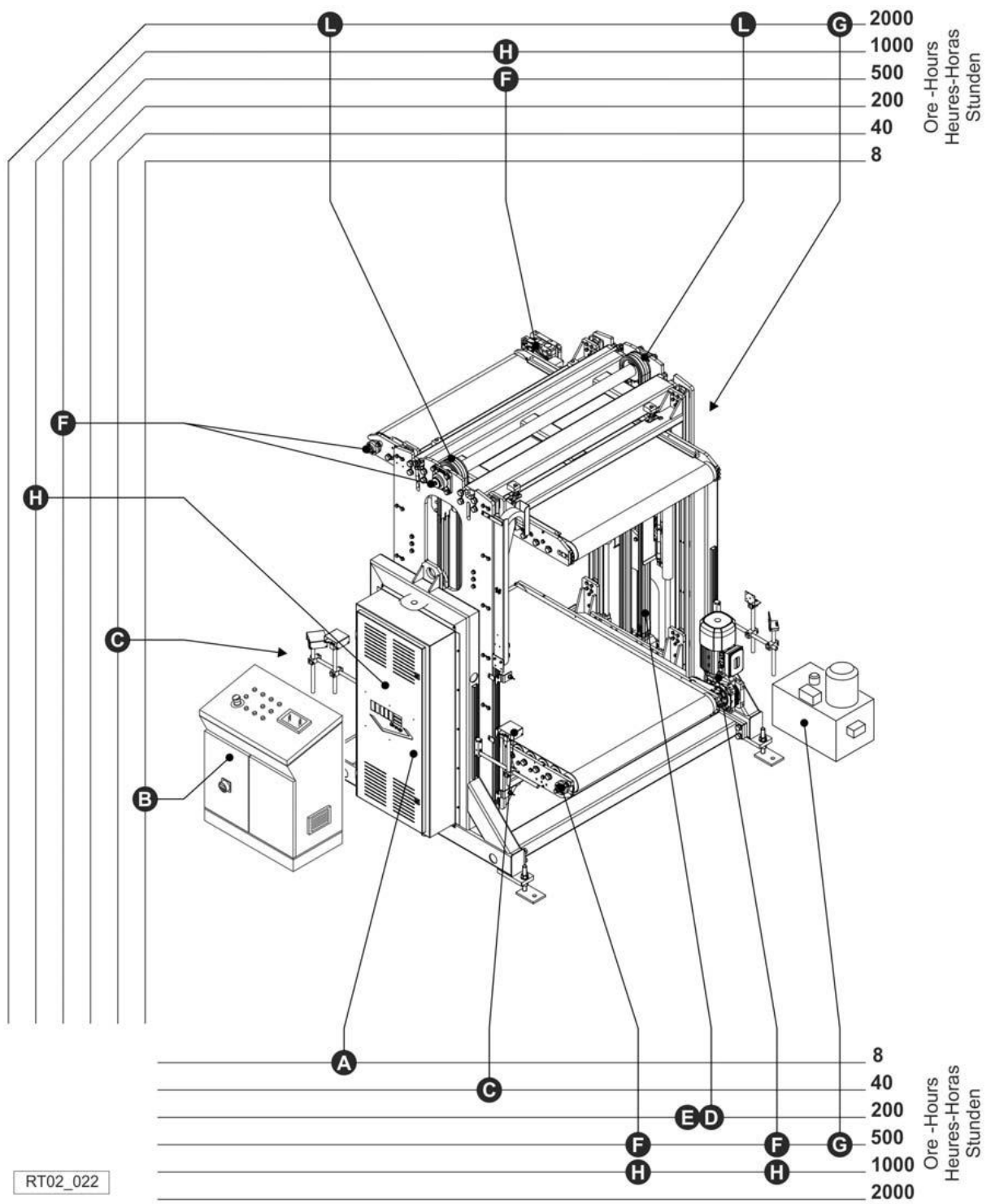
ANNEXES

Figure 1 :BISKRIA_CEMENT_Line

Figure 2 : Maintenance activities layout

REFERENCE	MAINTENANCE IN-TERVAL	TYPE OF ACTIVITY	NOTES	QUALIFIED PER-SONNEL
a	shift end/max. 8 hours	Overall cleaning of the machine		Operator
b	40 h/max. 1 week	Check that the EMERGENGY button works properly		Electric serviceman
c	40 h/max. 1 week	Check that the safety photocells work properly		Electrical technician
d	200 h/max. 1 month	Lubricate transmission chains		Mechanical technician
e	200 h/max. 1 month	Check chain tension		Mechanical technician
f	500 h/max 1 month	Grease UCF supports		Mechanical technician
g	500 h/max 1 month	Check oil level of hydraulic unit	See relative manual	Mechanical technician
h	1000 h/max. 6 months	Check the oil level in the reducers (excluding those lubricated for life)		Mechanical technician
i	1000 h/max. 6 months	Check chains for correct tension and wear		Mechanical technician
l	2000 h/max. 1 year	Check the condition of gear wheels		Mechanical technician
m	2000 h/max. 1 year	Check that all bolts are properly tightened	Not shown	Mechanical technician
n	2000 h/max. 1 year	Check the condition of all electric components	Not shown	Electric technician
o	2000 h/max. 1 year	Check the condition all hydraulic components	Not shown	Mechanical serviceman

Table 1 : Maintenance activities layout