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Title

**Automation of the Brick Forming Section in
the SPMC Unit Using Siemens PLC**

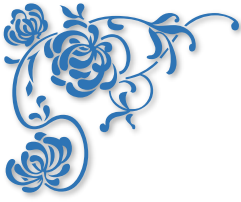
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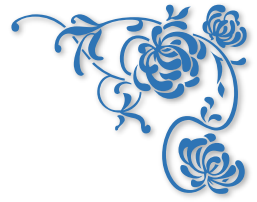
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Dedication

To our beloved parents,

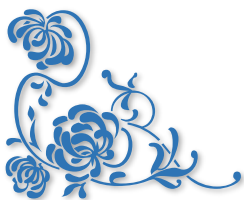
***Who supported us with unconditional love, endless patience, and
unwavering faith throughout every step of this journey.***

***To our families, whose prayers and encouragement lit our path
during moments of doubt and fatigue.***

***To our teachers and mentors, who planted in us the seeds of
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efforts but also the reflection of your support in our lives.***



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List of Abbreviations

SPMC	Société de Production de Matériaux de Construction
AC	Alternative Current
Ai	Analog Input
Ao	Analog Output
CPU	Central Processor Unit
DB	Data Block
DC	Direct Current
DCV	Directional Control Valve
Di	Digital Input
Do	Digital Output
FB	Functional Bloc
HMI	Human Machine Interface
I/O	Input and Output
LD	Ladder Diagram
OB	Organization Bloc
PLC	Programmable Logic Controller
PS	Power Supply
SFC	Sequential Function Chart
VFD	Variable Frequency Drive

General Introduction

General Introduction

After gaining independence in 1962, Algeria focused on developing its own economy by having the government take the lead in building and managing its own industries, this approach aimed to develop local industries and reduce the reliance on foreign imports, and gaining an economic independency. Between 1970 and 1980 period, Algeria went through the creation of heavy industries to fulfil the national market demands, such as crude oil, steel, food, chemicals, and most importantly construction materials like bricks and concrete blocks. This period contributed to shape the self-reliant country Algeria has become today.

Bricks are still the most widely used construction material in Algeria, despite the growing popularity of newer materials like concrete blocks, plasterboard, and wood. Red bricks still the go-to choice for Algerian people, due to the availability of the raw material, the low manufacturing cost, and to its ability to withstand Algeria's shifting weather conditions and the extreme heat throughout the year. All these factors make bricks a practical and affordable option to the consumers.

Touggourt hosts numerous manufacturing units producing various goods such as glass, tiles, and mostly construction bricks. Thanks to the rich presence of the raw clay, Touggourt became the national leader in brick production. In 2018 a staggering 1.6 million tons of bricks were produced in the Wilaya of Touggourt. [1] This production involves more than ten brick manufactory located in the communes of Touggourt, Blidet-amor, and Témachine. our internship took a place in SPMC association specialized in the manufacture of construction bricks, created in 1994. SPMC stands for (Société de Production de Matériaux de Construction) in Frensh.

At the SPMC unit, the brick production process goes through several sections to transform the raw materials into a usable construction brick. It starts with the preparation section where the raw clay is prepared for the next line of production, followed by the forming section, which is the most important as it determines the quality and durability of the final product. The section after this is the cooking section where the wet brick is dried and then fired. Each section plays

a critical role in the production, but the forming section is particularly critical for ensuring the product perfection. While entire the production line is controlled using modern **Programmable Logic Controller (PLC)** system for efficiency and precision, the forming section still operates with the older and legacy relay logic control system.

The problem with this approach is the limitations of relay logic control, limitations such as, difficulty in troubleshooting, complex wiring, and limited flexibility for modifications. It also offers limited functionality compared to a modern control system. For these reasons, we propose to replace the relay logic control system on this section to a PLC. In this thesis, we will go through four chapters in order to implement the replacement

- The first chapter representing the SPMC production line and its section
- The second chapter going through each equipment and instruments of the forming section.
- The third chapter planning of a station automation solution.
- The fourth chapter testing and observing the results in different scenarios.

Then, we will end with a general conclusion.

Chapter I

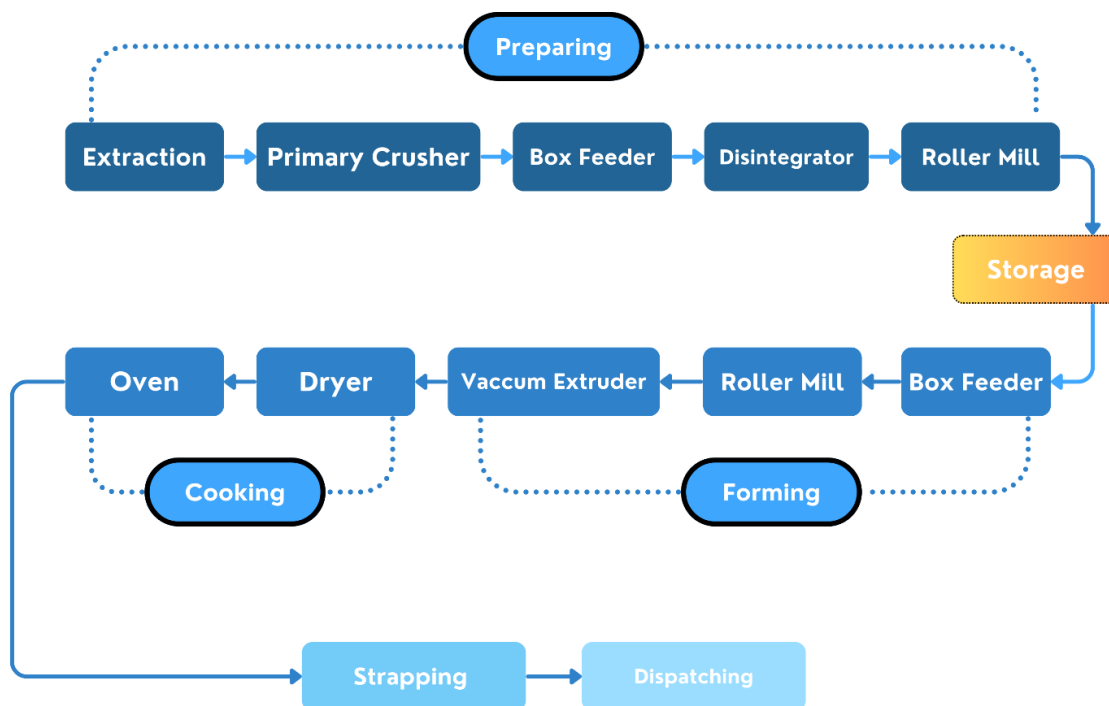
Overview of the SPMC Industrial Plant

I.1 Introduction

In this chapter, we will explore the entire production line at the SPMC manufactory, from the extraction of raw materials to the end result of a ready to use bricks, detailing each section and the functionality of every piece of equipment involved. While the entire process controlled and automated by a PLC, the forming section still operates using relay logic control system, we will end the chapter with highlighting the limitation and disadvantages of this control system after presenting the production process.

I.2 Presentation of the different areas of the factory

The brick manufacturing process from raw clay to a ready to use bricks goes through several successive sections which are sorted as follows:



I. Figure 1: BFD of the SBMC manufactory.

I.2.1 The Preparation section

Clay extraction:

Clay is one of the most common natural materials on Earth. For brick manufacturing, the clay must be plastic enough to be shaped or molded when mixed with water, must have enough wet and air-dried strength to maintain its shape after forming. Also, when heated to an appropriate temperature, the clay particles must be able to fuse together to form a solid brick. [2]



I. Figure 2: Extraction Field.

Primary Crusher:

This machine designed and manufactured to reduce the size of clay or similar material, equipped an upper shaft with blades pre-crush the big blocks of raw material, then the clay gets transferred to the other two shafts located below the first shaft, equipped with smaller blades that crush the material into more smaller pieces. With these three shafts combined the machine reduce the size of raw clay to below the 80mm. [3]



I. Figure 3: Primary Crusher.

Box feeder of the preparation section:

Box Feeder is a feeding unit composed of a hopper and a moving conveyor, designed for dry or wet use. The box feeder of the preparation process is charged from the primary crusher and feeds the crusher raw clay to the disintegrator.



I. Figure 4: Box Feeder of the preparation section.

Disintegrator:

This machine is designed for the grinding of dry clay, allowing an input of 40mm to 80 mm, in order to convert it into 5 to 20 mm. Disintegrator operate using two cylinders that rotate in opposite directions in order to crush the material. The large, smooth cylinder rotates slowly, while the other cylinder smaller in diameter equipped with blades, rotates rapidly. [4]



I. Figure 5: Disintegrator.

Roller Mill of the preparation section:

The roller mill designed to reduce the size of clay by pressure and friction through two rollers with differential speeds. The material is fed into the machine by load balancer on top of conveyor belt that feeds the machine, which causes it to fall across its width of the cylinders. The differential speed of the rollers creates friction between the clay, which is rolled at a specific separation and pressure, with the clay exiting from the lower part.



I. Figure 6: Roller Mill of the Preparation section.

Double Shaft Mixer:

The Double Shaft Mixer is the last step of the preparation before the clay arrives to the storage, the machinery mixes the clay with water using mixing blades, while pushing the clay forward. performing a very intense and efficient mixing action. Hydrated clay is an essential for the storage and the roller mill in the forming section.



I. Figure 7: Double Shaft Mixer.

Storage:

From the mixer the clay goes through Transporter to reach the storage area.



I. Figure 8: Transporter.



I. Figure 9: Storage Area.

I.2.2 The Forming Section**Box feeder of the forming section:**

Box Feeder of the forming section is similar to the box feeder of the preparation section, this box feeder is manually charged via a wheel loader truck from the storage. Inside the Box feeder there are these blades, designed to evenly and slowly feed the clay onto the conveyor belt.



I. Figure 10: Box Feeder of the forming section.

Roller Mill of the forming section (Pelerin 6R11 SH):

Similar to the roller mill used in the preparation section, in the forming section the clay is milled and grinded in thinner size between 1 mm and 5 mm.



I. Figure 11: Roller Mill of the forming section.

Vacuum Extruder (Verdés 069-RB):

This equipment designed for mixing and then extruding various types of materials including clay. The material enters the rear part of the mixer and the necessary amount of water is added to stretch the material with the appropriate humidity. The mixed clay and water make their ways to enter a vacuum chamber where it gets deaerated. It is then directed by the pressure of the auger and finally to the outlet mouth, where the die gives it the desired shape of our choosing. [5]

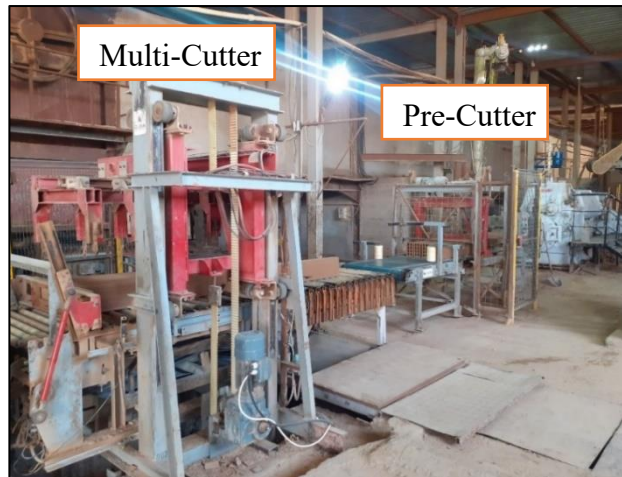


I. Figure 12: Vacuum Extruder.

I.2.3 Cooking Section

Pre-cutter and Multi-cutter:

The pre-cutter cut the extruded bricks to a one large piece, and the multi-cutter cut the large piece into 3 smaller pieces. Underneath the cutters, there are conveyors belts that leads the excess clay from the cutters back to vacuum extruder and avoiding any waste.



I. Figure 13: Pre-cutter and multi-cutter.

Rapid Dryer:

The freshly molded bricks are highly humid. Before being fired, must lose a large portion of its water. Drying continues until the bricks lose about 96% to 98% of the water. Without drying it, the expansion of water vapor inside the brick risk causing the brick to burst or cracks. Placed on moving trays inside a two-level dryer where hot air from gas burners circulates. After about 4 hours, [6] the bricks exit with less than 3% humidity, ready for firing.



I. Figure 14: Dryer.

Stacking Robot - Fanuc M410ib 700:

After exiting the dryer, the dried bricks pass through a stacking robot, stacking the bricks onto a wagon to proceed to the firing process.



I. Figure 16: Stacking Robot.



I. Figure 15: Wagons.

Oven:

The oven is divided into three zones, the first zone is the preheating zone, the bricks are gradually brought up to temperature. This heating is achieved by reusing the hot air coming from the firing zone. This eliminates any residual moisture from the bricks. Past pre-heating, the central zone of the oven is a firing zone, burners that operate continuously, raising the temperature to reach 800 to 850°C which is necessary to make clay particles fuse together. After the temperature has peaked, the bricks pass into the cooling zone, which brings the temperature gradually and slowly back down toward ambient temperature in a controlled way preventing a thermal shock. Cold ambient air is drawn in at the oven exit, the cooling process is around 8 to 10 hours long.



I. Figure 17: Oven.

Robot - Fanuc M410ib 700:

After the wagon exit the oven with you cooked bricks, it heads to two robots. One to remove the bricks from the wagon into a roller conveyor, and the second robot to stack the brick top of each other for the strapping machine



I. Figure 18: Robot Unloading the bricks off the wagon.



I. Figure 19: Stacking Robot for the strapping machine.

Messersi' Strapping machine:

After the bricks are stacked by the stacking robot, a roller conveyor leads the bricks into a strapping station equipped with a horizontal and a vertical strapping machine ensures that the bricks are securely bound, the dual-directional strapping make it possible for the forklift to lift or move the stack.



I. Figure 20: Strapping machine.

I.3 The Problem and The Goal

At the SBMC unit, the forming section of the brick manufacturing is still running on the legacy Relay Logic Control system dates back to the 90s. While it's been reliable over the years, while this system has served for the decades. it presents a numerous challenges today, from limited flexibility, difficulty in troubleshooting, inefficiency to the increase maintenance costs.

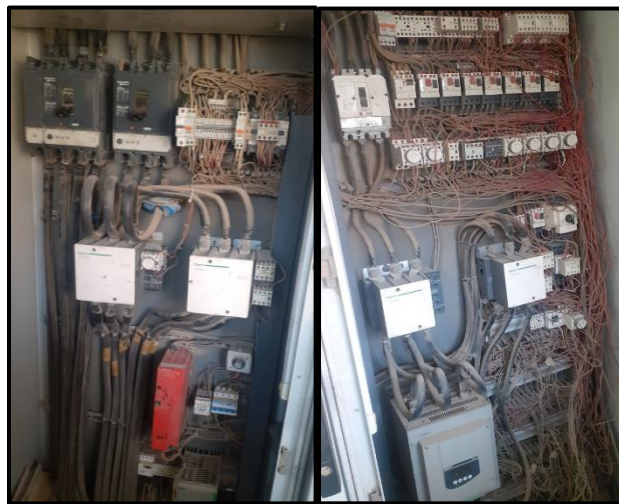
The goal of this research is to modernize or update the outdated relay logic system setup with a modern future proof controller which is the PLC "Programmable Logic Controller".

PLC are much more adaptable, easier to troubleshoot, and designed for today's industrial demands and standards. By switching to a PLC controller, we aim to make the Forming Section more efficient, easier to maintain, troubleshoot and futureproof for any upgrades we see fit, and assisting the SBMC unit to keep pace with modern manufacturing standards and improve overall productivity.

I.3.1 Relay Logic control

Relay Logic is a wire-based control system that function using timers, switches, contactors and relays. The relay logic control works efficiently to perform basic on/off operations process by opening or closing the relay contacts but it involves a humongous number wiring. [7]

At one time, relay logic was a cutting-edge development for industrial automation. Today, it is generally considered a legacy system, and its implementation is associated with challenges.



I. Figure 21: Relay Logic control system.

I.3.2 The different between PLC and Relay Logic Control [7]

Table 1: Different between PLC and Relay Logic Control system.

	PLC	Relay logic
Control Method	Microprocessor execute programmed instructions for controlling processes.	Electromechanical relays to open or close circuits based on electrical inputs.
Programming	Programmable using languages like Ladder Logic (LD), Function Block Diagram (FBD) and more...	Not programmable. Control established through physical wiring of relays
Flexibility	Modifying the software without altering hardware	Modifying control necessitates physical rewiring, which can be time-consuming and costly
Scalability	Simply by adding I/O modules or expanding the program to accommodate more inputs/outputs.	Challenging due to complexity and wiring requirements.
Space Requirements	More space friendly.	Take more space due to physical parts and wiring.
Maintenance	Simplified maintenance with diagnostic tools and software and easy to troubleshooting due to the HMI assisting.	manual maintenance and fault detection can be labor intensive and time-consuming.
Cost	Higher cost but cost-effective in the long run.	Lower cost but expensive overtime due maintenance and scalability limitations
Reliability	High reliability with fewer moving parts (less prone to mechanical failure).	Relays and contactors are mechanical components are more likely to fail.
Advanced Functions	Capable of complex operations like timers, counters or analog processing...	Limited to basic on/off processes

I.4 Conclusion

In this first chapter, we presented the SPMC manufactory, reviewed the process of manufacturing construction bricks, going through every section and outline the functionality of every machine of the production line. Introduced the challenge and disadvantages of using relay logic control system in the forming section. This foundation will allow us to introduce the forming section in a detailed view in the next chapter.

Chapter II

Equipment and Instruments Used in the Forming Section

II.1 Introduction

in the first chapter we went through the entire SPMC manufactory, and addressed the problems of using relay logic control in the forming process, and the plan to upgrade it with a PLC. Before implementing an automatic solution, we need to understand the equipment and instruments present on the forming section and their role. This will allow us to compile a table summarizing all the sensors and the actuators on the field.

II.2 Equipment

II.2.1 Box Feeder

This the first machine used as a feeding unit at the forming line, designed to control a continuous dosing for certain material, also can be used as a storage unit. Box feeder has two type, slat box feeders for handling wet material while rubber belt box feeders similar to this one are more suitable for dry and dusty material.

- Weight: ≈ 5000 kg
- Height: 2750 mm
- Length: 6800 mm
- Width: 2500 mm
- Motor power: 4 kw



II. Figure 22: Box Feeder.

II.2.2 Roller mill (Pelerin 6R11 SH)

This machine grinds the clay between two rollers to homogenize and obtain a compact structure. The fineness of the grinding ranges from 1 mm to 3mm which mill and compress the clay into small pieces. Roller mill makes the clay more absorbable to water, and facilitate the extrusion. [8]

Roller mill is also fitted with **scrapers blades** underneath each cylinder a powered by pneumatic air cylinder, the scrapers are for cleaning the cylinders from any clay stuck in them. And a **load balancer** located above the clay entrance of the roller mill, designed to evenly distribute clay all over the cylinder's length, preventing tears from the friction in the cylinders in a single spot.



II. Figure 23: Roller Mill.

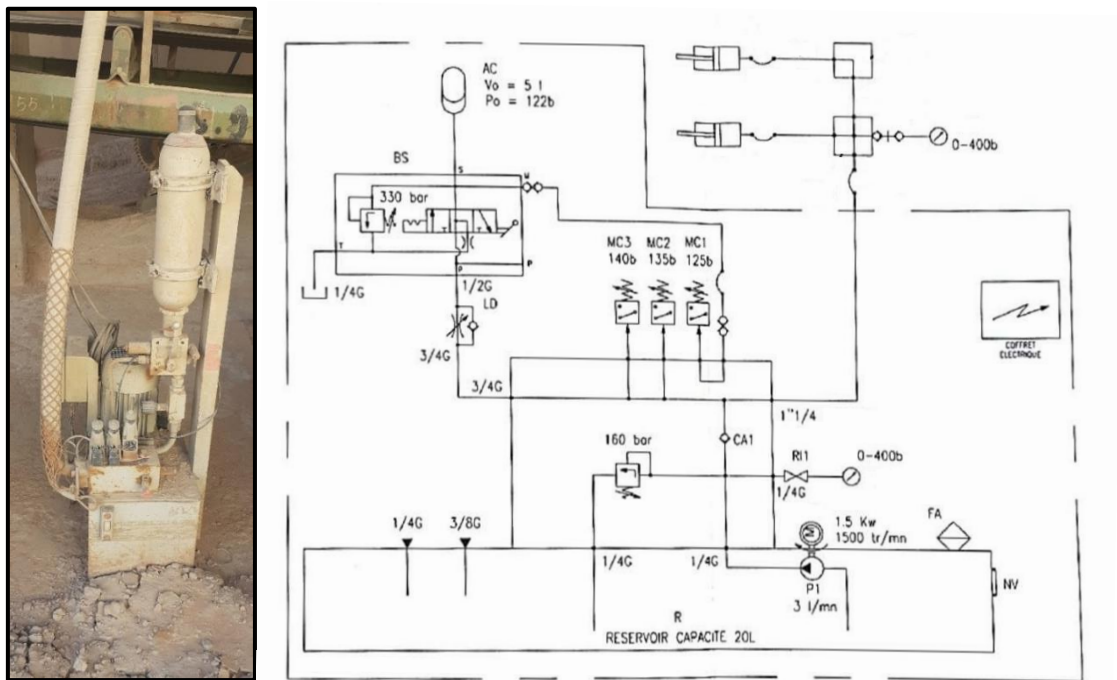
Technical Characteristics: [8]

- | | |
|---|--------------|
| • Diameter and width of cylinders: | 1100/1100 mm |
| • Diameter of the pulleys: | 1800 mm |
| Drive pulleys diameter for the High-speed cylinder: | 300 mm |
| Drive pulleys diameter for the Low-speed cylinder: | 236 mm |
| • Speed of the cylinders: | |
| motor installed on the high-speed cylinder: | 1500 rpm |
| speed of the high-speed cylinder: | 250 rpm |
| motor installed on the low-speed cylinder | 1500 rpm |
| speed of the low-speed cylinder | 197 rpm |
| • Pulleys' weight | 2120 kg |
| • Total weight | 17420 kg |

Hydraulic Power Unit:

The two cylinders runs in a different speed, one slow and fixed in place, and the other one at a higher speed, the different in speed provides a better friction to slice and mill the clay and rather than merely compressing it. For the safety of the machine the high-speed cylinder is equipped two hydraulic cylinders powered by a hydraulic power unit to ensures the protection of the cylinders in case of any oversized clay, rock or any foreign objects that have gone through the cylinders. The accidental passage of a hard large object between the two cylinders “maximum 30 mm” discharges the oil from the cylinders to the accumulator, then restores pressure to the cylinders and returns the cylinder to its initial position.

The hydraulic centrale function or controlled by three built in pressure switches, first one set at 125 Bar triggers a pressure drop alert, the second 135 Bar switch starts the motor of the hydraulic unit to raise the pressure to 140 Bar where the third switch is calibrated to, and this stops the motor.



II. Figure 24: Hydraulic Power Unit of the Roller Mill.

II.2.3 Vacuum Extruder (Verdés 069-RB)

This is the last machine of brick forming to shape the raw material as a usable outcome for the next stage of the production. The machine is composed of two main parts, the mixer and the screw type auger. The upper and the first part is the mixer, allows us to mix the clay one last time with water, then transfer the clay to perfectly sealed vacuum chamber located between the mixer and the auger area which ensure the removing the of air from the clay resulting in improved density and strength of the extruded clay. After, it passes from the vacuum chamber and enters the auger area where the pressure of the auger conveys and compresses the clay along the mold of our choosing.



II. Figure 25: Vacuum Extruder.

Technical Characteristics: [5]

- Technical dimensions

Diameter of the plodder propellers	500 / 550 / 600 mm
Width and Length of the mixer	990 / 2550 mm
Diameter of the mixer propellers	550 mm
Diameter and width of the machine pulley	980 x 264 mm
External diameter of the machine pulley	280 / 315 / 400 mm
- Machine speed:

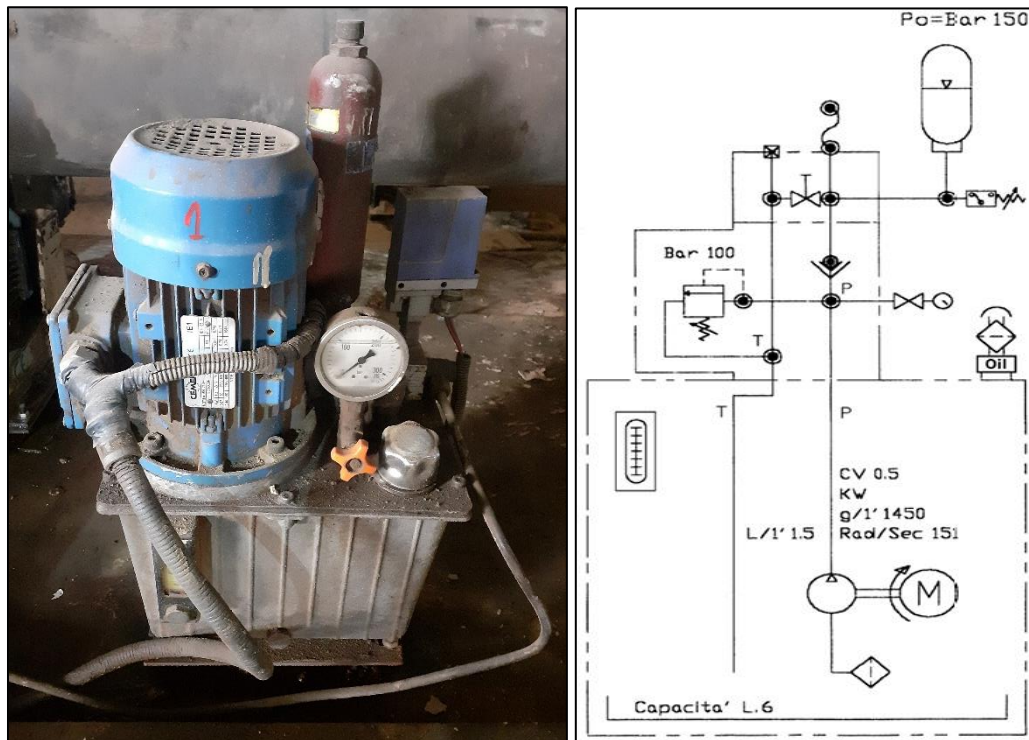
Machine pulley:	slow	414 rpm
	normal	467 rpm
	fast	597 rpm

- | | | |
|------------------|--------|--------|
| Propeller shaft: | slow | 18 rpm |
| | normal | 20 rpm |
| | fast | 26 rpm |
- Machine dimensions:

length	6783 mm
width	2425 mm
height	1870 mm
 - Weight: 18000kg

Hydraulic power unit:

During extrusion process, the machine undergoes a high level of stress. This is where the safety device plays a crucial role to prevent axial load from being applied to the propeller shaft axial bearing. This mechanism consists of a hydraulic cylinder on which the axial bearing rests. The load in the hydraulic circuit is converted into pressure, the value of which can be read on the contact pressure gauge. Free of any load the hydraulic circuit must be at a pressure of 50 Bar. We must set the pressure switch at 60 Bar maximum and 40 Bar minimum, and 165 Bar the maximum pressure of the contact pressure gauges installed on the machine. [5]



II. Figure 26: Hydraulic Power Unit of the vacuum extruder.

Diesel lubrication:

A hydraulic unit for auger area lubrication, designed to prevent material from adhering to the propeller area where clay enters. It operates by injecting diesel fuel, which helps minimize the risk of clay drying, sticking, and later detaching, dried clay can cause tears, cuts and defects in the extruded clay. The unit operates on a timed cycle, remaining “ON” for 10 seconds, “OFF” for 20 seconds. and can be changed as the operator see fit.



II. Figure 27: Diesel pump and injector.

Oil Lubrication:

In the vacuum extruder comes with an oil lubrication pump to oil the moving parts to reduce friction, preventing overheating, and extend the gearbox's lifespan of the vacuum extruder to ensure smooth power transmission.



II. Figure 28: Oil Lubrication Pump.

Two-Stage Liquid Ring Vacuum Pump:

A two-stage liquid ring vacuum pump is designed to create deep vacuum levels, making it essential for industrial processes that require the removing of air or gases. For the vacuum extruder, the ideal pressure for the vacuum chamber in the vacuum extruder must stay in the -0.75 Bar and -0.85 Bar range.



II. Figure 29: Vacuum Pump.

II.2.4 Other Techniques and equipment**Clay Presence:**

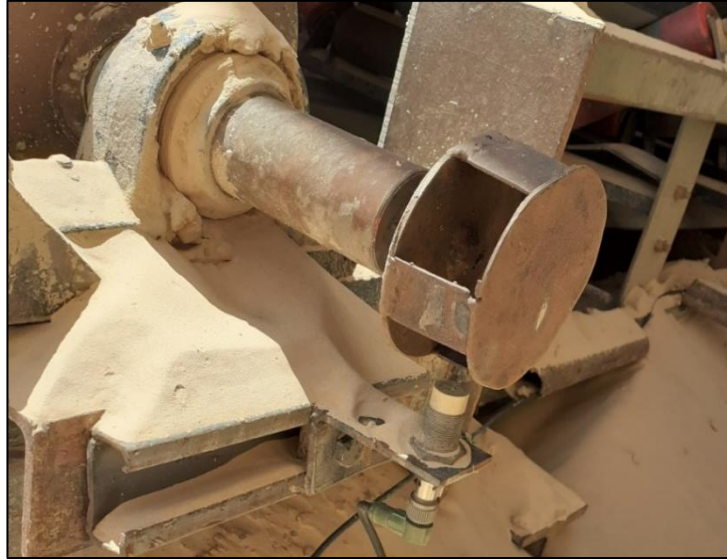
For each conveyor belt, this technique implemented, using inductive and capacitive sensors, first of all the presence of clay on each conveyor belt.



II. Figure 30: Clay Presence.

Conveyor Belt Health:

And this technique allows us to monitor the condition of the conveyor belts rubber in case of any cuts, and whether the motor of the conveyor has stopped working using a capacitive sensor.



II. Figure 31: Belts Health technique.

Conveyor Belts for leftover clay:

After the wet bricks get cut by the pre-cutter and multi-cutter, any leftover clay that falls off onto a conveyor belt beneath the cutters. From there, it goes through two more belts and is returned to the vacuum extruder, ensuring that no clay is being wasted.



II. Figure 32: Conveyor belts the leftover clay.

Division of the section: After we took a detailed view of every equipment from the forming section, we can summarize them in the next table:

Table 2: Equipment and instruments.

Equipment	Instruments
Box Feeder	One (1) motor One (1) ultrasonic sensor One (1) inductive sensor One (1) Alarm
Conveyor Belt Connection	Two (2) motors Two (2) inductive sensors Two (2) capacitive sensors Two (2) Emergency rope
Roller Mill	Two (2) motors One (1) motor load balancer One (1) limit switch One (1) DCV pneumatic scrapers One (1) pressure switch for the DCV Three (3) built-in pressure switches One (1) motor hydraulic power unit One (1) Alarm
Conveyor Belt Connection	Two (2) motors Two (2) inductive sensors Two (2) capacitive sensors Two (2) Emergency rope
Vacuum Extruder	One (1) motor One (1) motor vacuum pump One (1) pump vacuum pump oil One (1) oil cooling fan One (1) water pump One (1) DCV pneumatic One (1) motor diesel One (1) motor hydraulic power unit One (1) lubrication oil pump Two (2) motor for leftover clay One (1) pressure transmitter Five (5) pressure switch One (1) photoelectric sensor One (1) Contact pressure gauge One (1) Alarm

Now that we have categorized the equipment along with their respective instruments, we will proceed to examine the specific characteristics and functionality of each individual instrument in detail.

II.3 Instruments

Instrumentation is a field that involves the setup, calibration, and operation of all devices used for measurement, control, and action within an industrial process, and most importantly the safety of the workers and machine. Some instruments with the role to monitor the changes in the field includes sensors, detectors, and transmitters that provide measurements. And some instruments involved in the control actions like motors, pumps, fans, valves... and pre-actuators such as speed controllers, soft starters and contactors and relays

Every instrument within the forming section is Intended to operate using a 24-volt direct current (VDC) from the PLC, using relays, contactors, soft starter or variable frequency drivers (VFD) to manage the transformation of power and control the actuators on the field. 24 VDC is considered a safe voltage level for industrial applications, significantly reducing the risk of electric shock to the workers during installation or maintenance. with its compatibility across various instruments, 24vDC became an industrial standard.

II.3.1 Box Feeder

Ultrasonic Sensor (Telemcanique SC650AB00AFFP) “ADDITIONAL”:

Characteristics: [9]

- Supply Voltage: **12 - 24 VDC**
- Output signal: **Discrete**
- Current consumption: **60 mA**
- Nominal Sensing Distance: **254 mm**
- Electrical connection: Male connector M12, 4 pins
- IP degree of protection: **IP67**
- Ambient temperature for operation: **-25 - 70 °C**
- Height: **16.25 mm**
- Length: **84.32 mm**
- Width: **30 mm**
- Net weight: **70 g**



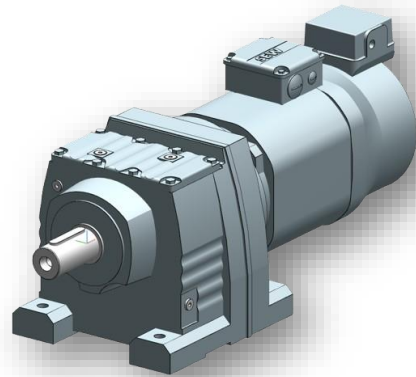
II. Figure 33: Ultrasonic sensor

Instrument role: Detect when the Box feeder is full with ultrasonic sound waves.

Gearmotor R87/DRS 112M4:

Characteristics: [10]

- Speed: 14350/39 RPM
- Ratio(i): **36.84 RPM**
- Input Voltage: 400 delta / 690 star
- Current: 8.10 A Delta / 4.70 A Star
- Frequency: **50hz**
- Output Power: **4 Kw**
- Efficiency: **83.8%**
- Power Factor: **0.84**
- Type of Duty: **S1**
- Ambient temperature for operation: **- 20...40 °C**
- IP degree of protection: **IP55**
- Weight: **94 Kg**



II. Figure 34: Gearmotor R87/DRS 112M4.

Instrument role: The main motor of the Box feeder

Inductive Proximity Sensor (Telemcanique XS7-C40PC440):

Characteristics: [11]

- Supply Voltage: **12 - 48 VDC**
- Maximum voltage drops: **< 2V**
- Current consumption: **0 - 10 mA**
- Nominal Sensing Distance: **15 mm**
- Discrete output type: PNP
- Discrete output function: **1 NO / 1 NC (Programmable)**
- IP degree of protection: **IP67**
- Ambient temperature for operation: **-25 - 70 °C**
- Height: **40 mm**
- Length: **40 mm**
- Width: **117 mm**
- Net weight: 0.22 kg



II. Figure 35: Inductive sensor.

Instrument role: Detect when the Box Feeder is empty

II.3.2 Roller Mill

Table 3: Roller mill main Motors.

Model	Dutchi DM1 280S4 Motor	JULAN YX3-250M-4 Motor
Picture		
Input Voltage	380/690 v	380 v
Current	134 A	103 A
Phases	3	3
Poles	4	4
Frequency	50-60hz	50hz
Speed	1484 rpm 50hz 1780 rpm 60hz	1480hz
Output Power	75 kw 50hz 90 kw 60hz	55 kw
Efficiency	94.4 %	93.5 %
Power Factor	0.87	0.87
Type of Duty	S1	S1
Ambient Temperature	43 °C	40 °C
IP protection	IP55	IP55
Height	958 mm	
Length	1479 mm	
Width	746 mm	
Net weight	510 kg	388 kg

Limit Switch (Telemecanique XC2-JC ZC2JC2) (fin de course) :

Characteristics: [12]

- Contacts type: 2 C/O
- Contact operation: Snap action
- Current: 10 A
- Width: 40 mm
- Height: 81 mm
- Depth: 41 mm
- IP degree of protection: IP65
- Ambient temperature: -25...70 °C

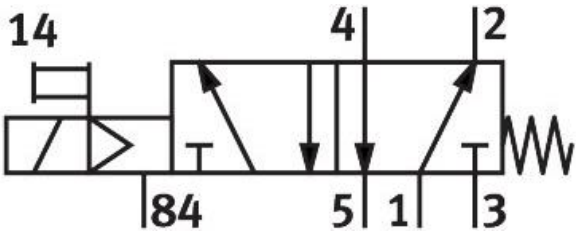
**II. Figure 36:** Limit switch.

Instrument role: Detect if the roller mill submitted to any oversized object.

Solenoid valve (FESTO MFH-5-1/4): [13]

Instrument role: Control the ascending and descending the Scrapers.

Table 4: Directional Control Valve.

DCV	Valve function	5/2 way, Monostable
	Standard nominal flow rate	1000 L/min
	Type of actuation	Electric
	pneumatic working port	G1/4
	Operating pressure	2.2 bar...8 bar
	Operating voltage Via	24 VDC Solenoid Coil
	Degree of protection	IP65
	Ambient temperature	-5 °C...40 °C
	Product weight	290 g
		

Capacitive proximity sensor (Telemecanique XT230A1FAL2):

Characteristics: [14]

- Supply voltage: **24VAC**
- Type of output signal: **Discrete**
- Wiring technique: **2-wire**
- Discrete output function: **1 NO**
- nominal sensing distance: **15mm**
- Maximum delay response: **30ms**
- Ambient temperature for operation: **-10 to 60 °C**
- IP degree of protection: **IP67**



II. Figure 37: Capacitive sensor.

Instrument role: To detect if the motors are spinning

Pressure Switch (Telemecanique XMLA010A2S11):

Characteristics: [15]

- Supply Voltage: **240 VAC**
- Rated current: **1.5A**
- Measuring Ranges: **0.6...10 bar**
- Maximum permissible accidental pressure: **22.5bar**
- Contacts type and Composition: **1 C/O**
- Destruction pressure: **45 bar**
- Controlled fluid:
 - Air (0...70 °C)
 - Water (0...70 °C)
 - Hydraulic oil (0...70 °C)
- Setting: **External**
- IP degree of protection: **IP66**
- Ambient temperature for operation: **-25 - 70 °C**
- Height: **113 mm**
- Depth: **75 mm**
- Width: **35 mm**



II. Figure 38: Pressure Switch.

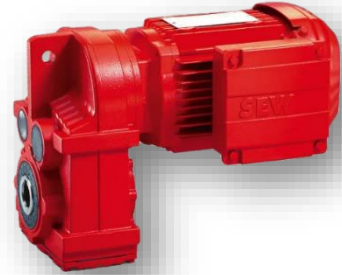
Instrument role: To detect the absence of air for the scrapers.

Gearmotor (FA67/G DRS100M4 SEW-eurodrive):

Characteristics: [16]

- Speed: 1400/56 RPM
- Ratio(i): **25.13 RPM**
- Input Voltage: 220 - 242 delta / 380 - 420 star
- Current: 11.30 A Delta / 6.50 A Star
- Frequency: **50hz**
- Output Power: **3 Kw**
- Efficiency: **82.4%**
- Power Factor: **0.82**
- Type of Duty: **S1**
- Ambient Temperature: **- 20...40 °C**
- IP degree of protection: **IP55**
- Weight: **57 Kg**

Instrument role: Motor of the laod balancer.



II. Figure 39: FA67/G DRS100M4.

II.3.3 Vacuum Extruder:**ABB M3BP 355SMB 4 Motor:**

Characteristics: [17]

- Input Voltage (U_{in}): **400/690v**
- Number of Phases: **3**
- Frequency: **50hz**
- Speed: 1488 RPM
- Output Power: **315 Kw**
- Efficiency: **95.90%**
- Current:
 - STAR connection: **690v - 318 A**
 - DELTA connection: **415v - 536 A**
 - DELTA connection: **400v - 550 A**
- Power Factor: **0.860**
- Type of Duty: **S1**
- Ambient Temperature: **40 °C**
- IP degree of protection: **IP55**
- Height: **958 mm**
- Length: **1479 mm**
- Width: **746 mm**
- Net weight: 1780 kg



II. Figure 40: Vacuum Extruder's motor.

Instrument role: The main motor of the vacuum extruder.

Dutchi DM1 160L4 Motor:

Characteristics: [18]

- Input Voltage: **380/690v**
- Frequency: **50-60hz**
- Speed: **1460 rpm 50hz**
- Output Power: **15 Kw at 50hz**
- Efficiency: **89.4%**
- Current:
 - DELTA: 400/480v ---28.6 A
 - STAR: 690v --- 16.5 A
- Power Factor: **0.84**
- Type of Duty: **S1**
- Ambient Temperature: **150 °C**
- IP degree of protection: **IP55**
- Net weight: **134 kg**



II. Figure 41: Vacuum Pump's motor.

Instrument role: The motor of the vacuum pump.

Pressure transmitter (Telemecanique XMLRM01G1P25):

II. Figure 42: Pressure transmitter.

Characteristics: [19]

- Supply Voltage: **24 VDC PNP**
- Analogue output: **4 - 20Ma**
- Type of output signal: **Analogue + discrete**
- Measuring Ranges: **-1 0 Bar**
- Maximum current: **250mA**
- Controlled fluid: **Fresh water (0...80 °C)**
 - **Air (-20...80 °C)**
 - **Hydraulic oil (-20...80 °C)**
 - **Refrigeration fluid (-20...80 °C)**

- Current consumption: < **50Ma**
- Contacts type: NO/NC programmable
- Electrical connection: Male connector M12, 4 pins
- Fluid connection: female G 1/4
- Destruction pressure: **3 Bar - 300 KPa - 43 Psi**

Instrument role: measuring vacuum chamber's pressure.

Pressure Switch (Telemcanique XMLB160D2S11):



II. Figure 43: Pressure Switch.

Characteristics: [20]

- Supply Voltage: **240 VAC**
- Rated current: **1.5A**
- range of switching point on rising pressure: **10...160 bar**
- range of switching point on falling pressure: **0.7...139.2 bar**
- Contacts type and Composition: **1 C/O**
- Maximum permissible accidental pressure: **360 bar**
- Destruction pressure: **720 bar**
- Controlled fluid: **Hydraulic oil (0...70 °C)**
- Setting: **External**
- IP degree of protection: **IP66**
- Ambient temperature for operation: **-25 - 70 °C**
- Height: **113 mm**
- Depth: **75 mm**
- Width: **35 mm**
- Weight: **0.75 kg**

Instrument role: Regulate the hydraulic pressure of the hydraulic power unit.

Pressure Switch (Telemcanique XMLA010A2S11):

Characteristics: [15]

- Supply Voltage: **240 VAC**
- Rated current: **1.5A**
- Measuring Ranges: 0.6 - 10 bar 8.7 - 145psi 60 - 1000Kpa
- Maximum permissible accidental pressure: **22.5 bar**
- Contacts type and Composition: **1 C/O**
- Destruction pressure: **45 bar**
- Controlled fluid:
 - Air (0...70 °C)
 - Water (0...70 °C)
 - Hydraulic oil (0...70 °C)
- Setting: **External**
- IP degree of protection: **IP66**
- Ambient temperature for operation: **-25 - 70 °C**
- Height: **113 mm**
- Depth: **75 mm**
- Width: **35 mm**

Instrument role: 2x Detect the absence of lubrication oil and pneumatic valve.

Pressure Switch (Telemcanique XMLA004A2S11):

Characteristics: [21]

- Supply voltage: **240 VAC**
- Rated current: **1.5A**
- Measuring ranges for stopping: **0.7 - 10 bar**
- Measuring ranges for starting: **7.5 - 0.57 bar**
- Maximum permissible accidental pressure: **22.5 bar**
- Contacts type and Composition: **1 C/O**
- Destruction pressure: **45 bar**
- Controlled fluid:
 - Air (0...70 °C)
 - Water (0...70 °C)
 - Hydraulic oil (0...70 °C)
- Setting: **External**
- IP degree of protection: **IP66**
- Ambient temperature for operation: **-25 - 70 °C**

Instrument role: 2x Detect the absence of water and diesel.

Photoelectric sensor (GSE10 P4211 SICK):**II. Figure 44:** Photoelectric sensor.

Characteristics: [22]

- Supply voltage: **10 to 30 VDC**
- Sensing range: **40m**
- Light type: **Red Light**
- Discrete output type: **PNP**
- IP degree of protection: **IP66**
- Width: **20mm**
- Height: **50mm**
- Length: **39mm**

Instrument role: Detecting no bricks are being extruded from the vacuum extruder.

Emergency rope and button:

Characteristics: [23]

- Supply voltage: **24vDC**
- Rated current: **2A**
- Enclosure protection: **IP66**
- Ambient temperature range: **-25...70°C**
- Weight: **0.6 kg**
- Rope length: **75m**

Instrument role: Emergency stop rope and button on every conveyor belt

**II. Figure 45:** Pull rope emergency.

Sensors, Transmitters and Actuators:

Sensors are detection devices that respond to physical changes in environments, converting these changes into measurable signals to the controller (PLC). Monitoring changes such as temperature, pressure or proximity. Providing real time data to the controller to implement decisions from the received information the actuators. In the other hand, **Transmitter** is an analog device that converts physical measurements from the sensor, such as pressure, temperature or flow into readable output signals to the controller (PLC) like 4...20 mA or 0...20 mA current or 1...5 V voltage. These signals are then sent to control systems. **Actuator** is a device that initiates movement in a mechanical machinery

Sensors and Transmitters present in the field:

- ✓ One (1) Pressure transmitter for the vacuum extruder signal type (4...20mA).
- ✓ One (1) Digital ultrasonic sensor indicates, Box feeder is full *ADDITIONAL*.
- ✓ Five (5) Inductive sensors for clay presence.
- ✓ Four (4) Capacitive sensors detect the rotation of the belts
- ✓ One (1) limit switch for roller mill oversized object detecting.
- ✓ Two (2) Pressure switch for air absence for water and scrapes DCV.
- ✓ Three (3) Pressure switch for diesel / oil / water absence for the vacuum extruder.
- ✓ One (1) Pressure switch for the vacuum extruders hydraulic power unit.
- ✓ Three (3) Pressure switch for the roller mill hydraulic power unit.
- ✓ One (1) Photoelectric Sensor for the presence of the formed Clay

Actuators present in the field:

- ✓ One (1) motor for the vacuum extruder
- ✓ Two (2) motors for the Roller mill
- ✓ One (1) motor for the Box feeder
- ✓ Six (6) motors for belt conveyors
- ✓ One (1) motor for the load balancer
- ✓ One (1) motor for vacuum pump
- ✓ One (1) pump for vacuum pump oil
- ✓ One (1) fan for oil coolant
- ✓ One (1) motor for vacuum extruder's hydraulic power unit
- ✓ One (1) motor for roller mill's hydraulic power unit
- ✓ One (1) motor for the diesel injector
- ✓ One (1) pump for water
- ✓ One (1) pump for oil
- ✓ Two (2) pneumatic DCV for water valve and scrapers

One (1) Photoelectric Sensor for the presence of the formed Clay

We can summarize the number and type of the input and outputs in this table:

Table 5: Number and Type of instruments.

Discrete Inputs (0...24 vdc)	Discrete Outputs (0...24 vdc)	Analog Inputs (4...20 mA)	Analog Outputs
- Twelve (12) sensors - Nine (9) pressure switch - One (1) Limit switch - Four (4) emergency rope	- Fifteen (15) motors - Three (3) pumps - Two (2) DCV - One (1) cooling fan - Three (3) alarms	- One pressure transmitter (1)	//

II.4 Conclusion

In this chapter, we examined the three main equipment and all the instruments involved in the forming process, explored their functionality, characteristics and role on the section. At the end we categorized the sensors and actuators as inputs and outputs based on their type and signal, which is a crucial step toward implementing an automated solution.

Chapter III

Automation

III.1 Introduction

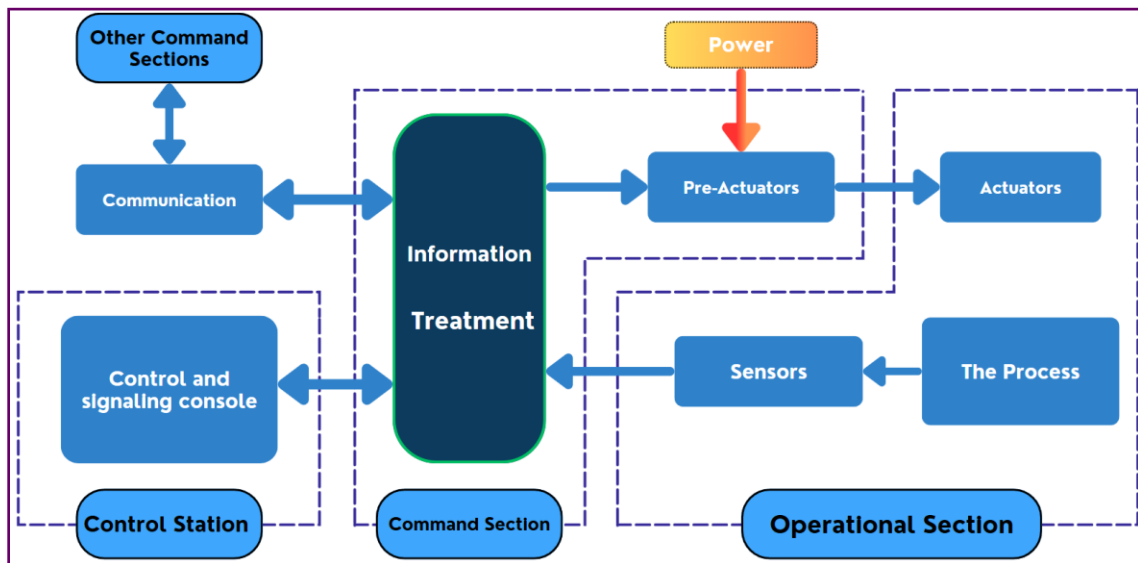
After extracting an instrument table in the last chapter, we'll move on step-by-step on designing the automatic solution for the forming section, the solution will be conducted in two parts, hardware side where we select the appropriate PLC hardware such as the CPU, power supply and the types and number of I/O modules, with the human machine interface and network. following that, the software side to configure the hardware we choose into the software and address and define the input and output variables, along with selecting the programming language.

III.2 Automation

Automation carry's out operations automatically without the need of human involvement. Assisting, or completely taking over with repetitive and physically demanding tasks, especially where accuracy and consistency are essential.

III.2.1 Structure of the automated system

Every automated system consists of a Command section and an Operational section, the two-section exchange information from and to field devices to accumulate the manufacturing process we need.



III. Figure 46: Structure of the automated system.

Control section

Includes the components intended to process the information (signals) delivered from the sensors and transmitters, Pushbuttons, Switches etc... and treats the information and the system takes action at the expense of the received data.

Operational section

Includes the actuators and sensors required to control actuator movement and actions, translating control command from control section into the field.

III.3 Hardware side

A Programmable Logic Controller (PLC) is a digital industrial computer specifically designed to automate various industrial processes. Used across all industrial applications, it functions as the central component of the control section within an automated system. Communicate with other PLC's and all field devices for input to outputs. A PLC with usable CPU speed and memory than can handle the complexity of the program, scan times, and data storage. and most importantly, ensure the supports of the necessary communication protocols we need like Ethernet/IP, Modbus or Profibus.

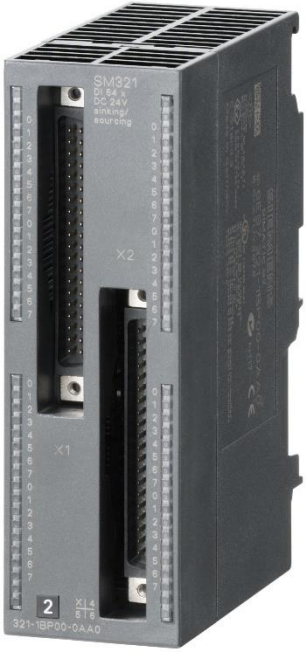
III.3.1 PLC Choice

We selected the SIMATIC S7-300 industrial programmable logic controller because of its capability to handle a large number of inputs and outputs, Discrete or Analog while executing and receiving instructions at high speed.

The S7-300 system consists of a Power Supply module, a Central Processing Unit and inputs and outputs modules. It can be expanded and connect to other PLCs in the same industrial facility.

For the input and output modules regarding voltage, current, number of channels and respond time, most importantly to choose between sourcing or sinking modules that is compatible with our instruments on the field

Table 6: The components of our PLC.

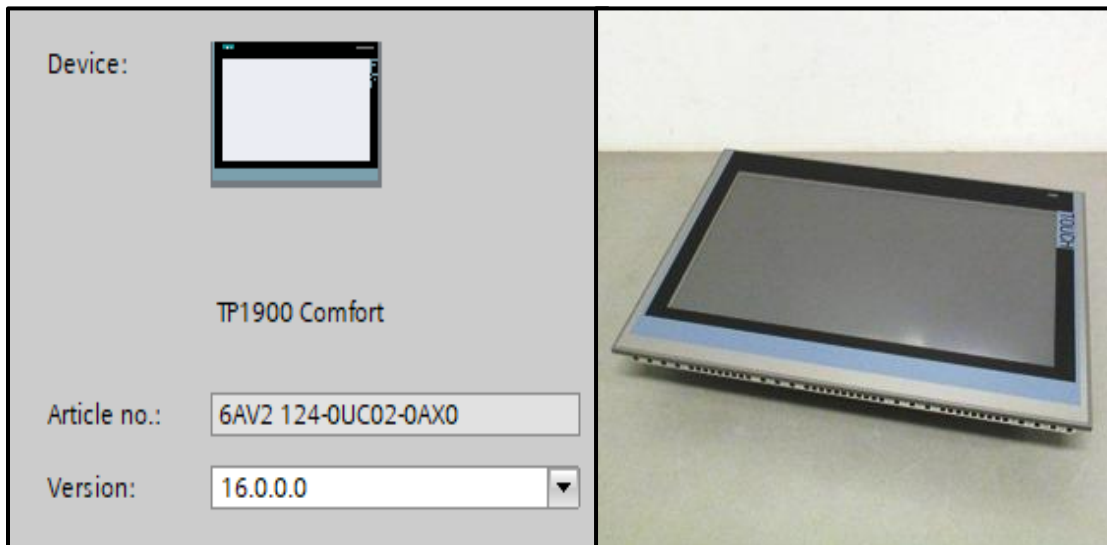
Designation	Central Processing Unit	
Model	CPU 315-2 PN/DP	
Reference number	6ES7 315-2EH14-0AB0	
Description	- Work memory 384KB - 1000 instructions in 0.05ms - PROFINET interface - PROFINET IO controller; - 2 ports TCP/IP transport protocol - MPI/DP interface (MPI or DP master or DP slave) - multi-tier configuration up to 32 modules - Current consumption = 0.75A	
Designation	Digital Input Module	
Model	DI 64x24VDC Sinking/Sourcing	
Reference	6ES7 321-1BP00-0AA0	
Description	- module TOR DI64 x DC24V - 32 channel sourcing - 32 channel sinking - Input Voltage: 24 V DC - Signal Delay: 3ms - Current consumption = 0.29A	

Designation	Digital Output Module	
Model	DO 32x24v DC/0.5A	
Reference number	6ES7 322-1BL00-0AA0	
Description	- 32 DO - 24v DC/0.5A - Front Connector 40-pin - Short Circuit Protection - Output Delay 0 to 1 100µs - Output Delay 1 to 0 500µs - Current consumption = 0.16A	
Designation	Analog Input Module	
Model	AI 8x16BIT	
Reference	6ES7 331-7NF00-0AB0	
Description	8 AI 16BIT - Measurement Type and Range: Current (4-wire transducer) 0...20mA, 4...20mA, or -/+20mA Voltage 1...5v, -/+ 5v and -/+10v - Front Connector 40-pin -Current consumption = 0.025A	

Designation	Power Supply Module	
Model	PS 307 5A	
Reference number	6ES7 307-1BA01-0AA0	
Description	External power supply Input: 230VAC Output: 24v DC/2A $0.75\text{ A} + 0.29\text{ A} + 0.16\text{ A} + 0.025\text{ A}$ $= 1.25\text{ A}$	

III.3.2 Human-Machine Interface

Human-Machine Interface (HMI) is a user-friendly system that enabled the users to interact and connect with the process. We use the TP1900 Comfort, stands for 19-inch Touch Panel enough for our application in this thesis.



III. Figure 47: HMI choice.

III.3.3 Communication Network

Industrial communication is a key component of automation technologies. For two devices to exchange data effectively, they must have the same communication protocol. For the communication between the PLC and the HMI, we'll use the PROFINET protocol since they both support it. PROFINET is an Industrial Ethernet standard for real-time communication between controllers and field devices in an automation system. for a reliable, efficient, high-speed data exchange in almost every industrial environment.

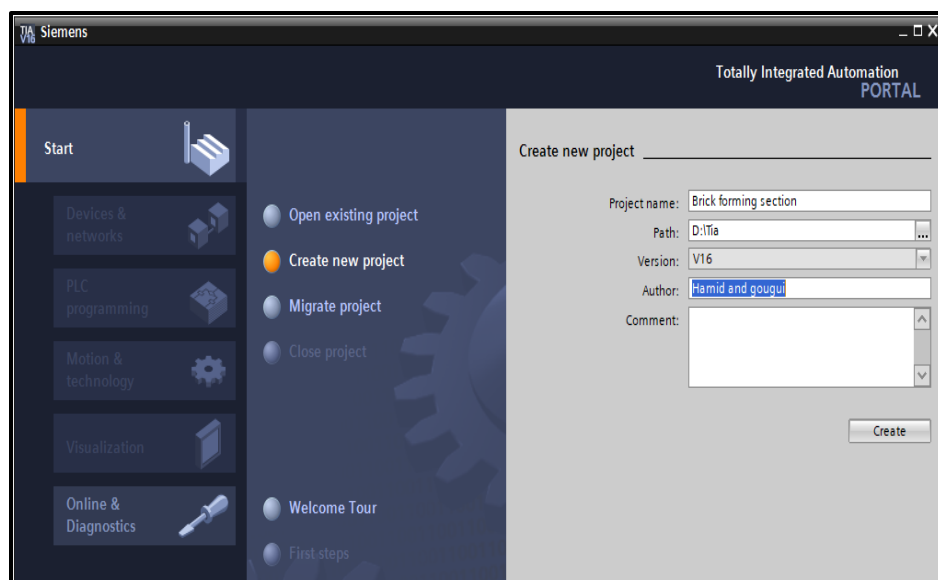
III.4 Software side

For the software side, we will use TIA portal V16 from Siemens which is an integrated software platform to configure and program automation devices like PLCs and HMIs. First of all, we'll create a project and name it, then configure our hardware into TIA portal and define our variable representing the instruments of the section, to then insert our program and configure the HMI.

III.4.1 Creating a Project

As soon as we open TIA PORTAL V16 we are greeted with this window.

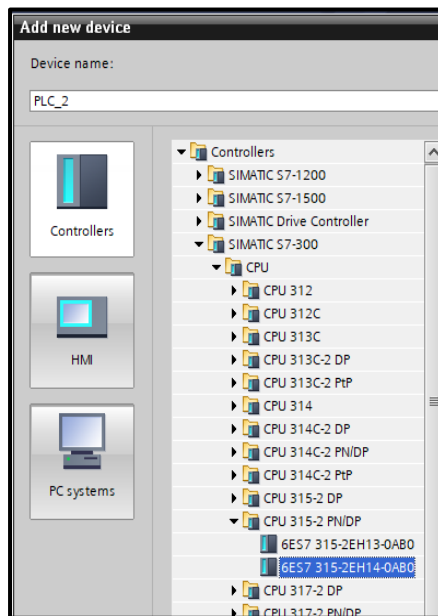
- “Create new project” to create fresh new project.
- We name it in the “Project name”
- choose the disk “Path”
- The “Author” and “Comment” are optional, then we click “Create”
- Then we click “open the project view” on the next page



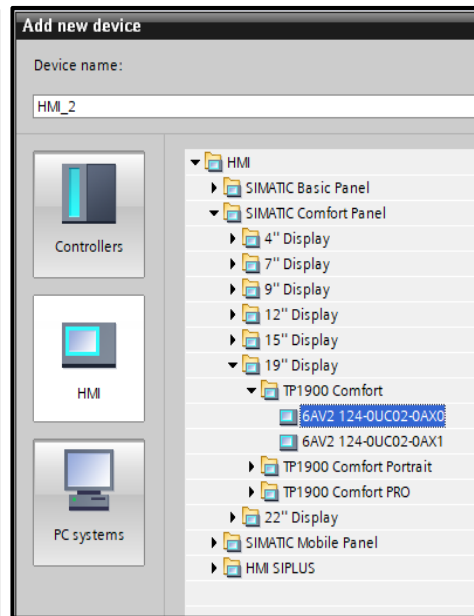
III. Figure 48: Creating a project.

III.4.2 Hardware configuration

Select the PLC and HMI we going to use in the automation



III. Figure 50: Choosing a CPU.

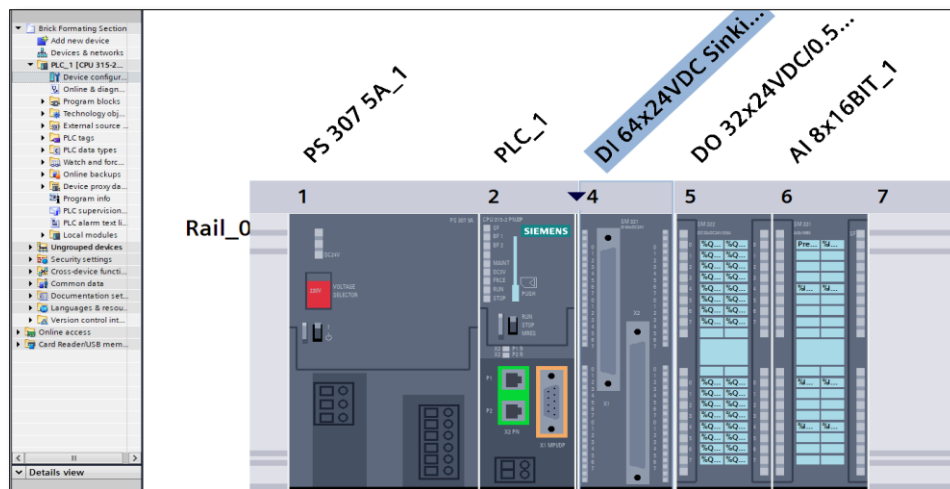


III. Figure 49: Choosing an HMI.

III.4.2.1 PLC configuration:

The Hardware components we choose is the SIEMENS PLC S7-300:

- ✓ Power supply: PS 307 5A_1
- ✓ CPU: PLC_1: 315-2 PN/DP
- ✓ Digital Input module: DI 64x24VDC: Sinking/Sourcing_1
- ✓ Digital Output module: DO 32x24VDC/0.5A_1
- ✓ Analog Input module: AI 8x16BIT_1



III. Figure 51: Hardware components.

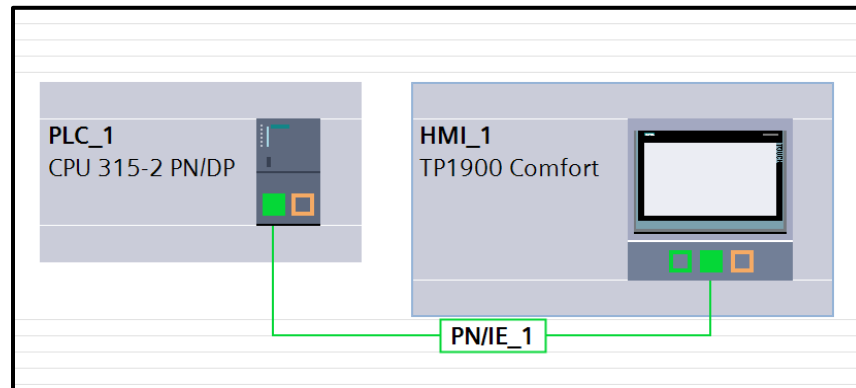
III.4.2.2 HMI configuration:

The TP1900 we choose has the following specification:

- ✓ 18.5" TFT display - 1366x768 pixels - 16m colors.
- ✓ Touch screen.
- ✓ 1 x MPI/PROFIBUS DP.
- ✓ 1x PROFINET/industrial Ethernet interface with MRP and RT/IRT support (2 ports).
- ✓ 1 x Ethernet (gigabit).
- ✓ 2 x SD card slot.
- ✓ 3x USB

III.4.2.3 Network

The PLC and the HMI are connected.



III. Figure 52: PLC to HMI connection.

III.4.3 Variable definition:

The tag table allows you to name and address the I/O into the software, and define their data types. Tag table facilitates and organizes the programming and maintenance. Our tag table contain 35 inputs, 23 output, 1 analog input and 40 interne variables.

	Name	Data type	Address ▲	Retain	Acces...	Visibl...	Comment
1	Ultrasonic	Bool	%I0.0				Clay Presence - SC650AB00AFFP Ultrasoni...
2	inductive 1	Bool	%I0.1				Clay Presence - XS7-C40PC440
3	inductive 2	Bool	%I0.2				Clay Presence - XS8-C40PC449
4	inductive 3	Bool	%I0.3				Clay Presence - XS8-C40PC449
5	inductive 4	Bool	%I0.4				Clay Presence - XS7-C40PC440
6	inductive 5	Bool	%I0.5				Clay Presence - XS8-C40PC449
7	Contact pressure gauge	Bool	%I0.6				Set to 160 BAR
8	Limit Switch (fin de course)	Bool	%I0.7				ZC2JC2
9	Photoelectric Sensor	Bool	%I1.0				DSE10-P4211 SICK
10	Pressure Switch - Diesel	Bool	%I1.1				XMLA004A2S11
11	Pressure Switch - Hydraulic Uni...	Bool	%I1.2				XMLB160D2S11
12	Pressure Switch - Hydraulic Uni...	Bool	%I1.3				XMLB160D2S11
13	Pressure Switch - Scrapers DCV	Bool	%I1.4				XMLA010A2S11
14	Pressure Switch - Lubrication Oil	Bool	%I1.5				XMLA010A2S11
15	Pressure Switch - Water valve D...	Bool	%I1.6				XMLA010A2S11
16	Pressure Switch - Water	Bool	%I1.7				XMLA004A2S11

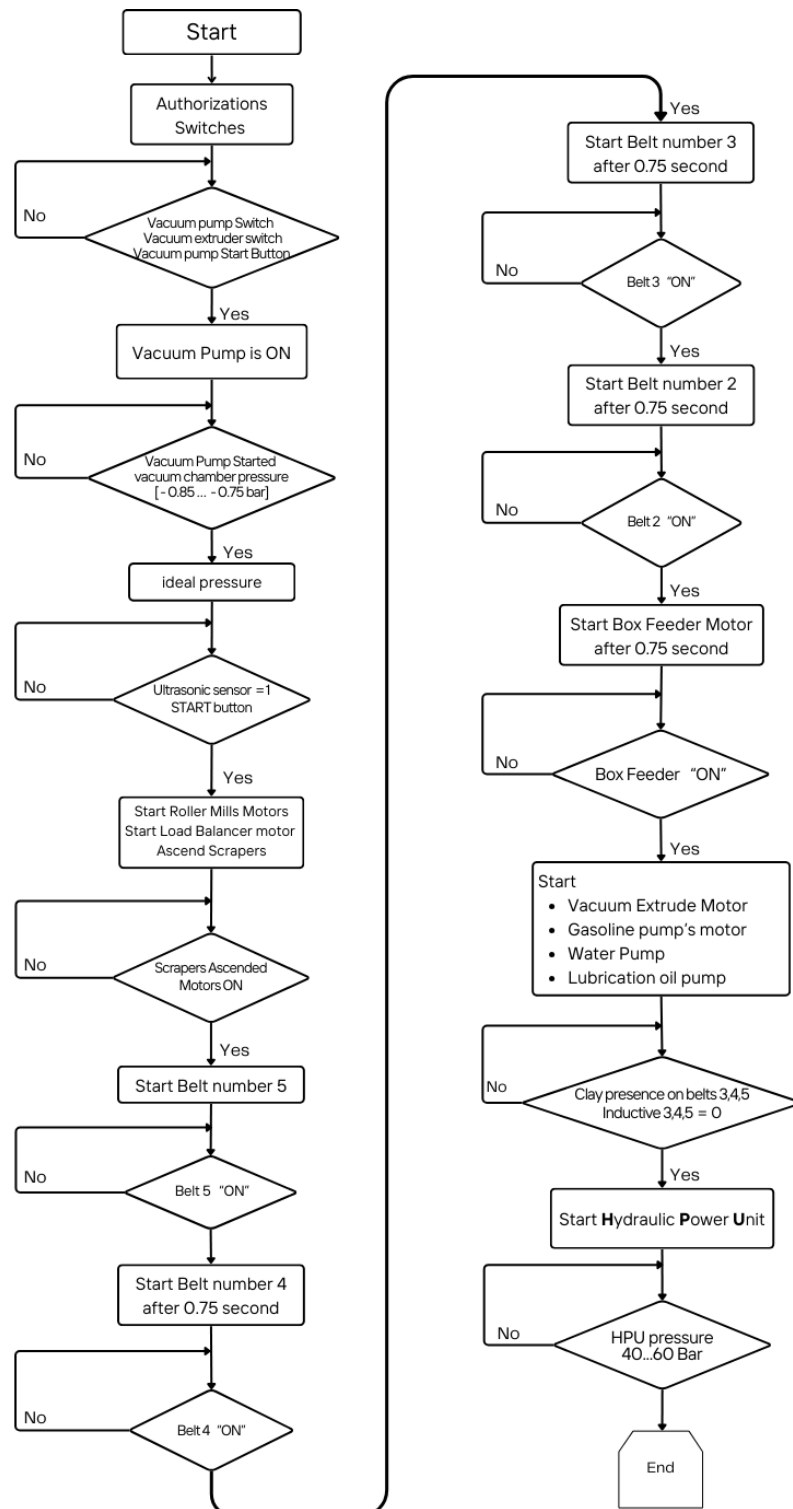
III. Figure 53: Tag table.

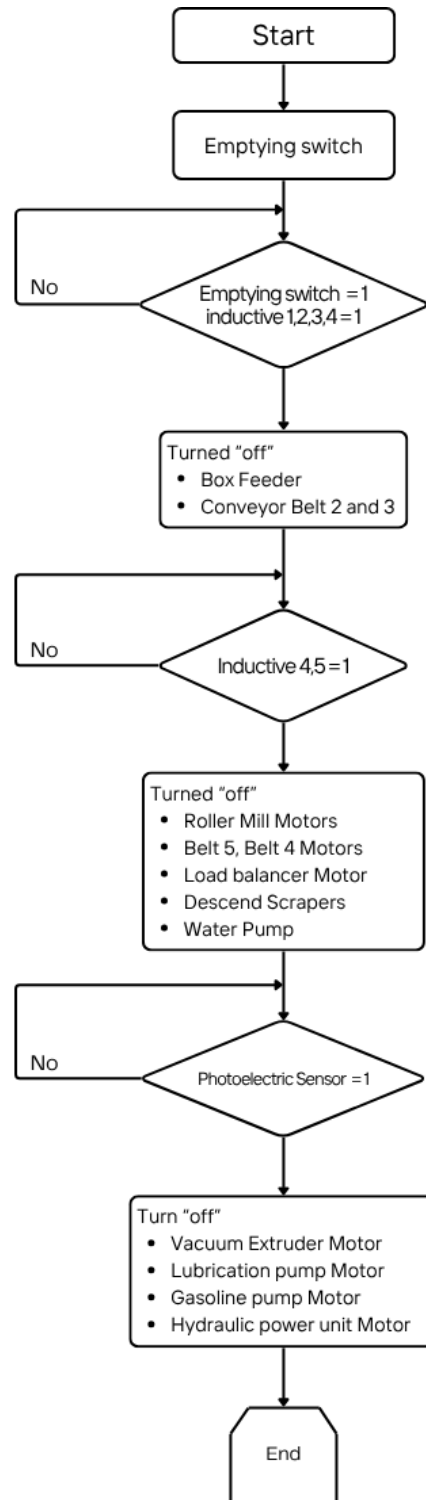
III.4.4 Programming

III.4.4.1 Flowchart

Before start programming, we created flowchart that explain the functionality of the process.

Production mode flowchart:



Emptying mode Flowchart:

After designing the flowchart for the two modes, we will implement and translate them in a programming language using TIA Portal.

III.4.4.2 Sequential Function Chart

Sequential Function Chart (SFC) also known in French as **GRAFCET** (Graphe Fonctionnel de Commande Étape/Transition) is a graphical tool used for designing and programming an automatic process. SFC consisted of initial step, transition and actions. The initial step is marked by a double bar line indicates the start of the program and it's the first active step when the system is powered. Transitions connect the steps together and function as a condition to the next step. Transitions can be defined using Ladder Diagrams (LD) or Function Block Diagrams (FBD).

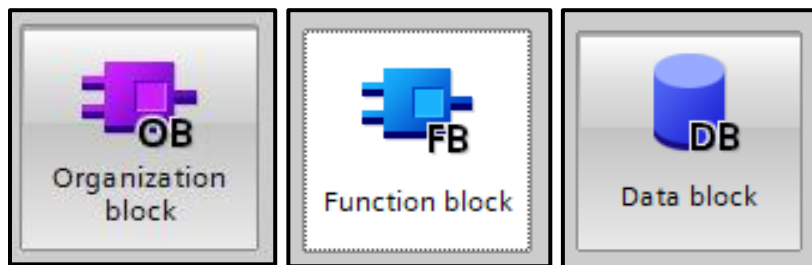
Programming blocks we used:

In TIA-PORATAL there are four (4) different programming blocks, each one has its own purpose and use. We only used three blocks which are:

Organization block (OB): Control the software execution. Everything has to be in (OB) for it to function.

Function blocks (FB): Code blocks that store their values permanently in instance data blocks, so that they remain available after the block has been executed. For us to use (SFC) we must select Function Block (FB) and the language and (GRAPH).

Data blocks (DB): Accessible by all program blocks (OBs, FBs, FCs) ideal for storing data like configuration parameters or global counters.

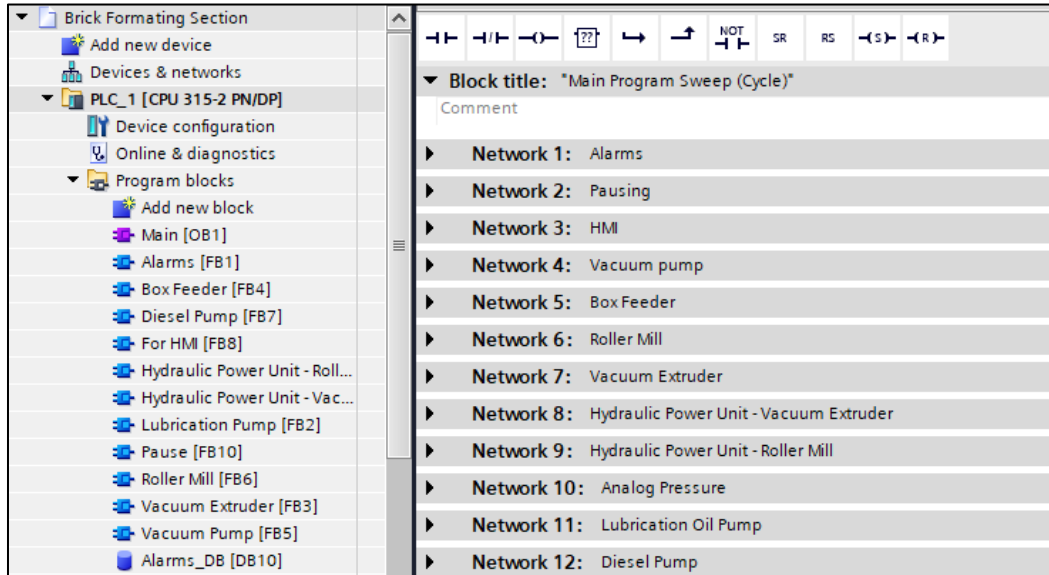


III. Figure 54: Programming blocks we used.

III.4.4.3 Program Blocks

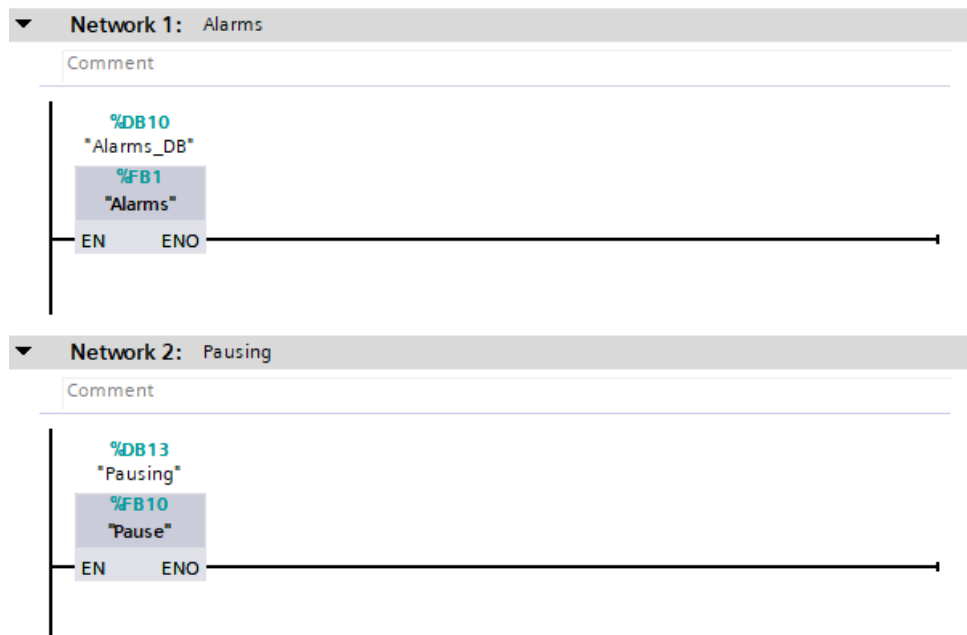
All the function blocks and necessary program line needed and organized in the Main OB1.

Each network represents a single part of the programming:



III. Figure 55: Program Blocks.

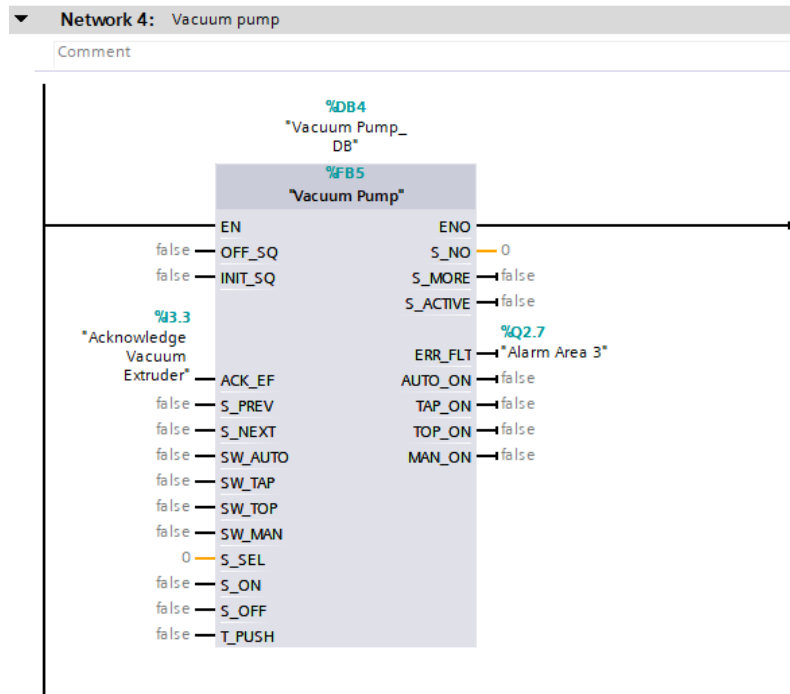
Network 1 and network 2: represent the function blocks (FB) responsible for process “Stop” and the process “Alarms”



III. Figure 56: Program of The Alarms and Process pause.

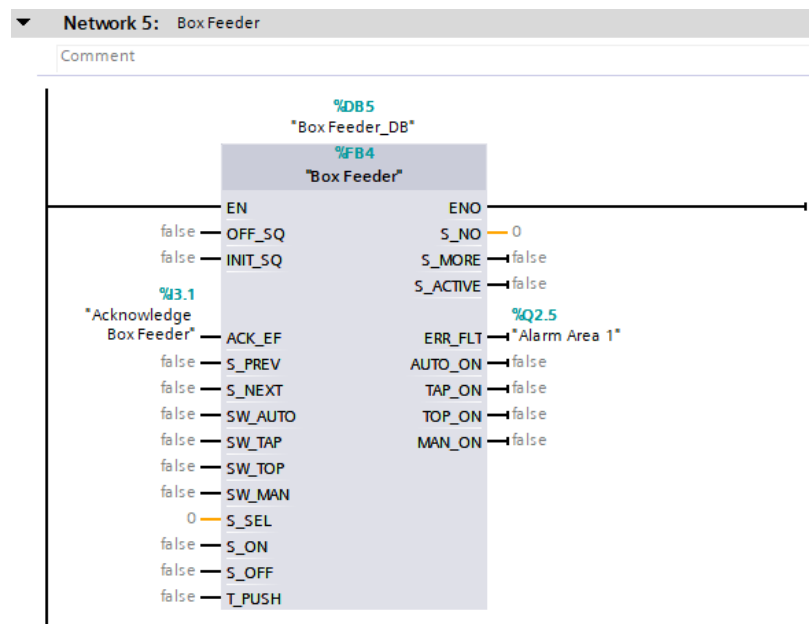
These are the four main networks located in the organization block:

Network 4: The figure below represents the function block (FB) of the sequential function chart containing the program of the operation of the "**Vacuum Pump**".



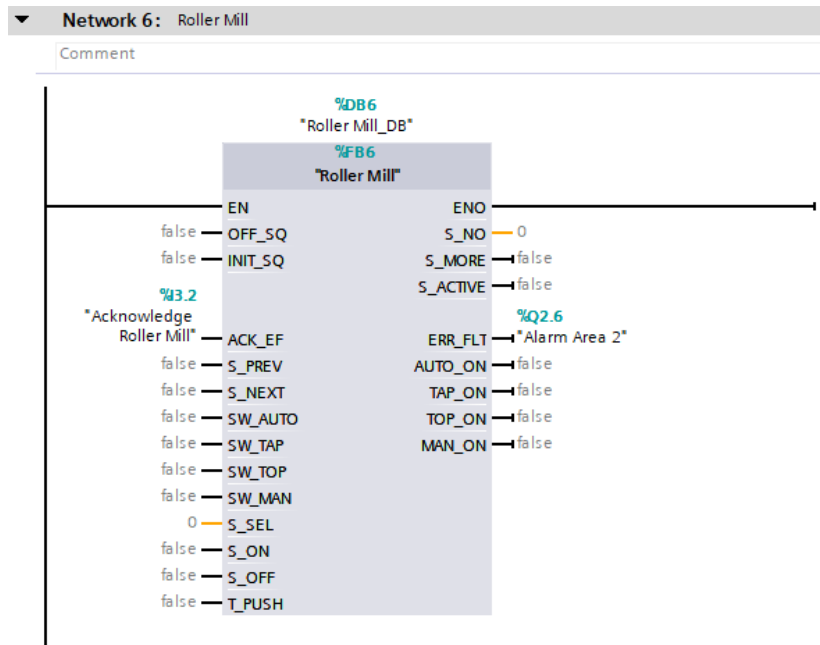
III. Figure 57: Program of The Vacuum pump.

Network 5: The figure below represents the function block (FB) of the sequential function chart containing the program of the operation of the "**Box feeder**".



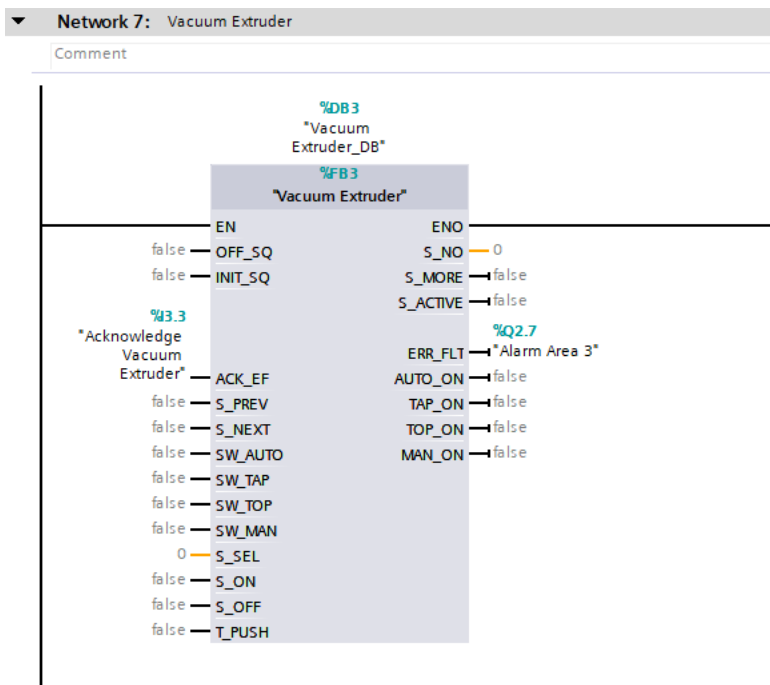
III. Figure 58: Program of The Box Feeder.

Network 6: The figure below represents the function block (FB) of the sequential function chart containing the program of the operation of the "**Roller mill**".



III. Figure 59: Program of The Roller mill.

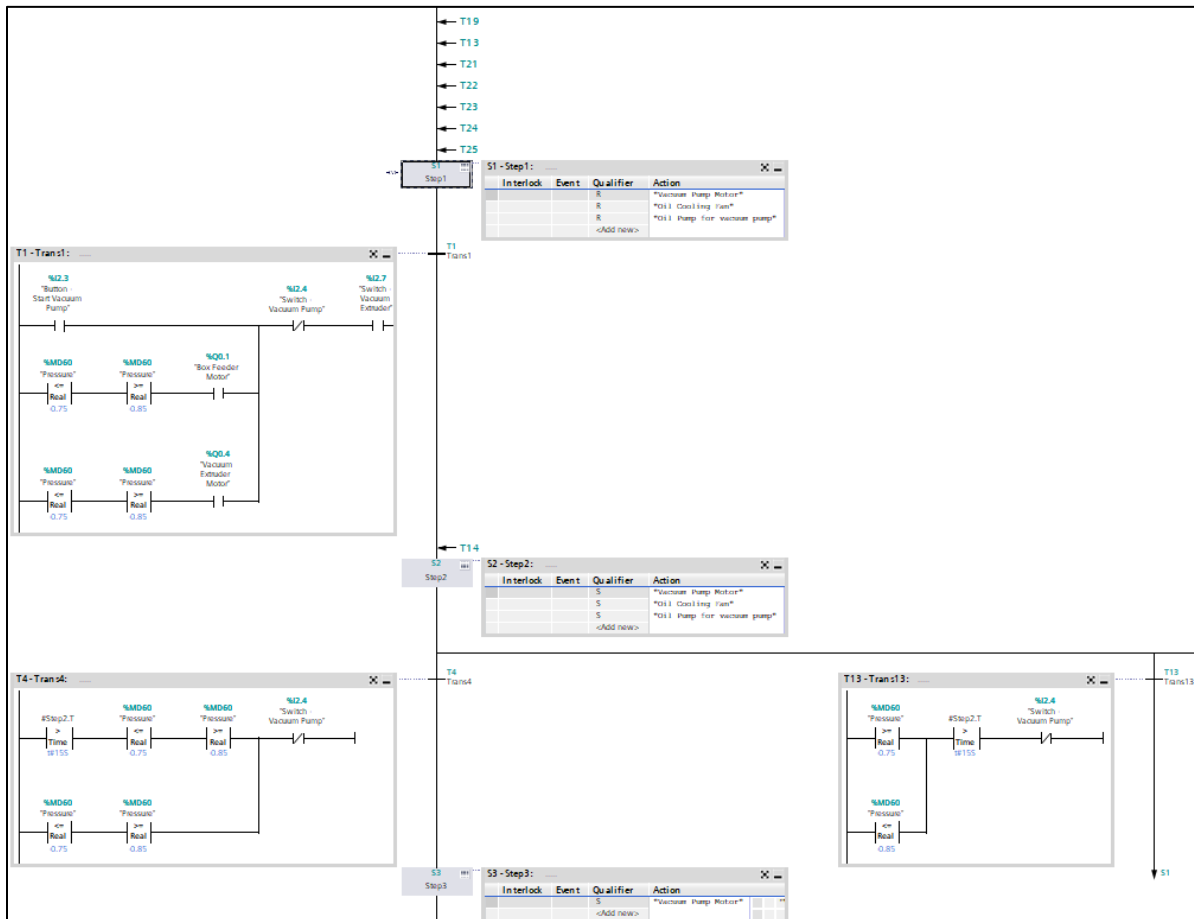
Network 7: The figure below represents the function block (FB) of the sequential function chart containing the program of the operation of the "**Vacuum extruder**".



III. Figure 60: Program of The Vacuum extruder.

Function Blocks FB:

After adding a block and selecting a function block with GRAPH language, a window will open where we can insert our program into an SFC. The figure below represents the inside of the function block of the "Vacuum pump".



III. Figure 61: Vacuum pump program.

In order to obtain the program, we made into the organization block (OB1) like the **figure 56**, we need to drag and drop the function block of the "Vacuum pump" into the main OB1

III.4.5 HMI Configuration

III.4.5.1 HMI tag table

After the connection between the TIA PORTAL project and the S7-300 PLC is established, it is possible to access all the PLC inputs, outputs and programming blocks from the HMI. HMI Tags allow communication and data exchange between the PLC and HMI. Each row

corresponds to an HMI variable. It is specified by: name, data type, connection number, acquisition cycle. And the name of which PLC is connected to, tag and address

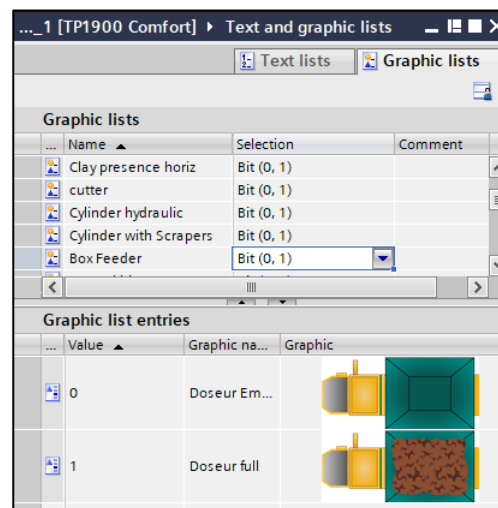
With connecting an HMI graphic to a PLC tag (input, output or a memory...), TIA PORTAL will automatically create an "HMI TAG" storing it in the "HMI tag table". Alternatively, you can manually name the variable, assign its data type, and choose the PLC tag you wanted it to be linked to. This will help us observe our program functionality via graphic figures.

Name	Data t...	Connection	PLC name	PLC tag	Address	Access ...	Acquisi...	Logged
Alarms and Error 2	Word	HMI_Connection_1	PLC_1	"Alarms and Error 2"	%MW106	<absolut...	1 s	☐
Alarms and errors	Word	HMI_Connection_1	PLC_1	"Alarms and errors"	%MW104	<absolut...	100 ms	☐
Pressure	Real	HMI_Connection_1	PLC_1	Pressure	%MD60	<absolut...	100 ms	☐
Gasoline pump motor	Bool	HMI_Connection_1	PLC_1	"Gasoline pump motor"	%Q2.1	<absolut...	1 s	☐
DCV pneumatic Scrapers	Bool	HMI_Connection_1	PLC_1	"DCV pneumatic Scrapers"	%Q1.7	<absolut...	100 ms	☐
Roller Mill Motor n2	Bool	HMI_Connection_1	PLC_1	"Roller Mill Motor n2"	%Q0.3	<absolut...	100 ms	☐
Roller Mill Motor n1	Bool	HMI_Connection_1	PLC_1	"Roller Mill Motor n1"	%Q0.2	<absolut...	100 ms	☐
Conveyor Belt 2	Bool	HMI_Connection_1	PLC_1	"Conveyor Belt 2"	%Q0.5	<absolut...	100 ms	☐
Vacuum Extruder Motor	Bool	HMI_Connection_1	PLC_1	"Vacuum Extruder Motor"	%Q0.4	<absolut...	100 ms	☐
Doseur Full	Bool	HMI_Connection_1	PLC_1	"Doseur Full"	%M108.0	<absolut...	100 ms	☐
Belt 5 Clay	Bool	HMI_Connection_1	PLC_1	"Belt 5 Clay"	%M108.4	<absolut...	100 ms	☐
Box Feeder Motor	Bool	HMI_Connection_1	PLC_1	"Box Feeder Motor"	%Q0.1	<absolut...	100 ms	☐
Security pump motor	Bool	HMI_Connection_1	PLC_1	"Security pump motor"	%Q2.2	<absolut...	1 s	☐
Switch - Vacuum Extruder	Bool	HMI_Connection_1	PLC_1	"Switch - Vacuum Extruder"	%I2.7	<absolut...	100 ms	☐
Switch - Roller Mill	Bool	HMI_Connection_1	PLC_1	"Switch - Roller Mill"	%I2.6	<absolut...	100 ms	☐
Switch - Box Feeder	Bool	HMI_Connection_1	PLC_1	"Switch - Box Feeder"	%I2.5	<absolut...	100 ms	☐
Button - Start Vacuum Pump	Bool	HMI_Connection_1	PLC_1	"Button - Start Vacuum Pump"	%I2.3	<absolut...	100 ms	☐
Button - Start	Bool	HMI_Connection_1	PLC_1	"Button - Start"	%I2.0	<absolut...	100 ms	☐
Button - Pause Roller Mill	Bool	HMI_Connection_1	PLC_1	"Button - Pause Roller Mill"	%I2.2	<absolut...	100 ms	☐
Button - Pause	Bool	HMI_Connection_1	PLC_1	"Button - Pause"	%I2.1	<absolut...	100 ms	☐

III. Figure 62: HMI tag table.

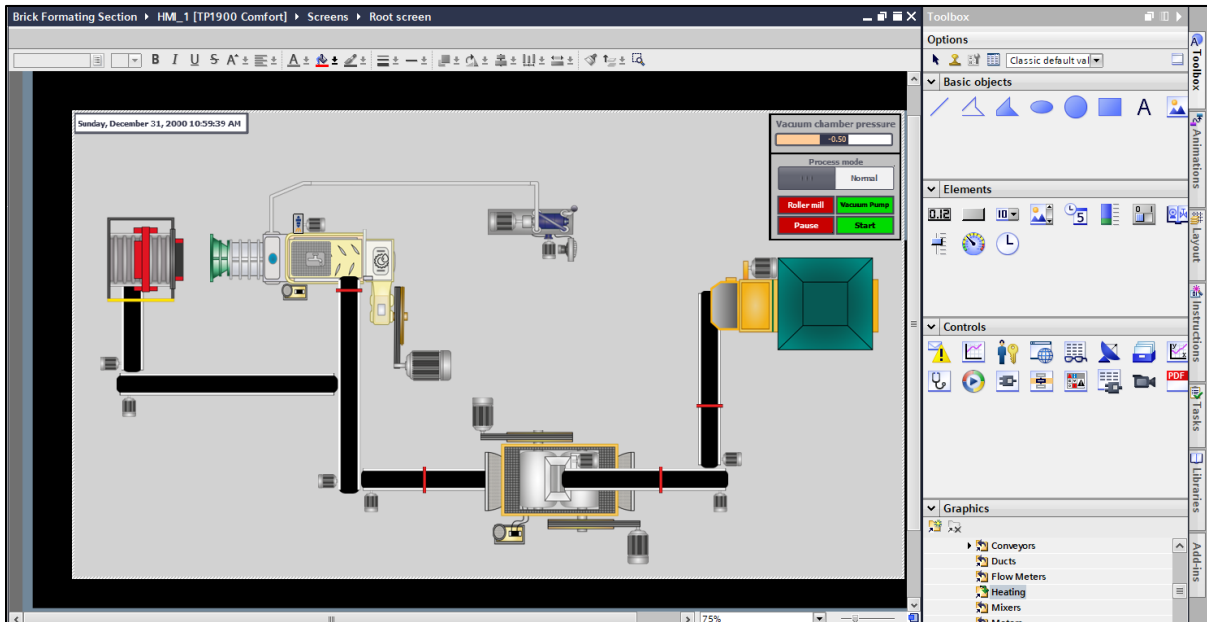
III.4.5.2 Synoptic Creation

With the lack of symbols on TIA portal graphic library, we had to create the figures with a third-party software as a PNG, and upload the pictures to TIA portal on **"Languages & resources > Project graphics"**, after that configure the graphic as Bit, Bit number or Value/range on **"HMI_1 > Text and graphic lists > Graphic lists"** as shown below.



III. Figure 63: Synoptic Creation.

And upload our graphics with the use of “Graphic I/O field” on the Toolbox.



III. Figure 64: HMI Creation.

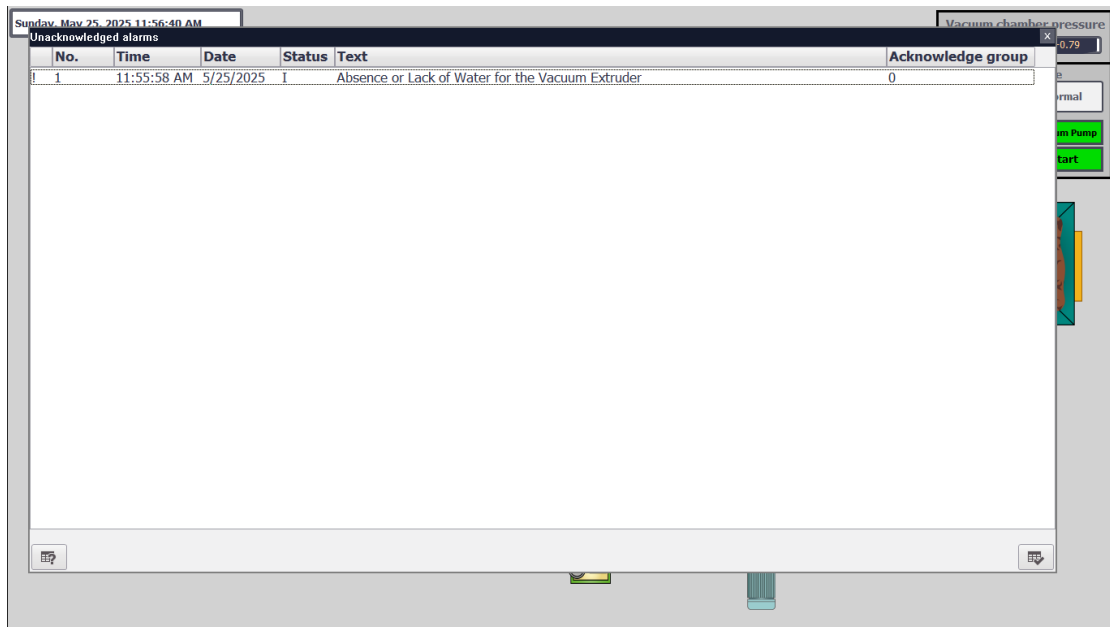
III.4.5.3 Alarm definition

To set the alarms we must head to “HMI_1 [TP1900 comfort] > HMI alarms”, and choose the name, the alarm text, the class either error or warning and the trigger tag and the trigger bit. ((Note that the HMI alarms only function with **Int** or **Word** variables)).

Discrete alarms							
	ID	Name	Alarm text	Alarm class	Trigger tag	Trigge..	Trigger address
	1	Water	Absence or Lack of Water for the Vac Errors	Alarms and er...	13	%M104.5	
	2	Pneumatic Valve	Absence of Air for the Pneumatic Val Errors	Alarms and er...	14	%M104.6	
	3	Diesel	Absence or Lack of Diesel for the Vac Errors	Alarms and er...	15	%M104.7	
	4	Oil	Absence or Lack of Lubrication Oil fo Errors	Alarms and er...	0	%M105.0	
	5	HPU - Vacuum Extr...	Overpressurized Hydraulic Power Un Errors	Alarms and er...	1	%M105.1	
	6	Clay	Absence of Clay	Errors	8	%M104.0	
	7	Roller Mill	Oversized Object	Errors	9	%M104.1	
	8	Scrapers	Absence or Lack of air for the Scrape Errors	Alarms and er...	10	%M104.2	
	9	Low Pressure	Vacuum Chamber at a Low Pressure Errors	Alarms and er...	2	%M105.2	
	10	Emergency 1	Emergency Shutdown at the Belt Nu Errors	Alarms and er...	11	%M104.3	
	11	Emergency 2	Emergency Shutdown at the Belt Nu Errors	Alarms and er...	12	%M104.4	
	12	Emergency 3	Emergency Shutdown at the Belt Nu Errors	Alarms and er...	3	%M105.3	
	13	Emergency 4	Emergency Shutdown at the Belt Nu Errors	Alarms and er...	4	%M105.4	
	14	Clay Density	Clay Density is High	Errors	5	%M105.5	
	15	HPU- Vacuum Extr...	Vacuum Extruder's Hydraulic power Errors	Alarms and er...	6	%M105.6	
	16	HPU - Roller Mill	Roller Mill's Hydraulic power Unit is a Errors	Alarms and er...	7	%M105.7	
	17	Belt number 2	The rubber on conveyor belt number Errors	Alarms and Er...	8	%M106.0	
	18	Belt number 3	The rubber on conveyor belt number Errors	Alarms and Er...	9	%M106.1	
	19	Belt number 4	The rubber on conveyor belt number Errors	Alarms and Er...	10	%M106.2	
	20	Belt number 5	The rubber on conveyor belt number Errors	Alarms and Er...	11	%M106.3	

III. Figure 65: HMI Alarms table.

In case of an error resulting from input readings, the process will stop as required, and the HMI will display the alarm code, times, and a message detailing the issue



III. Figure 66: HMI Alarm example.

III.5 Conclusion

At the end of this chapter, we conducted the selection of a suitable PLC which is the S7-300, along with the necessary input and output modules based on the number of instruments we deducted from the previous chapter, along with 19" comfort HMI panel and configured the corresponding tags to ensure proper communication with the PLC. The data exchange between the PLC and HMI established via PN/IE network, short for PROFINET/Industrial Ethernet ensuring the speed and reliability. For programming, we implemented the graphical programming language that is the sequential function chart (SFC), offers a structured programming approach of the process steps.

Chapter IV

Result and Discussion

IV.1 Introduction

After providing an automatic solution in the previous chapter, from choosing the PLC controller and HMI, and link them with the use of PROFINET network. In this chapter, we will simulate the forming process by modifying the states of the sensors in the PLC-SIM and from the buttons we created in the HMI in order to obtain the corresponding variation in the state devices on the field. this simulation will cover all the operating phases and scenarios of the section.

IV.2 Supervision Implementation

When the complexity of processes increases, machinery and installations must be at a high operational standards, operators and workers needs maximum transparency. This transparency is achieved using the human machine interface (HMI), a system that link the interface between the operator and the operating part.

After the HMI connect, it will allow the user to:

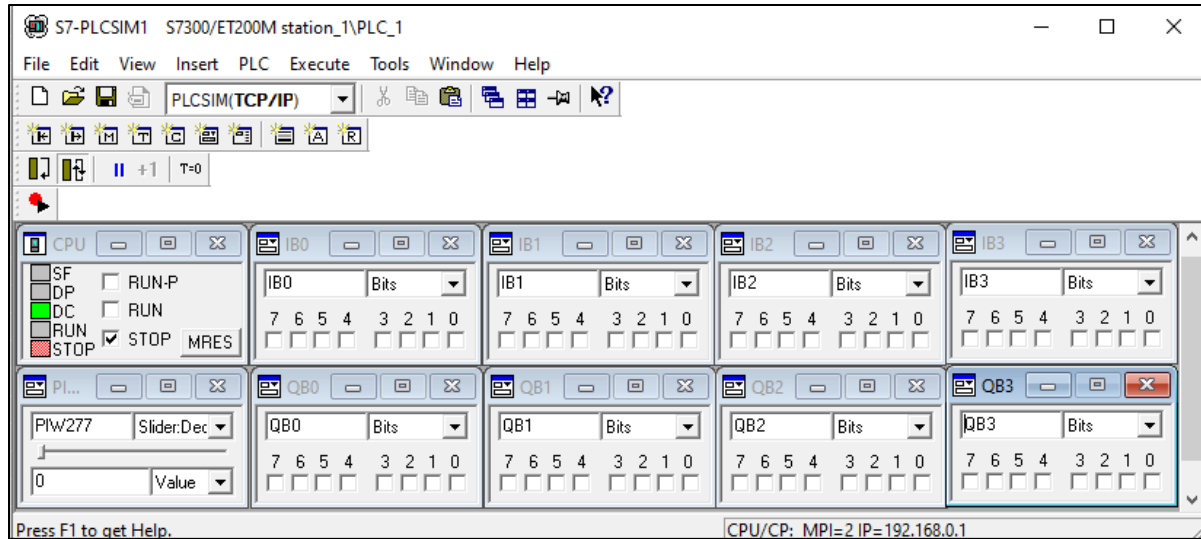
- View the status of all instruments and operate them as see fit.
- Display detailed alarms and notification.
- Act on the section.

IV.3 Compiling and Simulating

After creating the project and completing the configuration, it is essential to check the project's consistency and detect errors. Using the "simulation" command, then "start," and then verify that our system is working properly, to simulate our entire system, several steps must be performed.

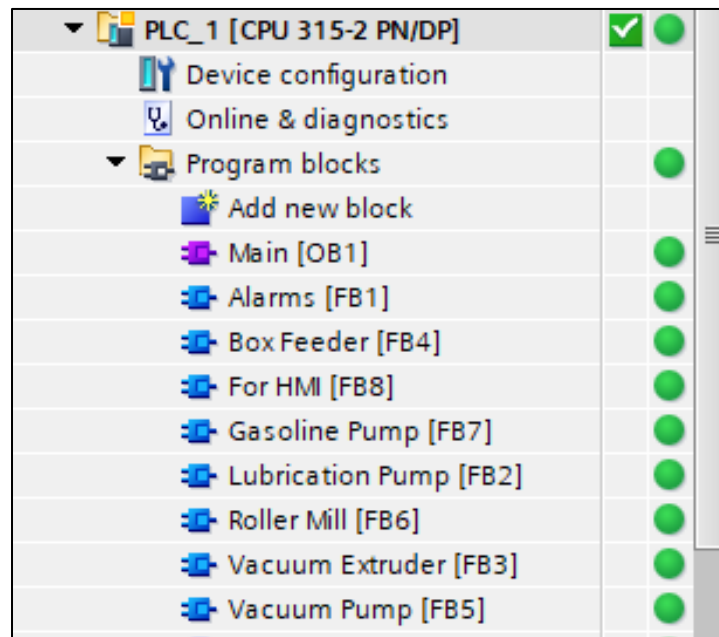
In our TIA portal we go to the top bar and click "compile" to see in our program has any programming issues.

The second step is to launch the simulation via "start simulation" button, then load the program using the "load" button in the left window, then click on the RUN-P button in the right window. The figure below represents the PLC SIM window.



IV. Figure 67: PLC sim.

After the program is compiled and loaded without errors, the following windows appear with green lights.



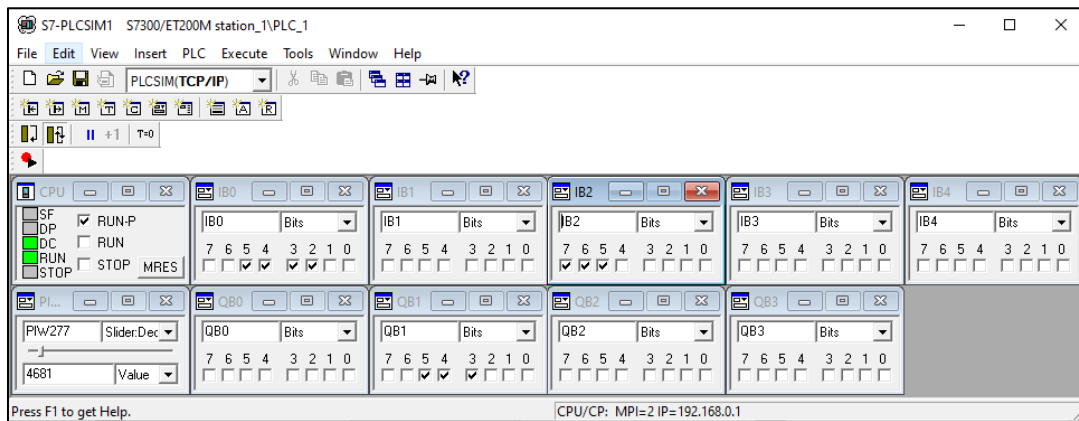
IV. Figure 68: Simulation without programming errors.

IV.4 Visualizing the results

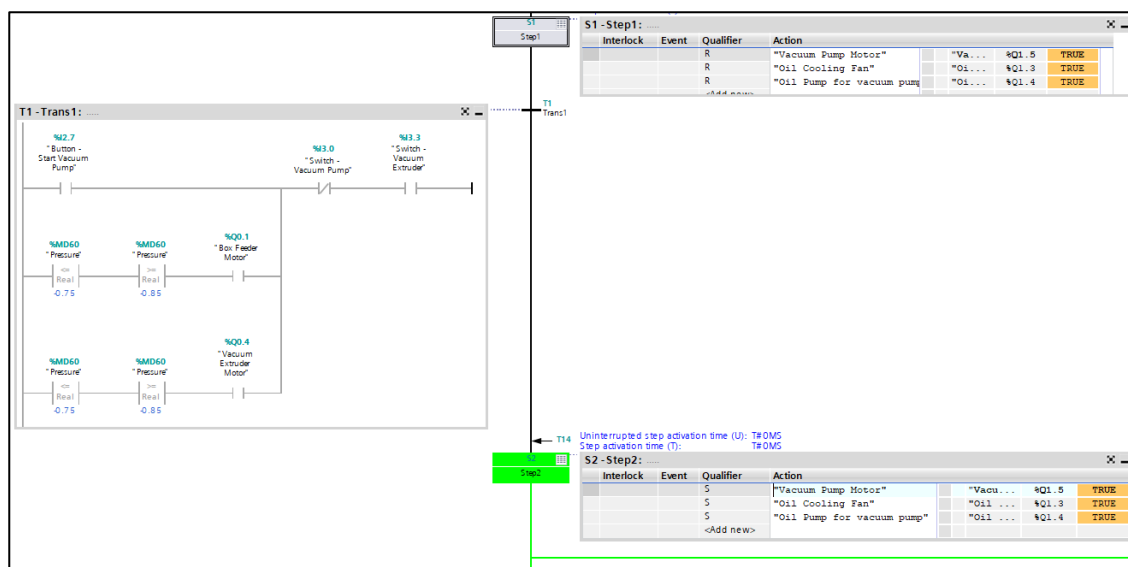
IV.4.1 First Scenario - Production mode

The switches (i2.5) for the box feeder and (i2.6) for the roller mill and (i2.7) for the vacuum extruder must be turned ON (value=1), the operators on the field to give the last three permissions, the vacuum pump to begin functioning anytime the button “Vacuum pump” is clicked.

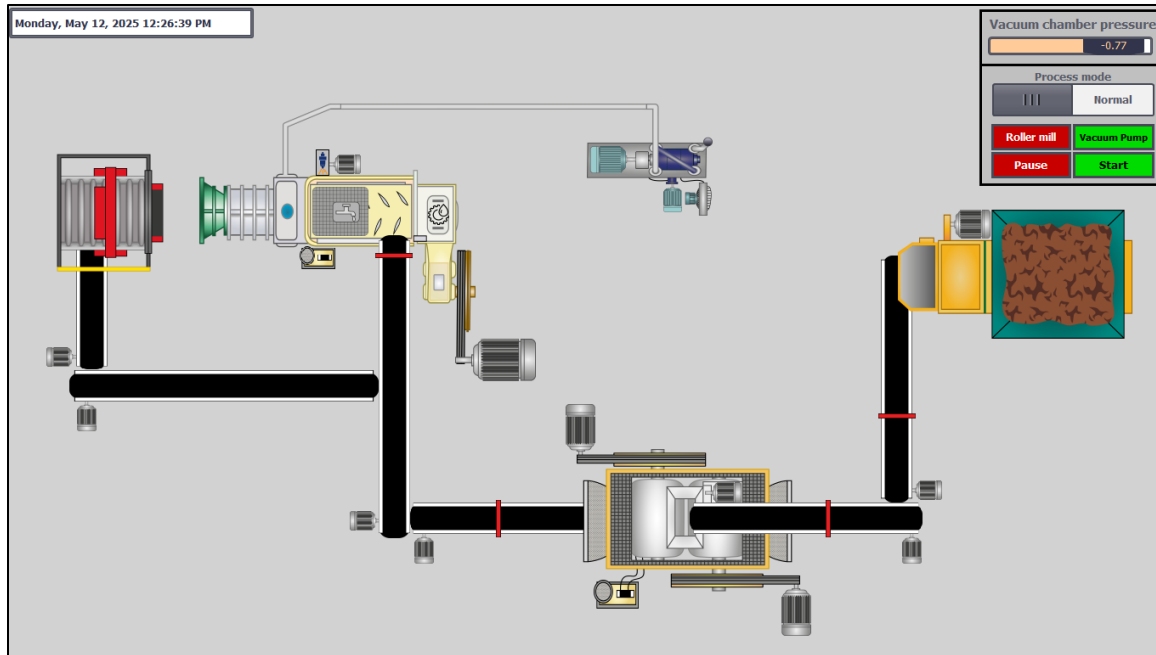
When the vacuum pump is started, the pressure must reach the ideal pressure [-0.75....-0.85 Bar] before 15 seconds, or else the pump turn itself off. And the ideal pressure give permission to the box feeder to start feeding the clay.



IV. Figure 69: PLC SIM with switches and analog ON.



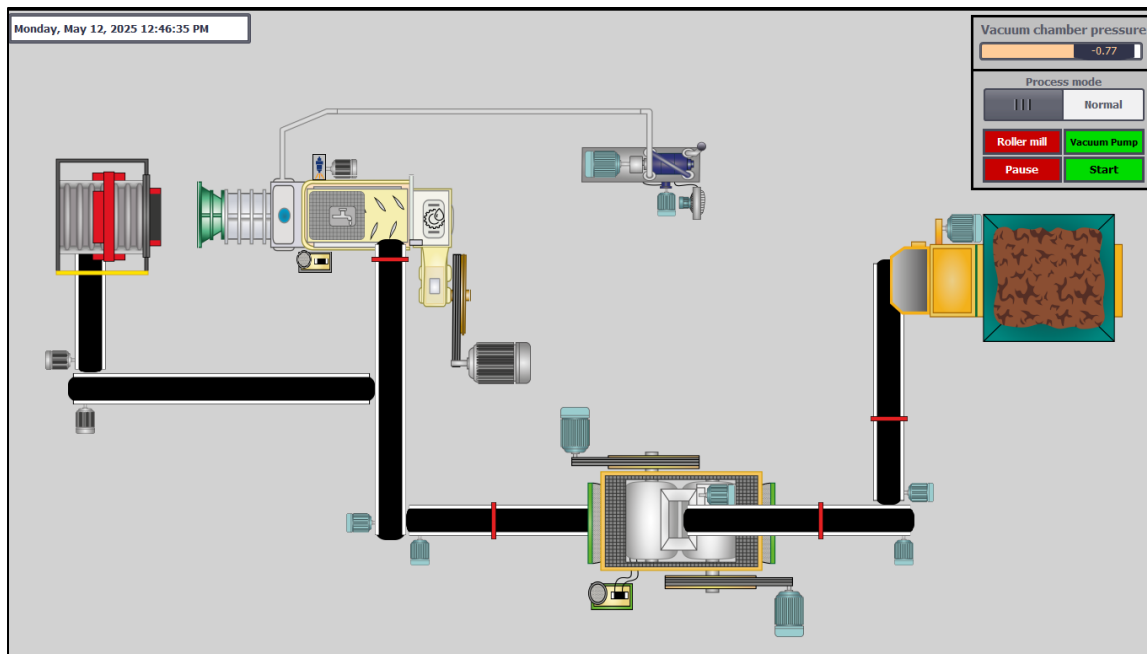
IV. Figure 70: Vacuum pump programming block.



IV. Figure 71: HMI with vacuum pump ON.

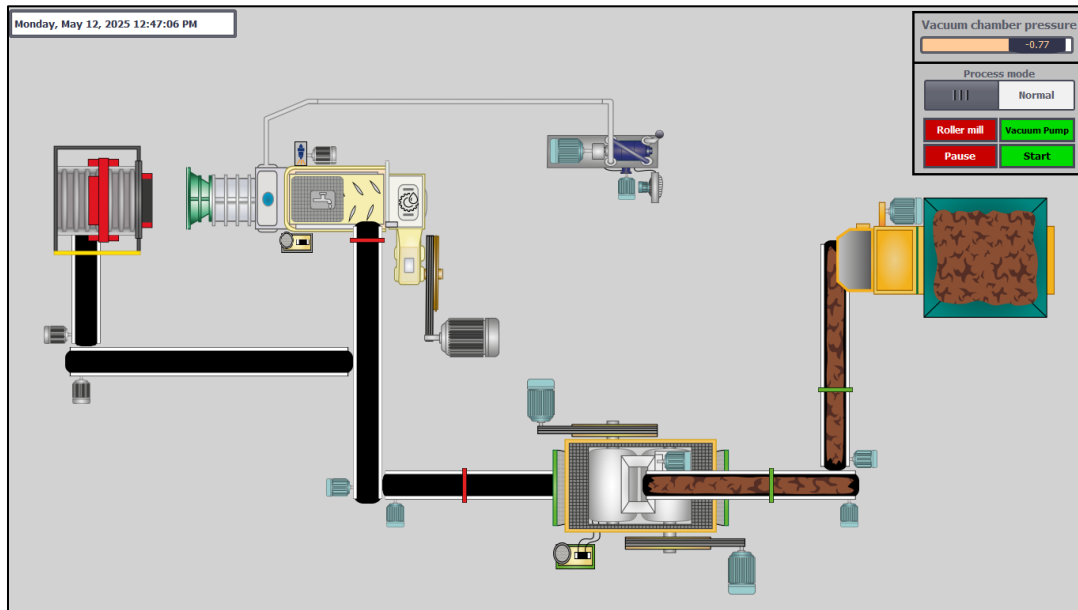
When the pressure is ideal and the “Start” button is clicked, the motors of the Roller Mill will start first and simultaneously the belts will start backward one by one with 0.75s gap between each other, then the Box feeder will begin feeding the clay.

If no clay gets detected on the belt number 1 after 5 seconds from the box feeder begin ON, an alarm will be triggered.



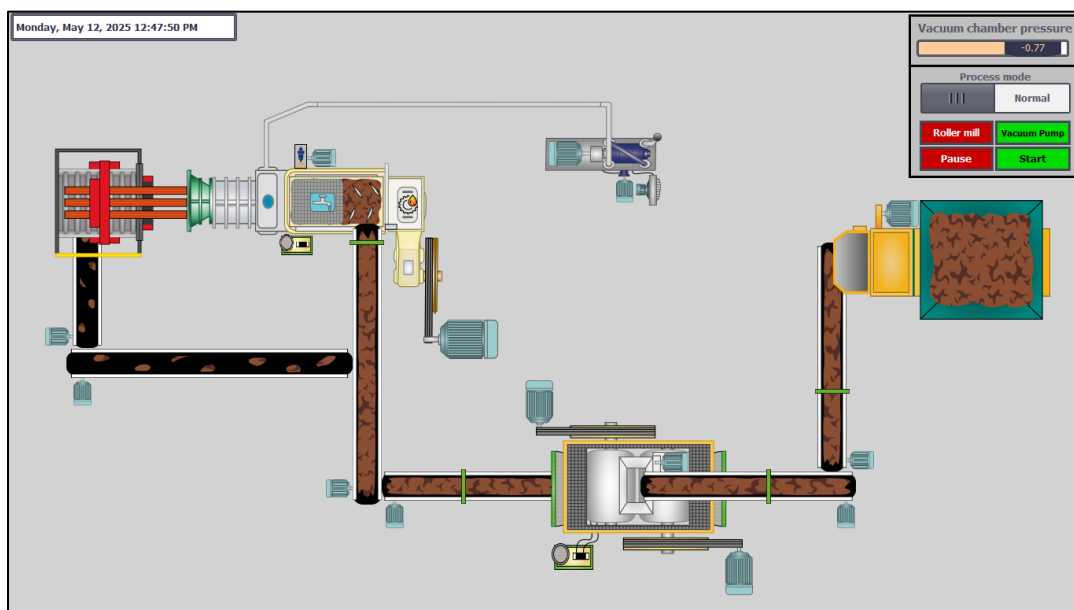
IV. Figure 72: HMI waiting for clay.

the clay present mechanism work in an opposite manner “**figure 30**”, when the value on an inductive sensor is 1=No clay, and when the value is 0 = there’s clay present.



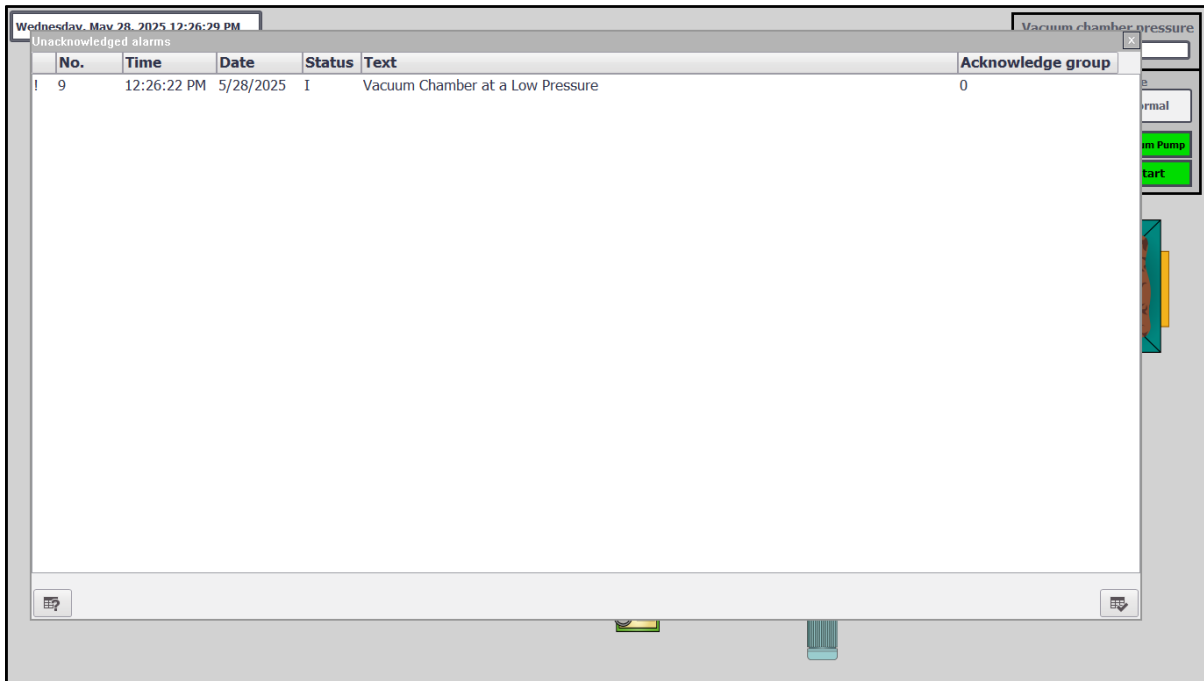
IV. **Figure 73:** HMI Clay presence.

After all the clay is present on every conveyor belt, the vacuum extruder will begin extrudes the clay into the mold shaping it and pushing it into the cutter. Simultaneously, its equipments that consist of a hydraulic power unit ,water pump, lubrication pump and diesel motor will also start.



IV. **Figure 74:** HMI process fully functioning.

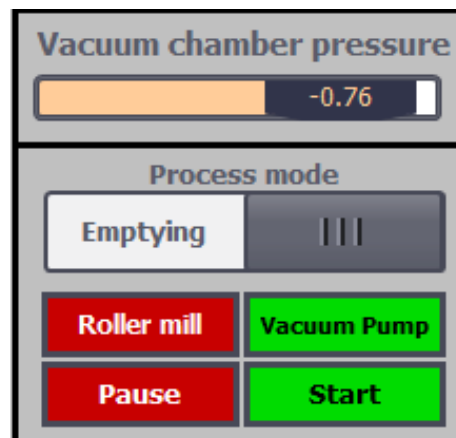
Low pressure alarm example, with moving the slider “PIW277” to low pressure this alarm will get activated.



IV. Figure 75: Low pressure alarm example.

IV.4.2 Second Scenario - Emptying mode

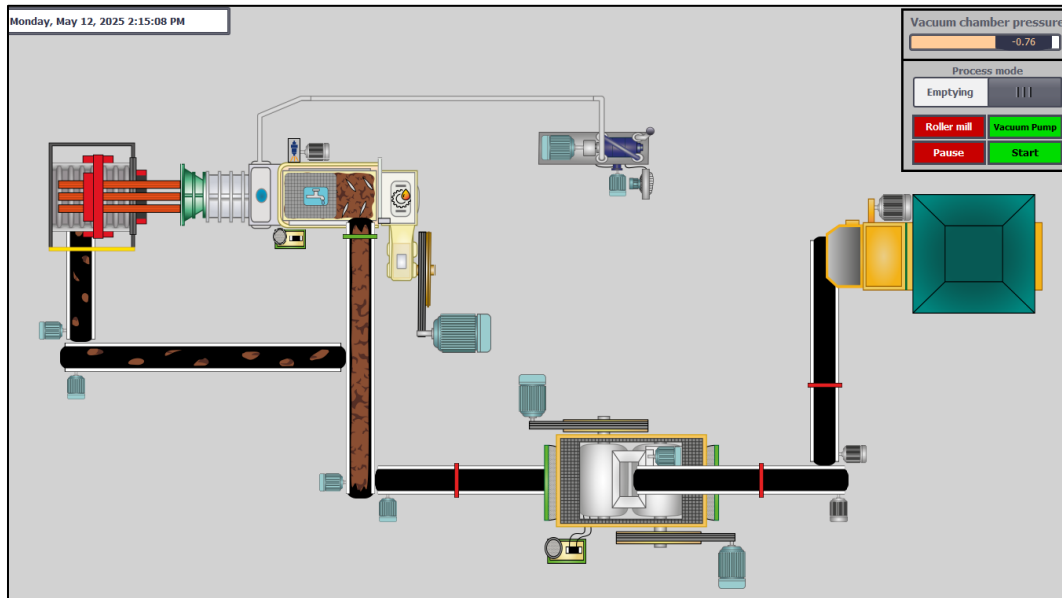
In case of a major malfunction that require emptying the machine from the clay. We got to switch the “process mode” switch in the HMI.



IV. Figure 76: HMI at Emptying mode.

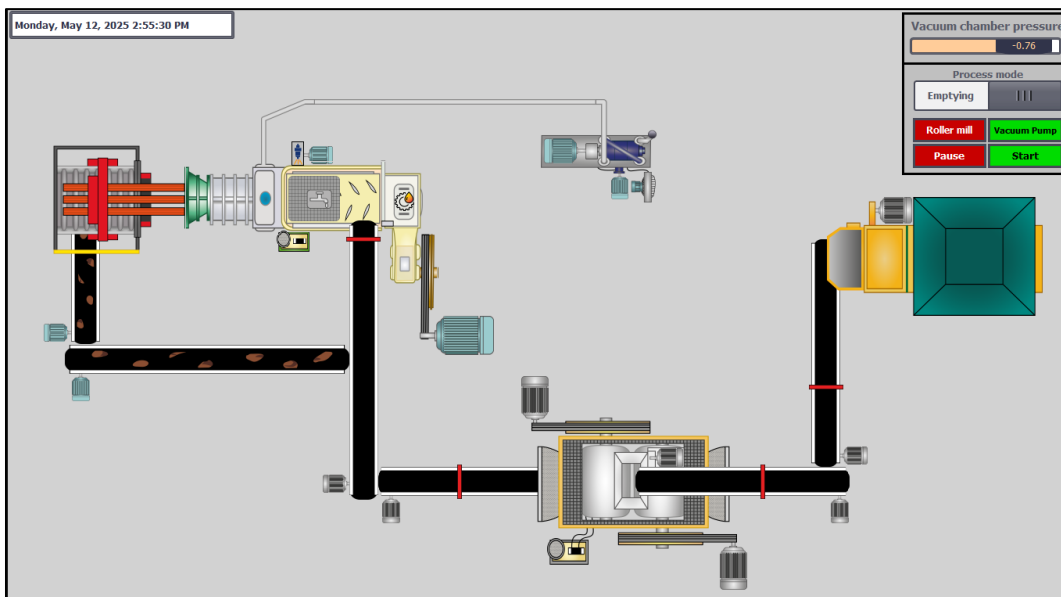
By switching to emptying mode, it will not give an ERROR when the box feeder is empty. And stop the process in three phases.

Phase 1 of the Emptying: After the first three belts and box feeder are empty, the box feeder and the first two belt turn OFF



IV. Figure 77: HMI emptying phase 1.

Phase 2 of the Emptying: After all the conveyor belt are empty, all of their motors and roller mill's motor will automatically get turned OFF. And vacuum extruder will continue extruding the clay.

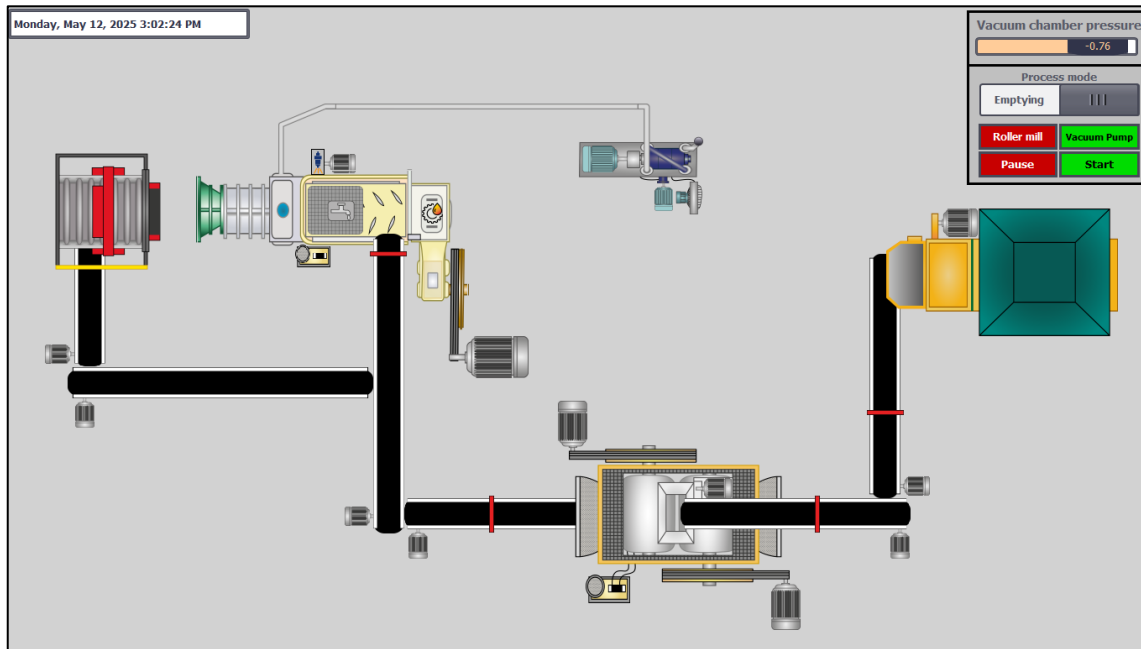


IV. Figure 78: HMI emptying phase 2.

Phase 3 of the Emptying

At the end of the emptying process, when the photoelectric sensor detecting no extruded clay is being pushed from the vacuum extruder, will stop the rest of the motors.

While the vacuum pump will automatically shut down 270 second after the vacuum extruder is turned off. Or manually deactivating it through “Vacuum pump switch”



IV. Figure 79: HMI emptying phase 3.

IV.5 Conclusion

PLC SIM enabled us to simulate, react and real-time monitoring of our program without the presence of physical hardware, and with the use of HMI we observed the reaction of our program in the two scenarios, "Production" mode and "Emptying" mode with its three phases. From examining the reaction of the system, we can say the automatic solution fulfill the required goal of replacing the relay logic control system with a programmable logic controller.

General conclusion

General Conclusion

The main objective of our project was to improve the reliability and maintainability of the forming section at the SPMC brick manufactory by replacing its outdated relay-based control system with a modern PLC-based system.

During this final year project, and our internship at the SPMC brick manufactory to bring our idea to light of improving the station, while the entire production process of the SPMC manufactory is accomplished with the use of modern automatic controller which is a PLC. Since the creation of the station, the forming section still operate using the legacy relay logic control with relays, timers and contactors, which bring so many challenges and limitations to the machines and staff. Based on our past knowledge acquired during our academic training, and internships, in this thesis we carried out the upgrade of the section from the old control system into a modern system. Enhance reliability, enable flexible and facilitate troubleshooting maintenance.

To establish this replacement, we began with a detailed and comprehensive analysis of the forming section's process and the functionality and role of the three main equipment, box feeder, roller mill and vacuum extruder and their components and instruments. At the end we abstract the required number and type of the instruments in order to select the module of the PLC and type and number of the input and output modules and configure them into TIA portal V16. Also select the HMI we see fit for the section to provide real-time visualization of the process, status indicators for each equipment, alarm history and detail, after the connection is accrued and the program is created, we will be able to control and monitor the reaction of our program.

With the use of PLC-SIM and HMI we observed the behavior of our system during production mode, emptying mode and in case of an alarms. Our program behaves as intended with prioritizing workers safety above all, followed by the protection of the machine. With this, we can confirm that our solution functioned effectively and successfully met the objectives of this thesis, the upgraded system offers a scalable platform for future integration with other sections of the factory, enabling full plant automation with a Siemens PLC.

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Annexes A

Digital Inputs:

	Name	Data type	Address ▲	Retain	Acces...	Visibl...	Comment
1	Ultrasonic	Bool	%I0.0				Clay Presence - SC650AB00AFFP Ultrasoni..
2	inductive 1	Bool	%I0.1				Clay Presence - XS7-C40PC440
3	inductive 2	Bool	%I0.2				Clay Presence - XS8-C40PC449
4	inductive 3	Bool	%I0.3				Clay Presence - XS8-C40PC449
5	inductive 4	Bool	%I0.4				Clay Presence - XS7-C40PC440
6	inductive 5	Bool	%I0.5				Clay Presence - XS8-C40PC449
7	Contact pressure gauge	Bool	%I0.6				Set to 160 BAR
8	Limit Switch (fin de course)	Bool	%I0.7				ZC2JC2
9	Photoelectric Sensor	Bool	%I1.0				DSE10-P4211 SICK
10	Pressure Switch - Diesel	Bool	%I1.1				XMLA004A2S11
11	Pressure Switch - Hydraulic Uni...	Bool	%I1.2				XMLB160D2S11
12	Pressure Switch - Hydraulic Uni...	Bool	%I1.3				XMLB160D2S11
13	Pressure Switch - Scrapers DCV	Bool	%I1.4				XMLA010A2S11
14	Pressure Switch - Lubrication Oil	Bool	%I1.5				XMLA010A2S11
15	Pressure Switch - Water valve D..	Bool	%I1.6				XMLA010A2S11
16	Pressure Switch - Water	Bool	%I1.7				XMLA004A2S11
17	Button - Start	Bool	%I2.0				
18	Button - Pause	Bool	%I2.1				
19	Button - Pause Roller Mill	Bool	%I2.2				
20	Button - Start Vacuum Pump	Bool	%I2.3				
21	Switch - Vacuum Pump	Bool	%I2.4				
22	Switch - Box Feeder	Bool	%I2.5				
23	Switch - Roller Mill	Bool	%I2.6				
24	Switch - Vacuum Extruder	Bool	%I2.7				
25	Switch - Emptying	Bool	%I3.0				
26	Acknowledge Box Feeder	Bool	%I3.1				
27	Acknowledge Roller Mill	Bool	%I3.2				
28	Acknowledge Vacuum Extruder	Bool	%I3.3				
29	Emergency 1	Bool	%I3.4				
30	Emergency 2	Bool	%I3.5				
31	Emergency 3	Bool	%I3.6				
32	Emergency 4	Bool	%I3.7				
33	Pressure switch Roller mill MC1	Bool	%I4.0				MC1 = 125 bar
34	Pressure switch Roller mill MC2	Bool	%I4.1				MC2 = 135 bar
35	Pressure switch Roller mill MC3	Bool	%I4.2				MC3 = 140 bar

Analog Input:

36	Pressure Transmitter	Int	%IW277				
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Digital Outputs:

37	Load balancer	Bool	%Q0.0				
38	Box Feeder Motor	Bool	%Q0.1				Gearmotor R87/DRS 112M4
39	Roller Mill Motor n1	Bool	%Q0.2				Dutchi DM1 280S4
40	Roller Mill Motor n2	Bool	%Q0.3				JULAN YX3-250M-4
41	Vacuum Extruder Motor	Bool	%Q0.4				ABB M3BP 355SMB
42	Conveyor Belt 2	Bool	%Q0.5				Gearmotor FA67/G DRS100M4
43	Conveyor Belt 3	Bool	%Q0.6				Gearmotor FA67/G DRS100M4
44	Conveyor Belt 4	Bool	%Q0.7				Gearmotor FA67/G DRS100M4
45	Conveyor Belt 5	Bool	%Q1.0				Gearmotor FA67/G DRS100M4
46	Conveyor Belt 6	Bool	%Q1.1				Gearmotor FA67/G DRS100M4
47	Conveyor Belt 7	Bool	%Q1.2				Gearmotor FA67/G DRS100M4

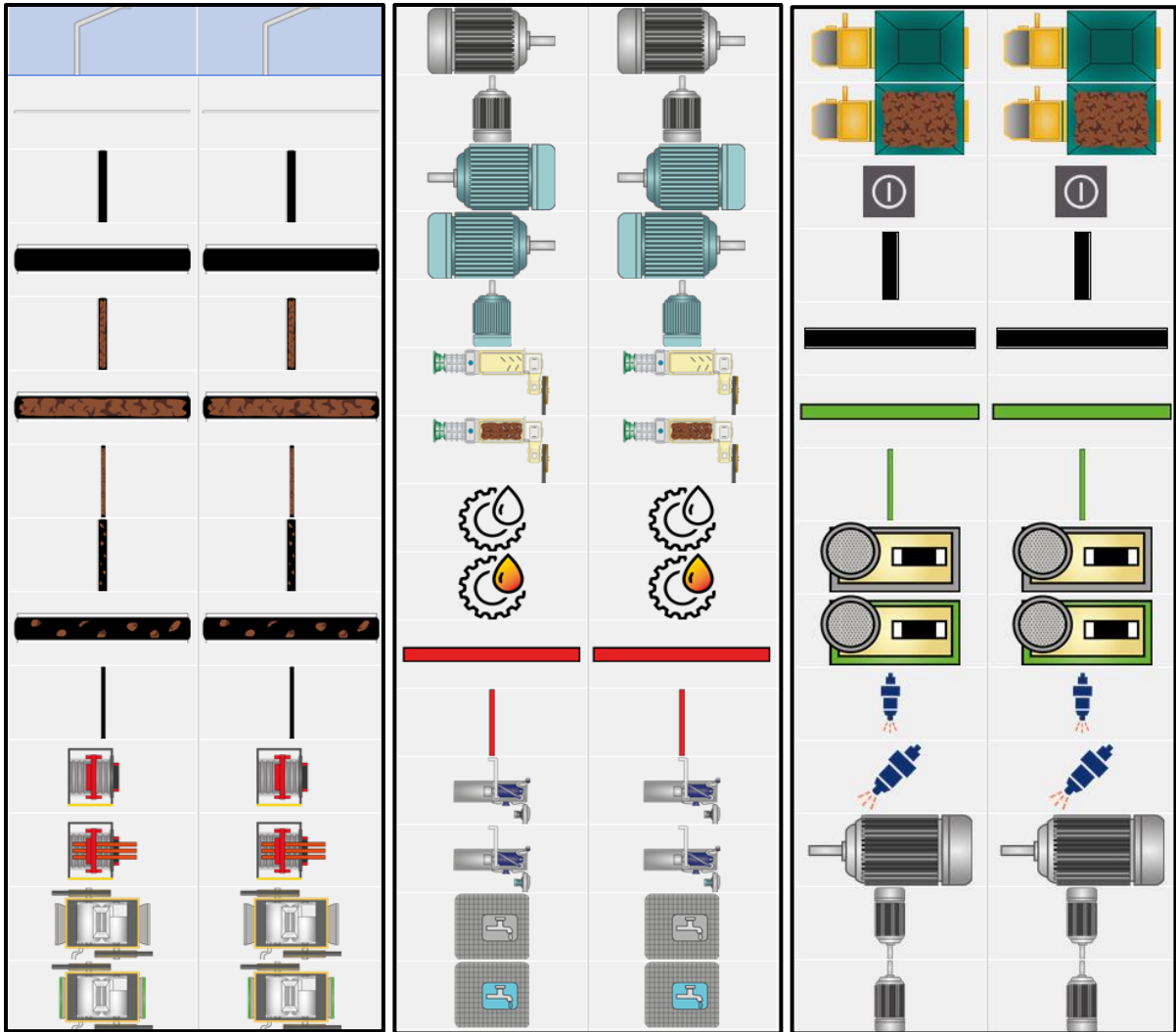
48		Oil Cooling Fan	Bool	%Q1.3				
49		Oil Pump for vacuum pump	Bool	%Q1.4				
50		Vacuum Pump Motor	Bool	%Q1.5				15 kW 1460 RPM
51		DCV pneumatic Valve (Water)	Bool	%Q1.6				distributeur pneumatique
52		DCV pneumatic Scrapers	Bool	%Q1.7				distributeur pneumatique
53		Gasoline pump motor	Bool	%Q2.1				1,1 kW 1000 RPM 3 bar
54		Security pump motor	Bool	%Q2.2				0.37kW 1370 RPM
55		Lubrication Oil Pump	Bool	%Q2.3				0.75kW 1500 RPM
56		Water Pump	Bool	%Q2.4				
57		Alarm Area 1	Bool	%Q2.5				
58		Alarm Area 2	Bool	%Q2.6				
59		Alarm Area 3	Bool	%Q2.7				
60		Security pump motor Roller mill	Bool	%Q3.0				1.5 kW 1500 RPM

Interne variables:

61		0	Bool	%M25.0			
62		Process Pause 2	Bool	%M30.0			
63		Process Pause 1	Bool	%M30.1			
64		Emptying + inductive 5	Bool	%M30.2			
65		1st Part off	Bool	%M30.4			
66		2nd Part off	Bool	%M30.5			
67		Pressure	Real	%MD60			
68		Error	Word	%MW100			
69		Alarms and errors	Word	%MW104			
70		No Clay Error	Bool	%M104.0			
71		Oversiwed error	Bool	%M104.1			
72		No air scarpers	Bool	%M104.2			
73		Emergency One	Bool	%M104.3			
74		Emergency Two	Bool	%M104.4			
75		No water	Bool	%M104.5			
76		No air water valve	Bool	%M104.6			
77		No gasoline	Bool	%M104.7			
78		No oil	Bool	%M105.0			
79		Security switch	Bool	%M105.1			
80		Low Pressure	Bool	%M105.2			
81		Emergency Three	Bool	%M105.3			
82		Emergency Four	Bool	%M105.4			
83		clay density	Bool	%M105.5			
84		HPU VE low pressure	Bool	%M105.6			
85		HPU RM low pressure	Bool	%M105.7			
86		Alarms and Error 2	Word	%MW106			
87		Rubber 2 HMI	Bool	%M106.0			
88		Rubber 3 HMI	Bool	%M106.1			
89		Rubber 4 HMI	Bool	%M106.2			
90		Rubber 5 HMI	Bool	%M106.3			
91		Doseur Full	Bool	%M108.0			
92		Belt 2 Clay	Bool	%M108.1			
93		Belt 3 Clay	Bool	%M108.2			
94		Belt 4 Clay	Bool	%M108.3			
95		Belt 5 Clay	Bool	%M108.4			
96		HPU VE couldnt reach pressure	Bool	%M108.5			
97		HPU RM Low pressure	Bool	%M108.6			
98		Rubber 2	Bool	%M108.7			
99		Rubber 3	Bool	%M109.0			
100		Rubber 4	Bool	%M109.1			
101		Rubber 5	Bool	%M109.2			

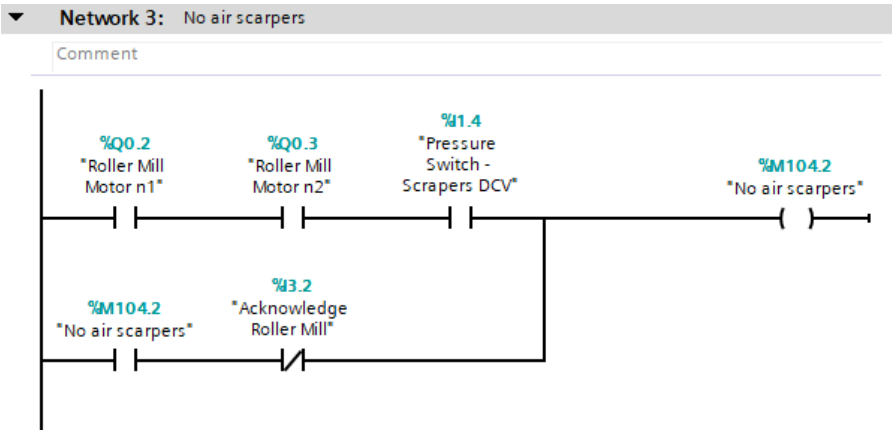
Annexes B

Project graphics:

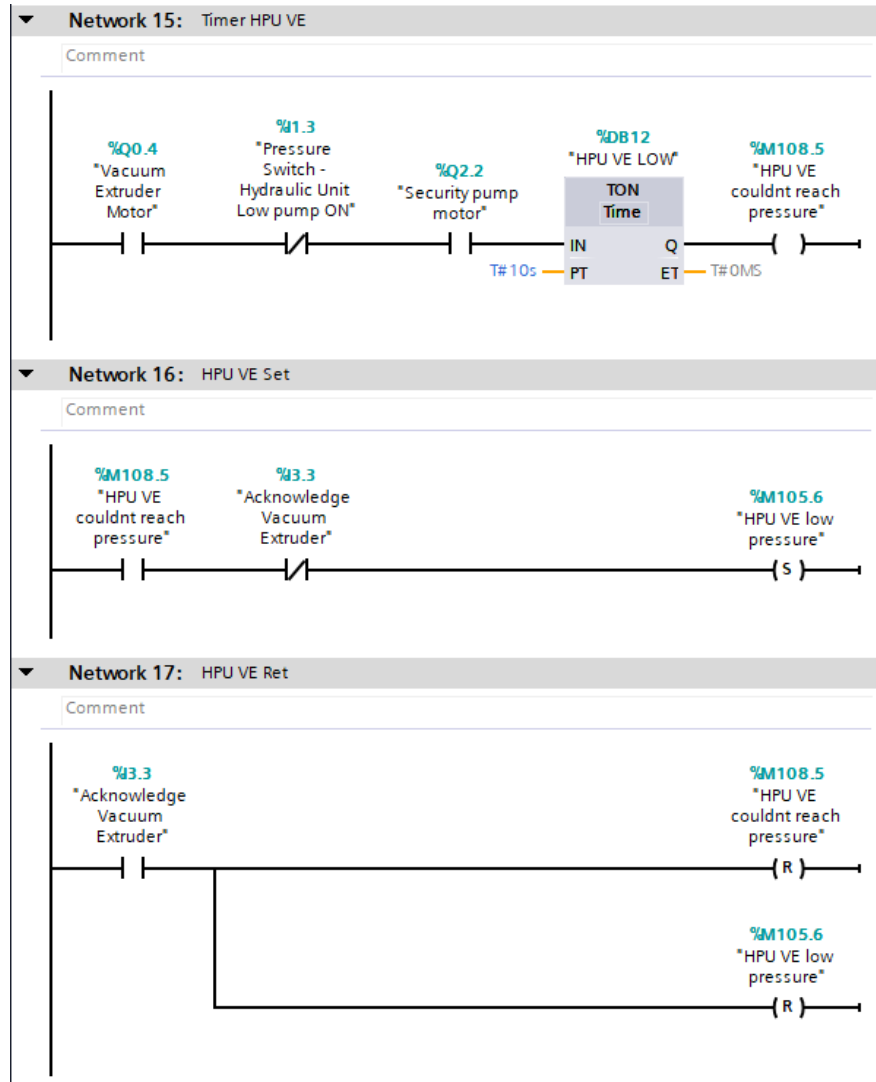


Annexes C

Alarm example 1:



Alarm example 2:



Abstract: The forming section is the section responsible for milling and shaping the bricks, located at the SPMC brick manufactory in the Wilaya Tougourt-Temacine, This section is primarily operated by three machines, Box feeder, Roller mill and Vacuum extruder, However, the section operate using outdated control system unlike the other sections, the relay logic controller on the forming section presents several challenges related to operation, troubleshooting and maintenance as well as absence of HMI supervision. Our project is to make a station improvement to integrate the automatic control of the station using a SIEMENS S7-300 PLC, as well as adding instruments to improve the performance and functionality of the section, for this we carried out a practical final internship within the SPMC unit to better understand the operation of the station and to acquire the necessary data for our project.

ملخص: القسم التشكيل هو القسم المسؤول عن طحن وتشكيل الطوب، ويقع في مصنع الطوب SPMC في ولاية توقرت - تماسين. يعتمد تشغيل هذا القسم بشكل أساسي على ثلاث آلات، مغذي، مطحنة، وآلة البثق الفراغي. إلا أن هذا القسم يعمل بنظام تحكم قديم على عكس باقي الأقسام، حيث يعتمد على متحكم منطقي يعمل بالمرحلات (Relay Logic Controller)، مما يسبب العديد من التحديات المتعلقة بالتشغيل، واستكشاف الأعطال، والصيانة، بالإضافة إلى غياب واجهة الإشراف (HMI). يهدف مشروعنا في تحسين محطة التشكيل في الشركة من خلال دمج التحكم الآلي فيها باستخدام جهاز التحكم من نوع SIEMENS S7-300، بالإضافة إلى إضافة أجهزة صناعية لتحسين أداء ووظائف القسم. ولتحقيق ذلك، أجرينا تدريباً نهائياً عملياً داخل شركة SPMC لفهم كيفية تشغيل المحطة بشكل أفضل وجمع البيانات اللازمة لإنجاز مشروعنا.

Résumé: La section de formage est responsable du broyage et moulage des briques, et elle est située dans l'usine de briques SPMC, à la wilaya de Tougourt - Temacine, Le fonctionnement de cette section repose principalement sur trois machines, Dosseur, Laminoir et Mouleuse. Cependant, contrairement aux autres sections, cette dernière utilise un système de commande obsolète basé sur un contrôleur logique à relais, ce qui engendre plusieurs difficultés en matière d'exploitation, de dépannage et de maintenance, en plus de l'absence d'une interface homme-machine (IHM). Notre projet vise à améliorer la station de formage de l'entreprise en intégrant un système de contrôle automatisé à l'aide d'un automate programmable SIEMENS S7-300, ainsi qu'à ajouter des dispositifs industriels pour améliorer les performances et les fonctionnalités de la section. Pour cela, nous avons effectué un stage pratique de fin d'études au sein de l'unité SPMC afin de mieux comprendre le fonctionnement de la station et de collecter les données nécessaires à la réalisation de notre projet.