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MASTER

In **Electrical and Electronic Engineering**

Option: **Control Engineering**

Title:

Programming a Stacking & Packaging Machine and a Pick & Place Robot using Omron CJ1M PLC

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Registration Number:……./2022

I- Abstract

Today, automation became critical in the field of industry. Eliminating the need for human labor is the main objective by making the different devices and machines do their specific operations and tasks without human intervention. In our project entitled “Programming a Stacking & Packaging Machine and a Pick & Place Robot”, we used our background in the industrial automation to automate the process of two machines. Stacking and Packaging machine is a machine that is the ending station of plinth production line, its task is to stack a certain number of plinth pieces and prepare it to be packaged in a box, then, these boxes will be dealt with by a Pick and Place robot that is responsible of placing the boxes on a pallet in a defined order. The two machines are related through a conveyor. Basically, these machines depend on the readings of sensors and buttons, those readings are collected by PLCs that treat this data and then give output signals depending on an already transferred PLC Program. The Human Machine Interfaces (HMIs) provide the visualization and control of the process, by displaying the different parameters and variables which will allow the operator to supervise the operations. We created a PLC program and an HMI for both machines ,we only implemented the Stacking and Packaging machine program because the Pick and Place robot is not ready yet.

II- Acknowledgement

We start first to thank our supervisor Dr. HACHOUR Ouarda for her support and advices and for believing in our abilities to accomplish this piece of work.

We cannot express enough thanks to the employees Céramique Boumerdes Company, especially Nabil Malouadjmi , Amine Boutaleb , Idriss , Abdelkarim … for helping and working with us along the period we spent in the company, we offer our sincere appreciation for the learning opportunities they gave us.

The completion of this project could not have been accomplished without the courses of Mr.OUADI who teached us the basics of the PLC.

Another special appreciation goes to all the teachers, and workers of INELEC and everyone who contributed in our formation at this institute during the last five years.

Finaly we are extremely grateful to our parents for their unconditional love, care, support and for the sacrifices they made to provide the best conditions for us to get the best possible education.

III- Dedication

This project is wholeheartedly dedicated to our beloved parents, who have been our source of inspiration and gave us strength when we thought of giving up, they continually provide their moral, spiritual, emotional and financial support.

To our brothers, sisters, relatives, mentor, friends, and classmates who shared their words of advice and encouragement to finish this study.

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VI- List of Abbreviations

CB	Céramique Boumerdes
CPU	Central Processing Unit
FBD	Functional Block Diagram
HMI	Human Machine Interface
IL	Instructions List
LD	Ladder Diagram
PAC	Programmable Automation Control
PLC	Programmable Logic Controller
SCADA	Supervisory Control And Data Acquisition
SFC	Sequential Functional Charts
ST	Structured Text
UI	Graphical User Interface

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GENERAL INTRODUCTION

General Introduction

Industrial automation is the control of machines and processes used in the industry through technologies to replace a human being. The main purpose of automation is to: increase the productivity since these systems can work 24 hours a day, decrease the cost associated with humans (i.e., wages and benefits) and reduce the errors. However, the automation has its negative side including: the high initial cost, minimizing the worker employment and the eradication of some ethical human oversight.

Due to its huge benefits and advantages the automation has spread in various industries, it has become essential to all factories whatever the nature of the production or the quantity. In brief, industrial automation is defined as the use of certain technologies and control devices that results an autonomous system with defined processes and a minimum human intervention. The automation devices include: PCs (Programmable Controller), PLCs (Programmable Logic Controller), PACs (Programmable Automation Controller) etc.

CB "Céramique Boumerdes" company produces all kinds of ceramic products: floor tiles, wall tiles, tile plinth…. Each product has its own production line and each line consists of different machines, these machines are controlled with systems based on PLCs, specifically OMRON PLCs.

In this project we are going to study the stacking and packaging machine and its process in order to provide a program to control the machine based on an industrial programmable logic controller OMRON CJ1M. After the stacking process is done, the worker has to fill the packaging boxes with the already stacked plinths by the machine and then place the box on a pallet which is inconvenient due to a lot of factors: safety risks, slow pace of human labor, possible product loss due to human error. So, we proposed to the company a PLC program for a pick and place robot machine for the purpose of minimizing the human intervention in the process.

Our work is divided into the following chapters:

- In the first chapter we are going to present and describe the PLC and its programming and the tools used to program it.
- The second chapter is devoted to disassemble both the stacking and packaging machine and the pick and place robot machine in order to discover the various components and understand their particular functions.
- In the third chapter, we will show and explain the features of the CX-Programmer software and how to create new projects and programs using ladder language.
- In the last chapter we will introduce CX-Designer, a software used to program and design Human-Machine Interfaces (HMIs) in order to test the functionality of our programs (Stacking and packaging machine + pick and place machine).

Chapter I
Programmable Logic Controller (PLC)

Chapter I: Programmable Logic Controller

1- Introduction:

This chapter will present automation systems, as well as their essential features and functionalities. Following that, we will show the PLC (Programmable Logic Controller) from all angles (important features, hardware components, programming) with a focus on the OMRON CJ1M, which is the PLC utilized in our project.

2- Automation systems:

An automation system is a collection of sensors, controllers, and actuators that work together to carry out a certain function or process. Automation systems are often generated from everyday manual tasks such as lifting, cutting, drilling, assembling, stacking, sorting, packing, and so on. Motors, pumps, valves, conveyors, and other machinery are used to carry out the procedures. These systems rely on collected measurements and control orders based on the nature of the operation with minimum human interaction [1].

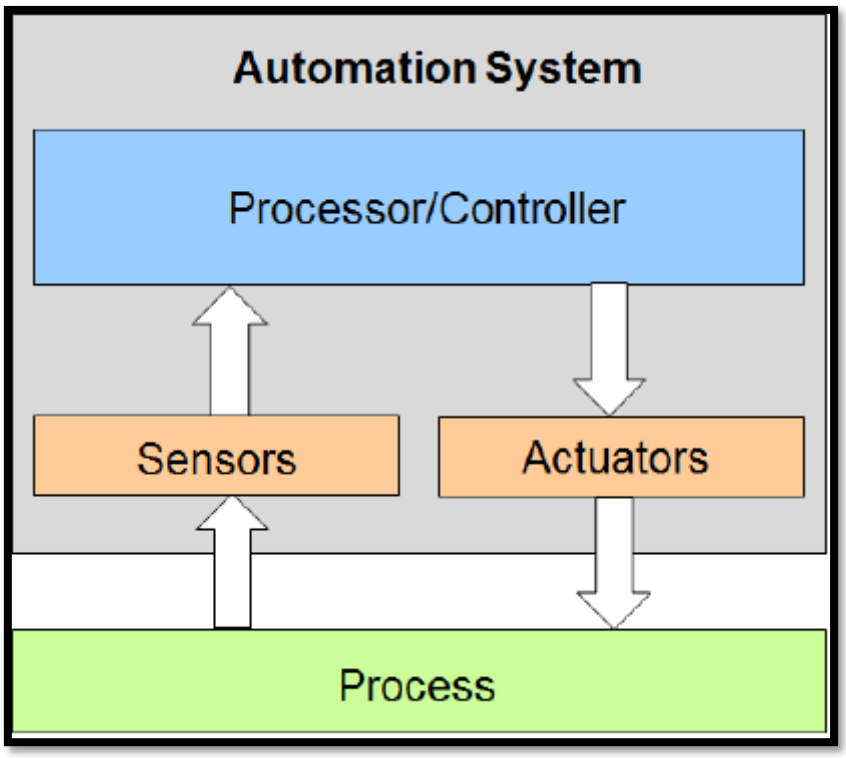


Figure 1.1:Basic elements of an automation system

3- Programmable logic controllers (PLCs):

A digital computer called a PLC (programmable logic controller) is used in industrial automation to automate a variety of electromechanical activities (machines or even entire production lines). A microprocessor that has been programmed is included. The program is created on a computer and then sent via cable to the plc. The program is then stored in a non-volatile memory after that. [3].

The PLC gathers information from sensors or other input devices, processes it, and then activates outputs in accordance with preset parameters. [14].

Depending on the inputs and outputs, a PLC may monitor and record run-time data such as machine productivity or operating temperature, start and stop operations automatically, produce alarms in the event of a machine breakdown, and more. [3].

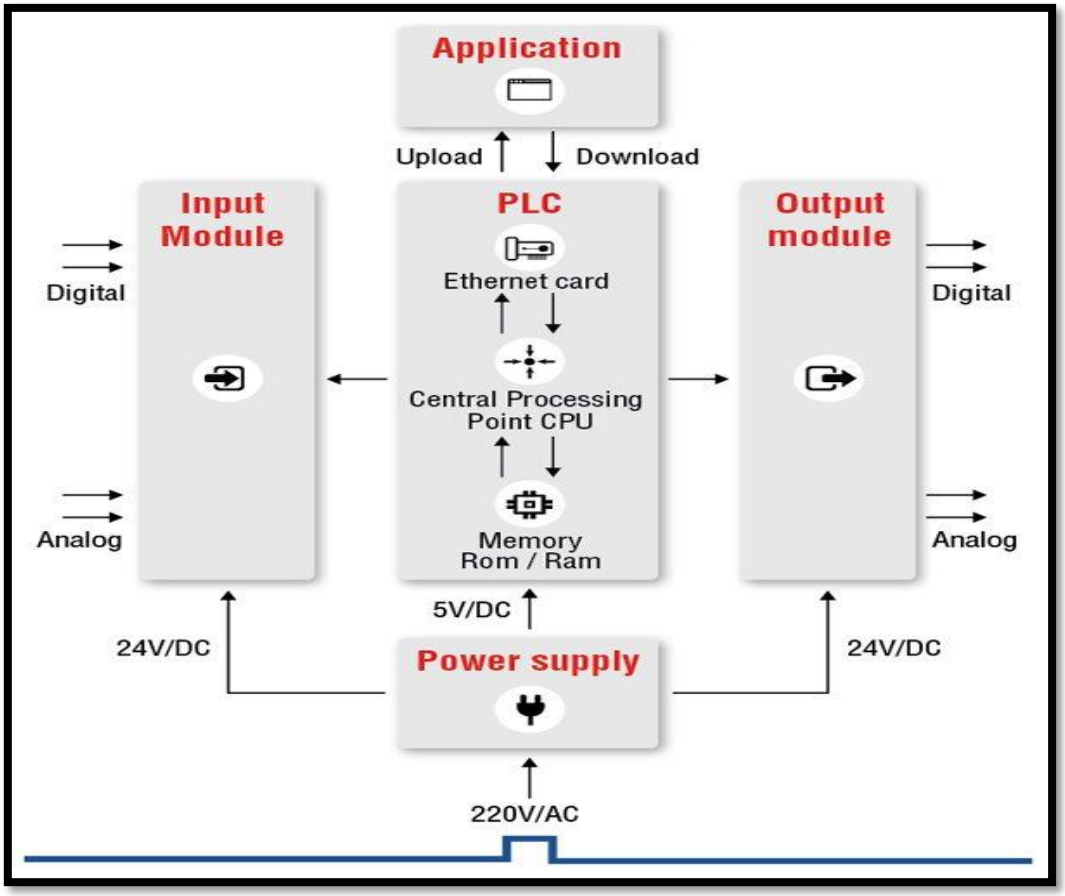


Figure 1.2: PLC's operating process

4- PLC's key features:

PLC's key features include:

I/O: While the input and output modules link the PLC to the machinery, the CPU stores and processes data. I/O modules deliver data to the CPU and cause certain outcomes. Analog or digital I/O modules are available. It should be noted that I/O can be combined to provide the ideal configuration for a given application [14].

Communications: PLCs must communicate with other system types in addition to input and output devices. For instance, a user could need to transmit data from a PLC application to a SCADA system (supervisory control and data acquisition) that can track several connected devices. A PLC has many communication protocols and ports to facilitate communication between the PLC and other systems [14].

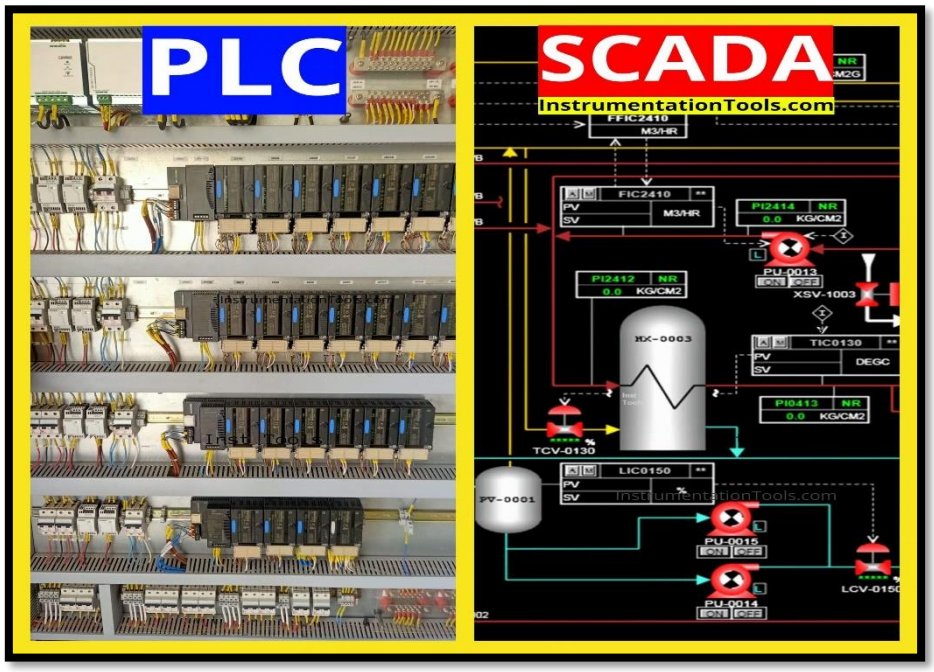


Figure 1.3: An example of a SCADA system.

HMI: An HMI, or Human Machine Interface, is required to communicate with the PLC in real time. These operator interfaces can range from basic text-readout displays with a keyboard to sizable touchscreen displays that resemble consumer electronics, but they are all designed to let operators examine and input data to the PLC in real time.

Figure 1.4: An example of an HMI

5- PLC Hardware:

PLC hardware components includes:

CPU: Checks the PLC on a regular basis to prevent faults and conducts functions such as arithmetic and logic operations.

Memory: System ROM maintains fixed data utilized by the CPU indefinitely, whereas RAM stores input and output device information, timer values, counters, and other internal devices.

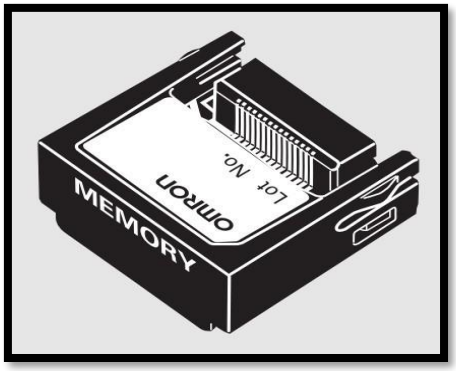


Figure 1.5: OMRON Memory unit

O/P section: This section gives output control over devices like pumps, solenoids, lights, and motors.

Figure 1.6: OMRON digital output module

I/O section: An input section that tracks on field devices like switches and sensors.

Figure 1.7: OMRON digital input module

Power supply: Though most PLCs work at 24 VDC or 220VAC, some have isolated power supplies.

Figure 1.8: OMRON Power Supply

Programming device: Is used to feed the program into the processor's memory.

6- PLC Programming:

A program consists of a sequence of program instructions. These instructions determine the functionality of the PLC and they are processed sequentially, in the order in which they were entered by the programmer. To create a PLC program, we need to analyze the process to be controlled and break it up into steps that can be represented by instructions.

The 5 most popular types of PLC Programming Languages are:

1. Ladder Diagram (LD)
2. Sequential Function Charts (SFC)
3. Function Block Diagram (FBD)
4. Structured Text (ST)
5. Instruction List (IL)

6.1- Ladder Diagram (LD):

Ladder Diagram was initially designed by relay-logic, which employed physical devices to regulate operations like as switches and mechanical relays.

Ladder Diagram replaces everything but the physical components that require an electrical signal to be triggered with internal logic.

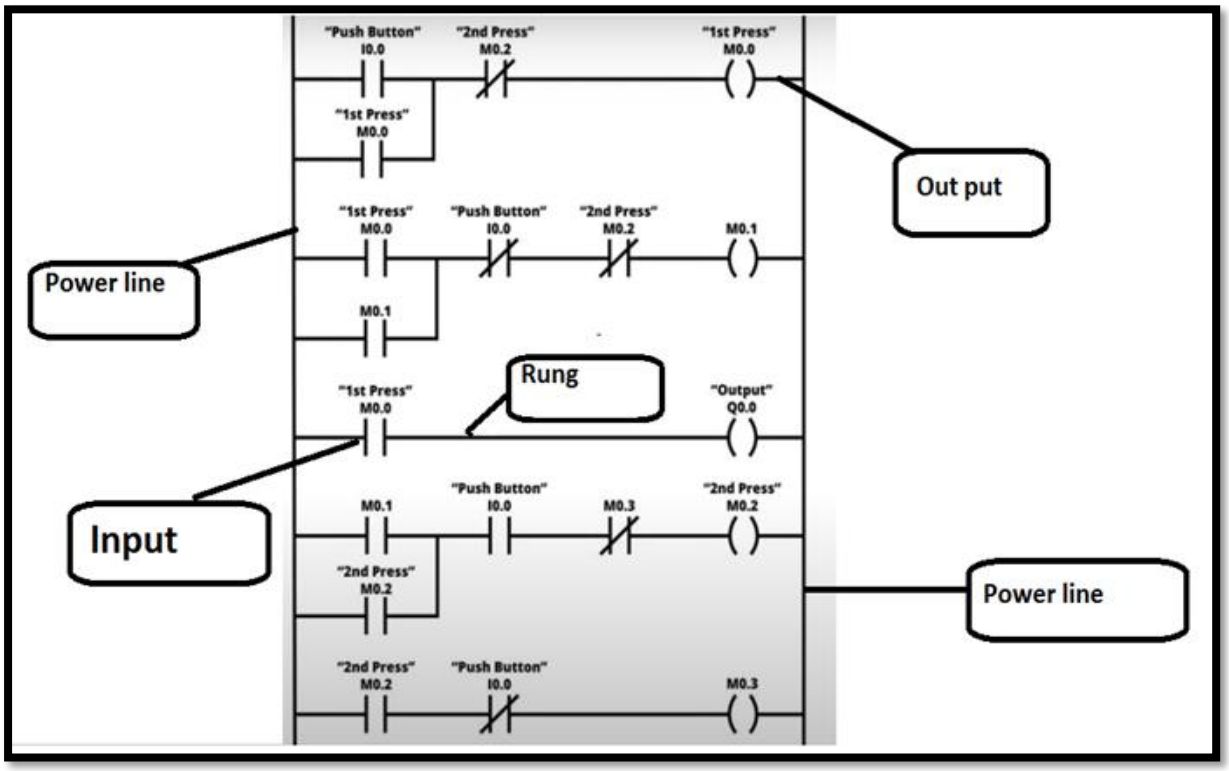


Figure 1.9: A Ladder Diagram program example.

We can program all the necessary input conditions to affect the output conditions, whether logical or physical [4].

- It is the language we are going to use in our project.

6.2- Sequential Functional Charts (SFC):

SFCs are visual programming languages, akin to flow charts for computer science algorithms, rather than text-based programming languages. Steps and transitions are the basic ideas underpinning SFCs. A step is essentially a function inside the entire system, such as a single machine process. A transition is just the movement from one phase or state to another [4].

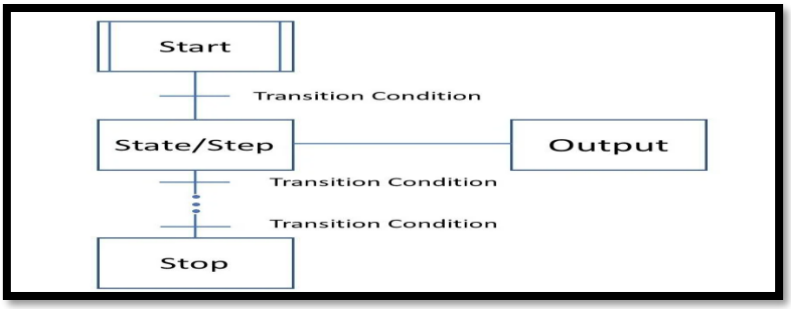


Figure 1.10: SFC Programming example.

6.3- Functional Block Diagram (FBD):

The Function Block Diagram is another graphical language. The Function Block Diagram depicts a function between inputs and outputs that are linked together in blocks by connecting lines [4].

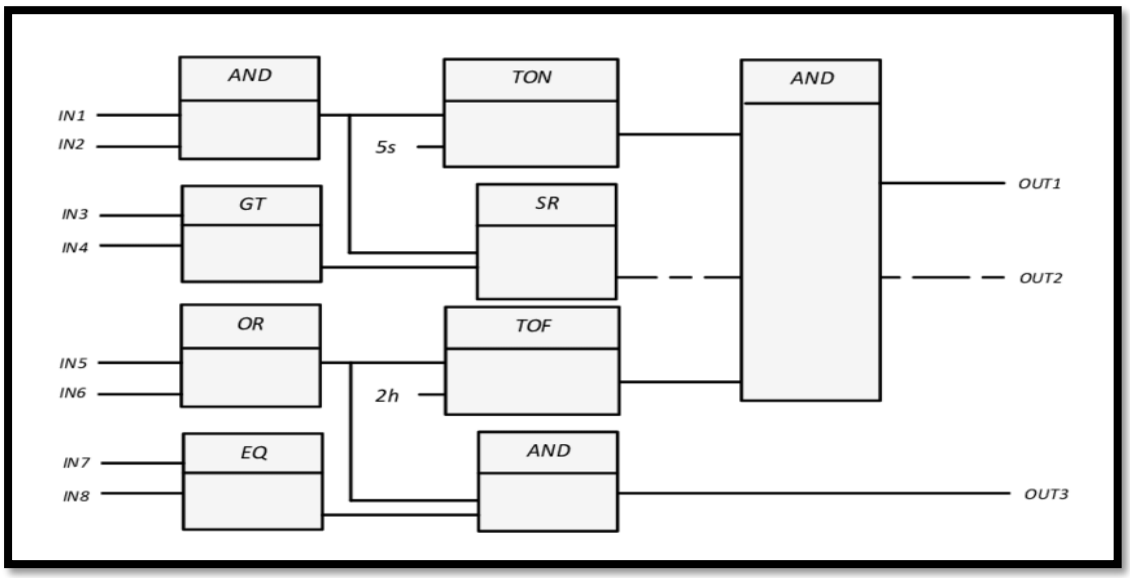


Figure 1.11: FBD Programming example.

6.4- Structured Text (ST):

In contrast to the graphics-based ladder diagram, SFC or FBD, the programming language is text-based. Structured Text is a high-level programming language similar to Basic, Pascal, and "C." It is an extremely powerful tool that can perform complex operations involving algorithms and mathematical functions, as well as repetitive jobs. The code employs statements separated by semicolons, and these statements change either inputs, outputs, or variables. [4].

```
IF START=1
THEN LAMP:=1;
ELSE IF STOP=1
THEN LAMP:=0;
END_IF;
END_IF;
```

Figure 1.12: ST program example.

6.5- Instruction List (IL):

Assembly Language is similar to the Instruction List language. The Instruction List comprises instructions, each on a new line, with any comments we wish to add at the end of each line [4].

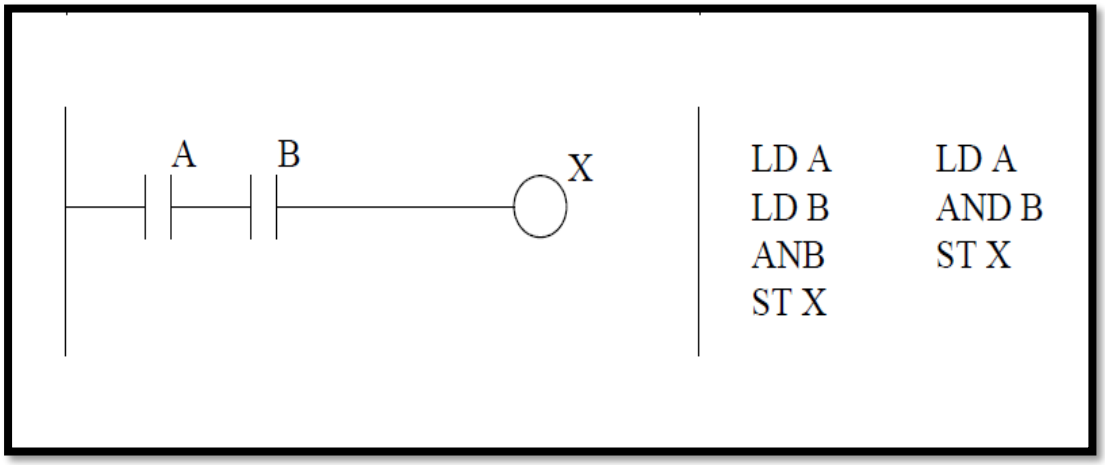


Figure 1.13: Ladder Diagram representation of an Instruction List program

- The main advantages of the Ladder Diagram language are:

1. The rungs allow it to be organized and easy to follow.
2. It also allows us to record remarks that are clearly apparent. It successfully supports online editing.
3. It supports online editing very successfully.

7- OMRON PLC:

In the automation sector, there are dozens of producers of Programmable Logic Controllers. Omron PLC is a major manufacturer of small PLCs for machine automation.

Omron PLC, a Japanese firm, is a prominent maker of tiny PLCs for machine automation. The Japanese firm offers a diverse range of scalable industrial PLC controllers for use in individual machines or as part of a larger machine control installation. It also offers multiple PLC hardware types with various processing and I/O options for modest to big factory automation systems [6].

8- CJ1M series PLC:

The CJ1M expands the CJ1 Series to satisfy the reduced requirements of smaller machine designs: more functionality, less memory, and built-in I/O. In compared to the more capable CJ1G/H CPUs, the CJ1M provides a low-cost alternative for applications requiring fewer I/Os and shorter programs [5].

Figure 1.14: CPU module of an OMRON CJ1M PLC

9- An overview on CX-Programmer:

CX programmer is a very handy programming software for all PLC of Omron, it is fully integrated into the CX-One software series. This software has a variety of features that speed up the pace of PLC program development, it also makes the programs simple and easy to read and edit [7].

10- Integrated simulator:

Integrated Simulation is a function of CX-One (version 2.0 or higher) that simultaneously tests interoperability between the ladder program and PT (touch panel) and checks screen operation on the computer [8].

11- Conclusion:

This chapter was dedicated to introducing the automation systems, control systems, and the PLC and the tools used to program it with an emphasis on the Omron CJ1M CPU12. In the next chapter, we are going to discover the “stacking and packaging” and the “pick and place” different components and their functionality.

Chapter II

The Stacking & Packaging Machine and Pick & Place Robot

1- Introduction:

In the preceding chapter we introduced the plc and its generalities. In this chapter, we will present the machines and the different components used on this project, and we will see a detailed presentation of them, there are two machines, the first one is the stacking and packaging machine, and the second one is the pick and place robot,

2- The stacking & packaging machine:

2.1- General Description:

It is the last part of the plinth's production line, it consists of transportation conveyor, a stacking part where a define of number of plinths is to be collected, this collection will be put down on the final conveyor through an elevator.

2.1.1- Conveyor:

2.1.1.1- Work Cycle Description:

The conveyor belt is designed for handling products, because it transports/handles the product on the machine itself a belt/pulley translation movement. It is used to complete a complex installation having the function of connection between the machines for processing the product. It is considered as a module when it is small, or as a line when it occupies several meters.

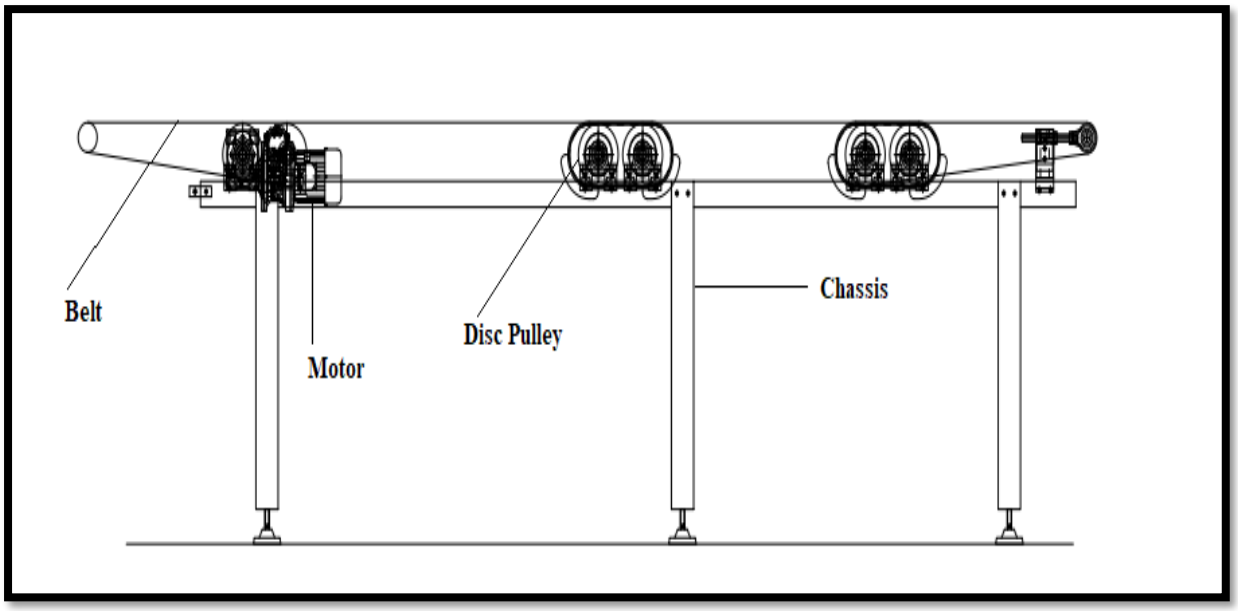


Figure 2.1: Conveyor's sideview

2.1.1.2- Main Components:

Chassis:

Structure determining the length and shape of the machine, consisting of L-profiles of steel, called slats, fixed by means of bolts form of H or Y.
The feet can be equipped with adjustment feet to allow you to at the machine and anchor it to the ground. The entire frame can be completely oven-painted or zinc-plated.

Disc pulley:

Built mainly in cast iron, the diameter and the geometry of its gorge change depending on the use of the BELT CONVEYOR. It can be fixed.

Belt:

Industrial model closed by a ring or heat welded, with section, type and length varies according to the conditions of use.

Closing arm:

Structure composed of several elements, having the function of bringing together and may connect the machine to other machines upstream or in downstream. This solution allows the passage of the product from one machine to another regular.

Deflection arm:

Mobile structure composed of different elements, having the function of deflecting the flow of the transported product towards the lines located at different heights. The translation can be carried out by means of a pneumatically controlled pusher or manually.

Transmission:

It is a system of transmission of the movement having the function of drawing and decrease or increase in the speed of transport in the areas concerned belt parts. The transmission is engaged by means of two sprockets mounted on the pulley chock shafts and connected between they by a simple steel roller chain.

Motorization:

For handling of pulleys and belts there are electric motors three-phase asynchronous coupled with a reducer and sometimes with a moto variator allowing manual adjustment of operating speed (adjustment to be made only when the motor is actuated to avoid breakage of the motor dimmer).

Adaptations:

In the project phase, depending on the requirements, the machine can be adapted to allow the application of other machines (compensators, dryers, feeders, etc.) or accessories (brushes, dollies, blower groups, etc.) on the conveyor.

Protective structures:

There are fixed guards to protect the operator in the areas dangerous. It is necessary to use tools to remove them and cannot be only when the machine is stopped by authorized personnel and must be put back in place before starting. The fixed protection structures applied to movable parts are:

- **Protective covers:**

Fixed with screws to the frame and constructed of plastic, they are positioned to protect the indirect transmission of the engine by isolating Dangerous area due to belt/pulley winding. They are also mounted to protect transmissions and isolate the area dangerous because of the chain winding. On the oscillating bearing supports are applied plastic material attached to the socket to isolate any drive hazard possibly produced by a small locking bolt and to protect the pad dusty.

- **Finger guards:**

These protections are located near the belt/pulley couplings in the area concerned by the transport. They are made of plastic and are positioned in the guides under the belt and secured with screws.

- **Containment protections:**

In areas where it is permissible to pass under the machine or at the on top of a structure, a fixed protection of perforated sheet metal is attached to the machine, having the function of confinement, in case of accidental fall of the product transported.

- **Fixed Protections:**

They are positioned to protect all moving elements and areas affected by the burner. They can only be removed by the authorized personnel when the machine is shut down and de-energized by zero energy level. The machine should only be operated as long as all the protections, possibly disassembled, are not put back in place properly.

- **Emergency Button:**

It is a red push button, sometimes highlighted by a yellow color unerring. The location of the emergency button covers the entire perimeter of the machine and its hazardous areas. The pusher allows the operator and possibly exposed persons to intervene by immediately setting the machine to zero energy.

- **Dam photocell:**

Located in the area where there can be no perimeter barriers, it acts when relieving a foreign object in the operational zone in putting the machine at zero energy.

2.1.2- Elevator:

If the line is running, the tiles will fit into the stacker. Once the stacker has reached the number of plinth tiles programmed for each stack, it automatically unloads the battery and it is expected to receive from other material, while the pneumatic pusher performs the ejection of the battery to the operator, who will remove it manually. If an alarm of any kind is triggered, the entire line stops and cuts the authorization to the machine by upstream.

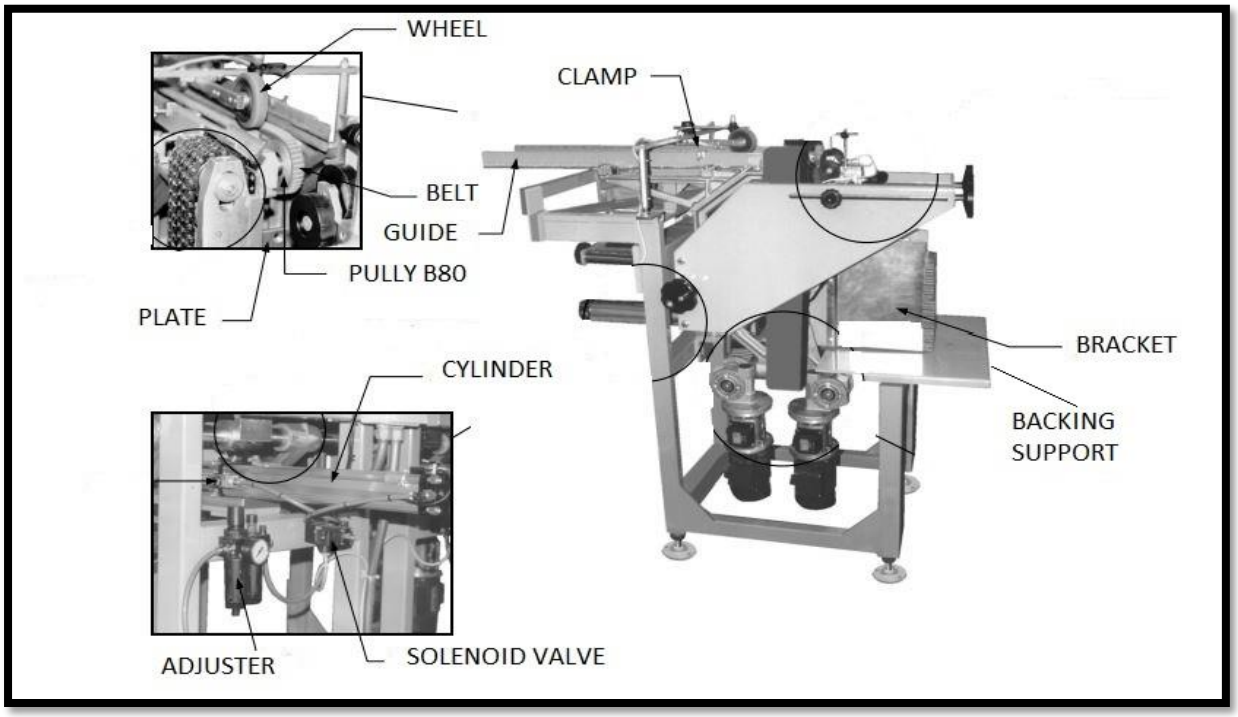


Figure 2.2: Elevator components.

2.1.2.1- Work Cycle Description:

When a plinth arrives to the stacking support, there exist two support wheels that are responsible for stopping the plinth. Now there is a certain space to be left for the next coming plinth, so there exists a photoelectric sensor that gives a signal that allows a small descending action until the sensor is off, that gives the right space to receive the next piece. This process recurs for each piece until a certain number of pieces is reached, at that time the whole set of pieces will be completely descended a photoelectric sensor will detect it and gives order to the pusher to push the set to the backing support. A worker is waiting with the packaging box, once the plinth is boxed, the worker put the box on second conveyor, he must make sense to put the box on his wider side. The box will be transported to the pick and place machine.

2.1.2.2- MAIN COMPONENETS:

Descending Chains:

The device contains four chains, two in each side, a chain has two metallic supports hanging on it able to receive the plinth piece. They are arranged in a way that after every descending action, two supports must be ready to take the working position

Pusher:

A photoelectric sensor will give a signal that allows the pneumatic piston to push the set into the conveyor.

Photoelectric sensors:

By disregarding ambient light and detecting changes in the transmitted light returning to its receiver, industrial photoelectric sensors send predetermined wavelengths of light to measure the distance, absence, or presence of an object. Rugged casings that are perfect for industrial settings house the sensors. The machine depends on a set of photoelectric sensors such as: counting sensor, level sensor, unloading sensor…. We used GRTE18-P2442 produced by Sick company with adjustable (potentiometer) sensing range from 10mm to 400mm.

Figure 2.3: Photoelectric sensor.

2.1.3- The second conveyor:

It is the same as the first one except for the height which is lower, it is the link between our two machines, it transports the packaged box into a position where it can be picked by the pick and place Robot.

3- Pick and place robot:

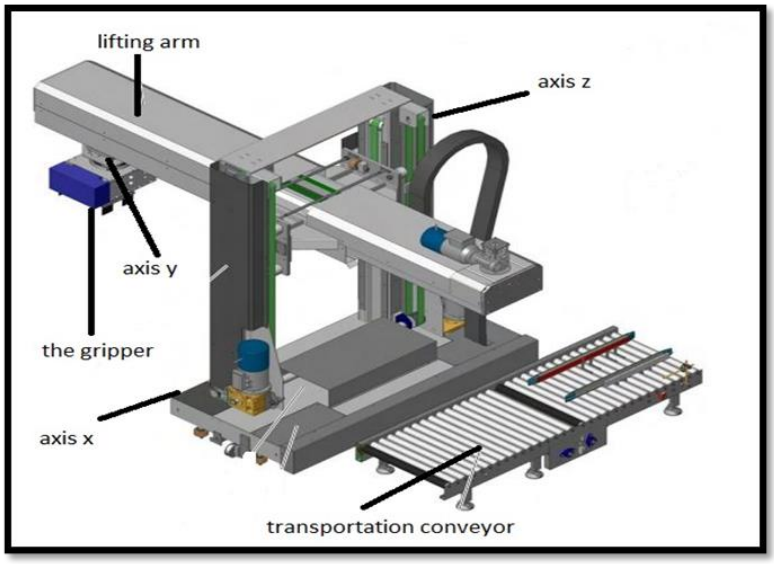


Figure 2.4: Pick and Place robot.

3.1- General Description:

The Pick and place machine is a Cartesian robot, programmable, equipped with a clutch and motorized roller conveyor at the sampling point. Can be equipped with various optional devices such as: a rotator which provides for 90° tipping of the incoming packet of the roller conveyor; other rotator which provides for tipping and to group one to two packages; the empty pallet's automatic picker arms, mounted on the clamp. It is composed from a column structure with the lifting arm, the axis x trolley and the axis y and lift column axis z. The gripper, which can be single (for a single package) or double (for two bundled packages), works with pneumatic control with regard to the pinching system and via a gear motor for rotation (j axis); with 90° clockwise rotation angles, 90° counter-clockwise. The rotation system is equipped with an electromagnetic brake, independent of the gearmotor, which guarantees stability of the position without any type of mechanical play due to transmissions motorization on the three Cartesian axes and the rotation of the clamp are carried out via three-phase asynchronous motor drivers, controlled by inverter. The management of the machine is entrusted to a PLC, equipped with bi-directional quick metering modules, which operate the inverters directly with a numerical control. There is also a series of transportation conveyor, electrical table with user interface. for the security there are protection barriers in metal on three sides, on the fourth side, there is a photo electric cells of the type emitter -receiver.

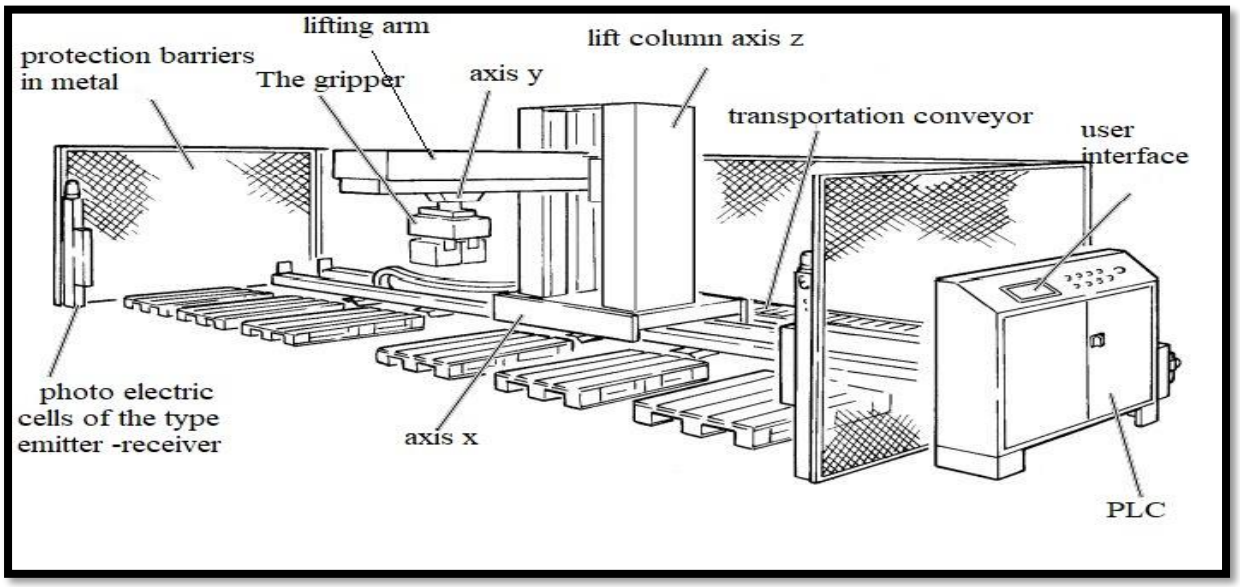


Figure 2.5: Key features for pick and place process.

3.2- Work Cycle Description:

The machine software plans to control the filling of the different pallets dynamically, allowing the operator to group pallets for various product .
The user interface is via an HMI (touch screen), placed on the electrical panel, which allows the operator to fully manage the operation of the entire palletizer.
The programming interface is made via a personal computer; it allows visualization and the manipulation of all the data relating to the pallets , able to store them on the hard disk, thus avoiding imposing significant limitations to the management of these schemes .The software, for the input data, asks to introduce the dimensions of the packets and pallets, and number of boxes per row (if already known, if not, automatically calculates the maximum possible) and possibly how much (measurement) the diagram should overflow from the pallet. Once the data entry phase is complete, everything takes place without possibility of error.
During automatic operation, when it is necessary to find a packet associated with a code that has a destination pallet at the pre-lift point, the machine picks the package also removing the packet will then be brought to the destination pallet, thus increasing the number of associated packets to the pallet in question. Once this is done, the machine returns to the pick point for repeat the cycle just described.

3.3- Industrial Encoder:

It is a commonplace technology in the industrial sector. Encoders are used in a variety of ways, it is the main device in the process of controlling the movements in the 3 axes, it is always used to detect the speed and direction of motion in one form or another. This is a critical process that enables all kinds of different motion applications, where each pulse from the encoder indicates a certain amount distance crossed.

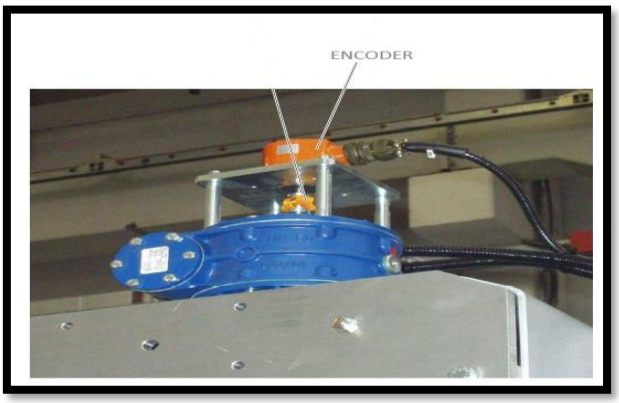


Figure 2.6: Y-axis slide's incremental encoder (4985254).

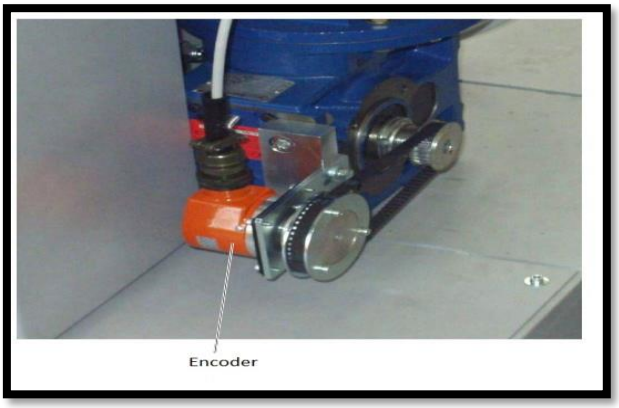


Figure 2.7: Z-axis slide's incremental encoder(4985254)..

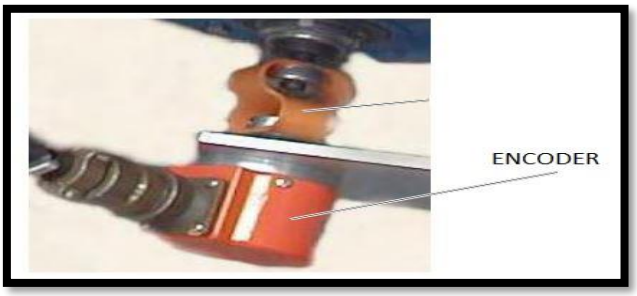


Figure 2.8: X-axis slide's incremental encoder (4985254).

3.4- The Pick and Place Process:

- Starting the process:

Before everything, the pick and place machine will not start working without this step, the box moves on the transportation conveyor, the moment when the photocell detects the box, it gives a signal to the pick and place machine to start the process the Gipper moves to the box location following the indicated coordinates by the user, if there is not a detection, nothing will start.

- **Picking step:**

As the starting step finshes , the pick and place machine commence the process of picking the box , the is open at the beginning , when the gripper ditects the box through a sensor, it will automaticaly close.

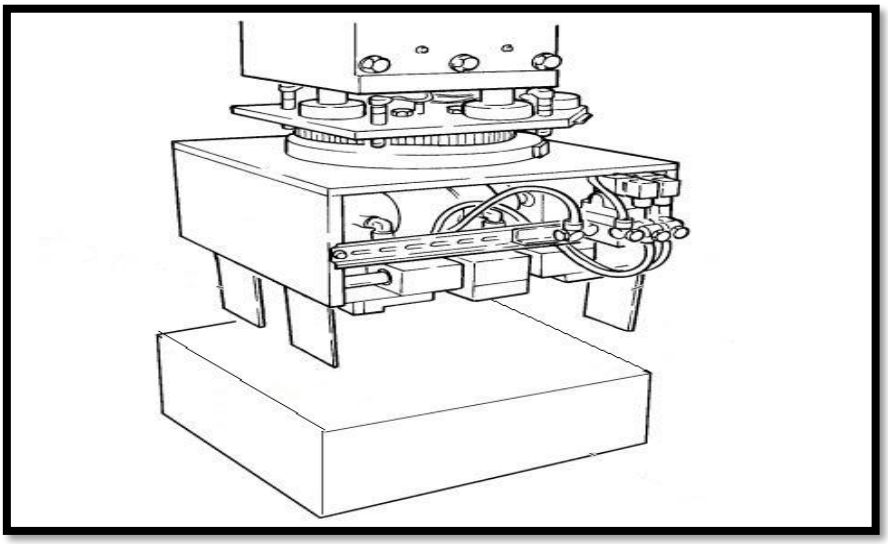


Figure 2.9: Robot's gripper.

- **Placing step:**

Once the box is picked by the Gipper, it goes back to the Gipper's initial position and then it restarts moving towards the 1st box 'position on the pallet according to the given coordinates, the same will be done for the rest of the boxes.

- **Position reinitialization:**

When the box is put on its position in the pallet, the Gripper returns to the initial position and it will check if there is another box to move to the next pick and place process of this box

3.5- Security of the machine:

The machine is equipped with devices for the protection of the worker when he is in the working area as shown in figure 2.10 .

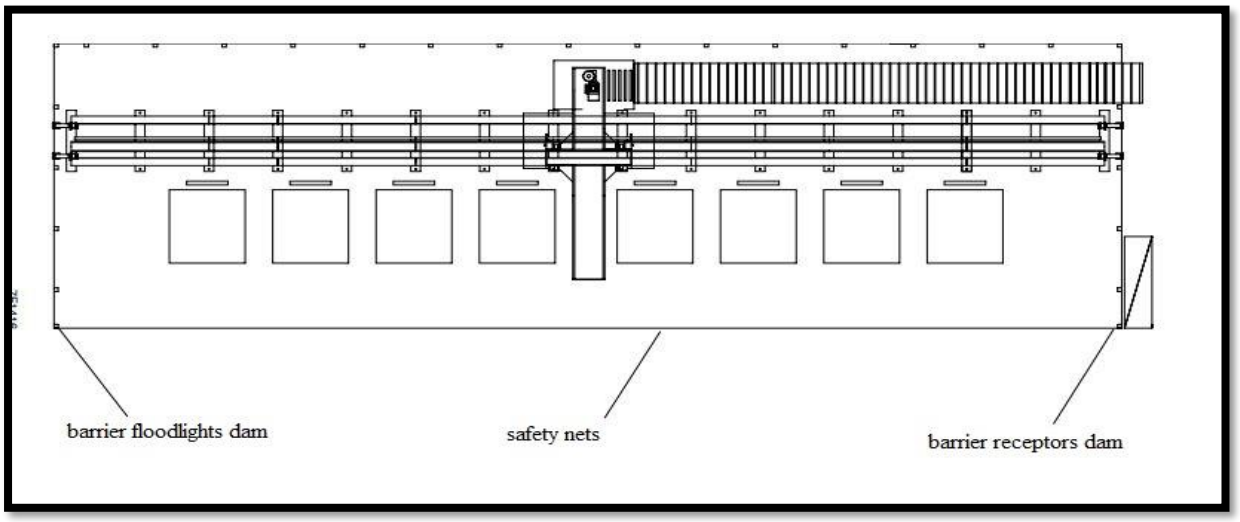


Figure 2.10: Pick and place safety system.

3.6- The desired result of the process:

The robot is designed to pick the boxes from the conveyor and place it on the pallet , the purpose of our robot is to place 100 box . The pallet will contain 10 layers , each layer is filled by 10 boxes . The neighbering layers are organised oppositely (if layer 1 is odered vertically , the boxes in layer 2 will be odered horizontally) , in order to maintain the stability of the pallet when transporting it .

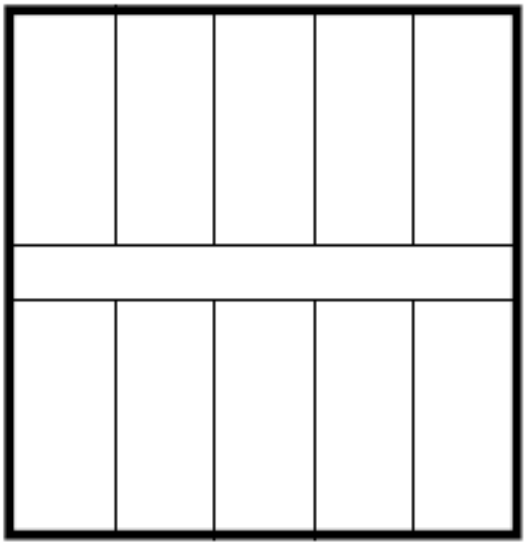


Figure 2.11: Horizontal order of the boxes.

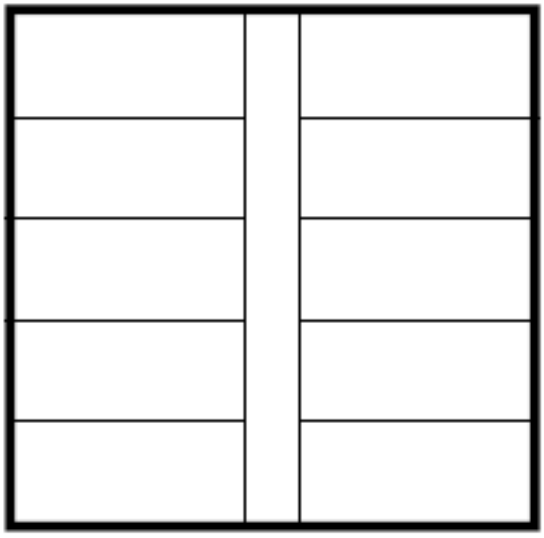


Figure 2.12: Vertical order of the boxes.

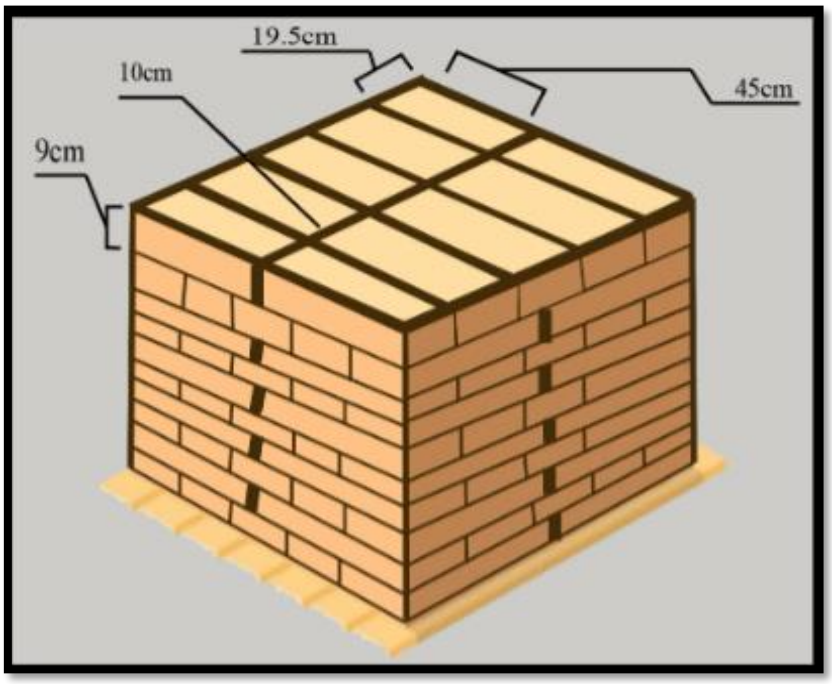


Figure 2.13: The desired final order of the pallet.

5- Conclusion:

At the end of this chapter, we are fully informed about the machines from all the different aspects, we can move to the programming part. Next chapter is a detailed introduction and explanation of CX programmer.

Chapter III

CX-Programmer Description and Programming Procedure

Chapter III: CX-Programmer Description and Programming Procedure

1- Introduction:

After introducing the two machines' components and explain how they function in the preceding chapter. In this chapter, our main objective is to provide a detailed explanation about CX-Programmer software and the steps followed in creating a new project and starting programming in ladder language.

2- CX-Programmer features:

When it comes to Omron PLCs, CX-Programmer is the standard programming software. It includes a variety of features to speed up the development of PLC program.

2.1– Structures and Arrays:

Data blocks, whether arrays or structures, can be used. Using structures and arrays as In/Out variables for a function block allows for the straightforward passing of any arguments in a consistent pattern, which can improve program readability during development and maintenance. [9].

2.2-Timers and counters:

To make it easier to use TIMERS (count-down) and COUNTER (count-up) symbols in ladder programs, CX-Programmer offers unique types for these symbols. We can only access them via their names in order to reset or check them. When a program grows or rungs are copied to a new project, address resolution requires zero maintenance. It also accepts as a type array of timers and counters [9].

2.3-Smart input:

For quicker programming, a smarter way to enter inputs with less keys to press, is available in the software. Intuitive windows, symbol browsing and tool tip help mean less typos. When typing, predictive-text browser pops up and shows possible matches to select. Symbol addresses for inputs and outputs are automatically incremented.
Copy/paste tool is available which allows quick duplication with sequential addresses. No need for manual drawing of the rungs because it will automatically be filled [9].

2.4-Other features:

- Address Reference Tool search with wildcards to find the symbol we want to check.

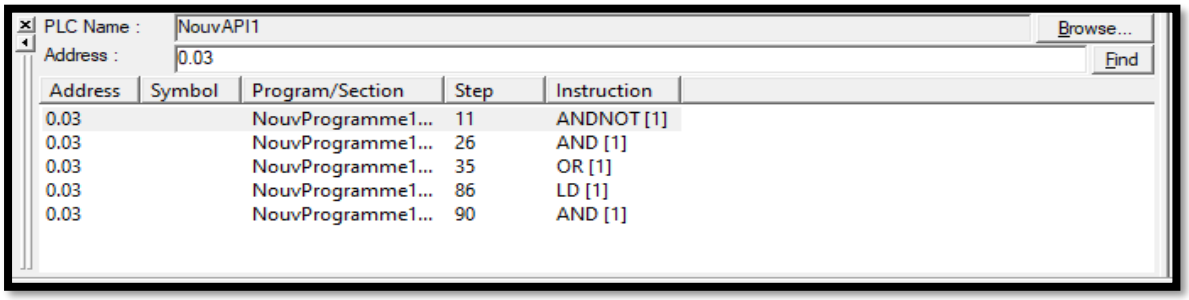


Figure 3.1: Address Reference Tool

- EM Area can be addressed as symbols including force SET /RESET functionality.
- The automatic connection to SERIAL (COM), USB and Ethernet IP devices.

Serial USB Ethernet

Figure 3.2: PLC's type of connections

- CX-Programmer supports whole OMRON PLC families CS1, CJ1/CJ2, C and CV [9].

3- Creating a new project:

- Initial screen when starting CX-Programming:

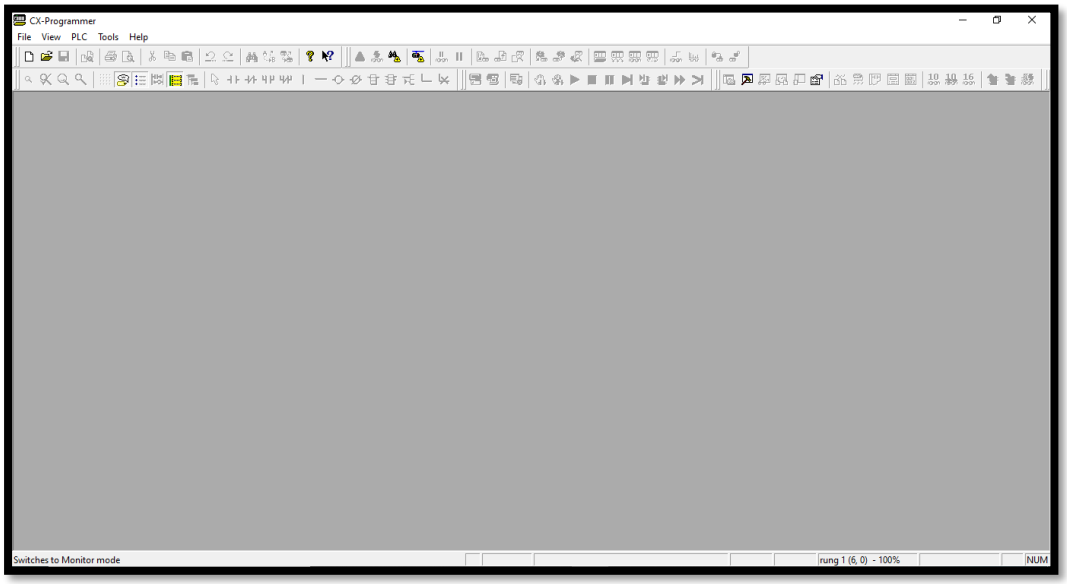


Figure 3.3: CX-Programmer starting screen

- We click on new project icon on the top left corner.

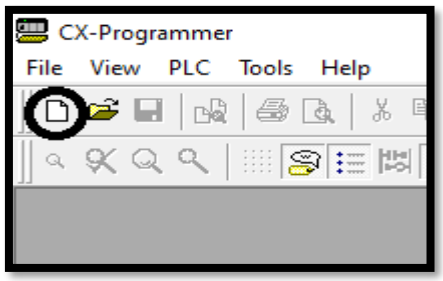


Figure 3.4: Creating new project

- "Change PLC" window will pop up, here we can choose the PLC type and the type of connection between the computer and the device. This window also allows us to choose the type of CPU when clicking on Device Type's "Settings".

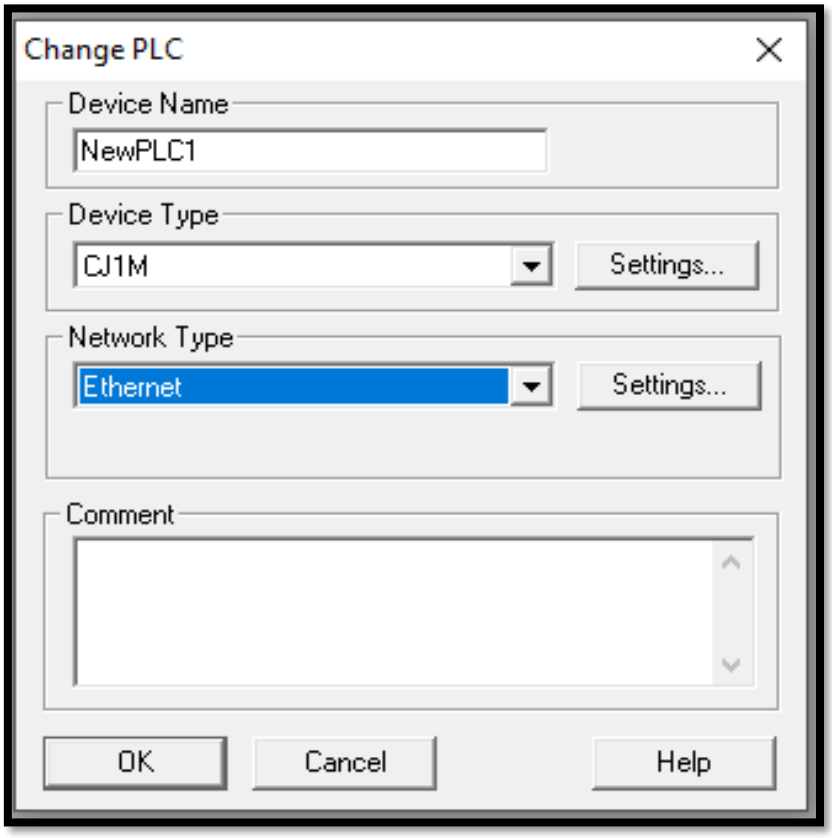


Figure 3.5: "Change PLC" window

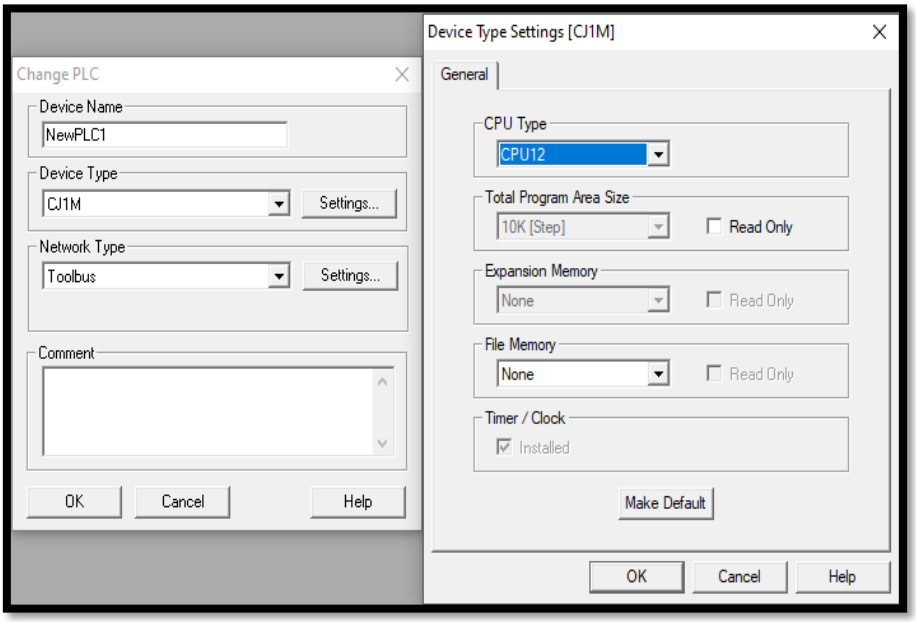


Figure 3.6: Device Type settings

- Now we can start ladder programming.

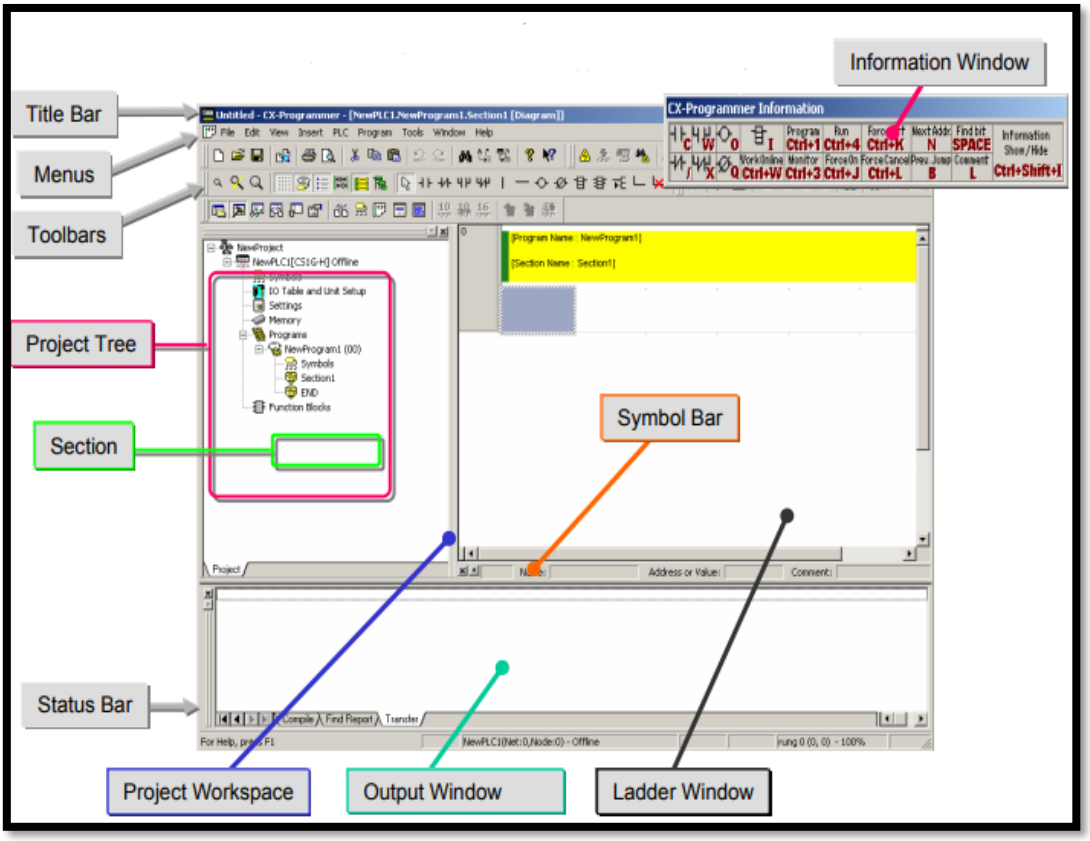


Figure 3.7: CX-Programmer's programming view

- **Title Bar:** Contains the saved file name.
- **Menus:** Enable us to select menu items.
- **Toolbars:** Enable us to select functions by clicking icons. Select [View] -> [Toolbars], and we can select toolbars to be displayed. Dragging toolbars allows us to change the display positions by the group.
- **Section:** Allows the division of one program into a given number of blocks. Each can be created, named and displayed.
- **Project workspace:** Controls programs and data. Enables you to copy data by the element by executing Drag and Drop between different projects or within a project.
- **Ladder window:** A space for creating and editing a ladder program.
- **Output window:** Shows error information in compiling (error check), the results of searching for contacts/coils in the list form and error details when errors occurred while loading a project file.
- **Status Bar:** Shows information such as a PLC name, online/offline, location of an active cell.
- **Information window:** Displays a small window to show the basic shortcut keys used in CX-Programmer.

- **Symbol Bar:** Displays the name, address or value, and comment of the symbol presently selected by the cursor.
- **Project Tree:** Displays information about the project we are working on including PLC specifications, Input Output, PLC Memory and Our program Data (in section).

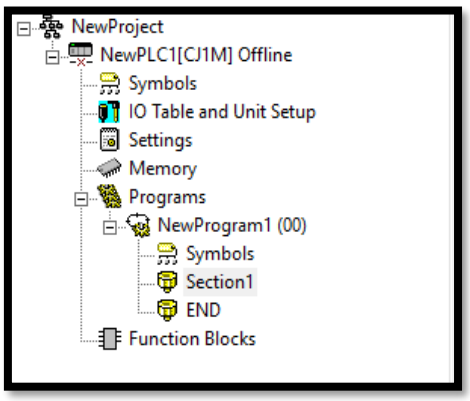


Figure3.8: Project Tree.

- **Data Types, Icons and size:**

Type	**Icon/Size**
BOOL	1Bit
REAL	32Bit
INT	16Bit
WORD (16)	16Bit
UDINT	32Bit
CHANNEL	16Bit
STRING	8Bits
DINT	32Bit
LINT	64Bit
LREAL	64Bit
UDINT-BCD	32Bit
DWORD (32)	32Bit
LWORD (64)	64Bit
FUNCTIONBLOCK	/
UINT	16Bit
UINT-BCD	16Bit
ULINT	64Bit
COUNTER	/ 16Bit
TIMER	/ 16Bit

Table 3.1: Types, Size and Icons of data.

4- Creating a program:

- After checking that the cursor is at the top left corner workspace window, we can start programming.

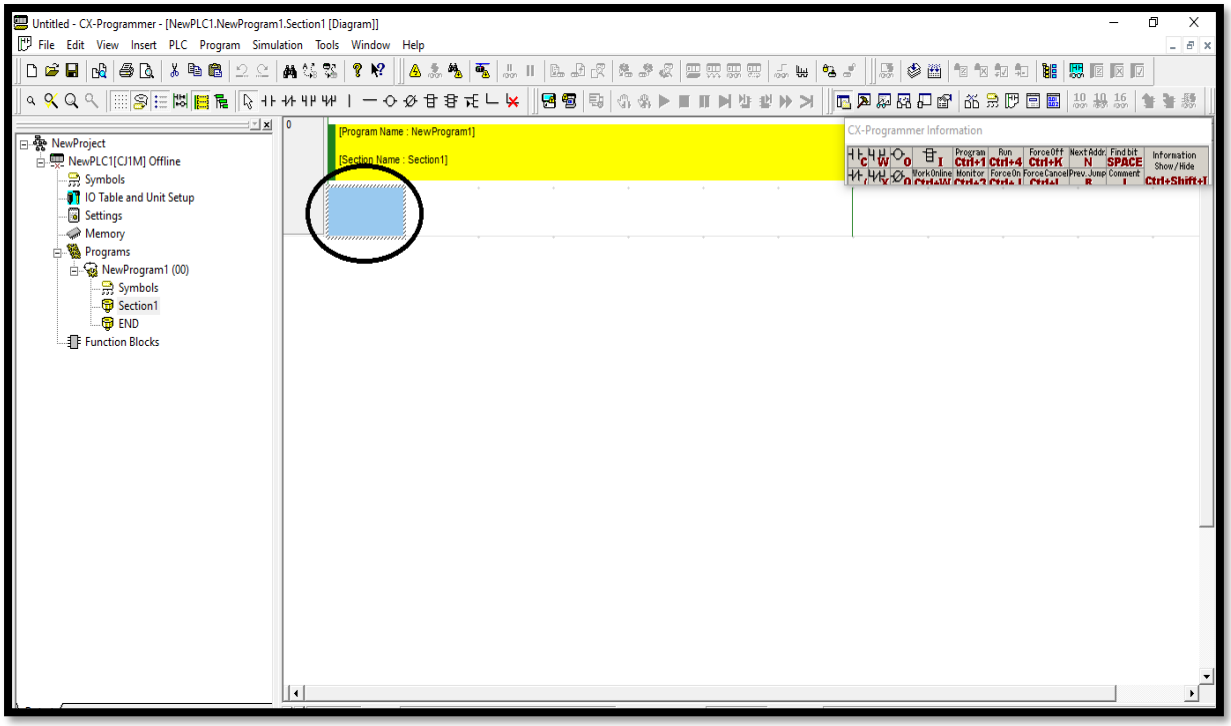


Figure 3.9: The initial screen of a new project

- We press 'C' to open 'New contact' dialog.

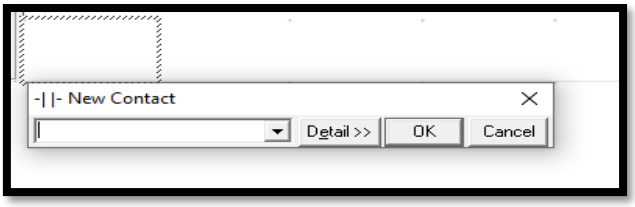


Figure 3.10: Creating New contact

- We write the address of the input.

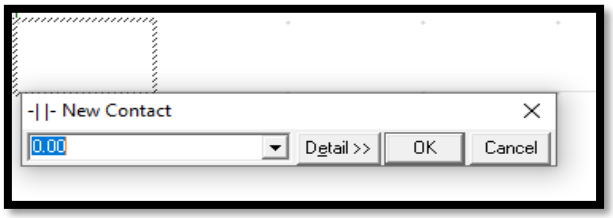


Figure 3.11: Address entering

- After pressing OK, we enter a symbol comment.

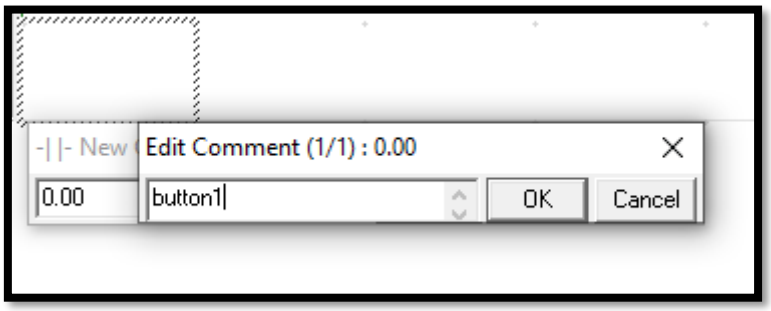


Figure 3.12: Entering comment

- Resulting:

Figure 3.13: Contact created

- Now we enter a coil by pressing 'O'

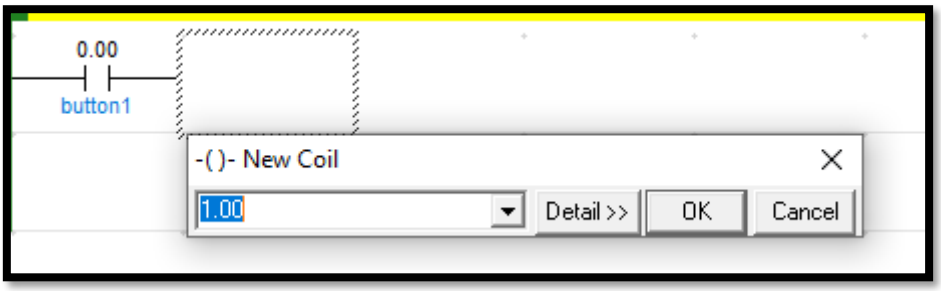


Figure 3.14: Creating New Coil

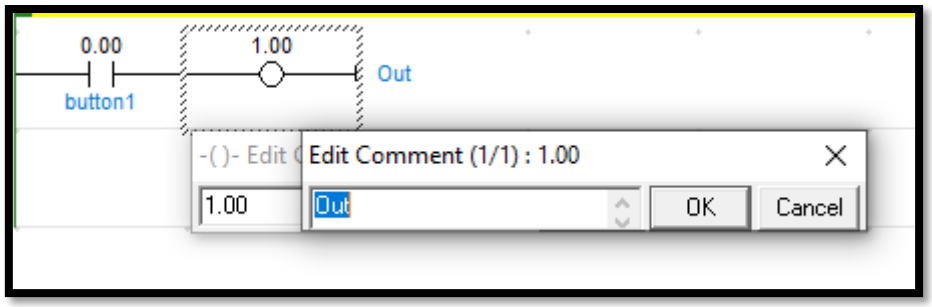


Figure 3.15: Entering a comment.

- By pressing 'R', the rung automatically will be filled

Figure 3.16: Input and Output connection

- Instead of pressing keyboard keys, we can use diagram toolbar by selecting an icon.

- To test the program, we first need to compile it by clicking on 'compile' icon situated on 'Program' toolbar or clicking on 'Program' menu> 'Compile'.

Figure 3.17: Program "Toolbars"

- Output Window will show up down the screen, where we can find the errors and their addresses if they exist.
- If no errors are found, the program now is ready to be simulated [10].

5- Testing a program:

CX-Programmer provides three kinds of connecting methods depending on usage:

- Normal online. Enables you to go online with a PLC of the device type and method specified when opening a project.
- Auto online. Automatically recognizes the connected PLC and enables you to go online with a PLC with one button. -> Uploads all data such as programs from the PLC.
- Online with Simulator. Enables you to go online with CX-Simulator with one button (You need to install CX-Simulator.) Online with Simulator. Enables you to go online with CX-Simulator with one button (You need to install CX-Simulator).

- To test the program, let's simulate it using Work Online Simulator by clicking on its icon:

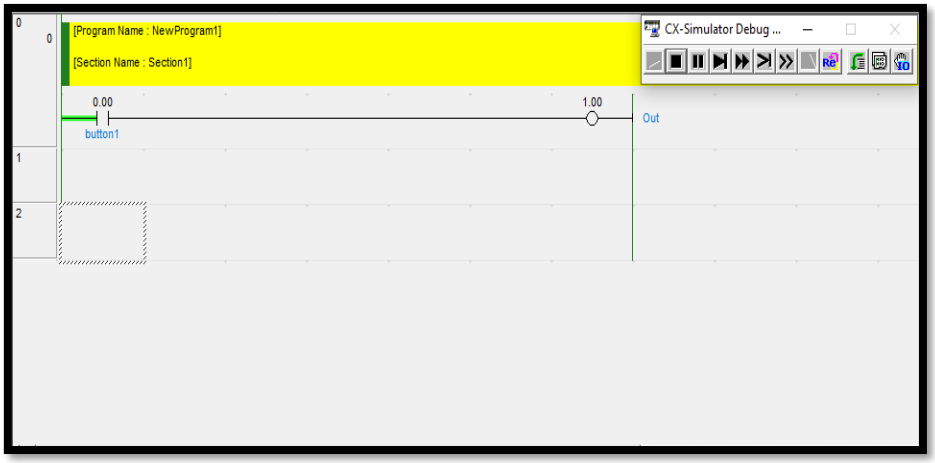


Figure 3.18: Online Work Simulation

- The window that popped up is the 'CX-Simulator Debug Console':

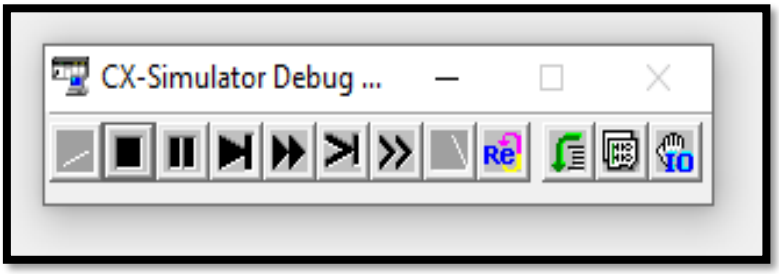


Figure 3.19: CX-Simulator Debug Console

- **CX-Simulator:** CX-Simulator enables the user to realize SYSMAC CS/CJ series CPU Units in the computer as a virtual PLC and operate it equally as actual CPU Units. Combination use of CX-Simulator and CX-Programmer enables us to verify ladder program operation and cycle time in advance on a PC without an actual PLC. Moreover, various debug functions of CX-Simulator make it possible to debug ladders, which used to be impossible by using an actual PLC only.
  When using the "Work Online Simulator" function of CX-Programmer Ver.3.0 or greater versions, CX-Simulator automatically starts up a virtual PLC of the current project's device type to open connection between CX-Programmer and the virtual PLC.
  - We can force the value of any symbol, simply by clicking on "Force" option found when right clicking on the symbol, the small lock icon is a symbol of a forced symbol. The force can be canceled by the 'Cancel' or 'Cancel All Forces' Option.

Figure 3.20: Result of forcing a contact.

6- Connecting with PLC:

- We can connect the PC to the Omron PLC by selecting on the 'PLC-Work Online Menu' bar or on the 'Work Online toolbar'.
- We can transfer the program from and to PLC or PLC to PC. To transfer the program, we select 'PLC' - 'Transfer-to PLC' or by clicking on 'PLC Transfer'.
- Then a dialog box will appear, we select the items to be transferred, one of which is the IO table that has been configured if the PLC is modular.
- After finishing click OK, if the transfer is no problem, then a successful download will display like this.
- We must make sure the PLC is in Run Mode so that the program that has been entered can be executed.

7- Our algorithms:

We are going to present the algorithms that we based our programs on using flowcharts. But first we need to declare Inputs and Outputs.

7.1- I/O Declaration:

Stacking & Packaging Machine:

Type	Address	Data Type	Description	Var Name
IN	0.00	BOOL	Manual/Automatic switch 0/1 (Works as an ON/OFF switch)	MAN/AUT
IN	0.01	BOOL	Counting Photoelectric Sensor	Counting sensor
IN	0.02	BOOL	Level Photoelectric Sensor	Stacking
IN	0.03	BOOL	1st Chain Standby position sensor	M3 Standby pos
IN	0.04	BOOL	1st Chain Working position sensor	M3 Working pos
IN	0.05	BOOL	2nd Chain Standby position sensor	M4 Standby pos
IN	0.06	BOOL	2nd Chain Working position sensor	M4 Working pos
IN	0.07	BOOL	Emergency Button	Emergency
IN	0.08	BOOL	Thermal Sensor	Thermal Alarm
IN	0.10	BOOL	Unloading Photoelectric Sensor	Unloading Done
IN	0.11	BOOL	Pusher Out Position sensor	Pusher out
IN	1.00	BOOL	Pusher In Position sensor	Pusher in
OUT	10.03	BOOL	Elevator Motors(M3, M4)	M3-M4 START
OUT	10.04	BOOL	1st Chain Motor activator.	M3 EF
OUT	10.05	BOOL	2nd Chain Motor activator.	M4 Ef
OUT	10.06	BOOL	Alarm lamp.	ALARM
OUT	10.07	BOOL	Elevator Activator.	Friction activation
OUT	11.00	BOOL	Transporting Conveyor's 1st Motor	M1
OUT	11.01	BOOL	Transporting Conveyor's 2nd Motor	M2
OUT	11.02	BOOL	2nd Conveyor's Motor5	M5
OUT	11.03	BOOL	2nd Conveyor's Motor6	M6

Table 3.2: I/O declaration of Stacking and Packaging Machine.

- **Pick & Place Robot:**

Type	Address	Data Type	Description	Var Name
IN	0.00	BOOL	Turning on/off the robot	ON/OFF
IN	0.03	BOOL	Sensor indication for the pallet	PRESENCE OF THE PALLET
IN	0.04	BOOL	There is an error	ALARME
IN	0.05	BOOL	Sensor indication for the box	PRESENCE OF THE BOX
IN	1.11	BOOL	The signals getting from the encoder of x	ENCODER X
IN	1.12	BOOL	The signals getting from the encoder of y	ENCODER Y
IN	1.13	BOOL	The signals getting from the encoder of z	ENCODER Z
IN	3.00	BOOL	Button to stop the robot	STOP
IN	3.01	BOOL	Emergency button	EMERGENCY
IN	7.01	BOOL	Reset button	RESET
IN	22.00	BOOL	Initial position indicator for X	SOX
IN	22.01	BOOL	Initial position indicator for Y	SOY
IN	22.02	BOOL	Initial position indicator for X	SOZ
IN	27.00	BOOL	90° indicator	90°
IN	27.01	BOOL	0° indicator	0°
OUT	7.02	BOOL	OPEN THE GRIPPER	OPEN THE GRIPPER
OUT	10.05	BOOL	The gripper rotates on clockwise dire	CLOCKWISE DIRECTION
OUT	10.06	BOOL	The robot moves forward on X	FORWARD X
OUT	10.07	BOOL	The robot moves forward on Y	FORWARD Y
OUT	13.02	BOOL	The robot moves forward on Z	FORWARD Z
OUT	11.01	BOOL	The gripper rotates counter clockwise dire	COUNTER CLOCKWISE
OUT	11.06	BOOL	The robot move reversed on X	REVERS X
OUT	11.08	BOOL	The robot move reversed on Y	REVERS Y
OUT	4.00	BOOL	The robot move reversed on Z	REVERS Z

Table 3.3: I/O declaration of Pick and Place Robot .

7.2- Flowcharts:

A flowchart is a graphical or pictorial representation of an algorithm that uses symbols, shapes, and arrows to show how a process or program works. We can readily grasp a program thanks to algorithms. The fundamental goal of a flowchart is to compare and contrast different techniques. In a flowchart, several standard symbols are used [12]:

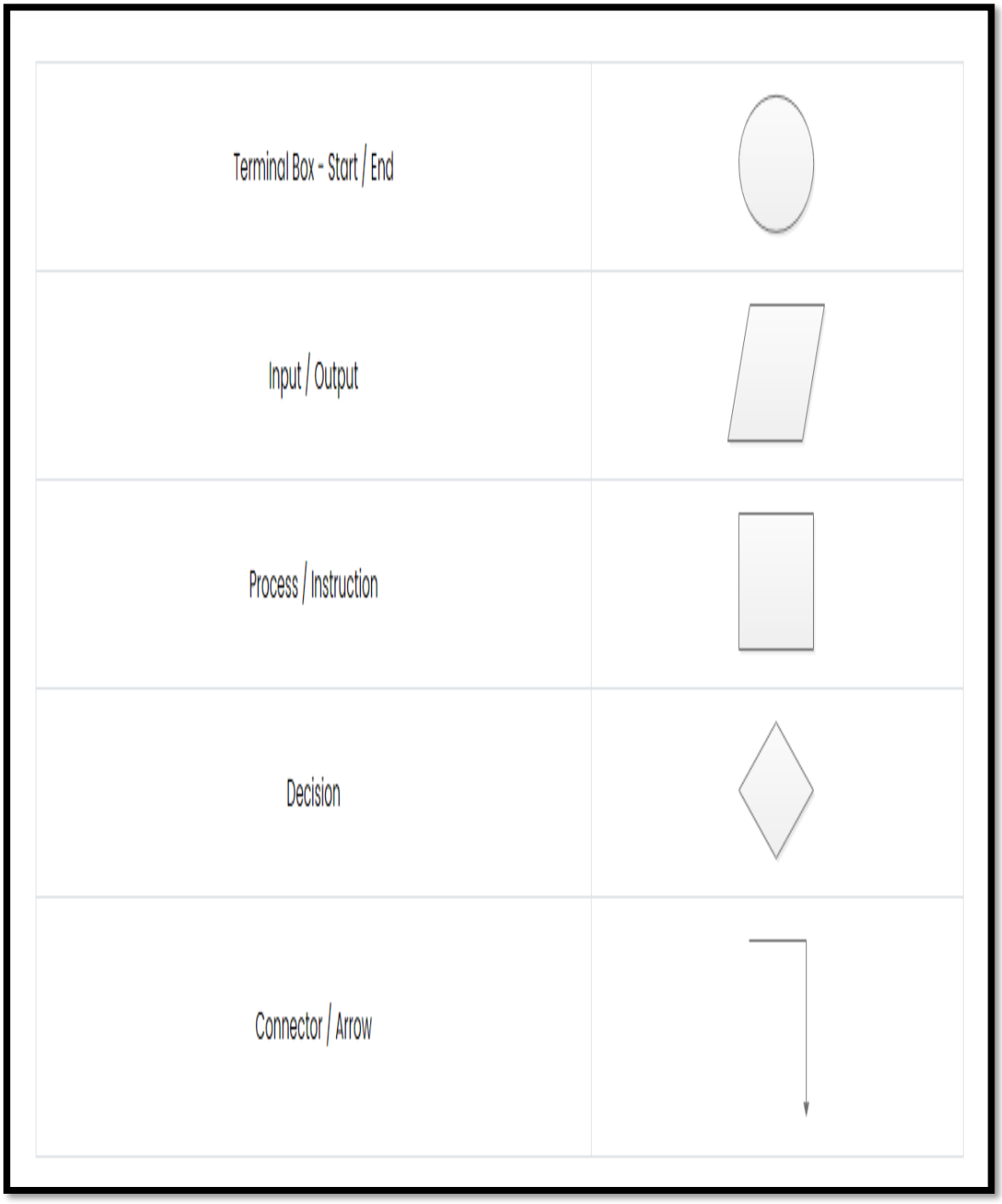


Figure 3.21: Shapes used in flowcharts and their meaning.

- **Stacking and Packaging Algorithm:**

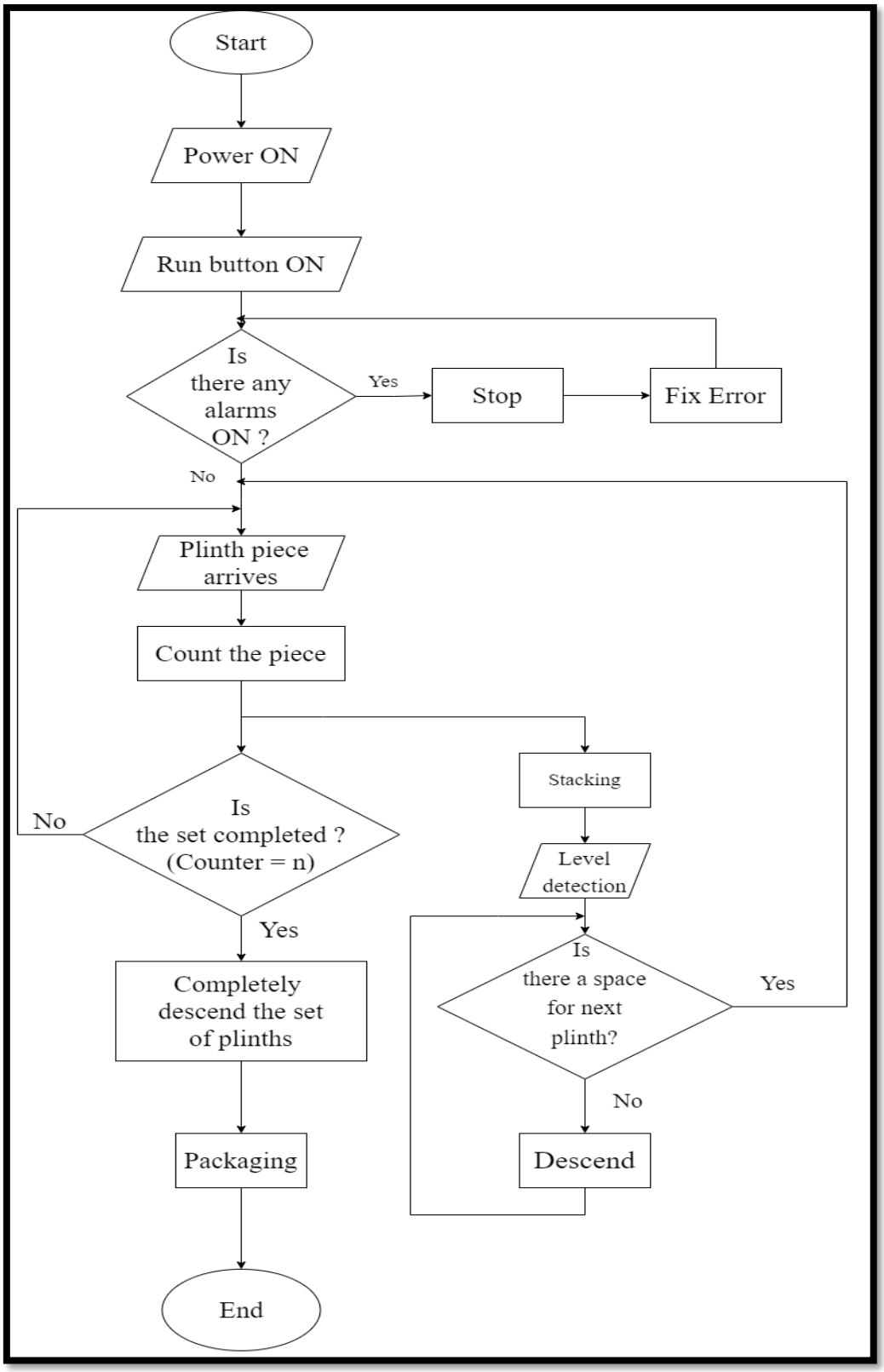


Figure 3.22: Stacking and Packaging program flowchart diagram (n is a preset number by the user that define total pieces in one set).

- **Pick and Place robot Algorithm:**

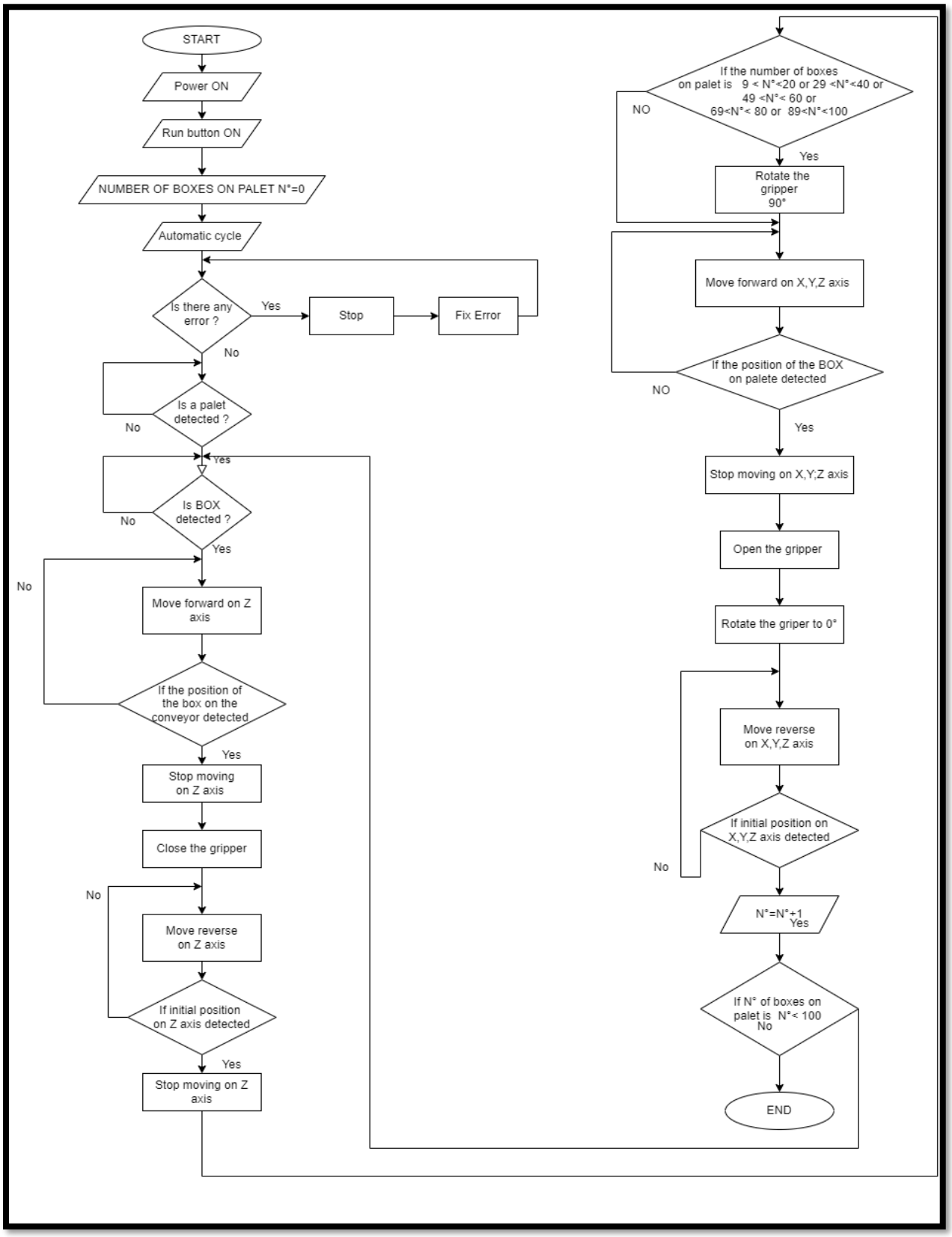


Figure 3.23: Pick and Place machine program flowchart diagram.

8- Conclusion:

At the end of this chapter, we are well informed about CX-Programmer features, every detail in the process of creating new projects and programs and we are ready to implement our algorithms and translate them into ladder programs.

Chapter IV

Supervision & Simulation Using CX-Designer

Chapter IV: Supervision & Simulation Using CX-Designer

1- Introduction:

So far, we provided an overview of the programming software and the procedure used to create a PLC program on CX-Programmer. Now, in this last chapter, we will create the HMIs so that we can simulate and test our programs and have a clear view on the processes.

2- Human Machine Interface:

A user interface or dashboard that connects a human to a computer, system, or device is known as a Human-Machine Interface (HMI). While HMI can technically refer to any screen that allows a user to interact with a device, it is most usually associated with industrial processes [11].

HMIs are usually screens or touchscreens that connect users to machines, systems, or devices in the industrial context. HMIs are used by factory operators to operate and automate machines and manufacturing lines. Simple screen displays mounted on factory equipment, complex touchscreens, multi-touch-enabled control panels, push buttons, laptops with keyboards, mobile devices, or tablets are all examples of HMIs [11].

3- Tasks of HMIs:

- **Process visualization:**

On the HMI device, the process is visualized. The HMI device's screen is dynamically refreshed. This is based on transitions in the process.

- **Operator control of the process:**

The GUI allows the operator to manage the procedure (Manual). The operator can, for example, establish control reference values or activate a motor.

- **Alarms display:**

When a preset value is surpassed, for instance, critical process conditions automatically generate an alarm.

- **Archiving process values and alarms:**

Alarms and process values can be logged by the HMI system. We can use this functionality to record process sequences and recover past production data.

- **Logging process values and alarms:**

Alarms and process value reports can be generated by the HMI system. At the end of a shift, you can print out production data.

- **Process and machine parameter management:**

Process and machine parameters can be saved in recipes via the HMI system. For example, to alter the product version for production, you can download these parameters from the HMI device to the PLC in one pass [12].

4- CX-Designer:

CX-Designer is the HMI software used for our 5.7 to 15 inches NS HMI series.

Figure 4.1: CX-Designer software.

- **New Project:**

After opening CX-Designer, here is the starting screen:

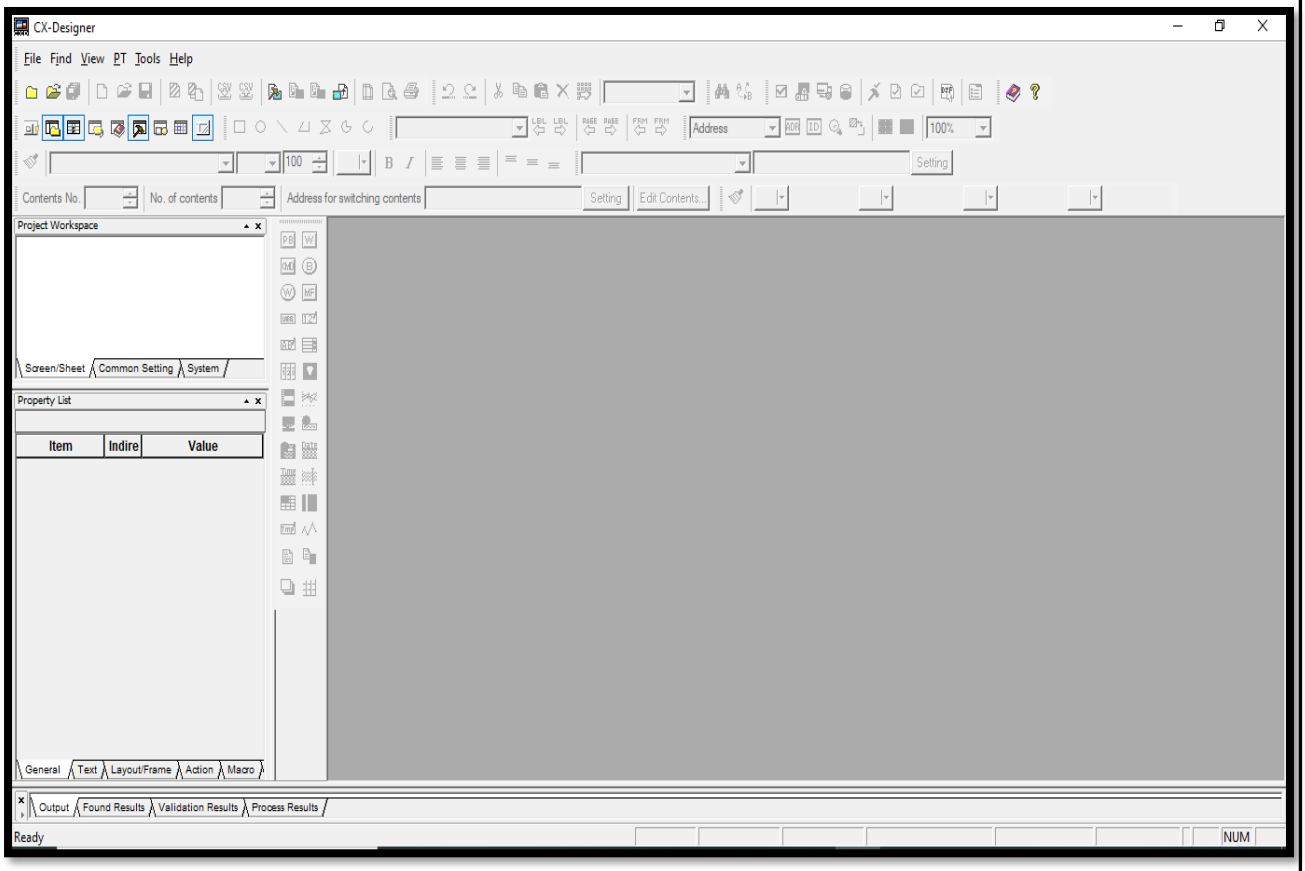


Figure 4.2: CX-Designer starting screen

-To create a new project, we click on: File ►New Project

-And then we chose the model of the HMI to be programmed:

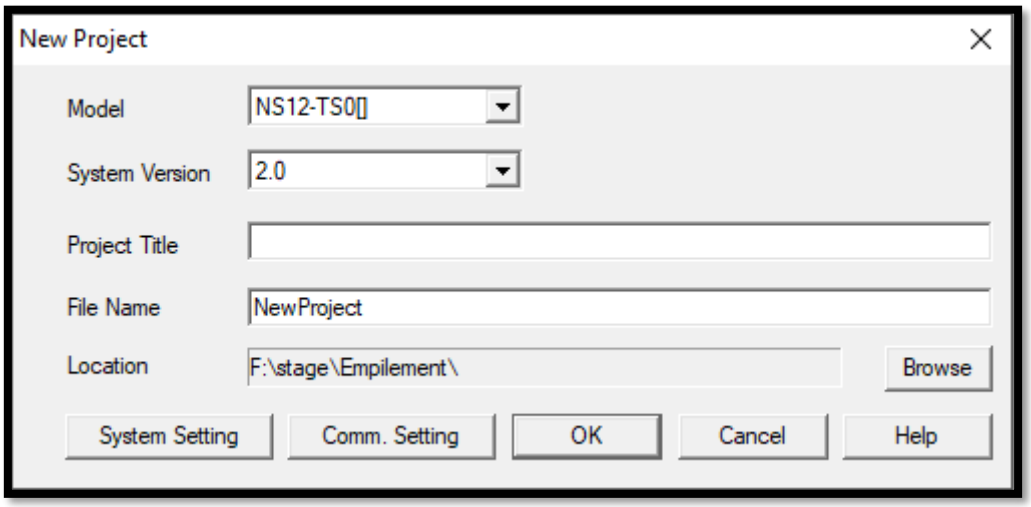


Figure 4.3: New Project window.

-Resulting:

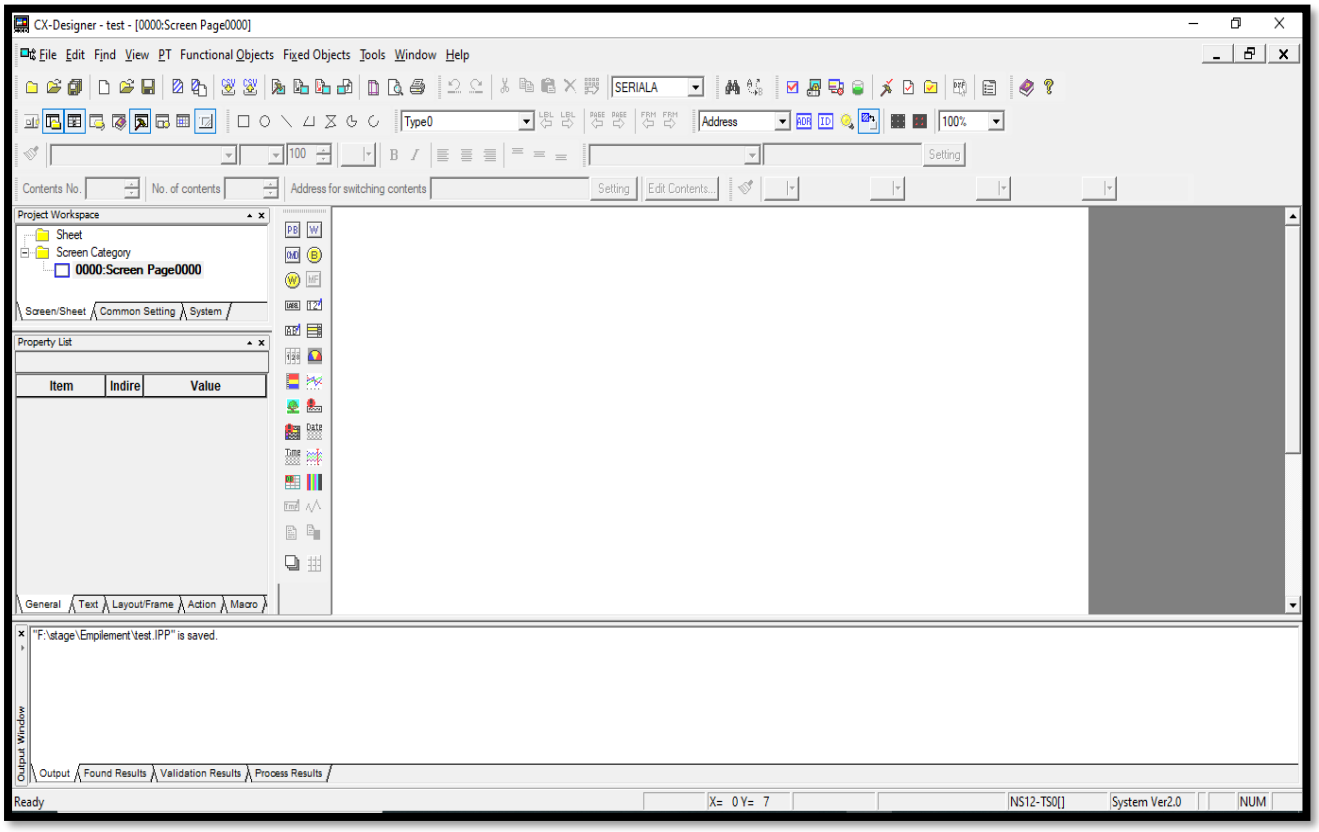


Figure 4.4: New Project

-Now, we can start designing and programming the HMI using the different tools provided by CX-Designer by just selecting the tool and putting it where it is wanted to be on the working sheet, and then we can edit its properties such as: shape, color, label (items, can be

programmed to have different properties for different states, for example: a bit lamp is green for on state and red for off state.) and addressing.

- **Main used objects:**

- **ON/OFF Button:** It has a function that turns on and off based on the ON/OFF states of a defined address (bit) via a touch switch input.
- **Command Button:** A command button is an object that allows us to transition between screens and deliver a string code.
- **Bit Lamp:** Bit lamp is an object that switches display color according to ON/OFF status of an address.
- **Label:** A label is used to display a fixed character string.
- **Numerical Display & Input:** Numeral Display & Input is an object that displays data of an address as numeral value and changes data by inputting numeral value from a virtual key board.

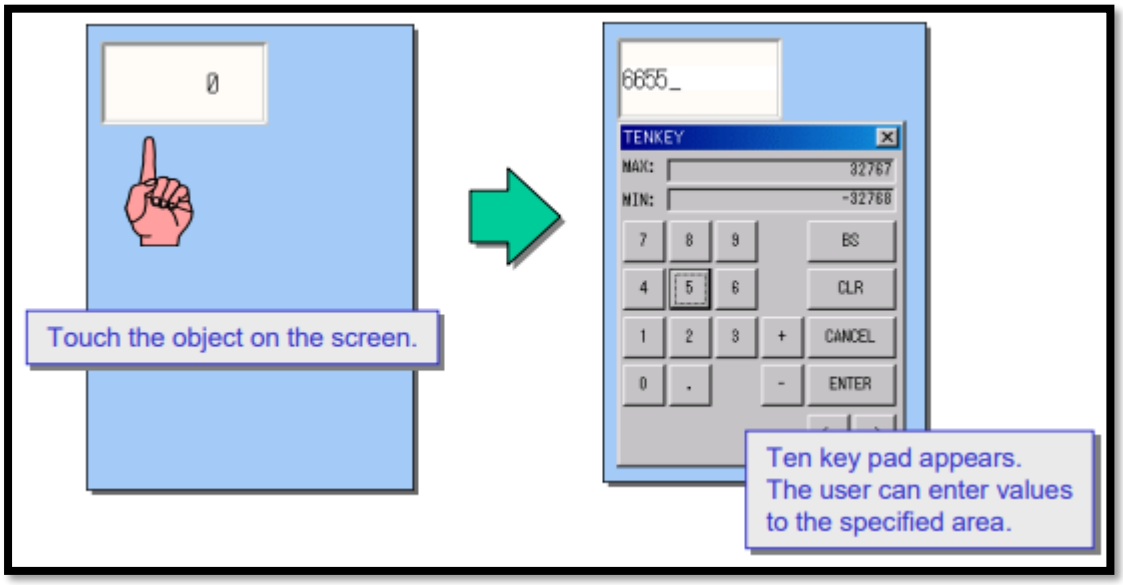


Figure 4.5: Entering a number on a numerical display/input object

- **Alarm/Event Display:** It is a functional object that displays a current recorded alarm/event in one line. Normally, the highest priority alarm/event is displayed, but it is also possible to display more than one alarm/event occurring at the same time according to the priority by specifying flowing string.
- **Alarm/Event Summary/History:** It is an object that displays current alarms/events in a list. We can specify display order such as checked time, priority and frequency.
- **Bitmap:** It is an object used to import images from the device [13].
- **Date:** Used to display the current date.
- **Time:** Used to display the current time.

- **Adding screens:**
  - Right click on Screen Category on Project Workspace, then we chose New Screen.

Figure 4.6: Project workspace window

- **Menus and toolbars:**

We may use the menus and toolbars to access all of the functionality given by CX-Designer.

Figure 4.7: Menus and toolbars.

- **Testing Function:**

Before transferring the data, we can check it on the CX-Designer simply by clicking on the icon: 

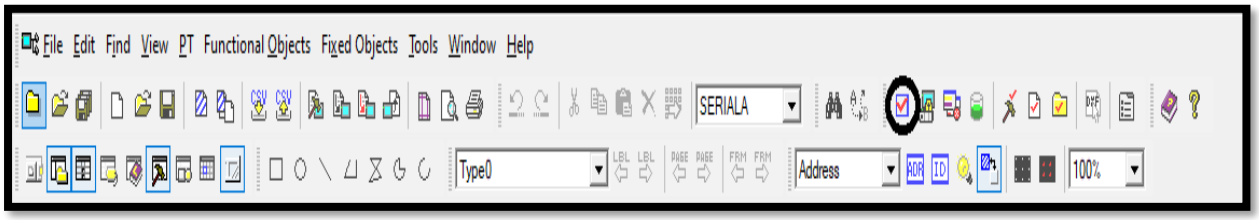


Figure 4.8: Testing icon.

- In this project, after creating ladder programs for the two machines, it is necessary to test their functionality, so we created, designed and programmed HMIs form two main purposes:

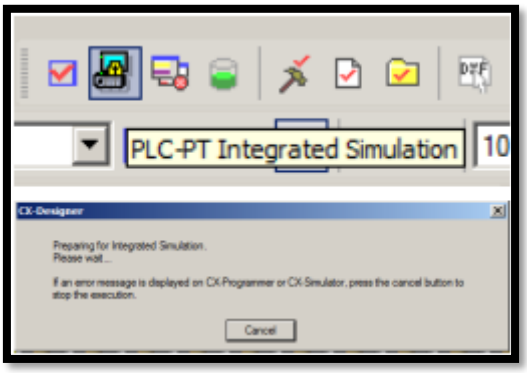
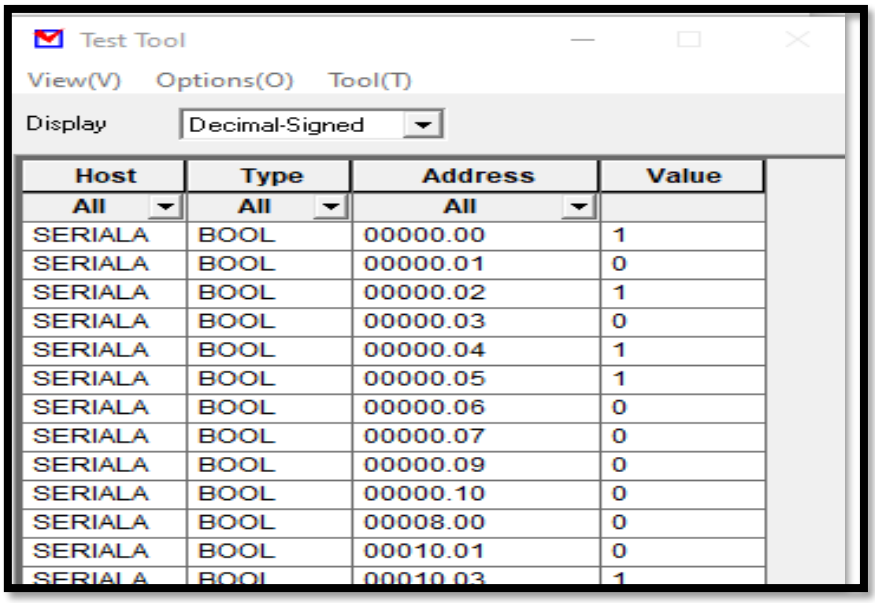


Figure 4.9: PLC-PT Integrated Simulation icon.

1- Simulating and Testing programs using the "PLC-PT Integrated Simulation" function which will connect the HMI (CX-Designer) and program (CX-Programmer) through a virtual PLC.
2- Supervising and Interacting with the processes of the machine after confirming the success of the program.

- **PLC-PT Integrated simulation:**
  CX-Programmer simulation can interact with CX-Designer offline testing. If the Start PLC-PT Integrated Simulation button is activated, the simulation generated on the CX-Designer may be linked to the program developed on the CX-Programmer.
- **Test Tool:**
  It is a tool that shows the addresses of the objects on the screen and gives access to set and modify values of each object.



Host	Type	Address	Value
All	All	All	
SERIALA	BOOL	00000.00	1
SERIALA	BOOL	00000.01	0
SERIALA	BOOL	00000.02	1
SERIALA	BOOL	00000.03	0
SERIALA	BOOL	00000.04	1
SERIALA	BOOL	00000.05	1
SERIALA	BOOL	00000.06	0
SERIALA	BOOL	00000.07	0
SERIALA	BOOL	00000.09	0
SERIALA	BOOL	00000.10	0
SERIALA	BOOL	00008.00	0
SERIALA	BOOL	00010.01	0
SERIALA	BOOL	00010.03	1

Figure 4.10: Test Tool window.

5- Simulation:

5.1- Stacking & Packaging machine

- **Home screen:**

The main screen is called “Home”, in this screen we can observe and supervise the different steps of the process in real-time from: the arriving of the plinth pieces, the stacking -through a numeral display that counts the arrived and stacked pieces- in real-time, the elevator actions -for both step by step descending or the complete descending- and the activation of the pusher and a numeral display that counts the number of boxes packaged by the worker.

The screen allows the user to observe the current states of different sensors, motors and alarms through a set of bit lamps:

- Sensors: Counting sensor, Level sensor, Unloading sensor, Thermal sensor.
- Conveyors and elevator motors (M1 M2 for conveyor1 motors, M3 M4 for the elevator motors, M5 M6 for conveyor2 motors).
- The elevator’s chains status (working and standby positions).
- An alarm indicator.

The screen also contains an Automatic/Manual switch (ON for the automatic cycle), Emergency stop button and command buttons that allow the user to access and navigate through the other screens: Parameters, Manual, Alarms.

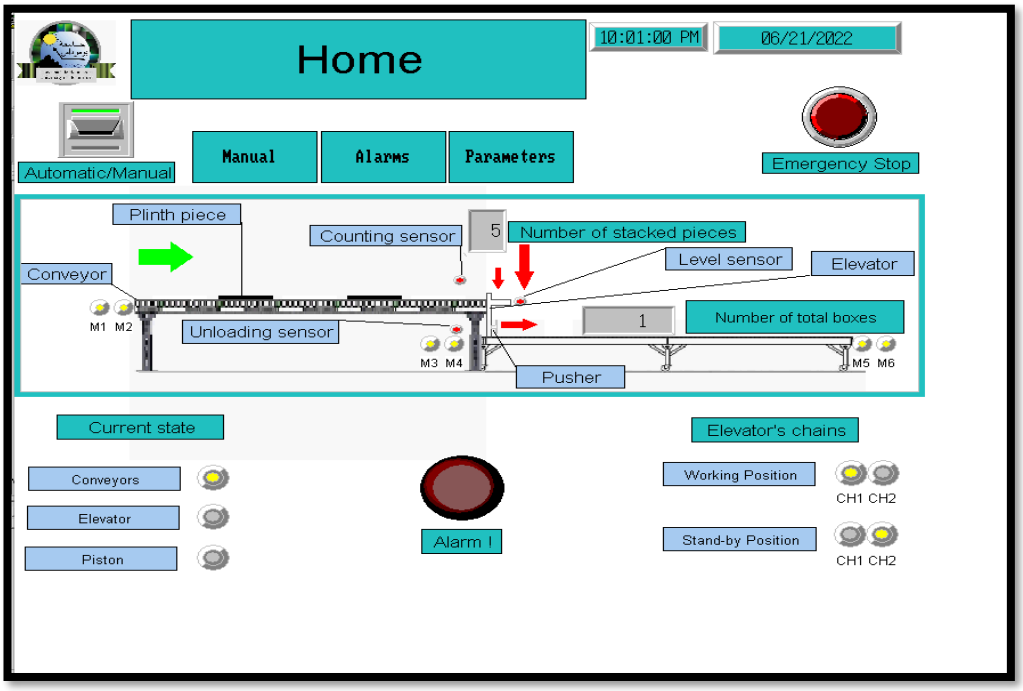


Figure 4.11: Stacking & Packaging machine’s HMI “Home” screen.

- **Parameters screen:**

This screen gives access to the user to enter pre-set values which are: number of pieces in one set, the allowed delay for the sensors and the pusher in 100ms.

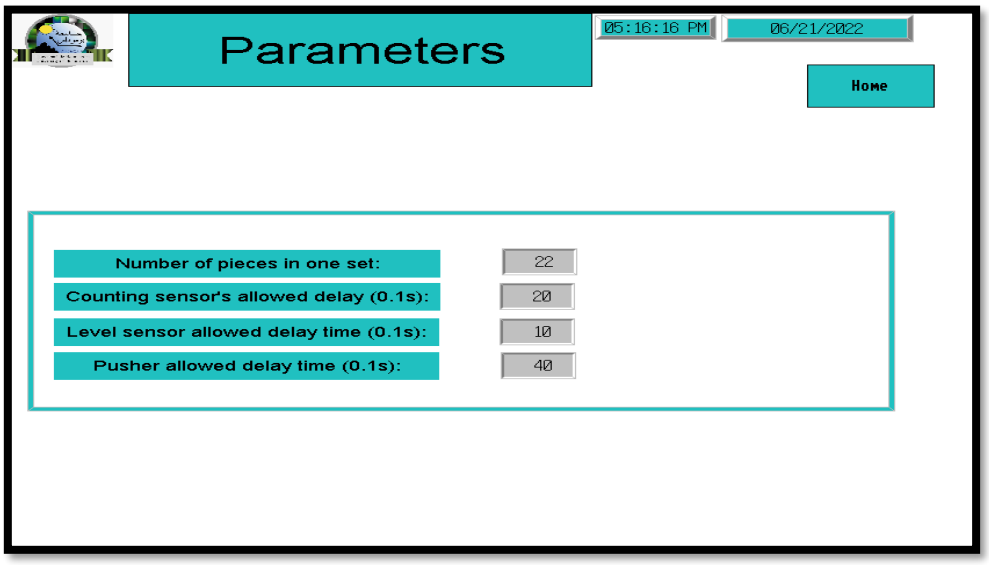


Figure 4.12: Stacking & Packaging machine's HMI "Parameters" screen.

- **Alarms screen:**

It is a screen dedicated to display and archive the different errors and their occurrence time; each error has a defined message that pops up.

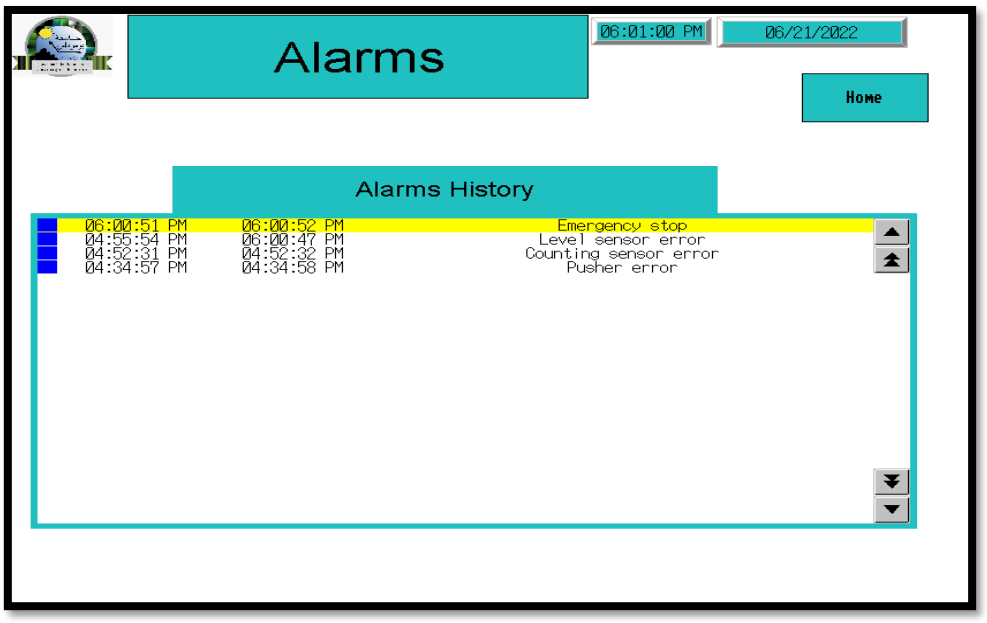


Figure 4.13: Stacking & Packaging machine's HMI "Alarms" screen.

- **Manual:**

In this screen, we programmed three buttons, each button when -manually pushed- will activate the conveyors, the elevator or the pusher.

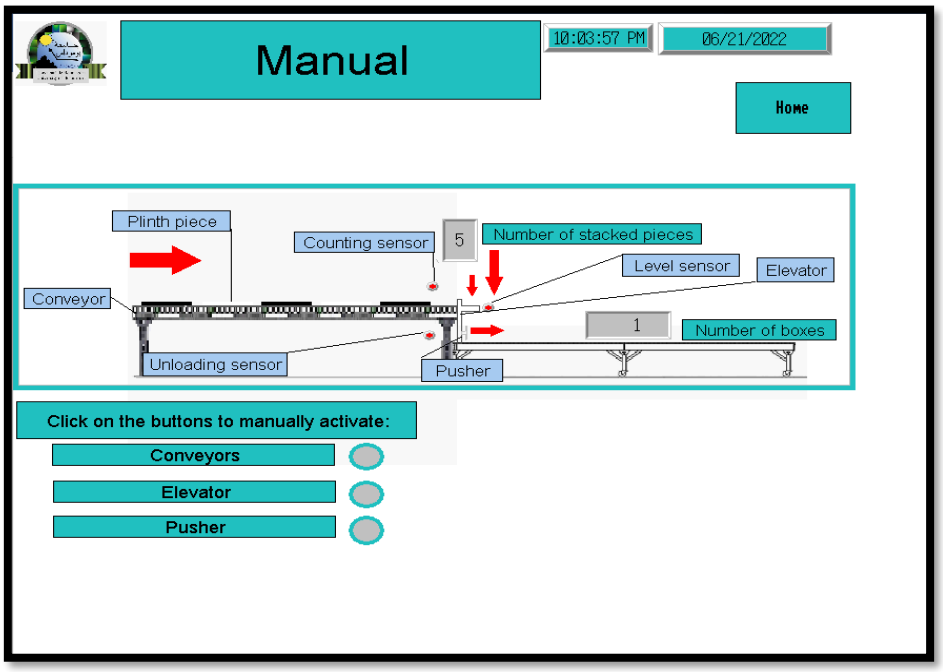


Figure 4.14: Stacking & Packaging machine's HMI "Manual" screen.

- The program is ready to be transferred to the CJ1M PLC already connected to the inputs and outputs of Stacking and Packaging machine.

5.2- Pick and place robot:

- Home screen :

It is the main scern of our HMI , it enables the user to observe and supervise the process in real time and the current state of sensors , motors ..

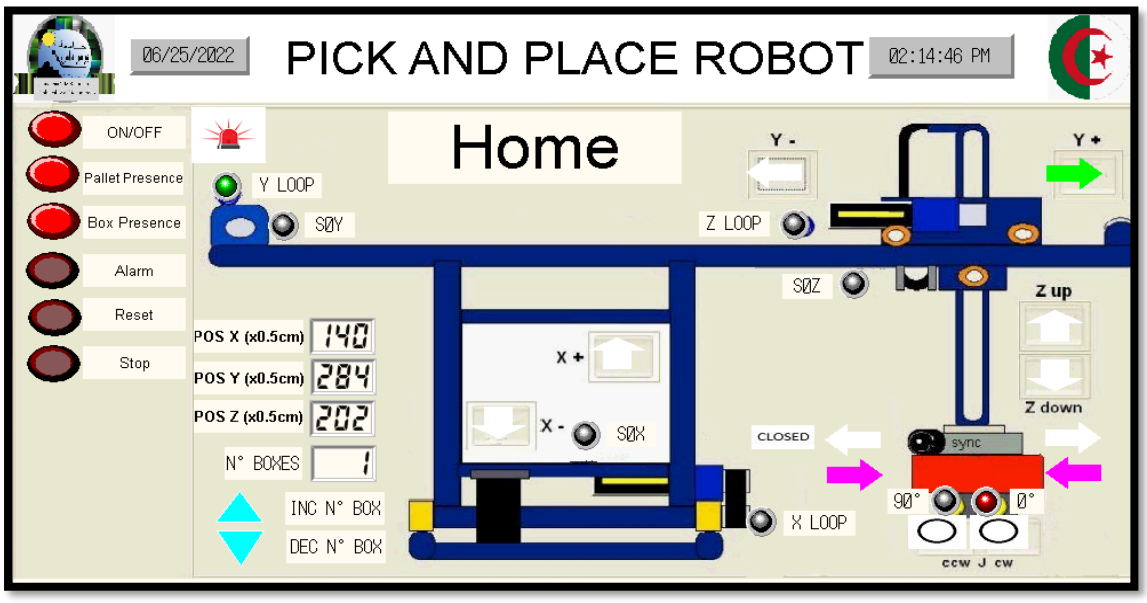


Figure 4.15: Pick & Place robot's Home screen of the HMI.

The whole process can be observed through this screen, thanks to its objects. The bit lamps gives the real-time state of sensors (Pallet presence sensor, Box presence sensor, Gripper angle, Initial positions in the three axes),Alarms , motors (X Loop, Y Loop, Z Loop) and also describe actions (Gripper closing or openning)and even the direction of movements across all the axes.

We also have buttons to control the process (ON/OFF button, Reset button, Stop button, increasing and decreasing the boxe's buttons).

The data related to the process such as the number of the currently treated box, the distance crossed along X, Y and Z axis (the number of impulses from the encoders that their ratio is 20 impulses per 10cm) are all displayed using Numeral Displays.

- **Alarms screen :**

This screen displays alarm messages and register them with their occurrence and deactivating times.

We programmed the screen to show two messages:

- Security Alert (it includes Emergency stop button and all safety issues' alarms).
- No Pallet Alert (the presence of the pallet is vital for our robot's process).

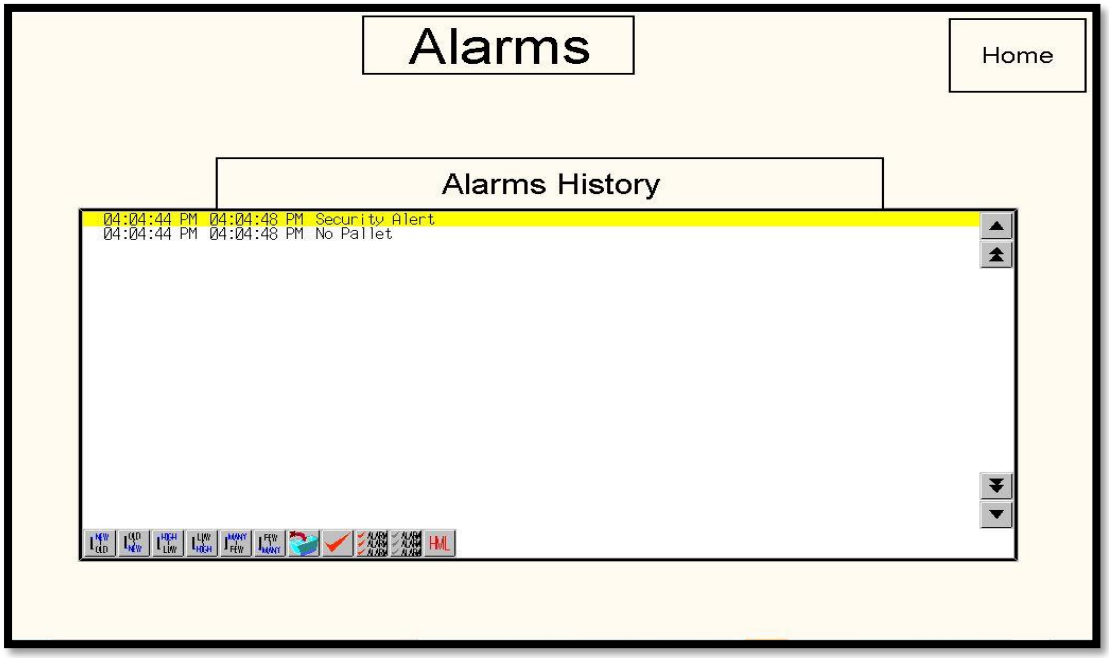


Figure 4.16: Pick & Place robot's HMI "Parameters" screen.

- The program is ready to be transferred to the PLC.

6- Conclusion:

In the last chapter, we showed the followed procedure to create Human-Machine Interfaces to visualize and control the processes of two machines. Creating an HMI is a task that requires a full knowledge of the process in order to have a good visualization and supervision, also, needs a set of skills in PLC programming language to assure the connection between addresses and the different objects and variables.

We created two HMIs:

- **Stacking & Packaging:** It consists of 4 screens:
- Home (Process view).
- Manual.
- Parameters.
- Alarms.
- **Pick & Place robot:** Contains two screens:
- Home (Process view).
- Alarms.

At the end of this chapter, we are confident about the functionality of our programs and that they are ready to be implemented by getting the approval from the 'CB' Company engineers.

General Conclusion

In this humble project, we studied the Stacking and Packaging machine that belongs to "Céramique Boumerdes" company, this allowed us to find a solution that guarantees and ensure the good conduct of stacking the plinth pieces and prepare them to the packaging which is done by a worker, and also pushed us to propose adding a Pick and Place robot to replace the worker in the process of placing the boxes on the pallets so that we have the minimum human intervention.

The objective of this project was to install CX-Programmer software and learn how to use it in order to create PLC programs for the two machines and test their functionality and create Human Machine Interfaces on the computer using CX-Designer which allowed us to perform the simulation of the programs and supervise the different aspects of the processes to ensure that they are ready to be transferred to the PLC.

The Stacking and Packaging machine's program was successfully transferred in the CJ1M PLC. Since the company is not ready to provide the Pick and Place robot yet, the program was unfortunately not transferred, but it will be as soon as the robot is ready.

We have been able to better grasp the project and become more familiar with the duties of field engineers in this region thanks to our professional background.

We are hoping that this modest project will be the depart point of our professional careers and that it will be a help for the next promotions students, God willing.

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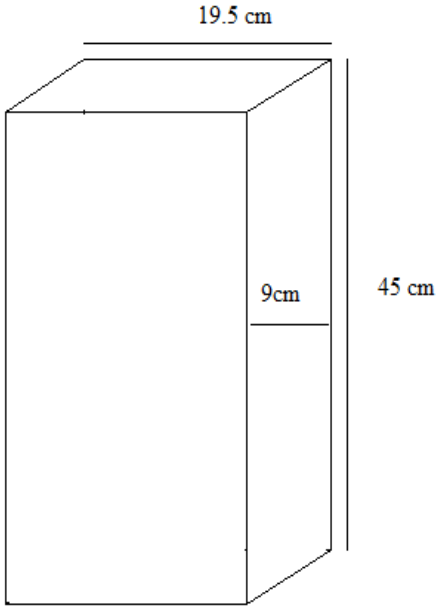
Dimensions and Coordinates

Appendix I

Box dimensions:

The picture shown below represent the dimensions of the box that we want to place it on the pallet.



The pallet coordinates :

The coordinates of the center of the first box from the initial coordinate of the robot until the desired place of the box on the pallet is (initial)=(50cm,275cm,101cm). for the 2^{nd} ,3^{rd} ,4^{th} and 5^{th} boxes the coordinates of y ,z remains the same , the only change is on the x coordinate , we add 20 cm to the coordinate x of the first box , we know that the width of the box is 19.5 , the difference of 0.5cm added is for the gripper ,and for the 6^{th} ,7^{th} ,8^{th} ,9^{th} , 10^{th} boxes , for the z axe remain the same with the first boxes and for the y we subtract 55 cm (45 com is for the length of the box , and the 10 cm is for the safety distance to maintain the balance between layer one and two , and for the x coordinate we do the same thing by adding 20cm .

Appendix I

x=130cm y=220cm z=101cm 10	x=110cm y=220cm z=101cm 9	x=90cm y=220cm z=101cm 8	x=70cm y=220cm z=101cm 7	x=50cm y=220cm z=101cm 6
x=130cm y=275cm z=101cm 5	x=110cm y=275cm z=101cm 4	x=90cm y=275cm z=101cm 3	x=70cm y=275cm z=101cm 2	x=50cm y=275cm z=101cm 1

The second layer is the same like the first one, the only difference is to rotate all the boxes of the 1st layer by 90°, and the explanation will be the same like the first one.

20 x=118cm y=208cm z=92cm		19 x=62.5cm y=208cm z=92cm	
18 x=118cm y=228cm z=92cm		17 x=62.5cm y=228cm z=92cm	
16 x=118cm y=248cm z=92cm		15 x=62.5cm y=248cm z=92cm	
14 x=118cm y=268cm z=92cm		13 x=62.5cm y=268cm z=92cm	
12 x=118cm y=288cm z=92cm		11 x=62.5cm y=288cm z=92cm	

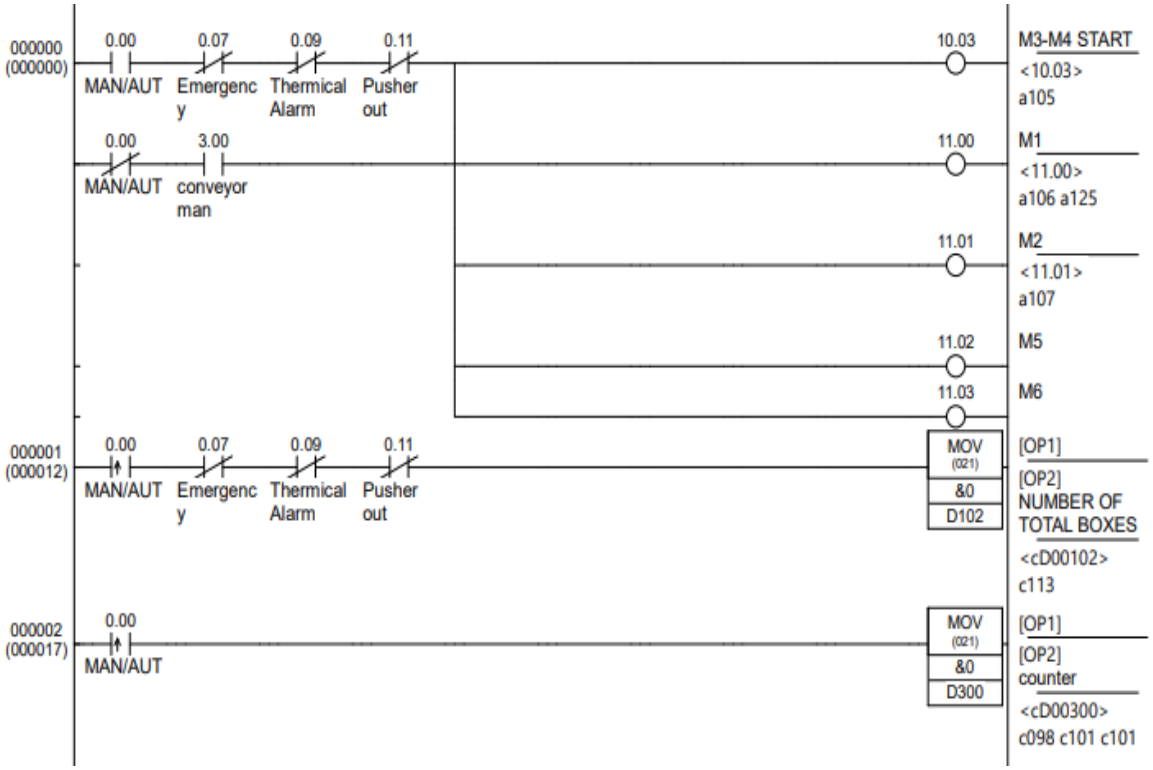
Ladder Diagram Programs

Appendix II

Stacking and Packaging machine Program:

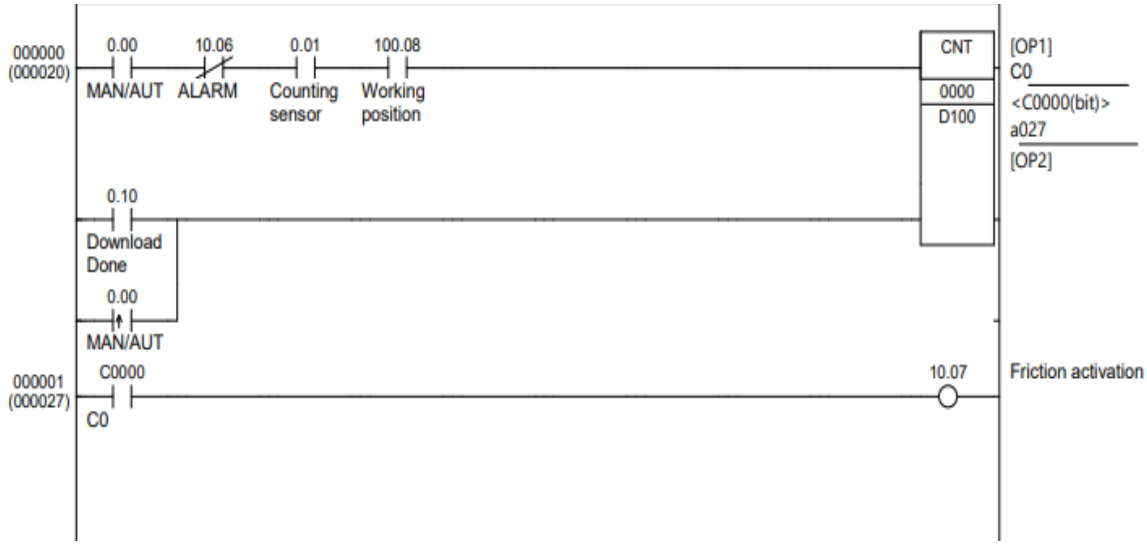
1- Run section:

This section is reserved for activating Motors and reinitializing Counters (Number of pieces, Number of boxes).



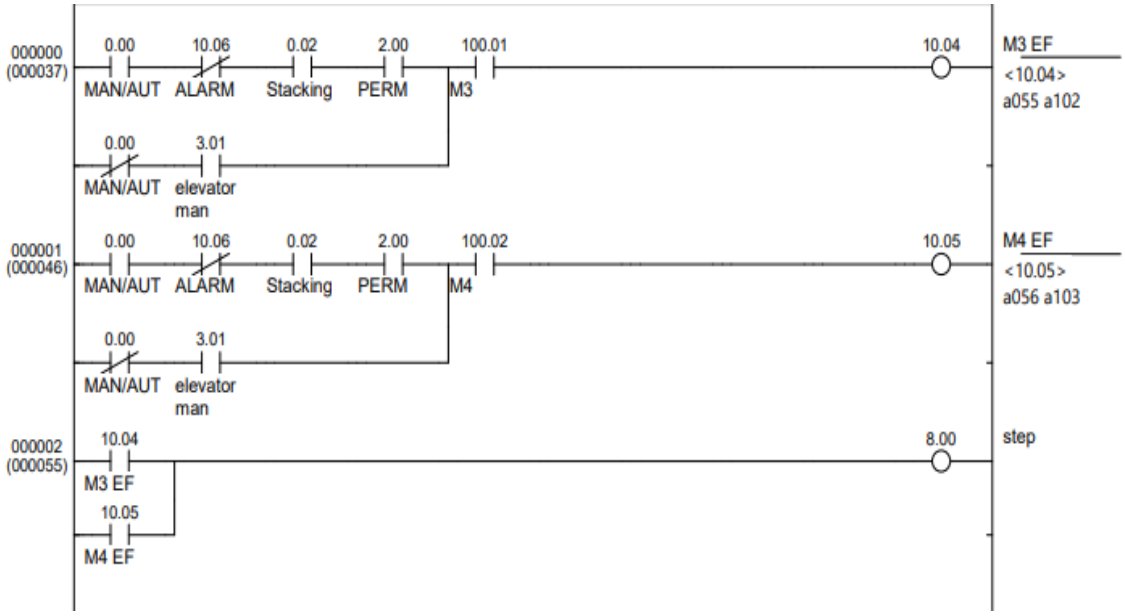
2- Counting section:

This section is reserved for counting pieces .



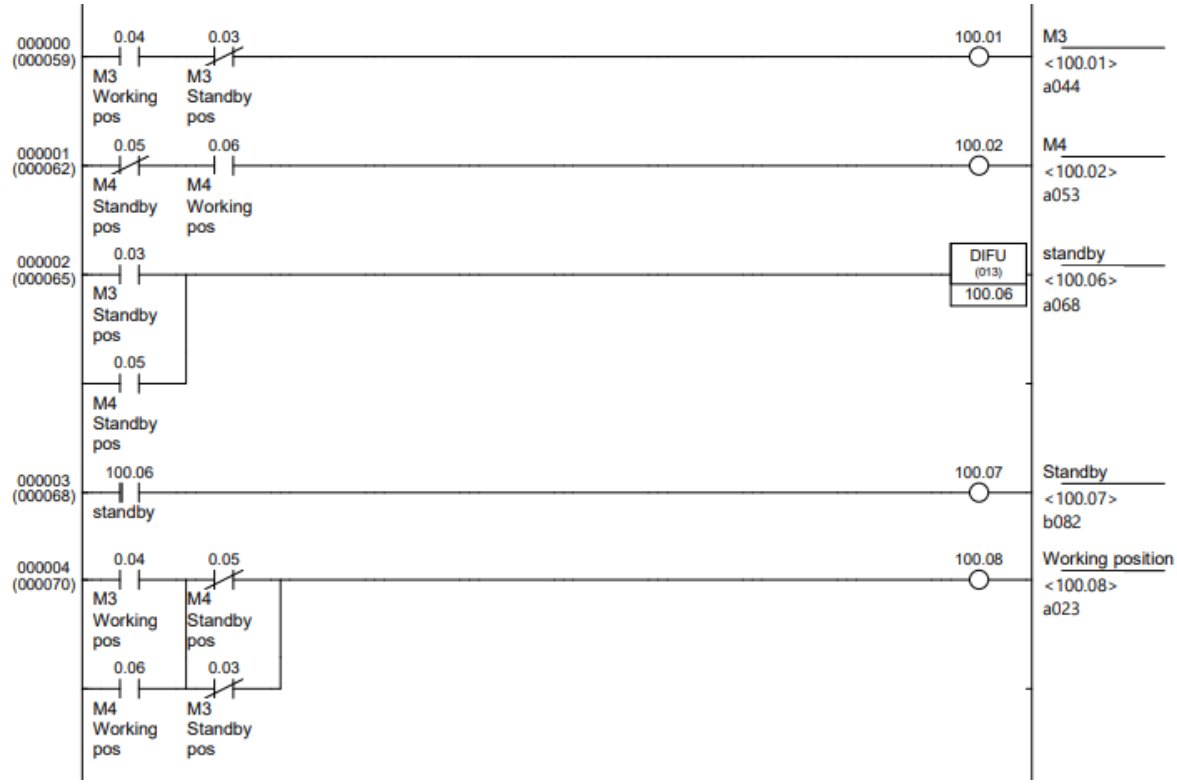
3- Small descending section:

This section is responsible of the small descending action of the elevator.



4- Chains section:

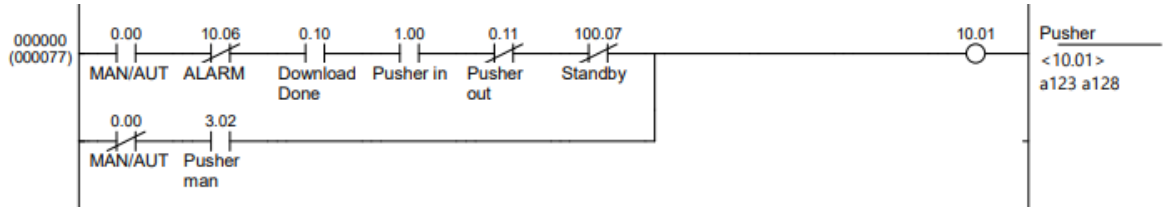
This section is responsible of deciding which chain is on the “working position” and which one is on “standby position”.



Appendix II

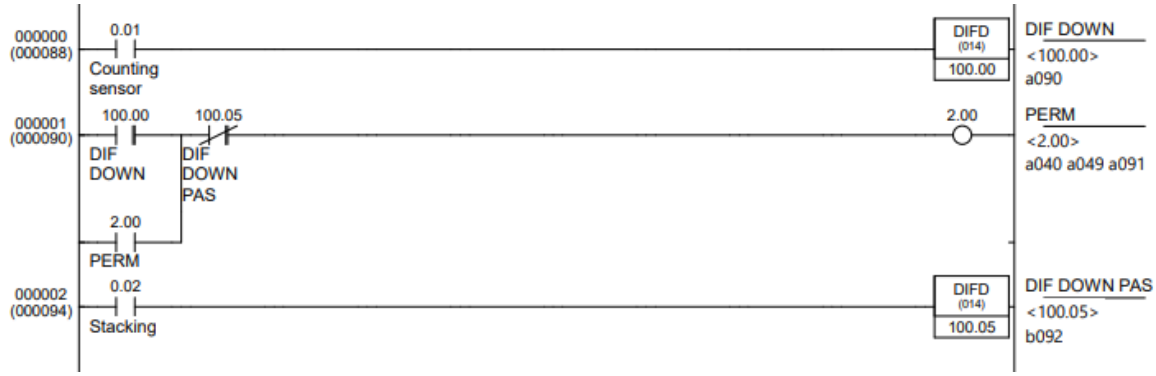
5- Pusher section:

This section is reserved for the Pusher.



6- Permission section:

This section's objective is to stop the sensors work when no pieces arrive.

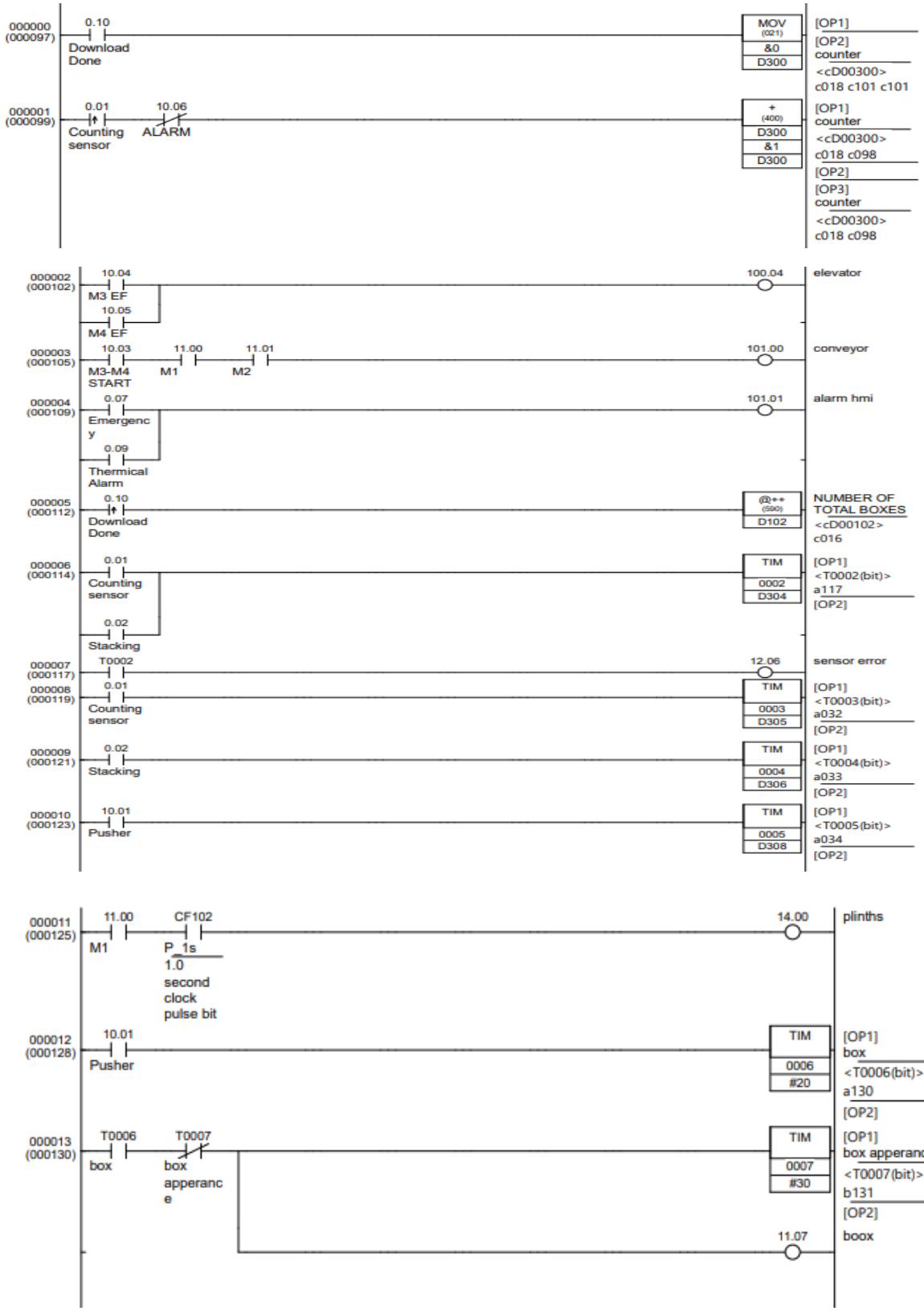


7- Alarms section:

This section is reserved for different alarms (Thermal Alarm, Sensors delay(T3,T4,T5) and emergency)

8- HMI section:

In this section, we linked the Program with the HMI.



Appendix II

Pick and Place Robot Program:

- Placing the boxes on the pallet with the pre-defined coordinates .