# Palestine Polytechnic University

College of Engineering and Technology
Electrical and Computer Engineering Department

Graduation Project

# Design and Implementation of Electromechanical Arm

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## Dedication

This project is dedicated to our parents who help and give us their love, and to oppressed people throughout the world and their struggle for social justice and egalitarianism.

## Acknowledgements

We would like to acknowledge all who collaborated to carry out this project, and we would like to make special thanks to our supervisor D.Sameer Kahder.

## Abstract

The Electromechanical Arm is a design of transporting a plastic pipe through many stages of production, which depend on motion in three dimensions. The Arm have two power systems : Electrical system of two Induction Motors and operating deceives, Pneumatic system of three pistons and rotary actuators.

The whole design is controlled by Programmable Logic Controller Unit (PLC), which used to convert the operation of Belling of the pipe from the manual situation to the full automatic situation. This is done by a special program written according to the sequence of the tasks of the full operation. These tasks are briefly : catching, leaving, lifting, debarking, rotating, pushing, and pulling.

In this project the Electromechanical Arm prototype is proposed. A positioning technique based on a mechanical screws is achieved with negligible errors.

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الفكرة تحت عنوان

Design And Implementation of Electromechanical Arm

و جاءت الفكرة بالاساس من خلال التواصل مع مجتمع الصناعة المحلية بالتنسيق مع مركز التكافل مع الصناعة في جامعة بوليتكنيك فلسطين، من أجل طرح المشاكل التقنية في المصانع المحلية كمشاريع تخرج تساهم في حل هذه المشاكل، و تقدم نموذجا لإبداع طلبة الجامعة و قدرتهم على المساهمة و التعامل التطبيقي الفعال في علاج المشاكل التقنية و الابتكار الهادف، لتعزيز قدرة و إمكانية الصناعة المحلية على التطور و النجاح.

من هنا تم التواصل مع شركة رويال الصناعية و التجارية، و عرضوا علينا مشكلة تتمثل في خط انتاج للأنابيب غير متكامل، بحيث نعمل على ابتكار تصميم ميكانيكي-كهربائي يمثل حلقة وصل بين جزئي هذا الخط،بحيث يعمل أوتوماتيكيا دون تدخل مباشر من الإنسان في عمله، و يسد مسد العامل الذي يتولى مهام نقل الانبوب من ماكينة القص إلى ماكينة التشكيل لنهاية الأنبوب، فطلبنا منهم و صفا عاما للمشكلة و الامكانيات الزمانية و المكانية و ظروف التشغيل الخاصة بهذا الجزء المقترح علينا للتصميم و التنفيذ.

و بالفعل مع أكتمال العام الدراسي قمنا بتصميم ذراع كهرميكانيكي يقوم بالمهام التالية:

١. الامساك بالأنبوب الخارج من ماكينة القص.
٢. رفعه و تدويره من زاوية صفر في الوضع الافقي إلى زاوية ٩٠ في الوضع العامودي.
٣. نقل الانبوب إلى ماكينة التشكيل.
٤. تسكين الانبوب في فوهة التسخين مدة زمنية قصيرة و كافية لتليين نهاية الانبوب.
٥. تسكين الانبوب في قالب التشكيل .
٦. رفع الانبوب و إرجاعه إلى الوضع الافقي.
٧. وضع الانبوب في سلة الانتاج.

# CHAPTER ONE
# INTRODUCTION

## 1.1 Importance of The Project

The project aims to design an electromechanical arm to achieve a specific tasks that done by human worker and implement the whole system as a module . The importance of this idea or project consists of the accuracy and fast operation to produce the pipes in the belling Machine . According to that we must exchange the operation of this machine from manual to automatic operation .

## 1.2 Electromechanical Arm Concept

The electromechanical arm has to move in three directions during the operation of transporting the pipe from the cutting area to the heating and framing machine. This motion produced by induction motors and cylinders .

## 1.3 Applications

The electromechanical arm is an intermediate part between two stages in the production line , it could be used in the factories to transport any production piece to specific stage in the production process, such as sorting machine, filling machine, and cars factories , etc. . the transportation of the pipes in the Belling Machine is one of the application of this technology.

## 1.4 Description Of The Project

The project is divided into five stages:

1. Catching the pipe by two clamps operated by two hydraulic cylinders , the pipe is in a horizontal situation.
2. Rotating the pipe from horizontal to vertical situation , after lifting it to a limited high.
3. Move in linear track to transport the pipe to the heating and framing machine.
4. Debarking the pipe into the heating barrel for a certain time .
5. Lifting the pipe and transport it to framing barrel.
6. framing the socket of the pipe.
7. leave the pipe in the production basket.

### 1.5 Project cost

**Table (1.2):** Cost of Project

| Component name | # | Price per component ( NIS ) | Total price / NIS |
|---|---|---|---|
| Induction Motor | 2 | 300 | 600 |
| Inverter | 2 | 700 | 1400 |
| Pneumatic pistons | 3 | 180 | 540 |
| Micro switches | 6 | 25 | 150 |
| PLC unit | 1 | 1100 | 1100 |
| Switches | 4 | 45 | 180 |
| Rollers | 14 | 7 | 98 |
| Lagers | 4 | 25 | 100 |
| Iron | -- | 700 | 700 |
| Wood | -- | 180 | 180 |
| Wires | -- | 150 | 150 |
| Pneumatic Tubes | 10 | 5 | 50 |
| Technical cost | -- | 3000 | 3000 |
| Pneumatic Valves | 3 | 150 | 450 |
| Relays | 9 | 25 | 225 |
| Circuit Breakers | 3 | 30 | 90 |
| Expenses | -- | 500 | 500 |
| Total Price | 9513 | | |

# CHAPTER TWO

# BELLING MACHINE

## 2.1 Background and Invention

This invention relates generally to the field of plastic pipe working machines, particularly is directed to a plastic pipe belling machine suitable to impress a bell shape on one end of a length of plastic pipe. The use of plastics such as ABS, PVC and other plastic materials for conveying liquids within pipes for various purposes is becoming increasingly popular throughout the world. As plastic fabricating techniques and pipe forming equipment have improved in quality and availability, the reliability of such material has resulted in a gradual increased acceptance by specifying engineers, by code officials and by the purchasing public in general.

In view of the greatly expanded use of the plastic piping materials, it has become increasingly important to develop efficient, reliable and automatic plastic pipe working machinery to enable production to keep pace with the demand. In this regard, automatically operating machinery has been developed by prior workers in the areas of automatic extrusion equipment, automatic cutting equipment, automatic perforating machines, chamfering equipment and similar production type designs to facilitate and expedite the production and processing of plastic pipes. With regard to pipe belling procedures in particular, prior workers in the field have generally incorporated many hand operations in the procedure. These present methods have accordingly proven to be too slow and too costly in view of the increased demand.

**2.2 Principle of the Belling Machine**

The present invention relates generally to the field of plastic pipe working machines and more particularly is directed to a novel plastic pipe belling machine capable of automatically preheating and rapidly shaping the ends of previously cut lengths of plastic pipe.

Pipe belling machine of the present invention includes a frame of generally elongated configuration having a plurality of chain conveyors functioning transversely thereof in unison to carry previously cut lengths of plastic pipe transversely across the frame toward a belling station. The chain conveyors include a plurality of spaced pins which function to push successive lengths of pipe upwardly along a slightly inclined path toward the belling station. A plurality of transversely positioned moving belts are associated with the chain conveyors and are wired for continuous operation during all periods when the machine is in use. The previously cut lengths of plastic pipe rest upon the moving belts as they are indexed across the machine so that the belts rotate each length of pipe continuously as it is conveyed across the machine by the chain conveyor.

Belling machine comprises five stations, the first one of which is the receiving station which receives pipes from an extruder after it is cut to length by a cutting saw. The next three stations are heating stations wherein one pipe end is indexed beneath an infra-red heater in a manner to permit the one end of the pipe to be continuously heated as the pipe is indexed and rotated. The final station is the belling station where a power operated mandrel presses a predetermined shape onto each previously heated end. The shape can be of any desired configuration which would be controlled by the design of the mandrel and jaws. Suitable controls are provided in the nature of limit switches, micro-switches, to control the function of the chain conveyors, the power mandrel and time of operation of the belling cycle. In a first mode, a plain bell shape can be applied whereby a stripping plate is employed to facilitate withdrawing the mandrel from the newly shaped end. In a second mode, an inwardly facing groove suitable for receiving a gasket can be formed whereby upper and lower mold sections are utilized, but no stripping plate is required It is, therefore, an object of the present invention to provide an improved plastic pipe belling machine of the type set forth.

## 2.3 Belling Machine used in project

This machine already exists, but it is included in the project in order to present a full imagination for the design and operation of the arm. Belling machine has two heating barriers are used to make the end of the pipe elastic and ready to be framed and socketed well. And it has one framing barrier to make a socket on the end of the pipe, the Belling machine shape and dimensions is shown in Figure (2.1) :

**Figure (2.1):** Belling Machine(L: Length; H: height; W: width ):

1. framing Barrier
2. heating Barrier

3. front side of Belling machine

# CHAPTER THREE

# SELECTION OF PROJECTS MOTORS

In our project we have chosen Squirrel Cage Induction Motor type according to , simple design, rugged, low-price, easy maintenance, wide range of power ratings: fractional horsepower to 10 MW, run essentially as constant speed from no-load to full load, it's speed depends on the frequency of the power source, not easy to have variable speed control, requires a variable-frequency power-electronic drive for optimal speed control, and can operate in dirty and explosive environments.

So there are two induction motors used, one motor to move the arm horizontally, and the other to move the arm vertically. These two movements are done by the motors through screws connected with each motor. The following block diagram shows the whole connection of electrical motors:

**Figure (3.1):** Block Diagram of the Squirrel Cage IM

## 3.1 Speed Control of Squirrel Cage Induction Motor:

The rotational speed of the rotor is controlled by the number of pole pairs (number of windings in the stator) and by the frequency of the supply voltage. Before the development of cheap power electronics, it was difficult to vary the frequency to the motor and therefore the uses for the induction motor were limited.

The general term for a power electronic device that controls the speed as well as other parameters is inverter. A typical unit will take the mains AC supply, rectify and smooth it into a "link" DC voltage, and, then convert it into the desired AC waveform. because the induction motor has no brushes and is easy to control, many older DC motors are being replaced with induction motors and accompanying inverters in industrial applications.

### 3.1.1 Inverter :

An inverter is an electrical or electro-mechanical device that converts direct current (DC) to alternative current (AC); the resulting AC can be at any required voltage and frequency with the use of appropriate transformers , switching, and control circuits. An inverter converts the DC electricity from sources such as batteries, solar panels , or fuel cells to AC electricity. The electricity can be at any required voltage; in particular it can operate AC equipment designed for mains operation, or rectified to produce DC at any desired voltage.

Grid tie inverters can feed energy back into the distribution network because they produce alternating current with the same wave shape and frequency as supplied by the distribution system. They can also switch off automatically in the event of a black out.

A Variable-frequency drives controls the operating speed of an AC motor by controlling the frequency and voltage of the power supplied to the motor. An inverter provides the controlled power. In most cases, the variable-frequency drive includes a rectifier so that DC power for the inverter can be provided from main AC power. Since an inverter is the key component, variable-frequency drives are sometimes called inverter drives or just inverters. The circuit of the inverter three phase inverter shown in figure (2.2):

**Figure (3.2):** Circuit of Inverter

# CHAPTER FOUR

# SELECTION OF PNEUMATIC ACTUATORS

## 4.1 Pneumatic Actuators

The other part in this project that supply the mechanical power for the system is Pneumatic actuators. Pneumatic actuators include linear cylinders and rotary actuators.

Cylinders is a device that converts air energy into linear mechanical force or motion .it usually consists of a movable element such as piston ,plunger , or ram operation within a cylindrical bore .The bore of a cylinder determines the maximum force that it can exert. The stroke of a cylinder determines the maximum linear movement that it can produce. The maximum working pressure depends on the cylinder design, cylinders are divided into two types :

1. Single acting cylinder
2. Double acting cylinder

In this project we will use three double acting cylinders. One for the jack and two double acting cylinder for clamps to catch the pipe.

Double acting cylinders are equipped with two working ports- one on the piston side and the other on the rod side as shown in Figure (4.1). To achieve forward motion of the cylinder, compressed air is admitted on the piston side and the rod side is connected to exhaust. During return motion supply air is admitted at the rod side while the piston side volume is connected to the exhaust. Force is exerted by the piston both during forward and return motion of cylinder .Double acting cylinders are available in diameters from few mm to around 300 mm and stroke lengths of few mm up to 2 meters.

**Figure(4.1):** Double Acting Cylinder

The other type of actuators we use in the project is Rotary Actuators . In order to achieve angular motion, rotary Actuators are used. Rotary actuators are mainly available in two designs. Vane type Construction: Further these actuators are available with 180 degrees rotation or 270 degrees angle of rotation. These actuators can be used for low torque requirement up to 10 N-m. .Rack and Pinion type construction**:** Can be used for angle or rotation close to 360 degrees. These actuators can develop torques up to 100-150 N-m depending on the diameter of the cylinder. Figure (4.2 ) shows the rotary cylinder.

**Figure (4.2):** Rotary Cylinder

## 4.2 Directional Control Valves

Pneumatic directional control valves and cylinders are most commonly used in power circuits with the valves controlling cylinders that in turn provide work. As we develop a few of these circuits, other accessory valves will be introduced along with some interesting ways of using them .The directional control valve in any power circuit should be mounted as close as possible to the cylinder it controls. Pressure drops in long hoses leading to the cylinder may cause the piston to move too slowly. Long hoses between the valve and cylinder may have more volume than the cylinder thus lubricated air might never reach the cylinder before it is exhausted back through the valve to the atmosphere. Short hoses between the valve and cylinder will help to solve both of these problems but when not possible try a “quick exhaust valve” mounted close to the cylinder.

We have chosen three valves .(5/2 directional control valve) to control motion of the jack cylinder. (5/2 Directional Control valve) to control the motion of clamps cylinder. (3/2 Directional Control valve with spring return) to determine the direction rotation of the rotary cylinder.

### 4.2.1 Solenoid Valves

Solenoid: converts an electrical signal into mechanical motion, usually rectilinear. Used when a large, sudden force must be applied to perform some job. Solenoid valves are electro-pneumatic relays. The state of an electrical input controls its convert to pneumatic output. Solenoid valves are the interface between electronic control systems and pneumatic power .solenoid valve consist of :

1. Pneumatic valve.
2. Coil which switches the valve.

## 4.3 Block Diagram of Pneumatic System

The following block diagram shows the whole connection of the Pneumatic system :

Figure (4.3) Block diagram of Pneumatic System

# CHAPTER FIVE

# DESIGN AND CONSRUCTION

## 5.1 Introduction

The system was designed to be suitable for the nature of the function of electromechanical Arm, and for the geographical environment of the production plant, as shown in the Figure (5.1):

**Figure (5.1):** Electromechanical Arm Design

We have chosen every part of the mechanical construction to accomplish specific function and to obtain the most suitable design of the mechanical system. so we will explain each part individually.

## 5.2 Flow Chart

**Figure (5.2)** : General Flow Chart

## 5.3 Arm Parts

The proposed Arm constructs of the following parts:

### 5.3.1 Pneumatic Jack

The Jack was designed to push the clamp's carrier frontward at framing, and basket level, this jack will be pushed by a double acting pneumatic cylinder. On the moving part of the jack there is a pneumatic rotary actuator is fixed to rotate the clamp's carrier by 90°, noted that these pneumatic actuators will be explained in the pneumatic system design. The jack is mounted on a moving part connected to a vertical lever by 8 rollers.

### 5.3.2 Clamps

A pair of clamps were designed to catch the pipe, these clamps are mounted on a hollow cylindrical square rod steel, these clamps are designed to catch and leave the pipe by a fixed double acting pneumatic cylinders plugged at the end of the clamp's carrier. Figure (5.2) shows the arm's design with all parts:

**Figure (5.3):** Arm's Design

### 5.3.3 Bearings

We have chosen the Bearing of the moving part that shown in the last figure according to bearing's catalogue, this bearing is show in Figure (5.3), which called (Cylindrical Bore Bearing ) .

**Figure (5.4):** Cylindrical Bore Bearing

Another type of bearings was chosen to fix the end of the screw in it, this bearing is ( Pillow Block Cast Housing Set Screw ), which shown in Figure (5.4):

**Figure (5.5):** Pillow Block Cast Housing Set Screw Type, And It's Dimensions.

### 5.3.4 Screw

The most important part of the arm is the screw, because of the accurate positioning and constant linear velocity resulted from the rotation of the screw. For our project we have chosen a screw with parameters shown in Figure (5.5).

**Figure (5.6):** Screw Dimensions

## 5.4 Cylinders and Rotary Actuators Calculations

As we described in the previous section, there are three cylinders will be used: one for the jack, and two for both clamps. And we will use a rotary actuator to rotate the carrier of the clamps by 90°. The requested parameters are described in the following calculations:

### 5.4.1 Cylinder of the Jack Calculations

The pressure is given by:

(5.1)

where, P: pressure, *Pascal*.

F: force (or perpendicular component of the force on the area), *Newton*.

A: area ,.

eq. (5.1) can be rewritten as:

(5.2)

From equation (5.2) , the internal area of the cylinder can be found as:

Where:

(5.3)

The internal radius of the cylinder rewritten from the previous equation. as:

**Figure (5.7):** Jack Cylinder

A stroke of **20cm** will be chosen for this cylinder as shown in Figure (5.6).

### 5.4.2 Cylinders of the Clamps

Both cylinders of the clamps are chosen to have the same parameters, in order to synchronize their function accurately.

According to equation (5.2) the internal area of the cylinder can be found as:

the radius of the area of the cylinder is :

**Figure (5.8)**: Clamps Cylinder

A stroke of **7 cm** will be chosen for this cylinder as shown in Figure (5.7).

### 5.4.3 Rotary Actuator

To find the parameters of the rotary actuator, we must calculate the moment of inertia for the design shown in Figure (5.8), the inertia can be found according to the equation:

(5.4)

where, *I* : Moment of Inertia (*kg.*) *M*: Mass (kg) , *L* : Length of bar

Then,

**Figure (5.9):** rotary actuator load distribution

The required torque needed to rotate the load(arm carrier, clamps, and pipe) is :

(5.5)

where, T: torque, *Nm* ; I: inertia, *kg.* ; : angular acceleration, : rotation angle *rad* ; *t* : time of rotation *sec*.

For low speed rotary, if the rotation time exceeds 2 sec per 90°, inertial load is calculated with rotation time of 1 sec per 90°. In our project t will be 3 sec, then:

The whole pneumatic circuit  and simulation of the actuators sequence of operation is shown in Figure (5.9):

(a)  Pneumatic Power Circuit.

(b) Simulation of the Circuit

**Figure (5.10):**Pneumatic System Configurations.

**5.5 Calculation  of the Induction Motors**

There are two induction motors will be used, one of them to move the load horizontally for 1.5 m at each direction, and the other  is to lift and lower the jack and the arm's components up and down for 0.5m. Each motor will be connected with a screw, to achieve a high level of positioning accuracy and to stabilize the linear velocity.

### 5.5.1 Screw calculations

We have chosen the screw's parameters as shown in Figure (5.10). The torque needed to move the load in linear transition is:

(5.6)

where , : torque needed to move the load,

: may be weight or inertial force,

: mean screw diameter,

: friction coefficient,

: lead of the screw.

**Figure (5.11):** Screw's Parameters

For the horizontal screw, it will move the whole arm and it's components that have a weight of 157 Ibf. To calculate the needed torque of the motor, we have assume the coefficient of the friction to be 0.1, then:

### 5.5.2 Motor's Calculations

After we calculate the torque needed to move the arm by the motor through the screw, we will find motor's speed that needed to transport the arm horizontally along 1.5 meters in 10 seconds, so that the linear velocity is given by now the screw's speed is given by:

(5.8)

where,  is the screw's pitch, such that:

then,

138.889 = 20.83 *rps*

Now, the power required to drive the screw could be calculated by:

(5.9)

then**:**

Hence, a 3-phase Δ- connected induction motor, 0.11output power, and 1250 *rpm* speed, will be chosen for our project.

Hence;

The load current is 0.15 A, so we choose a (Cu) wire of 1.5mm diameter and max length of 510 m .

For the other motor which will raise and lower the arm, it will transport vertically with speed of :

138.889 = 23. *rps*

then**:**

Hence, a 3-phase Δ- connected induction motor, 0.08output power, and 1380 *rpm* speed, will be chosen for our project.

Hence;

The load current is 0.1 A, so we choose a (Cu) wire of 1.5mm diameter and max length of 510 m .

The Figure (5.11) shows the power circuit for the used motor and the protection element that we need for two motor

**Figure(5.12)**: Power Circuit Of The Motors

## 5.6 Design of the PLC Program Of Electromechanical Arm

| Name | Function | State | PLC |
|---|---|---|---|
| Stop switch | Stop the system | NC | X1 |
| Start switch | Start system | NO | X0 |
| MS1 | Stop the horizontal motor to catch the pipe | NO | X2 |
| MS2 | Stop the vertical motor in last up position | NO | X3 |
| MS3 | Stop the vertical motor in last down position | NO | X4 |
| MS4 | Stop the horizontal motor at heating barrier | NO | X11 |
| MS5 | Stop the horizontal motor in framing barrier | NO | X13 |
| MS 6 | Indicate for existing pipe in first the operation | NO | X12 |

**Table (5.1):** Input of PLC Unit

| Title | Function | Symbol | PLC |
|---|---|---|---|
| Horizontal Induction motor | Move the motor to the right | K1 | Q10 |
| | Move the motor to the lift | K2 | Q5 |
| Vertical Induction motor | Move the motor to the up | K3 | Q6 |
| | Move the motor to the down | K4 | Q7 |
| 4/2 way directional control | push the Double acting cylinder | Y1 | Q0 |

| | | | |
|---|---|---|---|
| valve (1) | (jack) to the end stroke | | |
| | return push the Double acting cylinder (jack) to the start stroke | Y2 | Q2 |
| 2/1 way directional control valve with spring return | Active the rotary actuator to Rotate the arm (c c w) by 90 | Y5 | Q4 |
| 4/2 way directional control valve (2) | push the Double acting cylinder to catch the pipe | Y3 | Q3 |
| | return the Double acting cylinder to left the pipe | Y4 | Q1 |

**Table (5.2):** output of PLC Unit

### 5.6.1 PLC Connection

**Figure(5.13):** PLC Unit connection

# CHAPTER SIX

# IMPLEMENTATION AND CONCLUSION

The project of the Electromechanical Arm is a prototype module of an industrial application, so we won't have any simulation of any electrical or pneumatic device .In this chapter we will deal with the implementation features of the project, and explain the actual parts of the arm .In addition, we will introduce conclusions and recommendations about our project.

## 6.1 Implementation Procedure

1. Preparing the metallic body of whole parts of the Arm and it's auxiliary pieces.
2. Installation of the mechanical system.
3. Buying and installing the Electrical and Pneumatic devices.
4. Buying the control element and devices, like PLC unit, Invertors, Relays, switches, wires, electrical panel, and pneumatic selectors.
5. Connecting the control devices and power supply in the Electrical panel.

6. Manual testing of the power devices and control elements.
7. Programming the full operation of the Arm using PLC principles.
8. Downloading the PLC program on the PLC unit and operating the machine.

The following picture shows the general view of the project in final manner including all mechanical and electrical structures:

**Figure (6.1) :** General View of the Project

## 6.2 Parameters and Specifications of Electrical Devices

The electrical system consists of the following devices:

### 6.2.1 Motors

We have designed the motor’s parameters to be suitable for single phase AC drives, but we have changed these parameters for three phase AC drives, since we have chosen a three phase output Invertors for the motors that we will use in the project . The following pictures explain and show the motors and their nameplates:

| | | | | |
|---|---|---|---|---|
| THREE-PHASE INDUCTION MOTOR | | | | |
| TYPE: Y2-711-4 | | | | |
| 3 ~ MOTOR | | Nr. 07369 | | |
| Y 380V | | 0.79 A | | |
| 0.25 KW | S 1 | | Cosφ 0.74 | |
| 1345 min$^{-1}$ | | | | 50 Hz |
| | | | | |
| I.K.L. F | IP 54 | | | |
| F.H.SH.CO | | | | |

(a)

| | | | | |
|---|---|---|---|---|
| NUOVA GASSOLNOVA | | | | |
| Type 80 B2 | | | | |
| 3 ~ MOTOR | | Nr. 41613 | | |
| Δ/Y 220/380V | | 4.9/2.8 A | | |
| 0.37 KW | S 1 | | Cosφ 0.80 | |
| 1470 min$^{-1}$ | | | | 50 Hz |
| | | | | |
| I.K.L. F | IP 54 | | | |
| FASI | | | | |

(b)

**Figure (6.2): (a)** Nameplate of the Vertical Motor
**(b)** Nameplate of the Horizontal motor

### 6.2.2 Invertors

In order to control the speed and direction for the motors, Invertors are the most suitable and effective control devices that could be used to do so .According to the motor's output powers, we have chosen the parameters of the invertors, to be exactly the same parameters in order to achieve a correct drive .The full explanation of the operation and control methods and programming parameters of the Invertors are shown in Appendix (), and the following picture shows the tow invertors that we used:

**Figure (6.3):** The tow Invertors used to control the motors .

### 6.2.3 PLC Unit

The PLC unit is an electronic device that accepts analog or digital signal to control one operation or more and its sequence .So, a DELTA PLC unit )shown in the next figure (has been chosen to accomplish the specified operations of the Arm:

**Figure(6.4) :** Delta PLC Unit

This unit has inputs and outputs listed in the next tables:

| name | function | State | PLC |
|---|---|---|---|
| Stop switch | Stop the system | NC | X1 |
| Start switch | Start system | NO | X0 |
| MS1 | Stop the horizontal motor to catch the pipe | NO | X2 |
| MS2 | Stop the vertical motor in last up position | NO | X3 |
| MS3 | Stop the vertical motor in last down position | NO | X4 |
| MS4 | Stop the horizontal motor at heating barrier | NO | X11 |
| MS5 | Stop the horizontal motor in framing barrier | NO | X13 |
| MS 6 | Indicate for existing pipe in first the operation | NO | X12 |

**Table(6.1) :**Inputs of PLC Unit

| Title | function | Symbol | PLC |
|---|---|---|---|
| Horizontal Induction motor | Move the motor to the right | K1 | Q10 |
| | Move the motor to the lift | K2 | Q5 |
| Vertical Induction motor | Move the motor to the up | K3 | Q6 |
| | Move the motor to the down | K4 | Q7 |
| 5/2 way directional control valve (1) | push the Double acting cylinder (jack) to the end stroke | Y1 | Q0 |
| | return the Double acting cylinder (jack) to the start stroke | Y2 | Q2 |
| 3/2 way directional control valve with spring return | Active the rotary actuator to Rotate the arm (ccw) by 90 | YR1 | Q4 |
| 5/2 way directional control valve (2) | push the Double acting cylinder to catch the pipe | Y3 | Q3 |
| | return the Double acting cylinder to left the pipe | Y1 | Q1 |

**Table (6.2) :** Outputs of PLC Unit

Every output of the PLC is connected to a specific operating power device which are mentioned in Table (6.2) through a relay .This relay is used as a protection element since its operating as switch such that when any interrupt or short circuit in any device the relay well be opened .There for no dangerous current could flow the internal PLC circuit, the following figure shows the desired connection:

**Figure (6.5) :** The PLC Outputs Connected to the Relays

**PLC Program:**

The program that operates the hole system is written on a specific software program using the PLC LADDER technique according to the tasks and function that the machine would achieve .The program downloaded into the PLC unit and run exactly as designed as follows:

## 6.3 Parameters and Specifications of Pneumatic Devices

The pneumatic system has three features:

- Pneumatic Power Devices :

1- jack :its designed in order to push and pull the clamps carrier forward and backward respectively .So a cylindrical piston fixed on the guide of the jack and its stroke is connected to moving part as shown in the following picture:

**Figure (6.6) :**Actual view of the Jack

2- rotary actuator :in other word its pneumatic motor that used to rotate the clamps carrier from 0° to 90°. this angle of rotation is the require angle to transport the pipe from horizontal to vertical situation .this rotary actuator is connected to moving part of the jack as shown in following picture:

**Figure (6.7) :**General View of Rotary Actuator

3- Clamps : there are designed to catch the pipe mechanically using a small cylindrical piston for each clamps .these clamps are fixed on the ends of a whole steel rod in front of the piston as shown below:

**Figure(6.8):** Actual Clamp

- Pneumatic control valves :in order to control the pneumatic power elements that mentioned above , a pneumatic valves used to controlled each element :

1. Two 5/2 directional control valves actuated by two electrical solenoids, each solenoid actuates the valve to allow the piston to move forward or backward for the Jack, and allow the clamps to catch or leave the pipe.
2. 3/2 directional control valves actuated by single electrical solenoid, with spring return, the solenoid actuates the valve to allow the rotary actuator to rotate to 90° .

## 6.4 Conclusion and Recommendations

- **Conclusion:**

1. The prototype module has been fully designed, and all of the required functions and tasks have been achieved.
2. An experimental verification has been done for the pipe’s transportation, rotation, heating, and framing tasks with exact positioning .

- **Recommendations:**

1. We have tested the translational motion for low frequency applied the horizontal motor, to achieve an exact positioning, so its good idea to examine the positioning for high frequency.
2. The three motion of the system are operated individually without synchronization, so there an opportunity to achieve a synchronous motion for the translational, rotation, and vertical motions .