Palestine Polytechnic University

College of Engineering and Technology

Electrical and Computer Engineering Department

Graduation Project

Controlling a permanent magnet linear synchronous motor for vertical transportation as elevator

Project Team

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Jan-2009

بسم الله الرحمن الرحيم

Palestine Polytechnic University

College of Engineering and Technology
Industrial Automation Engineering

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In accordance with the recommendations of the project supervisor , And The acceptance of all examining committee members , this project has been submitted to the department of Electrical and Computer Engineering In the college of Engineering and technology in partial fulfillment of the requirements of the bachelor's degree in Industrial Automation Engineering.

Project supervisor signature

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Committee signature

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Department Head signature

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Dedication

We dedicate this simple work:

To our parents

To our brothers

To our friends

To our nation

To any person working hard…

Acknowledgments

First and for most we should offer our thanks, obedience and gratitude to Allah.

Our appreciation to:

Palestine Polytechnic University

College of Engineering & Technology

Electrical & Computer Engineering Department

Our supervisor Dr. ABDEL-KARIM DAUD

Abd-elhakeem iadeh

Anyone who helped us

Abstract

In this project we will use a previous project, permanent magnet linear synchronous motor (PMLSM), that project was done in Palestine Polytechnic University, the model is three levels elevator, in order to control a velocity and acceleration of the elevator, and we will control the position where the elevator stops accurately in order to prevent the elevator from stopping higher or lower from the requested position.

Additionally we will control the opening and closing of the elevator door, and control the position where the elevator will stop considering orders priority

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Chapter one

Introduction

An elevator or lift is a transport device used to move goods or people vertically. Now in these days in factories we need to lift heavy weights so we need to elevator to transport it from a level to another one. And for a higher building we need elevators that can carry heavy weights and have a high speed to make a best service. [9]

Elevators are often a legal requirement in new buildings with multiple floors.

1.1 Overview

In this project we will use a previous project, permanent magnet linear synchronous motor (PMLSM), that project was done in Palestine Polytechnic University, we will make a model for three levels elevator, in order to control a velocity and acceleration of the elevator, and we will control the position where the elevator stops accurately in order to prevent the elevator from stopping higher or lower from the requested position.

Additionally we will control the opening and closing of the elevator door, and control the position where the elevator will stop considering orders priority.

1.2 The importance of the project

This kind of motors can move in a very fast speed and can carry heavy loads. Because of that we can use it in skyscrapers, factories, and international organizations.

There is an increasing demand to reduce both the space needed for hoist ways in buildings and the size of elevator electrical supplies. These requirements have a strong influence on the selection of the hoisting machine, which can be remarkably improved by utilizing a linear motor. Because the linear motor produces straightforward movement without mechanical transformations thus improving the efficiency due to a smaller number of components, the usage of linear motors appears highly attractive. An intensive research in this field was aimed at surpassing conventional technology in performance and cost. The type of electric motor, i.e., induction, switched reluctance, or synchronous is important in the linear motor elevator technology. However, the elevator structure is even more important because requirements for the hoisting system vary with the arrangements of the elevator components. Sometimes the hoisting machinery must lift all traveling masses, whereas in other cases the counterweight does part of the work. [1]

1.3 Elevator Hoisting Machines [6]

Hoisting technology started when Archimedes constructed his first winch in 236 B.C. However, early primitive elevators did not guarantee any safety for passengers. The situation changed with Elisha Otis' invention of a reliable safety gear in 1853. In the first elevators the drum was used to collect the rope.

The major disadvantage was the necessity to lift the load together with the supporting structure. The next type, referred to as a rope traction elevator, has been constructed in such a way as to obtain the load balanced by the counterweight. This latter construction is widely used today. Elevators can be classified into three major categories based on their size:

- High-rise elevators used in the tallest buildings in major cities and manufactured at a volume of about 2,000 units annually. These elevators add image and prestige to the company manufacturing them.

- Mid-rise elevators installed in office buildings, hotels, and other similar structures (annual market size of approximately 20,000 units). The appearance, comfort and ride quality become most important for these installations.

• Low-rise elevators mostly installed in residential buildings (total annual sales of about 200,000 units world-wide).

There is an increasing demand to reduce both the space needed for hoistways in buildings and the size of elevator electrical supplies. These requirements have a strong influence on the selection of the hoisting machine, which can be remarkably improved by utilizing a linear motor. Because the linear motor produces straightforward movement without mechanical transformations thus improving the efficiency due to a smaller number of components, the usage of linear motors appears highly attractive. This technology matured in 1991 when Nippon Otis introduced the first commercial application of the linear motor elevator onto the Japanese market. Since then, the intensive research in this field was aimed at surpassing conventional technology in performance and cost. The type of electric motor, i.e., induction, switched reluctance, or synchronous is important in the linear motor elevator technology. However, the elevator structure is even more important because requirements for the hoisting system vary with the arrangements of the elevator components. Sometimes the hoisting machinery must lift all travelling masses, whereas in other cases the counterweight does part of the work. Moreover, in some elevators, the weight of the motor can be utilized as the part of the mass balance.

1.4 block diagram

The fig (1.1) is the block diagram of the elevator.

1. Order: this unit is the buttons panel in the car and outside of the car; which allows the user to order the level that he wants.
2. Control unit: controls the operations and when the motor must stop or move, by controlling the speed and position of the motor.
3. Frequency converter: is used as the main driver of the motor, it determines the speed of motor by changing the frequency.

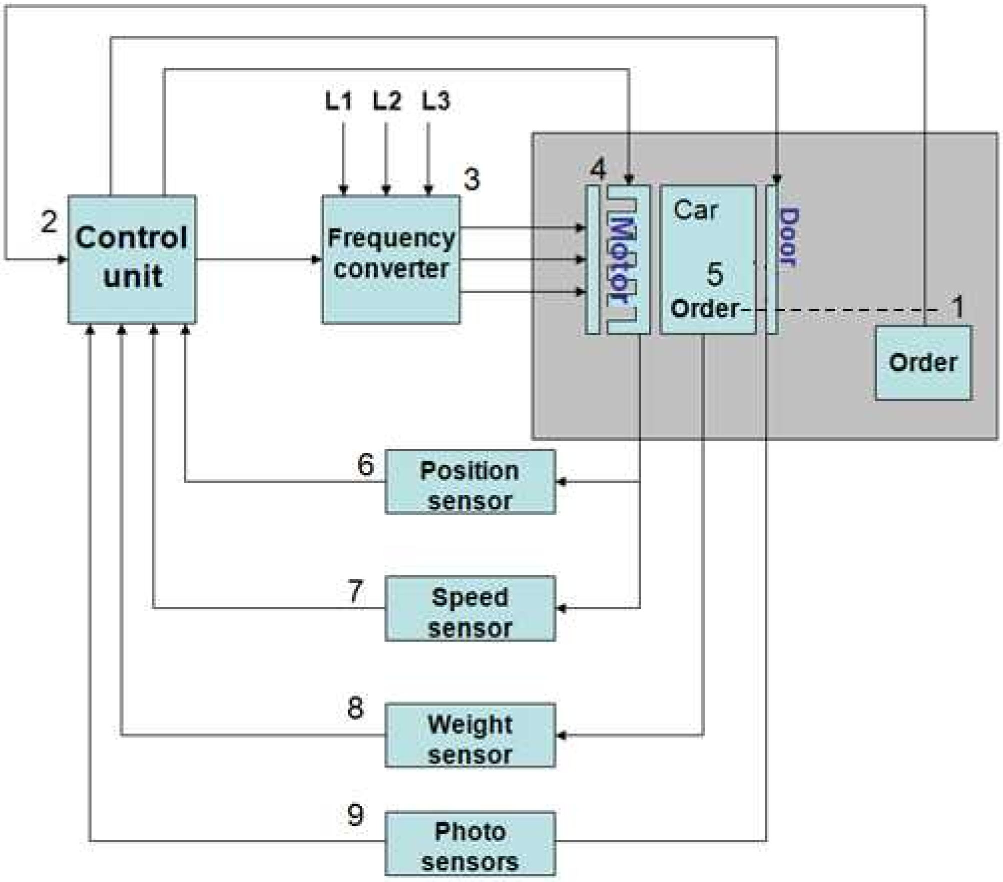


Fig (1.1) Block diagram of the elevator

4. Motor: this is the (PMLSM) that we will use to make this project. And it will carry the load that we need to transport.
5. Car: carries the load.
6. Position sensor: a sensor that indicate where the elevator must stop and to where it must move.
7. Speed sensor: to know the speed of the elevator, this sensor can be used for stability and safety.
8. Weight sensor: to grantee that the motor not over loaded and it will work on the name load or less.
9. Photo sensor: to detect the objects between the two sides of the door.

1.5 Table of Cost

Table 1.1: Table of cost of the project.

Items	**Cost (USA) Dollars**	**notes**
Motor and half of body	2820 $	From previous project
Elevator body (car)	131.6 $	
Rail of elevator	236.8 $	
Doors	26.3 $	
Brake	263.2 $	
Track	526.3 $	
Tools and Screws	52.6 $	
Sensors and limit switches	7.9 $	
Other expenses	157.9 $	
Total	4222.6 $	
Total without previous project	1402.6 $	

Chapter two

Electrical Elevators

2.1 Historical information [7]

There some previous projects and papers worked on PMLSM as horizontal and vertical transportation (elevator), to control speed, position, acceleration, or electromagnetic guiding system, and there some other projects about the control speed, position, and acceleration, of elevator. In this chapter we will talk about some previous researches.

Primitive elevators were in use as early as the 3rd century BC, operated by human, animal, or water wheel power. From about the middle of the 19th century, power elevators, often steam-operated, were used for conveying materials in factories, mines and warehouses.

In 1853, American inventor Elisha Otis demonstrated a freight elevator equipped with a safety device to prevent falling in case a supporting cable should break. This increased public confidence in such devices. Otis established a company for manufacturing elevators and patented (1861) a steam elevator. In 1846, Sir William Armstrong introduced the hydraulic crane, and in the early 1870s, hydraulic machines began to replace the steam-powered elevator. The hydraulic elevator is supported by a heavy piston, moving in a cylinder, and operated by the water (or oil) pressure produced by pumps.

Electric elevators came into to use toward the end of the 19th century. The first one was built by the German inventor Werner von Siemens in 1880.

In a typical elevator, the car is raised and lowered by six to eight motor-driven wire ropes that are attached to the top of the car at one end, travel around a pair of sheaves, and are again attached to a counterweight at the other end.

The counterweight adds accelerating force when the elevator car is ascending and provides a retarding effort when the car is descending so that less motor horsepower is required. The counterweight is a collection of metal weights that is equal to the weight of the car containing about 45% of its rated load. A set of chains are looped from the bottom of the counterweight to the underside of the car to help maintain balance by offsetting the weight of the suspension ropes.

Guide rails that run the length of the shaft keep the car and counterweight from swaying or twisting during their travel. Rollers are attached to the car and the counterweight to provide smooth travel along the guide rails.

The traction to raise and lower the car comes from the friction of the wire ropes against the grooved sheaves. The main sheave is driven by an electric motor.

Most elevators use a direct current motor because its speed can be precisely controlled to allow smooth acceleration and deceleration. Motor-generator (M-G) sets typically provide to dc power for the drive motor. Newer systems use a static drive control. The elevator controls vary the motor’s speed based on a set of feedback signals that indicate the car’s position in the shaft-way. As the car approaches its destination, a switch near the landing signals the controls to stop the car at floor level. Additional shaft-way limit switches are installed to monitor over-travel conditions.

2.2 Roped elevator [7]

The most popular elevator design is the roped elevator. In roped elevators, the car is raised and lowered by traction steel ropes rather than pushed from below. The ropes are attached to the elevator car, and looped around a sheave fig(2.1.(3)). A sheave is just a pulley with grooves around the circumference. The sheave grips the hoist ropes, so when you rotate the sheave, the ropes move too.

The sheave is connected to an electric motor fig(2.1.(2)). When the motor turns one way, the sheave raises the elevator; when the motor turns the other way, the sheave lowers the elevator. In gearless elevators, the motor rotates the sheaves directly. In geared elevators, the motor turns a gear train that rotates the sheave. Typically, the sheave, the motor and the control system fig (2.1.(1)) are all housed in a machine room above the elevator shaft .

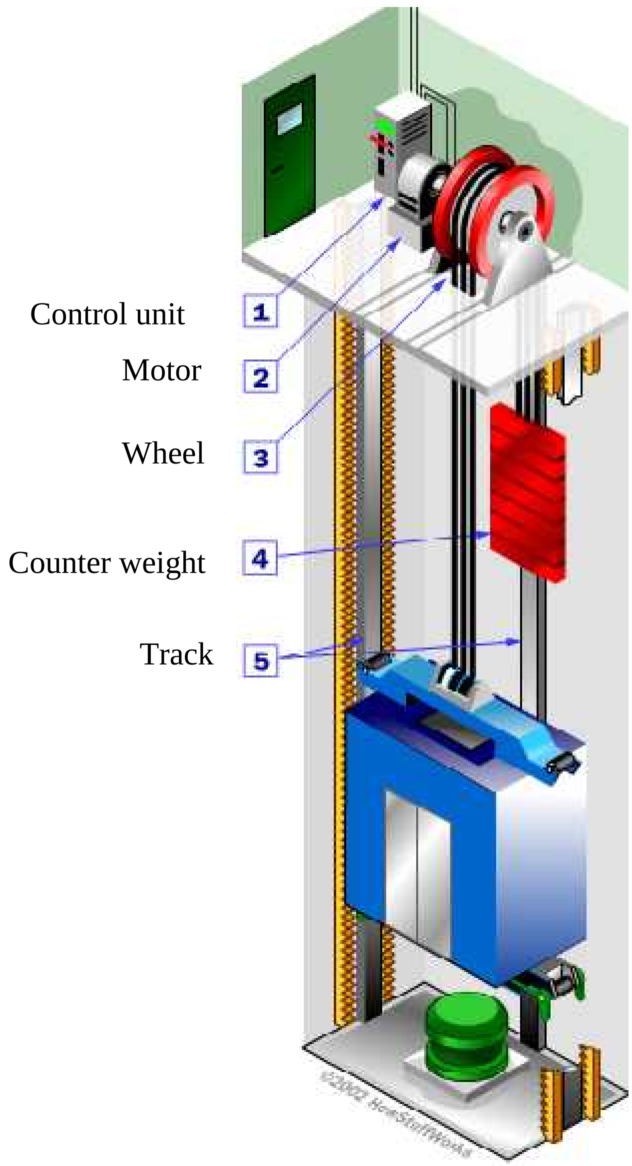


Fig (2.1) construction of robed elevator

The ropes that lift the car are also connected to a counterweight fig (2.1.(4)), which hangs on the other side of the sheave. The counterweight weighs about the same as the car filled to 40% capacity. In other words, when the car is 40% full (an average amount), the counterweight and the car are perfectly balanced

The purpose of this balance is to conserve energy. With equal loads on each side of the sheave, it only takes a little bit of force to tip the balance one way or the other. Basically, the motor only has to overcome friction the weight on the other side does most of the work. To put it another way, the balance maintains a near constant potential energy level in the system as a whole. Using up the potential energy in the elevator car (letting it descend to the ground) builds up the potential energy in the weight (the weight raises to the top of the shaft). The same thing happens in reverse when the elevator goes up. The system is just like a see-saw that has an equally heavy kid on each end .

Both the elevator car and the counterweight ride on guide rails fig (2.1(5)) along the sides of the elevator shaft. The rails keep the car and counterweight from swaying back and forth, and they also work with the safety system to stop the car in an emergency .

Roped elevators are much more versatile than hydraulic elevators, as well as more efficient. Typically, they also have more safety systems. In the next section, we'll see how these elements work to keep you from plummeting to the ground if something goes wrong.

2.3 Rope-less Elevator

In this type we use a (PMLM) and the track of the elevator carry the elevator; we will not use a counterweight, this type of elevator used in japan sence 1991 because of the some advantages of this type, the fig (2.2) shows descript of the rope-less elevator.

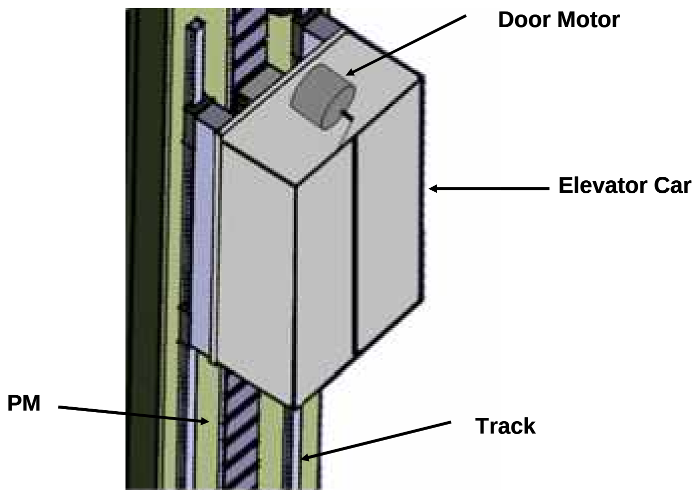
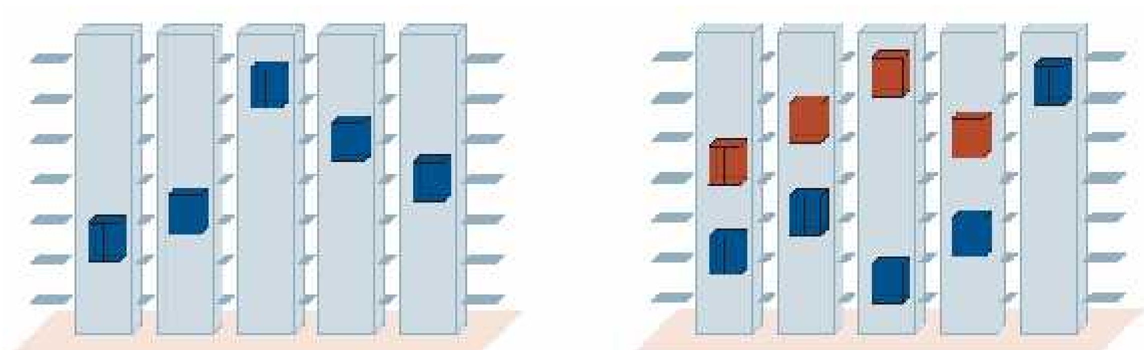


Fig (2.2) robe-less elevator

2.4 Rope-less vs. Roped Elevator

Rope-less elevator has some advantages that give this type of elevators a good reason to be used

- The rope-less elevator don't need a room to put the motor in but in roped elevator need a room for this reason (some roped elevator don't need this room ether)
- We can move it horizontally if it necessary.
- No need for cables. This is a very important issue because cables are limiting factor in the design of elevators when the building is very high.[2]
- The possibility to use several cabins on the same rail with the net effect of reducing the area necessary for the traditional elevator look at fig (2.3).[2]



A **B**

Fig (2.3) traditional and Twin elevator System:-

(A) Traditional and (B) Twin elevator System.

Chapter three

Construction of Elevator Using PMLSM

3.1 General construction of the PMLSM elevator

The basic structure of the LSM elevator is shown in fig(3.1). A rope-less elevator which is depend on the magnetic field of the LMS motor, and have no rope that mean no weight. It is consists of one single sided of LSM. The car elevator is placed on the track of the LSM which is covered of permanent magnet. The following sections describe the construction of LSM elevator.

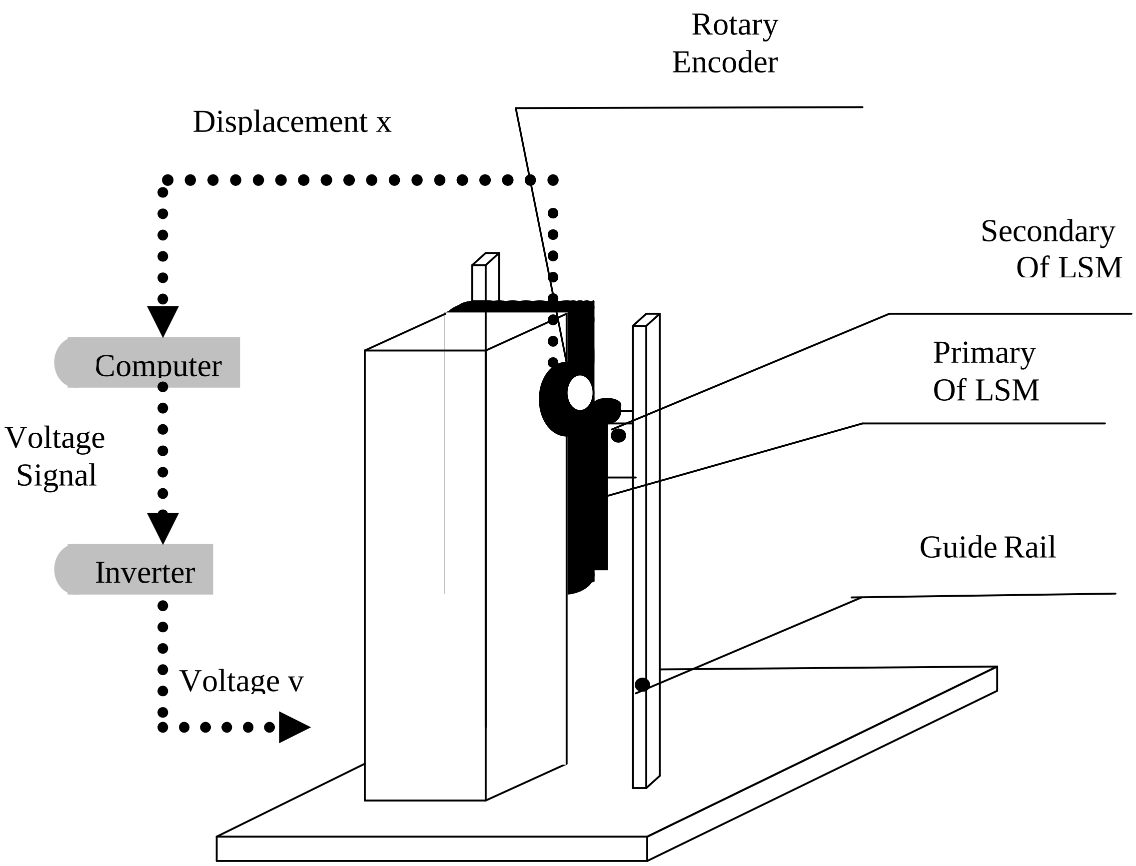


Fig 3.1: The Basic Structure of Elevator Equipment

3.2 Construction of the elevator

We depend on a last project that designed in Palestine Polytechnic University and the name of project "Design and Position Control of a Permanent Magnet Linear Synchronous Motor for Horizontal Transportation System" because of that, will add some parts to make the elevator but with keeping on the constriction of the project (that we depend on)

3.2.1 Type of PMLSM

There is more than one type of (PMLSM), in this project we will use single-sided LM as fig (3.2)

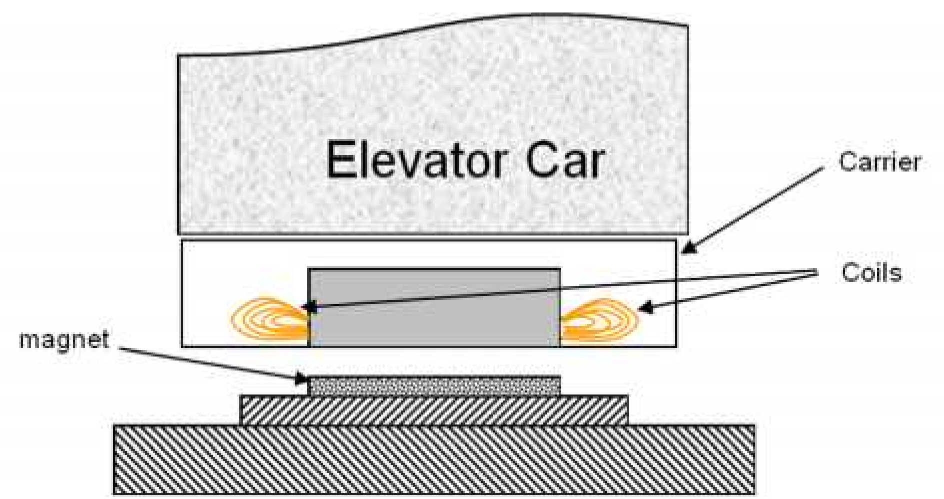


Fig (3.2) single-sided LM

There are other types of this motor but as we mention be for we are using the motor that built in Palestine Polytechnic University, because that we will not talk abut any other type of (PMLSM).

3.2.2 Elevator car

The elevator car is the cage that is left up and down on the secondary of the motor, and goes in and out the persons. The fig (3.3) has shown the elevator car.

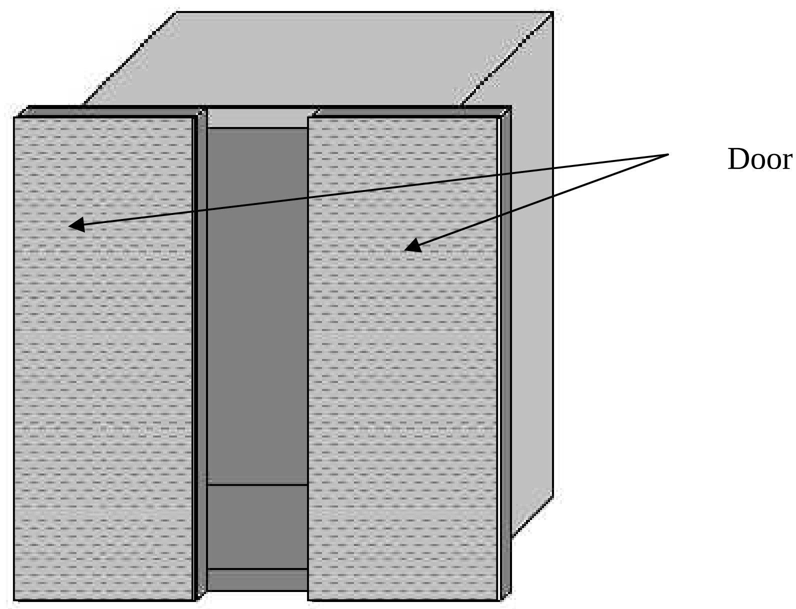


Fig (3.3): elevator car.

The elevator car is situated on the stator of linear synchronous motor that is goes up and down depending on the magnetic field that producing from the permanent magnetic on the stator of the linear synchronous motor (that we controlling it). The elevator car is to be controlled its position, the displacement, and the velocity. It is have an air gap that difference of the permanent magnet and coils that makes the magnetic field.

3.2.3 Elevator door

The elevator door is a part of elevator car that is driven by a motor; to opening and closing. It is allowing going in and out. Elevator door is shown in fig (3.3). And it's situated a lighting sensor to keeping open while going in or out.

3.2.4 Control plate

The control keyboard is shown in fig (3.4).

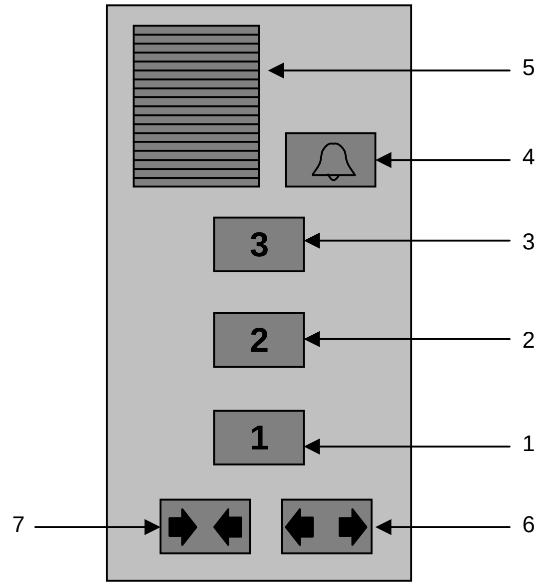


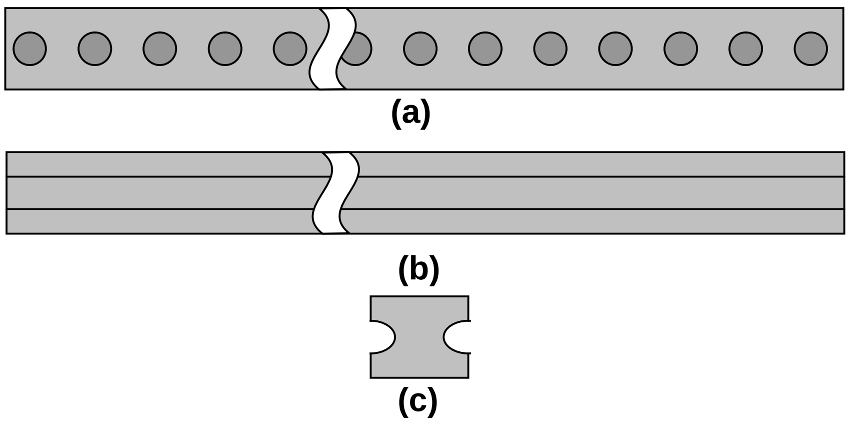
Fig. (3.4): Control Keyboard.

It is consists of group of button its function as follow:

- Button (1):- It's used to go down to the first floor.
- Button (2):- It's used to go up and down to the second floor.
- Button (3):- It's used to go up and down to the third floor.
- Button (4):- It's used for emergency to getting help.
- Button (4):- is the speaker to talk to the security if anything happened, like if the passenger is stuck or anything else.
- Button (6):- is used to open the door of elevator to go out of the elevator.
- Button (7):- is on the contrary of the above button, since it is using for closing the door after interring the elevator.

3.2.5 Track

The track that the elevator will move up/dawn on it, this track made of aluminum and has some holes, these holes can help us to controlling of the speed of the motor.
As fig(3.5).



Fig(3.5): track. (a) is a top view of this track (b) side view and (c) front view.

3.2.6 Frequency converter

A frequency changer or frequency converter is an electronic device that converts alternating current (AC) of one frequency to alternating current of another frequency. The device may also change the voltage, but if it does, that is incidental to its principal purpose.

Traditionally, these devices were built out of electromechanical components such as motor-generator sets or rotary converters. But with the advent of solid state electronics, it has become possible to build completely electronic frequency changers. These devices usually consist of a rectifier stage (producing direct current) which is then inverted to produce ac of the desired frequency. The inverter may use thyristors or IGBTs. If voltage conversion is desired, a transformer will usually be included in either the ac input or output circuitry and this transformer may also provide galvanic isolation between the input and output ac circuits. A battery may also be added to the dc circuitry to improve the converter’s ride-through of brief outages in the input power.

Frequency changers vary in power-handling capability from a few watts to megawatts. Frequency Converter also offers line isolation, harmonic cancellation, power factor correction, phase conversion, voltage conversion with balanced, smooth, controlled power output.

Frequency changers are used to control the speed and the torque of the AC motors. In this application, the most typical frequency converter topology is the three-phase two-level voltage source inverter.

Another application is in the aerospace and airline industries. Often airplanes use 400 Hz power, so 50 Hz or 60 Hz to 400 Hz frequency convertor is needed for use in the ground power unit used to power the airplane wile its on the ground.

Frequency changers are typically used to control the speed of pumps and fans. in many applications significant energy saving are achieved. The most demanding application areas are found in the industrial processing lines, where the control accuracy requirement can be high.

The frequency converter for the AC motor drives is a device that converts the standard three-phase AC line voltage to a variable-frequency, and variable-voltage three-phase AC waveforms. The AC motor drive supplied by the frequency converter becomes a variable speed drive and is used for the control of technologies and machines. The present-day frequency converter is a highly sophisticated device, which allows the manual control of motor rotation speed (but in this case we controlling in the linear speed), automatic control according to the signals of an appropriate sensor or computer-based control. The frequency converters usually utilize a converter-inverter structure as shown in Fig(3.6).

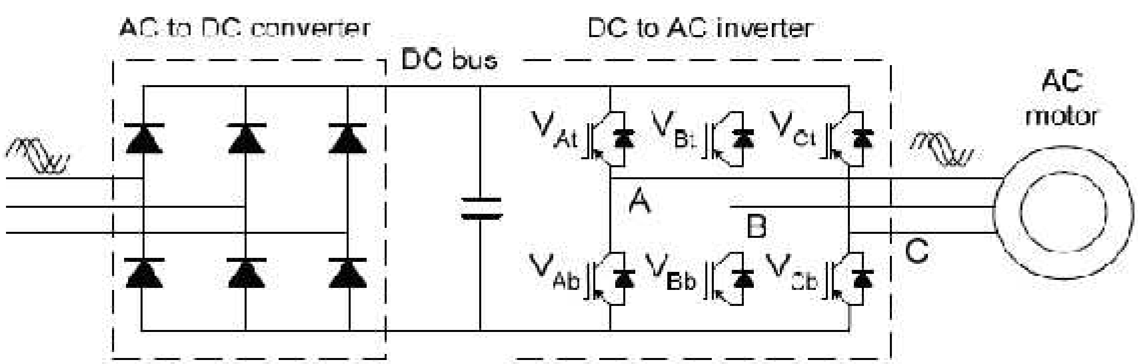


Figure (3.6): Simplified diagram of the frequency converter

The AC to DC converter fig(3.6) creates DC from the fixed AC line while the DC to AC inverter develops the variable-frequency, and variable-voltage AC from DC. The rectifier, which provides rectification of the fixed AC line voltage, is used for converting AC to DC. The primary part of the frequency converter is the DC to AC inverter. It includes the power stage, which contains six power switches. The IGBT transistors V_{At}-V_{Cb} commonly used as power switches are controlled by an algorithm, and which is executed in the control unit to create the proper AC waveforms.

The fault detection and shutdown circuitry must be incorporated into the inverter to guarantee safe operating of the power stage. Among the problems that are urgent in AC variable speed drives are fault situations when the motor, during the deceleration, starts to operate in a regenerative.

3.3 Sensors Switch

The sensors are automatic switches that work under certain conditions according to the type of switch, and we can find wide Varity of sensors, every one have a certain work defer from other one, such like limit switch, encoder, etc.

The sensors having wide advantages, in our project it useful for controlling the elevator, and we can detected the accurate position of the elevator go to or where to stop.

The project that we will to do it is need some these sensors, and its description, function, and work as follow:

3.3.1 Limit Switch

Limit switches limit the travel of moving parts driven by a motor-driven machine or other apparatus. It has either normally-open or normally-closed contacts (or both) and is actuated by contact with a moving part or machine. The most popular limit switch is the lever type, shown in the fig(3.7) The contact is opened or closed by a lever is a roller. The moving part of the machine comes in contact with the roller, which moves the lever to a position where the contacts in the switch either open or Close. Many times lever actuation will open the circuit to the coil of a magnetic motor controller, which disconnects the motor from the line. Typical applications of the lever-type limit switch in motor control are limit switches at the top and bottom of elevators, and motor driven doors.

Fig (3.7) limit switches.

When the lever-type limit switch is used in the door, some part of' the doors, some part of the door will contact the lever when the door is almost fully open. The limit switch contacts then open, and the motor is stopped. To close the door, a pushbutton switch is energized turning on the motor. When the door is fully closed, the lever of another limit switch is actuated, stopping the motor. [3]

In the project, we will use this kind of switch in three situations as follow:

- In the top of the of the stator of the LSM, however, it is used to detect the last situation on the top that the elevator will arrive to and stop the elevator by using the normally closed switch (limit switch) to stop the linear synchronous motor that rise the elevator up.

- In the bottom of the stator of the LSM, however, it is used to detect the ground that the elevator will stop and arrive to. Normally closed limit switch will used to stop the linear synchronous motor, which mean stop the elevator.

3.3.2 Weight sensor (strain gage)

Strain gage have alley inside content of elastic material which is construct of a mix of material. If we applied a stress it leads to increase the length.

The elevator will have a strain gage, so it wills cut-off when increasing the weight at the detected. The figure (3.8) shows the strain gage.

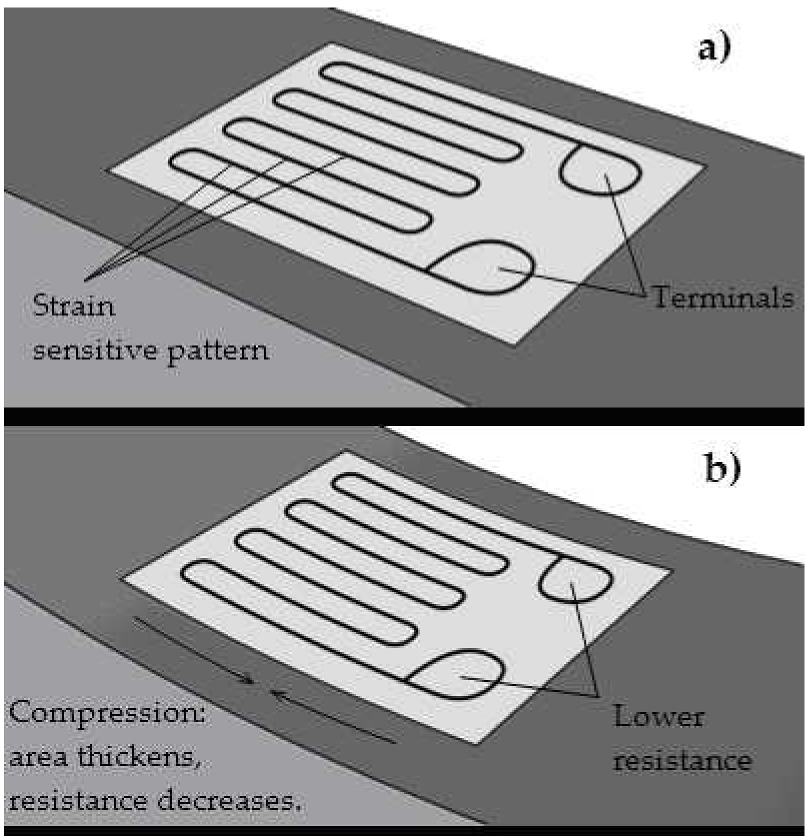
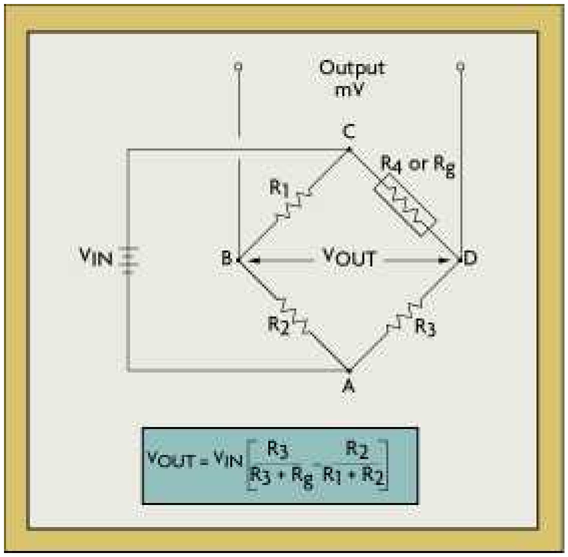


Fig (3.8) strain gage: (a) no Weight (b) a Weight on it

In order to measure strain with a bonded resistance strain gage, it must be connected to an electric circuit that is capable of measuring the minute changes in resistance corresponding to strain. Strain gage transducers usually employ four strain gage elements electrically connected to form a Wheatstone bridge circuit Fig(3.9).

A Wheatstone bridge is a divided bridge circuit used for the measurement of static or dynamic electrical resistance. The output voltage of the Wheatstone bridge is expressed in millivolts output per volt input. The Wheatstone circuit is also well suited for temperature compensation.



Fig(3.9). Wheatstone Bridge

In Fig(3.9), if R1, R2, R3, and R4 are equal, and a voltage, V_{IN}, is applied between points A and C, then the output between points B and D will show no potential difference. However, if R4 is changed to some value which does not equal R1, R2, and R3, the bridge will become unbalanced and a voltage will exist at the output terminals. In a so-called G-bridge configuration, the variable strain sensor has resistance Rg, while the other arms are fixed value resistors.

The sensor, however, can occupy one, two, or four arms of the bridge, depending on the application. The total strain, or output voltage of the circuit (Vout) is equivalent to the difference between the voltage drop across R1 and R4, or Rg. This can also be written as: $V_{out}=V_{CD}-V_{CB}$ … (3.1)

For more detail, see Fig(3.9). The bridge is considered balanced when R1/R2 = Rg/R3 and, therefore, Vout equals zero.[8]

Any small change in the resistance of the sensing grid will throw the bridge out of balance, making it suitable for the detection of strain. When the bridge is set up so that Rg is the only active strain gage, a small change in Rg will result in an output voltage from the bridge.

3.4 Programmable Logic Controller (PLC)

A programmable logic controller (PLC) or programmable controller is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, control of amusement rides, or control of lighting fixtures. PLCs are used in many different industries and machines such as packaging and semiconductor machines. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed or non-volatile memory. A PLC is an example of a real time system since output results must be produced in response to input conditions within a bounded time, otherwise unintended operation will result.

The main difference from other computers is that PLCs are armored for severe conditions (dust, moisture, heat, cold, etc) and have the facility for extensive input/output (I/O) arrangements. These connect the PLC to sensors and actuators. PLCs read limit switches, analog process variables (such as temperature and pressure), and the positions of complex positioning systems. Some even use machine vision. On the actuator side, PLCs operate electric motors, pneumatic or hydraulic cylinders, magnetic relays or solenoids, or analog outputs. The input/output arrangements may be built into a simple PLC, or the PLC may have external I/O modules attached to a computer network that plugs into the PLC.

PLCs may need to interact with people for the purpose of configuration, alarm reporting or everyday control.

A Human-Machine Interface (HMI) is employed for this purpose. HMIs are also referred to as MMIs (Man Machine Interface) and GUI (Graphical User Interface).

A simple system may use buttons and lights to interact with the user. Text displays are available as well as graphical touch screens. More complex systems use a programming and monitoring software installed on a computer, with the PLC connected via a communication interface.

3.4.1 PLC compared with other control systems

PLCs are well-adapted to a range of automation tasks. These are typically industrial processes in manufacturing where the cost of developing and maintaining the automation system is high relative to the total cost of the automation, and where changes to the system would be expected during its operational life. PLCs contain input and output devices compatible with industrial pilot devices and controls; little electrical design is required, and the design problem centers on expressing the desired sequence of operations in ladder logic (or function chart) notation. PLC applications are typically highly customized systems so the cost of a packaged PLC is low compared to the cost of a specific custom-built controller design. On the other hand, in the case of mass-produced goods, customized control systems are economic due to the lower cost of the components, which can be optimally chosen instead of a "generic" solution, and where the non-recurring engineering charges are spread over thousands or millions of units.

For high volume or very simple fixed automation tasks, different techniques are used. For example, a consumer dishwasher would be controlled by an electromechanical cam timer costing only a few dollars in production quantities.

A microcontroller-based design would be appropriate where hundreds or thousands of units will be produced and so the development cost (design of power supplies and input/output hardware) can be spread over many sales, and where the end-user would not need to alter the control. Automotive applications are an example; millions of units are built each year, and very few end-users alter the programming of these controllers. However, some specialty vehicles such as transit busses economically use PLCs instead of custom-designed controls, because the volumes are low and the development cost would be uneconomic.

Very complex process control, such as used in the chemical industry, may require algorithms and performance beyond the capability of even high-performance PLCs. Very high-speed or precision controls may also require customized solutions; for example, aircraft flight controls.

Programmable controllers are widely used in motion control, positioning control and torque control. Some manufacturers produce motion control units to be integrated with PLC so that G-code (involving a CNC machine) can be used to instruct machine movements.

PLCs may include logic for single-variable feedback analog control loop, a "proportional, integral, derivative" or "PID controller." A PID loop could be used to control the temperature of a manufacturing process, for example. Historically PLCs were usually configured with only a few analog control loops; where processes required hundreds or thousands of loops, a distributed control system (DCS) would instead be used. However, as PLCs have become more powerful, the boundary between DCS and PLC applications has become less clear-cut.

PLCs have similar functionality as Remote Terminal Units. An RTU, however, usually does not support control algorithms or control loops. As hardware rapidly becomes more powerful and cheaper, RTUs, PLCs and DCSs are increasingly beginning to overlap in responsibilities, and many vendors sell RTUs with PLC-like features and vice versa. The industry has standardized on the IEC 61131-3 functional block language for creating programs to run on RTUs and PLCs, although nearly all vendors also offer proprietary alternatives and associated development environments.

Chapter Four

Problem Analysis

4.1 The Fundamental Equations of the PM LSM: [1]

The PM LSM is the motor that we will use in our problem, which is used to driven the elevator, and this motor has been studied by Palestine Polytechnic University and the name of project "Design and Position Control of a Permanent Magnet Linear Synchronous Motor for Horizontal Transportation System". The motor equation is defined as follow:

The time-space distribution of the MMF (Magneto-Motive Force) of a symmetrical poly-phase winding with distributed parameters fed with a balanced system of currents can be expressed as [1]

$$\begin{aligned} F(x,t) &= \frac{N_1\sqrt{2}I_a}{\pi p}\sin\omega t\sum_{v=1}^{\infty}\frac{1}{v}k_{\omega 1v}\cos\left(v\frac{\pi}{\tau}x\right) \\ &+\frac{N_1\sqrt{2}I_a}{\pi p}\sin\left(\omega t-\frac{1}{m_1}2\pi\right)\sum_{v=1}^{\infty}\frac{1}{v}k_{\omega 1v}\cos\left(\frac{\pi}{\tau}x-\frac{1}{m_1}2\pi\right)+\ldots \\ &+\frac{N_1\sqrt{2}I_a}{\pi p}\sin\left(\omega t-\frac{m_1-1}{m_1}2\pi\right)\sum_{v=1}^{\infty}\frac{1}{v}k_{\omega 1v}\cos\left(\frac{\pi}{\tau}x-\frac{m_1-1}{m_1}2\pi\right) \\ &=\frac{1}{2}\sum_{v=1}^{\infty}F_{mv}\left\{\sin\left[\left(\omega t-v\frac{\pi}{\tau}x\right)+(v-1)\frac{2\pi}{m_1}\right]+\sin\left[\left(\omega t+v\frac{\pi}{\tau}x\right)-(v-1)\frac{2\pi}{m_1}\right]\right\} \end{aligned} \quad \ldots (4.1)$$

where *Ia* is the armature phase current, and m_1 is the number of phases, and *P* is the number of pole pairs, and *N1* is the number of turns per phase, and $k\omega 1v$ is the winding factor, $\omega = 2\pi f$ is the angular frequency, τ is the pole pitch and for the forward-traveling field and

$$v = 2m_1k+1 \qquad k = 0,1,2,3,4,5,\ldots \quad \ldots(4.2)$$

For the backward traveling field

$$v = 2m_1k - 1 \qquad k = 0,1,2,3,4,5,... \qquad ...(4.3)$$

The magnitude of the v harmonics of the primary MMF equals one, and for a single-phase winding, the time space distribution of the MMF is

$$F(x,t) = \frac{1}{2}\sum_{\nu=1}^{\infty} F_{m\nu}\left\{\sin\left[\left(\omega t - \nu\frac{\pi}{\tau}x\right) + (\nu-1)\,2\pi\right] + \sin\left[\left(\omega t - \nu\frac{\pi}{\tau}x\right) - (\nu-1)\,2\pi\right]\right\} \qquad ...(4.4)$$

For a single-phase winding and the fundamental harmonic $v = 1$

$$F(x,t) = \frac{1}{2}F_1 \sin\left(\omega t - \frac{\pi}{\tau}x\right) \qquad ... (4.5)$$

$$F_1 = \frac{2\sqrt{2}}{\pi p} N.I_a k_{\omega 1} \qquad ... (4.6)$$

Thrust of the LSM is given by the following equation:[4]

$$F = (\pi / \tau)\{\Phi i_q + (L_d - L_q)\, i_d i_q\} \qquad ... (4.7)$$

Where $\Phi = \sqrt{3}\Phi_0$, Φ_0: magnetic flux due to permanent magnet [Wb], i_d: direct axis current [1], i_q cross axis current [1], L_d: equivalent direct axis inductance [4], L_q: equivalent cross axis inductance [4], τ: pole pitch [m].

4.2 The Movement of Elevator Car

The elevator car is moving up and down in vertical line, thus there is a motion result from it, a speed and acceleration are result from it. The equation of motion is given by the following equation

$$ma = F - mg + F_r \qquad ...(4.8)$$

Where m: mass of the cage *[kg]*, *g*: acceleration of gravity *[m/s²]*, *Fr*: resistance force due to the wheels *[N]* and that upper direction of the guide way is positive of axis x.

The sign indicates that a plus sign is for falling and a minus sign is for rising. The defection of moving is determined by the magnitude of thrust;

Upward $F > mg + Fr;$ ...(4.9)

Downward $F < mg - Fr$ ...(4.10)

Stop $mg- Fr<F< mg +Fr;$ …(4.11)

The motion of the elevator is divided into three stages:

1. Constant acceleration: at the beginning of the motion from one floor to another.
2. Constant velocity: after specific period the inertia force overcame and the elevator begins to move with constant velocity.
3. Constant deceleration: when the elevator approach its destination.

Where: …(4.12)

$$a = \begin{bmatrix} a & 0 < t < t_1 \\ 0 & t_1 \le t \le t_f - t_s \\ -a & t_f - t_s \le t \le t_f \end{bmatrix}$$

Which means that the acceleration response must be make fine acceleration - then will be constant and finally make fine deceleration. This can be obviously note the next but in real life the jerk can be ignored because of the constant acceleration so the system description can be as in figure4.1.

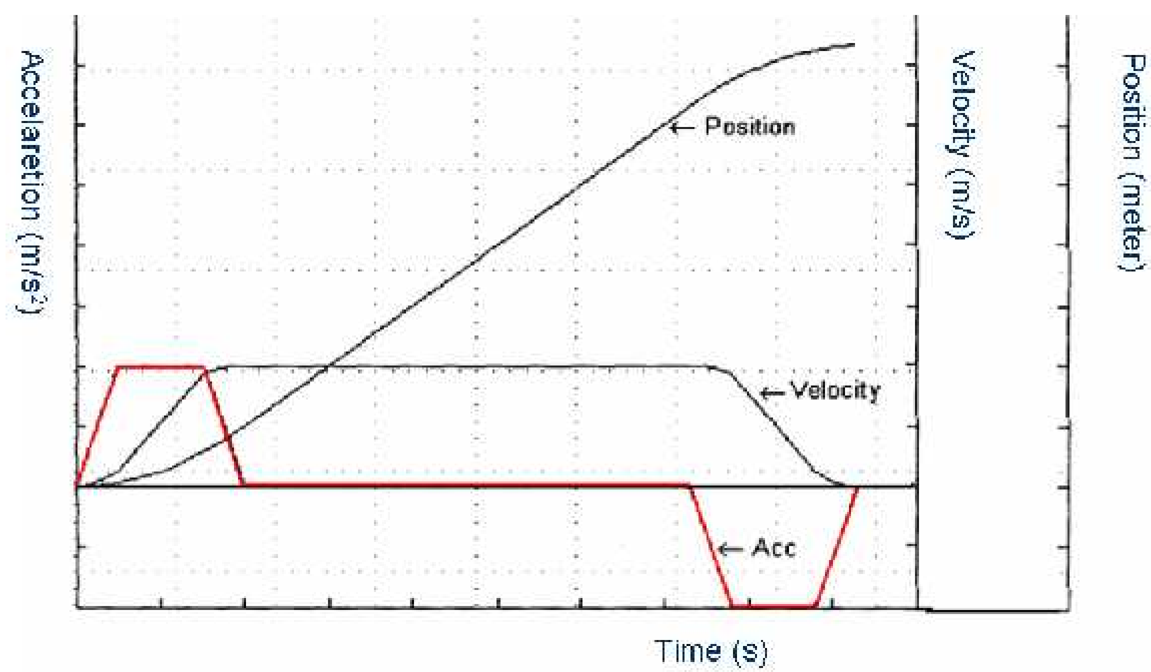


Figure 4. 1: Elevator position, velocity, and acceleration

The loading of the elevator is rated between four extreme cases:

1. Raising a full car.

2. Lowering a full car.

3. Raising an empty car.

4.Lowering an empty car.

1. Raising a full Load:

- During acceleration:

$(m_L + m_c)\ a = F - (m_L + m_c)\ g - 4F_r$

$F - F_r = (m_L + m_c)\ a + (m_L + m_c)\ g$

$F - 4F_r = (m_L + m_c)\ (a + g)$ … (4.13)

Where:

m_L: mass of the load on the cage in Kg.

***m_c*:** mass of the cage in *Kg*.

- During constant velocity:

$0 = F - (m_L + m_c)\ g - 4F_r$

$F - 4Fr = (m_L + m_c)\ g$ … (4.14)

- During deceleration:

$-(m_L + m_c)\ a = F - (m_L + m_c)\ g - 4F_r$

$F - 4F_r = -(m_L + m_c)\ a + (m_L + m_c)\ g$

$F - 4F_r = (m_L + m_c)\ (g - a)$ … (4.15)

2. Lowering empty car:

- During acceleration:

$m_c\, a = F - m_c\, g + 4F_r$

$F + 4F_r = m_c\, a + m_c\, g$

$$F + 4F_r = m_c\,(a + g) \qquad \ldots (4.16)$$

- During constant velocity:

$0 = F - m_c\, g + 4F_r$

$$F + 4F_r = m_c\, g \qquad \ldots (4.17)$$

- During deceleration:

$-\, m_c\, a = F - m_c\, g + 4F_r$

$F + 4F_r = -\, m_c\, a + m_c\, g$

$$F + 4F_r = m_c\,(g - a) \qquad \ldots (4.18)$$

3. Raising an empty car:

- During acceleration:

$m_c\, a = F - m_c\, g - 4F_r$

$F - 4F_r = m_c\, a + m_c\, g$

$F - 4F_r = m_c\,(a + g)$ … (4.19)

- During constant velocity:

$0 = F - m_c\, g - 4F_r$

$F - 4Fr = m_c\, g$ …(4.20)

- During deceleration:

$- m_c\, a = F - m_c\, g - 4F_r$

$F - 4F_r = -m_c\, a + m_c\, g$

$F - 4F_r = m_c\,(g - a)$ … (4.21)

4. Lowering a full car:

- During acceleration:

$(m_L+m_c)\, a = F - (m_L+m_c)\, g + 4F_r$

$F + 4F_r = (m_L+m_c)\, a + (m_L+m_c)\, g$

$F + 4F_r = (m_L+m_c)\,(a + g)$ … (4.22)

- During constant velocity:

$0 = F - (m_L + m_c)\, g + 4F_r$

$F + 4F_r = (m_L + m_c)\, g$ … (4.23)

- During deceleration:

$(m_L + m_c)\, a = F - (m_L + m_c)\, g + 4F_r$

$F + 4F_r = (m_L + m_c)\, a + (m_L + m_c)\, g$

$F + 4F_r = (m_L + m_c)\, (a + g)$ … (4.24)

4.3 Trapezoidal velocity profile:

By specifying the q_i, q_f, t_f, and the admissible velocity q_c for elevator car. Where:

q_i: The initial car position.

q_f: The final car position.

t_f: The final time for elevator car to reach the desired position.

$q_c = (q_i + q_f) / 2 - q_c / (t_f - t_c)$ … (4.25)

Also:

$q'_c = q_i + q_i\, t_c + 0.5\, q''_c\, t^2_c$ … (4.26)

$q'_c = q'_i + q_i''\, t_c$ … (4.27)

$q'_c = q_i'' t_c$ … (4.28)

$q_i'' = q'_c / t_c$ … (4.29)

$q_c = q_i + 0.5\ q\ t_c$ … (4.30)

$t_c = (q_i - q_f + q_i' tc) / q'_c$ … (4.31)

Constant speed in selecting the maximum speed q we know that $0 \leq tc \leq tf / 2$

$q_c \leq 2(q_i - q_f) / t_f$ … (4.32)

$(q_i - q_f) / t_f \leq q_c \leq 2(q_i - q_f) / t_f$

$$q(t) = \begin{cases} q_i + \frac{1}{2}\frac{q_c}{t_c}t^2 & ,0 < t < t_c \\ q_i + q_c(t - \frac{t_c}{2}) & ,t_c \leq t \leq t_f - t_c \\ q_f - \frac{1}{2}\frac{q_c}{t_c}(t_f - t)^2 & ,t_f - t_c \leq t \leq t_f \end{cases} \quad \ldots(4.33)$$

The elevator is designed to travel at $q_i = 0$, $q_f = 0\ .67$m in 1.67 second at each floor with a consisting of velocity q =lm/s, the number of floors is 3, then to calculate the car position and acceleration.

4.4 Dc Motor Drives:

The direct current (DC) motor is one of the first machines devised to convert electrical power into mechanical power, and its origins can be traced to the disc-type machines conceived and tested by Michael Faraday.

Dc drives are widely used in applications requiring adjustable speed, good speed regulation and frequent starting, braking and reversing. Some important applications are rolling mills, paper mills, mine winders, hoists, machine tools, traction, printing presses, textile mills, excavators and cranes. Fractional horsepower dc motors are widely used as servo motors for positioning and tracking.

Although, since late sixteen, it is being predicted that ac drives will replace dc drives, however, even today the variable speed applications are dominated by dc drives because of lower cost, reliability and simple control.

In a separately excited motor, field and armature voltages can be controlled independent of each other. In a shunt motor, field and armature are connected to a common source. In case of series motor, field current is same as armature current, and therefore, field flux is a function of armature current. In a cumulatively compound motor, the magneto-motive force of the series field is a function of armature current is the same direction as mmf of the shunt field.

The steady state equivalent circuit of armature of a dc machine is shown in fig4.2. Resistance Ra is the resistance of the armature circuit. For separately excited and shunt motors, it is equal to the resistance of armature winding and for series and compound motors; it is the sum of armature and field winding resistance. Basic equations applicable to all dc motors are: [4]

$$E = k_e \Phi W_m \quad \ldots (4.34)$$

$$V = E + R_a I_a \quad \ldots (4.35)$$

$$T = k_e \Phi W_m \quad \ldots (4.36)$$

Where Φ is the flux per pole, webers; I_a = armature current, *A; V* = armature voltage, *v; Ra* = resistance of the armature circuit, ohms; Wm = speed of armature, *rad/sec; T* = torque developed by the motor, Nm; and Ke = motor constant.

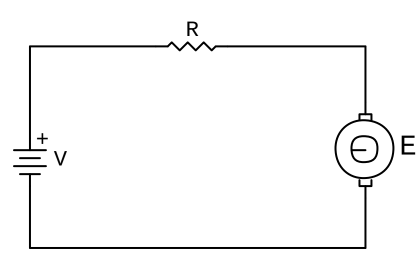


Figure4.2 The steady state equivalent circuit of armature of a dc machine

From above equation we get:

$$W_m = \frac{V - Ra \; Ia}{k_e \Phi} \qquad \dots (4.37)$$

$$W_m = \frac{V}{k_e \Phi} - \frac{Ra \; T}{(k_e \Phi)^2} \qquad \dots (4.38)$$

Chapter Five

Controlling PMLSM

5.1 Implementation:

This project can be implemented using the PLC (Siemens S5), this elevator is designed for three floors building.

The PLC is the controlling device that we use to controlling the elevator, and we use it to controlling the frequency converter, because the importance of PLC in the industrial process, and because of the advantages of PLC

5.1.1 Equipment

- The lift is to be controlled using a programmable controller (PLC).
- The lift motor has a forward (up) contactor K1and a reverse (down) contactor K2 for switching and thermal overload relay (El) for protection.
- Safety limit switches LM act as final stopping devices, breaking the control circuit to the motor contactors as well as supplying input signals to the programmable controller. (They are sometimes arranged for more direct control, interrupting the main supply to the motor itself.).

5.1.2 Specification:

1 .Under normal circumstances the system will be left in run mode and will operate according to signals from the call and dispatch pushbuttons.

2. The lift is allowed to move under the following conditions:

    - The access door are closed
    - The car door is closed
    - A valid call or dispatch command is given.

3. Once the lift departs from one level it must continue to the other level, regardless of any new commands.

5.1.3 The main circuit:

The circuit needs three kind of power, 3 phase is to feed the inverter to control the speed of motor, 1 phase is to feed PLC, and DC to feed contactors, motor door and lights of buttons, all controls and lights connected to PLC.

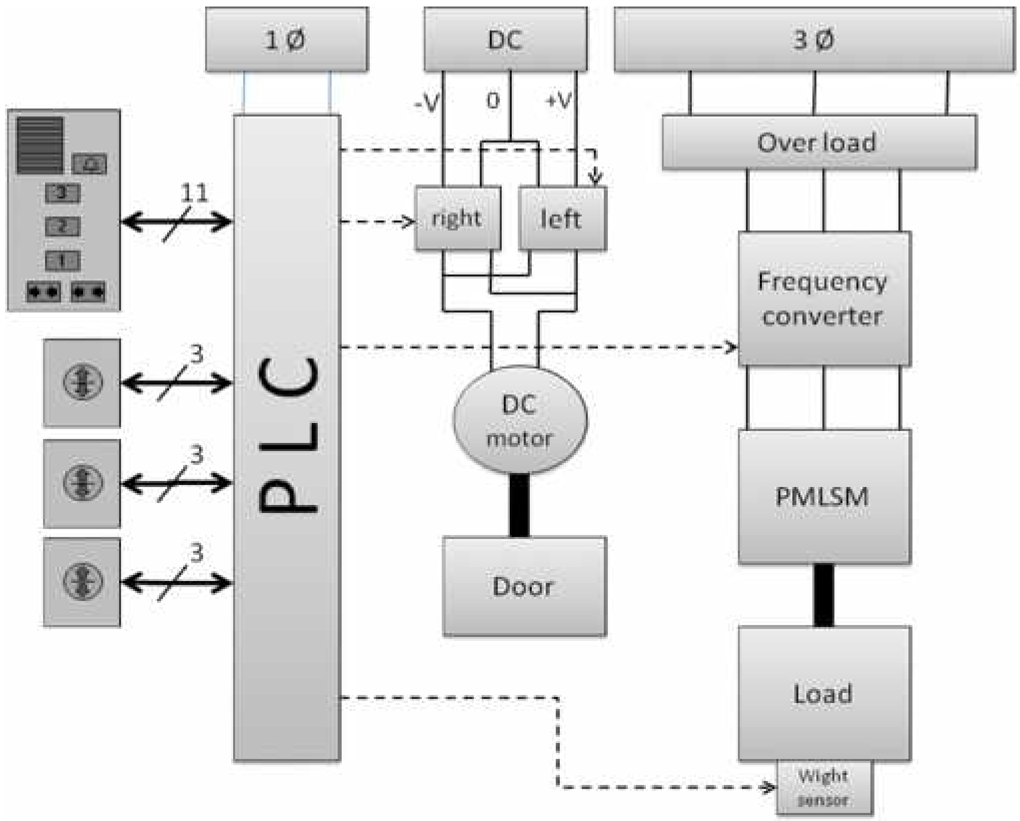


Fig (5.1): Main circuit block diagram

5.2 Control circuit:

Table 5.1 The schedule of inputs

Limit switch	Item	Input
Stop at floor one	S1	I0.0
Stop at floor one	S6	I0.6
Stop at floor two	S2	I0.2
Stop at floor two	S7	I0.7
Stop at floor three	S3	I0.3
Stop at floor three	S8	I1.0

The schedule of inputs we have chosen for this project appears in table 5.1, the schedule of output is given in table 5.2.the control circuit are developed for these tables. In both cases 24v dc, inputs are used.

Table 5.2 The schedule of outputs

Device	Item	Output
Moving up	K1	Q2.0
Moving down	K2	Q2.1
Open door	K3	Q2.2
Close door	K4	Q2.3

The table5.2 shows the output of the plc and determine the direction of the motor and the door according to the plc program.

Table 5.3 The schedule of sensors

Device	Item	Input
Weight sensor	S11	I1.3
Photo sensor	S9	I1.0
Limit switch	S12	I1.2
Limit switch	LM	I1.1
Proximity switch	SA	I1.4

The sensors determine the state of the motor whether run or stop according to the function of every sensor and its position.

Table 5.4 The schedule of flags

Device	Item
Floor one	H1
Floor two	H2
Floor three	H3
Count floor one	M1
Count floor two	M2
Count floor three	M3
Timer open	T1
Timer close	T2
Emergency switch	F0

5.3 Flowcharts

5.3.1 Elevator point of view

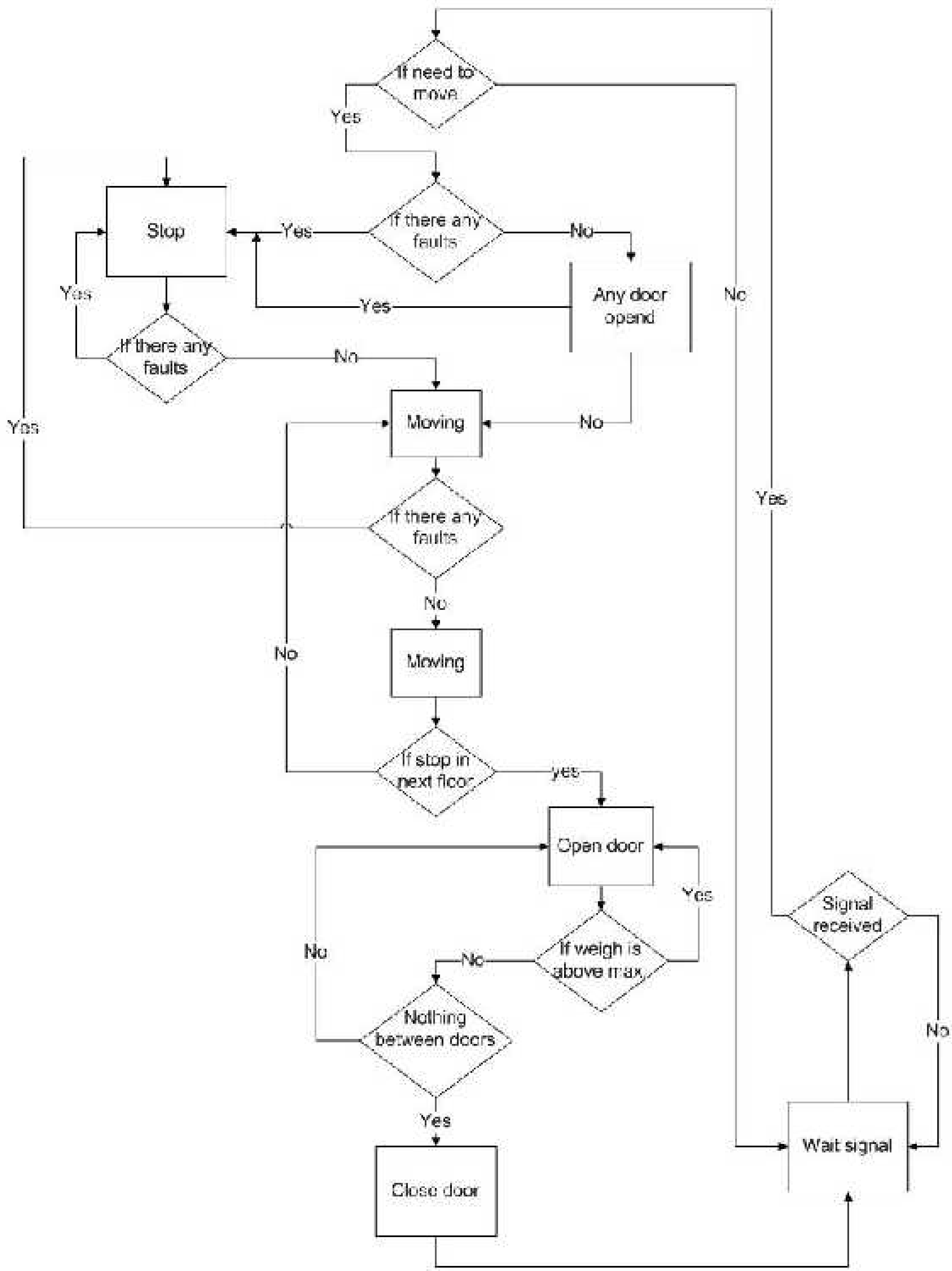


Fig (5.2) elevator point of view

5.3.2 Elevator works

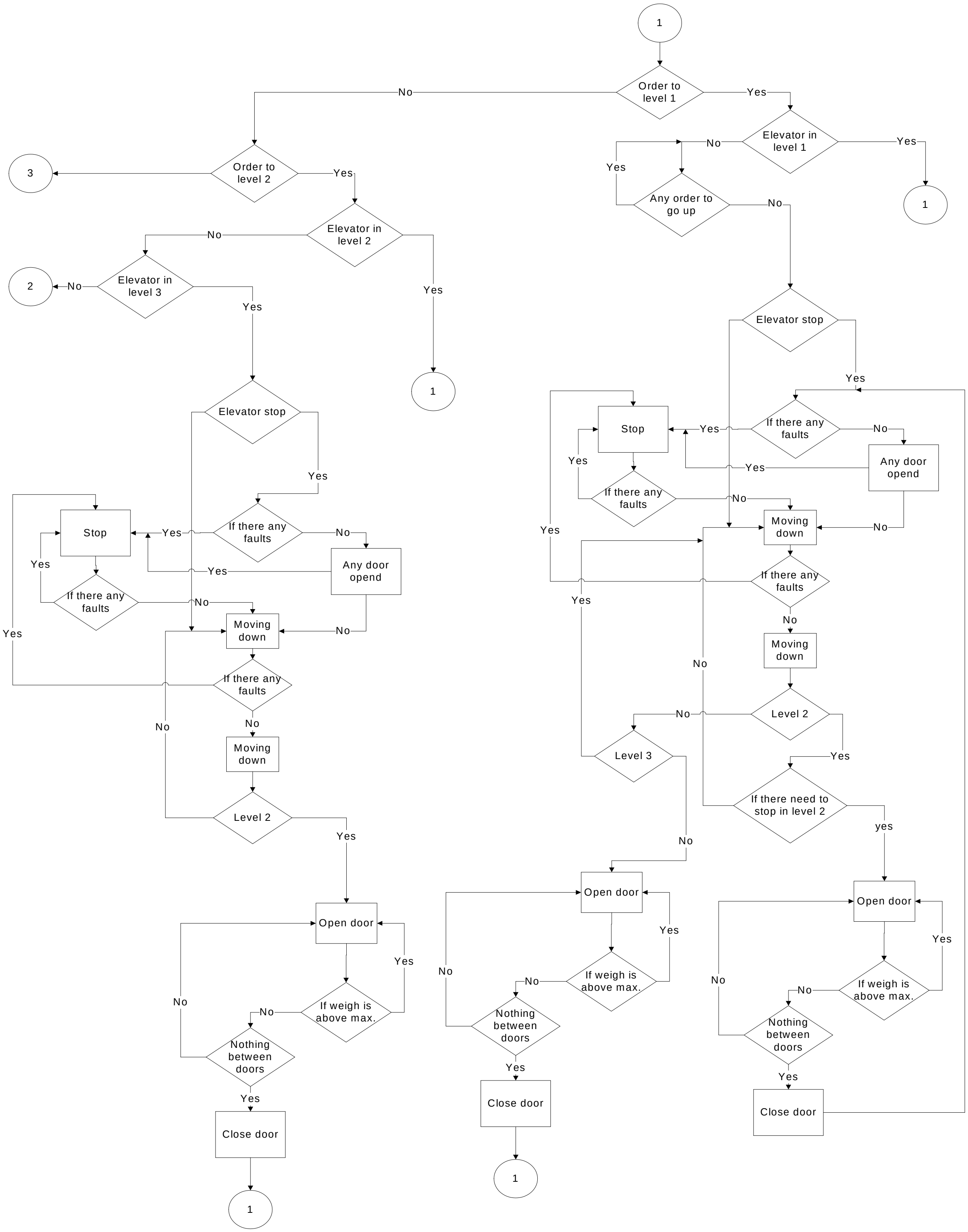


Fig (5.3) (a) elevator work

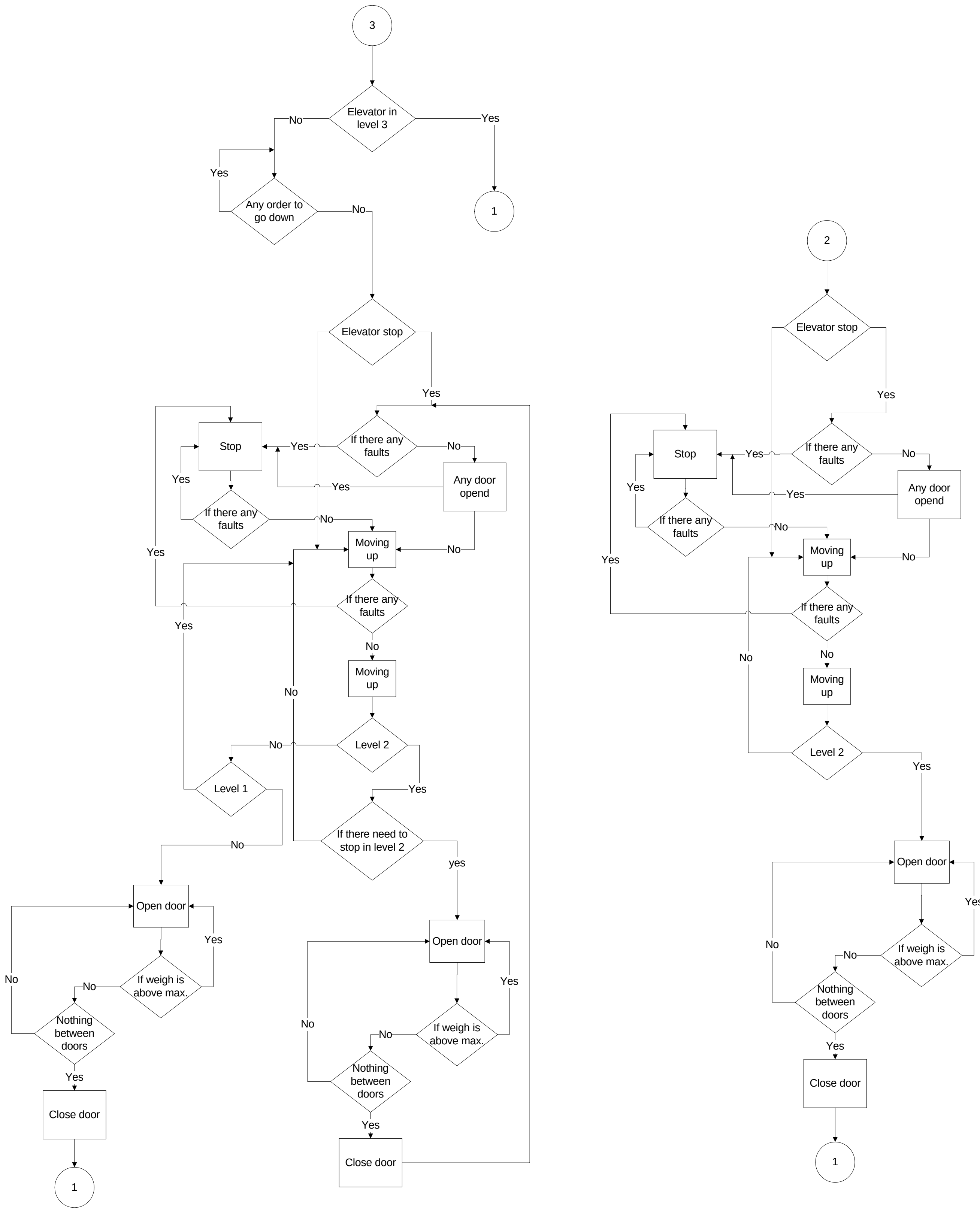


Fig (5.3) (b) elevator work

5. 4 the block diagram of PLC program

Upword movement

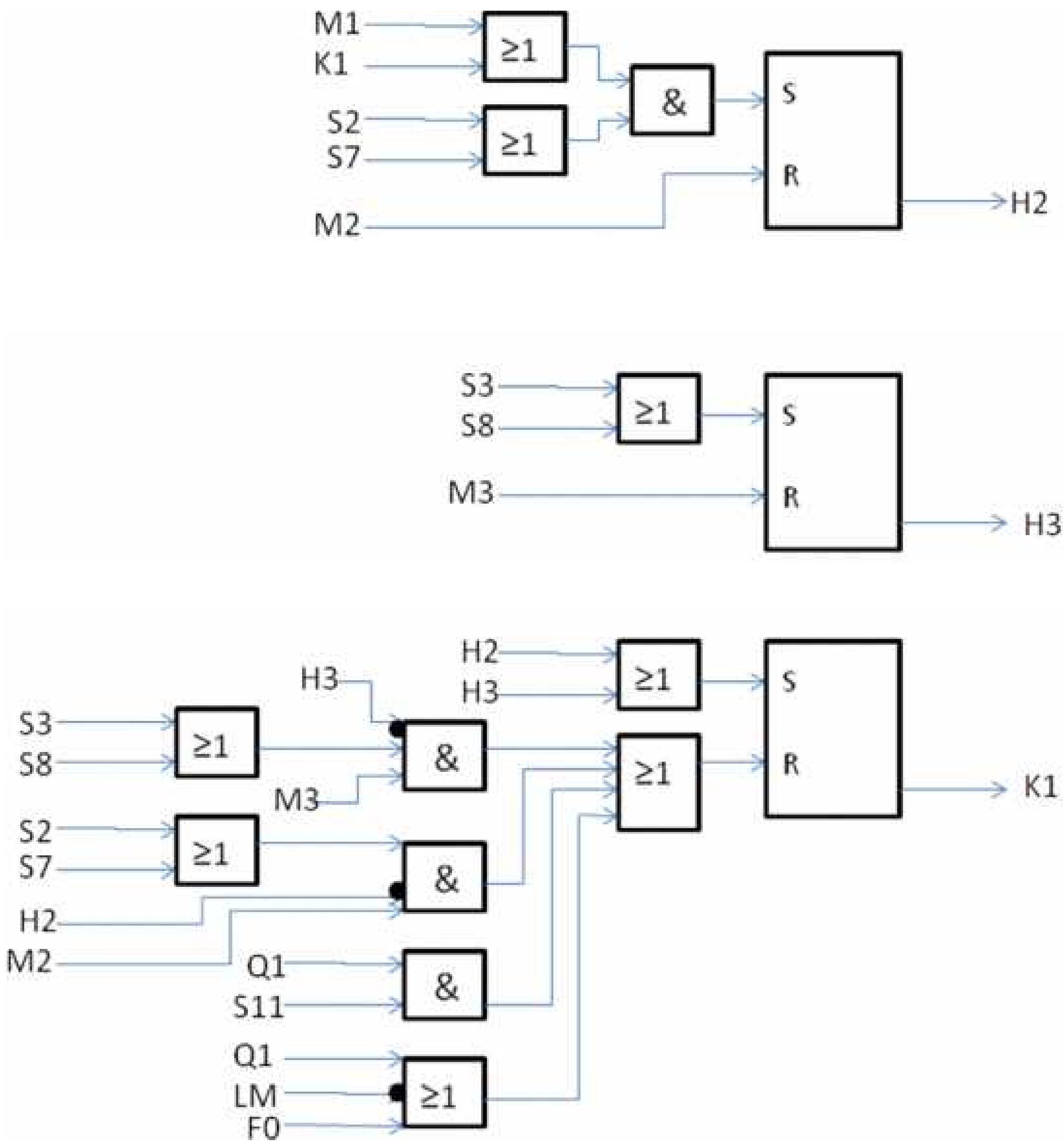


Fig (5.4) upword movement

Downwred movemint

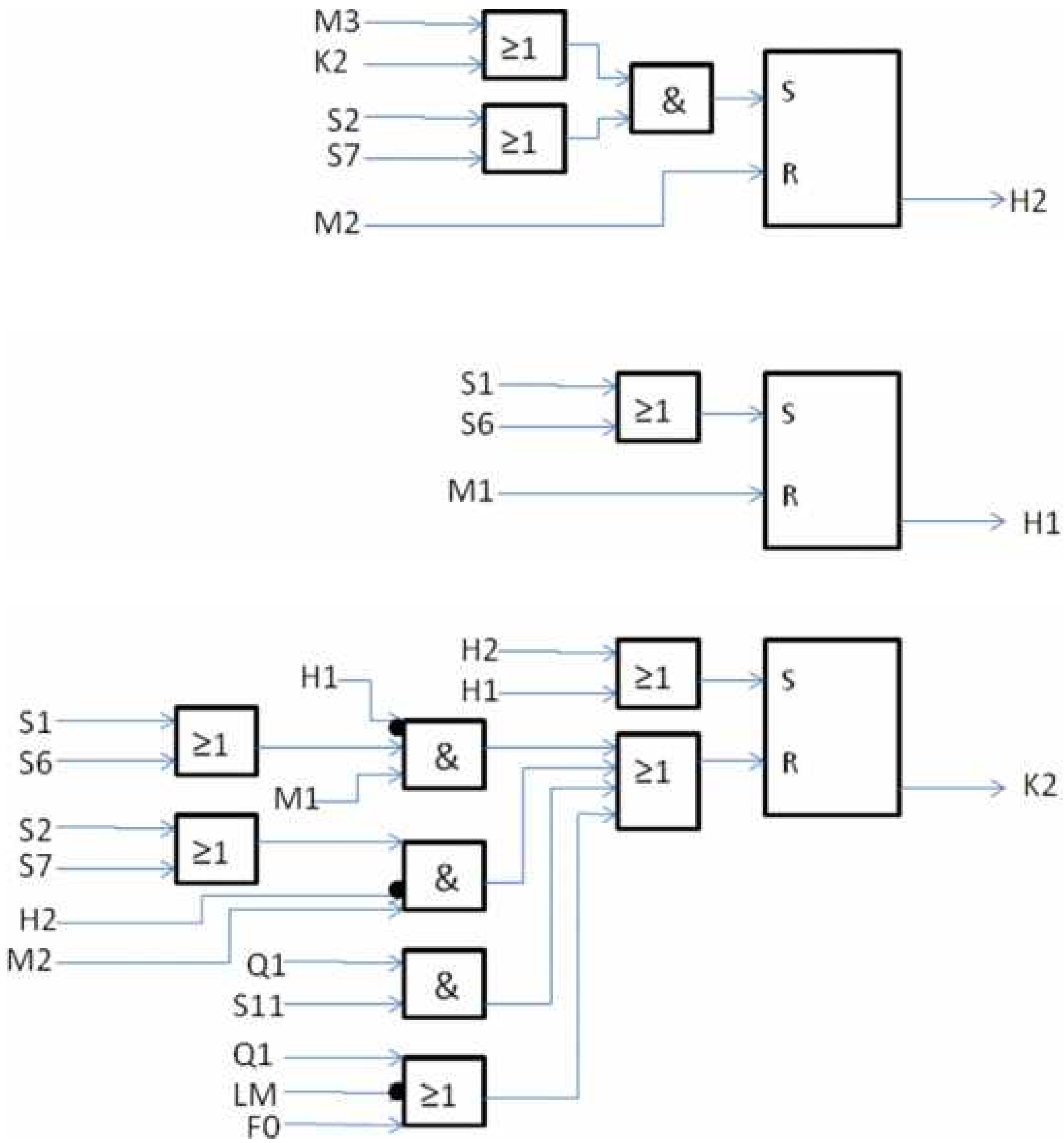


Fig (5.5) Downwred movemint

5.5 The door configurat

The door of our elevator will operate so that it can be opened and closed automatically in specified time unless there is a request.

The opening comes from the center of the door. When the elevator gets to the required floor a cam connected with the motor will contact with outer door and when the motor operates it will pull also the outer door and this also happened with closing operation. To ensure that the door get to its maximum opening there must be a sensors to give a signal.

The other signal that must he considered that is the photo cell, it is connected at the front of the, door which when its beams being cut the door will reopen for security of passengers.

We can control the direction of the door using the following circuit:

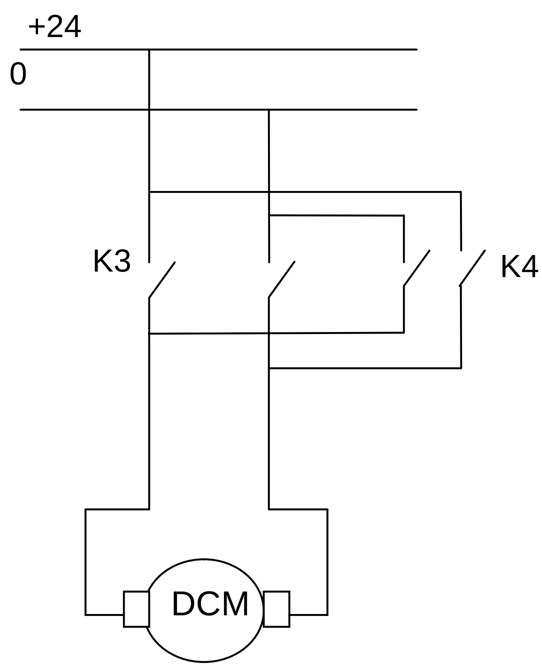


Figure5.6 : DC motor circuit

Opening door

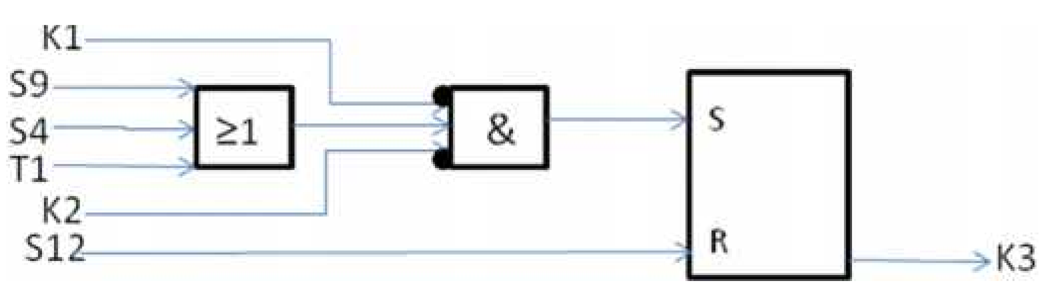


Fig (5.7) opening door

Closing door

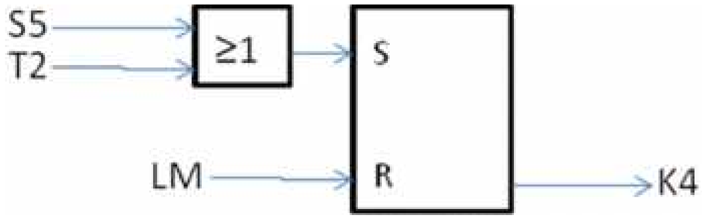


Fig (5.8) closing door

Timing for opening and closing

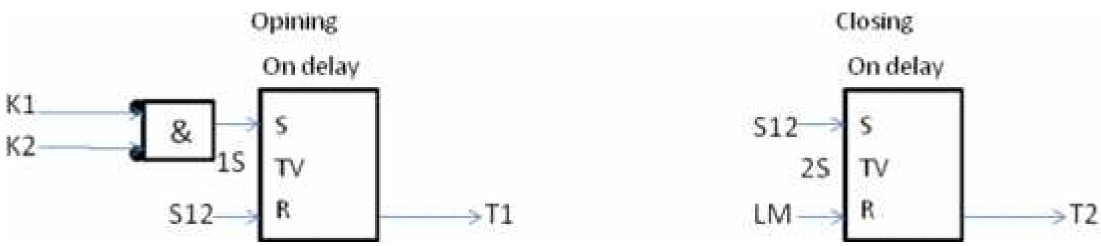


Fig (5.9) timing delay

Identify the position of elevator car

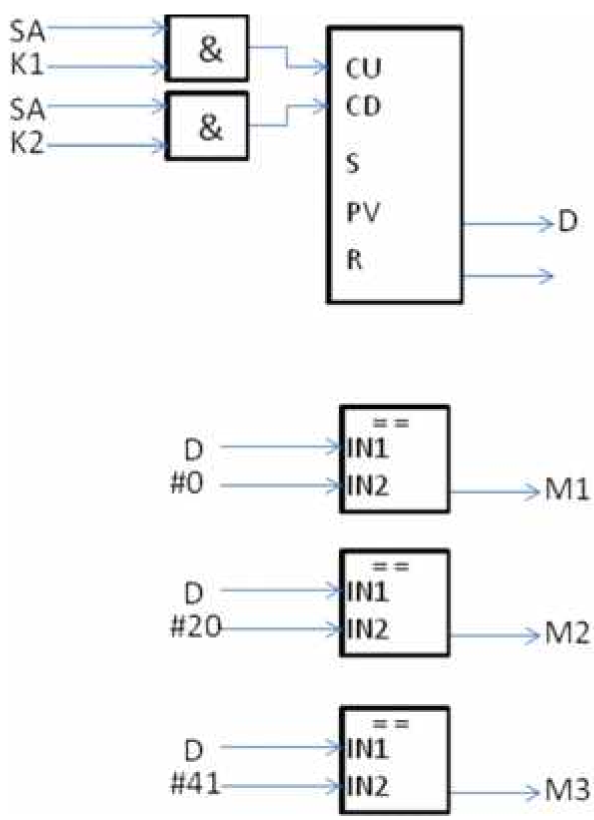


Fig (5.10) Identify the position of elevator car

Chapter six
Protection and Braking

6.1 Fuses:

Time delay fuses comprise one group of devices, which function to provide motor overload protection. The fuse is rated for 125 to 150 percent of normal running current. Only time delay fuses allow momentarily high startup currents a chance to clear before tripping the device. If the motor becomes overloaded and the operating current dies the fuse trip level, the power supply is interrupted. For three phase motors, some form of single phasing protection is required to switch off the power in cases where only one fuse blows on a three phase circuit. [3]

6.2 Relays protection:

Now that we understand how the PLC processes inputs, outputs, and the actual program we are almost ready to start writing a program. But first let's see how a relay actually works. After all, the main purpose of a PLC is to replace "real-world" relays. We can think of a relay as an electromagnetic switch. Apply a voltage to the coil and a magnetic field is generated. This magnetic field sucks the contacts of the relay in, causing them to make a connection. These contacts can be considered to be a switch. They allow current to flow between 2 points thereby closing the circuit.

Here we are using a dc relay to control an AC circuit. That's the good of relays When the switch is open no current can flow through the coil of the relay. As soon as the switch is closed, however, current runs through the coil causing a magnetic field to build up. This magnetic field causes the contacts of the relay to close. Now AC current flows through the circuit.. [3]

Fig(6.1) Relay

6.3 Heat Causes Motor Failures:

The most common cause of motor failure is excessive heating. Excessive motor heating is caused by a variety of problems ranging from low voltage to improper sizing of the motor**.**

Overload protection devices safeguard the motor from excessive heat conditions caused by mechanical overloads as well as damaging electrical conditions. Three categories of overload devices serve to protect a motor from damage caused by excessive heat. The categories are: Those that sense temperature, those that sense current, and those that sense both current and temperature. [3]

6.4 Over-current Protection:

Over-current protection devices interrupt the electrical circuit feeding a motor when there is an excessive current demand on the supply system. The National Electrical Code requires over-current protection devices in the form of fuses or circuit breakers in all electrical circuits. The purpose is to protect the electrical system from overloading events, which might damage electrical wires and possibly cause a fire. One problem with correctly sizing fuses and breakers for a motor circuit is that the motor may draw anywhere from 3 to 6 times its normal motor running current during startup.

Using normal fuse and circuit breaker sizing rules, this high starting current can potentially blow the fuse or trip the breaker every time the motor is started. Special fuses, like time delay fuses, can absorb this high starting current without blowing. Even though motor fuses and circuit breakers are rated at 3 to 6 times the normal operating current, they may still blow or trip in the event of a short circuit.

The primary concern, then, becomes motor overload conditions causing sufficiently high current which damages or burns the motor windings, but not severe enough to blow the fuses or trip the breakers. This possibility necessitates some type of motor overload protection. [3].

6.5 Contactors:

Magnetic contactors are electromagnetically operated switches that provide a safe and convenient means or connecting and interrupting branch circuits. The principal difference between contactor and a motor starter is that the contactor does not contain overload relays. Contactors re used in combination with pilot control devices to switch lighting and eating loads and to control ac motors in those cases where overload protection is provided separately.

The larger contactor sizes are used to provide remote control of relatively high-current circuits where it is too expensive to run the power leads to the remote controlling location,igure-3. This flexibility is one of the main advantages of electromagnetic control over manual control. Pilot devices such as push buttons. Load switches, pressure switches, limit switches, and thermostats are provided into operate the contactors. [3]

6.6 braking:

6.6.1Electrical braking:

By using DC current in the coils that makes a magnetic field to stop the car of elevator, that DC current can be used from the frequency converter.

The force that generated from this way is more enough to stop the elevator at the position we need and it’s stable for human using.

We use to apply this method a frequency converter, by using the parameters and Options from the frequency converter.

6.6.2 Electro-Mechanical braking:

Using a brake that if the current interpreted the brakes will stops the elevator, and this is very important to make the elevator safe from current interruption.

If the electric current has interrupted, the brake will applied immediately, by normal mood, the electric field that applied on the brake will make the brake open, but if the current interrupted, the brake will close and avoid the elevator of falling, this brake is very important to protect passengers life.

Chapter seven

Conclusions and Future work

This chapter presents the project conclusions; it also practical application of the results as well as presents suggestions and future work and.

7.1 Conclusions

Double-sided LM is better than single-sided LM, because of force in single-sided LM has half force of double-sided LM motor; because of that we must use double-sided LM to make the elevator moving better and more power.

The safety factor in the rope-less elevator is same in roped elevator, and the rope-less elevator does not only have the same advantages that the roped elevator have but better.

The mechanical construction is very important to make the elevator run smoothly and without noise.

The mistakes in mechanical construction will make bad Effect on the motion and motor torque.

7.2 Recommendations and Future work:

Stimulate the students to make more projects on PMLSM, specially on double-sided liner motor.

The magnets must be shielded to keep it safe and to make the magnetic field better.

Focus on the mechanical construction to make better results.

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