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Sudan University of Science and Technology

College of Graduate Studies

Design And Simulation Of a Multi Storey Smart Parking System

تصميم ومحاكاة لنظام موقف ذكى متعدد الطوابق

A Thesis Submitted In Partial Fulfillment of the Requirements For the Degree of M.Sc. In Mechatronics Engineering

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الآيـة

قال تعالى :

{ وَيَسْأَلُونَكَ عَنِ الرُّوحِ قُلِ الرُّوحُ مِنْ أَمْرِ رَبِّي وَمَا أُوتِيتُم مِّن الْعِلْمِ إِلاَّ قَلِيلاً (85) }

سورة الإسراء : 85

وقال تعالى :

{ فَتَعَالَى اللَّهُ الْمَلِكُ الْحَقُّ وَلَا تَعْجَلْ بِالْقُرْآنِ مِنْ قَبْلِ أَنْ يُقْضَى إِلَيْكَ وَحْيُهُ وَقُلْ رَبِّ زِدْنِي عِلْمًا (114) }

سورة طه : 114

صدق الله العظيم

DEDICATION

Each challenging work needs to self efforts as well as guidance of elders especially those who were very close to our heart.

My humble effort dedicate to my sweet and loving

MOTHER AND FATHER,

Whose affection, love, encouragement and pray of days and nights make me to able to get such success and honor,

Along with all hard working and respected teachers.

Acknowledgement

In the accomplishment of this project successfully, many people have best owned upon me their blessing and the heart pledged support, this time I am utilizing to thank all the people who have been concerned with project.

Primarily I would thank Allah for being able to complete this project with success. Then I would like to thank my supervisor Dr. Abdelfattah Bilal, the program supervisor Dr. alkhawadh and all teachers whose valuable guidance has been the ones that helped me patch this project and make it full proof success his suggestions and his instructions has served as the major contributor towards the completion the project.

Then I would like to thank my Parents again, brothers, sisters, family, friends and partners who have helped me with their valuable suggestion and guidance has been helpful in various phases of the completion of the project.

Last and not the least I would like to thank my classmates who have helped me a lot.

Abstract

With the increase in vehicle production and world population, more and more parking spaces and facilities are required. In this research a new parking system called Smart Parking System (SPS) is proposed to assist drivers to find vacant spaces in a car park in a shorter time and save effort. The new system uses sensors to detect either car park occupancy or improper parking actions. Features of SPS include display of available parking spaces, payment facilities and different types of parking spaces (vacant, occupied, reserved and handicapped). This research also describes the use of SPS system from the entrance into a parking lot until the finding of a vacant parking space and bring it back again by using a hydraulic lift and mechanical conveyors. The system is designed for a Three-level parking lot with 18 parking spaces, six parking a lot and one aisle on each floor. The system architecture defines the essential design features such as location of sensors, required number of sensors, motors location, parking space and elevator room.

مستخلص

زيادة إنتاج وتصنيع السيارات في العالم واستخدامها في الطرقات تقابلها دائما زيادة في حوجة مواقف السيارات وخدمات الطريق. في هذا البحث هناك نظام مواقف سيارات جديد يسمى مواقف السيارات الذكية Smart Parking System (SPS) مقترحة لمساعدة السائق لإيقاف سيارته في فترة زمنية قصيرة وبأقل مجهود.النظام الجديد يستخدم الحساسات لتحديد إذا كان الموقف محتل بسيارة أخرى أم فارغ وإذا ما كانت السيارة واقفة بطريقة صحيحة أم لا. ميزة المواقف الذكية تشمل أيضا عمليات الدفع وتحديد حالة الموقف إذا ما كان فارغا أو مشغولا بسيارة أو محجوز أو مخصص للأصحاب الحالات الخاصة. هذا البحث يصف عملية استخدام نظام المواقف الذكية من عملية الدخول لغاية وصولها إلى الموقف وعملية استرجاعها مرة أخرى باستخدام المصاعد الهيدروليكية وناقل الحركة الميكانيكية. هذا النظام مصمم لثلاث طوابق تحوي ثمانية عشر موقفا ستة مواقف وممر واحد في كل طابق. الشكل المعماري يوضع مواقع الحساسات وعددها في كل طابق وأماكن الموتورات ومواقف السيارات والمصعد.

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LIST OF SYMBOLS

P	-	Power
ω	-	Angular speed (rad/s)
N	-	Rotational speed (rad/min)
g	-	Gravity acceleration
T	-	Torque
Q	-	Flow rate
mi	-	Load due idler
mb	-	Load due belt
mm	-	Load due materials
l	-	Conveyor length
f	-	fraction coefficient
H	-	Vertical height of conveyor
δ	-	Inclination angle of conveyor
Pp	-	Power to drive pulley
Tbs	-	Belt tension while starting
Tb	-	Belt tension while steady state
Ks	-	Start up factor
V	-	Volt
I	-	Current
t	-	Time
μ	-	efficiency

CHAPTER ONE

INTRODUCTION

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INTRODUCTION

1.1 Preface

Today, most of the world population live in cities. Economic centers, touristic cities and capitals are becoming more and more populated every year. This rising number of people affects the infrastructure of these cities, streets are becoming overcrowded with people traffic. Cities today are continuously looking for new solution for problems like congestion in road networks. One of the main issues facing planers today is finding parking space for the rising number of vehicles. For a person driving a car in a congested city, finding a vacant parking lot consumes money, time and effort. A lot of solutions have arisen to solve this problem: car towers contain floors above and below the ground level. This solution saves space as an advantage but some health issues may occur. Reaching and leaving the vehicle maybe tiresome for the driver and the tower can become contaminated with excessive car smoke. In a final research thesis to propose a solution for this issue: a smart parking system that parks cars automatically. This project will be under the title "Design and simulation of multi store smart parking system". Smart parking system appeared decades ago and there are several forms and uses for them such as smart parking systems for commercial and Investment usage. This system has a ticketing machine for payment. There is also a smart parking system for security usage where surveillance equipment such as cameras, monitors and alarm bells are used to protect the vehicles from dangers like robbery and vandalism. Another smart parking system has a screen in the entrance to display any available positions. Some smart parking systems compute car numbers and the entry and departure time for each car. The Smart parking system aims to increase comfort for the driver, and save money, time and effort.

1.2 Problem statement:

As mentioned above in large cities the search for parking space in becoming more and more difficult. The parking shortage in such cities keeps creating more problems, wrong parking can cause streets to overcrowd and hinder the flow of traffic. Other problems may include the hours of time wasted in search of available parking space. One may walk tens or Hundreds of meters to reach his destination. Driving around in search of an empty parking space costs money in the shape of fuel consumption. The search of parking can also increase the risk of car accidents and environmental hazards like contamination. Quickly finding a vacant space in a multilevel parking lot is difficult if not impossible, especially on weekends or public holidays

1.3 Methodology:

The smart parking system proposed in this research is composed of three sub systems: a mechanical system, an electrical system and a control system. The design is based on linking these three systems together accurately by using a specific design and the soft logic program. In the mechanical system a hydraulic lift will be used for vertical movement. For horizontal movement on the floor a motor will be selected to operate a conveyor belt in order to move the vehicle right and left, and to rotate the vehicle around itself. In the electrical system the electrical loads will be computed and a protection and emergency system will also be designed. In the control system which is the most important system a PLC controller will be used. The design of the hardware part will include drawings of the components. The design of the software part will be done by writing the soft logic program. In addition, some components like sensors, relays, push button switch and so on will be chosen. All design processes will include drawings and calculations and the proper components will be chosen according to standard specifications. Also "AutoCAD" program will be used to illustrate the design. The simulation will be made using "WinCC Flexible" and the (soft logic program) will be written in the form of a ladder diagram using "Simatic Manager step 7".

1.4Objectives and limitations:

The aim of this research is to design and simulate a smart parking system that accommodates fifty cars. The project will be designed for a three floors building, each floor contains ten parking lots. The building have two entrances and two lifts. The driver puts his car in one entrance where the system receives and stores it automatically in an empty position. When the driver requests the car, the system automatically locates and returns it to the designated collection point. The smart parking system can be used for a residential or an office building. But since a payment system won't be included and only two entrances will be used It is not suitable for commercial use.

CHAPTER TWO

Hydraulic And Electrical Components

CHAPTER TWO

Hydraulic And Electrical Components

2.1 literature review:

The smart parking system is a new system which is appear recently in the world. It has been executed in some countries such as United Arab Emirates, Kuwait, Saudi Arabia, Turkish, South Korea, Japan and some European countries. This system has a simple shape contains a small mechanical structural system on small area and complicated shape built on building tower or underground. There some studies, paper and presentation for this system. A paper titled, "Smart Parking System (SPS) Architecture Using Ultrasonic Detector", 3.7.2012 in International Journal of Software Engineering and Its Applications has been written by Amin Kianpisheh, Norlia Mustaffa, Pakapan Limtrairut and Pantea Keikhosrokiani. This paper explained how to use sensor to detect a car in parking and how to make electronic circuit to control system. And "Smart Parking System with Image Processing Facility", May 2012 in *Intelligent Systems and Applications has been written by* M.O. Reza, M.F. Ismail, A.A. Rokoni, M.A.R. Sarkar. They designed small building from simple material to simulate a smart parking system. They explained how to use motors and sensors in the system and also they designed control circuit and made simulation for the system by specific software. "Design and implementation of car parking system FPGA", 3.6.2012 in International Journal of VLSI design & Communication Systems (VLSICS) has been written by Ramneet Kaur and Balwinder Singh. "Design and Fabrication of Prototype of Automated. Smart Car Parking System using Programmable Logical Controllers (PLC)", 1.9.2013 in International Journal of Scientific Engineering and Technology has been written by S.Sarayu, Sri. Sree Rajendra, V.V.Bongale. And also there is two researches studies for master degree the first addressed by "Automated parking system", May. 2008 has been written by LINA LO. And the second addressed by "Smart parking system", 2005 has been written by TEE YIAN PHING.

2.2 Introduction:

Fluid power is the technology that deals with the generation, control and transmission of forces and movement of mechanical element or system with the use of pressurized fluids in a confined system. Fluid power system includes a hydraulic system and a pneumatic system. Oil hydraulic employs pressurized liquid petroleum oils and synthetic oils, and pneumatic employs compressed air that is released to the atmosphere after performing the work.

2.3 Hydraulic circuits

Hydraulic pumps are primarily used to convert energy and next hydraulic cylinders or motors do the work. Hydraulic energy and its associated transfer of power exist in a hydraulic circuit in the form of pressure and flow. In this form, their size and direction of action are effected by variable displacement pumps and open loop and closed loop control valves. The pressure fluid, which is fed through pipes, hoses and bores within a manifold, transports the energy or only transfers the pressure. Hydraulic circuits components will be described in the subsequent paragraphs.

2.3.1 Prime-Movers (Electric motors)

Standard AC motors are available in four speeds 750, 1000, 1440, 3000 RPM. In hydraulic generally 1440 RPM is used. Motors are made in many grade of protection against entry of water and dust etc. generally commercial grade of motor are with protection grade of IP44. But better grade protection is IP65 in which case water cannot enter in motor from rear. At full load and working pressure electric motor should draw only 90% of its full rated current. When a hydraulic system starts and motor is switch on, motor may start with no load on it, or full load on it. In case of no load start equipment, use slip ring type of electric motor, and in full load start type of requirement use squire cage type of electric motor. Up to 15HP and no load start type of requirement DOL starter could be used while above 15HP use star-delta type of motor-starter. [Khan, Q. S. & Mesh and B. E, (2002)].

2.3.2 Pumps

The hydraulic pump is the heart of a hydraulic system. It pumps oil in hydraulic system and converts the mechanical energy of prime-mover into hydraulic energy. The following types of pumps are used in hydraulic circuits:

A. Vane Pumps

Vane pump consists of vanes (Blades) which slide in slots in a rotor. Rotor eccentrically rotates in a cam-ring. Vanes, rotor and cam-ring are covered from both sides by pressure plates. When rotor rotates by drive shaft, it throws out vanes (blades) due to centrifugal force against cam ring. Vanes rub against cam-ring under centrifugal force as rotor rotates. But as rotor is eccentrically located in cam-ring, hence while rubbing against cam-ring blades also reciprocate in and out in slots in rotor. Because of this action the volume between two vanes increase and decrease in one rotation of rotor. When volume between vanes increase, the vacuum get created which suck oil between vanes. And when volume between vanes decreases it push out oil between vanes. This cause the pumping action of vane pump. To throw out vanes against cam-ring, and to make a leak proof joint between cam-ring and vanes minimum 600 RPM of rotor is required. See appendices no.1

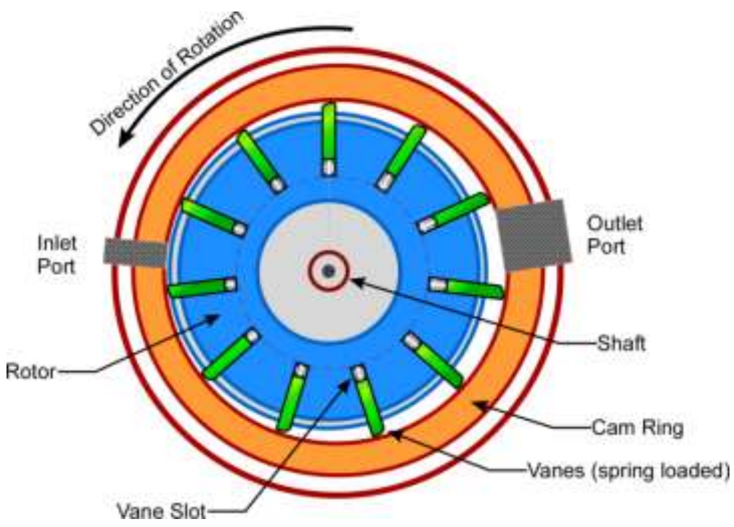


Figure 2.1 : Vane pump [Posted by Design aerospace LLC website 2012]

B. Gear Pump

Gear pump consist of two gears, harden and ground and engaged with each other. They are enclosed by pump casing and side-pressure plates, all fitted with very close tolerance. When gear rotates the side where teeth disengaged create partial vacuum, which sucks oil in pump casing. Oil is carried between gear teeth and casing, and the side where teeth of gears start engaging due to reduction in volume oil is pushed out of pump. This is how gear pump works. As there is high pressure on one side and low pressure on other side of gears, hence gear pumps are always of unbalance type. And heavy duty bearings are to be used in gear pump. Two, three or four gear pump could be assembled on single shaft, and could be used for independent circuit or could be used collectively. See appendix no.2.

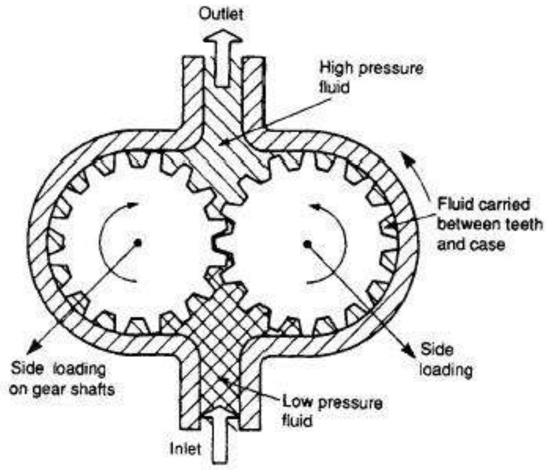


Figure 2.2 : Gear pump [Posted by Goodwin trading LLC website 2013]

C. Piston Pump

Piston pump consists of number of pumping elements. Each pumping element consists of a small cylinder, a small piston, two non-return valves and a mechanism to generate reciprocating motion between piston and cylinder.

In outward stroke of piston, cylinder sucks fluid, and in inward motion of piston, cylinder delivers fluid. Similar numbers of small pumping units are used in one piston pump. The mechanism to reciprocate piston differs in different type of pump.

Piston pump is available in two types namely.

a) Radial Piston Pump.
b) Axial Piston Pump.

In redial piston pump the cylinder of pumping element is fixed to main pump-body an piston is forced against rotor by spring, as shown in below sketch. Rotor is placed eccentric to the pump body, hence when it rotates it produces reciprocating motion of piston assemblies.

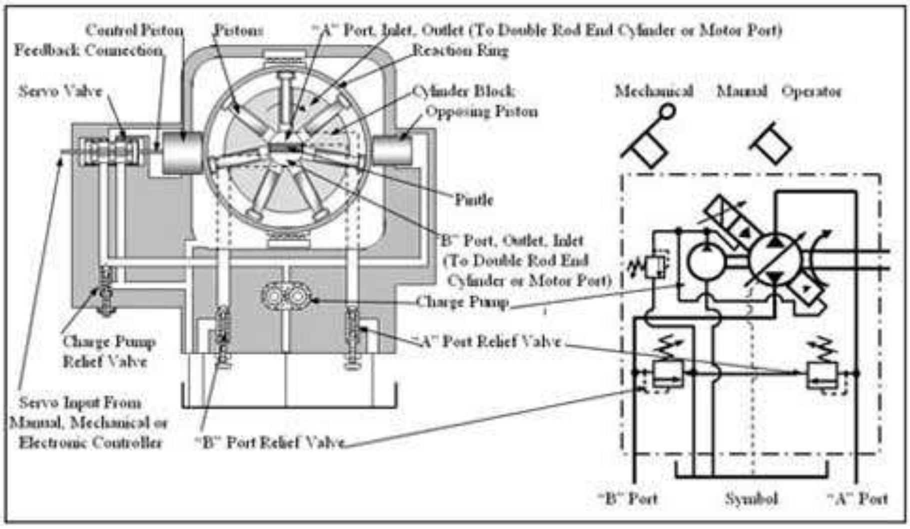


Figure 2.3 : Radial piston pump [Posted by Shadi website 2009]

In radial piston pump, piston reciprocates perpendicular to axis of rotor. In case of axial piston pump, the pumping assemblies have similar cylinder, piston and check valves, but piston reciprocates either parallel or at some angle to pump shaft axis, but not perpendicular to it.

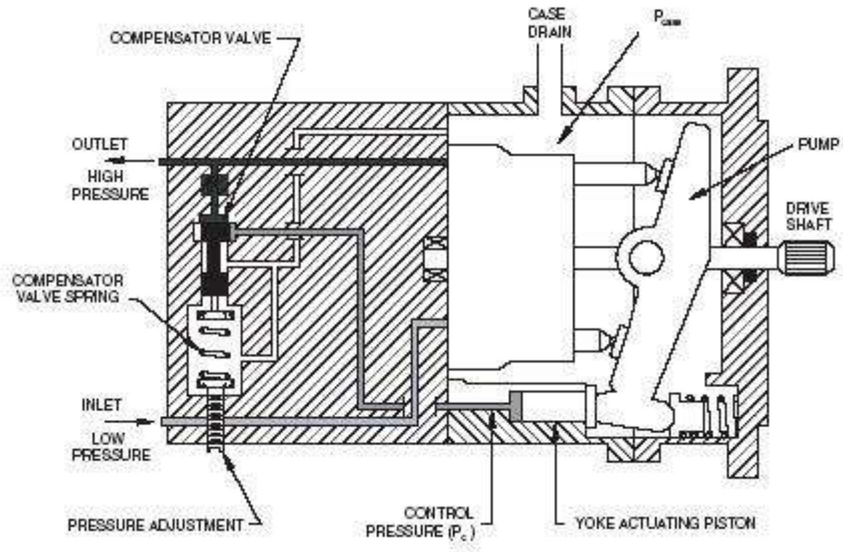


Figure 2.4 : Axial piston pump [Posted by Goodwin trading LLC website 2013]

2.3.3 Control valve

The control valves are divided to the fallowing types:

2.3.3.1 Pressure Control Valves

Pump only generates the flow of oil. It does not develop pressure. Pressure gets developed when flow of oil opposed by the some restriction. If development of pressure is not checked and controlled then pressure may keeps on building up, and may reach beyond the safe limit of hydraulic component, resulting in permanent damage to system or an accident. Hence pressure relief valve is basic and most important part of a hydraulic system. In addition to controlling maximum pressure, a hydraulic system demand manipulation of pressure and flow of oil in many ways. To fulfill such need various types of hydraulic valves have been developed.

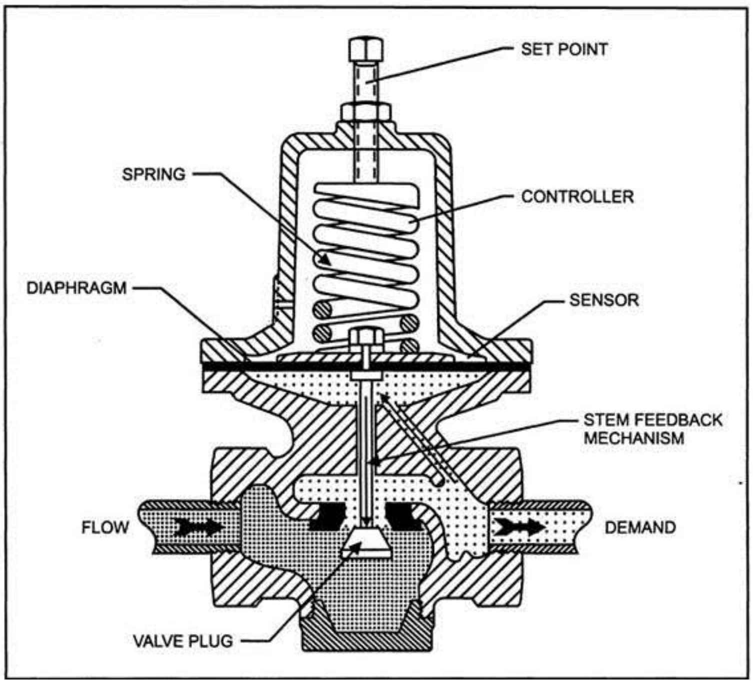


Figure 2.5 : pressure control valve [Posted by HIS Engineering website 2010]

A. Relief valves

Relief valve is used to control and regulate the pressure in a hydraulic system. The relief valve could be classified in two categories.

a) Direct Acting Relief Valve.
b) Pilot Operated Relief valve.

Pilot operated relief valve has its one more modified category, which is important and most widely used in industry and is called "Unloading Valve". For unloading valve basic pilot operated relief valve is modified slightly and used along with a check valve. In unloading valve the basic pilot operated relief valve has a small piston in its vent port, which on sensing remote pressure, only lift-up poppet of direct acting relief valve from its valve seat. But piston does not allow oil to pass across it. Unloading valves are used in a circuit, where two pumps are used. One high flow and low pressure pump and second low flow and high-pressure pump Unloading relief valve is connected to low-pressure pump. After reaching certain required pressure, a pilot pressure from high-pressure pump is used to actual small piston in vent port of unloading valve to by- pass all oil of low-pressure pump to tank. Second most important application of unloading valve is charging of accumulator. Pump keep on charging accumulator and when accumulator reaches its full pressure, the piston in vent port of unloading relief valve senses the pressure and unload full discharge of pump to tank. Till the accumulator remains charged, the pump will be unloaded to tank, and as soon as pressure of accumulator drops pump again start charging to accumulator. Unloading valve releases pressurized oil from pump to tank when pressure reaches to its set pressure. As well as when it senses pilot pressure from external source.[Khan, Q. S. & Mesh and B. E, (2002)]

B. Pressure Reducing Valve

A pressure regulator is a valve that automatically cuts off the flow of a liquid or gas at a certain pressure. Regulators are used to allow high-pressure fluid supply lines or tanks to be reduced to safe and/or usable pressures for various applications. A pressure regulator's primary function is to match the flow of gas through the regulator to the demand for gas placed upon the system. If the load flow decreases, then the regulator flow must decrease also. If the load flow increases, then the regulator flow must increase in order to keep the controlled pressure from decreasing due to a shortage of gas in the pressure system. In the pictured single-stage regulator, a force balance is used on the diaphragm to control a poppet valve in order to regulate pressure. With no inlet pressure, the spring above the diaphragm pushes it down on the poppet valve, holding it open. Once inlet pressure is introduced, the open poppet allows flow to the diaphragm and pressure in the upper chamber increases, until the diaphragm is pushed upward against the spring, causing the poppet to reduce flow, finally stopping further increase of pressure. By adjusting the top screw, the downward pressure on the diaphragm can be increased, requiring more pressure in the upper chamber to maintain equilibrium. In this way, the outlet pressure of the regulator is controlled.

C. Counter balance valve, back pressure valve, unloading valve.

A basic direct acting spool-type valve modified in number of ways to get many types of valves of different application. Second we will describe the basic valve. It consists of:

a) Valve body, which is in three pieces.
b) A spool sliding in middle part of valve body.
c) Spool has an orifice along its axis.
d) Small piston fitted in lower part of body.
e) A spring and an adjusting screw fitted in top part of body.
f) A check valve (optional) fitted in middle part of body.

D. Sequence Valve

Consider a hydraulic press, which has a main pressing cylinder and an auxiliary cylinder. sequence of operation could be achieved by using two direction control valves. It could also be achieved by a simple sequence valve, which supplies oil to other cylinder only after first cylinder develops some pressure. The spring side oil chamber is connected to the external drain, and bottom side small piston connected to primary side of system pressure line. Hence spring is opposed only by primary pressure. At atmospheric pressure spring shift spool to one side and completely block the oil port of secondary side. When primary side develops pressure, and when this pressure overcome the compression of spring, spool slides up to open oil port secondary side. As spring compression is adjustable hence cracking pressure, and secondary pressure could be adjusted and selected.

E. Back Pressure Valve

Many hydraulic circuits require continuous backpressure in system. Direct acting spool type valve is one alternation, by using which we can precisely select and adjust the backpressure. Back-pressure valve is similar to sequence valve in operation with some modification.

F. Unloading Valve

The unloading valve, which made by modifying pilot operated relief valve. Unloading valve also can be made by modifying direct acting spool-type valve.

G. Counter Balance Valve

In case of large vertical presses, the piston rods are very heavy, In case of those applications in which heavy loads are attached to piston rod, piston-rod try to slide-down by its own weight, and forward-speed is un-controlled and faster than what it should be. Because of which upper side of piston may develop vacuum or low-pressure. At low-pressure air get released from oil and causes spongy and jerky action of piston rod. To avoid this pressure is developed in exhaust side of piston, so that it supports the piston, and avoid free fall. This controlled exhaust of oil in forward stroke of cylinder is achieved by using a valve called “counter-balance-valve”. Counter-balance-valve is a modification of direct-acting spool type valve.

2.3.3.2 Flow Control Valve

Flow control valves are used to control the speed of hydraulic actuator that is hydraulic cylinder and motor. A simple orifice or a needle valve could be used to control the flow of fluid and can be called as “Flow-Control-Valve”.

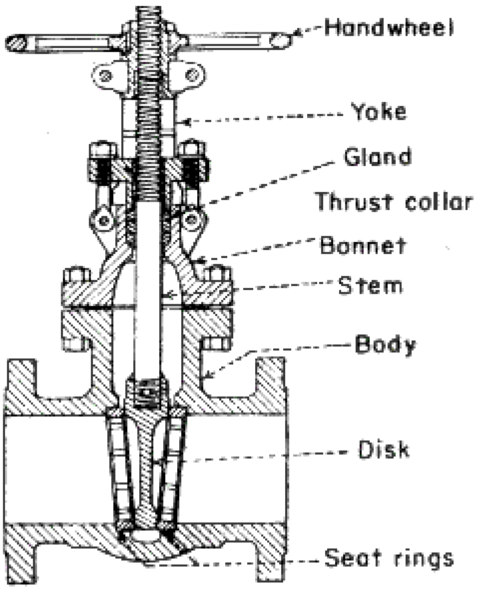


Figure 2.6 : Flow control valve [Posted by HIS Engineering website 2010]

Factors affecting flow:

a) Size of Orifice: Larger the size of orifice higher is the flow.

b) Temperature: - Higher the temperature, lower viscosity of oil, causes high flow rate across the orifice

c) Pressure difference across the orifice: - Higher the pressure difference, higher the flow across the orifice.

Method of using Flow-Control-Valve:

a) Meter-in-circuit

In meter-in-circuit we control the flow of oil going into the cylinder. That means we control the supply of oil to the cylinder. This method of control of speed has a disadvantage that it could not control a pulling load precisely.

b) Meter-out-circuit In case of meter-out circuit we control the flow of oil coming out from the cylinder.

c) Bleed-off-circuit.

In case of bleed-off circuit, we by-pass some of the oil to tank to control the speed of cylinder. This system has following features.

1. It cannot control speed of cylinder with pulling load.
2. Speed of cylinder change with its working pressure. This system had advantage that pump always do not work at full rated pressure.

in case of non-pressure compensated type flow control valve flow across flow control valve do not remain fixed but changes with pressure. A needle valve or a simple orifice is example of non-compensated flow control valve.

2.3.3.3 . Direction control valve

Direction control valves are used to start, stop and control the direction of fluid flow. The direction controlling elements in the valve body of direction control valve may be a poppet (piston or ball) a sliding spool or a rotary spool. In industrial hydraulic generally we use sliding spool type direction control valve. Direction control valve may be actuated by manual, electrical, hydraulic, pneumatic, and mechanical activator or combination of these. A direction control valve could be connected by threading, flange or could be mounted on sub-plate or on manifold block. The following the valves mounting on manifold block is more common.

- 2/2 Directional control valve
- 3/2 Directional control valve
- 5/2 Directional control valve

The first number represents the number of ports; the second number represents the number of positions.

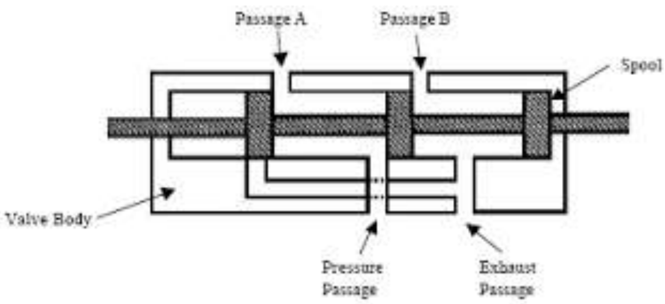


Figure 2.7 : directional control valve [Posted by HIS Engineering website 2010]

2.3.3.4 Check valve

Check valve is one-way direction control valve. It allows flow in one direction while blocking flow in other direction. Check valve consists of a valve body, a ball or a poppet and a light spring, which hold ball or poppet on valve seat. In one direction oil flow lifts the poppet/ball against spring force, and passes to the other side. While in reverse direction ball/poppet sits on valve seat and do not allow the flow of oil. Check valve in addition to control flow in one direction also used to develop backpressure. If a strong spring is used the oil require some pressure to lift it and by-pass. Pilot operated check valve is similar to simple check valve. But this valve can also allow reverse flow if it is supplied with a pilot pressure to lift the poppet. These types of valve are used to hold and lock the cylinder under pressure. And release the pressure by providing pilot pressure to valve when it is not required.

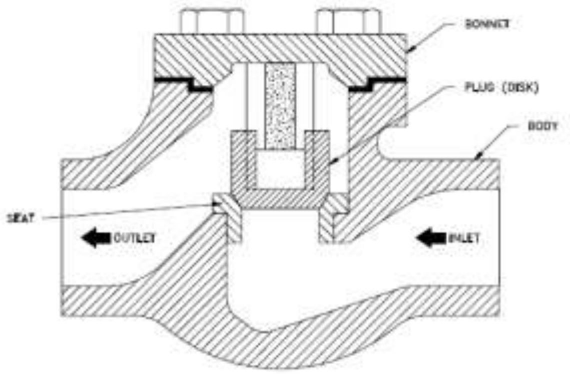


Figure 2.8 : Check valve [Posted by HIS Engineering website 2010]

2.3.4 Actuators

Actuators are the mechanical components that transforms the hydraulic energy into mechanical energy. Two types of hydraulic actuators are used, namely, hydraulic motors and hydraulic cylinders.

2.3.4.1 Rotary Actuator (Hydraulic Motors)

Piston-type motors are the most commonly used in hydraulic systems. They are basically the same as hydraulic pumps except they are used to convert hydraulic energy into mechanical (rotary) energy. Details of hydraulic motor types shown below. [Reported by Hydraulic & Pneumatic website 2014].

a) Gear Motors

A gear motor (external gear) consists of two gears, the driven gear (attached to the output shaft by way of a key, etc.) and the idler gear. High pressure oil is ported into one side of the gears, where it flows around the periphery of the gears, between the gear tips and the wall housings in which it resides, to the outlet port.

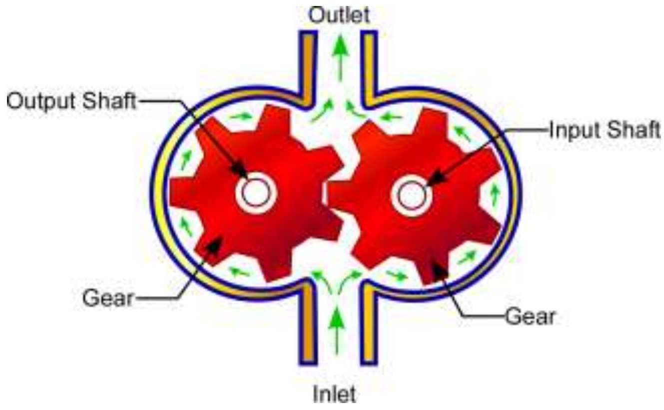


Figure 2.9 : Gear motor [Posted by Design aerospace LLC website 2012]

In the following two types of gear motors:

1-External gear motors

Consist of a pair of matched gears enclosed in one housing. Both gears have the same tooth form and are driven by pressure fluid. One gear is connected to an output shaft; the other is an idler. Pressure fluid enters the housing at a point where the gears mesh. It forces the gears to rotate, and follows the path of least resistance around the periphery of the housing. The fluid exists at low pressure at the opposite side of the motor. Close tolerances between gears and housing help control fluid leakage and increase volumetric efficiency. Wear plates on the sides of the gears keep the gears from moving axially and help control leakage.

2-Internal Gear Motors

Internal gear motors classified into three categories.

- A direct-drive gear motor

consists of an inner-outer gear set and an output shaft. The inner gear has one less tooth than the outer. The shape of the teeth is such that all teeth of the inner gear are in contact with some portion of the outer gear at all times. When pressure fluid is introduced into the motor, both gears rotate. The motor housing has an integral kidney-shaped inlet and outlet ports. The centers of rotation of the two gears are separated by a given amount known as the eccentricity. The center of the inner gear coincides with the center of the output shaft.

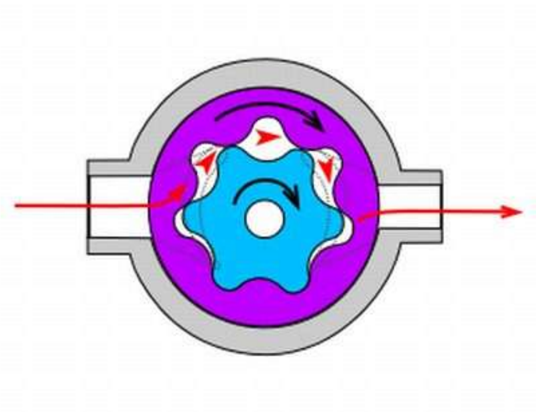


Figure 2.10 : Internal gear motor[Posted by Design aerospace LLC website 2012]

- Orbiting Gerotor Motor

An orbiting Gerotor motor, Consists of a set of matched gears, a coupling, an output shaft, and commutator or valve plate. The stationary outer gear has one more tooth than the rotating inner gear. The commutator turns at the same rate as the inner gear and always provides pressure fluid and a passageway to tank to the proper spaces between the two gears.

- Roller-Vane Gerotor Motor

A roller-vane Gerotor motor, is a variation of the orbiting gerotor motor. It has a stationary ring gear (or stator) and a moving planet gear (or rotor). Instead of being held by two journal bearings, the eccentric arm of the planetary is held by meshing of the 6 tooth rotor and the 7 tooth socket stator. Instead of direct contact between the stator and rotor, roller vanes reduce wear, enabling the motors to be use in closed-loop, high pressure hydrostatic circuits as direct-mounted wheel drives.

b. Vane Motors

Vane motor, have a slotted rotor mounted on a drive shaft that is driven by the rotor. Vanes, closely fitted into the rotor slots, move radially to seal against the cam ring. The ring has two major and two minor radial sections joined by transitional sections or ramps. These contours and the pressures introduced to them are balanced diametrically. In some designs, light springs force the vanes radially against the cam contour to assure a seal at zero speed so the motor can develop starting torque. The springs are assisted by angular momentum at higher speeds. Radial grooves and holes through the vanes equalize radial hydraulic forces on the vanes at all times. Pressure fluid enters and leaves the motor housing through openings in the side plates at the ramps. Pressure fluid entering at the inlet ports moves the rotor counterclockwise. The rotor transports the fluid to the ramp openings at the outlet ports to return to tank. If pressure were introduced at the outlet ports, it would turn the motor clockwise. Vane motors provide good operating efficiencies, but not as high as those of piston motors.

However, vane motors generally cost less than piston motors of corresponding horsepower ratings.

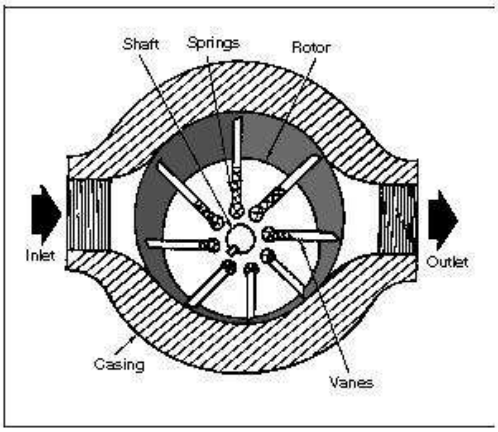


Figure 2.11 : Vane motor [Posted by Design aerospace LLC website 2012]

c. Piston-Type Motors

Radial-Piston Motors, have a cylinder barrel attached to a driven shaft; the barrel contains a number of pistons that reciprocate in radial bores. The outer piston ends bear against a thrust ring. Pressure fluid flows through a pintle in the center of the cylinder barrel to drive the pistons outward. The pistons push against the thrust ring and the reaction forces rotate the barrel. Motor displacement is varied by shifting the slide block laterally to change the piston stroke. When the centerlines of the cylinder barrel and housing coincide, there is no fluid flow and therefore the cylinder barrel stops. Moving the slide past center reverses direction of motor rotation. Radial piston motors are very efficient. Although the high degree of precision required in the manufacture of radial piston motors raises initial costs, they generally have a long life. They provide high torque at relatively low shaft speeds and excellent low speed operation with high efficiency; they have limited high speed capabilities. Axial-piston motors also use the reciprocating piston motion principle to rotate the output shaft, but motion is axial, rather than radial. Their efficiency characteristics are similar to those of radial-piston motors. Initially, axial-piston motors cost more than vane or gear motors of comparable horsepower, and have a long operating life. Because of this, their higher initial cost may not truly reflect the expected overall costs during the life of a piece of equipment.[Reported by Hydraulic & Pneumatic website 2014].

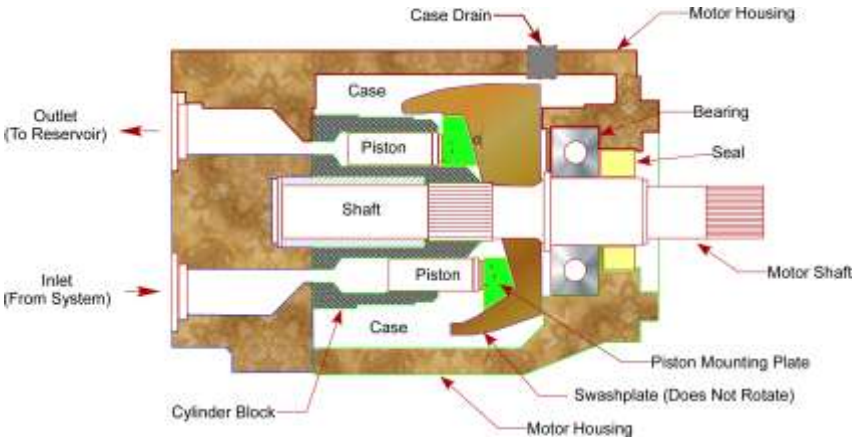


Figure 2.12 : piston pump [Posted by Design aerospace LLC website 2012]

2.3.4.2 Hydraulic Cylinder

Hydraulic cylinders convert the energy produced from a hydraulic pump into a linear mechanical output so that they can perform useful work. Hydraulic cylinders are sometimes also referred to as hydraulic rams, hydraulic jacks, linear hydraulic actuators, and hydraulic actuators. These terms are all synonymous although the terms "hydraulic ram" and "hydraulic jack" are usually applied to short stroke, single acting cylinders with large diameter piston rods. Hydraulic cylinders are the muscles of machinery. Hydraulic cylinders are so named because they consist of a piston that moves through a smooth round cylinder or tube. This cylindrical tube must be sealed at both ends with end plates. The end plates are also called end caps or cylinder heads. The piston is firmly connected to a shaft called a piston rod that exits the cylinder through a hole in one end cap. This is called the rod end. The opposite end of the cylinder is called the cap end or the blind end (because it does not have an eye for the rod to stick out). The piston rod is the working end of the cylinder and is usually fastened to a load that must be moved. The opposite end of the cylinder body is called the cap end or blind end. It is usually attached to a surface which the actuator pushes against although a large variety of mountings are available that can be mounted at various positions over the body of the actuator. The cylinder barrel or tube is usually made from high strength seamless steel tubing that has been honed or skive roller burnished to a fine finish on the inside diameter. This will provide a smooth surface for the hydraulic piston to slide through. The tube must be of sufficient thickness to bears the hydraulic pressure that will be used.

Hydraulic cylinders are specified by bore size, stroke, mounting style, rod diameter, and pressure rating. Hydraulic cylinders are designed to be either single acting or double acting. [Jaffar, S , 2009]

a) A single acting hydraulic cylinder is the most simple and least expensive design. Pressurized hydraulic fluid is pumped into the cylinder at one end only and pushes the piston in one direction, usually to extend the rod. Once the work is accomplished, the oil is depressurized and diverted back to the oil reservoir. The piston is returned to its retracted position by an external force such as gravity or a compressed return spring. The piston of a single acting cylinder requires only one seal to contain the pressurized hydraulic fluid on the one side of the piston.

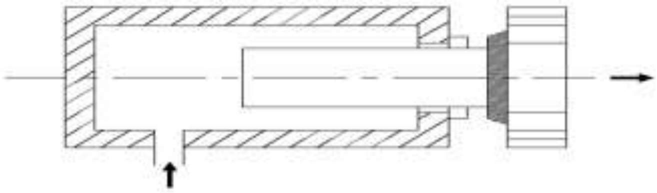


Figure 2.13 : Single acting cylinder[Posted by Jungwoo Hydraulic website 2007]

b) A double acting cylinder is more complicated as it uses pressurized hydraulic fluid to both extend and retract the piston rod. It thus requires fluid ports at both ends of the actuator in order for the oil to be directed onto both sides of the piston. The piston must be equipped with seals that will contain the pressure from both sides. The hole from which the piston rod extends out of the one end of the actuator must also be sealed to prevent fluid pressure loss. This area is often called the rod gland. It also consists of a bearing surface to guide and support the piston rod as it moves back and forth. Another seal called a rod wiper is usually installed here to clean the rod as it re-enters the cylinder. The rod wiper excludes contamination that might damage the inner seals or the oil quality. Under extreme conditions a special hardened, heavy duty rod wiper called a rod scraper can be used to remove sticky contaminants from the piston rod as it re-enters the cylinder. Special Hydraulic Cylinder Designs include the following:

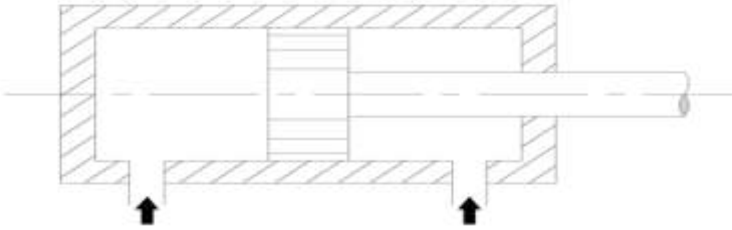


Figure 2.14 : Double acting cylinder [Posted by Jungwoo Hydraulic website 2007]

a) Double Rod End Cylinders

Double rod end cylinders have piston rods extending out both end caps. Thus when the piston is pushed down the barrel, one piston rod extends while the other is retracting. This design is sometimes used when the actuator is mounted by the two rod ends and the load is fastened to the cylinder body. The load thus traverses back and forth with the cylinder body. Another reason for using this design is to equalize the areas or volumes on both sides of the piston. The result is that the extend and retract speed and the forces produced in both directions will be exactly the same. A double rod end cylinder also enables the user to attach devices to the back end of the cylinder to adjust the stroke of the actuator or to measure or indicate the distance traveled.

b) Multi-Stage Hydraulic Cylinders

Sometimes cylinders are assembled to provide several discrete, exactly repeatable strokes without the need for complicated feedback control systems. This can be accomplished by integrating two or more cylinders together to produce multiple stages of extension.

One multi-stage configuration consists of mounting two cylinders back to back by their rear heads. Thus when one cylinder (A) is extended, one discrete travel is produced. When the other cylinder (B) is extended, another discrete travel is produced. If the two cylinder bodies used are of different strokes, 4 discrete travels can be produced from the two actuators (0, A, B, and A+B).

If yet a third cylinder (C) is added to the assembly by attaching it to the rod end of cylinder B, AS many AS 8 discrete travels can be produced (0, A, B, A+B, C, A+C, B+C, A+B+C). Three cylinders are usually the limit to this assembly style due to cost, overall length, and weight considerations. Any more position requirements can be usually be provided more effectively by a feedback control system.

c) Tandem Cylinders

Tandem cylinders are closely related to multistage cylinders but are used to produce a force multiplying output effect rather than a number of discrete stroke outputs. A tandem cylinder arrangement is often used when a large bore cylinder cannot be fitted into a narrow space. Thus two or more cylinders mounted end to end are combined to push along the same line of force.

d) Telescopic Hydraulic Cylinders

Often cylinders are required to produce an long output travel from a very small retracted space. This would not be able to be accomplished using a standard rod style cylinder. Instead a series of hydraulic tubes nested like sleeves that telescope within each other are used to provide a long total output travel. Telescoping style cylinders are available in designs using 3, 4 or as many as 6 stages or sleeves. Travels of up to 500 inches can be provided. Most telescopic cylinders are single acting cylinders. They are usually retracted using gravity. Telescopic cylinders can be built as double acting cylinders too. These are much more complex and more expensive. They must be used carefully as the internal pressures produced if they are not retracted properly can burst the seals.

2.4Conveyors

Conveyors are mechanized devices used to move materials in relatively large quantities between specific locations over a fixed path. There are over 400 types of conveyors. What comes next is a discussion of the most commonly conveyors that can relate to the research topic.[Wood, S. & Huff, R, 2007]

i. Roller

A roller track for a storage rack or roller conveyor, comprising a wall arrangement, and a longitudinally-extending array of freely rotatable roller units supported on the wall for supportive engagement with a load, the roller units being disposed for rotation about generally parallel horizontal axes which are horizontally spaced along a longitudinally-extending conveying direction, each roller unit including an annular roller housing supported through an annular array of antifriction bearing elements on a support spindle for rotation about the respective horizontal axis.

ii. Portable

Portable conveyors are used primarily for applications involving mobility and space is a high priority.

iii. Vibrating

Vibrating conveyor’s operation is typically based on the natural frequency principle. At the natural frequency, the conveyor will vibrate indefinitely with only a small energy input. Once the drive initiates the conveyor's vibration, the supporting springs, by alternately storing and releasing most of the required energy, help maintain constant motion under the conveyed load.

iv. Screw/Spiral

Spiral conveyors are used mainly for heating, cooling or accumulation. Screw conveyors use a rotating screw in a channel or tube to move material.

v. Belt

Conveyor belts are used in a wide variety of material transport applications such as manufacturing, food processing, and heavy industry.

vi Overhead

Overhead Conveyor Systems are typically used to convey unit loads in a variety of industrial applications depend on the difference height between two terminals.

2.4.1 CONVAYORS BASIC DESIGN REQUIREMENTS

The basic design information required are: Length of Conveyor: Measured in feet from center to center of pulleys, parallel to belt line. Inclination of conveyor: Measured in degrees off the horizontal. Maximum and Minimum Material Density: Measured in pounds per cubic foot (PCF), the maximum density is used for power calculations while the minimum density is used in the conveyor calculations. Peak Capacity: Measured in tons per hour (TPH), the capacity used should be the peak capacity at which the conveyor is expected to perform, not a lesser average capacity.

2.4.2 Calculations for Conveyor Belt Systems

The conveyor belt calculations of different parameters are very important for designing a conveyor system. The belt conveyor is used for conveying different materials from one location to another. The different components of a belt conveyor system typically are electric drives, pulleys, idlers, and a long belt.

- Design of conveyor belt:

The basics of the Calculations of Conveyor Belt Design Parameters:

- **Belt tension:** The belt of the conveyor always experience a tensile load due to the rotation of the electric drive, weight of the conveyed materials, and due to the idlers. The belt tension at steady state can be calculated as:

$T_b = 1.37 * f * L * g * [2 * m_i + (2 * m_b + m_m) * \cos(\delta)] + (H * g * m_m)$ … (2.1) [Reported by bright hub engineering website 2010].

T_b is in Newton.

f = Coefficient of friction

L = Conveyor length in meters. Conveyor length is approximately half of the total belt length.

g = Acceleration due to gravity = 9.81 m/sec

m_i = Load due to the idlers in Kg/m.

m_b = Load due to belt in Kg/m.

m_m = Load due to the conveyed materials in Kg/m.

δ = Inclination angle of the conveyor in Degree.

H = vertical height of the conveyor in meters.

- **Load due to idlers (mi):** This can be calculated as below:

  m_i = (mass of a set of idlers) / (idlers spacing) … (2.2)

- **Power at drive pulley:** The power required at the drive pulley can be calculated from the belt tension value as below:

  P_p = (Tb*V)/1000 … (2.3)

  Where,

  P_p is in KW.

  T_b = steady state belt tension in N.

  v = belt speed in m/sec.

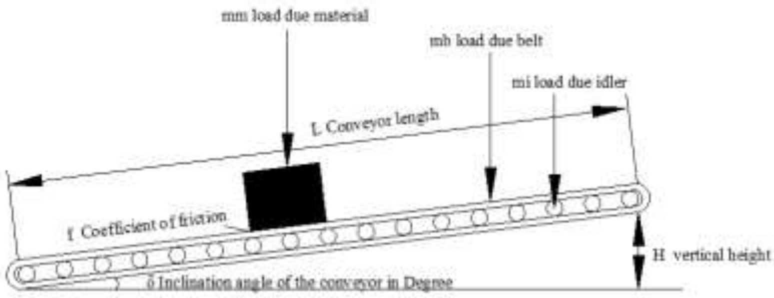


Figure 2.15 : Conveyor parameter [by autocad]

- **Belt tension while starting the system:** Initially during the start of the conveyor system, the tension in the belt will be much higher than the tension in steady state. The belt tension while starting can be calculated as:

  $T_{bs} = T_b * K_s$ ... (2.4)

  Where,

  T_{bs} is in N.

  T_b = the steady state belt tension in N.

  K_s = the start-up factor

- **Sizing of the motor:** The minimum motor power can be calculated as:

  $P_m = P_p / K_d$ … (2.5)

  Where, P_m is in Kw.

  P_p = the power at drive pulley in Kw

K_d = Drive efficiency. [Reported by bright hub engineering website 2010].

2.5ELECTRIC MOTORS

An electric motor is composed of a rotating center, called the rotor, and a stationary outside, called the stator. These motors use the attraction and repulsion of magnetic fields to induce forces, and hence motion. Typical electric motors use at least one electromagnetic coil, and sometimes permanent magnets to set up opposing fields. When a voltage is applied to these coils the result is a torque and rotation of an output shaft. There are a variety of motor configuration the yields motors suitable for different applications. Most notably, as the voltages supplied to the motors will vary the speeds and torques that they will provide. A control system is required when a motor is used for an application that requires continuous position or velocity. A typical controller is shown in Figure 2.16. In any controlled system a command generator is required to specify a desired position. The controller will compare the feedback from the encoder to the desired position or velocity to determine the system error. The controller with then generate an output, based on the system error. The output is then passed through a power amplifier, which in turn drives the motor. The encoder is connected directly to the motor shaft to provide feedback of position.[Jack, H, 2003]

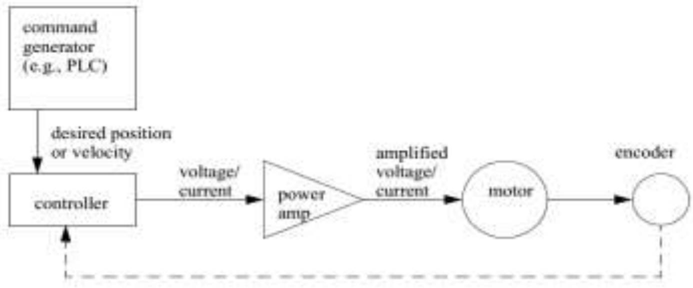


Figure2.16 :closed control system with command generator [Jack, H. (2003)]

2.5.1 Basic Brushed DC Motors

In a DC motor there is normally a set of coils on the rotor that turn inside a stator populated with permanent magnets. The magnetic provide a permanent magnetic field for the rotor to push against. When current is run through the wire loop it creates a magnetic field. The power is delivered to the rotor using a commutator and brushes. The direction of rotation will be determined by the polarity of the applied voltage, and the speed is proportional to the voltage. A feedback controller is used with these motors to provide motor positioning and velocity control. These motors are losing popularity to brushless motors. The brushes are subject to wear, which increases maintenance costs. In addition, the use of brushes increases resistance, and lowers the motors efficiency.

2.5.2 AC Motors

- Power is normally generated as 3-phase AC, so using this increases the efficiency of electrical drives.
- In AC motors the AC current is used to create changing fields in the motor.
- Typically AC motors have windings on the stator with multiple poles. Each pole is a pair of windings. As the AC current reverses, the magnetic field in the rotor appears to rotate.

- The number of windings (poles) can be an integer multiple of the number of phases of power. More poles results in a lower rotation of the motor.
- Rotor types for induction motors are listed below. Their function is to intersect changing magnetic fields from the stator. The changing field induces currents in the rotor. These currents in turn set up magnetic fields that oppose fields from the stator, generating a torque.
  - Squirrel cage - has the shape of a wheel with end caps and bars
  - Wound Rotor - the rotor has coils wound. These may be connected to external contacts via commutator
- Induction motors require slip. If the motor turns at the precise speed of the stator field, it will not see a changing magnetic field. The result would be a collapse of the rotor magnetic field. As a result an induction motor always turns slightly slower than the stator field. The difference is called the slip. This is typically a few percent. As the motor is loaded the slip will increase until the motor stalls.

An induction motor has the windings on the stator. The rotor is normally a squirrel cage design. The squirrel cage is a cast aluminum core that when exposed to a changing magnetic field will set up an opposing field. When an AC voltage is applied to the stator coils an AC magnetic field is created, the squirrel cage sets up an opposing magnetic field and the resulting torque causes the motor to turn. The motor will turn at a frequency close to that of the applied voltage, but there is always some slip. It is possible to control the speed of the motor by controlling the frequency of the AC voltage. Synchronous motor drives control the speed of the motors by synthesizing a variable frequency AC waveform These drives should be used for applications that only require a single rotational direction. When the motor is used with a fixed frequency AC source the synchronous speed of the motor will be the frequency of AC voltage divided by the number of poles in the motor. The motor actually has the maximum torque below the synchronous speed. For example a motor 2 pole motor might have a synchronous speed of (2*60*60/2) 3600 RPM, but be rated for 3520 RPM. When a feedback controller is used the issue of slip becomes insignificant.

- Single phase AC motors can run in either direction. To compensate for this a shading pole is used on the stator windings. It basically acts as an inductor to one side of the field which slows the field buildup and collapse. The result is that the field strength seems to naturally rotate.
- Thermal protection is normally used in motors to prevent overheating.
- Synchronous motors are different from induction motors in that they are designed to rotate at the frequency of the fields, in other words there is no slip.
- Synchronous motors use generated fields in the rotor to oppose the stators field.
- Starting AC motors can be hard because of the low torque at low speeds. To deal with this a switching arrangement is often used. At low speeds other coils or capacitors are connected into the circuits. At higher speeds centrifugal switches disconnect these and the motor behavior switches.

2.5.3 Brushless DC Motors

Brushless motors use a permanent magnet on the rotor, and use windings on the stator. Therefore there is no need to use brushes and a commutator to switch the polarity of the voltage on the coil. The lack of brushes means that these motors require less maintenance than the brushed DC motors. A typical Brushless DC motor could have three poles, each corresponding to one power input, as shown in Figure 2.17 Each of coils is separately controlled. The coils are switched on to attract or repel the permanent magnet rotor.

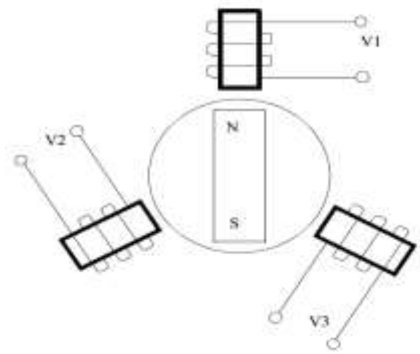


Figure2.17:Brushless motors use a permanent magnet [Jack, H. (2003)]

To continuously rotate these motors the current in the stator coils must alternate continuously. If the power supplied to the coils was a 3-phase AC sinusoidal waveform, the motor will rotate continuously. The applied voltage can also be trapezoidal, which will give a similar effect. The changing waveforms are controller using position feedback from the motor to select switching times. The speed of the motor is proportional to the frequency of the signal.

2.5.4 Wound Field Motors

Types DC power on the rotor and stator to generate the magnetic field:

2.4.4.1 Shunt motors

- Have the rotor and stator coils connected in parallel.
- When the load on these motors is reduced the current flow increases slightly, increasing the field, and slowing the motor.
- These motors have a relatively small variation in speed as they are varied, and are considered to have a relatively constant speed.
- The speed of the motor can be controlled by changing the supply voltage, or by putting a rheostat/resistor in series with the stator windings.

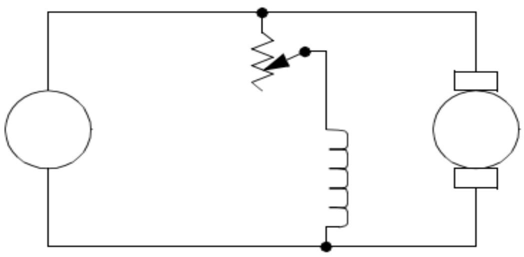


Figure2.18 :Shunt motors [Jack, H. (2003)]

2.5.4.2 Series motors

- Have the rotor and stator coils connected in series.
- As the motor speed increases the current increases, the motor can theoretically accelerate to infinite speeds if unloaded. This makes the dangerous when used in applications where they are potentially unloaded.

- These motors typically have greater starting torques that shunt motors.

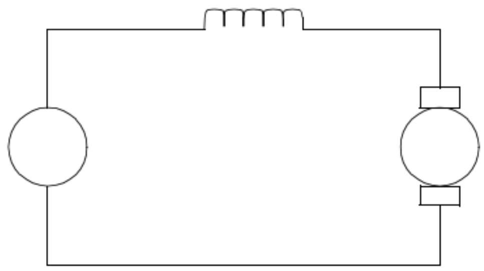


Figure2.19 :Series motors [Jack, H. (2003)]

2.5.4.3 Compound motors

- Have the rotor and stator coils connected in series.
- Differential compound motors have the shunt and series winding field aligned so that they oppose each other.
- Cumulative compound motors have the shunt and series winding fields aligned.

2.5.5 Motor selection

There are many types of motor, from high cost high performance servos to models at the cheaper end of the range, including many specialist types of motors. Choosing the right one for any given application depends on many variables, but very often a standard industrial AC induction motor is the best answer. These are relatively low cost, reliable, efficient, and well understood by engineers across all industrial sectors. The main considerations for selection for motors can be outlined as follows:[G.E Industry, 1999]

A- Voltage

The motor nameplate voltage is determined by the available power supply which must be known in order to properly select a motor for a given application. The nameplate voltage will normally be less than the nominal distribution system voltage. The distribution voltage is the same as the supply transformer voltage rating; the utilization (motor nameplate) voltage is set at a slightly lower level to allow for a voltage drop in the system between the transformer and the motor leads. Some specifications still call for 220, 440 or 550 volt motors which were the long accepted standards. However, modern distribution systems have transformers located adjacent to secondary unit substations or load centers, plant wide power factor correction and shorter power line runs. The result is a stiffer distribution system which delivers higher voltage at the motor. The following motor nameplate voltages provide the best match to distribution system voltages and meet current motor design practices.

B- Frequency standards

The predominant frequency in the United States is 60 hertz. However, 50 hertz systems are common in other countries. Other systems, such as 40 and 25 hertz are isolated and relatively few in number.

C- Poly-phase single-phase power

A power system can be either single-phase or poly-phase. Single-phase power, which is most commonly found in homes, rural areas and in small commercial establishments. A poly-phase power system consists of 2 or more alternating currents of equal frequency and amplitude but offset from each other by a phase angle. A three-phase power system having phases A, B and C. Each phase is offset by 120 degrees, 360 degrees being the span of one complete cycle .For motors, an advantage of three-phase power is simpler construction which requires less maintenance. Also, a more powerful machine can be built into a smaller frame and will generally operate at a higher efficiency than single-phase motors of the same rating.

D-Motor output rating - Speed

The speed at which an induction motor operates is dependent upon the input power frequency and the number of electrical magnetic poles for which the motor is wound. The higher the frequency, the faster the motor runs. The more poles the motor has, the slower it runs. The speed of the rotating magnetic field in the stator is called synchronous speed. To determine the synchronous speed of an induction motor, the following equation is used:

Synchronous Speed (rpm) = (60 x 2 x Frequency) / (Number of Poles) … (2.6)

Actual full-load speed (the speed at which an induction motor will operate at nameplate rated load) will be less than synchronous speed. The difference between synchronous speed and full-load speed is called slip. Percent slip is defined as follows:

Percent Slip = ((Synchronous Speed - Full Load Speed) / Synchronous Speed) x 100 … (2.7)

Induction motors are built having rated slip ranging from less than 5% to as much as 20%. A motor with a slip of less than 5% is called a normal slip motor. Motors with a slip of 5% or more are used for applications requiring high starting torque (conveyor) and/or higher than normal slip (punch press) where, as the motor slows down, increased torque allows for flywheel energy release.

E- Torque & Horsepower

Torque and horsepower are two keys motor characteristics that determine the size of motor for an application. Torque is merely a turning effort or force acting through a radius and horsepower is a measure of the rate at which work is done. By definition, the relationship between torque and horsepower is as follows:

$$P(w) = (2 \times \pi \times rpm \times T) / 60 \quad \ldots (2.8)$$

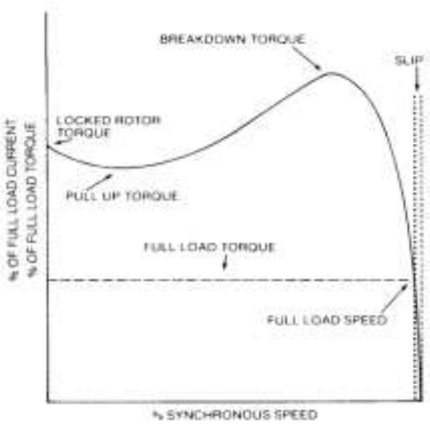


Figure 2.20 : Typical speed torque curve for NEMA design B induction motor [G.E Industry. (1999)]

The figure 2.20 illustrates a typical speed torque curve for a NEMA design B induction motor. An understanding of several points on this curve will aid in properly applying motors.

i. Locked-rotor torque

Locked-rotor torque is the torque which the motor will develop at rest (for all angular positions of the rotor) with rated voltage at rated frequency applied. It is also sometimes known as starting torque and is usually expressed as a percentage of full-load torque.

ii. Pull-up Torque

Pull-up torque is the minimum torque developed during the period of acceleration from locked-rotor to the speed at which breakdown torque occurs. For motors which do not have a definite breakdown torque (such as NEMA design D) pull-up torque is the minimum torque developed up to rated full-load speed. It is usually expressed as a percentage of full-load torque.

iii. Breakdown torque

Breakdown torque is the maximum torque the motor will develop with rated voltage applied at rated frequency without an abrupt drop in speed. Breakdown torque is usually expressed as a percentage of full-load torque.[G.E Industry, 1999]

iv. Full-load torque

Full-load torque is the torque necessary to produce rated horsepower at full-load speed.

F- Motor current

In addition to the relationship between speed and torque, the relationship of motor current to these two values is an important application consideration. The speed/torque curve is repeated in figure 2.21 with the current curve added to demonstrate a typical relationship.

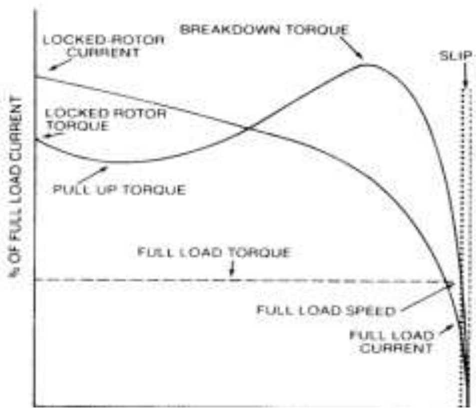


Figure2.21 :Motor torque status curve [G.E Industry. (1999)]

Two important points on this current curve need to be examined:

i. Full-load current

The full-load current of an induction motor is the steady-state current taken from the power line when the motor is operating at full-load torque with rated voltage and rated frequency applied.

ii. Locked-rotor current

Locked-rotor current is the steady-state current of a motor with the rotor locked and with rated voltage applied at rated frequency. NEMA has designated a set of code letters to define locked-rotor kilovolt-amperes-per-horsepower. This code letter appears on the nameplate of all AC squirrel-cage induction motors. KVA per horsepower is calculated as follows:

For three-phase motors:

KVA = ($\sqrt{3}$ x current (in amperes) x volts) / 1000 x Hp … (2.9)

For single-phase motors:

KVA = current (in amperes) x volts) / 1000 x Hp … (2.10)

2.6Electric System

2.6.1Three-phase A.C.

A three-phase voltage is generated in exactly the same way as a single-phase A.C. voltage. For a three-phase voltage three separate windings, each separated by 120°, are rotated in a magnetic field. The generated voltage will be three identical sinusoidal waveforms each separated by 120°

2.6.2 Star and delta connections

The three phase windings may be star connected or delta. The square root of 3 is simply a constant for three-phase circuits, and has a value of 1.732. The delta connection is used for electrical power transmission because only three conductors are required. Delta connection is also used to connect the windings of most three-phase motors because the phase windings are perfectly balanced and, therefore, do not require a neutral connection.

Making a star connection has the advantage that two voltages become available – a line voltage between any two phases, and a phase voltage between line and neutral which is connected to the star point. In any star-connected system currents flow along the lines (IL), through the load and return by the neutral conductor connected to the star point. In a balanced three-phase system all currents have the same value and when they are added up by phase or addition, we find the resultant current is zero. Therefore, no current flows in the neutral and the star point is at zero volts. The star point of the distribution transformer is earthed because earth is also at zero potential. A star-connected system is also called a three-phase four-wire system and allows us to connect single-phase loads to a three-phase system.[Linsley, T, 2005]

2.6.3Three-phase power

In any balanced three-phase system, the total power is equal to three times the power in any one phase.

Three phase power = 3 V_P I_P cosØ … (2.11)

But in star connection $V_P = \frac{Vl}{\sqrt{3}}$ … (2.12)

And in delta connection $I_P = \frac{Il}{\sqrt{3}}$ … (2.13)

So three phase power = $\sqrt{3}Vl.Ilcos\emptyset$ … (2.14)

2.6.4 Power-factor correction

Most electrical installations have a low power factor because loads such as motors, transformers and discharge lighting circuits are inductive in nature and cause the current to lag behind the voltage. A capacitor has the opposite effect to an inductor, causing the current to lead the voltage. Therefore, by adding capacitance to an inductive circuit the bad power factor can be corrected. The load current IL is made up of an in-phase component I and a quadrature component IQ. The power factor can be corrected to unity when the capacitor current IC is equal and opposite to the quadrature or reactive current IQ of the inductive load. The quadrature or reactive current is responsible for setting up the magnetic field in an inductive circuit. To achieve a unity, that is when IQ IC. A low power factor is considered a disadvantage because a given load takes more current at a low power factor than it does at a high power factor.

2.6.5 Transformers

A transformer is an electrical machine which is used to change the value of an alternating voltage. They vary in size from miniature units used in electronics to huge power transformers used in power stations. A transformer will only work when an alternating voltage is connected. It will not normally work from a D.C. supply such as a battery. A transformer, consists of two coils, called the primary and secondary coils, or windings, which are insulated from each other and wound onto the same steel or iron core. An alternating voltage applied to the primary winding produces an alternating current, which sets up an alternating magnetic flux throughout the core. This magnetic flux induces an emf in the secondary winding, as described by Faraday's law, which says that when a conductor is cut by a magnetic field, an emf is induced in that conductor. Since both windings are linked by the same magnetic flux, the induced emf per turn will be the same for both windings. Therefore, the emf in both windings is proportional to the number of turns. In symbols. Most practical power transformers have a very high efficiency, and for an ideal transformer having 100% efficiency the primary power is equal to the secondary power.

$$\frac{Vp}{Vs} = \frac{IS}{Ip} = \frac{Np}{Ns} \ \ldots (2.15)$$

Where (V-Volt, I-current and N-number of coil turns)

2.5.5.1 Transformer losses

As they have no moving parts causing frictional losses, most transformers have a very high efficiency, usually better than 90%. However, the losses which do occur in a transformer can be grouped under two general headings: copper losses and iron losses. Copper losses occur because of the small internal resistance of the windings. They are proportional to the load, increasing as the load increases because copper loss in I^2R . Iron losses are made up of hysteresis loss and eddy current loss.

2.6.5.2 Transformer efficiency

The efficiency of any machine is determined by the losses incurred by the machine in normal operation. The efficiency of rotating machines is usually in the region of 50–60% because they incur windage and friction losses; but the transformer has no moving parts so, therefore, these losses do not occur. However, the efficiency of a transformer can be calculated in the same way as for any other machine. The efficiency of a machine is generally given by:

$$\mu = \frac{outputpower}{inputpower} \ \ldots (2.16)$$

Input power = Output power + Losses … (2.17)

2.6.6 Electricity supply system

The Generation of electricity in most modern power stations is at 25kV, and this voltage is then transformed to 400kV for transmission. Virtually all the generators of electricity throughout the world are three-phase synchronous generators. The generator consists of a prime mover and a magnetic field exciter. The magnetic field is produced electrically by passing a direct current through a winding on an iron core, which rotates inside three phase windings on the stator of the machine. The magnetic field is rotated by means of a prime mover which may be a steam turbine, water turbine or gas turbine. The generators in modern power stations are rated between 500 and 1000MW. A 2000MW station might contain four 500MW sets, three 660MW sets and a 20MW gas turbine generator or two 1000MW sets. Having a number of generator sets in a single power station provides the flexibility required for seasonal variations in the load and for maintenance of equipment. When generators are connected to a single system they must rotate at exactly the same speed, hence the term synchronous generator. Very high voltages are used for transmission systems because, as a general principle, the higher the voltage the cheaper is the supply. Since power in an A.C. system is expressed as $P=VI\cos\theta$ it follows that an increase in voltage will reduce the current for a given amount of power. A lower current will result in reduced cable and switchgear size and the line power losses, given by the equation $P=IR^2$, will also be reduced. The 132kV grid and 400kV Super grid transmission lines are, for the most part, steel-cored aluminum conductors suspended on steel lattice towers, since this is about 16 times cheaper than the equivalent underground cable. The conductors are attached to porcelain insulator strings which are fixed to the cross-members of the tower Three conductors comprise a single circuit of a three-phase system so that towers with six arms carry two separate circuits Primary distribution to consumers is from 11kV substations, which for the most part are fed from 33kV substations, but direct transformation between 132 and 11kV is becoming common policy in city areas where over 100MW can be economically distribute at 11kV from one site. Distribution systems at 11kV may be ring or radial systems but a ring system offers a greater security of supply. The maintenance of a secure supply is an important consideration for any electrical engineer or supply authority because electricity plays a vital part in an industrial society, and a loss of supply may cause inconvenience, financial loss or danger to the consumer or the public. The principle employed with a ring system is that any consumer’s substation is fed from two directions, and by carefully grading the overload and cable protection equipment a fault can be disconnected without loss of supply to other consumers. High-voltage distribution to primary substations is used by the electricity boards to supply small industrial, commercial and domestic consumers. This distribution method is also suitable for large industrial consumers where 11kV substation. Regulation 9 of the Electricity Supply Regulations and Regulation 31 of the Factories Act require that these substations be protected by 2.44m high fences or enclosed in some other way so that no unauthorized person may gain access to the potentially dangerous equipment required for 11kV distribution. In towns and cities the substation equipment is usually enclosed in a brick building. The final connections to plant, distribution boards, commercial or domestic loads are usually by simple underground radial feeders at 400V/230V. These outgoing circuits are usually protected by circuit breakers in a distribution board. The 400V/230V is derived from the 11kV/400V substation transformer by connecting the secondary winding in star The star point is earthed to an earth electrode sunk into the ground below the substation, and from this point is taken the fourth conductor, the neutral. Loads connected between phases are fed at 400V, and those fed between one phase and neutral at 230V. A three-phase 400V supply is used for supplying small industrial and commercial loads such as garages, schools and blocks of flats. A single-phase 230V supply is usually provided for individual domestic consumers.

2.6.7 Balancing three-phase loads

A three-phase load such as a motor has equally balanced phases since the resistance of each phase winding will be the same. Therefore the current taken by each phase will be equal. When connecting single-phase loads to a three phase supply, care should be taken to distribute the single-phase loads equally across the three phases so that each phase carries approximately the same current. Equally distributing the single-phase loads across the three-phase supply is known as 'balancing' the load. A lighting load of 18 luminaries would be 'balanced' if six luminaries were connected to each of the three phases.

2.6.8 Advantages of a three-phase four-wire supply

A three-phase four-wire supply gives a consumer the choice of a 400V three-phase supply and a 230V single-phase supply. Many industrial loads such as motors require a three-phase 400V supply, while the lighting load in a factory, as in a house, will be 230V. Industrial loads usually demand more power than a domestic load, and more power can be supplied by a 400V three-phase supply than is possible with a 230V single-phase supply for a given size of cable since

$$\text{power} = VI \cos\theta \text{ (watts)} \ldots (2.18)$$

2.6.9 Low-voltage supply systems

The voltages used previously in low-voltage supply systems of 415 and 240V have become 400V for three-phase supplies and 230V for single-phase supplies. The Electricity Supply Regulations 1988 have also been amended to permit a range of variation from the new declared nominal voltage. From January 1995 the permitted tolerance is the nominal voltage +10% or -6%. Previously it was (+ or -)6%. This gives a voltage range of 216–253V for a nominal voltage of 230V and 376V to 440V for a nominal voltage of 400V. The next change comes in 2005 when the tolerance levels will be adjusted to (+ or -) 10% of the declared nominal voltage. Most countries will adjust their voltages to comply with a nominal voltage of 230V single-phase and 400V three-phase. The low-voltage supply to a domestic, commercial or small industrial consumer's installation is usually protected at the incoming service cable position with a 100A high breaking capacity (HBC) fuse. Other items of equipment at this position are the energy meter and the consumer's distribution unit, providing the protection for the final circuits and the earthing arrangements for the installation. Five systems are described in the definitions but only the TN-S, TN-C-S and TT systems are suitable for public supplies. A system consists of an electrical installation connected to a supply. Systems are classified by a capital letter designation.

2.6.10 The installation earthing

Arrangements are indicated in this paragraph, where T means the exposed conductive parts are connected directly to earth and N means the exposed conductive parts are connected directly to the earthed point of the source of the electrical supply.

The earthed supply conductor

Arrangements are indicated in this paragraph, where S means a separate neutral and protective conductor and C means that the neutral and protective conductors are combined in a single conductor.

2.6.10.1 TN-S System

This is one of the commonest types of supply system to be found in the UK where the electricity companies' supply is provided by underground cables. The neutral and protective conductor are separate throughout the system. The protective earth conductor (PE) is the metal sheath of the underground cable, and this is connected to the consumer's main earthing terminal. All exposed conductive parts of the installation, gas pipes, water pipes and any lightning protective system are connected to the protective conductor via the main earthing terminal of the installation.

2.6.10.2 TN-C-S System

This type of underground supply is becoming increasingly popular to supply new installations in the UK. It is more commonly referred to as protective multiple earthing (PME). The supply cable uses a combined protective earth and neutral conductor (PEN conductor). At the supply intake point a consumer's main earthing terminal is formed by connecting the earthing terminal to the neutral conductor. All exposed conductive parts of the installation, gas pipes, water pipes and any lightning protective system are then connected to the main earthing terminals. Thus phase to earth faults are effectively converted into phase to neutral faults.

2.6.10.3 TT System

This is the type of supply more often found when the installation is fed from overhead cables. The supply authorities do not provide an earth terminal and the installation's circuit protective conductors must be connected to earth via an earth electrode provided by the consumer. An effective earth connection is some- times difficult to obtain and in most cases a residual current device is provided when this type of supply is used.

2.6.10.4 TN-C System

The supply cable and the consumer's installation use a PEN conductor. All exposed conductive parts of an installation are connected to the PEN conductor. The applications of this supply system are limited to privately owned generating plants or transformers.

2.6.10.5 IT System

The supply is isolated from earth and therefore there is no shock or fire risk involved when an earth fault occurs. Protection is afforded by monitoring equipment which gives an audible warning if a fault occurs. This type of supply is used in mines, quarries and chemical processes where interruption of the process may create a hazardous situation. The system must not be connected to a public supply

2.6.11 Low-voltage distribution in building

In domestic installations the final circuits for lights, sockets, cookers, immersion heating, etc. are connected to separate fuse ways in the consumer's unit mounted at the service position In commercial or industrial installations a three phase 400V supply must be distributed to appropriate equipment in addition to supplying single-phase 230V loads such as lighting. It is now common practice to establish industrial estates speculatively, with the intention of encouraging local industry to use individual units. This presents the electrical contractor with an additional problem. The use and electrical demand of a single industrial unit are often unknown and the electrical supply equipment will need to be flexible in order to meet a changing demand due to expansion or change of use. Bus bar chambers incorporated into cubicle switchboards or on-site assemblies of switchboards are to be found at the incoming service position of commercial and industrial consumers, since this has proved to provide the flexibility required by these consumers. Distribution fuse boards, which may incorporate circuit breakers, are wired by sub main cables from the service position to load centers in other parts of the building, thereby keeping the length of cable to the final circuit as short as possible. When high-rise buildings such as multi-storey flats have to be wired, it is usual to provide a three-phase four-wire rising main. This may comprise vertical bus bars running from top to bottom at some central point in the building. Each floor or individual flat is then connected to the bus bar to provide the consumer's supply. When individual dwellings receive a single-phase supply the electrical contractor must balance the load across the three phases.

2.6.12 Cables

Most cables can be considered to be constructed in three parts: the conductor which must be of a suitable cross-section to carry the load current; the insulation, which has a color or number code for identification, and the outer sheath which may contain some means of providing protection from mechanical damage. The conductors of a cable are made of either copper or aluminum and may be stranded or solid. Solid conductors are only used in fixed wiring installations and may be shaped in larger cables. Stranded conductors are more flexible and conductor sizes from 4.0mm² to 25mm² contain seven strands. A 10mm² conductor, for example, has seven 1.35mm diameter strands which collectively make up the 10mm² cross sectional area of the cable. Conductors above 25mm² have more than seven strands, depending upon the size of the cable. Flexible cords have multiple strands of very fine wire, as fine as one strand of human hair. This gives the cable its very flexible quality.

2.6.12.1 Existing fixed cable core colors

Single phase – red phase conductors, black neutral conductors and green combined with yellow for earth conductors. **Three phase** – red, yellow and blue phase conductors, black neutral conductors and green combined with yellow for earth conductors.

2.6.12.2 PVC Insulated and sheathed cables

Domestic and commercial installations use this cable, which may be clipped direct to a surface, sunk in plaster or installed in conduit or trunking. It is the simplest and least expensive cable. The conductors are covered with a color coded PVC insulation and then contained singly or with others in a PVC outer sheath.

2.6.12.3 PVC/SWA cable

PVC insulated steel wire armor cables are used for wiring underground between buildings, for main supplies to dwellings, rising sub mains and industrial installations. They are used where some mechanical protection of the cable conductors is required. The conductors are covered with color-coded PVC insulation and then contained either singly or with others in a PVC sheath. Around this sheath is placed an armor protection of steel wires twisted along the length of the cable, and a final PVC sheath covering the steel wires protects them from corrosion. The armor sheath also provides the circuit protective conductor (CPC) and the cable is simply terminated using a compression gland.

2.6.12.4 High-voltage power cables

The cables used for high-voltage power distribution require termination and installation expertise beyond the normal experience of a contracting electrician. The regulations covering high-voltage distribution are beyond the scope of the IEE Regulations for electrical installations. Operating at voltages in excess of 33kV and delivering thousands of kilowatts, these cables are either suspended out of reach on pylons or buried in the ground in carefully constructed trenches.

2.6.12.5 High-voltage over head cables

Suspended from cable towers or pylons, overhead cables must be light, flexible and strong. The cable is constructed of stranded aluminum conductors formed around a core of steel stranded conductors. The aluminum conductors carry the current and the steel core provides the tensile strength required to suspend the cable between pylons. The cable is not insulated since it is placed out of reach and insulation would only add to the weight of the cable.

2.6.13 lightning protection – Definitions

Lightning protective system – The whole system of conductors used to protect a structure from the effects of lightning.

Air termination or Air termination network – The part of a lightning protective system intended to intercept lightning discharges.

Down conductor – A conductor that connects an air termination to the earth termination.

Earth termination – That part of a lightning protective system that is intended to discharge lightning currents into the general mass of earth. (These consist of all parts below the lowest testing point in a down conductor.)

Earth electrode – That part of the earth terminal that makes direct electrical contact with the earth.

Bond – A conductor intended to provide electrical connection between the lightning protective system and other metalwork.

Joint – A mechanical and electrical junction between two or more portions of the lightning protective system.

Testing joint – A joint designed and situated so as to enable resistance or continuity measurements to be made. [Linsley, T, 2005]

2.6.14 Over-current protection

The consumer's mains equipment must provide protection against over current; that is, a current exceeding the rated value (Regulation 431–01–01). Fuses provide over current protection when situated in the live conductors; they must not be connected in the neutral conductor. Circuit breakers may be used in place of fuses, in which case the circuit breaker may also provide the means of isolation, although a further means of isolation is usually provided so that maintenance can be carried out on the circuit breakers themselves. Over current can be subdivided into overload current, and short-circuit current. An overload current can be defined as a current which exceeds the rated value in an otherwise healthy circuit. Overload currents usually occur because the circuit is abused or because it has been badly designed or modified. A short circuit is an over current resulting from a fault of negligible impedance connected between conductors. Short circuits usually occur as a result of an accident which could not have been predicted before the event. An overload may result in currents of two or three times the rated current flowing in the circuit. Short circuit currents may be hundreds of times greater than the rated current. In both cases the basic requirements for protection are that the fault currents should be interrupted quickly and the circuit isolated safely before the fault current causes a temperature rise which might damage the insulation and terminations of the circuit conductors. The selected protective device should have a current rating which is not less than the full load current of the circuit but which does not exceed the cable current rating. The cable is then fully protected against both overload and short-circuit faults

2.6.15 Cable selection/calculation

The size of a cable to be used for an installation depends upon the current rating of the cable under defined installation conditions and the maximum permitted drop in voltage. The factors which influence the current rating are:

The design current – the cable must carry the full load current. The type of cable – PVC, MICC, copper conductors or aluminum conductors. The installed conditions – clipped to a surface or installed with other cables in a trunking. The surrounding temperature – cable resistance increases as temperature increases and insulation may melt if the temperature is too high. The type of protection – for how long will the cable have to carry a fault current? the drop in voltage from the supply terminals to the fixed current-using equipment must not exceed 4% of the mains voltage. That is, a maximum of 9.2V on a 230V installation. The volt drop for a particular cable may be found from

V_D = Factor X Design current X Length of run … (2.19)

The cable rating, denoted It, may be determined as follows:

$$I_t = \frac{Currentratingofprotectivedevice}{anyapplicablecorrectionfactor} \quad \ldots (2.20)$$

The correction factors which may need applying are given below as:

C_a: The ambient or surrounding temperature correction factor.

C_g: The grouping correction factor.

C_r: The 0.725 correction factor to be applied when semi-enclosed fuses protect the circuit

C_i: The correction factor to be used when cables are enclosed in thermal insulation.

Having calculated the cable rating, the smallest cable should be chosen from the appropriate table which will carry that current. This cable must also meet the voltage drop Regulation 525–01 and this should be calculated as described earlier. When the calculated value is less than 4% of the mains voltage the cable may be considered suitable. If the calculated value is greater than the 4% value, the next larger cable size must be tested until a cable is found which meets both the current rating and voltage drop criteria.

CHAPTER THREE

The Control System Components

CHAPTER THREE

The Control System Components

3.1 Introduction

Control engineering has evolved over time. In the past humans were the main method for controlling a system. More recently electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It was common to use relays to make simple logical control decisions. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls. PLCs have been gaining popularity on the factory floor and will probably remain predominant for some time to come. Most of this is because of the advantages they offer such as:

- Cost effective for controlling complex systems.
- Flexible and can be reapplied to control other systems quickly and easily.
- Computational abilities allow more sophisticated control.
- Trouble shooting aids make programming easier and reduce downtime.
- Reliable components make these likely to operate for years before failure.

3.2 PLC Hardware

Many PLC configurations are available, even from a single vendor. But, in each of these there are common components and concepts. The most essential components are:

- **Power Supply** - This can be built into the PLC or be an external unit. Common voltage levels required by the PLC (with and without the power supply) are 24Vdc, 120Vac, 220Vac.
- **CPU (Central Processing Unit)** - This is a computer where ladder logic is stored and processed.
- **I/O (Input/Output)** - A number of input/output terminals must be provided so that the PLC can monitor the process and initiate actions.
- **Indicator lights** - These indicate the status of the PLC including power on, program running, and a fault. These are essential when diagnosing problems.

3.2.1 Inputs and outputs

Inputs to, and outputs from, a PLC are necessary to monitor and control a process. Both inputs and outputs can be categorized into two basic types: logical or continuous. Consider the example of a light bulb. If it can only be turned on or off, it is logical control. If the light can be dimmed to different levels, it is continuous. Continuous values seem more intuitive, but logical values are preferred because they allow more certainty, and simplify control. As a result most controls applications (and PLCs) use logical inputs and outputs for most applications. Hence, we will discuss logical I/O.

Outputs to actuators allow a PLC to cause something to happen in a process. A short list of popular actuators is given below in order of relative popularity.

Solenoid Valves - logical outputs that can switch a hydraulic or pneumatic flow.

Lights - logical outputs that can often be powered directly from PLC output boards.

Motor Starters - motors often draw a large amount of current when started, so they require motor starters, which are basically large relays.

Servo Motors - a continuous output from the PLC can command a variable speed or position.

Outputs from PLCs are often relays, but they can also be solid state electronics such as transistors for DC outputs or Triacs for AC outputs. Continuous outputs require special output cards with digital to analog converters.

Inputs come from sensors that translate physical phenomena into electrical signals. Typical examples of sensors are listed below in relative order of popularity.

Proximity Switches - use inductance, capacitance or light to detect an object logically.

Switches- mechanical mechanisms will open or close electrical contacts for a logical signal.

Potentiometer- measures angular positions continuously, using resistance.

LVDT (linear variable differential transformer)- measures linear displacement continuously using magnetic coupling.

Inputs for a PLC come in a few basic varieties, the simplest are AC and DC inputs. Sourcing and sinking inputs are also popular. This output method dictates that a device does not supply any power. Instead, the device only switches current on or off, like a simple switch.

Sinking - When active the output allows current to flow to a common ground. This is best selected when different voltages are supplied.

Sourcing - When active, current flows from a supply, through the output device and to ground. This method is best used when all devices use a single supply voltage.[Jack, H, 2003]

3.2.2 Inputs modules

In smaller PLCs the inputs are normally built in and are specified when purchasing the PLC. For larger PLCs the inputs are purchased as modules, or cards, with 8 or 16 inputs of the same type on each card. For discussion purposes we will discuss all inputs as if they have been purchased as cards. The list below shows typical ranges for input voltages, and is roughly in order of popularity.

- 12-24 Vdc
- 100-120 Vac
- 10-60 Vdc
- 12-24 Vac/dc
- 5 Vdc (TTL)
- 200-240 Vac

- 48 Vdc
- 24 Vac

PLC input cards rarely supply power, this means that an external power supply is needed to supply power for the inputs and sensors. inputs are normally high impedance. This means that they will use very little current. PLC inputs must convert a variety of logic levels to the 5Vdc logic levels used on the data bus.

There are many trade-offs when deciding which type of input cards to use.

- DC voltages are usually lower, and therefore safer (i.e., 12-24V).
- DC inputs are very fast, AC inputs require a longer on-time. For example, a 60Hz wave may require up to 1/60sec for reasonable recognition.
- DC voltages can be connected to larger variety of electrical systems.
- AC signals are more immune to noise than DC, so they are suited to long distances, and noisy (magnetic) environments.
- AC power is easier and less expensive to supply to equipment.
- AC signals are very common in many existing automation devices.

3.2.3 Output Modules

As with input modules, output modules rarely supply any power, but instead act as switches. External power supplies are connected to the output card and the card will switch the power on or off for each output. Typical output voltages are listed below, and roughly ordered by popularity.

- 120 Vac
- 24 Vdc
- 12-48 Vac
- 12-48 Vdc
- 5Vdc (TTL)
- 230 Vac

These cards typically have 8 to 16 outputs of the same type and can be purchased with different current ratings. A common choice when purchasing output cards is relays, transistors or triacs. Relays are the most flexible output devices. They are capable of switching both AC and DC outputs. But, they are slower (about 10ms switching is typical), they are bulkier, they cost more, and they will wear out after millions of cycles. Relay outputs are often called dry contacts. Transistors are limited to DC outputs, and triacs are limited to AC outputs. Transistor and triac outputs are called switched outputs. PLC outputs must convert the 5Vdc logic levels on the PLC data bus to external voltage levels.

Dry contacts - a separate relay is dedicated to each output. This allows mixed voltages (AC or DC and voltage levels up to the maximum), as well as isolated outputs to protect other outputs and the PLC. Response times are often greater than 10ms. This method is the least sensitive to voltage variations and spikes.

Switched outputs - a voltage is supplied to the PLC card, and the card switches it to different outputs using solid state circuitry (transistors, triacs, etc.) triacs are well suited to AC devices requiring less than 1A. Transistor outputs use NPN or PNP transistors up to 1A typically. Their response time is well under 1ms.

3.2.4 Relays

Although relays are rarely used for control logic, they are still essential for switching large power loads. Some important terminology for relays is given below.

Contactor - Special relays for switching large current loads.

Motor Starter - Basically a contactor in series with an overload relay to cut off when too much current is drawn.

Arc Suppression - when any relay is opened or closed an arc will jump. This becomes a major problem with large relays. On relays switching AC this problem can be overcome by opening the relay when the voltage goes to zero (while crossing between negative and positive). When switching DC loads this problem can be minimized by blowing pressurized gas across during opening to suppress the arc formation.

AC coils - If a normal relay coil is driven by AC power the contacts will vibrate open and closed at the frequency of the AC power. This problem is overcome by adding a shading pole to the relay.

The most important consideration when selecting relays, or relay outputs on a PLC, is the rated current and voltage. If the rated voltage is exceeded, the contacts will wear out prematurely, or if the voltage is too high fire is possible. The rated current is the maximum current that should be used. When this is exceeded the device will become too hot, and it will fail sooner. The rated values are typically given for both AC and DC, although DC ratings are lower than AC. If the actual loads used are below the rated values the relays should work well indefinitely. If the values are exceeded a small amount the life of the relay will be shortened accordingly. Exceeding the values significantly may lead to immediate failure and permanent damage.

3.2.5 Logical sensors

Sensors allow a PLC to detect the state of a process. Logical sensors can only detect a state that is either true or false. Examples of physical phenomena that are typically detected are listed below.

- inductive proximity - is a metal object nearby?
- capacitive proximity - is a dielectric object nearby?
- optical presence - is an object breaking a light beam or reflecting light?
- mechanical contact - is an object touching a switch?

When a sensor detects a logical change it must signal that change to the PLC. This is typically done by switching a voltage or current on or off. In some cases the output of the sensor is used to switch a load directly, completely eliminating the PLC. Typical outputs from sensors (and inputs to PLCs) are listed below in relative popularity.

Sinking/Sourcing - Switches current on or off.

Plain Switches - Switches voltage on or off.

Solid State Relays - These switch AC outputs.

TTL (Transistor Transistor Logic) - Uses 0V and 5V to indicate logic levels.

3.2.5.1 Presence detection

There are two basic ways to detect object presence; contact and proximity. Contact implies that there is mechanical contact and a resulting force between the sensor and the object. Proximity indicates that the object is near, but contact is not required. The following sections examine different types of sensors for detecting object presence. These sensors account for a majority of the sensors used in applications.

Contact Switches

Contact switches are available as normally open and normally closed. Their housings are reinforced so that they can take repeated mechanical forces.

Reed Switches

Reed switches are very similar to relays, except a permanent magnet is used instead of a wire coil. When the magnet is far away the switch is open, but when the magnet is brought near the switch is closed.

Optical (Photoelectric) Sensors

Light sensors have been used for almost a century - originally photocells were used for applications such as reading audio tracks on motion pictures. But modern optical sensors are much more sophisticated.

Optical sensors require both a light source (emitter) and detector. Emitters will produce light beams in the visible and invisible spectrums using LEDs and laser diodes. Detectors are typically built with photodiodes or phototransistors. The emitter and detector are positioned so that an object will block or reflect a beam when present.

3.2.5.2 Capacitive Sensors

Capacitive sensors are able to detect most materials at distances up to a few centimeters. Recall the basic relationship for capacitance. In the sensor the area of the plates and distance between them is fixed. But, the dielectric constant of the space around them will vary as different materials are brought near the sensor. an oscillating field is used to determine the capacitance of the plates. When this changes beyond a selected sensitivity the sensor output is activated. For this sensor the proximity of any material near the electrodes will increase the capacitance. This will vary the magnitude of the oscillating signal and the detector will decide when this is great enough to determine proximity. These sensors work well for insulators (such as plastics) that tend to have high dielectric coefficients, thus increasing the capacitance. But, they also work well for metals because the conductive materials in the target appear as larger electrodes, thus increasing the capacitance. In total the capacitance changes are normally in the order of pF.The range and accuracy of these sensors are determined mainly by their size. Larger sensors can have diameters of a few centimeters. Smaller ones can be less than a centimeter across, and have smaller ranges, but more accuracy.

3.2.5.3 Inductive Sensors

Inductive sensors use currents induced by magnetic fields to detect nearby metal objects. The inductive sensor uses a coil (an inductor) to generate a high frequency magnetic field. If there is a metal object near the changing magnetic field, current will flow in the object. This resulting current flow sets up a new magnetic field that opposes the original magnetic field. The net effect is that it changes the inductance of the coil in the inductive sensor. By measuring the inductance the sensor can determine when a metal have been brought nearby. These sensors will detect any metals, when detecting multiple types of metal multiple sensors are often used. these work by setting up a high frequency field. If a target nears the field will induce eddy currents. These currents consume power because of resistance, so energy is in the field is lost, and the signal amplitude decreases. The detector examines filed magnitude to determine when it has decreased enough to switch. The sensors can detect objects a few centimeters away from the end. But, the direction to the object can be arbitrary. The magnetic field of the unshielded sensor covers a larger volume around the head of the coil. By adding a shield (a metal jacket around the sides of the coil) the magnetic field becomes smaller, but also more directed. Shields will often be available for inductive sensors to improve their directionality and accuracy.

3.2.5.4 Ultrasonic

An ultrasonic sensor emits a sound above the normal hearing threshold of 16KHz. The time that is required for the sound to travel to the target and reflect back is proportional to the distance to the target. The two common types of sensors are;

- electrostatic - uses capacitive effects. It has longer ranges and wider bandwidth, but is more sensitive to factors such as humidity.
- piezoelectric - based on charge displacement during strain in crystal lattices. These are rugged and inexpensive.

These sensors can be very effective for applications such as fluid levels in tanks and crude distance measurement.

3.2.5.5 Hall Effect

Hall effect switches are basically transistors that can be switched by magnetic fields. Their applications are very similar to reed switches, but because they are solid state they tend to be more rugged and resist vibration. Automated machines often use these to do initial calibration and detect end stops.

3.2.5.6 Solenoids

Solenoids are the most common actuator components. The basic principle of operation is there is a moving ferrous core (a piston) that will move inside wire coil. Normally the piston is held outside the coil by a spring. When a voltage is applied to the coil and current flows, the coil builds up a magnetic field that attracts the piston and pulls it into the center of the coil. The piston can be used to supply a linear force. Well known applications of these include pneumatic values and car door openers. As mentioned before, inductive devices can create voltage spikes and may need snubbers, although most industrial applications have low enough voltage and current ratings they can be connected directly to the PLC outputs. Most industrial solenoids will be powered by 24Vdc and draw a few hundred mA.

3.3 Programming languages

As PLCs have developed and expanded, programming languages have developed with them. Programming languages allow the user to enter a control program into a PLC using an established syntax. Today's advanced languages have new, more versatile instructions, which initiate control program actions. These new instructions provide more computing power for single operations performed by the instruction itself. For instance, PLCs can now transfer blocks of data from one memory location to another while, at the same time, performing a logic or arithmetic operation on another block. As a result of these new, expanded instructions, control programs can now handle data more easily. In addition to new programming instructions, the development of powerful I/O modules has also changed existing instructions. These changes include the ability to send data to and obtain data from modules by addressing the modules' locations. For example, PLCs can now read and write data to and from analog modules. All of these advances, in conjunction with projected industry needs, have created a demand for more powerful instructions that allow easier, more compact, function-oriented PLC programs.

3.3.1 Types of PLC languages

The three types of programming languages used in PLCs are:

- Ladder
- Boolean
- Grafcet

The ladder and Boolean languages essentially implement operations in the same way, but they differ in the way their instructions are represented and how they are entered into the PLC. The Grafcet language implements control instructions in a different manner, based on steps and actions in a graphic oriented program

3.3.1.1 Ladder language

The programmable controller was developed for ease of programming using existing relay ladder symbols and expressions to represent the program logic needed to control the machine or process. The resulting programming language, which used these original basic relay ladder symbols, was given the name ladder language. Figure 3.1 illustrates a relay ladder logic circuit and the PLC ladder language representation of the same circuit.

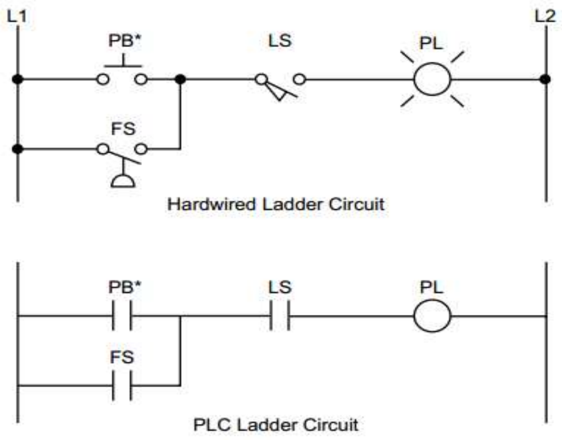


Figure3.1 :relay ladder logic circuit and the PLC ladder language representation of the same circuit [Jack, H. (2003)]

The evolution of the original ladder language has turned ladder programming into a more powerful instruction set. New functions have been added to the basic relay, timing, and counting operations. The term functions used to describe instructions that, as the name implies, perform a function on data — that is, handle and transfer data within the programmable controller. These instructions are still based on the simple principles of basic relay logic, although they allow complex operations to be implemented and performed. New additions to the basic ladder logic also include function blocks, which use a set of instructions to operate on a block of data. The use of function blocks increases the power of the basic ladder language, forming what is known as enhanced ladder language. Figure 3.2 shows enhanced functions driven by basic relay ladder instructions. As shown in the figure, a block or a functional instruction between two contact symbols represents an enhanced functional block.

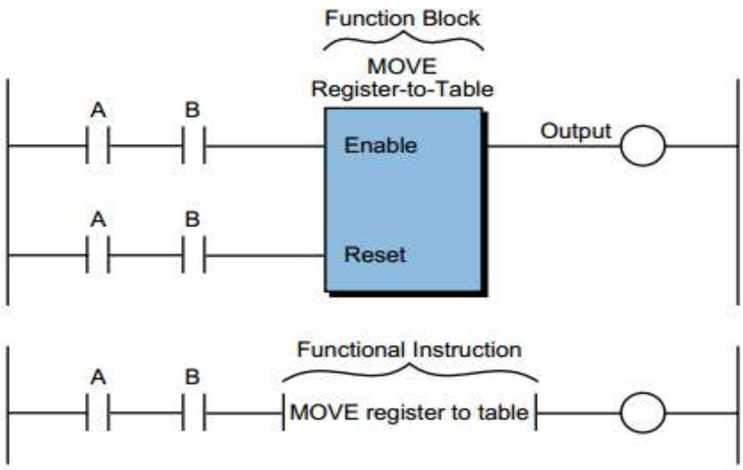


Figure3.2 :enhanced functions driven by basic relay ladder instructions [Jack, H. (2003)]

The format representation of an enhanced ladder function depends on the programmable controller manufacturer; however, regardless of their format, all similar enhanced and basic ladder functions operate the same way.

As indicated earlier, the ladder languages available in PLCs can be divided into two groups:

- basic ladder language
- enhanced ladder language

Each of these groups consists of many PLC instructions that form the language. The classification of which instructions fall into which categories differs among manufacturers and users, since a definite classification does not exist. However, a de facto standard has been created throughout the years that sorts the instructions into either the basic or enhanced ladder language. Basic ladder instructions are referred to as low-level language, while enhanced ladder functions are referred to as high-level language. The line that defines the grouping of PLC ladder instructions, however, is usually drawn between functional instruction categories. These instruction categories include:

- ladder relay
- timing
- counting
- program/flow control
- arithmetic
- data manipulation
- data transfer
- special function (sequencers)
- network communication

Although these categories are straightforward, the classification of them is subjective. For example, some people believe that basic ladder instructions include ladder relay, timing, counting, program/flow control, arithmetic, and some data manipulation. Others believe that only ladder relay, timing, and counting categories should be considered basic ladder instructions. Regardless of classification, the effects of instruction categories are simple—the more instruction categories a PLC has, the more powerful its control capability becomes. Usually, small PLCs have only basic instructions with, perhaps, some enhanced instructions. Larger PLCs usually have more advanced instruction sets. However, recent advances in software development and I/O hardware have increased the computational power of small PLCs through advanced instructions. This new trend has made small PLCs very desirable in single, as well as distributed control, applications.[Jack, H, 2003]

3.3.1.2 Boolean

Some PLC manufacturers use Boolean language, also called Boolean mnemonics, to program a controller. The Boolean language uses Boolean algebra syntax to enter and explain the control logic. That is, it uses the AND, OR, and NOT logic functions to implement the control circuits in the control program. Figure 3.3 shows a basic Boolean program.[Jack, H, 2003]

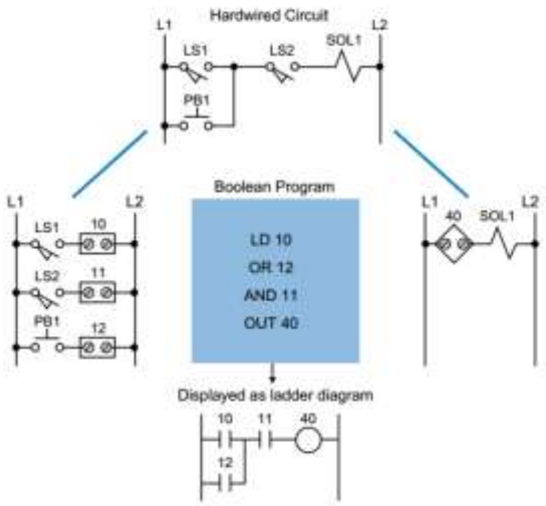


Figure3.3 : basic Boolean program [Jack, H. (2003)]

The Boolean language is primarily just a way of entering the control program into a PLC, rather than an actual instruction-oriented language. When displayed on the programming monitor, the Boolean language is usually viewed as a ladder circuit instead of as the Boolean commands that define the instruction.

3.3.1.3 Grafcet

Grafcet (Graphe Fonctionnel de Command eÉtape Transition) is a symbolic, graphic language, which originated in France, that represents the control program as steps or stages in the machine or process. In fact, the English translation of Grafcet means "step transition function charts." Grafcet is the foundation for the IEC 1131 standard's sequential function charts (SFCs), which allow several PLC languages to be used in one control program. Figure 3.4 illustrates a simple circuit represented in Grafcet. Note that Grafcet charts provide a flowchart-like representation of the events that take place in each stage of the control program. These charts use three components—steps, transitions, and actions—to represent events. The IEC 1131 standard's SFCs also use these components; however, the instructions inside the actions can be programmed using one or more possible languages, including ladder diagrams.[Jack, H, 2003]

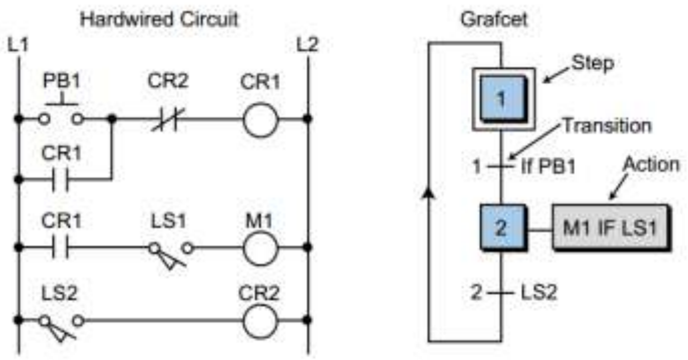


Figure3.4 :illustrates a simple circuit represented in Grafcet [Jack, H. (2003)]

3.3.2 Ladder diagram format

The ladder diagram language is a symbolic instruction set that is used to create PLC programs. The ladder instruction symbols can be formatted to obtain the desired control logic, which is then entered into memory. Since this type of instruction set consists of contact symbols, it is also referred to as contact symbology. A thorough understanding of ladder diagram programming, including functional blocks, is extremely beneficial, even when using a PLC with IEC 1131 programming language capabilities. Because ladder diagrams are easy to use and implement, they provide a powerful programming tool when used in the IEC 1131 environment. The main functions of a ladder diagram program are to control outputs and perform functional operations based on input conditions. Ladder diagrams use rungs to accomplish this control. Figure 3.5 shows the basic structure of a ladder rung. In general, a rung consists of a set of input conditions (represented by contact instructions) and an output instruction at the end of the rung (represented by a coil symbol). The contact instructions for a rung may be referred to as input conditions, rung conditions, or the control logic.

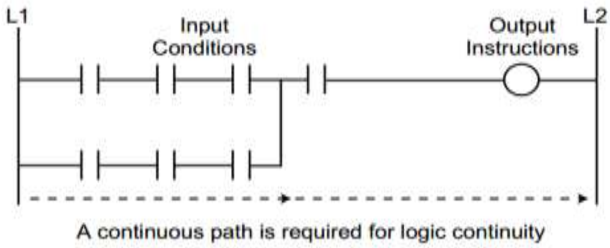


Figure3.5 :basic structure of a ladder rung [Jack, H. (2003)]

A ladder rung is TRUE (i.e., energizing an output or functional instruction block) when it has logic continuity. Logic continuity exists when power flows through the rung from left to right. The execution of logic events that enable the output provide this continuity. In a ladder rung, the left-most side (left power line) simulates the L1 line of a relay ladder diagram, while the right-most side (right power line) simulates the L2 line of the electromechanical representation. Continuity occurs when a path between these two lines contains contact elements in a closed condition, allowing power to flow from left to right. These contact elements either close or remain closed according to the status of their reference inputs.

3.3.3 Ladder relay instruction

Ladder relay instructions are the most basic instructions in the ladder diagram instruction set. These instructions represent the ON/OFF status of connected inputs and outputs. Ladder relay instructions use two types of symbols: contacts and coils. Contacts represent the input conditions that must be evaluated in a given rung to determine the control of the output. Coils represent a rung’s outputs. Table 3.1 lists common ladder relay instructions. In a program, each contact and coil has a referenced address number, which identifies what is being evaluated and what is being controlled. The address number references the I/O table location of the connected input/output or the internal or storage bit output. A contact, regardless of whether it represents an input/output connection or an internal output, can be used throughout the control program whenever the condition it represents must be evaluated. The format of the rung contacts in a PLC program depends on the desired control logic. Contacts may be placed in whatever series, parallel, or series / parallel configuration is required to control a given output. When logic continuity exists in at least one left-to-right contact path, the rung condition is TRUE; that is, the rung controls the given output. The rung condition is FALSE if no path has continuity.

Table 3.1 :Ladder relay instruction

Ladder Relay Instructions *(Purpose: To provide hardwired relay capabilities in a PLC)*		
Instruction	**Symbol**	**Function**
Examine-ON/Normally Open	—| |—	Tests for an ON condition in a reference address
Examine-OFF/Normally Closed	—|/|—	Tests for an OFF condition in a reference address
Output Coil	—( )—	Turns real or internal outputs ON when logic is 1
NOT Output Coil	—(/)—	Turns real or internal outputs OFF when logic is 1
Latch Output Coil	—(L)—	Keeps an output ON once it is energized
Unlatch Output Coil	—(U)—	Resets a latched output
One-Shot Output	—(OS)—	Energizes an output for one scan or less
Transitional Contact	—|↑|—	Closes for one scan when its trigger contact makes a positive transition

The relay-type instructions covered in this section are the most basic programmable controller instructions. They provide the same capabilities as hardwired relay logic, but with greater flexibility. These instructions provide the ability to examine the ON/OFF status of specific bit addresses in memory and control the state of internal and external outputs.

3.4 Ladder scan evaluation

Scan evaluation is an important concept, since it defines the order in which the processor executes a ladder diagram. The processor starts solving a ladder program after it has read the status of all inputs and stored this information in the input table. The solution starts at the top of the ladder program, beginning with the first rung and proceeding one rung at a time. As the processor solves the control program, it examines the reference address of each programmed instruction, so that it can assess logic continuity for the rung being solved. Even if the output conditions in the rung being solved affect previous rungs, the processor will not return to the previous rung to resolve it.

3.5 PLC Operation

For simple programming the relay model of the PLC is sufficient. As more complex functions are used the more complex VonNeuman model of the PLC must be used. A VonNeuman computer processes one instruction at a time. Most computers operate this way, although they appear to be doing many things at once. Consider the computer components input is obtained from the keyboard and mouse, output is sent to the screen, and the disk and memory are used for both input and output for storage. A PLC is also a computer controlling a process. When fully integrated into an application the analogies become;

- **inputs** - the keyboard is analogous to a proximity switch.
- **input circuits** - the serial input chip is like a 24Vdc input card.
- **computer** - the 686 CPU is like a PLC CPU unit.
- **output circuits** - a graphics card is like a triac output card.
- **outputs** - a monitor is like a light.

- **storage** - memory in PLCs is similar to memories in personal computers.

It is also possible to implement a PLC using a normal Personal Computer, although this is not advisable. In the case of a PLC the inputs and outputs are designed to be more reliable and rugged for harsh production environments.

3.5.1 Operation sequence

All PLCs have four basic stages of operations that are repeated many times per second. Initially when turned on the first time it will check it's own hardware and software for faults. If there are no problems it will copy all the input and copy their values into memory, this is called the input scan. Using only the memory copy of the inputs the ladder logic program will be solved once, this is called the logic scan. While solving the ladder logic the output values are only changed in temporary memory. When the ladder scan is done the outputs will updated using the temporary values in memory, this is called the output scan. The PLC now restarts the process by starting a self check for faults. This process typically repeats 10 to 100 times per second.

3.5.1.1 SELF TEST - Checks to see if all cards error free, reset watch-dog timer, etc. (A watchdog timer will cause an error, and shut down the PLC if not reset within a short period of time - this would indicate that the ladder logic is not being scanned normally).

3.5.1.2 INPUT SCAN - Reads input values from the chips in the input cards, and copies their values to memory. This makes the PLC operation faster, and avoids cases where an input changes from the start to the end of the program (e.g., an emergency stop). There are special PLC functions that read the inputs directly, and avoid the input tables.

3.5.1.3 LOGIC SOLVE/SCAN - Based on the input table in memory, the program is executed 1 step at a time, and outputs are updated. This is the focus of the later sections.

3.5.1.4 OUTPUT SCAN - The output table is copied from memory to the output chips. These chips then drive the output devices.

The input and output scans often confuse the beginner, but they are important. The input scan takes a snap shot of the inputs, and solves the logic. This prevents potential problems that might occur if an input that is used in multiple places in the ladder logic program changed while half way through a ladder scan. Thus changing the behaviors of half of the ladder logic program. This problem could have severe effects on complex programs. One side effect of the input scan is that if a change in input is too short in duration, it might fall between input scans and be missed. When the PLC is initially turned on the normal outputs will be turned off. This does not affect the values of the inputs.

A- The Input and Output Scans

When the inputs to the PLC are scanned the physical input values are copied into memory. When the outputs to a PLC are scanned they are copied from memory to the physical outputs. When the ladder logic is scanned it uses the values in memory, not the actual input or output values. The primary reason for doing this is so that if a program uses an input value in multiple places, a change in the input value will not invalidate the logic. Also, if output bits were changed as each bit was changed, instead of all at once at the end of the scan the PLC would operate much slower.

B- The Logic Scan

Ladder logic programs are modeled after relay logic. In relay logic each element in the ladder will switch as quickly as possible. But in a program elements can only be examines one at a time in a fixed sequence. The ladder logic will be interpreted left-to-right, top-to-bottom. The ladder logic scan begins at the top rung. At the end of the rung it interprets the top output first, then the output branched below it. On the second rung it solves branches, before moving along the ladder logic rung. The logic scan sequence become important when solving ladder logic programs which use outputs as inputs. It also becomes important when considering output usage. The actual outputs are only updated when the ladder logic scan is complete. Therefore the output scan would update the real outputs based upon the final line of ladder logic, and the first line of ladder logic would be ineffective.

C- PLC STATUS

The lack of keyboard, and other input-output devices is very noticeable on a PLC. On the front of the PLC there are normally limited status lights. Common lights indicate;

- **power on -** this will be on whenever the PLC has power
- **program running -** this will often indicate if a program is running, or if no program is running
- **fault -** this will indicate when the PLC has experienced a major hardware or software problem

3.6 LATCHES, TIMERS, AND COUNTERS

More complex systems cannot be controlled with combinatorial logic alone. The main reason for this is that we cannot, or choose not to add sensors to detect all conditions. In these cases we can use events to estimate the condition of the system. Typical events used by a PLC include;

- first scan of the PLC - indicating the PLC has just been turned on
- time since an input turned on/off - a delay
- count of events - to wait until set number of events have occurred
- latch on or unlatch - to lock something on or turn it off

The common theme for all of these events is that they are based upon one of two questions "How many?" or "How long?"

The input to the device is a push button. When the push button is pushed the input to the device turns on. If the push button is then released and the device turns off, it is a logical device. If when the push button is release the device stays on, is will be one type of event based device. To reiterate, the device is event based if it can respond to one or more things that have happened before. If the device responds only one way to the immediate set of inputs, it is logical.

3.6.1 LATCHES

A latch is like a sticky switch - when pushed it will turn on, but stick in place, it must be pulled to release it and turn it off. A latch in ladder logic uses one instruction to latch, and a second instruction to unlatch.

3.6.2 TIMERS

There are four fundamental types of timers shown in Figure 9.7. An on-delay timer will wait for a set time after a line of ladder logic has been true before turning on, but it will turn off immediately. An off-delay timer will turn on immediately when a line of ladder logic is true, but it will delay before turning off. Consider the example of an old car. If you turn the key in the ignition and the car does not start immediately, that is an on-delay. If you turn the key to stop the engine but the engine doesn’t stop for a few seconds, that is an off delay. An on-delay timer can be used to allow an oven to reach temperature before starting production. An off delay timer can keep cooling fans on for a set time after the oven has been turned off.

3.6.3 COUNTERS

There are two basic counter types: count-up and count-down. When the input to a count-up counter goes true the accumulator value will increase by 1 (no matter how long the input is true.) If the accumulator value reaches the present value the counter DNbit will be set. A count-down counter will decrease the accumulator value until the present value is reached.

3.7 MASTER CONTROL RELAYS (MCRs)

In an electrical control system a Master Control Relay (MCR) is used to shut down a section of an electrical system, This concept has been implemented in ladder logic also. A section of ladder logic can be put between two lines containing MCR’s. When the first MCR coil is active, all of the intermediate ladder logic is executed up to the second line with an MCR coil. When the first MCR coil in inactive, the ladder logic is still examined, but all of the outputs are forced off. If a normal input is used inside an MCR block it will be forced off. If the output is also used in other MCR blocks the last one will be forced off. The MCR is designed to fully stop an entire section of ladder logic, and is best used this way in ladder logic designs.

3.7.1 INTERNAL RELAYS

Inputs are used to set outputs in simple programs. More complex programs also use internal memory locations that are not inputs or outputs. These are sometimes referred to as ’internal relays’ or ’control relays’. Knowledgeable programmers will often refer to these as ’bit memory’. The programmer is free to use these memory locations however they see fit.

3.8 PLC Flowchart based design

A flowchart is ideal for a process that has sequential process steps. The steps will be executed in a simple order that may change as the result of some simple decisions. The symbols used for flowcharts are shown in Figure 3.6. These blocks are connected using arrows to indicate the sequence of the steps. The different blocks imply different types of program actions. Programs always need a start block, but PLC programs rarely stop so the stop block is rarely used. Other important blocks include operation sand decisions. The other functions may be used but are not necessary for most PLC applications.

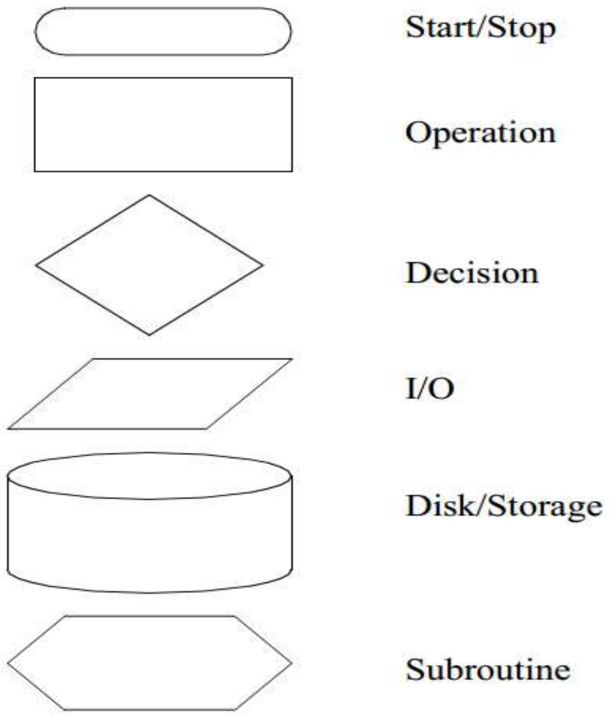


Figure3.6: Flowchart based design [Jack, H. (2003)]

3.9 INDUSTRIAL SENSORS

This section describes sensors that will be of use for industrial measurements. The sections have been divided by the phenomena to be measured. Where possible details are provided.

3.9.1 Angular Displacement

A. Potentiometers

Potentiometers measure the angular position of a shaft using a variable resistor. The potentiometer is resistor, normally made with a thin film of resistive material. A wiper can be moved along the surface of the resistive film. As the wiper moves toward one end there will be a change in resistance proportional to the distance moved. If a voltage is applied across the resistor, the voltage at the wiper interpolate the voltages at the ends of the resistor. Potentiometers are popular because they are inexpensive, and don't require special signal conditioners. But, they have limited accuracy, normally in the range of 1% and they are subject to mechanical wear. Potentiometers measure absolute position, and they are calibrated by rotating them in their mounting brackets, and then tightening them in place. The range of rotation is normally limited to less than 360 degrees or multiples of 360 degrees. Some potentiometers can rotate without limits, and the wiper will jump from one end of the resistor to the other. Faults in potentiometers can be detected by designing the potentiometer to never reach the ends of the range of motion. If an output voltage from the potentiometer ever reaches either end of the range, then a problem has occurred, and the machine can be shut down.

B. Encoders

Encoders use rotating disks with optical windows. The encoder contains an optical disk with fine windows etched into it. Light from emitters passes through the openings in the disk to detectors. As the encoder shaft is rotated, the light beams are broken. There are two fundamental types of encoders; absolute and incremental. An absolute encoder will measure the position of the shaft for a single rotation. The same shaft angle will always produce the same reading. The output is normally a binary or grey code number. An incremental (or relative) encoder will output two pulses that can be used to determine displacement. Logic circuits or software is used to determine the direction of rotation, and count pulses to determine the displacement. The velocity can be determined by measuring the time between pulses.

C. Tachometers

Tachometers measure the velocity of a rotating shaft. A common technique is to mount a magnet to a rotating shaft. When the magnetic moves past a stationary pick-up coil, current is induced. For each rotation of the shaft there is a pulse in the coil. When the time between the pulses is measured the period for one rotation can be found, and the frequency calculated. This technique often requires some signal conditioning circuitry.

3.9.2 Linear Position

A. Potentiometers

Rotational potentiometers were discussed before, but potentiometers are also available in linear/sliding form. These are capable of measuring linear displacement over long distances.

B. Linear Variable Differential Transformers (LVDT)

Linear Variable Differential Transformers (LVDTs) measure linear displacements over a limited range. Device consists of outer coils with an inner moving magnetic core. High frequency alternating current (AC) is applied to the center coil. This generates a magnetic field that induces a current in the two outside coils. The core will pull the magnetic field towards it, so in the figure more current will be induced in the left hand coil. The outside coils are wound in opposite directions so that when the core is in the center the induced currents cancel, and the signal out is zero (0Vac).

C. Accelerometers

Accelerometers measure acceleration using a mass suspended on a force sensor. When the sensor accelerates, the inertial resistance of the mass will cause the force sensor to deflect. By measuring the deflection the acceleration can be determined. In this case the mass is cantilevered on the force sensor. A base and housing enclose the sensor. A small mounting stud (a threaded shaft) is used to mount the accelerometer. Accelerometers are dynamic sensors, typically used for measuring vibrations between 10Hz to 10KHz. Temperature variations will affect the accuracy of the sensors. Standard accelerometers can be linear up to 100,000 m/s^2: high shock designs can be used up to 1,000,000 m/s^2. There is often a trade-off between a wide frequency range and device sensitivity (note: higher sensitivity requires a larger mass).The sensitivity of two accelerometers with different resonant frequencies. A smaller resonant frequency limits the maximum frequency for the reading. The smaller frequency results in a smaller sensitivity. The units for sensitivity is charge per m/s^2.The force sensor is often a small piece of piezoelectric material.

3.9.3 Forces and Moments

A. Strain Gages

Strain gages measure strain in materials using the change in resistance of a wire. The wire is glued to the surface of a part, so that it undergoes the same strain as the part (at the mount point).Basically, the resistance of the wire is a function of the resistivity, length, and cross sectional area. After the wire has been deformed it will take on the new dimensions and resistance. If a force is applied, the wire will become longer, as predicted by Young’s modulus. But, the cross sectional area will decrease, as predicted by Poison’s ratio. The new length and cross sectional area can then be used to find a new resistance. Strain gauges are inexpensive, and can be used to measure a wide range of stresses with accuracies under 1%. Gages require calibration before each use. This often involves making a reading with no load, or a known load applied. An example application includes using strain gages to measure die forces during stamping to estimate when maintenance is needed.

B. Piezoelectric

When a crystal undergoes strain it displaces a small amount of charge. In other words, when the distance between atoms in the crystal lattice changes some electrons are forced out or drawn in. This also changes the capacitance of the crystal. This is known as the Piezoelectric effect. The charge generated is a function of the force applied, the strain in the material, and a constant specific to the material. The change in capacitance is proportional to the change in the thickness. These crystals are used for force sensors, but they are also used for applications such as microphones and pressure sensors. Applying an electrical charge can induce strain, allowing them to be used as actuators, such as audio speakers. When using piezoelectric sensors charge amplifiers are needed to convert the small amount of charge to a larger voltage. These sensors are best suited to dynamic measurements, when used for static measurements they tend to drift or slowly lose charge, and the signal value will change.[Jack, H, 2003]

3.9.4 Liquids and Gases

There are a number of factors to be considered when examining liquids and gasses.

- Flow velocity
- Density
- Viscosity
- Pressure

A. Pressure

Figure 3.7 shows different two mechanisms for pressure measurement. The Bourdon tube uses a circular pressure tube. When the pressure inside is higher than the surrounding air pressure (14.7psi approx.) the tube will straighten. A position sensor, connected to the end of the tube, will be elongated when the pressure increases. These sensors are very common and have typical accuracies of 0.5%.

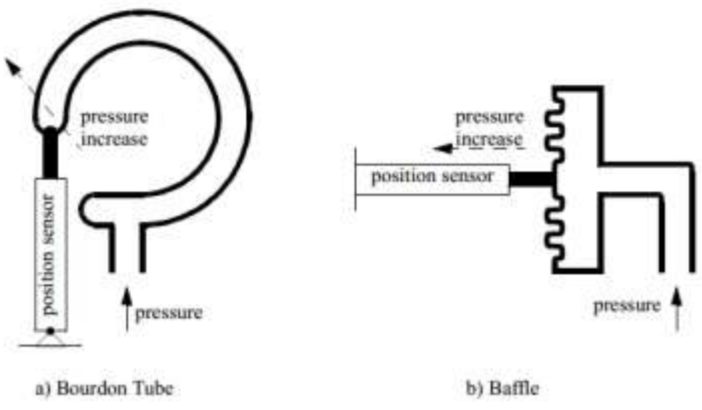


Figure3.7 :different two mechanisms for pressure measurement [Jack, H. (2003)]

B. Venturi Valves

When a flowing fluid or gas passes through a narrow pipe section (neck) the pressure drops. If there is no flow the pressure before and after the neck will be the same. The faster the fluid flow, the greater the pressure difference before and after the neck. This is known as a Venturi valve. Figure 3.8 shows a Venturi valve being used to measure a fluid flow rate. The fluid flow rate will be proportional to the pressure difference before and at the neck (or after the neck) of the valve.[Jack, H, 2003]

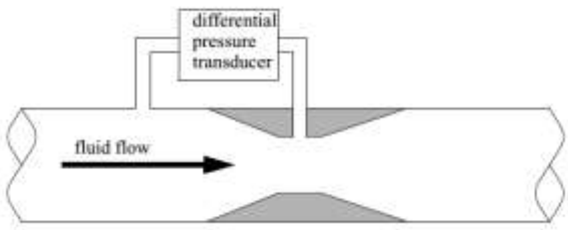


Figure3.8 :Venturi valve to measure a fluid flow rate [Jack, H. (2003)]

C. Coriolis Flow Meter

Fluid passes through thin tubes, causing them to vibrate. As the fluid approaches the point of maximum vibration it accelerates. When leaving the point it decelerates. The result is a distributed force that causes a bending moment, and hence twisting of the pipe. The amount of bending is proportional to the velocity of the fluid flow. These devices typically have a large constriction on the flow, and result is significant loses. Some of the devices also use bent tubes to increase the sensitivity, but this also increases the flow resistance. The typical accuracy for a corriolis flow meter is 0.1%. [Jack, H, 2003]

D. Magnetic Flow Meter

A magnetic sensor applies a magnetic field perpendicular to the flow of a conductive fluid. As the fluid moves, the electrons in the fluid experience an electromotive force. The result is that a potential (voltage) can be measured perpendicular to the direction of the flow and the magnetic field. The higher the flow rate, the greater the voltage. The typical accuracy for these sensors is 0.5%.These flow meters don’t oppose fluid flow, and so they don’t result in pressure drops.[Jack, H, 2003]

E. Ultrasonic Flow Meter

A transmitter emits a high frequency sound at point on a tube. The signal must then pass through the fluid to a detector where it is picked up. If the fluid is flowing in the same direction as the sound it will arrive sooner. If the sound is against the flow it will take longer to arrive. In a transit time flow meter two sounds are used, one traveling forward, and the other in the opposite direction. The difference in travel time for the sounds is used to determine the flow velocity. A Doppler flow meter bounces a sound wave off particle in a flow. If the particle is moving away from the emitter and detector pair, then the detected frequency will be lowered, if it is moving towards them the frequency will be higher. The transmitter and receiver have a minimal impact on the fluid flow, and therefore don’t result in pressure drops.[Jack, H, 2003]

F. Vortex Flow Meter

Fluid flowing past a large (typically flat) obstacle will shed vortices. The frequency of the vortices will be proportional to the flow rate. Measuring the frequency allows an estimate of the flow rate. These sensors tend be low cost and are popular for low accuracy applications.[Jack, H, 2003]

G. Positive Displacement Meters

In some cases more precise readings of flow rates and volumes may be required. These can be obtained by using a positive displacement meter. In effect these meters are like pumps run in reverse. As the fluid is pushed through the meter it produces a measurable output, normally on a rotating shaft.

H. Pitot Tubes

Gas flow rates can be measured using Pitot tubes, as shown in Figure 3.9 These are small tubes that project into a flow. The diameter of the tube is small (typically less than 1/8") so that it doesn't affect the flow.[Jack, H, 2003]

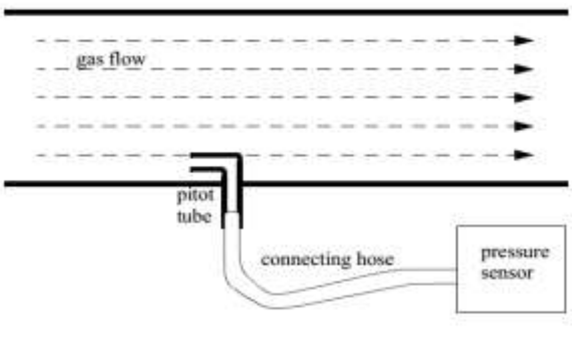


Figure3.9 :Gas flow rates can be measured using Pitot tubes [Jack, H. (2003)]

3.9.5 Temperature

Temperature measurements are very common with control systems. The temperature ranges are normally described with the following classifications.

- very low temperatures <-60 deg C - e.g. superconductors in MRI units
- low temperature measurement -60 to 0 deg C - e.g. freezer controls
- fine temperature measurements 0 to 100 deg C - e.g. environmental controls
- high temperature measurements <3000 deg F - e.g. metal refining/processing
- very high temperatures > 2000 deg C - e.g. plasma systems

A. Resistive Temperature Detectors (RTDs)

When a metal wire is heated the resistance increases. So, a temperature can be measured using the resistance of a wire. Resistive Temperature Detectors (RTDs) normally use a wire or film of platinum, nickel, copper or nickel-iron alloys. The metals are wound or wrapped over an insulator, and covered for protection. A current must be passed through the RTD to measure the resistance. (Note: a voltage divider can be used to convert the resistance to a voltage.) The current through the RTD should be kept to a minimum to prevent self heating. These devices are more linear than thermocouples, and can have accuracies of 0.05%. But, they can be expensive.

B. Thermocouples

Each metal has a natural potential level, and when two different metals touch there is a small potential difference, a voltage. (Note: when designing assemblies, dissimilar metals should not touch, this will lead to corrosion.) Thermocouples use a junction of dissimilar metals to generate a voltage proportional to temperature. This principle was discovered by T.J. See beck. The junction where the thermocouple is connected to the measurement instrument is normally cooled to reduce the thermocouple effects at those junctions. When using a thermocouple for precision measurement, a second thermocouple can be kept at a known temperature for reference. A series of thermocouples connected together in series produces a higher voltage and is called a thermopile. Readings can approach an accuracy of 0.5%.

C. Thermistors

Thermistors are non-linear devices, their resistance will decrease with an increase in temperature. (Note: this is because the extra heat reduces electron mobility in the semiconductor.) The resistance can change by more than 1000 times. often metal oxide semiconductors The calculation uses a reference temperature and resistance, with a constant for the device, to predict the resistance at another temperature. Thermistors are small, inexpensive devices that are often made as beads, or metalized surfaces. The devices respond quickly to temperature changes, and they have a higher resistance, so junction effects are not an issue. Typical accuracies are 1%, but the devices are not linear, have a limited temperature/resistance range and can be self heating.

3.9.6 Other Sensors : Light (Light Dependant Resistors (LDR))

Light dependant resistors (LDRs) change from high resistance (>M ohms) in bright light to low resistance (<K ohms) in the dark. The change in resistance is non-linear, and is also relatively slow (ms).

A. Chemical (Conductivity)

Conductivity of a material, often a liquid is often used to detect impurities. This can be measured directly be applying a voltage across two plates submerged in the liquid and measuring the current. High frequency inductive fields is another alternative.

A number of other detectors/sensors are listed below,

- Combustion - gases such as CO2 can be an indicator of combustion
- Humidity - normally in gases
- Dew Point - to determine when condensation will form

3.10 INPUT ISSUES

Signals from sensors are often not in a form that can be directly input to a controller. In these cases it may be necessary to buy or build signal conditioners. Normally, a signal conditioner is an amplifier, but it may also include noise filters, and circuitry to convert from current to voltage. Analog signal are prone to electrical noise problems. This is often caused by electromagnetic fields on the factory floor inducing currents in exposed conductors. Some of the techniques for dealing with electrical noise include;

- twisted pairs - the wires are twisted to reduce the noise induced by magnetic fields.

- shielding - shielding is used to reduce the effects of electromagnetic interference.
- single/double ended inputs - shared or isolated reference voltages (commons).

When a signal is transmitted through a wire, it must return along another path. If the wires have an area between them the magnetic flux enclosed in the loop can induce current flow and voltages. If the wires are twisted, a few times per inch, then the amount of noise induced is reduced. This technique is common in signal wires and network cables. A shielded cable has a metal sheath. This sheath needs to be connected to the measuring device to allow induced currents to be passed to ground. This prevents electromagnetic waves to induce voltages in the signal wires. When connecting analog voltage sources to a controller the common, or reference voltage can be connected different ways. The least expensive method uses one shared common for all analog signals, this is called single ended. The more accurate method is to use separate commons for each signal, this is called double ended. Most analog input cards allow a choice between one or the other. But, when double ended inputs are used the number of available inputs is halved. Most analog output cards are double ended.

Signals from transducers are typically too small to be read by a normal analog input card. Amplifiers are used to increase the magnitude of these signals. The amplifier is in an inverting configuration, so the output will have an opposite sign from the input. Adjustments are provided for gain and offset adjustments. op-amps are used in this section to implement the amplifiers because they are inexpensive, common, and well suited to simple design and construction projects.

When purchasing a commercial signal conditioner, the circuitry will be more complex, and include other circuitry for other factors such as temperature compensation.

3.11 Continuous actuators

Continuous actuators allow a system to position or adjust outputs over a wide range of values. Even in their simplest form, continuous actuators tend to be mechanically complex devices. For example, a linear slide system might be composed of a motor with an electronic controller driving a mechanical slide with a ball screw. The cost for such an actuators can easily be higher than for the control system itself. These actuators also require sophisticated control techniques. In general, when there is a choice, it is better to use discrete actuators to reduce costs and complexity.

3.12Serial communication

Multiple control systems will be used for complex processes. These control systems may be PLCs, but other controllers include robots, data terminals and computers. For these controllers to work together, they must communicate. This part will discuss communication techniques between computers, and how these apply to PLCs. The simplest form of communication is a direct connection between two computers. A network will simultaneously connect a large number of computers on a network. Data can be transmitted one bit at a time in series, this is called serial communication. Data bits can also be sent in parallel. The transmission rate will often be limited to some maximum value, from a few bits per second, to billions of bits per second. The communications often have limited distances, from a few feet to thousands of miles/kilometers. An example of a networked control system is shown in Figure 3.10. The computer and PLC are connected with an RS-232 (serial data) connection. This connection can only connect two devices. Device-net is used by the Computer to communicate with various actuators and sensors. Device-net can support up to 63 actuators and sensors. The PLC inputs and outputs are connected as normal to the process.

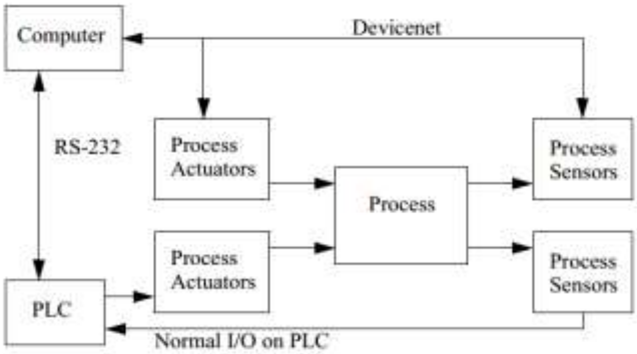


Figure3.10 :Serial communication [Jack, H. (2003)]

Serial communications send a single bit at a time between computers. This only requires a single communication channel, as opposed to 8 channels to send a byte. With only one channel the costs are lower, but the communication rates are slower. The communication channels are often wire based, but they may also be can be optical and radio. Figure 3.11 shows some of the standard electrical connections. RS-232c is the most common standard that is based on a voltage change levels. At the sending computer an input will either be true or false. The line driver will convert a false value into a Txd voltage between +3V to +15V, true will be between -3V to -15V. A cable connects the Txd and com on the sending computer to the Rxd and com inputs on the receiving computer. The receiver converts the positive and negative voltages back to logic voltage levels in the receiving computer. The cable length is limited to 50 feet to reduce the effects of electrical noise. When RS-232 is used on the factory floor, care is required to reduce the effects of electrical noise - careful grounding and shielded cables are often used.

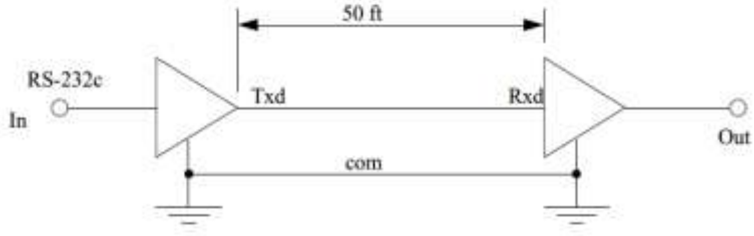


Figure3.11 :standard electrical connections. RS-232c [Jack, H. (2003)]

The RS-422a cable uses a 20 mA current loop instead of voltage levels. This makes the systems more immune to electrical noise, so the cable can be up to 3000 feet long. The RS-423a standard uses a differential voltage level across two lines, also making the system more immune to electrical noise, thus allowing longer cables. To provide serial communication in two directions these circuits must be connected in both directions.

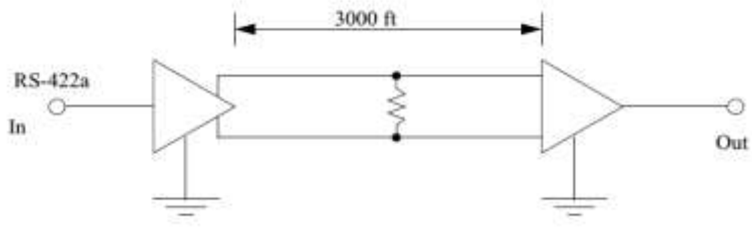


Figure3.12 :standard electrical connections. RS-222a [Jack, H. (2003)]

3.12.1 RS-232

The RS-232c standard is based on a low/false voltage between +3 to +15V, and an high/true voltage between -3 to -15V (+/-12V is commonly used). In all connection methods the txd and rxd lines are crossed so that the sending txd outputs are into the listening rxd inputs when communicating between computers. When communicating with a communication device (modem), these lines are not crossed. In the modem connection the dsr and dtr lines are used to control the flow of data. In the computer the cts and rts lines are connected. These lines are all used for handshaking, to control the flow of data from sender to receiver. The null-modem configuration simplifies the handshaking between computers. The three wire configuration is a crude way to connect to devices, and data can be lost. Common connectors for serial communications are shown in Figure 3.13. These connectors are either male (with pins) or female (with holes), and often use the assigned pins shown. The DB-9 connector is more common now, but the DB-25 connector is still in use. In any connection the RXD and TXDpins must be used to transmit and receive data. The COM must be connected to give a common voltage reference. All of the remaining pins are used for handshaking.

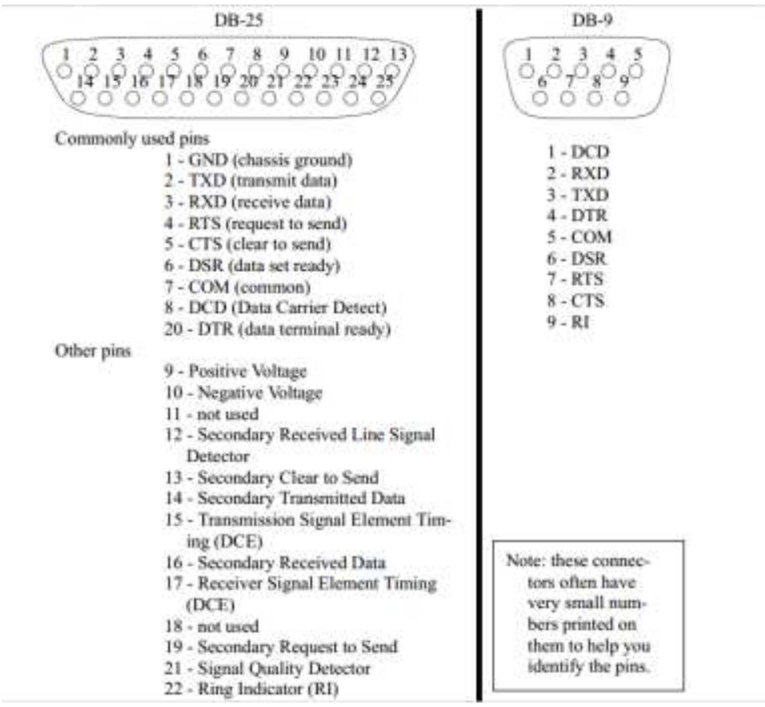


Figure3.13 :RS-232 [Jack, H. (2003)]

The handshaking lines are to be used to detect the status of the sender and receiver, and to regulate the flow of data. It would be unusual for most of these pins to be connected in any one application. The most common pins are provided on the DB-9 connector, and are also described below.

- **TXD/RXD** - (transmit data, receive data) - data lines
- **DCD** - (data carrier detect) - this indicates when a remote device is present
- **RI** - (ring indicator) - this is used by modems to indicate when a connection is about to be made.
- **CTS/RTS** - (clear to send, ready to send)
- **DSR/DTR** - (data set ready, data terminal ready) these handshaking lines indicate when the remote machine is ready to receive data.
- **COM** - a common ground to provide a common reference voltage for the TXD and RXD.

3.12.2 PARALLEL COMMUNICATIONS

Parallel data transmission will transmit multiple bits at the same time over multiple wires. This does allow faster data transmission rates, but the connectors and cables become much larger, more expensive and less flexible. These interfaces still use handshaking to control data flow. These interfaces are common for computer printer cables and short interface cables, but they are uncommon on PLCs.

3.13 Networking

A computer with a single network interface can communicate with many other computers. This economy and flexibility has made networks the interface of choice, eclipsing point-to-point methods such as RS-232. Typical advantages of networks include resource sharing and ease of communication. But, networks do require more knowledge and understanding. Small networks are often called Local Area Networks (LANs). These may connect a few hundred computers within a distance of hundreds of meters. These networks are inexpensive, often costing $100 or less per network node. Data can be transmitted at rates of millions of bits per second. Many controls system are using networks to communicate with other controllers and computers. Typical applications include;

- taking quality readings with a PLC and sending the data to a database computer.
- distributing recipes or special orders to batch processing equipment.
- remote monitoring of equipment.

Larger Wide Area Networks (WANs) are used for communicating over long distances between LANs. These are not common in controls applications, but might be needed for a very large scale process. An example might be an oil pipeline control system that is spread over thousands of miles.

3.13.1 Networking Hardware

The following is a description of most of the hardware that will be needed in the design of networks.

- Computer (or network enabled equipment)

- Network Interface Hardware - The network interface may already be built into the computer/PLC/sensor/etc. These may cost $15 to over $1000.
- The Media - The physical network connection between network nodes.10baseT (twisted pair) is the most popular. It is a pair of twisted copper wires terminated with an RJ-45 connector.10base2 (thin wire) is thin shielded coaxial cable with BNC connectors10baseF (fiber optic) is costly, but signal transmission and noise properties are very good.
- Repeaters (Physical Layer) - These accept signals and retransmit them so that longer networks can be built.
- Hub/Concentrator - A central connection point that network wires will be connected to. It will pass network packets to local computers, or to remote networks if they are available.
- Router (Network Layer) - Will isolate different networks, but redirect traffic to other LANs.
- Bridges (Data link layer) - These are intelligent devices that can convert data on one type of network, to data on another type of network. These can also be used to isolate two networks.
- Gateway (Application Layer) - A Gateway is a full computer that will direct traffic to different networks, and possibly screen packets. These are often used to create firewalls for security.

3.14 Human machine interfaces (HMI)

- These allow control systems to be much more interactive than before.
- The basic purpose of an HMI is to allow easy graphical interface with a process.

- These devices have been known by a number of names.
    - touch screens
    - displays
    - Man Machine Interface (MMI)
    - Human Machine Interface (HMI)
- These allow an operator to use simple displays to determine machine condition and make simple settings.
- The most common uses are,
    - display machine faults
    - display machine status
    - allow the operator to start and stop cycles
    - monitor part counts
- These devices allow certain advantages such as,
    - color coding allows for easy identification (eg. red for trouble)
    - pictures/icons allow fast recognition
    - use of pictures eases problems of illiteracy
    - screen can be changed to allow different levels of information and access
- The general implementation steps are,
    - Layout screens on PC based software.
    - Download the screens to the HMI unit.
    - Connect the unit to a PLC.
    - Read and write to the HMI using PLC memory locations to get input and update screens.

- To control the HMI from a PLC the user inputs set bits in the PLC memory, and other bits in the PLC memory can be set to turn on/off items on the HMI screen.

3.15 Selecting PLC

After the planning phase of the design, the equipment can be ordered. This decision is usually based upon the required inputs, outputs and functions of the controller. The first decision is the type of controller; rack, mini, micro, or software based. This decision will depend upon the basic criteria listed below.

- Number of logical inputs and outputs.
- Memory - Often 1K and up. Need is dictated by size of ladder logic program. A ladder element will take only a few bytes, and will be specified in manufacturers documentation.
- Number of special I/O modules - When doing some exotic applications, a large number of special add-on cards may be required.
- Scan Time - Big programs or faster processes will require shorter scan times. And, the shorter the scan time, the higher the cost. Typical values for this are 1 microsecond per simple ladder instruction
- Communications - Serial and networked connections allow the PLC to be programmed and talk to other PLCs. The needs are determined by the application.
- Software - Availability of programming software and other tools determines the programming and debugging ease.

CHAPTER FOUR

Smart Parking System Design

CHAPTER FOUR

Smart Parking System Design

4.1 Introduction:

Figure 4.1 the smart parking system plan proposed in this research is composed of three sub systems: a mechanical system, an electrical system and a control system. The design is based on linking these three systems together accurately by using a specific design and the soft logic program. In the mechanical system a hydraulic lift will be used for vertical movement. For horizontal movement on the floor a motor will be selected to operate a conveyor belt in order to move the vehicle right and left, and to rotate the vehicle around itself. In the electrical system the electrical loads will be computed and a protection and emergency system will also be designed. In the control system which is the most important system a PLC controller will be used. The design of the hardware part will include drawings of the components. The design of the software part will be done by writing the soft logic program.

4.2Hydraulic System Design

Figure 4.2 shows the hydraulic system (including the hydraulic motor)that is used to lift a car that weighs 2.5 tons. The system will be able to lift the car a height of 9 meters in 18 second. Calculations need to be made in order to select and specify the size of all system components correctly. The given values below will be used as the basic requirements in designing and calculating the system.

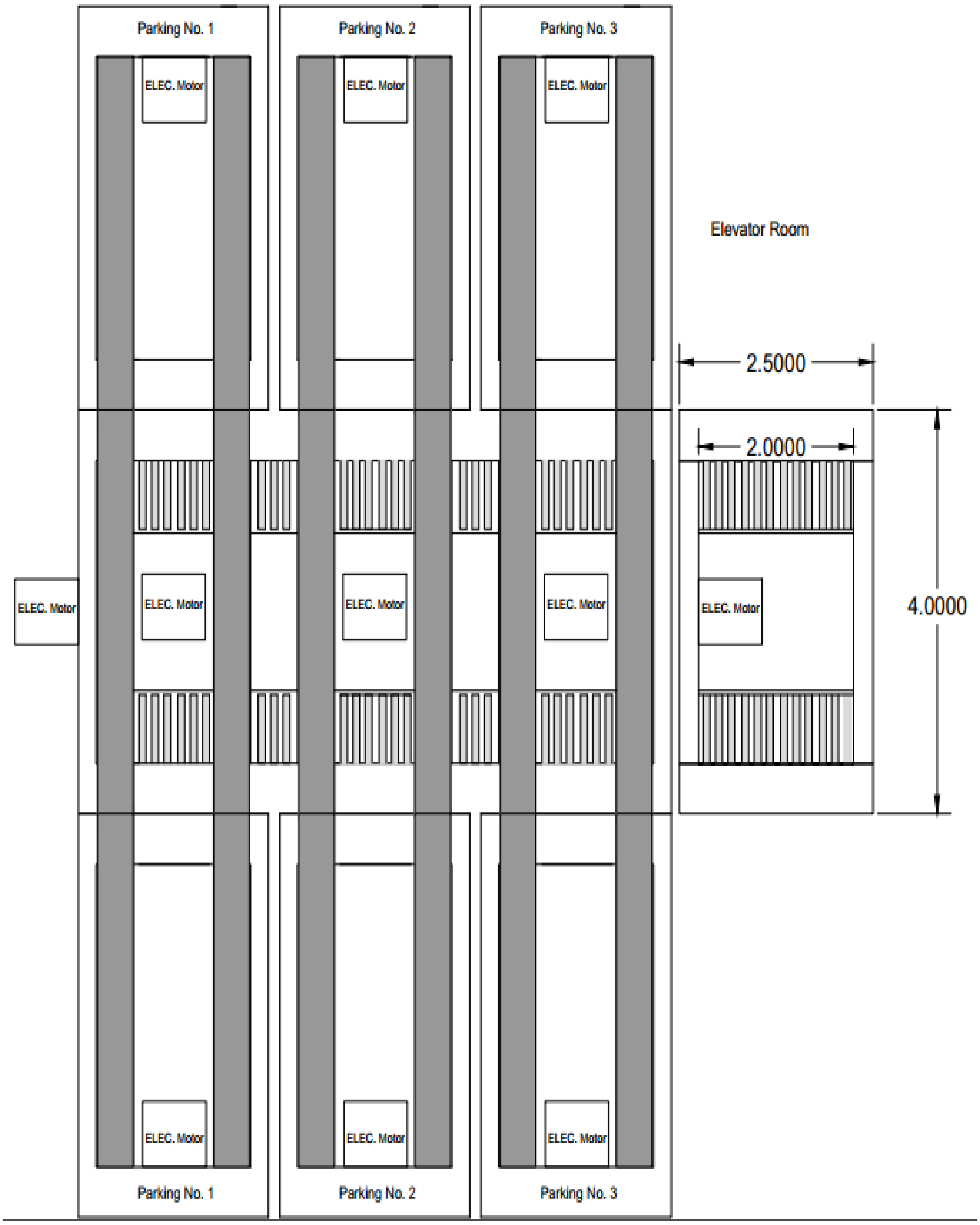


Figure4.1 :Parking space Plan [by AutoCAD]

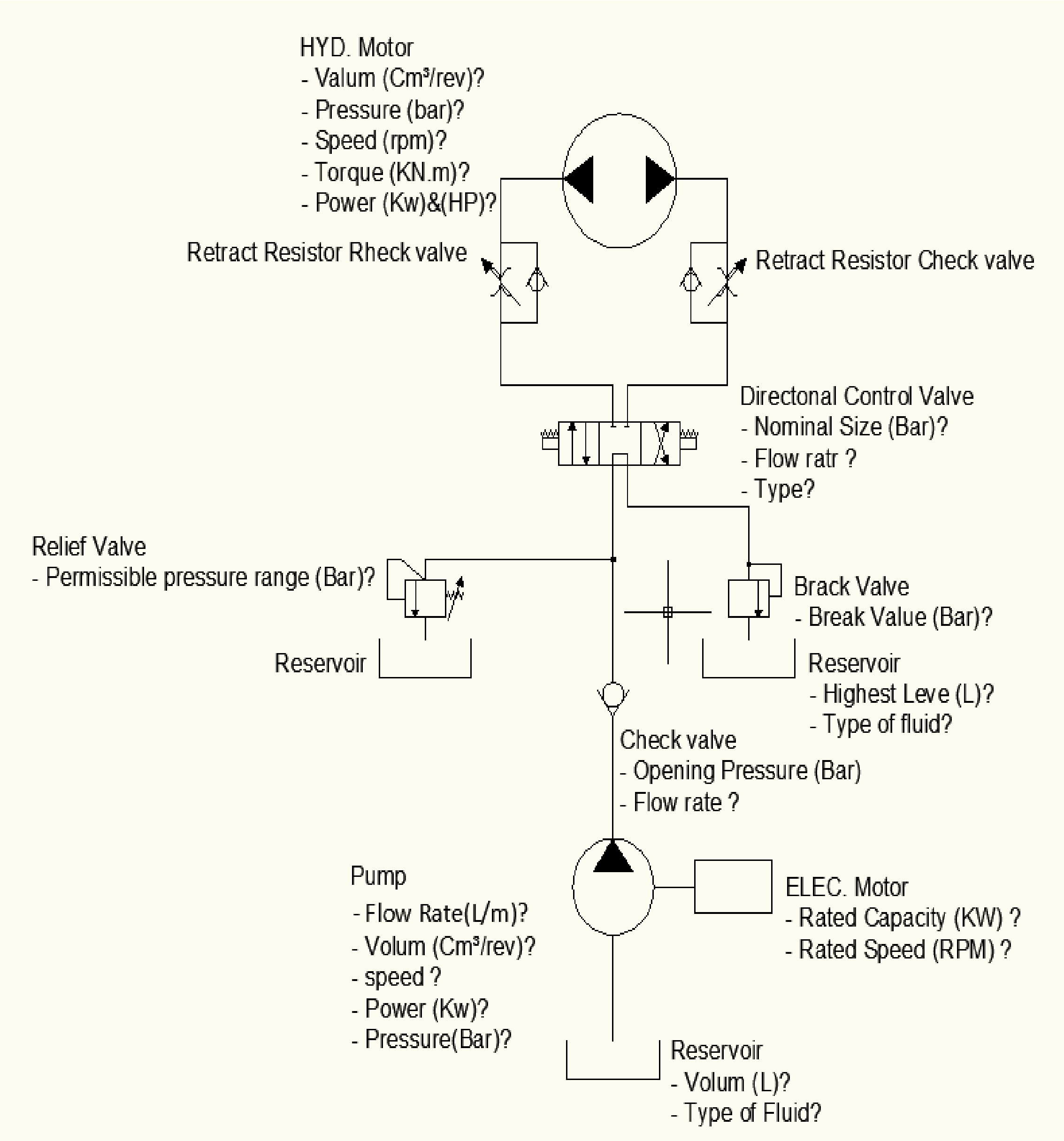


Figure 4.2: Hydraulic Lift System Design Diagram [by AutoCAD]

4.2.1 Selection of The Hydraulic Motor:

Design inputs:

- *weight of car = 2 ton = <u>2000Kg</u>*
- *total load (m)* = 2*1.25 = 2.5 ton = 2500 Kg
- *Speed Required (S) = <u>0.5 m/s</u>*
- *Diameter of drum (D) = <u>0.4 m</u>*

- *Work pressure (P) = 250 Bar*
- *Balancing pressure (Pb) = 5bar*
- *Distance (L) = 9 m*
- *Time of Work (t)= 18 s*
- *Hydro – mechanic efficiency (μm) = 95%*
- *Volumetric efficiency (μv) =95%*
- *Total efficiency (μt) =μm * μv= 0.9*

The elevator carriage moves up and down using a rope connected to the drum. The drum is linked to a Gearbox. The Gearbox transfers speed and torque from a motor to the drum. The speed, torque and specifications of the drum and hydraulic motor need to be calculated.

4.2.2 Drum size:

The required speed of the carriage is 0.5m/s linear speed. the corresponding angular speed of the drum is calculated as follows:

Linear Speed (R) =Angular Speed (ω) * Radius(R)

$\omega = \frac{S}{R} = \frac{0.5*1000}{200}$ = 2.5 rad/s … (4.1)

The rotational speed needed (rpm) for the drum is calculated by the following equation:

N(rpm) drum $= \frac{60*\omega \text{ rad/s}}{2\pi} = \frac{60*2.5}{2\pi} =$ 24rpm … (4.2

Now the drum torque can found by:

Torque of drum (T_d) = Force(F) * Radius(R) … (4.3)

To calculate the force of the car, the car mass is multiplied by gravity:

F = 2500Kg * 9.8m/s² = 24500N … (4.4)

T(drum) = 24500N * 0.2m = 4900Nm

The torque (T)is multiplied by an application factor of 1.2 to improve it and reduce the time needed to reach the maximum speed.

T = 4900*1.2N.m = 5880N.m … (4.5)

The power needed to feed the system:

H(motor) = F * S … (4.6)

H = 24500N * 0.5m/s = 12.250 Kw

To start operation and overcome the inertia power needed must be increases and multiplying by 1.2 Therefore the power is 14.7kw

Because of the loses that always happens during normal operations, the power should be increased by a certain efficiency factor. The total power is divided by the efficiency factor:

H = $\frac{P}{\mu t}$ = $\frac{14.7K}{0.9}$ = 16.3 Kw … (4.7)

To find Horse Power:

HP= $\frac{16.3Kw}{0.746}$= 21.85 HP … (4.8)

The specifications of the selected drum

- Diameter of drum (D) = 0.4 m
- Velocity N =24rpm
- T = 5880 N.m

4.2.3Hydraulic Motors:

The motor will be selected according to a power of 16.3Kw shown in the table 4.1.

From the table the rotational Speed(N) (motor) = 287rpm

To calculate the torque of the motor, assuming no loses of power therefore the powers on both sides of the gearbox are equal:

Tm * ωm =TD * ωD … (4.9)

The rotational motor speed should be changed to angular speed:

$\omega = \frac{2*\pi*N}{60} = \frac{2*\pi*287}{60} = 30.04$ rad/s

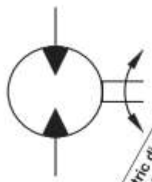
The motor torque equals:

$Tm = \frac{TD*\omega D}{\omega M} = \frac{5880*2.50}{30.04} = 483.5$N.m

- <u>The requirments for the Motor selection:</u>

> - Speed N = <u>287rpm</u>
> - Torque Tm = 483.5Nm
> - Power H =16.3 Kw
> - HP = 21.85 HP

Table4.1:Hydraulic Motor Selection



Motor Series TJ	Geometric displacement Geom. Schluckvolumen Cylindrée Despazamientos	Max. speed @ Max. intermittent flow Max. Drehzahl Intermittierender Betrieb: Vitisse de rotation maxi Velocidad maxima a caudal intermittente maximo	Max. oil flow Max. Schluckstrom Débit d'huile maxi Caudal Maximo de Aceite		Max differential pressure Max. Druckgefälle Chute de pression maxi Presion diferencial maxima		Max. supply pressure Max. Eingangsdruck Pression maxi entrée Presion maxima de alimentacion	Max. torque Max. Drehmoment Couple maxi Torque Maximo		Max. performance Max. Leistungabgabe Puissance de sortie maxi Maximo rendimieto	Min. starting torque Min. Anlaufmoment Couple min. fourni au dé manrage Torque minimo de arranque	
	cm³/rev in³/rev	rev/min	cont / int* l/min g/min		cont / int* bar psid		max bar psig	cont / int* Nm lb-in		max KW HP	cont / int* Nm lb-in	
TJ 0045	41 2.5	1024	34 9	42 11	140 2000	190 2750	200 2900	71 624	99 876	10.4 13.9	46 411	64 565
TJ 0050	49 3.0	1020	34 9	50 13	140 2000	190 2750	200 2900	90 796	127 1120	12.8 17.2	72 637	98 871
TJ 0065	65 4.0	877	45 12	57 15	140 2000	190 2750	200 2900	125 1106	176 1558	14.7 19.8	100 885	137 1211
TJ 0080	82 5.0	695	45 12	57 15	140 2000	190 2750	200 2900	160 1416	220 1947	17.3 23.2	128 1133	171 1515
TJ 0100	98 6.0	582	45 12	57 15	140 2000	190 2750	200 2900	190 1682	264 2337	17.4 23.4	152 1345	205 1819
TJ 0130	130 8.0	438	45 12	57 15	140 2000	190 2750	200 2900	255 2257	352 3116	17.3 23.2	204 1806	274 2423
TJ 0165	163 10.0	348	45 12	57 15	140 2000	190 2750	200 2900	310 2744	436 3846	17.0 22.8	248 2195	338 2992
TJ 0195	195 11.9	292	45 12	57 15	140 2030	190 2750	200 2900	390 3452	528 4673	17.4 23.4	312 2762	411 3637
TJ 0230	228 13.9	328	57 15	75 20	120 1750	165 2400	200 2900	380 3363	514 4554	17.7 23.8	304 2691	411 3637
TJ 0260	260 15.9	287	57 15	75 20	110 1650	155 2250	200 2900	400 3540	550 4870	16.7 22.4	320 2832	449 3977
TJ 0295	293 17.9	256	57 15	75 20	100 1550	145 2100	200 2900	428 3784	582 5180	15.7 21.0	328 2903	445 3939
TJ 0330	328 20.0	228	57 15	75 20	100 1550	135 1960	200 2900	443 3926	600 5312	14.8 19.8	344 3045	453 4014
TJ 0365	370 22.6	203	57 15	75 20	95 1325	125 1825	200 2900	467 4133	648 5728	13.6 18.2	373 3301	477 4223
TJ 0390	392 24.0	191	57 15	75 20	85 1250	120 1740	200 2900	445 3935	628 5562	12.5 16.8	348 3080	462 4090

From the above table the motor speed is(287 rpm). In order to reduce the motor speed (287 rpm) to the drum speed (24 rpm as calculated above), the gear box should have a gear ratio of 164:12 as in the figure 4.3:

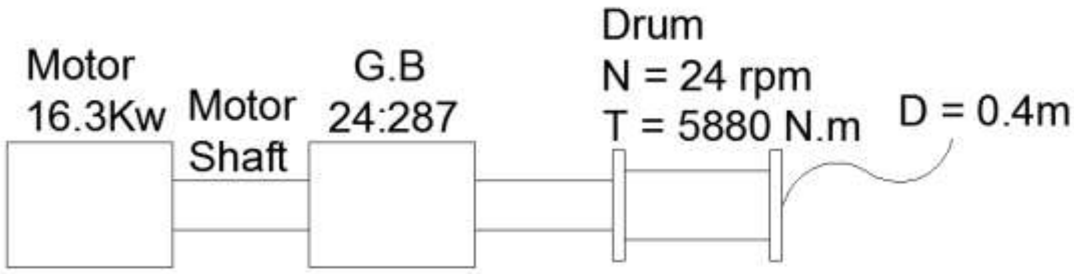


Figure 4.3 :Gear Box [by AutoCAD]

Based on the previous calculations and by looking at the specifications table of Parker's brand, The best choice is a motor series TJ (TJ0260). See appendices no. 3

4.2.4 Pump selection

The pump provides the required flow rate for the hydraulic motor, so the flow rate that passes through the pump and to the motor must be equal to or greater than the hydraulic motor flow rate.

Flow rate Q = 57 L/m (from the table 4.1)

The pump displacement is calculated by:

Flow rate Q = V (displacement) * N (speed) … (4.10)

The speed value can be found from the specification table 4.2.

$V = \frac{Q}{N} = \frac{57}{1200} = 0.0475 m^3/rev$ … (4.11)

V = 47.5 cm³/rev

Each in³/rev = 0.06 Cm³/rev. So:

V = 2.85 in³/rev

Flow rate Q = 57 L/m

Displacement V = 47.5 Cm³/rev =2.85 in³/rev

Pressure P = 248Bar

Table4.2 : Pump Selection

Pump Model	Displacement cc/rev (In³/rev)	Pump Delivery @ 21 bar (300 PSI) in LPM (GPM)		† Approx. Noise Levels dB(A) @ Full Flow 1800 RPM (1200 RPM)					Input Power At 1800 RPM, Max. Displacement & 248 bar (3600 PSI)	Operating Speed (RPM) (Maximum)	Pressure bar (PSI) Continuous (Maximum)
		1200 RPM	1800 RPM	34 bar (500 PSI)	69 bar (1000 PSI)	138 bar (2000 PSI)	207 bar (3000 PSI)	248 bar (3600 PSI)			
PVP16	16 (.98)	19.7 (5.2)	29.5 (7.8)	53 (47)	55 (50)	59 (54)	62 (56)	65 (59)	13.1 kw (17.5 hp)	3000	248 (3600)
PVP23	23 (1.4)	28.0 (7.4)	42.0 (11.1)	61 (57)	64 (59)	67 (63)	69 (65)	70 (65)	19.7 kw (26.5 hp)	3000	248 (3600)
PVP33	33 (2.0)	39.4 (10.4)	59.0 (15.6)	64 (59)	66 (59)	68 (62)	70 (64)	71 (65)	27.2 kw (36.5 hp)	3000	248 (3600)
PVP41	41 (2.5)	49.2 (13.0)	73.8 (19.5)	68 (60)	70 (61)	73 (65)	74 (67)	75 (69)	33.2 kw (44.5 hp)	2800	248 (3600)
PVP48	48 (2.9)	57.6 (15.2)	86.4 (22.8)	69 (60)	71 (62)	73 (65)	75 (68)	76 (69)	40.3 kw (54.0 hp)	2400	248 (3600)

- Pressure P(cont.) = 100Bar
- Pressure P(peak) = 200Bar
- Displacement V = 328Cm³/rev
- Flow Rate Q = 57 L/m

Based on the previous calculations and by looking at the specifications table of Parker's brand, The best choice is a Pump model (PVP48).rotary pump. See appendices no.4

4.2.5 reservoir selection

- Requirements for reservoir selection :

Reservoir selection theoretically must be approximately (3-5) times the flow rate

- Reservoir capacity = 5 * 57= 285 liter

4.2.6 Valves selection

- Requirements for the pressure valve selection :

Permissible pressure range required to operate the system should be equal to the pressure of the system See appendices no.5

- Pressure P = 100Bar

- Requirements for non-return valve selection :

The pressure needed to pass fluid through non-return valve should be very small. Assume 0.001

- Pressure P = 0.001Bar

So the pressure of fluid needed for it to pass through the valve = 100 – 0.001 = 99.999. See appendices no.6

Table 4.3 :Non-return valve Specification

Rated Flow	60 LPM (16 GPM)
Maximum Inlet Pressure	350 Bar (5000 PSI)
Leakage at 150 SSU (32 cSt)	2 drops/min. (.13 cc/min.) at 350 Bar (5000 PSI)
Cartridge Material	All parts steel. All operating parts hardened steel.
Operating Temp. Range/Seals	-45°C to +93.3°C ("D" Ring) (-50°F to +200°F) -31.7°C to +121.1°C (Fluorocarbon) (-25°F to +250°F)
Fluid Compatibility/ Viscosity	Mineral-based or synthetic with lubricating properties at viscosities of 45 to 2000 SSU (6 to 420 cSt)
Filtration	ISO code 16/13, SAE Class 4 or better
Approx. Weight	.09 kg (0.2 lbs.)
Cavity	C10-2 (See BC Section for more details)
Form Tool	Rougher None Finisher NFT10-2F

- Requirements for directional control valve selection :

The pressure needed to pass fluid through directional control valve should be equal to the pressure coming from the non-return valve. Figure 4.4 shows the relation between flow rate and pressure. See appendices no.7.

- Pressure p = 100Bar
- Flow rate = 57 L/m

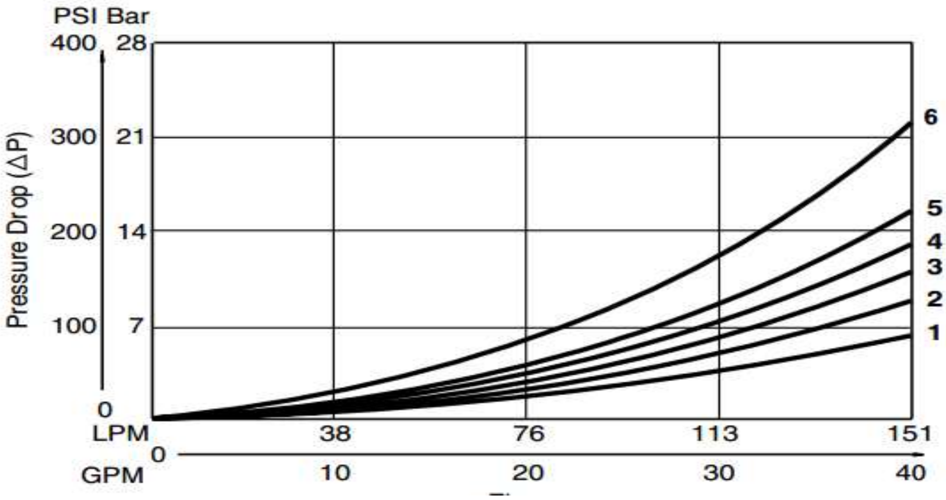


Figure 4.4 :Directional valve Curve [Khan, Q. S. & Mesh, B. E. (2002)]

4.2.7 Motor selection

Requirements for electric motor selection :

The electric motor used needs to provide rotational mechanical power and torque enough to rotate the pump.

Based on the figure 4.5, the power Loss through the system is approximately 30%

Pw in pump = $\frac{40KW}{0.7}$= 60 Kw (40KW from the table 4.2)

Hp = $\frac{60Kw}{0.746}$ = 80 HP

- Rated speed of motor 415V, 50Hz = 1500rpm
- Power = 60Kw (80HP)

Based on the previous calculations, the pump speed= 1200rpm and the electric motor speed = 1500rpm. Therefore the gearbox chosen should have a gear ratio = 2:5.

Based on the previous calculations and by looking at the specifications table (4.4) of Monarch brand, The best choice is an induction motor (75Kw).

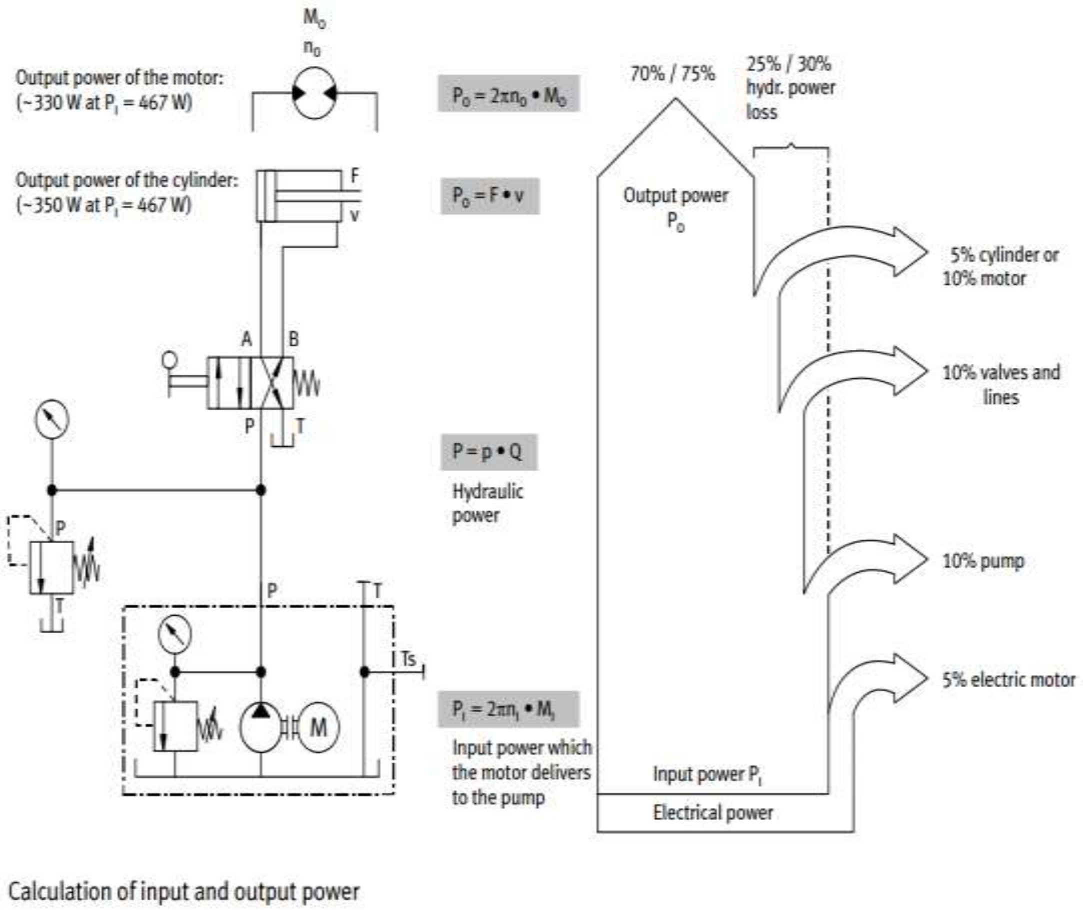


Figure 4.5 :Power Lose Diagram [Khan, Q. S. & Mesh, B. E. (2002)]

Table4.4 : motor selection

CAST IRON TEFC 3 - PHASE SQUIRREL CAGE INDUCTION MOTORS
MONARCH GX RANGE 80 - 400L FRAME (415V 50Hz)

OUT PUT kW	FULL LOAD RPM	FRAME NO.	EFFICIENCY			POWER FACTOR			CURRENT		TORQUE			INERTIA	dB(A)	WEIGHT foot mount (kg)
			FULL LOAD (%)	3/4 LOAD (%)	1/2 LOAD (%)	FULL LOAD (%)	3/4 LOAD (%)	1/2 LOAD (%)	FULL LOAD (A)	LOCKED ROTOR (%)	FULL LOAD Nm	LOCKED ROTOR %FLT	BREAK DOWN %FLT	ROTOR J = GD2/4 kg-m2		
22	2945	180M	92.2	92.0	91.0	90.0	89.0	84.0	36.2	750	71.6	220	230	0.0808	81	176
	1470	180L	92.6	92.6	91.8	86.0	85.0	77.0	37.8	780	143	220	230	0.187	68	206
	980	200L	91.8	91.9	91.3	83.0	80.0	74.0	40.2	750	214	210	210	0.371	68	258
	735	225M	91.2	91.6	90.7	78.0	72.0	61.0	43.3	660	287	190	200	0.626	65	309
30	2955	200L	92.9	92.6	91.8	90.0	90.0	86.0	49.0	750	96.9	200	230	0.163	84	250
	1475	200L	93.2	93.5	93.0	86.0	84.0	78.0	52.8	720	195	220	230	0.285	71	255
	985	225M	92.5	92.9	92.2	84.0	81.0	73.0	52.4	710	291	210	210	0.533	68	303
	740	250M	92.1	91.8	90.7	79.0	71.0	60.0	59.3	660	388	190	200	0.914	67	401
37	2955	200L	93.3	93.0	92.3	90.0	89.0	85.0	60.6	750	120	200	230	0.172	84	258
	1480	225S	93.6	93.8	93.2	87.0	84.0	79.0	64.2	740	239	200	230	0.473	73	305
	985	250M	93.0	92.7	91.8	85.0	83.0	75.0	64.0	700	358	210	210	0.877	70	395
	741	280S	92.7	92.6	91.3	78.0	74.0	64.0	69.0	660	477	190	200	1.85	68	567
45	2970	225M	93.7	93.8	93.2	90.0	89.0	86.0	72.7	750	145	200	230	0.302	84	336
	1480	225M	93.9	93.9	93.6	87.0	85.0	80.0	78.1	740	290	220	230	0.554	73	342
	991	280S	93.5	93.7	92.6	86.0	83.0	75.0	77.0	700	434	210	200	1.85	72	567
	742	280M	93.2	93.6	92.5	79.0	76.0	66.0	84.0	660	579	190	200	2.22	68	651
55	2975	250M	94.0	94.1	93.7	90.0	90.0	86.0	89.5	750	177	200	230	0.420	85	434
	1480	250M	94.2	94.2	93.5	87.0	87.0	81.0	91.6	740	356	200	220	0.751	75	428
	990	280M	93.9	94.4	93.5	87.0	84.0	80.0	94.0	700	531	210	200	2.12	72	625
	741	315S	93.7	93.6	92.4	78.0	73.0	62.0	101	660	710	180	210	2.97	74	1000
75	2979	280SA	94.6	94.4	92.6	90.0	89.0	84.0	121	750	241	200	230	0.986	86	616
	1485	250M***	94.7	94.5	93.4	88.0	88.0	83.0	127	740	483	220	230	0.824	78	515
	1487	280S	94.7	95.2	94.4	87.0	84.0	76.0	127	720	482	220	230	1.92	78	657
	989	315S	94.4	94.1	93.3	85.0	80.0	73.0	128	700	729	200	200	2.61	77	990
	741	315M	94.4	94.2	93.3	79.0	75.0	65.0	136	660	967	180	200	3.96	74	1100
90	2978	280M	94.8	94.5	92.8	91.0	90.0	88.0	145	750	289	200	230	1.04	86	660
	1486	280M	95.0	95.2	94.4	87.0	84.0	77.0	151	720	579	220	230	2.32	78	748
	988	315M	94.8	94.9	94.5	86.0	83.0	76.0	153	700	872	200	200	3.04	77	1080
	741	315L	94.7	94.6	93.8	81.0	77.0	68.0	161	660	1161	180	200	4.65	74	1160
110	2980	280M***	95.1	95.4	94.9	92.0	91.0	90.0	177	710	353	180	220	1.30	86	755
	2975	315S	95.1	94.8	93.1	92.0	91.0	89.0	177	710	353	180	220	1.33	88	980
	1486	280M***	95.3	95.3	94.6	88.0	86.0	79.0	185	720	708	220	230	2.47	85	780
	1489	315S	95.3	95.2	94.3	89.0	89.0	84.0	182	690	706	210	220	2.34	85	1000
	989	315L	95.1	95.1	94.4	86.0	83.0	76.0	187	670	1062	200	200	3.71	77	1150
	741	315L	95.1	94.8	94.1	81.0	79.0	72.0	196	660	1422	180	200	5.40	74	1230
132	2978	315M	95.4	95.2	94.1	91.0	89.0	84.0	211	710	423	180	220	1.50	88	1080
	1488	315M	95.5	95.5	94.7	89.0	88.0	84.0	219	690	847	210	220	2.58	85	1100
	988	315L	95.4	95.8	95.0	87.0	85.0	79.0	223	670	1275	200	200	4.24	77	1210
	742	355M	95.4	95.5	94.7	82.0	78.0	67.0	235	640	1700	180	200	8.36	82	1700
160	2978	315L	95.5	95.2	94.3	90.0	89.0	84.0	256	710	513	180	220	1.67	91	1160
	1488	315L	95.7	95.9	95.1	90.0	88.0	80.0	261	690	1028	210	220	2.96	89	1160
	991	355M	95.6	95.7	95.4	87.0	86.0	80.0	265	670	1544	190	200	7.44	84	1650
	742	355M	95.7	95.6	95.1	82.0	79.0	72.0	284	640	2061	180	200	9.59	82	1750
200	2978	315L	95.6	95.7	95.2	91.0	90.0	84.0	320	710	641	180	220	1.88	87	1190
	1487	315L	95.5	95.6	95.0	89.0	88.0	84.0	328	690	1284	200	220	3.46	89	1270
	990	355M	95.6	95.7	95.2	88.0	87.0	82.0	331	670	1929	190	200	9.10	84	1750
	741	355L	95.7	95.8	95.3	82.0	81.0	75.0	355	640	2570	180	200	11.30	73	1850

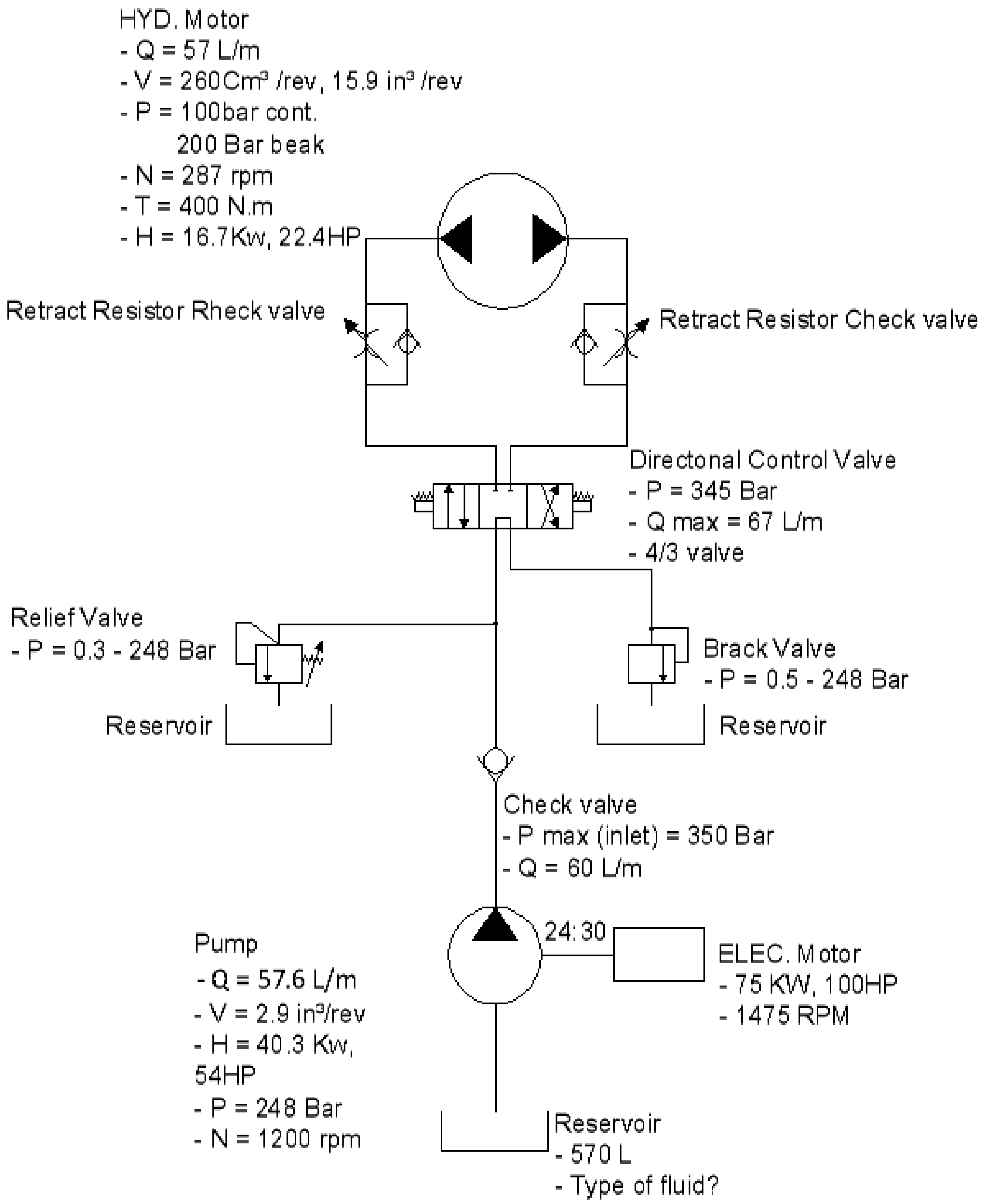


Figure 4.6 :Hydraulic Motor Diagram with values [by AutoCAD]

4.3Roller Conveyor & Conveyor Belt Selection

The figure 4.1 shows two combined systems including a conveyor belt and a roller conveyor that works for a car with a maximum load of 2.5 ton. Calculations need to be made to select and specify the size of all system components correctly. The given values below will be used as the basic requirements to design and calculate the system:

4.3.1Given:

- *weight of car = 2 ton =* <u>*2000Kg*</u>
- *total load (m)* = 2*1.25 = 2.5 ton = 2500 Kg
- *Car dimension = 2.5 * 3*
- *Speed Required (S) =* <u>*0.5 m/s*</u>
- *Conveyor length = 8 m*

The conveyor is used to convey different materials from one location to another. The different components of a conveyor system typically are electric drives, pulleys, idlers or long belt. To select the motor that moves the car on the conveyor, the components of the conveyor must be chosen correctly. These components are selected based on the system capacity, length, roller dimension, belt width, speed, material, plate size … etc. Firstly start to design the plate. To design the plate the average car dimensions must be known. Table 4.5 the distance between the tires and the tire width taken as a random sample from different vehicle models:

Table4.5 : Distance between tires and tire width sample

No	Car type	Distance Between Tires (cm)	Tire Width (cm)
1	ATOS	115	18
2	COROLLA	12	18
3	CAMRY	125	19
4	SANTAFE	140	20
5	LANDCRUISER	140	25

Based on the values shown in the table 4.5, two Plates will be used with a 1 meter distance between them. The width of each plate is 0.5 meters and the length is 3 meters.

The maximum load will be applied on the two plates together. Therefore the load applied on one plate will be:

Load on one plat = $\frac{2500Kg}{2}$ = 1250Kg

The figure 4.7 shows the plate shape with full dimensions by (m) as mentioned above

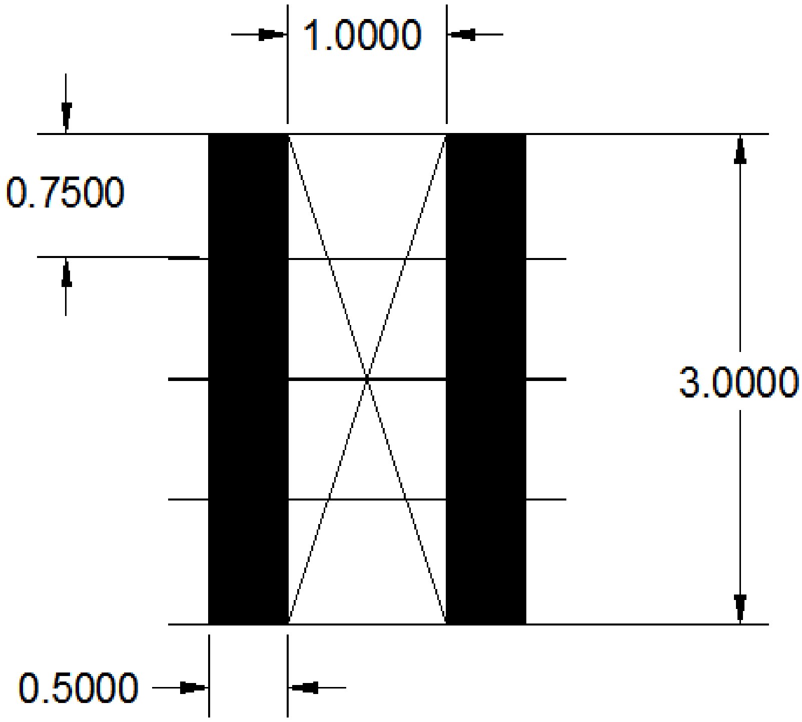


Figure 4.7 :Plate Details [by AutoCAD]

4.3.2 Roller System:

4.3.2.1 Motor selection for Conveyor in the Corridor:

To select the motor, the conveyor system should be designed. In order to design the conveyor there are a number of parameters that need to be taken in the calculation such as the dimension and weight .

The load affecting the conveyor could be found by equation (2.1):

$T_b = 1.37 * f * L * g * [2 * m_i + (2 * m_b + m_m) * \cos(\delta)] + (H * g * m_m)$. [Reported by bright hub engineering website 2010].

Two conveyors are needed in the corridor in order to move a car. Therefore the total load 2.5 ton should be divided by 2.

m_i (idler load) = 42 rollers X 5Kg/roller = 210kg

m_b = (belt load) = 0

f (friction coefficient) = 0.033

L (length) = 6 m

g = 9.8

θ = 0

H = 0

T_b = 1.37 * 0.033 * 6 * 9.8 * [2 * 210 + (1250cos0)] = 4440N = 4.44KN

Tension while starting system apply (2.3):

$T_{bs} = T_b * K_s$ (starting factor)

K_s = 1.5

T_{bs} = 4440N * 1.5 = 6660N = 6.66KN

Power at drive pulley apply (2.4):

$P_b = T_b * V$

P_b = 4440N * 0.5m/s = 2220 W = 2.22Kw

Motor size apply (2.5) :

$P_m = P_b/k_d$(Drive efficiency)

K_d = 90%

P_m = 2.22 / 0.9 = 2.46Kw = 3.3 HP

See the appendices no.8 the specification required of rollers from "Automated Conveyor Systems, Inc.". It's suitable for the conveyor of this project. Note: the value of power from the calculations above is similar to the power requirements in the specification table 4.6.

4.3.2.2 Motor selection for Conveyor in Elevator:

Two conveyors are needed in the elevator in order to move a car. Therefore, the total load 2.5 ton is divided by 2.

m_i (idler load) = 12 rollers X 5Kg/roller = 60 kg

f (friction coefficient) = 0.033

L (length) = 2m

$g = 9.8\ m/s^2$

$T_b = 1.37 * 0.033 * 2 * 9.8 * [2 * 60 + (1250\cos 0)] = 1214N$

Tension while starting system apply (2.3):

$T_{bs} = T_b * K_s$ (starting factor)

$K_s = 1.5$

$T_{bs} = 1214N * 1.5 = 1821N$

Power at drive pulley apply (2.4):

$P_b = T_b * V$

$P_b = 1214N * 0.5m/s = 607W = 0.6074Kw$

Motor size apply (2.5) :

$P_m = P_b/k_d$(Drive efficiency)

$K_d = 90\%$

P_m = 0.74 / 0.9 = 0.7Kw = 1 HP

See appendices no. 9 & 10

Table4.6 : Roller Conveyor Selection

Conveyor Length	Conveying Surface	19"	27"	29"	33"	41"	47"	53"	55"
	Between Rail Width	23"	31"	33"	37"	45"	51"	57"	59"
	Overall Frame Width	27"	35"	37"	41"	49"	55"	61"	63"
5'		792	900	927	981	1089	1170	1251	1278
10'	WEIGHTS (Lbs.)	1284	1490	1541	1644	1849	2003	2157	2208
15'		1776	2079	2155	2306	2609	2836	3063	3138
20'		2268	2668	2768	2968	3368	3668	3968	4068
25'		2760	3258	3382	3631	4128	4501	4873	4998
30'	Weights Based on 6" Roller Centers	3252	3863	4015	4320	4931	5388	5846	5998
40'		4236	5026	5223	5617	6407	6999	7590	7788
50'		5220	6204	6450	6942	7926	8664	9402	9648
60'		6204	7383	7678	8267	9446	10330	11214	11508
70'		7188	8562	8905	9592	10965	11995	13025	13368
80'		8172	9740	10132	10916	12484	13660	14836	15228
90'		9156	10918	11360	12241	14004	15236	16648	17088
100'		10140	12096	12588	13566	15524	16812	18460	18948

Load Capacity Chart

HP	HORIZONTAL CONVEYOR ROLLER BED @ 30 FPM								
	27"-38" OAW			40"-52" OAW			58"-66" OAW		
	TOTAL LOAD			TOTAL LOAD			TOTAL LOAD		
	30'	60'	90'	30'	60'	90'	30'	60'	90'
2	21000	19200	17400	20400	18000	15600	19400	16000	12500
3	27000	25200	23400	26400	24000	21600	25400	22000	18500

4.3.2.3 Number of rollers in the Elevator room:

Selection the conveyor roller depends on the dimensions of the roller (m), conveyor length (m) and roller capacity (kg).

From the data specifications the data required to specify the number of roller:

- Conveying surface = 27in = 68cm
- Length =23 foot = 7m
- Roller dimension = 3.5in = 8.89Cm

- Roller capacity =3258Ib = 1477 Kg

The number of rollers under one plate is calculated by dividing the width of the plate by the diameter of a roller :

$\frac{50Cm}{8.89Cm}$ = 5 rollers without space.

In order to keep distances between rollers three rollers are used instead than five. The capacity of three rollers 1477kg * 3 = 4231kg > 1250kg.Therefor 3 rollers are enough. See figure 4.9.

4.3.2.iv Specifying the space between two rollers:

The total Dimension of three rollers is 27Cm and the remaining space under the plate = 23Cm. In order to calculate the distance between the rollers, the total empty distance (23cm) is divided by the number of rollers. The result is divided by 2 to calculate the distance on each side of the roller.

$\frac{23Cm}{2*3roller}$ = 3.5cm and the distance between each two rollers =3.5Cm * 2 = 7Cm

Therefore the total number of rollers under the plates in the elevator room = 3rollers * 4 = 12 Rollers. Each 0.5m contains 3rollers.The figure 4.9 and figure 4.11 shows the rollers in the elevator and the plate with full details and dimensions:

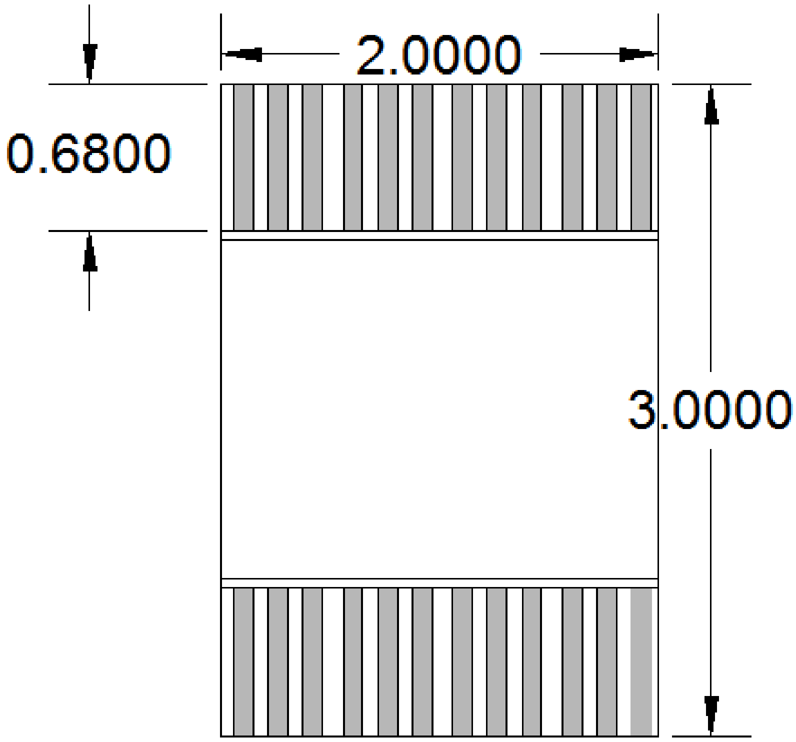


Figure 4.8 :Roller Dimension [by AutoCAD]

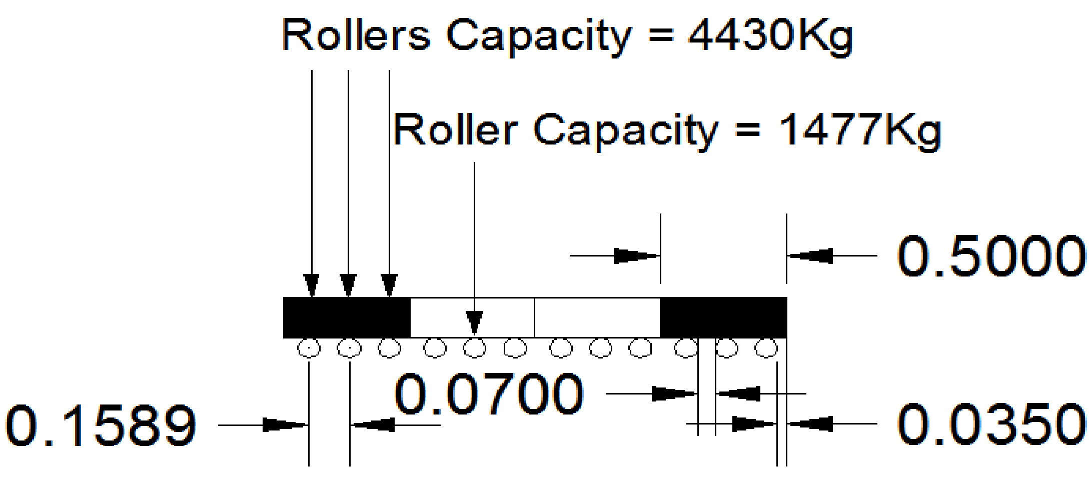


Figure 4.9 :Roller and Plate Details [by AutoCAD]

4.3.2.4 Number of rollers in a Corridor

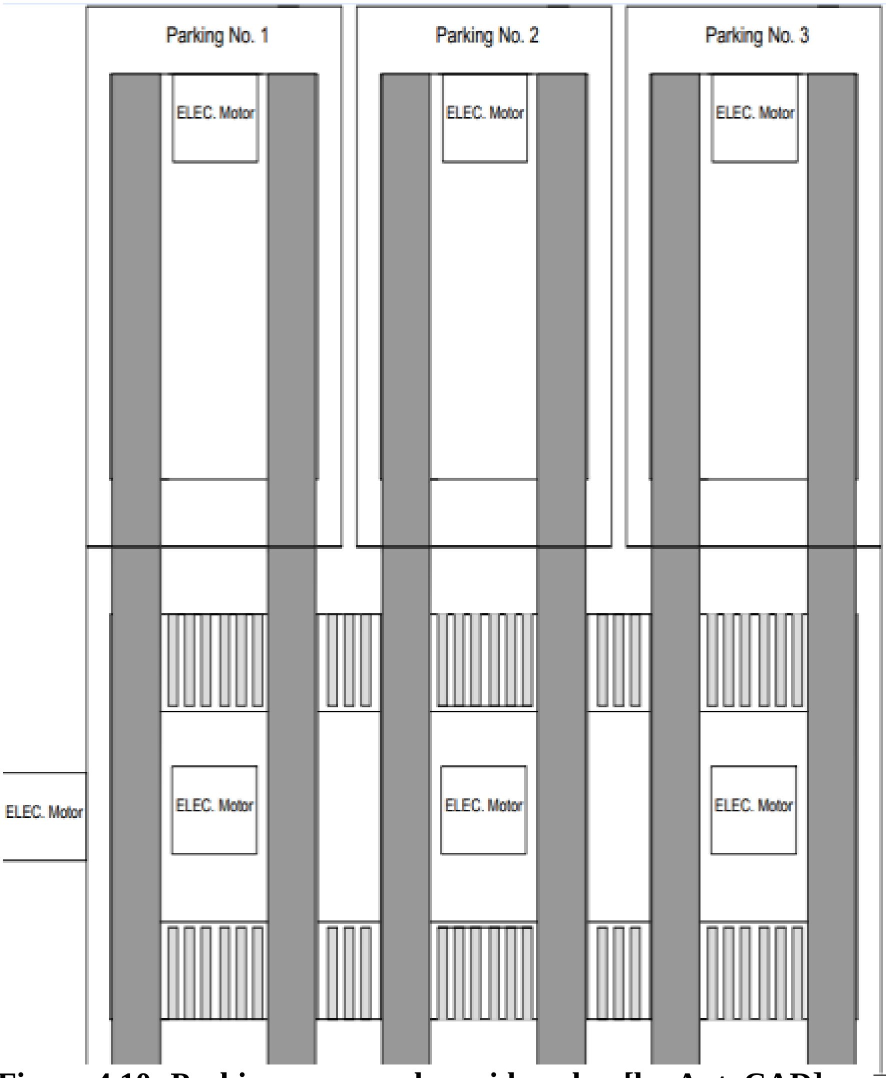


Figure 4.10 :Parking space and corridor plan [by AutoCAD]

The main movement in the corridors is to the left and right. This movement is achieved using rollers. The rollers have the same specifications, considerations, dimensions and measurements of the rollers in the elevator room. The secondary movement in this stage is transporting the car from the main corridor into the parking space. This movement is achieved by using Conveyor belts in order to move the car back and forth. Therefore, the rollers will be removed in the section of the roller conveyor that intersects with the conveyor belt.

4.3.3 Conveyor belt system:

4.3.3.1 Motor selection:

To select the motor, the conveyor system should be designed. In order to design the conveyor there are a number of parameters that need to be taken in the calculation such as weight.

The load affecting the conveyor could be found by equation (2.1):

$T_b = 1.37 * f * L * g * [2 * m_i + (2 * m_b + m_m) * \cos(\delta)] + (H * g * m_m)$. [Reported by bright hub engineering website 2010].

Two conveyor belts are used to move the car from the corridor and into the parking space. Therefore, the total load 2.5 ton is divided by 2.

m_i (idler load) = 18 roller X 5Kg/roller = 90kg

m_b = (belt load) = 30 Kg

f (friction coefficient) = 0.033 L (length) = 3 m

$g = 9.8\ m/s^2$

$\theta = 0$

H = 0

$T_b = 1.37 * 0.033 * 3 * 9.8 * [2 * 90 + (2*30 + 1250)\cos 0] = 1980N = 1.98KN$

Tension while starting system apply (2.3):

$T_{bs} = T_b * K_s$ (starting factor)

$K_s = 1.5$

T_{bs} = 1980N * 1.5 = 2970N = 2.97KN

Power at drive pulley apply (2.4):

$P_b = T_b * V$

P_b = 1980N * 0.5m/s = 990 W = 1 Kw

Motor size apply (2.5):

$P_m = P_b/k_d$(Drive efficiency)

K_d = 90%

P_m = 1 / 0.9 = 1.12Kw = 1.5 HP

Selection the conveyor belt depends on the width of the belt (m), conveyor length (m) and the belt Capacity (kg). See the table 4.7 of Conveyor belts from "titan conveyors company – London". It's suitable for the conveyors in this project. Note: the value of power in calculation is similar to the power specified in the table 4.7 : See appendix no.12

Table4.7 :Conveyor belt selection.

MAXIMUM UNIFORMLY DISTRIBUTED LIVE LOAD						
Slider Bed Belt Conveyor @60 FPM						
HP	18 - 30 in. Belt Width		36 - 48 in. Belt Width		54 - 60 in. Belt Width	
	5 - 50 ft.	55 - 100 ft.	5 - 50 ft.	55 - 100 ft.	5 - 50 ft/	55 - 100 ft.
1/2	470	60	200			
3/4	900	550	680	60	210	
1	1420	1040	1150	550	680	
1-1/2	2400	2000	2150	1500	1650	850
2	3350	2970	2800	2000	2300	1500

From the data specification the data required to specify the belt:

Belt width = 18in = 46Cm < 50Cm (available width)

Distributed Live Load (conveyor Capacity) = 3350Ib = 1519 kg > 1250Kg (given).

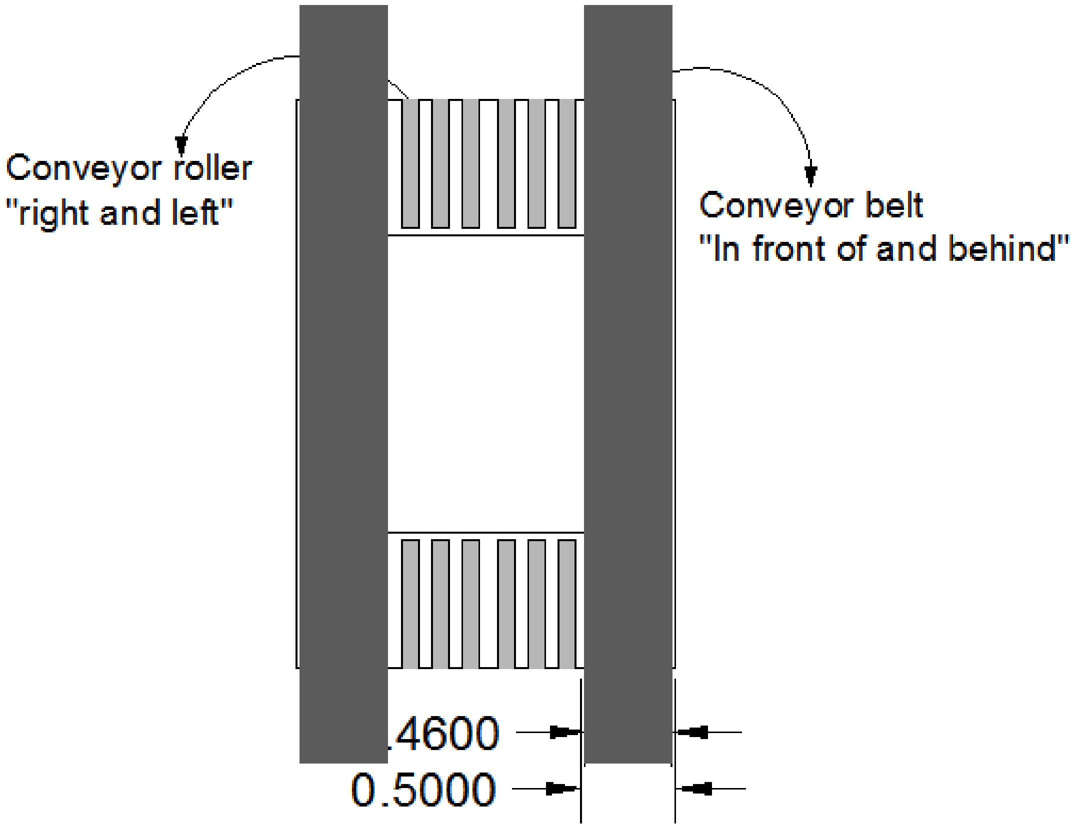


Figure 4.11 :Conveyor Belt and Roller Conveyor Details [by AutoCAD]

4.4 Electric System Design

The electric design must be done to specify the power needed to supply the parking system. To design the electric system and specify component size, the load calculation should be studied. In order to make the load calculation the designer must know all the components that consume power, how much power is consumed and number of components used. The table 4.7 shows the components of the parking system as per attached typical floor drawing in figure 4.12 , also the power consumption and the quantities.

Table4.8 :Power consumption and Quantities for building

NO.	Items	Power consumption (KW)	Quantities
1	Electric Motor for Hyd. Lift System	60	1
2	Electric Motor for main Conveyor on Corridor	5	3
3	Electric Motor for Conveyor on Elevator	0.7	1
4	Electric Motor Conveyor Belt on Corridor	1	9
5	Electric Motor for Conveyor on Parking	1	18
6	Lighting & power	10	1
7	AC& other load	50	1

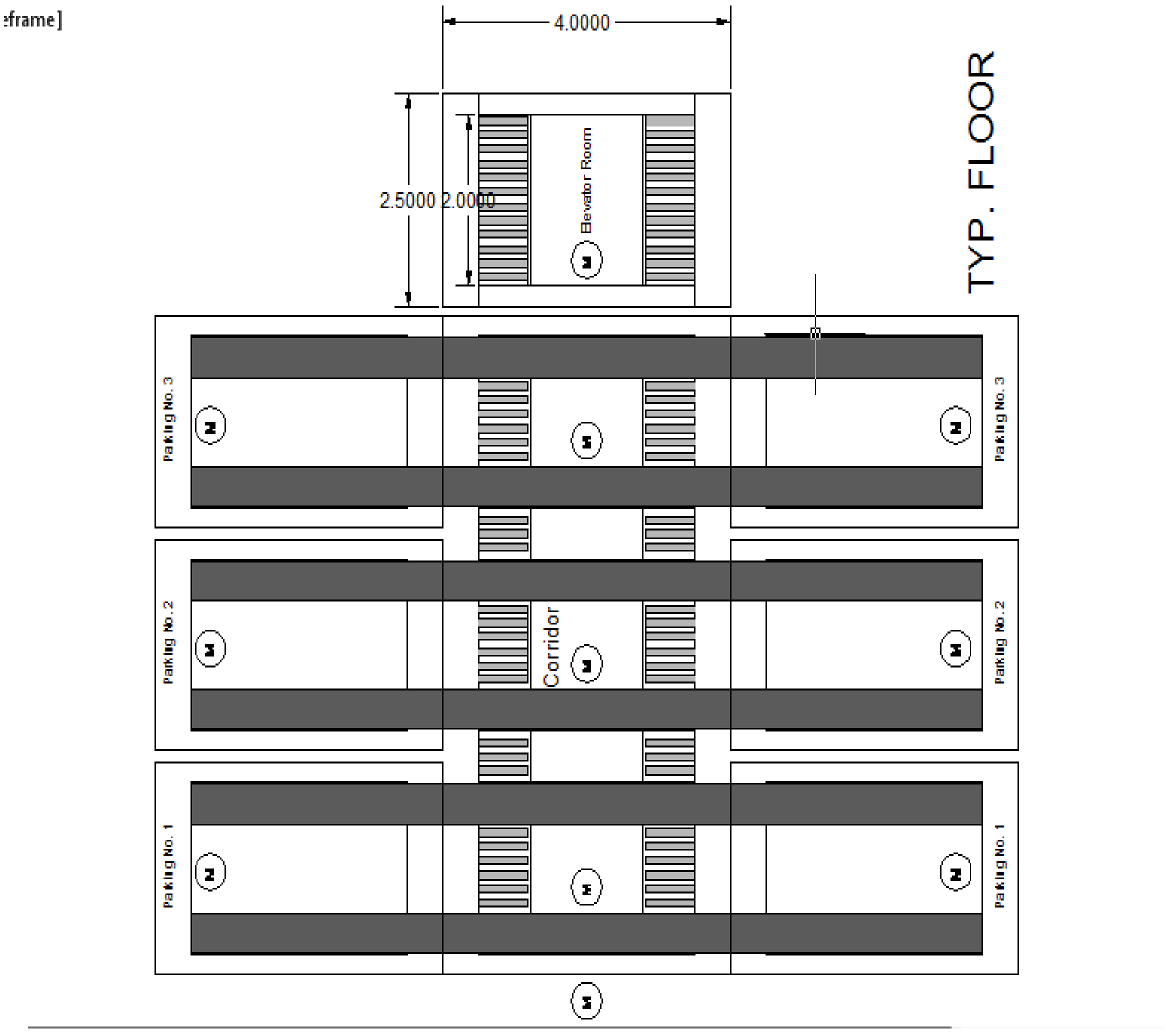


Figure 4.12 :Typical Floor Plan [by AutoCAD]

4.4.1 Curcuit breaker selection:

To calculate a curciut breaker value the follwing equation shoud be apply (2.18):

$$I\ Breaker = \frac{power(KW)}{voltXcos\phi}$$

The safety factor 1.25 should be considered for circuit breaker selection to ensure the system running in the safe mode.

So when the above equation applied on the circuits the results will be:

- rated current for Electric Motor for Hyd. Lift System = 350A
- rated current for Electric Motor for main Conveyor on Corridor = 32A
- rated current for Electric Motor for Conveyor on Elevator = 15A
- rated current for Electric Motor Conveyor Belt on Corridor = 15A
- rated current for Electric Motor for Conveyor on Parking = 15A
- rated current for Lighting & power = 125A
- rated current for AC& other load = 300A
- rated current for SMDB = 400A
- rated current for MCC = 100A
- rated current for MDB = 1250A
- rated current for capacitor bank = 800A

4.4.2 Cable selection:

To select cable size for the whole system and other devises the cable catalog should be used so results will be:

- cable size for Electric Motor for Hyd. Lift System =4CX240mm²+1CX120 mm²
- cable size for Electric Motor for main Conveyor on Corridor = 4CX16mm²+1CX16mm²
- cable size for Electric Motor for Conveyor on Elevator = 4CX10mm²+1CX10 mm²
- cable size for Electric Motor Conveyor Belt on Corridor = 4CX10mm²+1CX10mm²

- cable size for Electric Motor for Conveyor on Parking = 4CX10mm²+1CX10 mm²
- cable size for Lighting & power = 4CX50mm²+1CX25 mm²
- cable size for AC& other load = 4CX185mm²+1CX95 mm²
- cable size for SMDB = 4CX300mm²+1CX150 mm²
- cable size for MCC = 4CX35mm²+1CX16 mm²
- cable size for MDB = 2(4CX630mm²)+2(1CX300 mm²)
- cable size for capacitor bank =2(4CX300mm²)+2(1CX150 mm²)

4.4.3 Capacitor bank selection:

The capacitor bank used to reduce the extra active power consumption and to reduce the cost also.

To calculate the capacitor KVAR equation below shoud be apply:

KVAR = KVA sinθ … (4.12)

CB = 105 KVR

4.4.4 Power selection:

Now the main power needed to operate the system should calculate by using the following equation:

KVA = V . I … (4.13)

Or KVA = $\frac{KW}{cos\theta}$ (4.14)

P = 204 KVA

The size of cables and circuit breakers shown above will be used in the final distribution board. For arrangement purposes sub distribution board will be used and the loads related to each other will be placed in same distribution board.

It is better to draw a Single line diagram to describe the complete system and show all the system components and their sizes in a simple diagram. See the figure 4.13 the single line diagram for the SMDB and 4.14 the single line diagram MCC for motors.

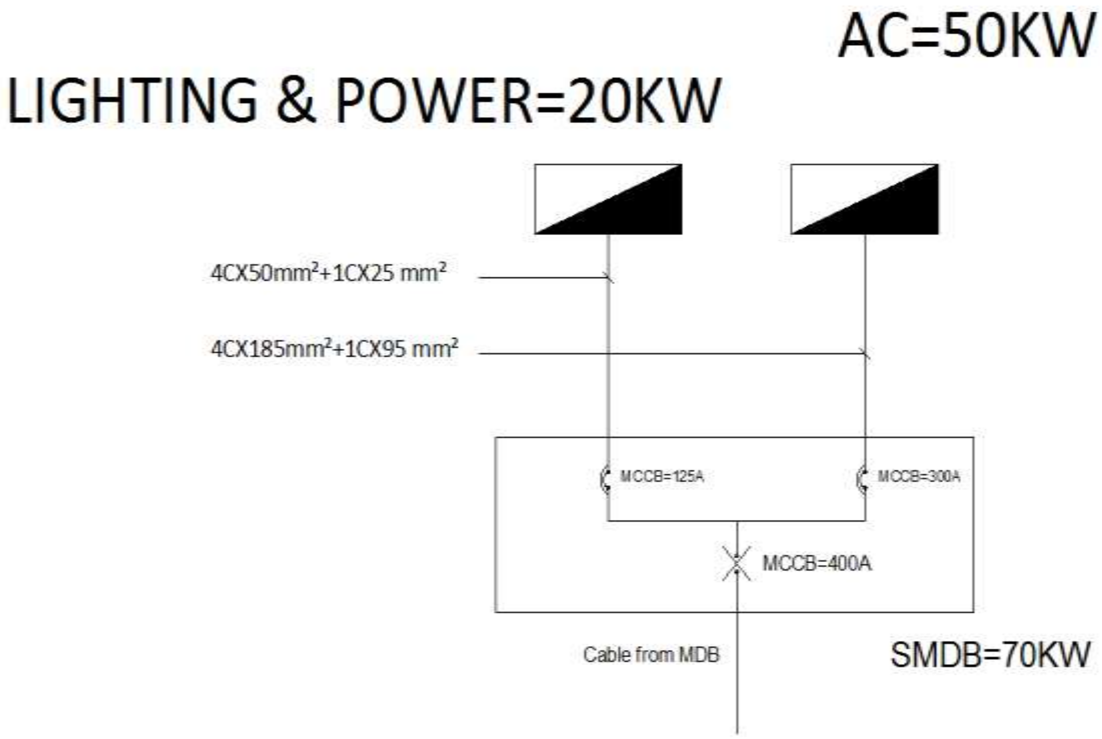


Figure 4.13 :SMDB Diagram [by AutoCAD]

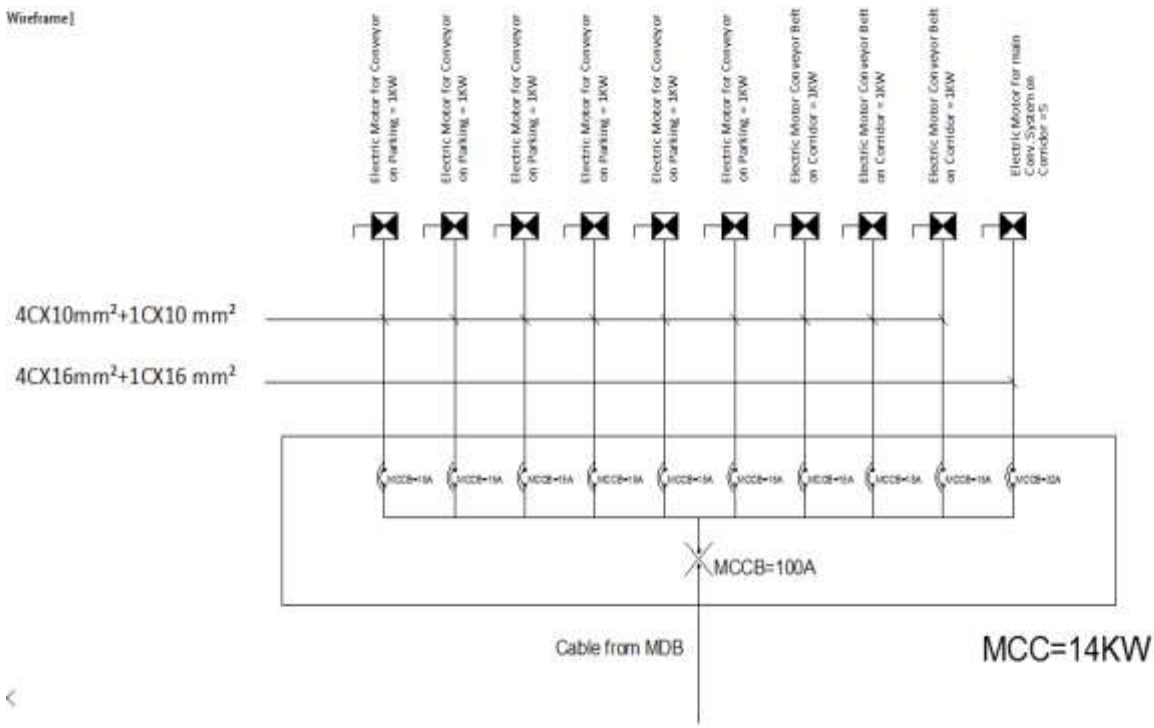


Figure 4.14 :MCC Diagram [by AutoCAD]

Finally, it is better to draw the complete single line diagram as a power riser that describes all sections of the electric system and how they relate to each other. This makes the system more simple and easy to follow and understand. So the main system components such as the main circuit breaker, the main cable, the transformer, the generator and the MDB must be determined. The diagram 4.15 shows the main system details in single line diagram.

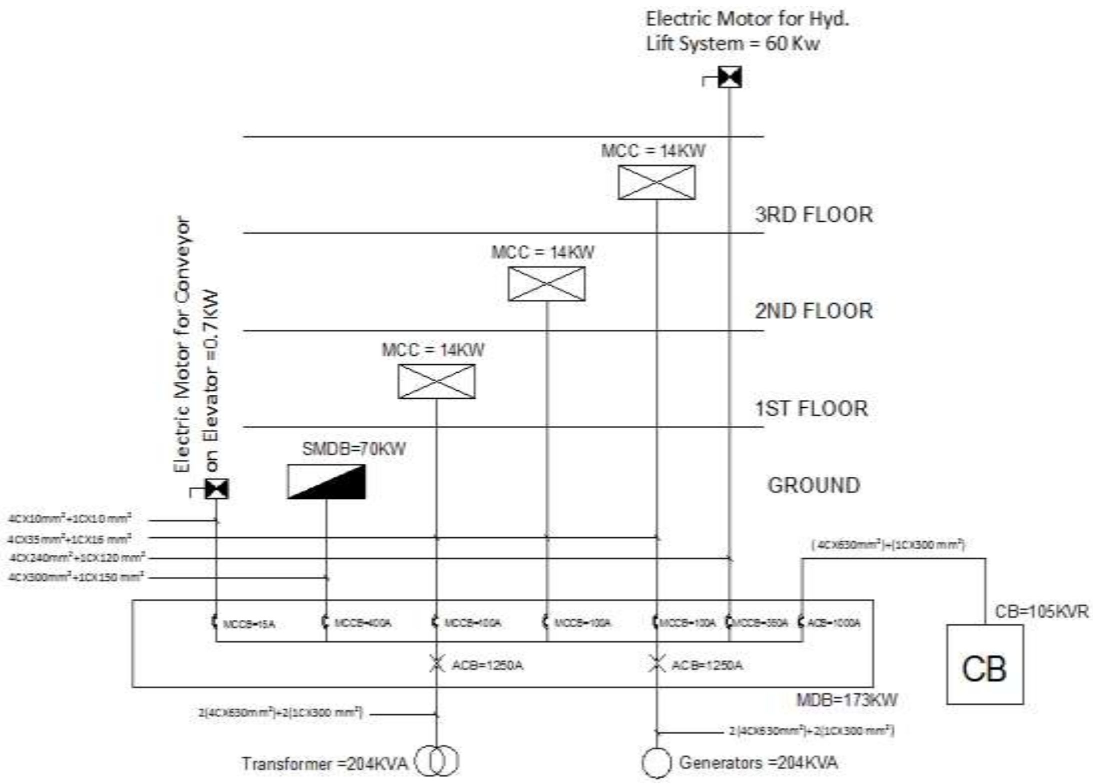


Figure 4.15 :MDB Diagram[by AutoCAD]

CHAPTER FIVE

SYSTEM DESIGN THROUGH SIMULATION

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SYSTEM DESIGN THROUGH SIMULATION

5.1 System Design

Programmable Logic Controller (PLC) has been used to control the system. The control system always contain two section, hardware and software. The hardware usually mean the installation and wiring such as the figure 5.1 below. The software usually mean the programming.

Hard ware :

S7-300 – SIEMENS brand – has been selected as controller in our project design for many reasons :

Most common brand and available in local market.

High reliability product.

Availability of spare part.

From the mechanical design side This controller consider as Rak Modular type. PLC manufacture classifying the controller to two type, single box and modular – rak. So the designer should to be select the appropriate rak, appropriate power supply, appropriate central processing unit, appropriate inputs & output, appropriate communication unit and any other units. The rak-modular type is suitable and usually used for big and complicated projects such as our project. So the items has been selected in this project are:

- Mater rak modular contain. Figure 5.1 :
    - PS 307 10A, order no. 6ES7 307-1KA00-0

- CPU 315-2 DP order no. 6ES7 315-2AF01-0AB0
- DP

- Local rak modular address 5 IM 153-1. Figure 5.2
  - DI16/DO16x24v/0.5A, order no. 6ES7 323-1PL00 -0AA0
  - DI16/DO16x24v/0.5A, order no. 6ES7 323-1PL00 -0AA0
  - DI8/DO8x24v/0.5A, order no. 6ES7 323-1PH00 -0AA0
- Local rak modular address 6 IM 153-1. Figure 5.3
  - DI16/DO16x24v/0.5A, order no. 6ES7 323-1PL00 -0AA0
  - DI16/DO16x24v/0.5A, order no. 6ES7 323-1PL00 -0AA0
  - DI8/DO8x24v/0.5A, order no. 6ES7 323-1PH00 -0AA0
- Local rak modular address 7 IM 153-1. Figure 5.4
  - DI16/DO16x24v/0.5A, order no. 6ES7 323-1PL00 -0AA0
  - DI16/DO16x24v/0.5A, order no. 6ES7 323-1PL00 -0AA0
  - DI8/DO8x24v/0.5A, order no. 6ES7 323-1PH00 -0AA0

Because the system is complicated, more than one local rak have been selected. Therefore the profibus DB also has been selected to link between the master rak and local rak. Profibus DB is appropriate communication technique for this project as per manufacture recommendation.

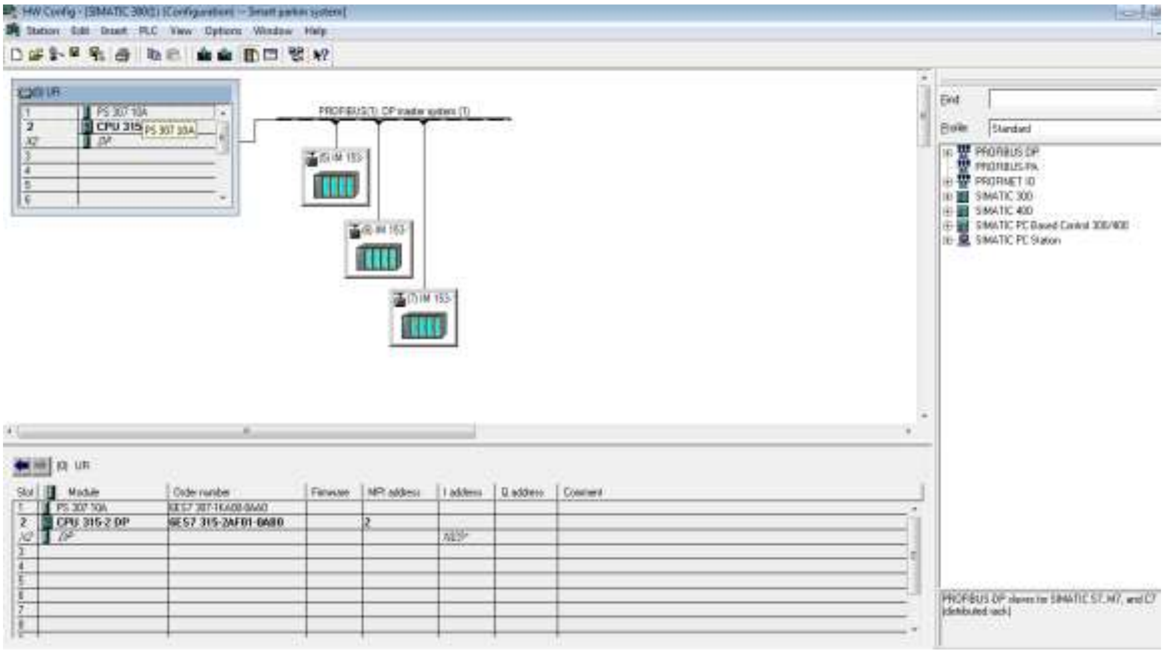


Figure 5.1 : Mater rak modular

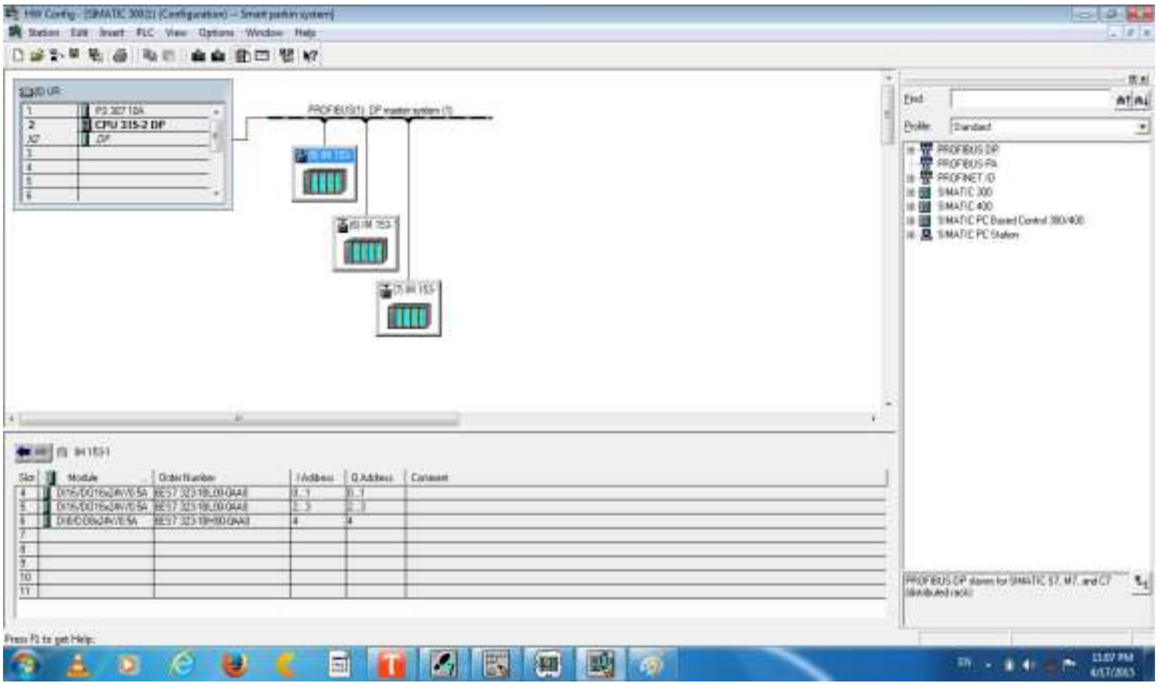


Figure 5.2 : Local rak modular address 5 IM 153-1

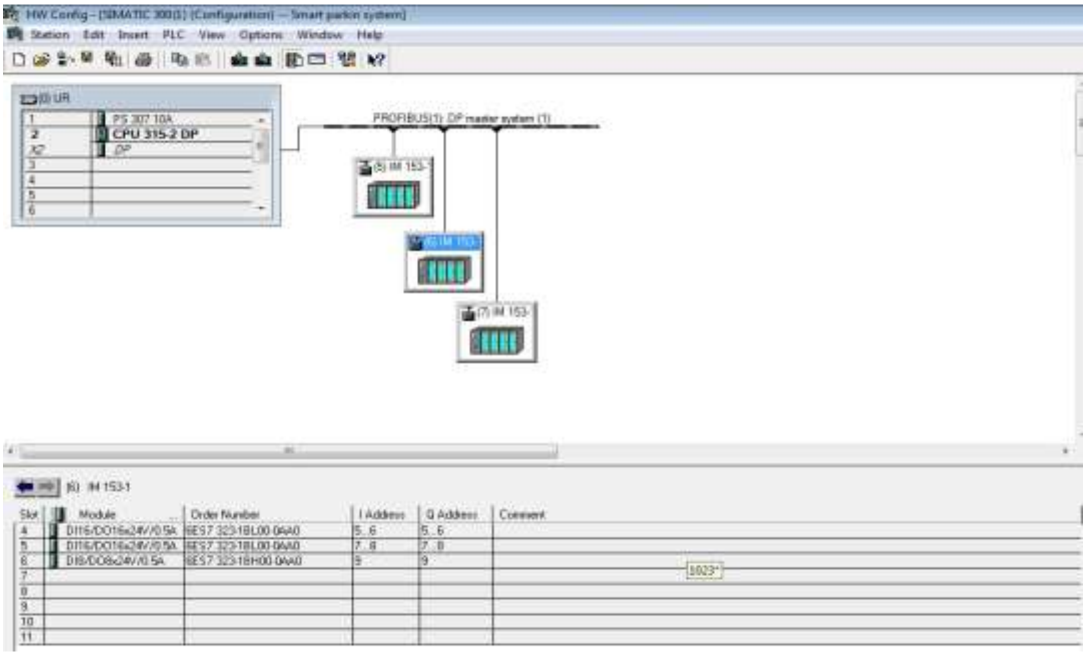


Figure 5.3 : Local rak modular address 6 IM 153-1

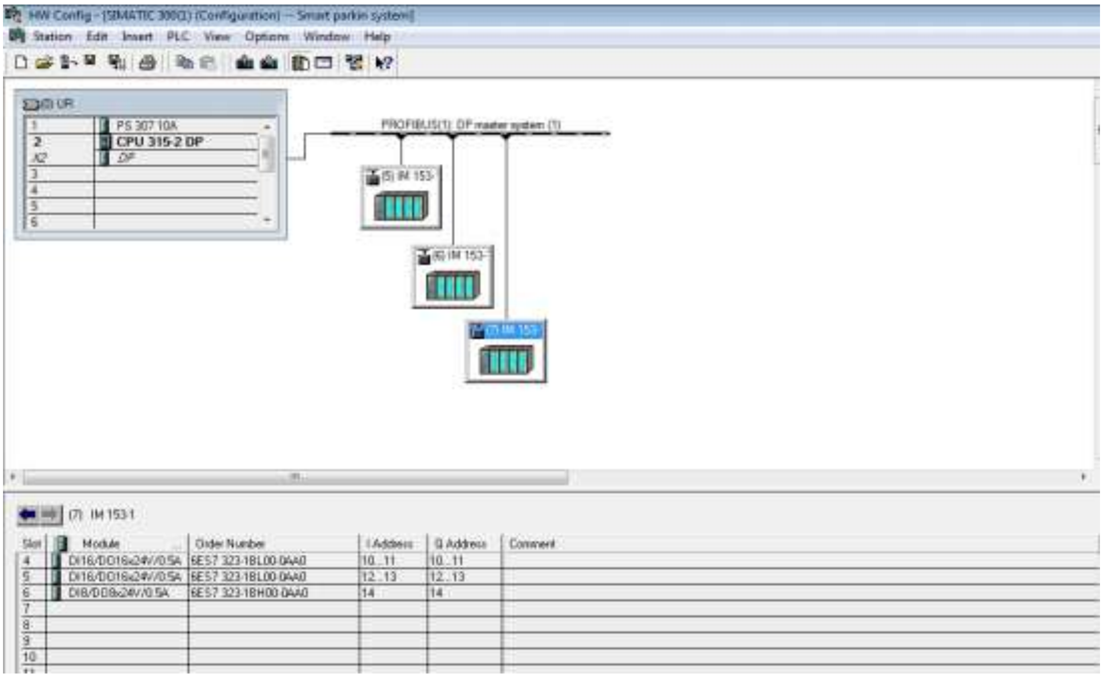


Figure 5.4 : Local rak modular address 7 IM 153-1

5.2 Software

To starting the system Programming, the system work plan should to be clear for programmer. Below the work plan for smart parking system has been written to explain how to operate a system and to help us to write a software program.

5.2.1 operation plan :

A. Parking operation

1. Firstly the car press on a limit switch which is located before the main entrance gate. And then the driver should press a push button to open the gate and to put the car inside lift.
2. A photo sensor which is fixed inside the life sense the car .and then the driver should close customer door lock and also press on push button switch which is located near costumer door to close main entrance gate.
3. After closing the main gate completely, the left will start immediately and it will move up to the first vacant parking available. Searching for parking will arranged to be from down floors to up floors one by one.
4. When the lift reach to floor, a proximity sensors which is located in each floor will sense the lift. And the lift roller conveyor and main corridor roller conveyor will start work forward from the lift to corridor.
5. While the care moving over the conveyor roller the photo sensor which is located on the corridor and opposite the parking, will sense the care. The cylinder in the corridor between the two opposite parking, cylinder in the vacant parking which specified to receive a car, conveyor belt in the corridor between the two opposite parking and the conveyor belt in the vacant parking will start work forward from the corridor to parking space.

6. A photo sensor which is located inside the parking will sense the car, now the system finish the parking operation successfully and all machine that operate the system will stop.

B. Call operation

7. For car calling the driver should press push button switch. Each parking space has a separate call push button switch. This calling will operate conveyor belt in the corridor between the two opposite parking and the conveyor belt inside the parking reversely, and also operate the cylinder in the corridor between the two opposite parking and cylinder inside the parking. Now the car will move out the parking.
8. A photo sensor which is located in the corridor will sense the car. At the same time the lift will move up to receive a car from the specified floor. When the lift reach to the floor a proximity sensor will sense the lift.
9. The lift roller conveyor and the main corridor roller conveyor will start work reversely. Then the car will move to lift. And the photo sensor which is located inside the lift will sense the car.
10. Now the lift will move down to main entrance. The main gate will open to exit the car. Now and all machine that operate the system will stop.
11. After the car going out, the photo sensor will lose the signal and the main entrance gate will close. Now the system finish the call operation successfully.

After the work plan became cleared for the programmer. Writing program should to start. And to start, the input and output should to be Known and specified. As shown in table 5.1:

Table 5.1 : Input & Output parameter.

Comment	Datatype	A	Symbol	S
	BOOL	M	Call	
CylinderinparkingA floor1tohold Car	BOOL	Q	CDN.A1	
CylinderinparkingA floor2tohold Car	BOOL	Q	CDN.A2	
CylinderinparkingA floor3tohold Car	BOOL	Q	CDN.A3	
CylinderbetweenparkingA,Bfloor2tohold Car	BOOL	Q	CDN.AB2	
CylinderbetweenparkingA,Bfloor3tohold Car	BOOL	Q	CDN.AB3	
CylinderinparkingB floor1tohold Car	BOOL	Q	CDN.B1	
CylinderinparkingB floor2tohold Car	BOOL	Q	CDN.B2	
CylinderinparkingB floor3tohold Car	BOOL	Q	CDN.B3	
CylinderinparkingC floor1tohold Car	BOOL	Q	CDN.C1	
CylinderinparkingC floor2tohold Car	BOOL	Q	CDN.C2	
CylinderinparkingC floor3tohold Car	BOOL	Q	CDN.C3	
CylinderbetweenparkingC,Dfloor1tohold Car	BOOL	Q	CDN.CD1	
CylinderbetweenparkingC,Dfloor2tohold Car	BOOL	Q	CDN.CD2	
CylinderbetweenparkingC,Dfloor3tohold Car	BOOL	Q	CDN.CD3	
CylinderinparkingD floor1tohold Car	BOOL	Q	CDN.D1	
CylinderinparkingD floor2tohold Car	BOOL	Q	CDN.D2	
CylinderinparkingD floor3tohold Car	BOOL	Q	CDN.D3	
CylinderinparkingE floor1tohold Car	BOOL	Q	CDN.E1	
CylinderinparkingE floor2tohold Car	BOOL	Q	CDN.E2	
CylinderinparkingE floor3tohold Car	BOOL	Q	CDN.E3	
CylinderbetweenparkingE,Ffloor1tohold Car	BOOL	Q	CDN.EF1	
CylinderbetweenparkingE,Ffloor2tohold Car	BOOL	Q	CDN.EF2	
CylinderbetweenparkingE,Ffloor3tohold Car	BOOL	Q	CDN.EF3	
CylinderinparkingF floor1tohold Car	BOOL	Q	CDN.F1	
CylinderinparkingF floor2tohold Car	BOOL	Q	CDN.F2	
CylinderinparkingF floor3tohold Car	BOOL	Q	CDN.F3	
	BOOL	M	cilndera	
	BOOL	M	cilnderab	
CylinderbetweenparkingA,Bfloor1tohold Car	BOOL	Q	CND.AB1	
ConvayorbeltinparkingA floor1tomovescarforward	BOOL	Q	CONVB.A	
ConvayorbeltinparkingA floor2tomovescarforward	BOOL	Q	CONVB.A	
ConvayorbeltinparkingA floor3tomovescarforward	BOOL	Q	CONVB.A	
ConvayorbeltinparkingA floor1tomovescarreverse	BOOL	Q	CONVB.A	
ConvayorbeltinparkingA floor2tomovescarreverse	BOOL	Q	CONVB.A	
ConvayorbeltinparkingA floor3tomovescarreverse	BOOL	Q	CONVB.A	
ConvayorbeltbetweenparkingA,Bfloor1tomovescarforward	BOOL	Q	CONVB.A	
ConvayorbeltbetweenparkingA,Bfloor2tomovescarforward	BOOL	Q	CONVB.A	
ConvayorbeltbetweenparkingA,Bfloor3tomovescarforward	BOOL	Q	CONVB.A	
ConvayorbeltbetweenparkingA,B floor1tomovescarreverse	BOOL	Q	CONVB.A	
ConvayorbeltbetweenparkingA,B floor2tomovescarreverse	BOOL	Q	CONVB.A	
ConvayorbeltbetweenparkingA,B floor3tomovescarreverse	BOOL	Q	CONVB.A	
ConvayorbeltinparkingB floor1tomovescarforward	BOOL	Q	CONVB.B	
ConvayorbeltinparkingB floor2tomovescarforward	BOOL	Q	CONVB.B	
ConvayorbeltinparkingB floor3tomovescarforward	BOOL	Q	CONVB.B	
ConvayorbeltinparkingB floor1tomovescarreverse	BOOL	Q	CONVB.B	
ConvayorbeltinparkingB floor2tomovescarreverse	BOOL	Q	CONVB.B	
ConvayorbeltinparkingB floor3tomovescarreverse	BOOL	Q	CONVB.B	
ConvayorbeltinparkingC floor1tomovescarforward	BOOL	Q	CONVB.C	
Convayor belt inparking C floor 2to moves carforward	BOOL	Q	CONVB.C	

Convayor belt inparking C floor 3to moves carforward	BOOL	Q 1	CONVB.C .FW.3	
Convayor belt inparking C floor 1to moves carreverse	BOOL	Q	CONVB.C	
Convayor belt inparking C floor 2to moves carreverse	BOOL	Q	CONVB.C	
Convayor belt inparking C floor 3to moves carreverse	BOOL	Q	CONVB.C	
Convayor belt between parking C,D floor 1to moves	BOOL	Q	CONVB.C	
Convayor belt between parking C,D floor 2to moves	BOOL	Q	CONVB.C	
Convayor belt between parking C,D floor 3to moves	BOOL	Q	CONVB.C	
Convayor belt between parking C,D floor 1to moves	BOOL	Q	CONVB.C	
Convayor belt between parking C,D floor 2to moves	BOOL	Q	CONVB.C	
Convayor belt between parking C,D floor 3to moves	BOOL	Q	CONVB.C	
Convayor belt inparking D floor 1to moves carforward	BOOL	Q	CONVB.	
Convayor belt inparking D floor 2to moves carforward	BOOL	Q	CONVB.	
Convayor belt inparking D floor 3to moves carforward	BOOL	Q	CONVB.	
Convayor belt inparking D floor 1to moves carreverse	BOOL	Q	CONVB.	
Convayor belt inparking D floor 2to moves carreverse	BOOL	Q	CONVB.	
Convayor belt inparking D floor 3to moves carreverse	BOOL	Q	CONVB.	
Convayor belt inparking E floor 1to moves carforward	BOOL	Q	CONVB.E	
Convayor belt inparking E floor 2to moves carforward	BOOL	Q	CONVB.E	
Convayor belt inparking E floor 3to moves carforward	BOOL	Q	CONVB.E	
Convayor belt inparking E floor 1to moves carreverse	BOOL	Q	CONVB.E	
Convayor belt inparking E floor 2to moves carreverse	BOOL	Q	CONVB.E	
Convayor belt inparking E floor 3to moves carreverse	BOOL	Q	CONVB.E	
Convayor belt between parking E,F floor 1to moves	BOOL	Q	CONVB.E	
Convayor belt between parking E,F floor 2to moves	BOOL	Q	CONVB.E	
Convayor belt between parking E,F floor 3to moves	BOOL	Q	CONVB.E	
Convayor belt between parking E,F floor 1to moves	BOOL	Q	CONVB.E	
Convayor belt between parking E,F floor 2to moves	BOOL	Q	CONVB.E	
Convayor belt between parking E,F floor 3to moves	BOOL	Q	CONVB.E	
Convayor belt inparking F floor 1to moves carforward	BOOL	Q	CONVB.F	
Convayor belt inparking F floor 2to moves carforward	BOOL	Q	CONVB.F	
Convayor belt inparking F floor 3to moves carforward	BOOL	Q	CONVB.F	
Convayor belt inparking F floor 1to moves carreverse	BOOL	Q	CONVB.F	
Convayor belt inparking F floor 2to moves carreverse	BOOL	Q	CONVB.F	
Convayor belt inparking F floor 3to moves carreverse	BOOL	Q	CONVB.F	
Gate No. 1Forward	BOOL	Q	G1.FW	
Gate No. 1Reverse	BOOL	Q	G1.RV	
Hydraulic Motor No. 1	BOOL	Q	HYD.M1	
Customer Door No.1	BOOL	I	LOC.1	
elevater1 bottom limitswitch	BOOL	I	LS.B	
Limitswitch to open gate No. 1	BOOL	I	LS.G1	
ButtomLimitswitch gateNo.1	BOOL	I	LS.G1.B	
Top Limitswitch gate No. 1	BOOL	I	LS.G1.T	
m/open G	BOOL	M	m/open G	
Call Posh botton forparking No. 1	BOOL	I	PB.C.1	
Call Posh botton forparking No. 10	BOOL	I	PB.C.10	
Call Posh botton forparking No. 11	BOOL	I	PB.C.11	
Call Posh botton forparking No. 12	BOOL	I	PB.C.12	
Call Posh botton forparking No. 13	BOOL	I	PB.C.13	
Call Posh botton forparking No. 14	BOOL	I	PB.C.14	
Call Posh botton forparking No. 15	BOOL	I	PB.C.15	
Call Posh botton forparking No. 16	BOOL	I	PB.C.16	
Call Posh botton forparking No. 17	BOOL	I	PB.C.17	
Call Posh botton forparking No. 18	BOOL	I	PB.C.18	

Call Posh botton forparking No. 2	BOOL	I 3.	PB.C.2	
Call Posh botton forparking No. 3	BOOL	I	PB.C.3	
Call Posh botton forparking No. 4	BOOL	I	PB.C.4	
Call Posh botton forparking No. 5	BOOL	I	PB.C.5	
Call Posh botton forparking No. 6	BOOL	I	PB.C.6	
Call Posh botton forparking No. 7	BOOL	I	PB.C.7	
Call Posh botton forparking No. 8	BOOL	I	PB.C.8	
Call Posh botton forparking No. 9	BOOL	I	PB.C.9	
Posh pottom gate No. 1to open main gate	BOOL	I	PB.G1.1	
Posh pottom gate No. 1to operate lift	BOOL	I	PB.G1.2	
Posh pottom gate No. 2to open main gate	BOOL	I	PB.G2.1	
Posh pottom gate No. 2to operate lift	BOOL	I	PB.G2.2	
Main roller convayor Motor floor No. 1	BOOL	Q	RL.M.F1.	
Main roller convayor Motor RV floor No. 1	BOOL	Q	RL.M.F1.	
Main roller convayor Motor FW floor No. 2	BOOL	Q	RL.M.F2.	
Main roller convayor Motor RV floor No. 2	BOOL	Q	RL.M.F2.	
Main roller convayor Motor FW floor No. 3	BOOL	Q	RL.M.F3.	
Main roller convayor Motor RV floor No. 3	BOOL	Q	RL.M.F3.	
Lift roller conayorNo. 1forward	BOOL	Q	RL.M.G1.	
Lift roller conayorNo. 1reverse	BOOL	Q	RL.M.G1.	
Lift roller convayorNo.2 forward	BOOL	Q	RL.M.G2.	
Lift roller convayorNo.2 reverse	BOOL	Q	RL.M.G2.	
Photo sensor Parking A floor No. 1	BOOL	I	S.A1	
Photo sensor Parking A floor No. 2	BOOL	I	S.A2	
Photo sensor Parking A floor No.3	BOOL	I	S.A3	
Photo sensor btween Parking A,B floor No.1	BOOL	I	S.AB1	
Photo sensor btween Parking A,B floor No.2	BOOL	I	S.AB2	
Photo sensor btween Parking A,B floor No.3	BOOL	I	S.AB3	
Photo sensor Parking B floor No.1	BOOL	I	S.B1	
Photo sensor Parking B floor No.2	BOOL	I	S.B2	
Photo sensor Parking B floor No.3	BOOL	I	S.B3	
Photo sensor Parking C floor No.1	BOOL	I	S.C1	
Photo sensor Parking C floor No.2	BOOL	I	S.C2	
Photo sensor Parking C floor No.3	BOOL	I	S.C3	
Photo sensor btween Parking C,D floor No.1	BOOL	I	S.CD1	
Photo sensor btween Parking C,D floor No.2	BOOL	I	S.CD2	
Photo sensor btween Parking C,D floor No.3	BOOL	I	S.CD3	
Photo sensor Parking D floor No.1	BOOL	I	S.D1	
Photo sensor Parking D floor No.2	BOOL	I	S.D2	
Photo sensor Parking D floor No.3	BOOL	I	S.D3	
Photo sensor Parking E floor No.1	BOOL	I	S.E1	
Photo sensor Parking E floor No.2	BOOL	I	S.E2	
Photo sensor Parking E floor No.3	BOOL	I	S.E3	
Photo sensor btween Parking E,F floor No.1	BOOL	I	S.EF1	
Photo sensor btween Parking E,F floor No.2	BOOL	I	S.EF2	
Photo sensor btween Parking E,F floor No.3	BOOL	I	S.EF3	
proxmity sensor Floor No.1	BOOL	I	S.F.1	
proxmity sensor Floor No.2	BOOL	I	S.F.2	
proxmity sensor Floor No.3	BOOL	I	S.F.3	
Photo sensor Parking A floor 1	BOOL	I	S.F1	
Photo sensor Parking A floor 1	BOOL	I	S.F2	
Photo sensor Parking A floor 1	BOOL	I	S.F3	
Photo sensor to detect Car gateNo.1	BOOL	I	S.G1	

Photo sensor to detect Car gateNo.2	BOOL	I 0.	S.G2	
Photo sensor to detect plateon parking A floor No.1	BOOL	I	S.P.A1	
Photo sensor to detect plateon parking A floor No.2	BOOL	I	S.P.A2	
Photo sensor to detect plateon parking A floor No.3	BOOL	I	S.P.A3	
Photo sensor to detect plateon parking B floor No.1	BOOL	I	S.P.B1	
Photo sensor to detect plateon parking B floor No.2	BOOL	I	S.P.B2	
Photo sensor to detect plateon parking B floor No.3	BOOL	I	S.P.B3	
Photo sensor to detect plateon parking C floor No.1	BOOL	I	S.P.C1	
Photo sensor to detect plateon parking C floor No.2	BOOL	I	S.P.C2	
Photo sensor to detect plateon parking C floor No.3	BOOL	I	S.P.C3	
Photo sensor to detect plateon parking D floor No.1	BOOL	I	S.P.D1	
Photo sensor to detect plateon parking D floor No.2	BOOL	I	S.P.D2	
Photo sensor to detect plateon parking D floor No.3	BOOL	I	S.P.D3	
Photo sensor to detect plateon parking E floor No.1	BOOL	I	S.P.E1	
Photo sensor to detect plateon parking E floor No.2	BOOL	I	S.P.E2	
Photo sensor to detect plateon parking E floor No.3	BOOL	I	S.P.E3	
Photo sensor to detect plateon parking F floor No.1	BOOL	I	S.P.F1	
Photo sensor to detect plateon parking F floor No.2	BOOL	I	S.P.F2	
Photo sensor to detect plateon parking F floor No.3	BOOL	I	S.P.F3	
Photo sensor to detect plateon gateNo.1	BOOL	I	S.P.G1	
Photo sensor to detect plateon gateNo.2	BOOL	I	S.P.G2	
UltraSonic sensor	BOOL	I	S.SF.2	
Photo sensor to prevent gate No.1 closeon car	BOOL	I	S.SF.G1	
Photo sensor to prevent gate No.2 closeon car	BOOL	I	S.SF.G2	
Directional control alve drives motor forward No.1	BOOL	Q	VLV.1.F	
Directional control alve drives motor revers No.1	BOOL	Q	VLV.1.R	

5.2.2 Soft ware programming:

As mentioned before the program software which is used for the system called SIMATIC manager. Is the software for SEMANSE PLC controller. The programming executed by LADDER DIAGRAM.

SIMATIC   sps\SIMATIC 300(1)\CPU 312\...\OB1 - <offline>   04/21/2015 07:11:35 PM

OB1 - <offline>

""

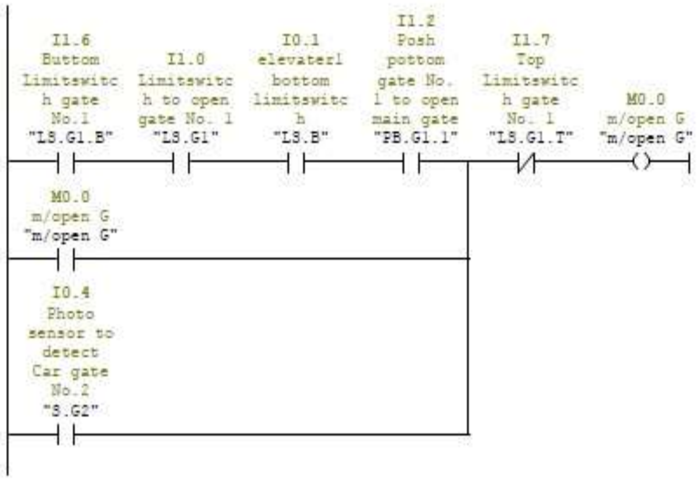
Name: **Family:**
Author: **Version:** 0.1
Block version: 2
Time stamp Code: 04/21/2015 05:25:32 PM
Interface: 02/15/1996 04:51:12 PM
Lengths (block/logic/data): 00796 00598 00022

Name	Data Type	Address	Comment
TEMP		0.0	
OB1_EV_CLASS	Byte	0.0	Bits 0-3 = 1 (Coming event), Bits 4-7 = 1 (Event class 1)
OB1_SCAN_1	Byte	1.0	1 (Cold restart scan 1 of OB 1), 3 (Scan 2-n of OB 1)
OB1_PRIORITY	Byte	2.0	Priority of OB Execution
OB1_OB_NUMBR	Byte	3.0	1 (Organization block 1, OB1)
OB1_RESERVED_1	Byte	4.0	Reserved for system
OB1_RESERVED_2	Byte	5.0	Reserved for system
OB1_PREV_CYCLE	Int	6.0	Cycle time of previous OB1 scan (milliseconds)
OB1_MIN_CYCLE	Int	8.0	Minimum cycle time of OB1 (milliseconds)
OB1_MAX_CYCLE	Int	10.0	Maximum cycle time of OB1 (milliseconds)
OB1_DATE_TIME	Date_And_Time	12.0	Date and time OB1 started

Block: OB1 "Main Program Sweep (Cycle)"

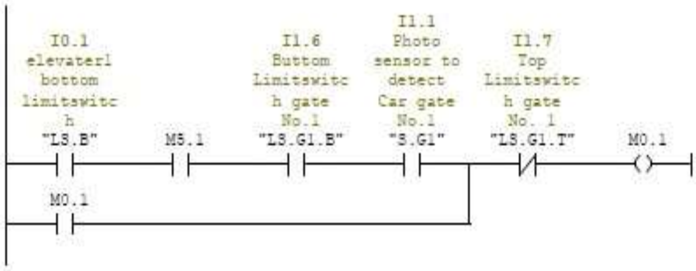
Network: 1 m/open G

system to open the Gate



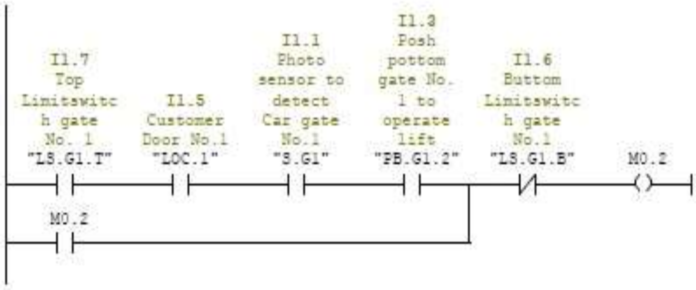
Network: 2

system to open the Gate after car calling



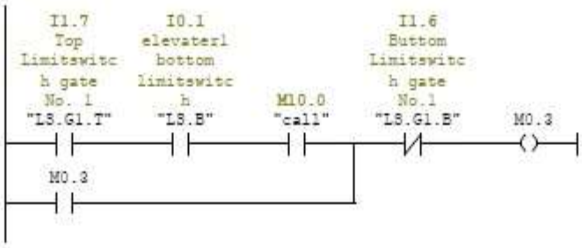
Network: 3

stop system for stopping the motor (up dirction)



Network: 4

stop system for stopping the motor (down dirction)



Network: 5 Gate No. 1 Forward

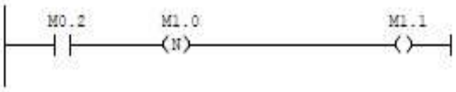
open gate

Network: 6 Gate No. 1 Reverse

close gate

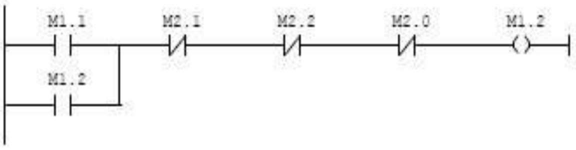
Network: 7

system to run hydrolic motor (up dirction)



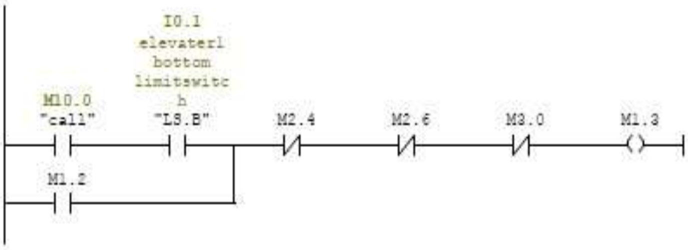
Network: 8

system to run hydrolic motor (up dirction)

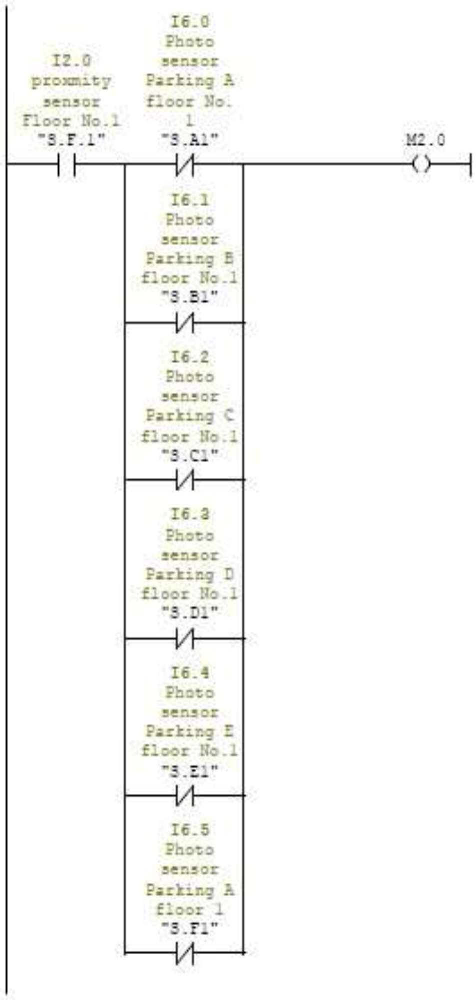


Network: 9

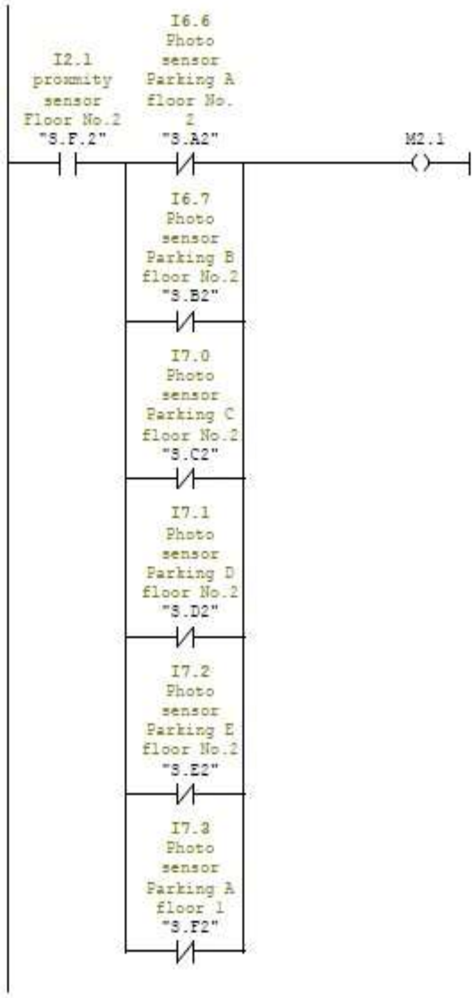
system to open the valve (forward)



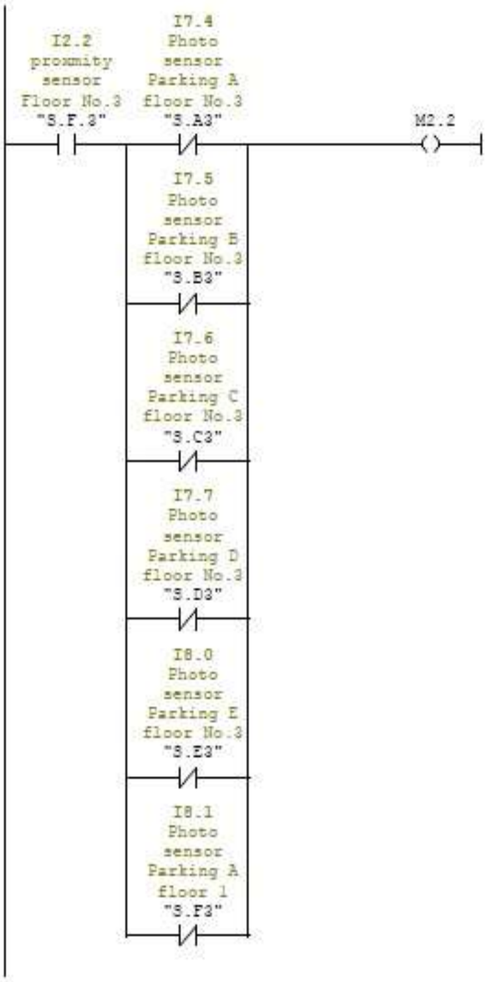
Network: 10
stop system to stopping HYD motor in 1.st floor



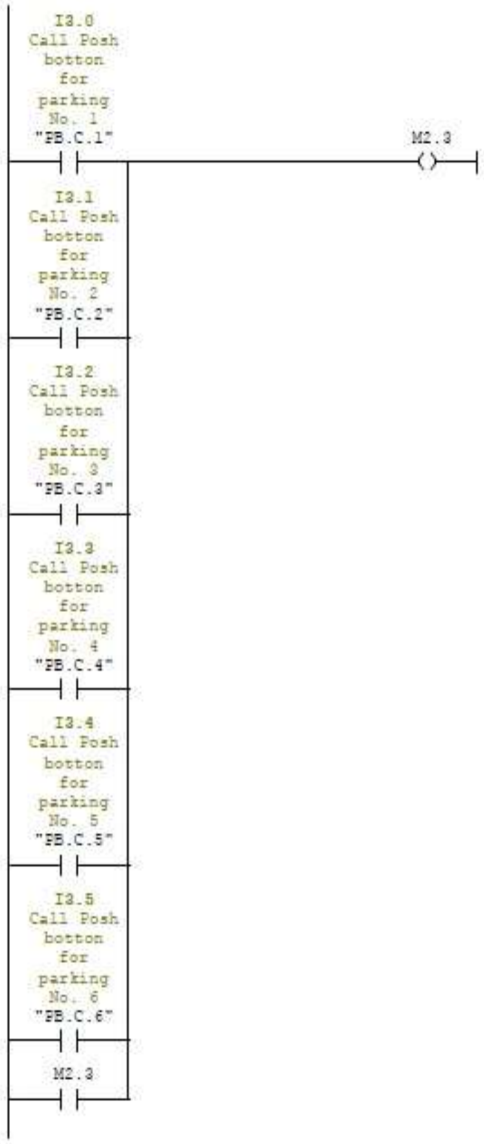
Network: 11
stop system to stopping HYD motor in 2.nd floor



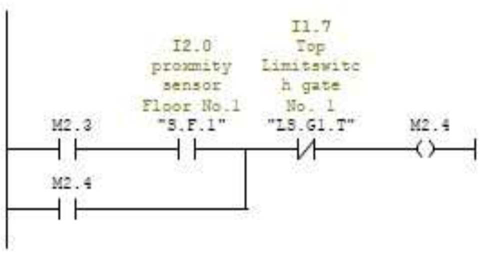
Network: 12
stop system to stopping HYD motor in 3.rd floor



Network: 13
1.st floor calling system

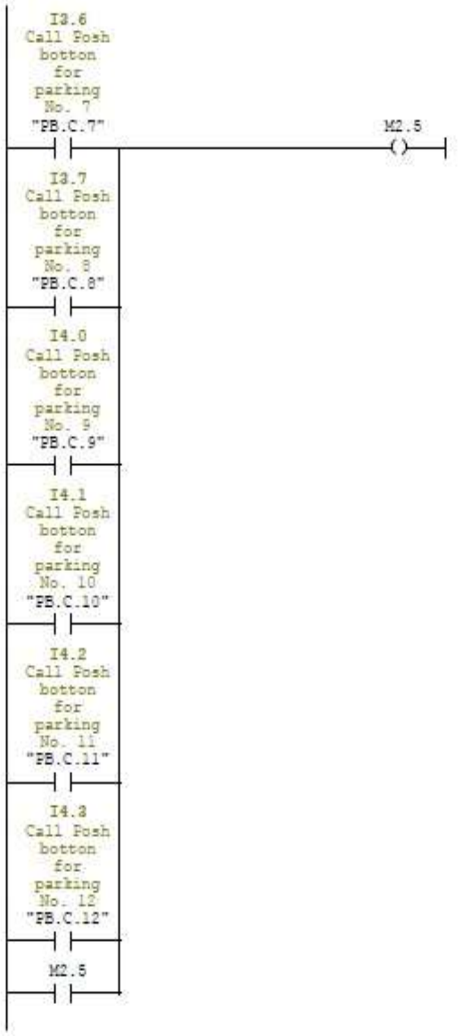


Network: 14
system to run HYD (Down Dirction)



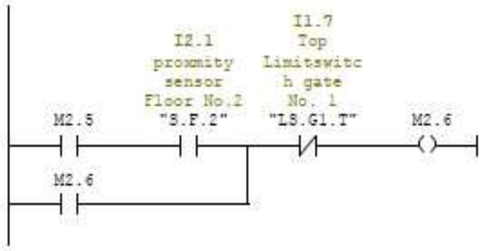
Network: 15

2.nd floor calling system



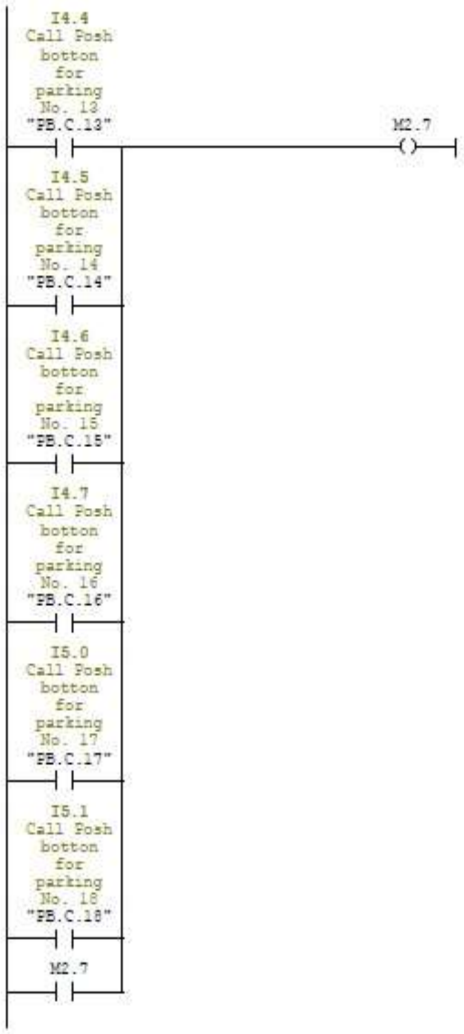
Network: 16

system to run HYD (Down Dirction)



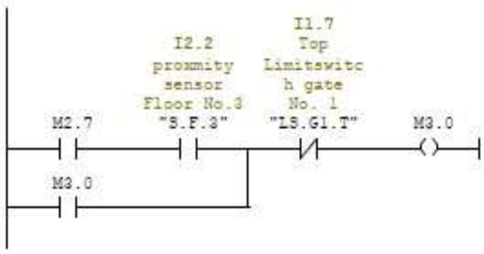
Network: 17

3.rd floor calling system

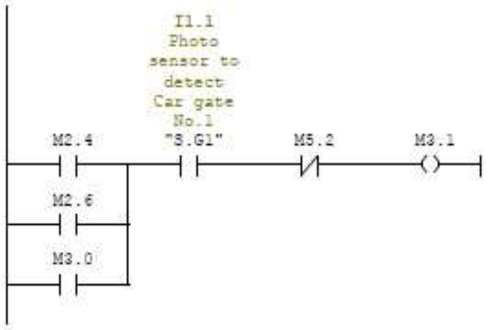


Network: 18

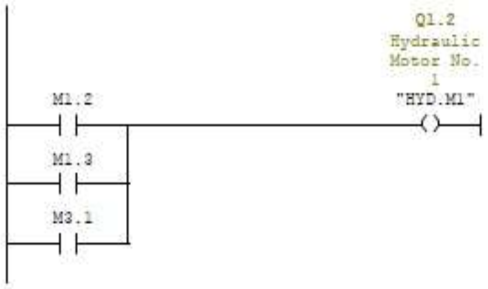
system to run HYD (Down Dirction)



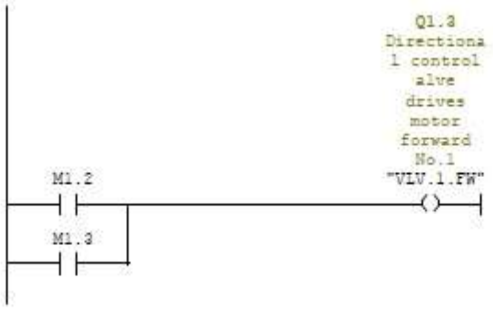
Network: 19
system to open valve (reverse diriction)



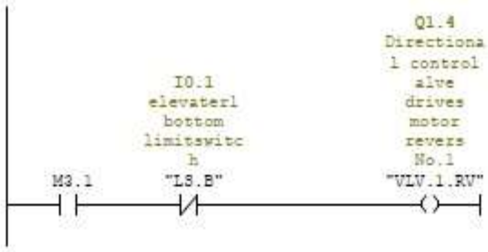
Network: 20 Hydraulic Motor No. 1
HYD motor run



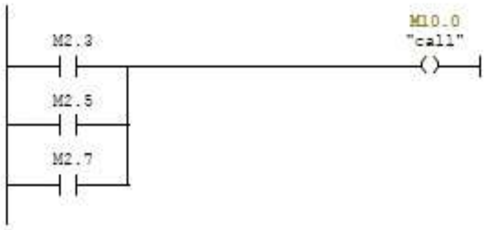
Network: 21 Directional control alve drives motor forward No.1
open valve forward



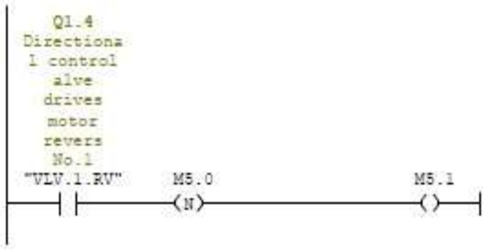
Network: 22 Directional control alve drives motor forward No.2
open valve reverse



Network: 23
system call

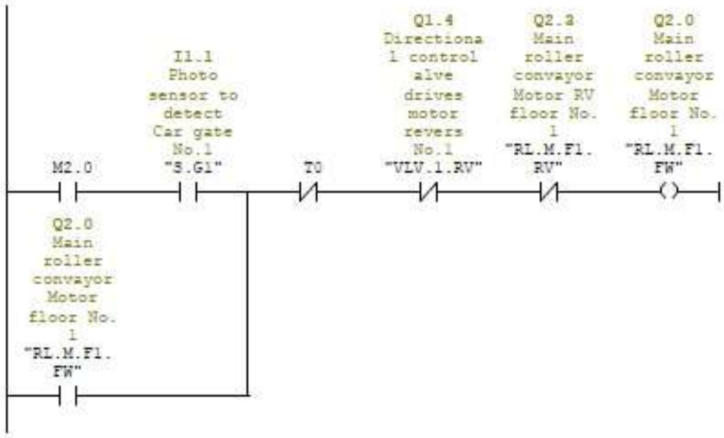


Network: 24
stop system to close the reverse valve

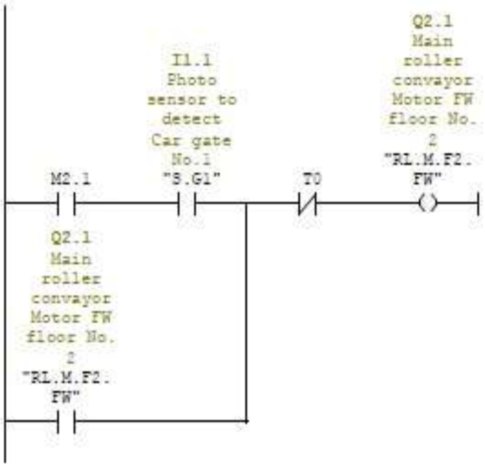


Network: 25
stop system to close the reverse valve

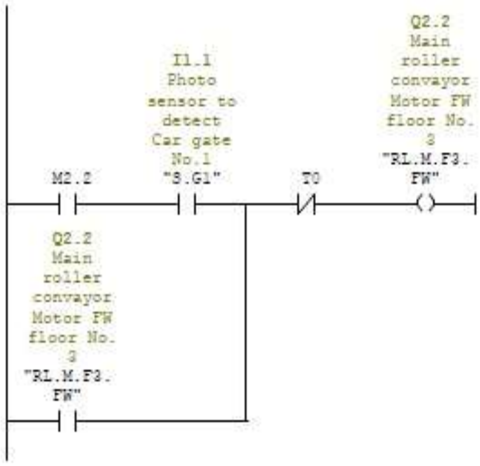
Network: 26 Main roller convayor Motor floor No. 1
roll main 1st fw start running



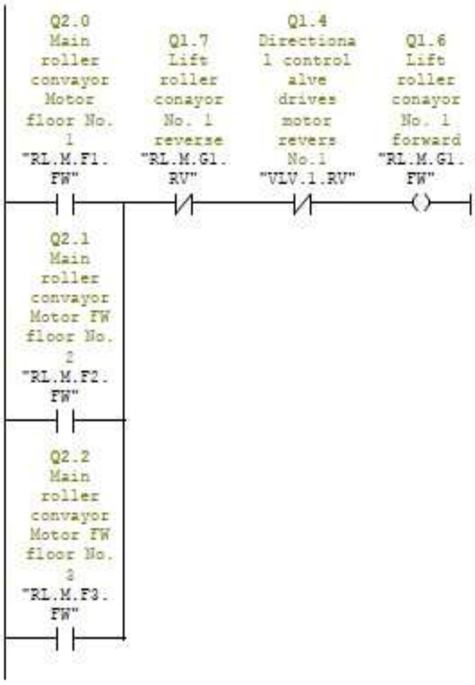
Network: 27 Main roller convayor Motor floor No. 1
roll main 2nd fw



Network: 28 Main roller convayor Motor floor No. 1
roll main 3rd fw

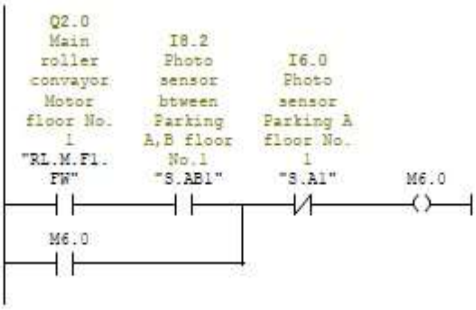


Network: 29 Lift roller conayor No. 1 forward
lift roll fw



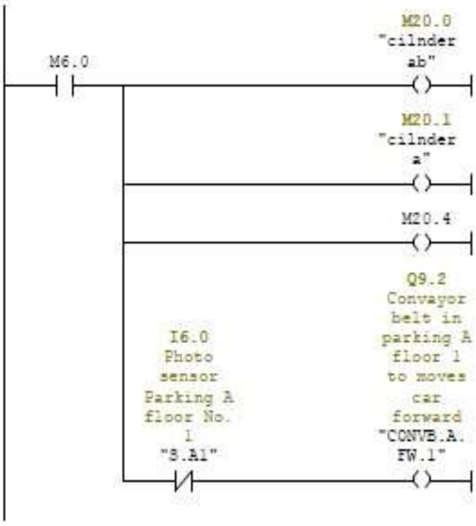
Network: 30

park in parking a



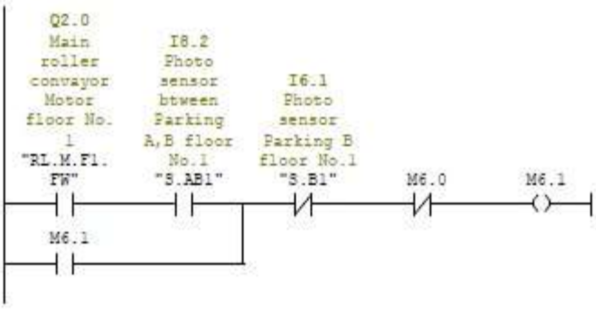
Network: 31 Cylinder between parking A,B floor 1 to hold Car

system to start the cylinders

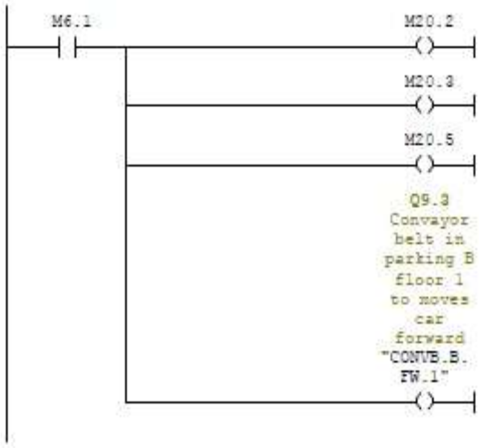


Network: 32

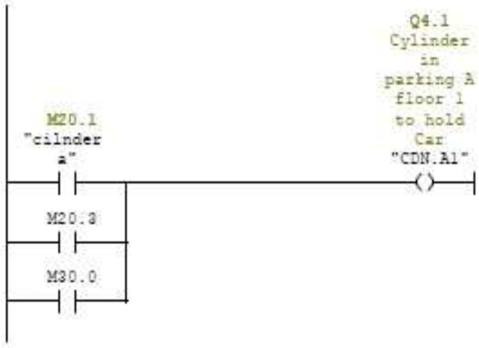
park in parking a



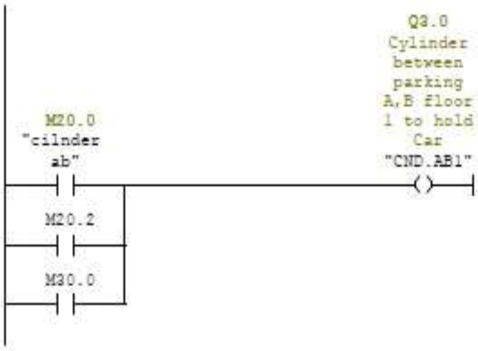
Network: 33 Cylinder between parking A,B floor 1 to hold Car
system to start the cylinders



Network: 34 Cylinder in parking A floor 1 to hold Car
start the cylinder Park no. A

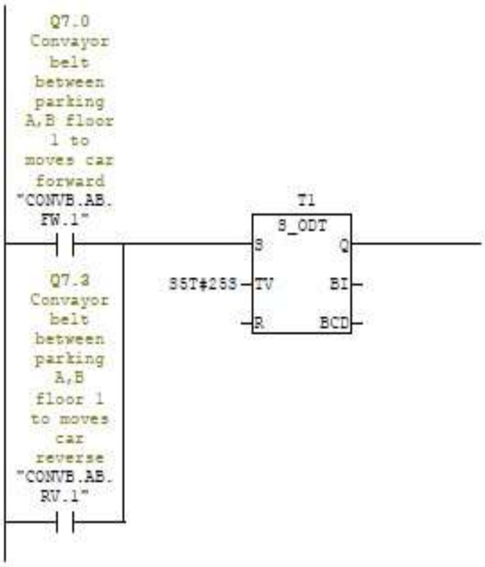


Network: 35 Cylinder between parking A,B floor 1 to hold Car
start the cylinder AB 1.st



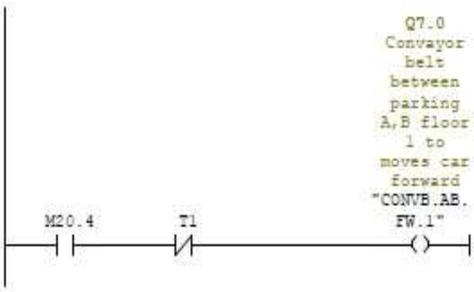
Network: 36

system to stop after delay time for conveyors



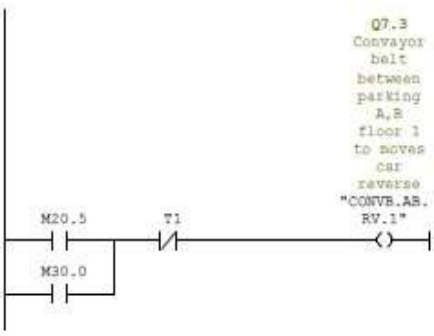
Network: 37 Convayor belt between parking A,B floor 1 to moves car forward

conveyor belt

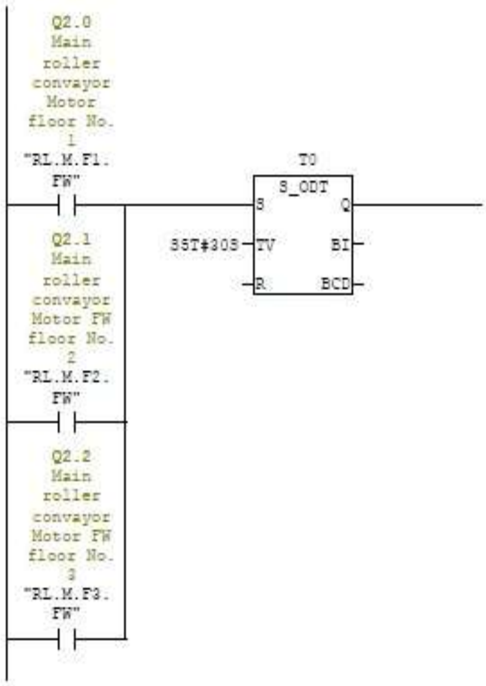


Network: 38 Convayor belt between parking A,B floor 1 to moves car reverse

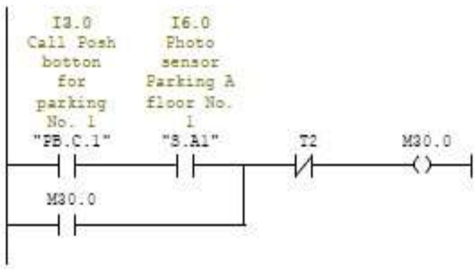
conveyor belt



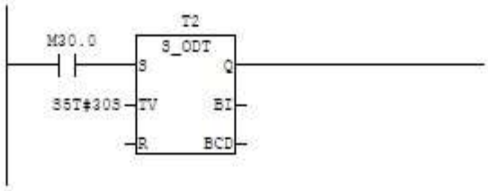
Network: 39
system to stop after delay time for cylinders and rollers



Network: 40
clinder call ab



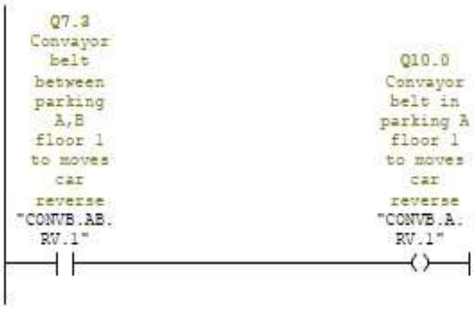
Network: 41
stopping system



Network: 42 Main roller convayor Motor RV floor No. 1

Network: 43 Lift roller conayor No. 1 reverse

Network: 44 Convayor belt in parking A floor 1 to moves car reverse



CHAPTER SIX

RESULTS

CHAPTER SIX

RESULTS

6.1 Simulation results:

1- system before work (rest mode)

- I0.1 bottom limit switch for elevator (active) : the elevator in the main entrance.
- I1.6 bottom limit switch for door (active) : the entrance main gate closed

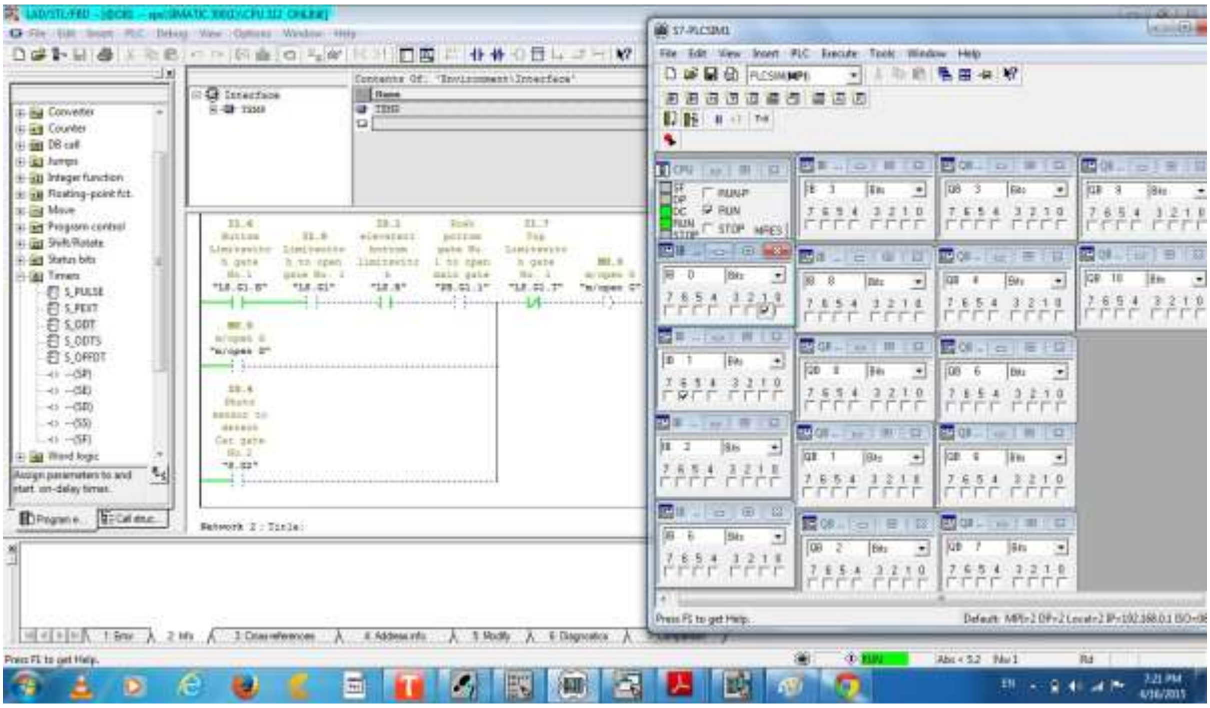


Figure6.1 : simulation 1

2- Open main entrance gate

- I0.1 bottom limit switch for elevator (active) : the elevator in the main entrance.

- I1.6 bottom limit switch for door (active) : the entrance main gate closed
- I1.0 limit switch before main gate. (active) : car should pass and stop over this limit switch.
- I1.2 push bottom switch (active) : the driver should press this switch to open gate.
- Result Q1.0 (active) : door opening.

The door will touch the top limit switch so:

- I1.6 bottom limit switch for door (deactivate) : the entrance main gate opened
- I1.7 top limit switch for door (active) : the main entrance gate opened

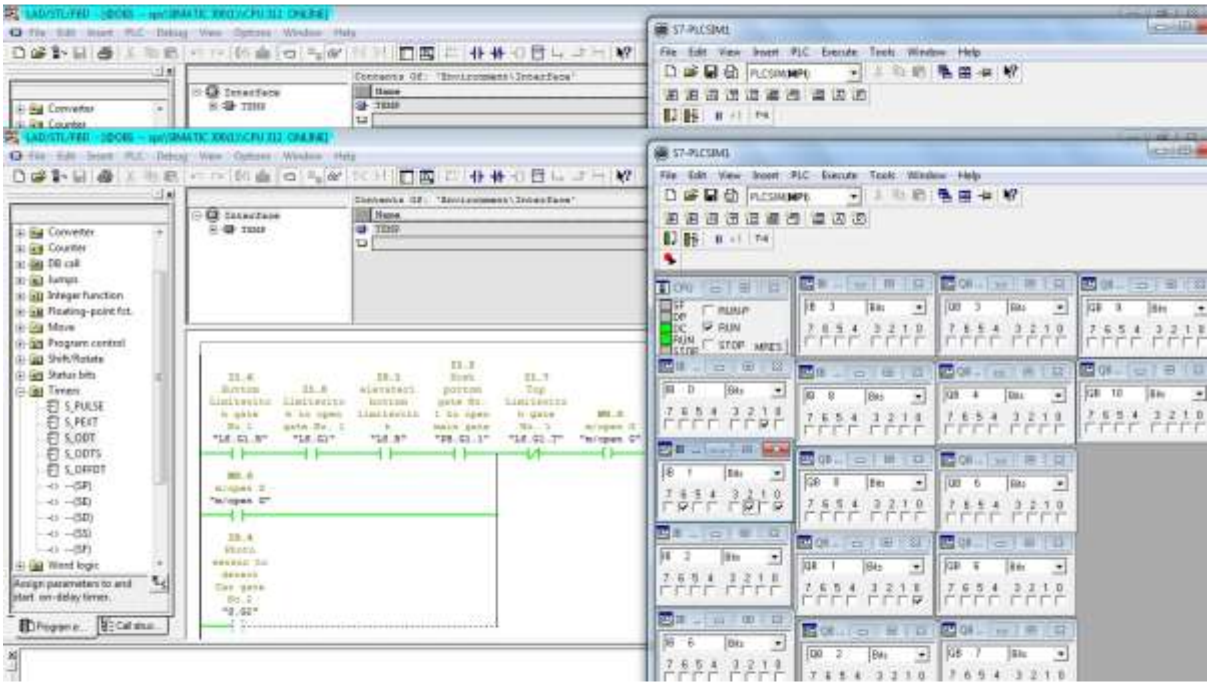


Figure6.2 : simulation 2

3- the car inside lift (close the main gate)

- I1.0 limit switch before main gate (deactivate) : the car left the limit switch
- I1.1 photo sensor inside lift (active) : the car inside the lift
- I1.5 customer door lock (active) : the driver should close the customer door manually.
- I1.3 push bottom (active) : the customer should press the push bottom to close main entrance gate.
- Result Q1.1 (active) : door closing

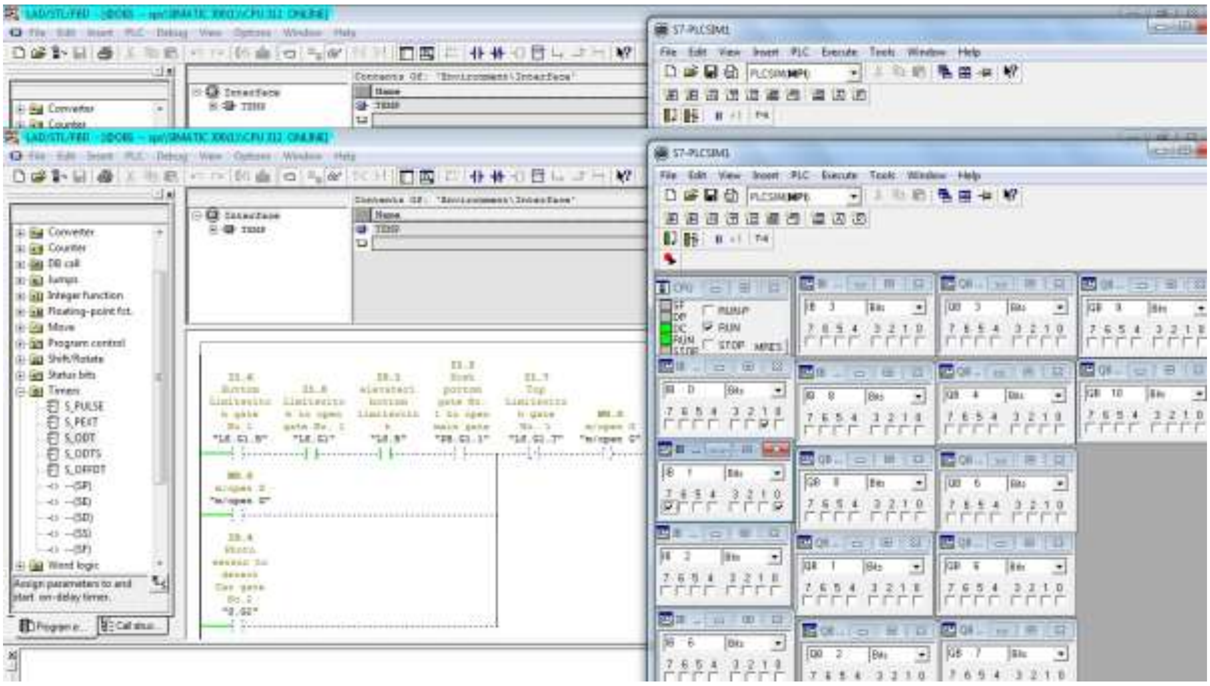


Figure6.3 : simulation 3

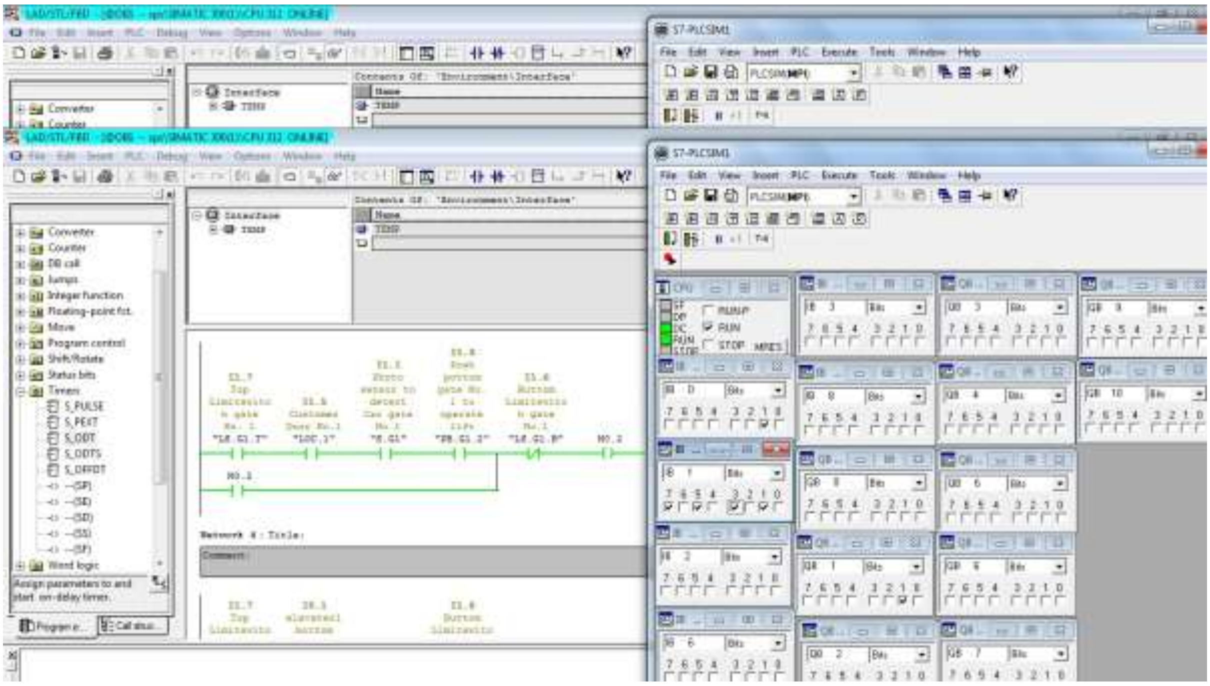


Figure6.4 : simulation 4

4-motor start forward

- I1.7 top limit switch for door (deactivate) : the entrance main gate closed
- I1.3 push bottom (deactivate) : push bottom.
- I1.6 bottom limit switch for door (active) : the entrance main gate closed
- I0.1bottom limit switch for lift (deactivate) : the lift start moving up.
- I1.1 photo sensor inside lift (active) : the car inside the lift
- I1.5 customer door lock (active) : customer lock closed
- Result Q1.3 directional control valve forward (active) : operate motor forward

- Result Q1.2 motor (active) : motor work.

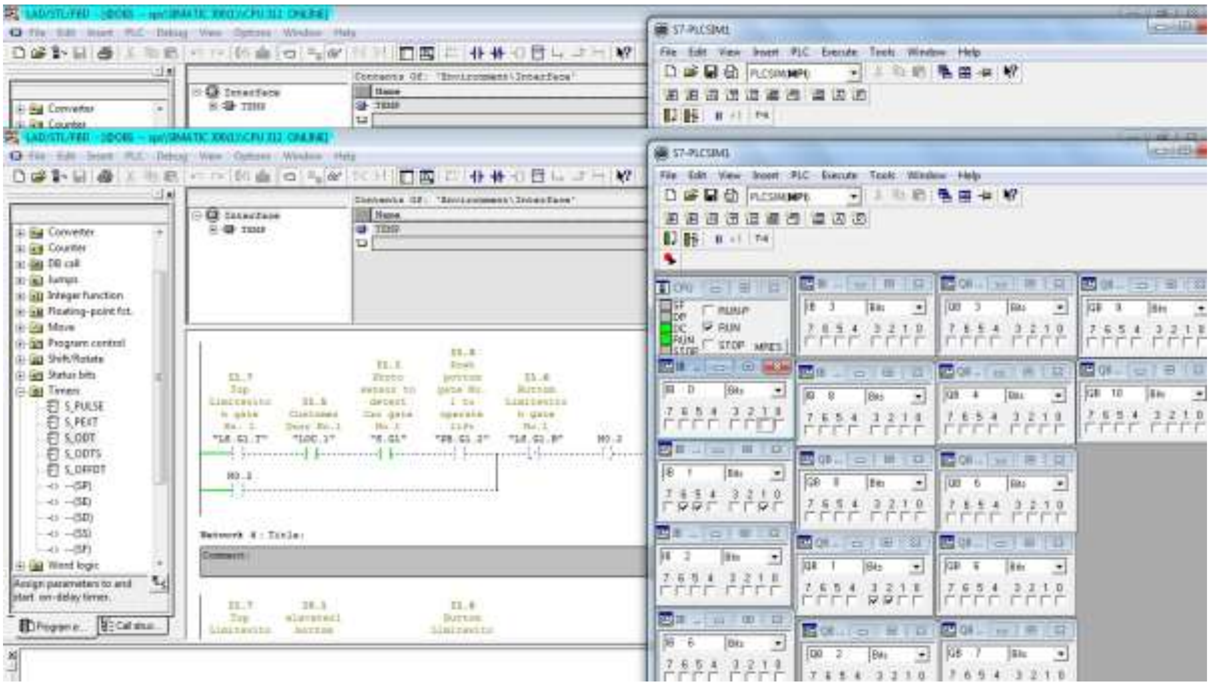


Figure6.5 : simulation 5

5- Roller conveyor on the lift and corridor

- I1.1 photo sensor inside lift (active) : the car inside the lift
- I1.5 customer door lock (active) : customer lock closed
- I1.6 bottom limit switch for door (active) : the entrance main gate closed
- I2.0 proximity sensor (active) : sense the car in the first floor.
- Result Q1.6 lift roller forward (active) : car moved from the lift to main corridor.
- Result Q2.0 main roller forward (active) : car moving on the corridor roller.

Figure6.6 : simulation 6

6- car moved inside parking

- I1.1 photo sensor inside lift (deactivate) : the car left the lift
- I1.5 customer door lock (active) : customer lock closed
- I1.6 bottom limit switch for door (active) : the entrance main gate closed
- I2.0 proximity sensor (active) : sense the lift in the first floor.
- I8.2 photo sensor between parking A&B (active) : the car now ready to go inside lift.
- Result Q3.0 cylinder between A&B (active)
- Result Q4.1 cylinder in parking A (active)
- Result Q7.0 Conveyor belt between forward A&B (active) the car moving to inside parking.

- Result Q9.2 conveyor belt for A forward (active)

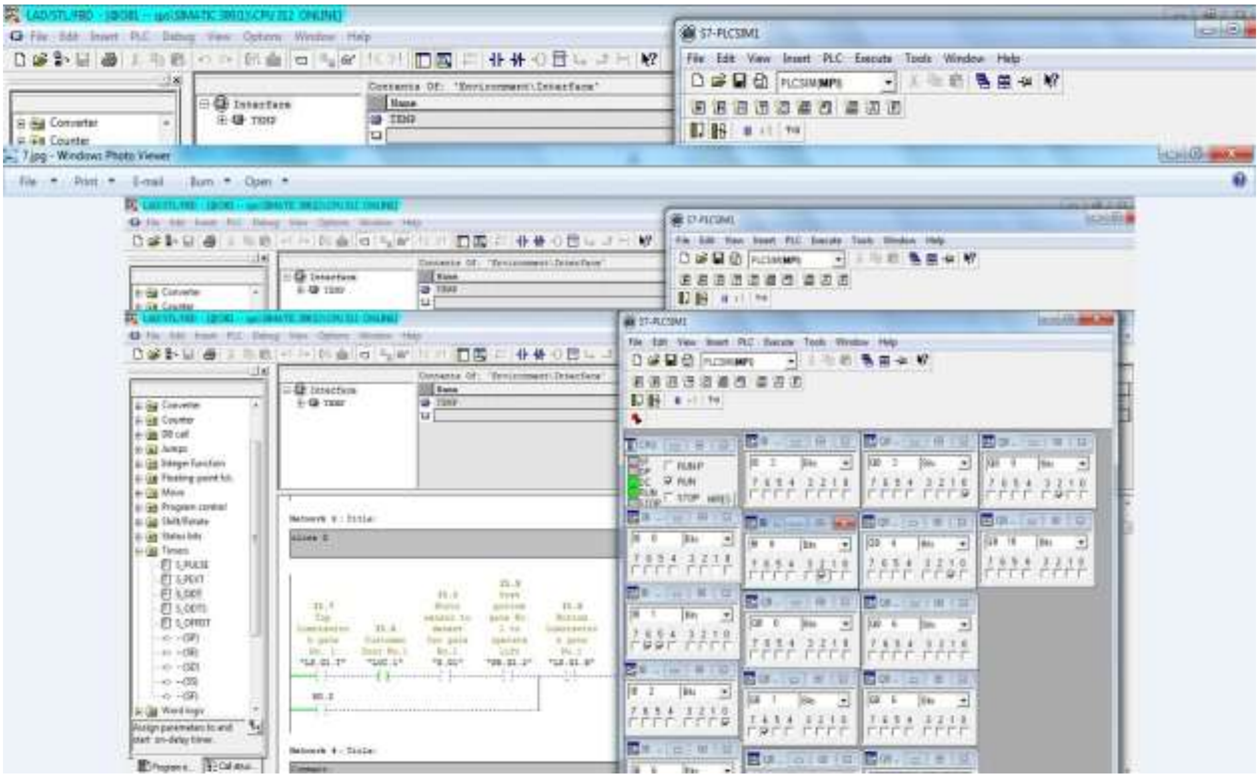


Figure6.7 : simulation 7

7- car in the parking.

- I1.5 customer door lock (active) : customer lock closed
- I1.6 bottom limit switch for door (active) : the entrance main gate closed
- I2.0 proximity sensor (active) : sense the lift in the first floor.
- I8.2 photo sensor between parking A&B (deactivate) : the car left a corridor.
- I6.0 sensor in parking A (active) : the car inside the parking
- Result: all out put (deactivate)

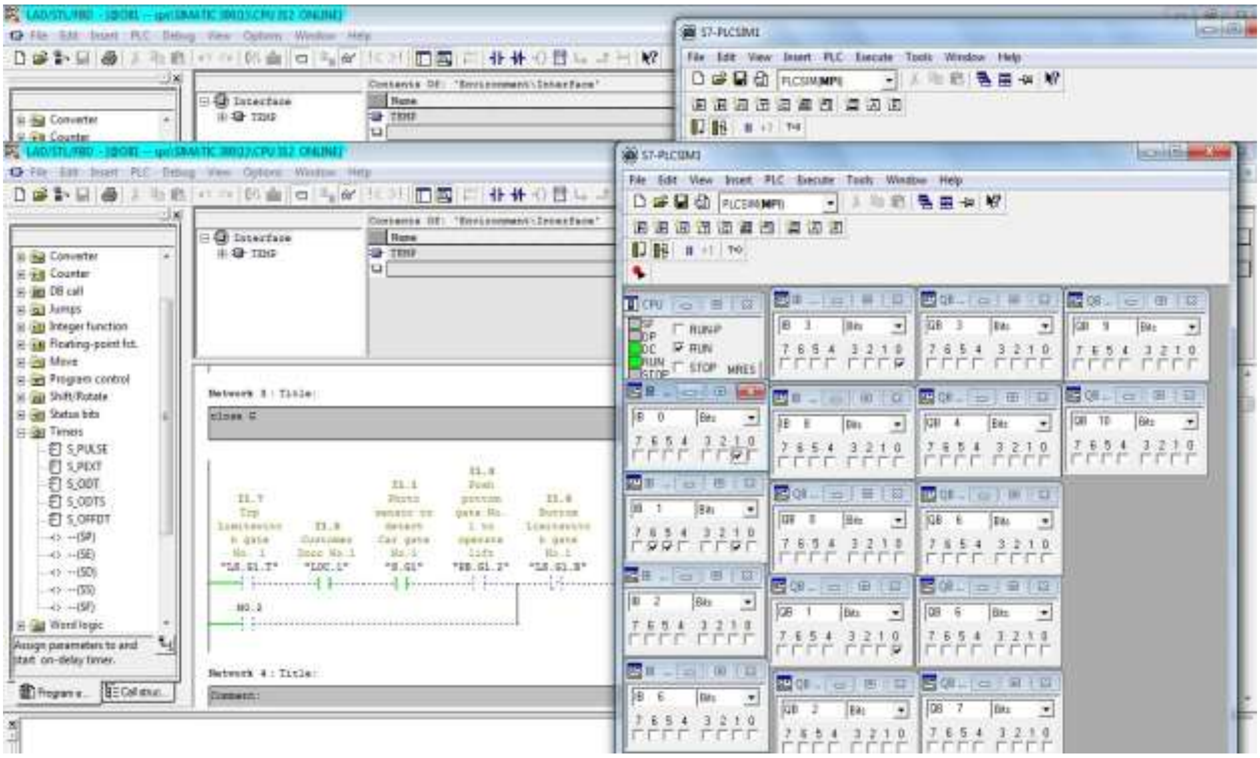


Figure6.8 : simulation 8

8- car calling

- reset mode (status before call)
- I1.5 customer door lock (active) : customer lock closed
- I1.6 bottom limit switch for door (active) : the entrance main gate closed
- I2.0 proximity sensor (active) : sense the lift in the first floor.
- I6.0 sensor in parking A (active) : the car inside the parking
- Result all out put (deactivate)

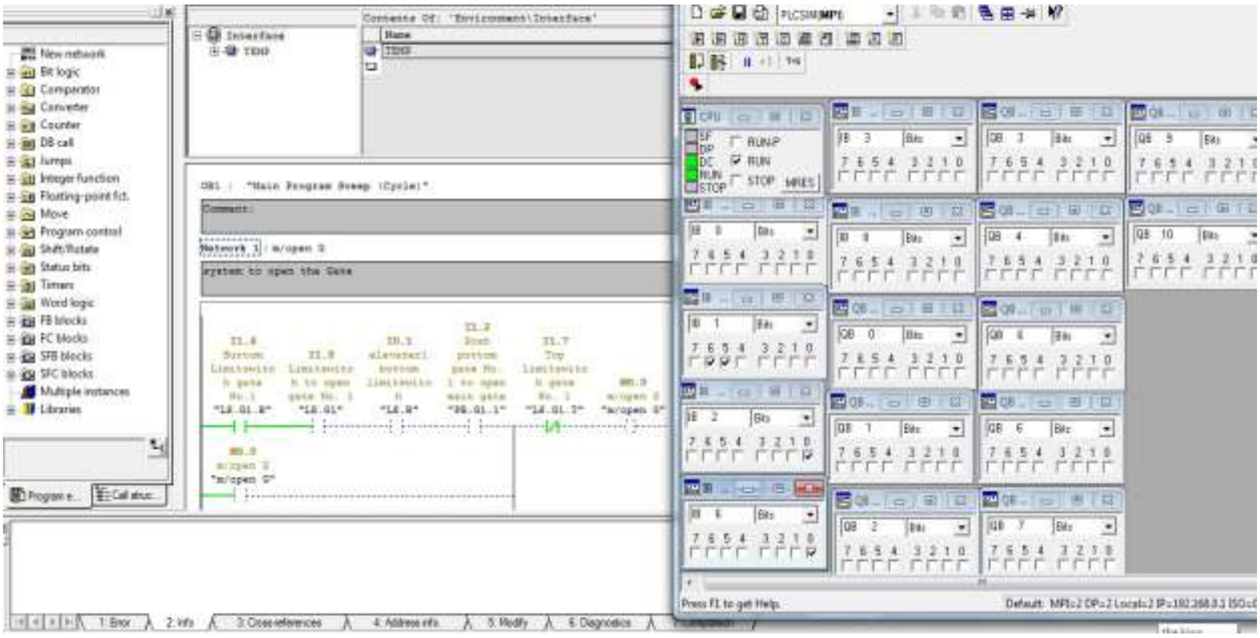


Figure6.9 : simulation 9

Start call

- I3.0 push bottom (active) : to call car from the parking
- I1.5 customer door lock (active) : customer lock closed
- I1.6 bottom limit switch for door (active) : the entrance main gate closed
- I2.0 proximity sensor (active) : sense the lift in the first floor.
- I6.0 sensor in parking A (active) : the car inside the parking
- Result Q1.7 left roller conveyor reverse (active)
- Result Q2.3 main roller conveyor (active)
- Result Q3.0 cylinder between A&B (active)
- Result Q4.1 cylinder in parking A (active)
- Result Q7.3 conveyor belt between parking A,B reverse (active)
- Result Q10.0 conveyor belt for A reverse (active)

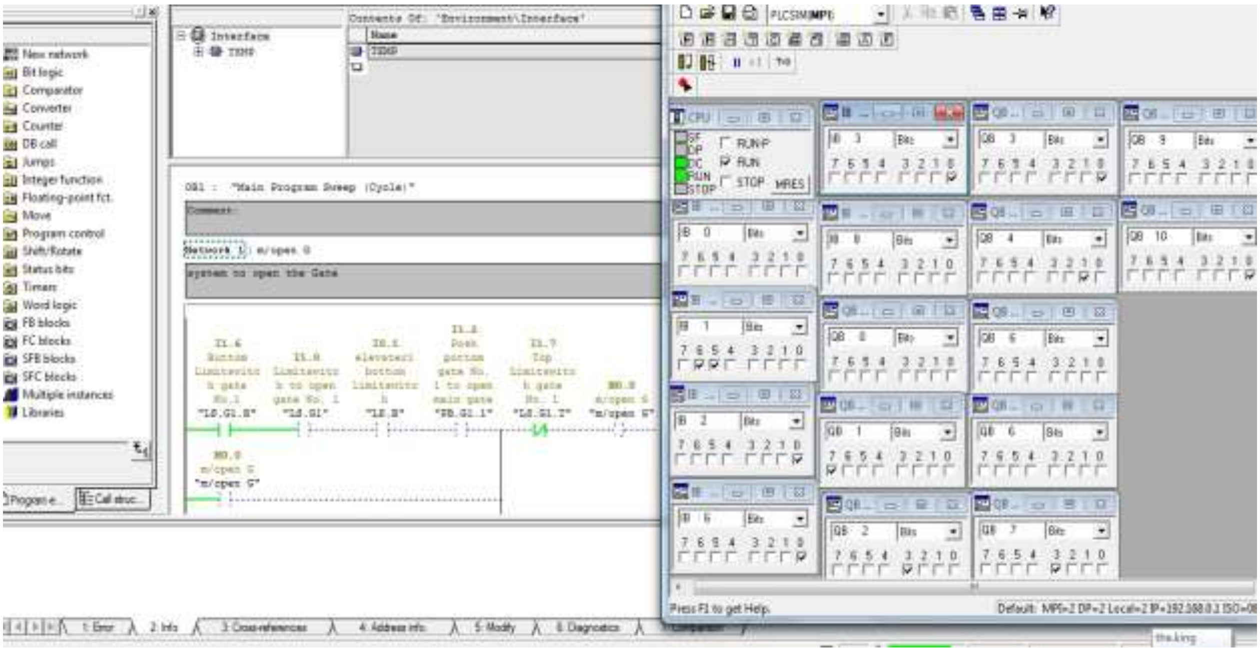


Figure6.10 : simulation 10

9- Car reach to lift from the corridor.

- I1.1 photo sensor inside lift (not active) : the car left the lift
- I1.5 customer door lock (active) : customer lock closed
- I1.6 bottom limit switch for door (active) : the entrance main gate closed
- I6.0 sensor in parking A (deactivate) : the car out of the parking
- Result Q1.7 left roller conveyor reverse (not active)
- Result Q2.3 main roller conveyor (not active)
- Result Q3.0 cylinder between A&B (not active)
- Result Q4.1 cylinder in parking A (not active)
- Result Q7.3 conveyor belt between parking A,B reverse (not active)
- Result Q10.0 conveyor belt for A reverse (not active)
- Result Q1.4 directional control valve reverse (active) : to operate motor reverse

- Result Q1.2 motor (active) : motor work.

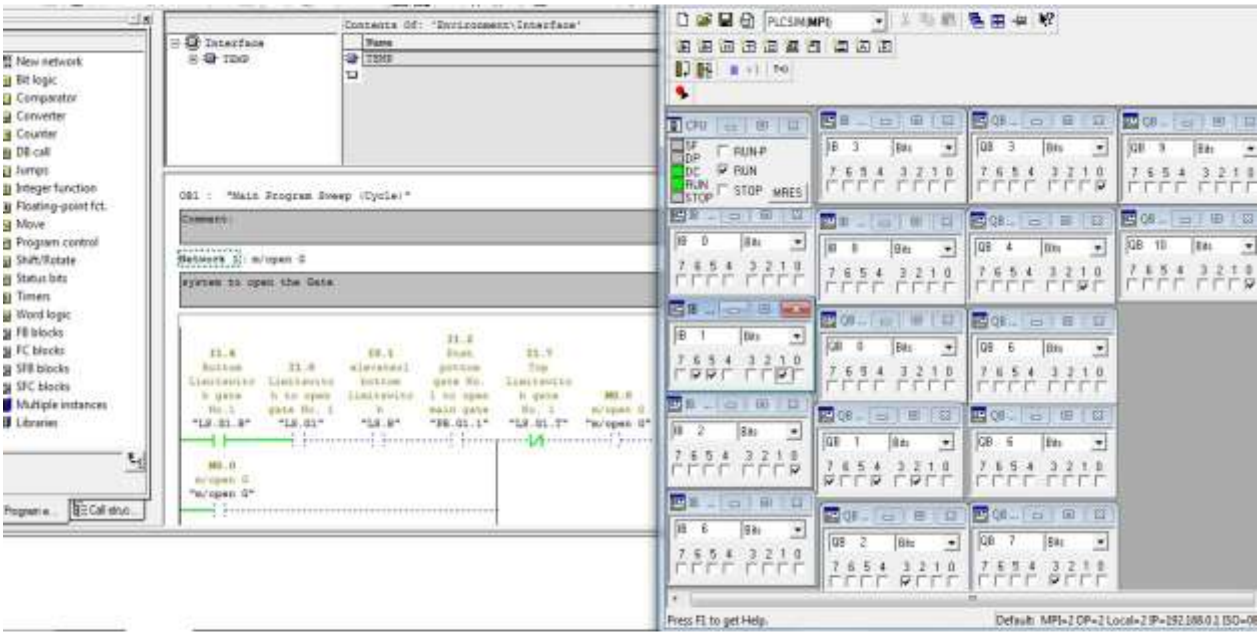


Figure6.11 : simulation 11

10- car in the main entrance

- I0.1 bottom limit switch for elevator (active) : the elevator in the main entrance.
- I1.1 photo sensor inside lift (not active) : the car left the lift
- I1.5 customer door lock (active) : customer lock closed
- I1.6 bottom limit switch for door (active) : the entrance main gate closed.
- Result Q1.0 (active) : door opening.

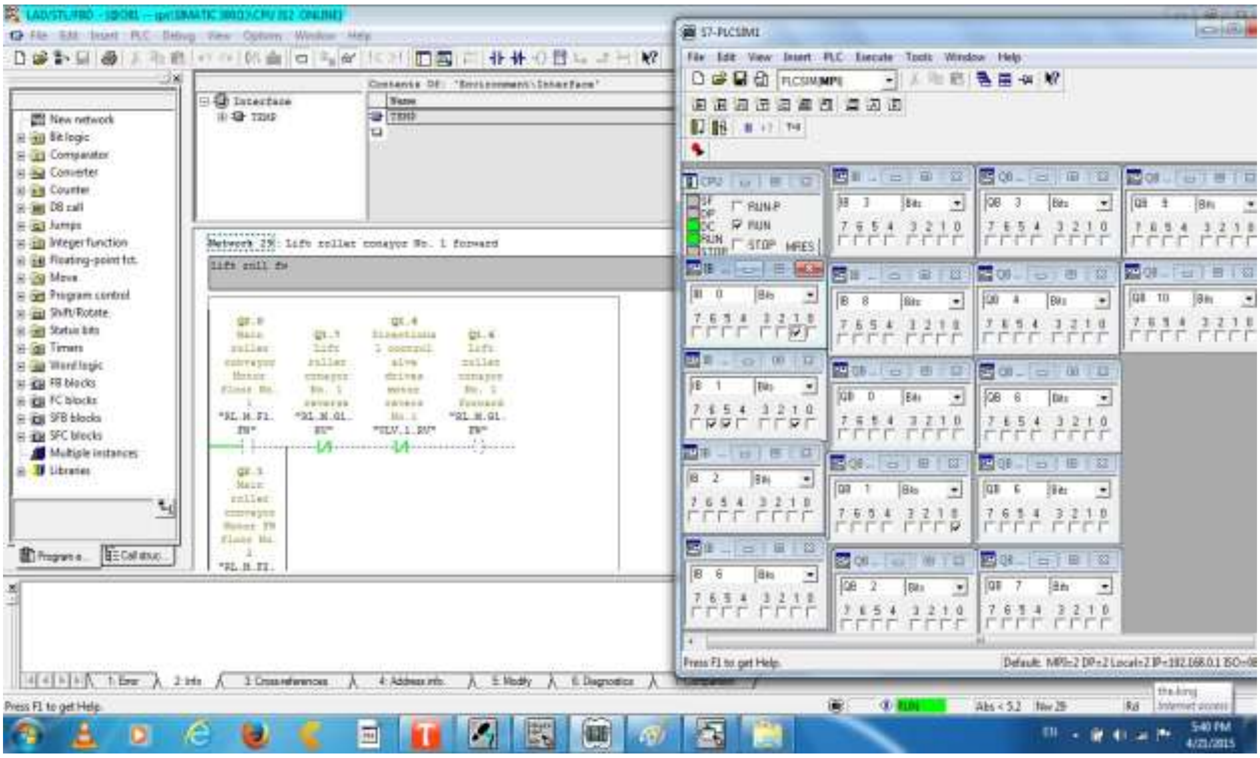


Figure6.12 : simulation 12

11- final parking operation.

- I0.1 bottom limit switch for elevator (active) : the elevator in the main entrance.
- I1.1 photo sensor inside lift (not active) : the car left the lift
- I1.5 customer door lock (active) : customer lock closed
- I1.6 bottom limit switch for door (deactivate) : the entrance main gate opened.
- Result Q1.0 (active) : door opening.

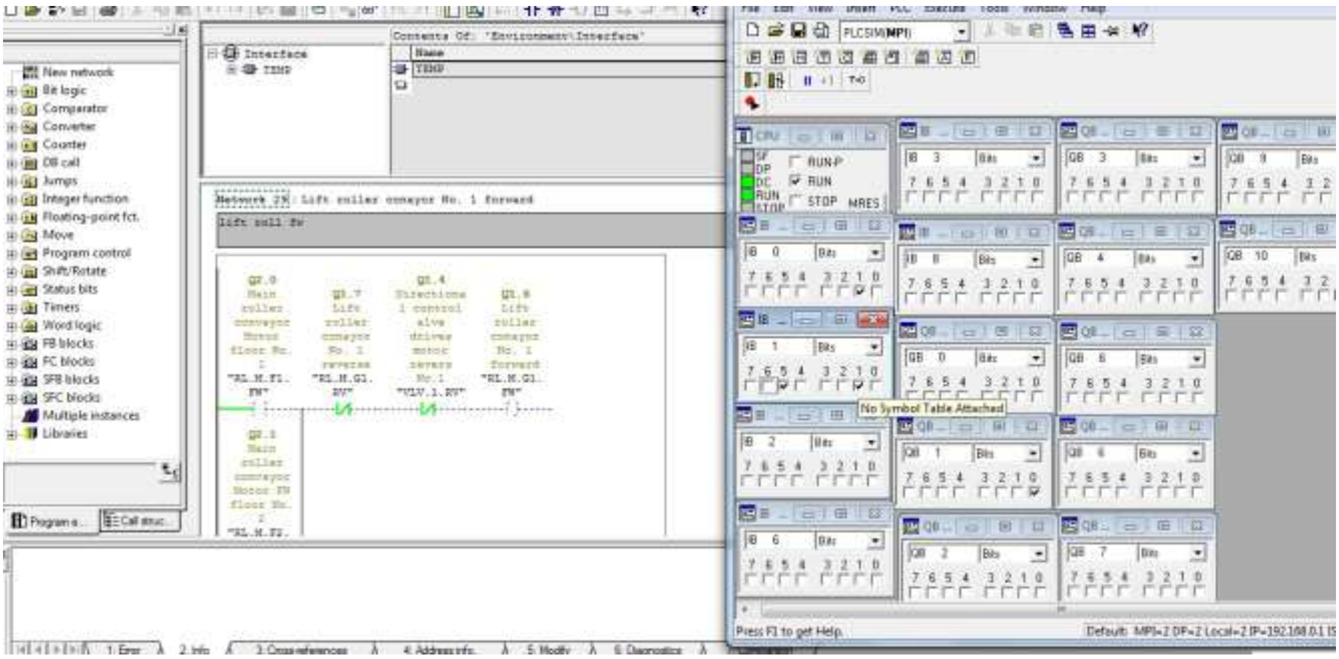


Figure6.13: simulation 13

CHAPTER SEVEN

Conclusions and recommendations

CHAPTER SEVEN

Conclusions and recommendations

7.1 Conclusions:

The main objective of this project is to propose a solution for car parking in high density urban areas. In many cases high land value and the lack of empty open plots make adding traditional new parking lots a difficult non economic solution. The project proposes using modern technology to create an adequate solution that uses less space and saves time and effort for vehicle drivers by maximizing the use of the horizontal and vertical space available for parking.

The project is based on a 3 floor building; each floor contains 6 parking lots. A Hydraulic lift is used to elevate & descend vehicles moving them vertically across the y axis whilst motors are used for moving vehicles horizontally across the x and z axes back and forth and to the right and left in order to move the vehicles to and from the lift and into the parking spaces. Hydraulic lifts are used to load the vehicle into the parking space and out of it. A number of mathematical and physics calculation have been made in order to design the lift and select the system's components (pump, hydraulic motor, electric motor, valve, etc..). The operating system is illustrated in AutoCAD drawings. A number of internationally known company catalogues have been used in order to select the system components and some demonstrative images are used to further explain the idea.

An electrical source is needed to power the electrical pump and motors used in the system. In order to select the electrical source, circuit breakers and cables, a study of the building's electrical loads in kilowatts using mathematical calculations was made in order to run the system in a safe mode. AutoCAD was also used to illustrate the Single Line Diagram and Microsoft Office Excel Sheet to calculate the loads mathematically. The last past remaining to achieve a mechatronic system after selecting the mechanical system and calculating the electrical power source needed to operate it is the control of the system. This is achieved by using the PLC for the control and operation of the system by using the ladder diagram and the SIMATIC Manager software(a product of Siemens company). In addition, a simulation of the operation process was made.

The conclusion of this study is as following:

1. The study has made use of different types of technology and scientific advancements in order to solve a problem of modern communities. This is established through using the hydraulic lift with electrical engines which are programmed and controlled using the PLC to help solve the lack of parking space issues by providing more space for parking lots and making the parking process easier and less stressful.
2. The study has made use of hydraulic motors and the design of elevators that can carry heavy weight objects such as vehicles. However it must be noted that hydraulic motors have less speed than motors operated by diesel or electricity. This is a disadvantage that should be rectified in future studies.
3. The study has made use of motors with belts and rollers in order to create conveyors for heavy objects such as vehicles. These conveyors are high-speed, efficient and accurate.

4. The study uses permanent power sources (Transformers) and emergency sources (generators) to power the system and ensure the continuation of its work.
5. PLC controllers are used to control the system. These controllers are highly accurate, efficient and reliable. It shows that they are the most appropriate for this system because of their high efficiency, there adaptability to environmental conditions and the ease of their replacement and modification in the future if needed.
6. The PLC is programmed using a ladder diagram. This has been done because of the easiness of writing logical operations and following up with them using the program as is modifying them if needed in the future.
7. This study has been made for a small three floor building that contains 6 parking spaces only. However the same calculations and theories can be used for a larger project with more floors and parking spaces per floor. The only modification needed will be taking into consideration the additional requirements when studying the electrical and mechanical loads and when writing the program.
8. A number of different types of sensors and switches are used in the control process as shown in the system design to benefit from them in writing the program and using the relay and actuators for the actions required.
9. In this study the process of parking and retrieving the vehicle is done using the push bottom switch for study purpose only. However this can be developed by searching for better options such as access cards if the building was a residential unit or private offices. Another option could be using tickets, money or tokens for public and commercial uses.

7.2Recommendations:

1. Use electric motor for the elevator instead of the hydraulic motor and compare between the new system and the system which is applied in this project and find which one better efficient and better performance.
2. Use other conveyor like rail conveyor instead of belt conveyor and roller conveyor. And compare between the new system and the system which is applied in this project and find which one faster and smoother.
3. Increase the parking plot per one floor and increase the floors and write new software and consider the additional parking.
4. Use access control such as cash money, access cards, tokens and tickets instead of the push button switch and compare between the new system and the system which is applied in this project and find which one easier for user.

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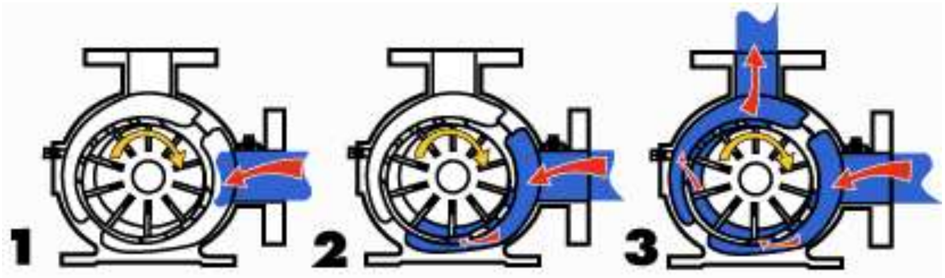
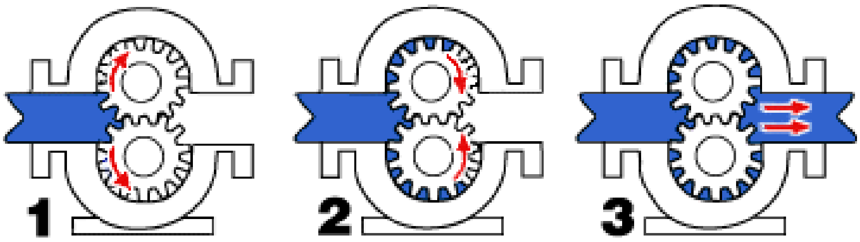
Appendices

Appendices :



Appendices no.1 : Vane Pump



Appendices no.2 :Gear Pump

14 Displacements 14 Schluckvolumen 14 Cylindrée 14 Despazamientos		(2.5 – 24.0 in^3/rev) **41 . . . 390 cm^3/rev**
	Cont	**Int**
Maximum Pressure **Eingangsdruck** **Pression entrée** **Presion Maxima**	(2030 psid) **. . .140 bar**	(2750 psid) **. . .190 bar**
Maximum Oil Flow **Schluckstrom** **Débit d'huile** **Caudal Maximo de Aceite**		(20 gpm) **. . . 75 lpm**
Maximum Speed **Drehzahl** **Vitisse de rotation Maxi** **Velocidad Maxima**		(1024 rpm) **1024 rpm**
	Cont	**Int**
Maximum Torque **Max Drehmoment** **Couple Maxi** **Torque Maximo**	(4139 lb in) **467 Nm**	(5728 lb in) **648 Nm**
Maximum Side Load at Key **Seitenlast** **Charges latèrales** **Carga Maxima Lateral**		(3150 lb) **. . . 14000 N**

The Ultimate in Performance from a Medium Frame Motor

Parker's TJ Series motor provides all that could be expected of a general purpose motor and more. Unique 60:40 spline geometry provides drivetrain strength for severe applications. Roller vanes and sealed orbit commutation assure high volumetric efficiency and smooth slow speed operation. Cooling fluid flow across splines and seals mean long, trouble-free life.

Appendices no.3 motor series model TJ (TJ0330).

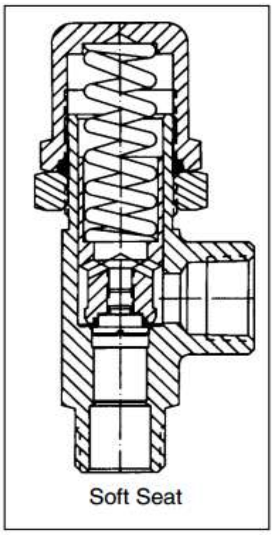
Appendices no.4 Pump model (PVP48)

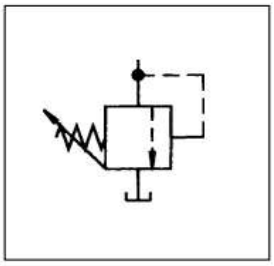
General Description

Series 620 - 649 in-line pressure control valves open the system to tank when the system pressure reaches the pressure setting of the control valve. The pressure setting is externally adjustable so that it can be tuned accordingly within its range. However, the valve can be factory set to a specified pressure setting.

Specifications

Service App.	Hydraulic and Pneumatic
Maximum Operating Pressure	Working: 0.3 to 248.4 Bar (4 to 3600 PSI) in 13 ranges Reseat: Range 1: 80% of cracking press. Ranges 2 - 13: 90% of cracking pressure
Sizes	NPT 1/4", 1/2", 3/4" IST 6, 10, 12 FLD 6, 10, 12
Ports	NPT Pipe threads IST Internal straight threads FLD Flared Tube Connection SAE 37°
Material	Body, Cap: Brass, aluminum alloy, stainless steel Finish: Aluminum alloy, anodized; stainless steel Poppet: 416 Stainless Steel (Hard seat) 303 Stainless Steel (Soft seat) Seat (soft): Ranges 1 -3: Synthetic rubber - Code 2 Ranges 4 - 7: PTFE Spring: Stainless steel Cap O-ring: Synthetic rubber
Operating Range of Seal Compound	-40°C to +121°C (-40°F to +250°F) Nitrile -26°C to +205°C (-15°F to +400°F) Fluorocarbon





Features

- Externally adjustable.
- Available for hydraulic or pneumatic service.
- Quick response for venting applications.

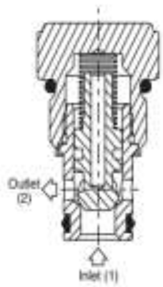
Appendices no.5 pressure valve Specification

General Description

Cartridge Style Check Valve. For additional information see Technical Tips on pages CV1-CV4.

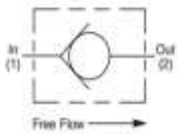
Features

- Spherical poppet for low leakage
- "D"-Ring eliminates back-up rings
- Dual sense paths for reduced ΔP
- All external parts zinc plated



Performance Curve

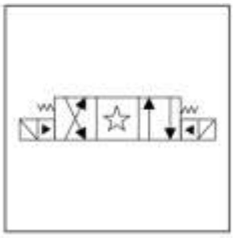
Pressure Drop vs. Flow (Through cartridge only)

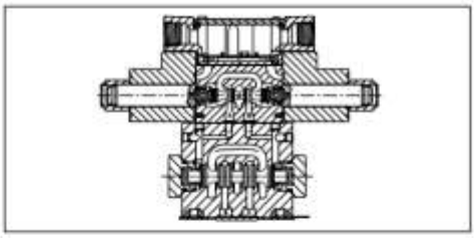


Appendices no.6 :Non-return valve

General Description

Series D31*W directional control valves are 5-chamber, pilot operated, solenoid controlled valves. The valves are suitable for manifold or subplate mounting.





Features

- **World design –** Available worldwide.
- **Mounting bolts below center line of spool –** Minimizes spool binding.
- **Five chamber style –** Eliminates pressure spikes in tubes, increasing valve life.
- **High pressure and flow ratings –** Increased performance options in a compact valve.

Specifications

Mounting Pattern	NFPA D05H, CETOP 5 NFPA D05HE, CETOP 5H
Max. Operating Pressure	345 Bar (5000 PSI) Standard CSA 207 Bar (3000 PSI)
Max. Tank Line Pressure	Internal Drain Model: 103 Bar (1500 PSI) AC Std. 207 Bar (3000 PSI) DC Std./AC Opt. External Drain Model: 207 Bar (3000 PSI) CSA 103 Bar (1500 PSI)
Max. Drain Pressure	103 Bar (1500 PSI) AC only 207 Bar (3000 PSI) DC Std./AC Opt. CSA 103 Bar (1500 PSI)
Min. Pilot Pressure	6.9 Bar (100 PSI)
Max. Pilot Pressure	345 Bar (5000 PSI) Standard CSA 207 Bar (3000 PSI)
Nominal Flow	76 Liters/Min (20 GPM)
Maximum Flow	See Switching Limit Charts

Appendices no. 7 :Directional valve Specification

STANDARD SPECIFICATIONS

Bed - Conveying surface width 19", 27", 29", 33", 41", 47", 53" and 55". 6" x 8.2 lb. and 8" x 11.5 lb. powder painted structural channel frame with powder painted structural channel cross braces in each section. Sections are 5 feet long and bolted together with butt couplings and floor supports.

Tread Rollers - $3\frac{1}{2}$" diameter x .30 wall steel tread rollers spaced on 6" or 12" centers, No. 80 sprockets, $1\frac{1}{16}$" hex shaft.

Drive Chain - No. 80 roller chain.

Floor Supports - Heavy duty structural supports are fixed at 18" elevation from floor to top of roller. One support at each end of conveyor and at each bed joint.

Center Drive - Mounted below conveyor bed section. Can be placed most anywhere in conveyor length.

Bearings - Removable, sealed, prelubricated ball bearings.

Chain Guard - Lower chain guard is mounted on bottom of roller frame, and upper chain guard is mounted above roller frame to totally enclose drive chain.

Speed Reducer - C-Face mounted heavy duty worm gear reducer.

Motor - 2 HP 230/460-3-60 TE motor.

Capacity - 2000 lbs. per foot maximum. Not to exceed Load Capacity Chart.

Speed - 30 FPM constant.

OPTIONAL EQUIPMENT

Floor Supports - Lower or higher supports are available.

Side Mounted Drive - Center drive mounted to side of conveyor frame. Drive is higher than conveyor frame. Minimum elevation to top of rollers is $10\frac{3}{8}$". Specify which side.

Rollers Set Low - Tread rollers set low in 8" x 11.5 pound structural steel channel frame to form $1\frac{5}{8}$" high guards.

Tread Rollers - $3\frac{1}{2}$" diameter x .30 wall steel tread rollers spaced on 6" or 12" centers, No. 60 sprockets, $1\frac{1}{16}$" hex shaft.

Drive Chain - No. 60 roller chain.

Motor - Single phase, energy efficient, explosion proof, etc. Other HP available.

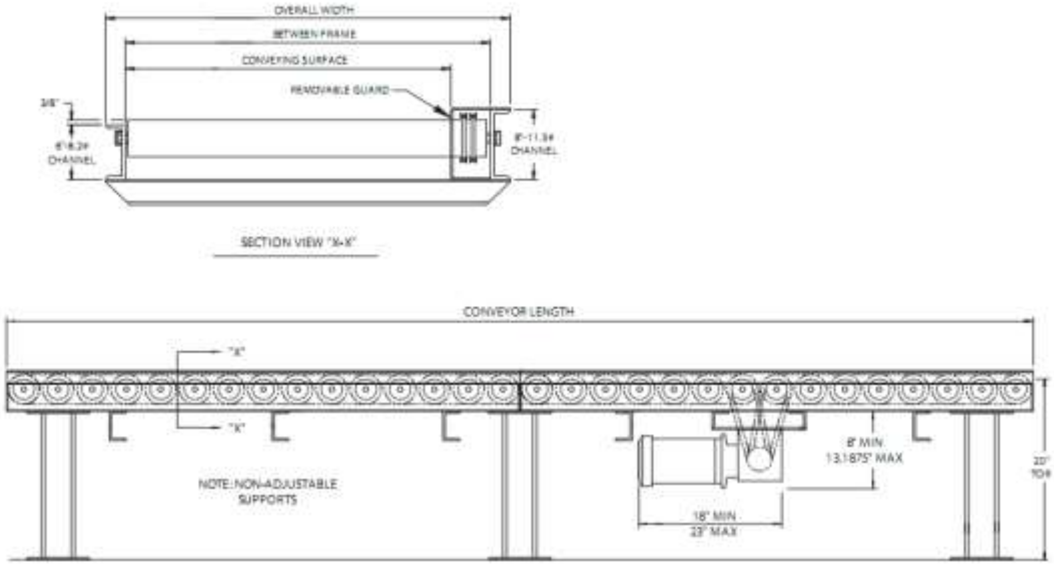
Electrical Controls - Magnetic starter and push button stations; manual motor starters with overload protection, others.

Speed - Constant and variable speeds available.

Appendices **no. 8 :Roller Conveyor Specification**

- **Heavy duty conveying**
- **Positive drive**
- **Pallets**
- **Heavy drums**
- **Reversible drums**

Appendices no.9 :Roller Conveyor sample



Appendices no. 10 :Roller Conveyor Section

MODEL 108 SPECIFICATIONS

STANDARD

Belt Widths: 12", 18", 24", 30", 36", 48"

Lengths: 5' minimum, 150' maximum

Motor: 1/2 HP 230/460/3/60 TENV

Speed: 60 FPM fixed

Drive Location: End drive bottom mount

Belt: Black PVC 120

Paint: One coat Titan gray enamel

Supports: 30" TOB "H" type adjustable, specify elevations required

Controls: None supplied

OPTIONS

Belt Widths: 6", 8", 10", 14", 16", 20", 40", 42", 54", 60"

Lengths: 3' minimum, up to 180' based on application

Motor: 3/4, 1, 1-1/2, 2 HP, 115/230/1/60, 575/3/60, TEFC, washdown, severe duty, inverter duty, brake motor

Speed: Fixed speeds – specify speed required, variable speed with DC motor and SCR controller or AC inverter

Drive Location: Center drive and take-up, side mount, top mount

Belt: Rough top, food grade, v-guide on bottom, belt to fit application

Paint: Titan will match color chip provided, unit can be primed and painted epoxy or food grade

Supports: Knee braces or ceiling hanger brackets (less rod)

Controls: Specify type required

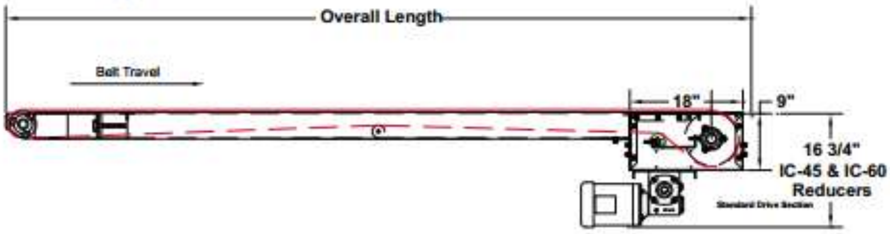
ACCESSORIES:

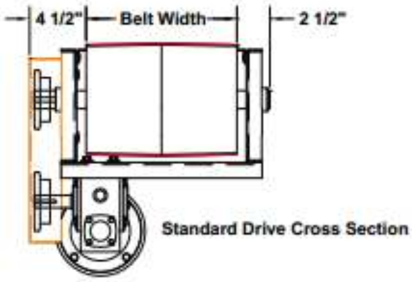
Siderails – 1", 3-1/2" or 6" high fixed channel, 3-1/2" high adjustable
Bolt-on bottom pans
Casters – 4" or 6" diameter rigid or swivel with brake
Transfer roller, bolt-on end stop and belt scrapper
Stainless steel construction
Internal take-up
Units assembled (some restrictions apply)
E-stop with pull cord
V-guided belt for positive tracking
Machined and balanced pulleys for high speed
Siderail skirting

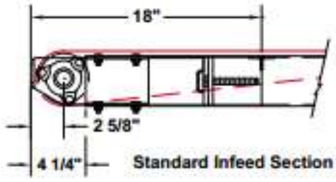
Appendices **no. 11 : Conveyor belt Specification**

Model 108 Slider Bed Conveyor

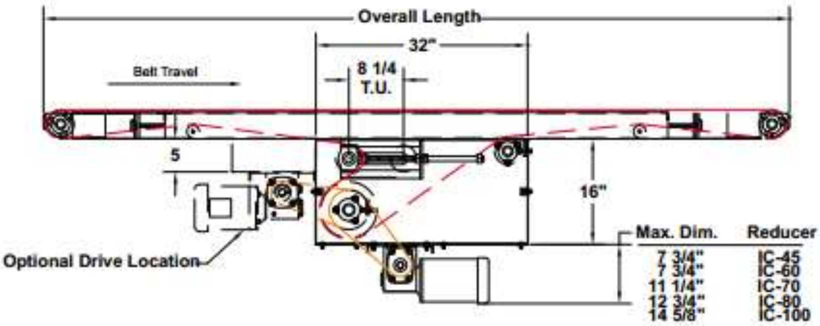
Model 108 features a 8" Drive pulley for heavy duty work. Ideal for packing, testing and inspection.







Optional Center Drive & Take-Up



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Appendices no.12 : Conveyer Belt Sample and Section