Amirkabir University of Technology
(Tehran Polytechnic)

Industrial control project Report

PLC Based
Elevator Controller with variable speed drive

Melika Salehian
Mehban Gholi Jafari
Fatemeh Karar
Maryam Heydari

Professor: Dr Afshar

Winter 2022

Part 1 :

Elevators are the important medium of vertical transportation in both residential environment and the industrial environment. Now days, there is tremendous development in structural and architectural engineering for multi storage buildings. The main requirement of the multi storage buildings are elevators. Elevators ease the work human being and keep him/her in the comfortable zone. Elevators are used in almost all the multi storage buildings of the metropolitan cities, hence it is essential to replace the traditional elevators with PLC technology based elevators.

Traditional elevator control systems are relay logic controlled systems. These relay controlled systems have several limitations such as: high fault ratio, highly complex circuits, difficult to replace the defected parts of the automated system. It is difficult to provide fault tolerance using the relay logic.

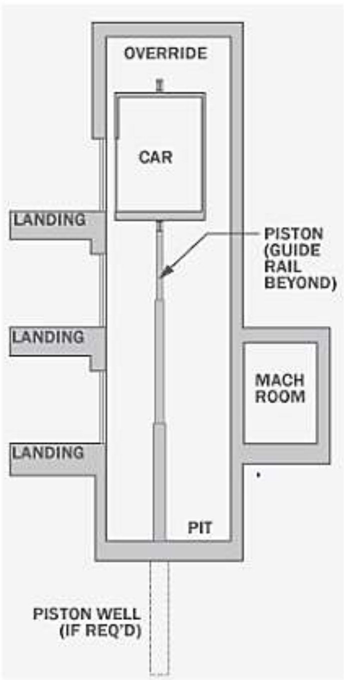

Figure 1 - structure of a hydraulic elevator system

PLC is the replacement to relay logic controller, one can make the better use of PLC in the designing of the elevator control system. The ladder logic programming is used to simulate the proposed system Hydraulic elevators Figure 1 describes the structure of a hydraulic elevator system.

The car is attached to a piston at the bottom that pushes it up when the electric motor pumps some hydraulic fluid into the piston. It is moves down by releasing fluid using a valve. Elevators of this type are used in buildings with up to eight floors.

As shown in Figure 2, traction elevators are moved using electrically driven wheels, ropes and counterweights. They produce higher travel speeds and hydraulic elevators and are used for mid and high-rise buildings. to the wheel's motor. They can reach a maximum travel speed of 153m/s and a maximum distance of about 75 meters.

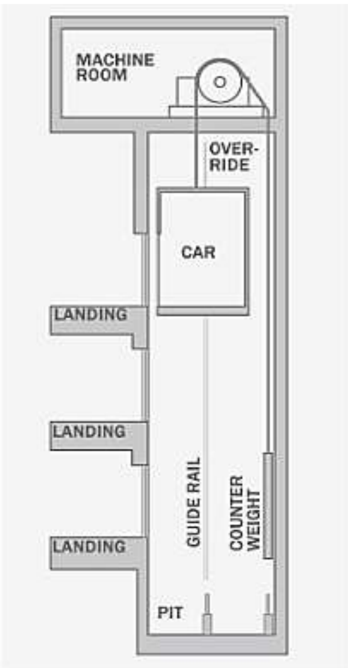

Figure 2 - Traction elevators with Machine Room

A variation of this type, called a geared traction elevator is added with gearboxes attached MRL Elevators, as shown in Figure 3, are traction elevators with no machine room above the shaft. Instead, there are control boxes placed in a control room above the highest landing floor. Although they produce the same travel speed as geared traction elevators, MRL elevators are the most reliable for mid-rise building thanks to their space and energy efficiency

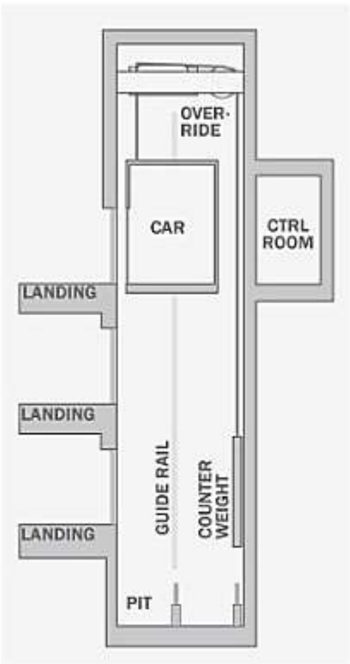

Figure 3 - traction elevators with no machine room

The main design considerations for choosing either electric traction drive or hydraulic for a particular project are the number of floors, the height of the building, the number of people to be transported, desired passenger waiting times and frequency of use.

This project is to design and construct an elevator using a programmable logic controller. Hall Effect sensor is used to know the elevator position. Hydraulic and roped elevators are the two types of elevators in use today.

Elevators are prevalent throughout many multi-level structure.

And now if we want to have an overall look to determine the outline of our project we have :

In an elevator system we have the push buttons outside of the cabin so whenever it gets pushed the signals need to be sent to signal processor and after that from headquarter should control over the speed and breaks and when by reaching to desired level it needs to activate its break ,after that the user will use the panel inside and push the wanted level and this cycle will continue to run over and over again.this is the outline but if we want to zoom in,in every stop the elevator needs to check before closing the door so it wont cause problem for its users and if our elevator has speaker while reaching each level to announce the right level,also before closing the door the weight needs to be checked so it doesn’t get overweight.

A PLC controlled elevator requires a control room for placing a cabinet which is connected to the motor. Therefore, these can be classified as MRL elevators.

Figure 4 demonstrates the components inside the cabinet that controls the elevator’s operation. The PLC is in charge of reading inputs such as push buttons, sensor signals and make logic commands, which are sent to the elevator drive. Logic programs can be downloaded into the PLC through a remote PLC gateway or by plugging a USB device that contains the program.

The elevator drive directly controls the elevator motor that lifts or lower the car.

The regenerative drive is a replacement for traditional braking resistors that dissipates excess kinetic energy. Particularly, when lifting a fully loaded car, the elevator drives transfer electrical power to the motor.

When the car descends, energy stored in the mechanical system is converted back into electrical energy (KEB Automation, n.d). As a result, the braking the resistor dissipates this energy as wasted heat. With the addition of regenerative drive, it allows current to flow back in the system's DC circuit or onto the building power supply line.

The HMI (Human-Machine Interface) visualizes the activities of the elevators and enable the operator to interact with the system.

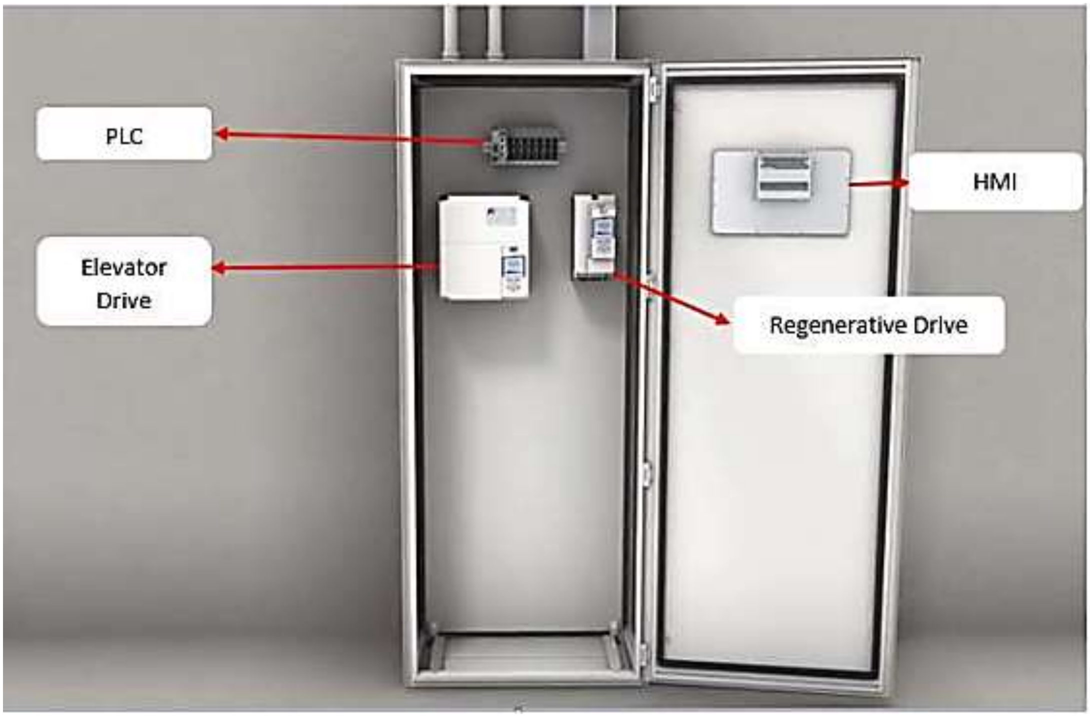

Figure 4 - components inside the cabinet

Programmed operations

The elevator is designed to move between four floors. Initially, the car is at the first floor, meaning that the it is at the very start of the operation. If the elevator is at another floor from the beginning, it makes no problem for the program. Signals from call buttons will activate the movement of the car. It will move in a power saving order, which means if the car is moving in one direction and there is another call to an opposite direction, it will respond to all the calls in the initial direction before responding to the latter. For example, if the elevator just went up from floor 1 to floor 3 and there are two more calls to floor 5 and floor 1, it will continue moving up to floor 5.

The elevator finishes a call when the call signal matches the floor level sensor. For example, a call to the second floor is finished when the signal from that floor’s level sensor is high and a floor call was made. Then, all the call signal to the second floor is reset to 0. The door is then opened for a fixed period then closed before the car moves to another floor. The car can only resume moving when the door is fully closed. When the Open button is pressed, the door is reopened if it is closing, if it is still opened then the open time is reset. There is also a fixed period after the door is fully closed again to wait for the Open button signal before the car moves again.

If there is an obstacle between the doors or the elevator is overloaded, then the door is remained opened or reopened if is closing.

An HMI screen will be shown in the simulation step to for visualization of all operations.

Part 2:

Lift control system is to implement the following functions:

1) Directions decided by the signal, forward priority implementation.

2) When driving in case of call signals, forward section, does not stop the car when reversing.

3) Within the selected signal, the call signal own function of memory, deletes the signal after the implementation.

4) Call signal, directions, car location is indicated by the car dashboard.

5) When reaching the floor, the door can be delayed opening automatically or manually, (in the process of closing) when the next floor is in the same direction, the door will open and take the passengers.

6) If there is any signal from car dashboard, the door will be delayed to close automatically and then will be delayed to move the car automatically.

7) When there is no signal form car dashboard, the door will be closed after 5s automatically, but can't automatically move

8) When the lift is running, it cannot be manually opened or the called from the same floor to open, the car cannot move when the door is open. (Changchu)

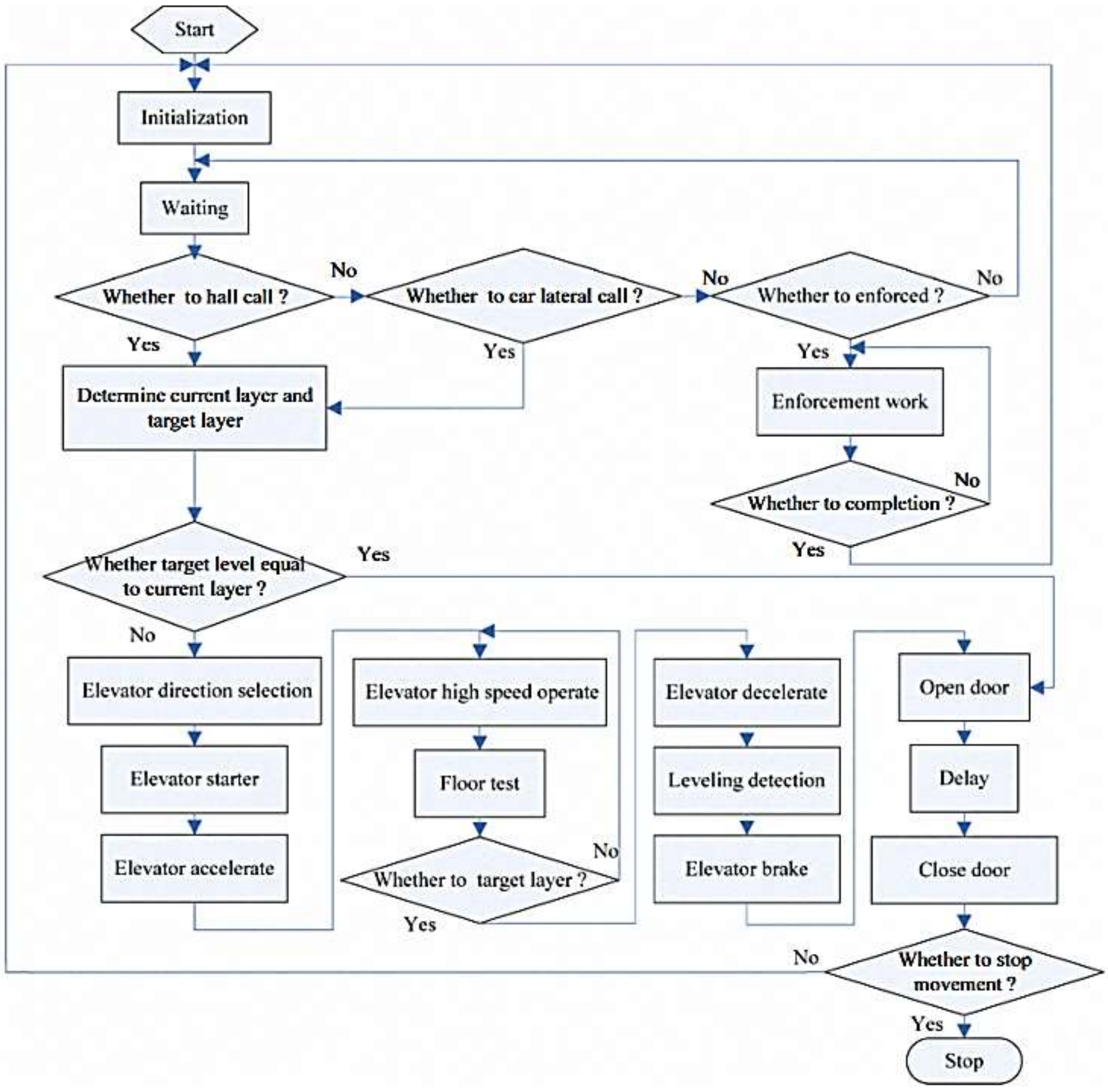

Figure 5 - Flowchart

<u>Part 3 & 4:</u>

All steps are done in an automatically way and the only part you can say need man power is the part which the user push the buttons whether on the inside or outside and the control is local usually there is a cabinet next to the elevator which we put our plc in it and then the whole process is under plc observation.

Logic programs can be downloaded into the PLC through a remote PLC gateway or by plugging a USB device that contains the program.

Part5:

If obstacle sensor detects there is an object or person between the door sides, the door stays open or opens if it is closing.

If overload sensor detects the elevator is overloaded the door stays open and the alarm sounds.

Also, if the fire sensor is activated, the elevator will stop on the nearest floor and the alarm will sound and it will stop until the sensor is deactivated.

Part6:

Controlled and simulated elevator components:

The listed components below are classified as either inputs or outputs fordeclaration in the program.

Floor door and cabin door (outputs): Since the car door and floor door operates simultaneously in real time, there is one output signal that simulates their operation.

Car motor (outputs): There are two output signals for moving the elevator car upwards and downwards.

Sensors (inputs):

– Obstacle sensor: Detects if there is an object or person between the door sides.

– Overload sensor: Detects if the elevator is overloaded.

– Floor level sensor: Indicate which floor the elevator is at.

Buttons (inputs)

– Open and Close buttons in elevator car.

– Car call buttons: Call buttons inside the elevator car.

– Floor call buttons: Call buttons on each floor

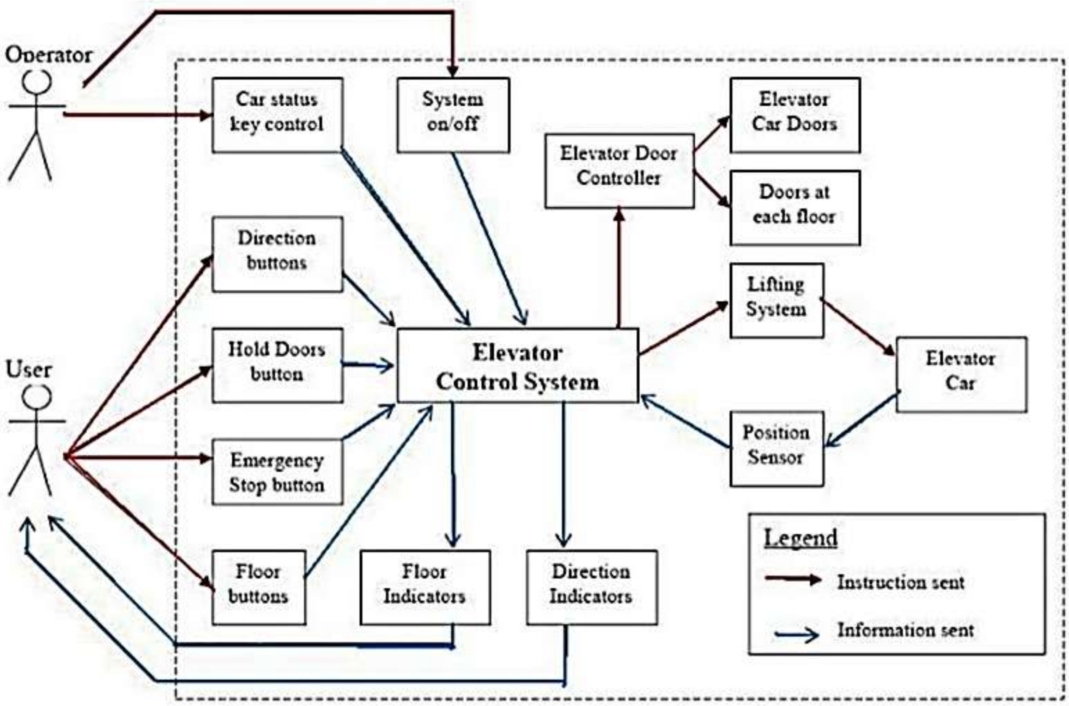

Figure 6 - Input & Outputs

Part 7:

Elevator movement process control and safety process are done by using sensors. If one of these sensors has a problem, the process should be stopped and the sensor should be repaired or replaced. Therefore, it is necessary to add one or two additional sensors of each type for the possible failure cases.

Part 8 & 14 :

Preventive Maintenance Inspections: These are similar to a tune up for an automobile. Conducted at regular intervals (often in the evening when the Metro system is closed to prevent disruption to the customer), maintenance staff oil and grease moving parts and check wear on chains, handrails, and other parts. These inspections enable staff to proactively identify and address maintenance problems early. If problems are identified, the unit stays out of service for Preventive Maintenance Repairs. If problems can be resolved within a day, the unit goes out of service for Minor Repairs. If problems are significant, the unit goes out of service for Major Repairs. If no problems are identified, the unit goes back into service the next day.

Modernization: Each elevator/escalator is made up of thousands of moving parts; and with heavy usage over time, the parts become less reliable despite regular preventive maintenance. Elevators/escalators should be modernized every 20-25 years and replaced after 40-50 years. This translates into Metro modernizing approximately 12 elevators and 26 escalators a year. The modernization schedule can vary year-to-year based on the age and condition of units and available funding. Modernized escalators are typically out of service from 10-20 weeks, depending on the length of the escalator, as the old units are removed and new components installed. The time frame for elevator rehabilitation is approximately 8-12 weeks. Modernized units are as much as 30% more energy efficient than the old units due to premium efficiency motors and adjustable frequency drives. Metro also benefits from new technology in rehabilitated units that provide real-time data to monitor performance. The customer gets a more reliable elevator and escalator.

Walker: When there are only two escalators side-by-side, if one escalator is out of service for repair (typically, for a modernization that takes many weeks to complete) the other escalator must be turned off so that customers may either walk up or down the remaining escalator. This is done to ensure the station remains accessible to customers by foot. Metro recommends using caution when walking on escalators and being courteous of other passengers.

Service Call: When an elevator/escalator is observed out of service unexpectedly by a station manager, Metro maintenance staff is called to complete an unscheduled repair. Staff evaluates the cause of the outage and begins repairs in order to bring the unit back in service and minimize customer inconvenience.

Scheduled Support: Elevators/escalators are occasionally taken out of service to support other maintenance activity in a station. Examples include lighting replacement and repairs to station ceiling and platform tiles.

Safety Inspection: Building codes require that elevators/escalators be inspected on a regular basis to ensure units are operating safely. Preventive maintenance compliance inspections are conducted to ensure repairs conform to maintenance standards. If an equipment problem is identified, the unit stays out of service as maintenance staff makes the necessary Inspection Repairs.

Customer Incident: Keeping elevators/escalators safe is Metro's top priority. If an incident/accident does takes place in/on an elevator/escalator, the unit is shut down so it can be inspected to ensure the unit is safe. See safety tips to prevent injury in a Metro elevator or on an escalator. If an equipment problem is identified, the unit stays out of service as maintenance staff makes the necessary Inspection Repairs.

Power Outage: When severe weather causes power outages, elevators/escalators can go out of service for several hours until power is restored by the utility company. Power surges can cause shorts in electrical equipment and motor rooms, taking units out of service until repairs are made.

Fire Alarm: If a sprinkler system is activated in a station due to a fire alarm, elevators and escalators are designed to shut off. If the sprinkler system remains on for an extended period of time, units may become deluged with water causing damage to mechanical and electrical systems. These units are taken out of service for repair.

Water Intrusion: An elevator/escalator may go out of service many weeks after a rain event as water seeps into the ground and collects at the bottom of the unit, causing damage to the equipment.

Weather Conditions: Mechanical and/or electrical damage may occur the day of a heavy rain event for elevators/escalators exposed to the elements as water cascades down the units, particularly entrance elevators and escalators. Winter icing and snow events also cause units to go out of service.

Whether it's worn sheaves or simply an old operating system, many different factors can contribute to elevator malfunctions and breakdowns.

Taking proactive, preventative steps, however, is much easier than fixing an already broken elevator, and regular inspection is the first step to ensuring smooth and reliable operation.

In fact, thorough inspections combined with routine maintenance can significantly increase productivity by eliminating downtime, and can also decrease energy consumption by up to 15%.

No one wants long wait times or breakdowns. Not only are these obvious signs an elevator system has seen too much wear, but they can also run up costs. Below are five common elevator issues, with tips on how to fix them.

Problem: Power Failure

Since elevators require a large supply of power from commercial building utility systems, voltage updates can affect motor operations, and updates to systems can even cause damage to the elevator.

Solution: Power Quality Survey

Power quality surveys can uncover common faults like under/over voltage. Infrared thermography, for instance, measures extreme temperature fluctuations, helping to identify potential issues before they cause an expensive system failure; fuses running hot are much more easily seen using infrared technology.

Problem: Worn Sheaves

Worn sheaves place excess wear on ropes, in turn further increasing the level of wear on the sheaves. Ideally, proper inspection will prevent this from occurring, but once it does begin, damage is inevitable.

Solution: Regrooving

Either replacing or regrooving sheaves can help prevent premature hoist rope failure, so it’s important to check groove profiles in order to ensure a proper fit between sheaves and ropes. Magnetic standard tools and a straight edge can help you visually check wear on grooves.

Problem: Contamination

With wear comes the release of small metal particles into the oil, which interferes with elevator system functioning. Improper lubrication or worn-out seals can also interfere with proper functioning.

Solution: Oil and Lubrication Analysis

To ensure your elevator isn’t affected by these contaminations, a proper analysis should be completed, in which you check for certain properties in the oil that can indicate contamination or motor wear. For instance, a high level of bronze in gear case oil can mean premature wear has occurred on the gear’s crown. Or, a high level of aluminum in a hydraulic tank can mean wear has occurred on the pump housing.

Problem: Bearing Malfunction or Loud Bearings

More than 50% of all motor failures can be traced back to bearing malfunction, and vibrations within the motor can result in noisy bearings. Although variable frequency drives can helpdecrease the motor’s energy use, they can also introduce common mode current — a byproduct that increases vibrations to hazardous levels.

Solution: Inductive Absorbers

An inductive absorber, CoolBLUE can absorb these currents and provide protection from potential breakdowns. This absorber also ensures all grounds are connected and secure, minimizing issues from electrical noise on the ground that can trip out systems.

Problem: Misaligned Motor Drive

Shaft alignment is critical when another piece of equipment is coupled to an electric motor, as improper alignment can cause wear on motor bearings.

Solution: Laser Measuring

Shaft alignment can be detected through the use of laser measuring equipment, or simply employing a straight edge and string. The need for alignment can be eliminated altogether, however, by purchasing a geared machine with a flange-mounted motor, which doesn’t require aligning if the machine is disassembled.

Renown Electric offers preventative maintenance and on-site elevator repair services for companies and organizations across all types of industries.

Part 9 :

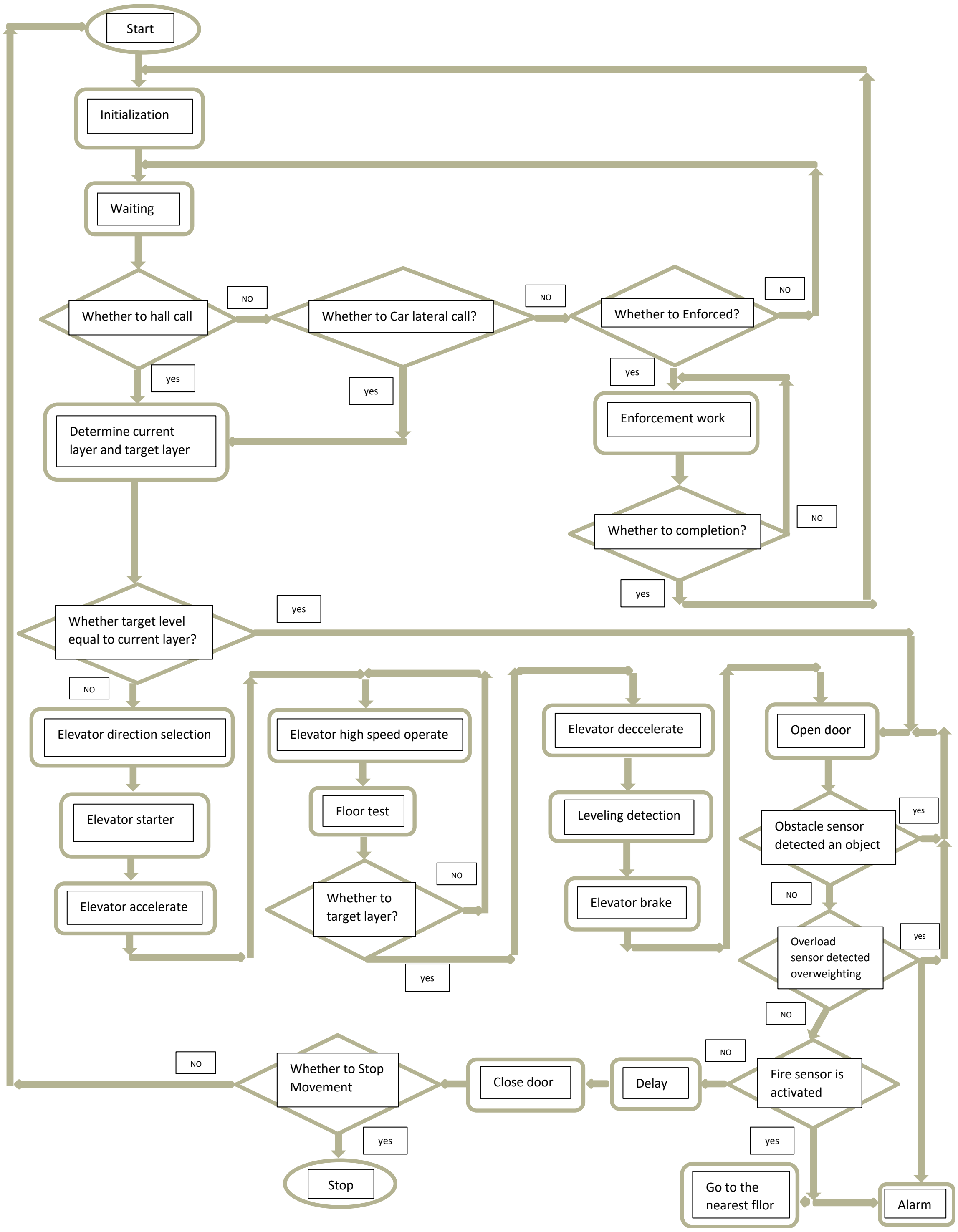

Figure 7 -Updated Flowchart

Part 10 :

Elevator Speed Curve : Beforethe elevator control system design is completed and put into operation, the elevator control indicators include three aspects:

(1) The efficiency of the elevator which means the speed;

(2) The comfort of elevator which means the stability;

(3) The leveling accuracy;

The operation process of all elevators can be summed up in three stages, start-up stage, stable operation stage and the stop stage. Here, the main thing we discussed is the feeling caused by the change of elevator speed during the operation process. This feeling is called the riding comfort. This refers to the feeling of the elevator at the start up and deceleration stage. This feeling will change with the acceleration and deceleration. The greater the change is, the worse the riding comfort will be. However, if the design is only focused on the comfort of the elevator and its operating speed is ignored, it will greatly reduce the efficiency of the elevator. Therefore, it is required that the elevator should satisfy the comfort of the passenger, while ensuring the efficiency and accuracy of the elevator. Finally, the ideal elevator speed curve is proposed and the speed curve is shown in Figure 8.

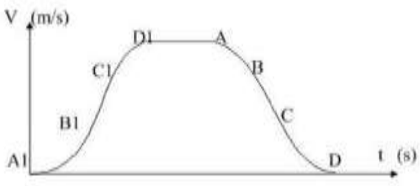

Figure 8 - The Ideal Elevator Speed Control

It can reduce the passengers' sense of being overweight and weightlessness during the process of starting and stopping.In this paper, the control system needs to be based on the above elevator speed curve to achieve the stable operation of the elevator. The passengers can avoid the sense of overweight and weightlessness to achieve the goal of a comfortable ride ladder.

Modeling of the Elevator Control System

(1) Permanent magnet synchronous motor model based on steady state.

The mathematical model of the permanent magnet synchronous motor and frequency converter is very complicated, and it is difficult to establish.In order to facilitate the experiment, the mathematical model is simplified as follows：

$$G_1(S) = \frac{4}{75S^2 + 0.8S + 2.64}$$

(2) Inverter model

In engineering practice, the transfer function of inverter can be set as a small inertia link or a proportion link in the specific circumstances. In this paper, the inverter mathematical model is set as an inertia link. So the transfer function between the control voltage and the output voltage is shown as follows:

$$G_2(S) = \frac{K_S}{T_S + 1}$$

(3) Elevator control system model

According to the analysis of the mathematical model of the elevator body in front of the elevator, the simulation model of the speed response can be established. Reducer can be simplified as a proportion link. The model of elevator control system is shown as follows:

$$G(S) = G_1(S) + G_2(S)$$

$$G(S) = \frac{20}{80S^2 + 0.5S + 2.64}$$

Part 11:

Obstacle sensors

An obstacle avoidance sensor mainly consists of an infrared transmitter, an infrared receiver and a potentiometer. If there is an obstacle encountered by the infrared rays, the rays will be reflected back to the infrared receiver. Then the receiver detects the signal and confirms an obstacle in front.

Figure 9 - Obstacle sensors

weight sensor /Overload sensor

A weight sensor is a type of transducer, specifically a weight transducer. It converts an input mechanical force such as load, weight, tension, compression, or pressure into another physical variable, in this case, into an electrical output signal that can be measured, converted and standardized.

Figure 10 - Overload sensor

Floor level sensor

Leveling sensors transmits floor number of car to control center in order to activate brake mechanism and make sure elevator stops desired level. Sensors, achieving this, are actually optoelectronic sensors or smart position sensors mounted in elevator shaft or at top of car.

Figure 11 - Floor level sensor

speed sensor

Figure 12 - speed sensor

Flame detector

Figure 13 - Flame Detector

A flame detector is a sensor designed to detect and respond to the presence of a flame or fire, allowing flame detection. A flame detector can often respond faster and more accurately than a smoke or heat detector due to the mechanisms it uses to detect the flame.

Part12 :

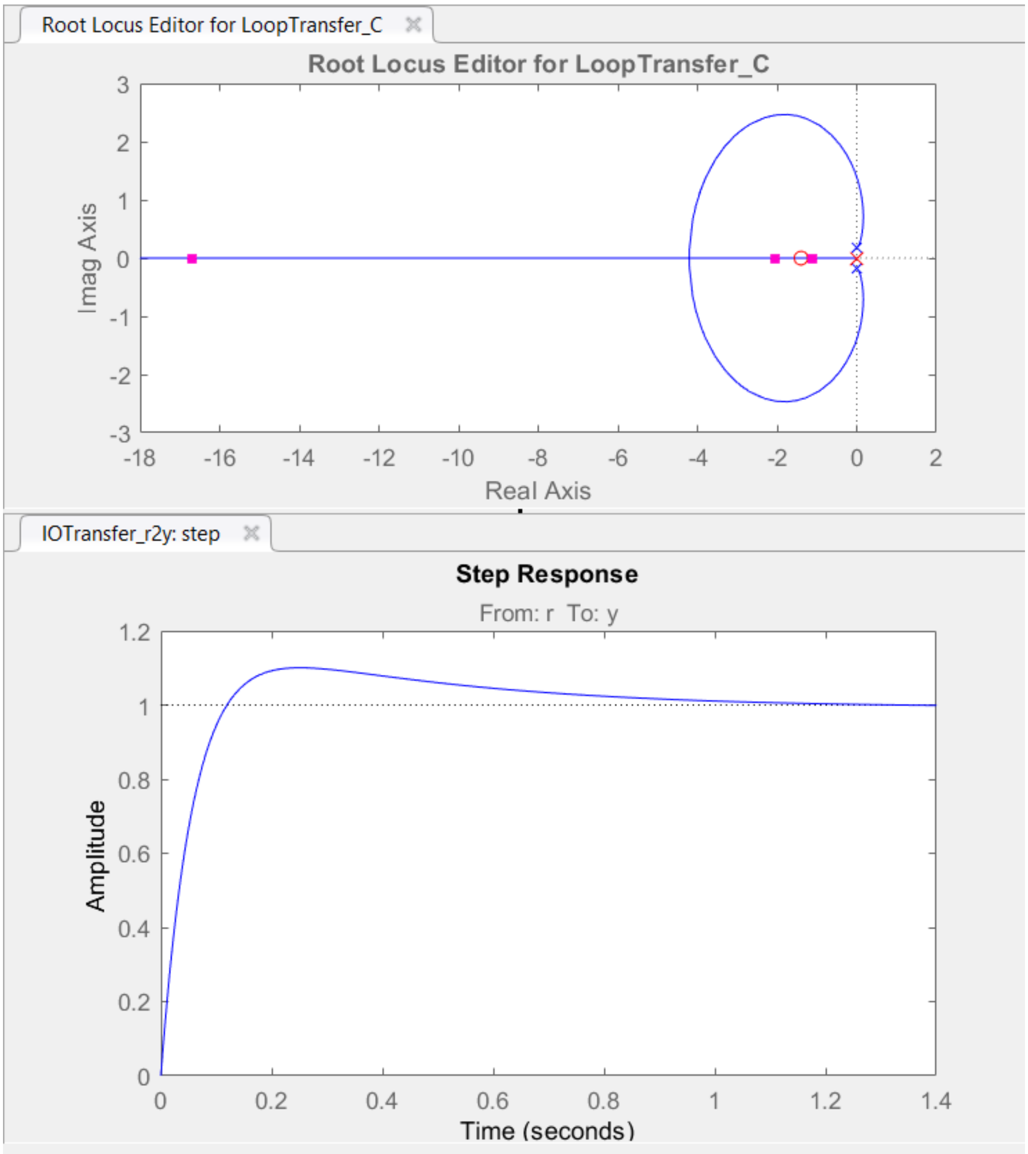

Figure 14 - PID tuning

```
     RiseTime: 0.0853
 SettlingTime: 0.8512
  SettlingMin: 0.9084
  SettlingMax: 1.1051
    Overshoot: 10.5077
   Undershoot: 0
         Peak: 1.1051
     PeakTime: 0.2549
```

Figure 15 - Stepinfo by PID

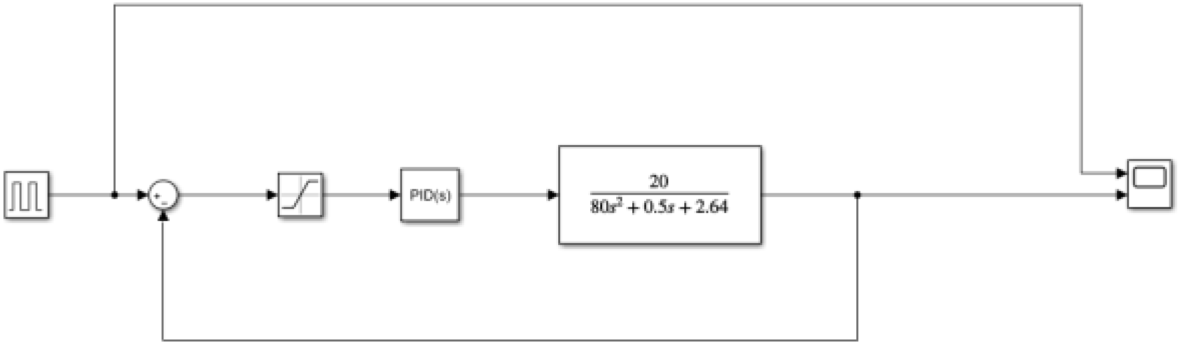

Figure 16 - Simulink system with PID controller

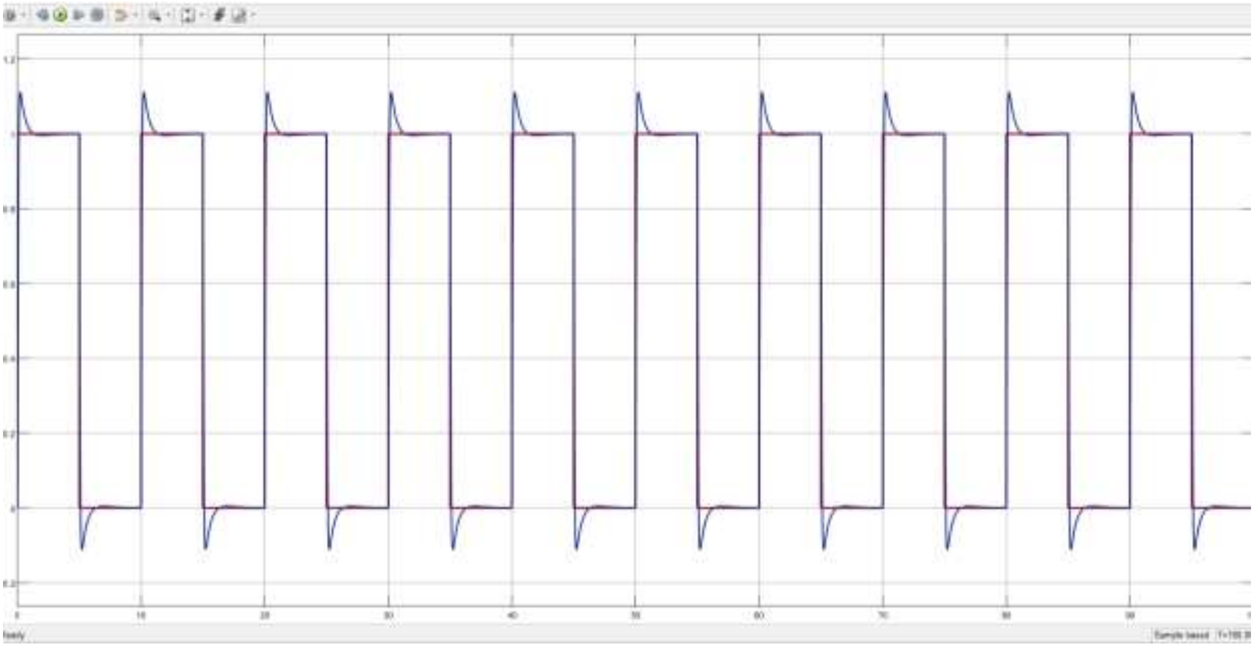

Figure 17 - Setpoint & Output Wave

Part 13 :

By Adding Disturbance : Changing of the elevator load

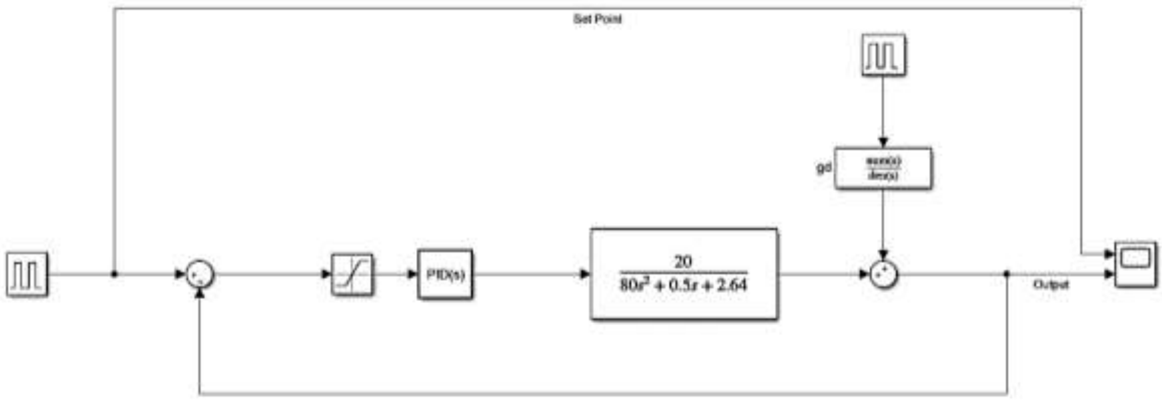

Figure 18 - Add Disturbance to System & PID

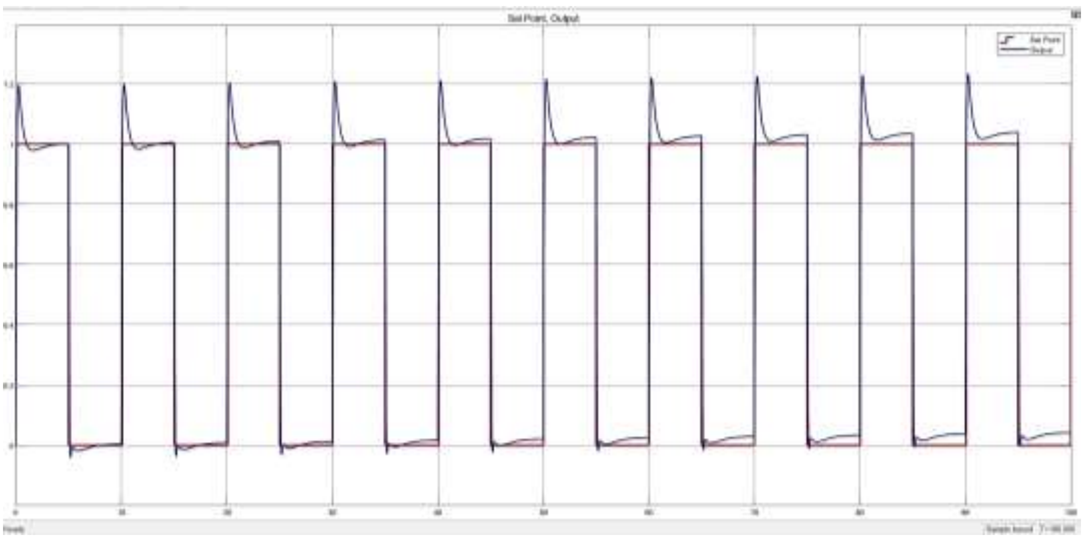

Figure 19 - Setpoint & Output Wave

Feedforward Controller:

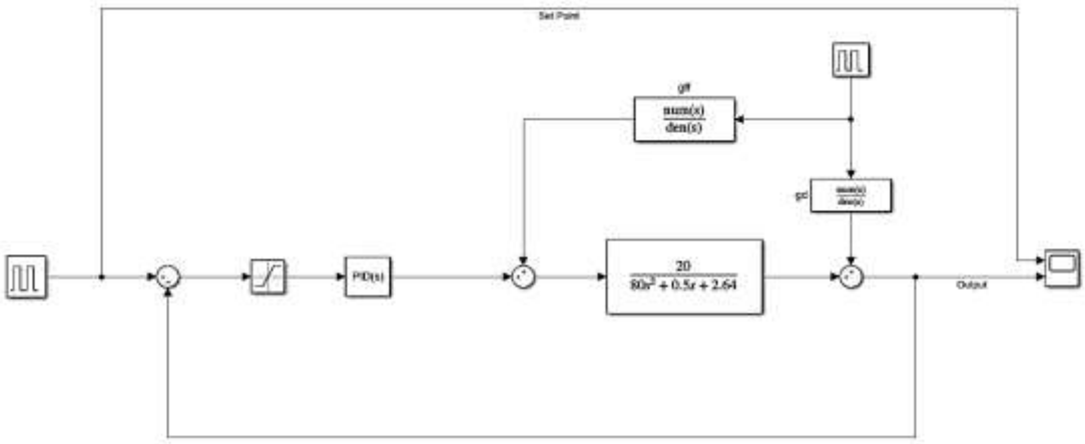

Figure 20 - Feedforward Controller

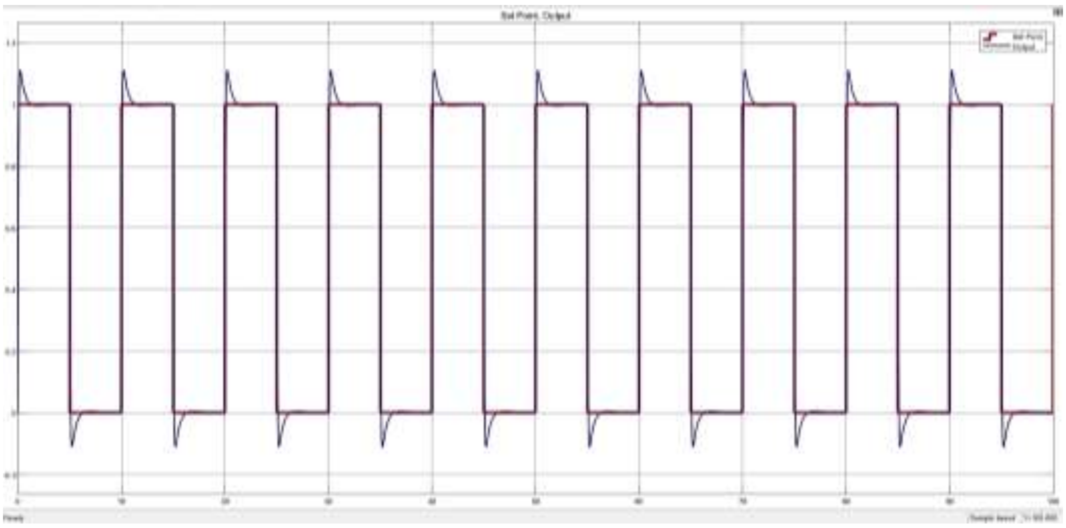

Figure 21 - Setpoint & Output Wave for Feedforward controller

Part 15 :

In case of power outage or any problem, it is necessary to ignore all previous elevator commands and stop the elevator on the lowest floor.

Part 17 :

In this project, the used PLC-unit is s7313c as shown in figure

and has the following features:

• 16 digital inputs

• 16 digital outputs

• Memory:

o Ram

▪ Integrated: 32KB for program and data

▪ Expandable: no

o Load memory

▪ Upgradable FEPROM : with micro

memory card (MMC)UP TO 4 MB

o Backup

▪ Without battery: program and data

• Profibus-DP/Device Net

• Execution times

o Pit operation: 0.1 µs to 0.2 µs

o Word operation: 0.5 µs

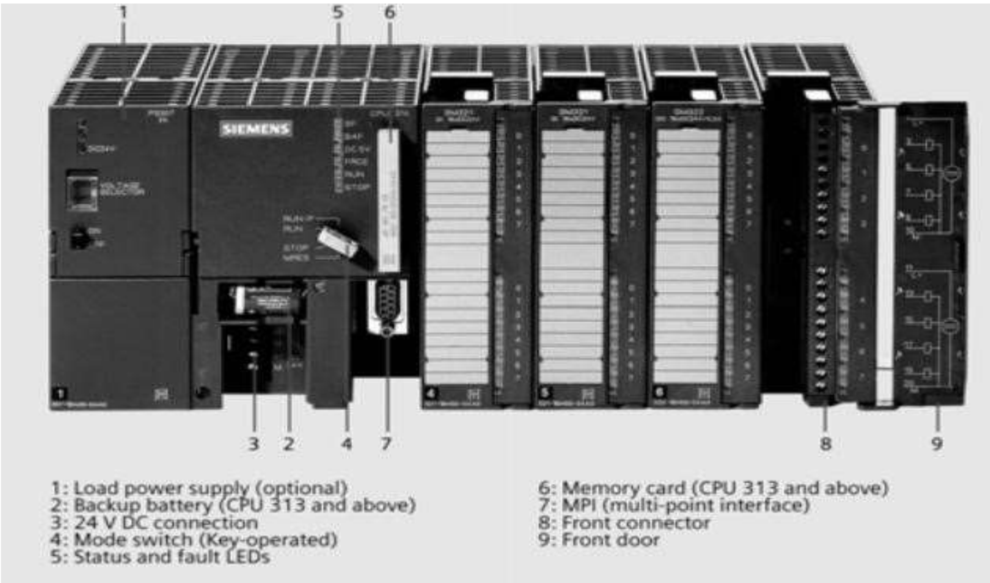

Figure 22 -Choosen PLC

Part18:

Output & Inputs

Input	Task	Output	Task
Q:1.1	Floor 1	Q:0.1	Motor 1
Q:1.2	Floor 2	Q:0.2	Motor 2
Q:1.3	Floor 3	Q:0.3	Motor 3
Q:1.4	Floor 4	Q:0.4	Motor 4
M:0.1	Start 1	M:1.1	Out 1
M:0.2	Start 2	M:1.2	Out 2
M:0.3	Start 3	M:1.3	Out 3
M:0.4	Start 4	M:1.4	Out 4
M:3.2	Up		
M:3.4	Down		

Part 19 & 20:

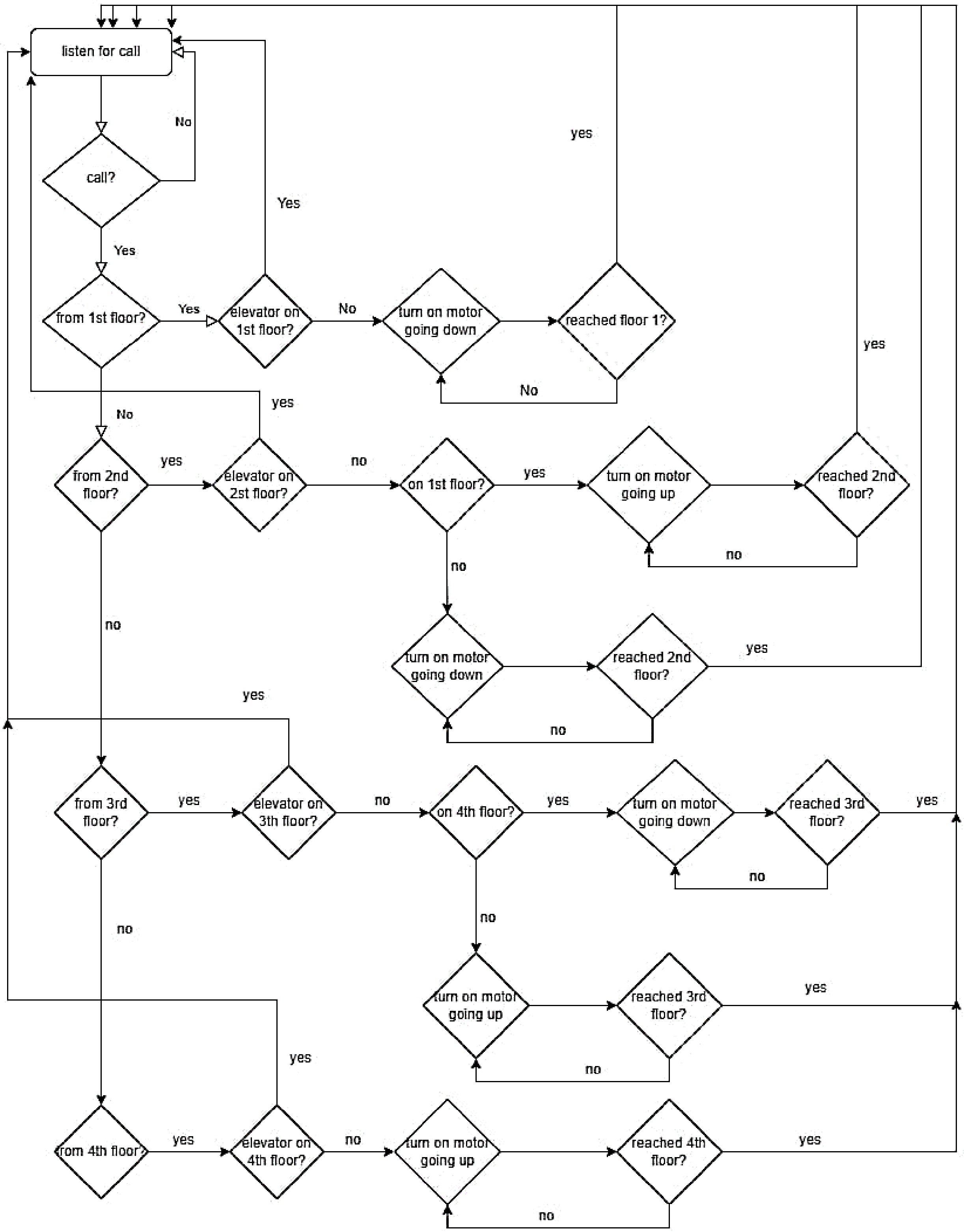

Figure 23 - PLC Structure

2 protection	Bool	%M10.6
3 protection	Bool	%M9.4
down	Bool	%M3.4
floor1	Bool	%Q1.1
floor2	Bool	%Q1.2
floor3	Bool	%Q1.3
floor4	Bool	%Q1.4
motor1	Bool	%Q0.1
motor2	Bool	%Q0.2
motor3	Bool	%Q0.3
motor4	Bool	%Q0.4
sensor1	Bool	%M4.1
sensor2	Bool	%M4.2
sensor3	Bool	%M4.3
sensor4	Bool	%M4.4
start1	Bool	%M0.1
start2	Bool	%M0.2
start3	Bool	%M0.3
start4	Bool	%M0.4
up	Bool	%M3.2
out1	Bool	%M1.1
out2	Bool	%M1.2
out3	Bool	%M1.3
out4	Bool	%M1.4

Figure 24 - The Tags which is used

in	in	out		tiger
q1.1	m1.4	up		q1.4
q1.1	m1.3	up		q1.3
q1.1	m1.2	up		q1.2
q1.2	m1.3	up		q1.3
q1.2	m1.4	up		q1.4
q1.3	m1.4	up		q1.4
q1.4	m1.3	down		q1.3
q1.4	m1.2	down		q1.2
q1.4	m1.1	down		q1.1
q1.3	m1.2	down		q1.2
q1.3	m1.1	down		q1.1
q1.2	m1.1	down		q1.1

Figure 25 - Priorities

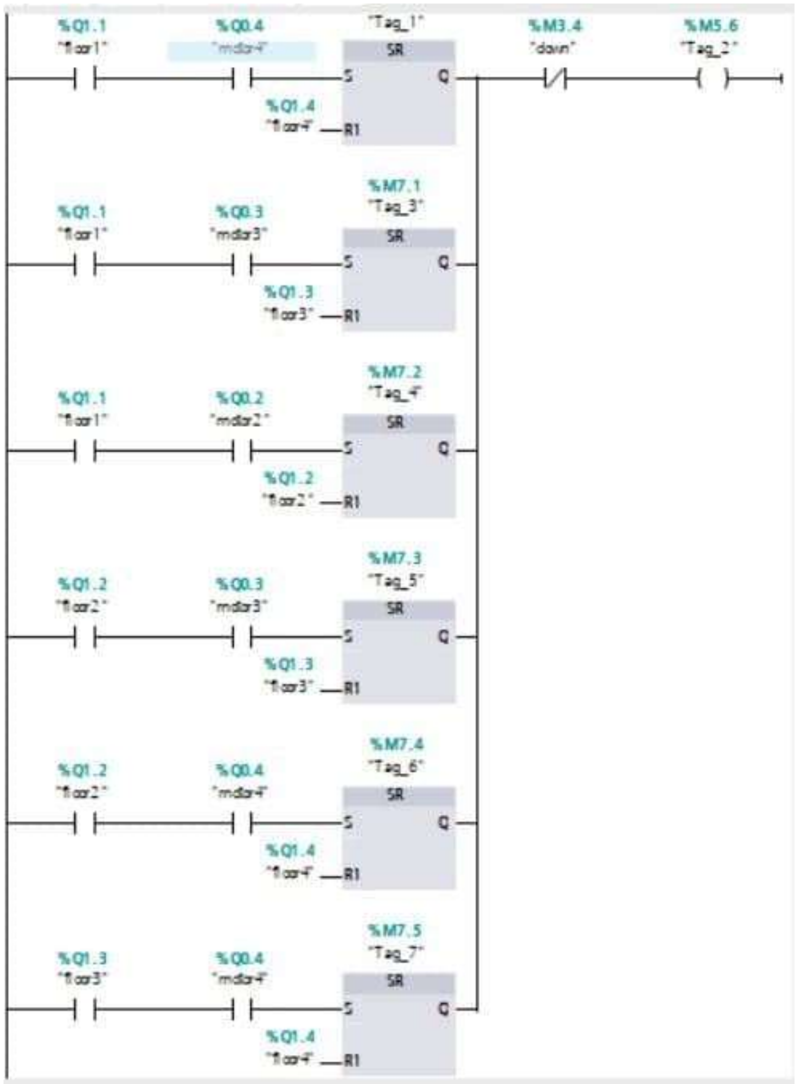

Figure 26 - Top floor priority for example

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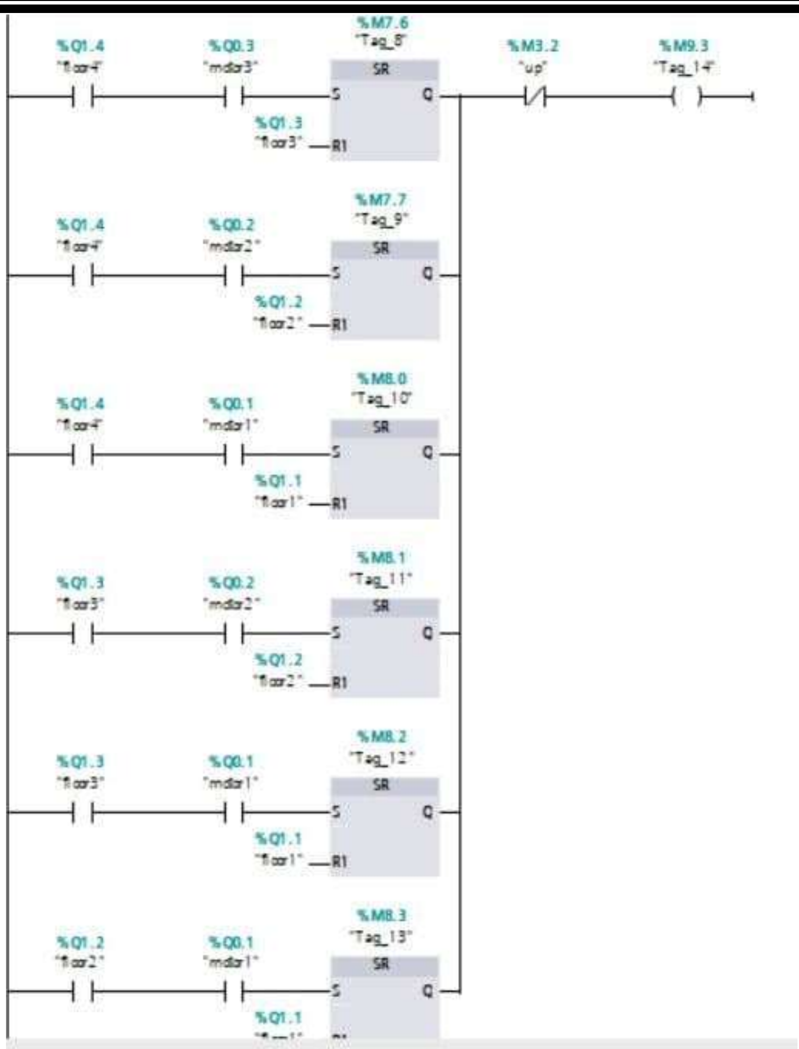

Figure 27- Bottom floor priority for example

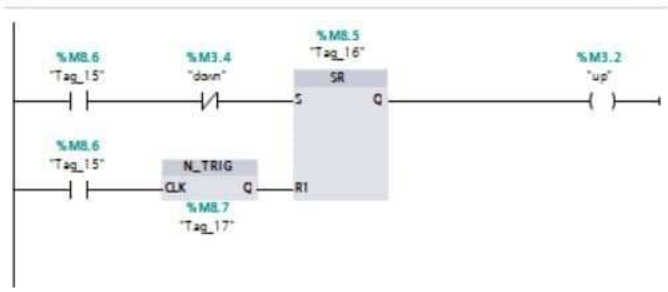

Figure 28-Default Return Floor

For example, when the elevator is moving up and you are on the second floor, it wants to go to the 4th floor. Then someone presses the first floor. This part of the diagram causes it to go to the 4th floor first and then return to the first floor.

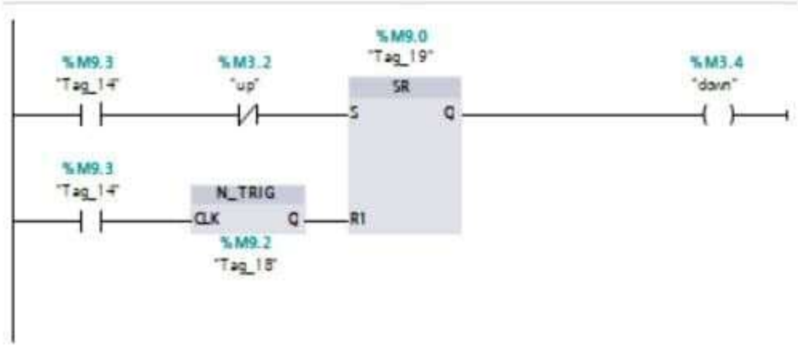

Figure 29-Default Return Floor

And similarly the elevator is moving down and you are on the 3th floor, it wants to go to the 1th floor. Then someone presses the 4th floor. This part of the diagram causes it to go to the 1th floor first and then return to the 4th floor.

Figure 30-To start moving the first floor

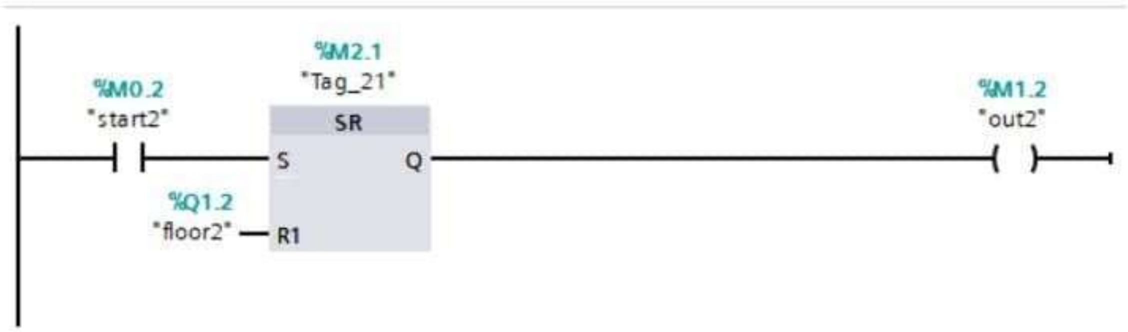

Figure 31-To start moving the 2th floor.

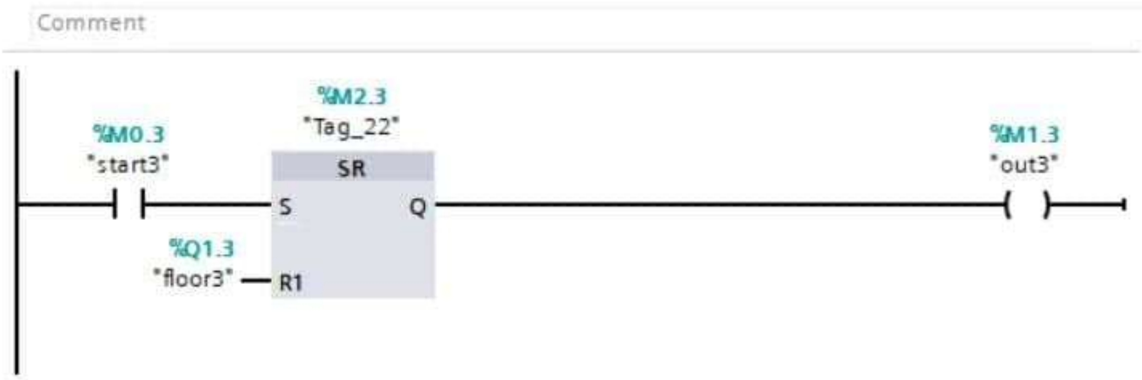

Figure 32-Start of 3rd floor

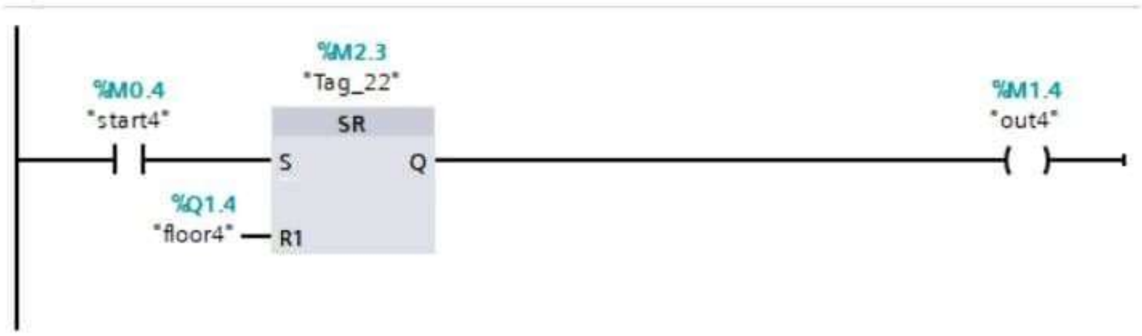

Figure 33-Start of 4th floor

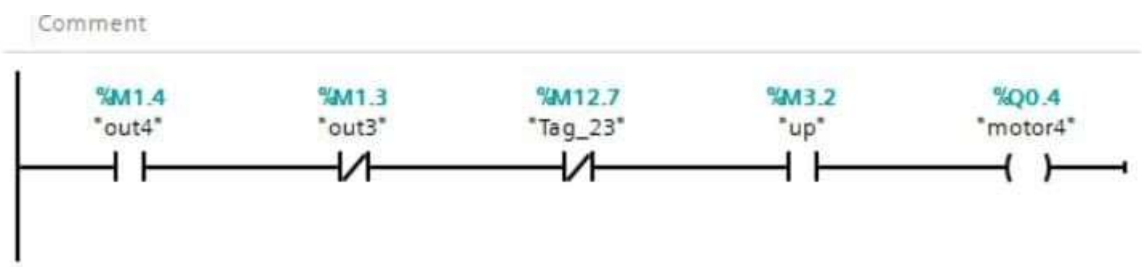

Figure 34-Start the engine for the fourth floor

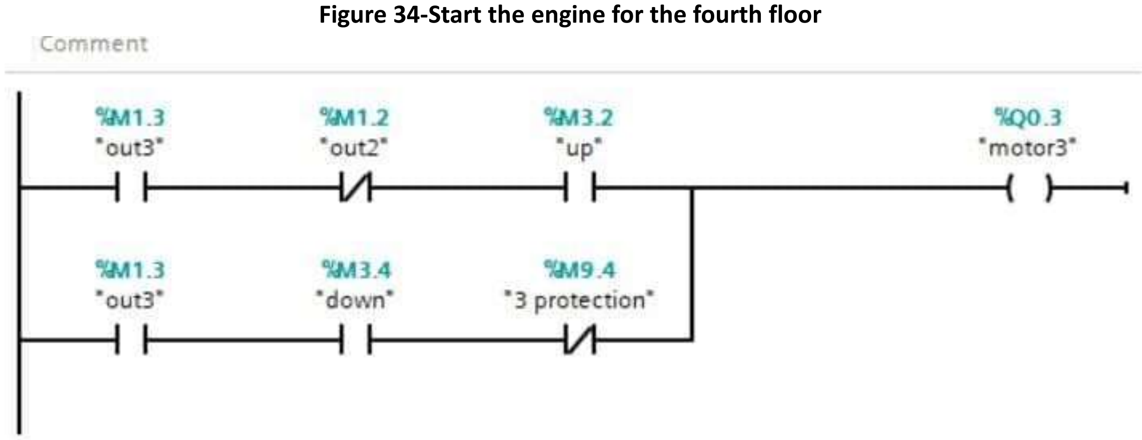

Figure 35-Start the engine for the third floor

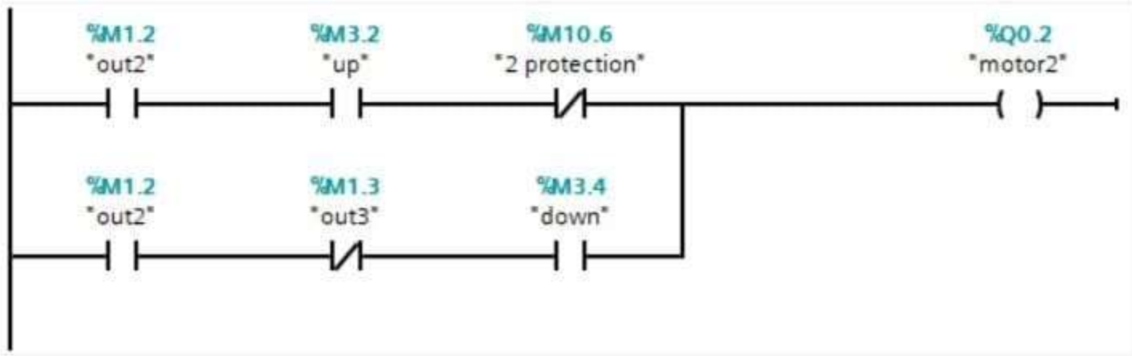

Figure 36-Command to the second floor engine

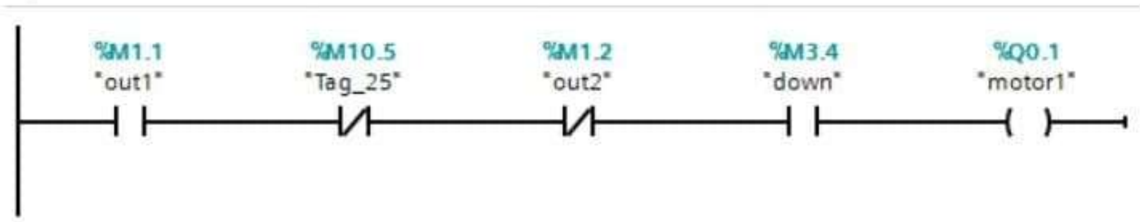

Figure 37-And finally command to the first floor engine

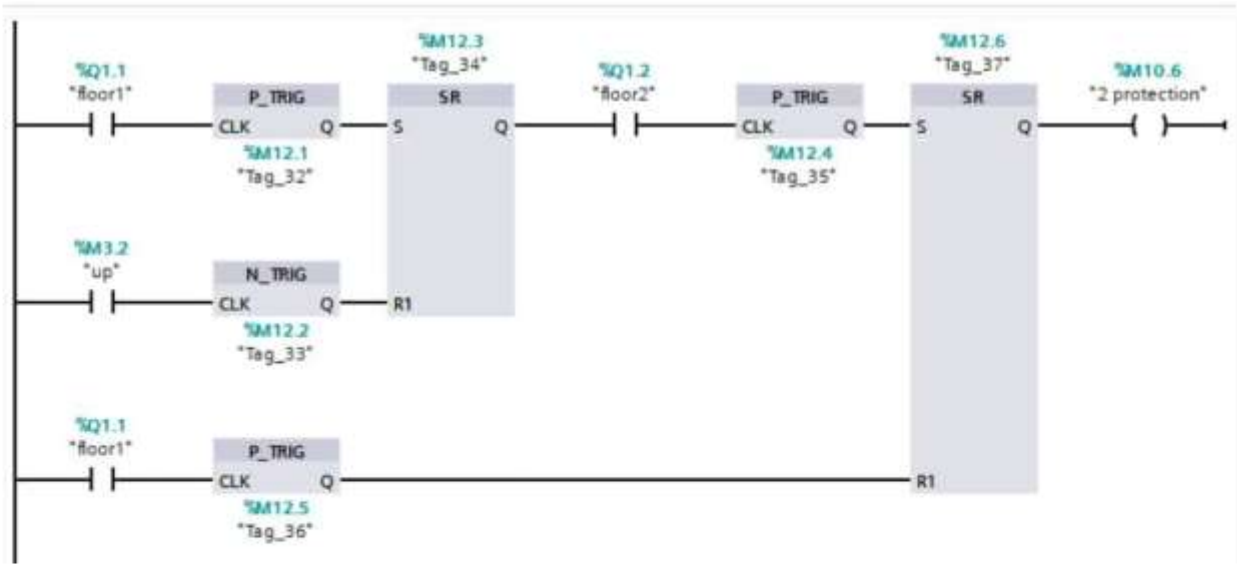

Figure 38-Second floor protection

Second floor protection: Suppose we are on the way back to the second floor, we press the first floor button and then the second floor button, first we go to the first floor then we go back to the second floor.

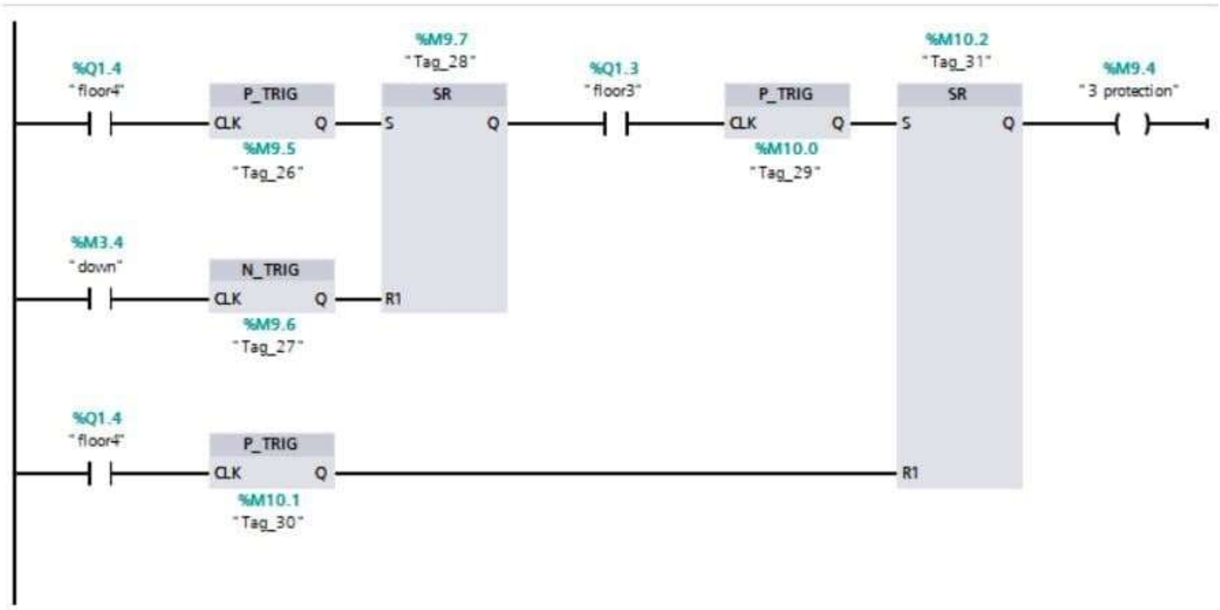

Figure 39-3rd floor protection

The same thing happens for the third floor.

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