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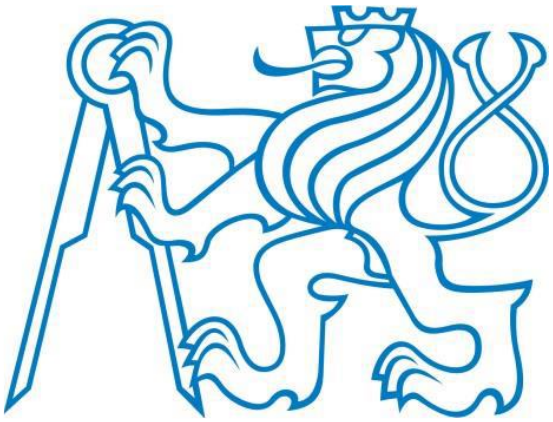


FACULTY OF MECHANICAL ENGINEERING

DEPARTMENT OF INSTRUMENTATION AND CONTROL ENGINEERING

MASTER'S THESIS IN INSTRUMENTATION AND CONTROL ENGINEERING

CONTROL AND VISUALIZATION OF THE PNEUMATIC DRIVES APPLICATION USING VALVE TERMINALS

BURAK SUSAM

PRAGUE, 2019

SUPERVISOR: ING. MARIE MARTINÁSKOVÁ, Ph.D.

STATEMENT

I declare that I have worked out this thesis independently, assuming that the results of the thesis can also be used at the discretion of the supervisor of the thesis as its co-author. I also agree with the possible publication of the results of the thesis or its substantial part provided I will be listed as the co-author.

Prague, 2019

Signature: _____

ANNOTATION

Title: Control and Visualization of the Pneumatic Drives Application Using Valve Terminals.

Aim: Designing a sequence, simulating it, building a part of it and debugging it in the real world, visualizing a part of it and making communication.

Methods: To simulate it Festo FluidSIM® software used but inside of the software, three different languages, standard relay method, ladder logic and GRAFCET language used. A part of the sequence is also programmed with the same three languages. To build it in the real world, standard relay method, valve terminals method and ladder logic, by the help of PLC, used. To make visualisation Reliance SCADA software used. For communication between SCADA and PLC, OPC Server used.

Results: Achieved the same results for the same circuit in simulations and in the real world for all types of methods used.

Keywords: Pneumatics, PLC, PLC SIMATIC S7-200, Actuators, Linear Drive, Semi-Rotary Drive, Vacuum Technology, FluidSIM®, RELIANCE SCADA, OPC, OPC Server, PC Access, Virtual PLC, GRAFCET, Ladder Diagram, Valve Terminals, VTEM

CONTENTS

1. INTRODUCTION 1
1.1. DRIVES AND COMPONENTS 2
1.1.1. PNEUMATIC DOUBLE ACTING CYLINDER 3
1.1.2. SEMI-ROTARY DRIVE AND ROTARY DISC 3
1.1.3. LINEAR DRIVE 4
1.1.4. VACUUM GENERATOR 4
1.1.5. VACUUM SUCTION CUPS 5
1.1.6. 3/2-WAY VALVE 5
1.1.7. 5/2-WAY VALVE 6
1.1.8. DOUBLE ONE WAY FLOW CONTROL VALVE 6
1.1.9. VACUUM GAUGE 7
1.1.10. MAGNETIC PROXIMITY SWITCH (SENSOR) 7
1.1.11. FESTO VALVE TERMINAL 7
1.1.12. SIEMENS PLC S7-200 8
1.1.13. FESTO MOTION TERMINAL (VTEM) 9
1.2. SOFTWARE LIST 9
1.2.1. FESTO FLUIDSIM® 9
1.2.2. SCADA 10
1.2.3. STEP7 - MICRO/WIN 10
1.2.4. OPC SERVER 10
1.3. STRUCTURES AND LANGUAGES USED 11
1.3.1. ELECTRICAL CIRCUIT 11
1.3.2. GRAFCET LANGUAGE 12
1.3.3. LADDER DIAGRAM 12
2. SIMULATING, PROGRAMMING AND TESTING 13
2.1. SIMULATION AND ANALYSING THE OPERATING BEHAVIOUR OF SEMI-ROTARY DRIVE WITH DIFFERENT WEIGHTS 13
2.1.1. FIRST MEASUREMENTS 15
2.1.2. SECOND MEASUREMENTS 17

2.1.3. THIRD MEASUREMENTS 19
2.1.4. FOURTH MEASUREMENTS 20
2.1.5. FIFTH MEASUREMENTS 25
2.1.6. CONCLUSION 31
2.2. SIMULATION AND ANALYSING THE OPERATING BEHAVIOUR OF LINEAR DRIVE WITHOUT LOAD AND WITH LOAD 32
2.2.1. MEASUREMENTS WITHOUT LOAD 34
2.2.2. MEASUREMENTS WITH LOAD 35
2.2.3. CONCLUSION 35
2.3. SIMULATION AND TESTING OF TASKS 35
2.3.1. TASK-1 DESCRIPTION 36
2.3.2. TASK-1 SIMULATION WITH ELECTRO-PNEUMATIC CIRCUIT 37
2.3.3. TASK-1 CIRCUIT WITH GRAFCET 39
2.3.4. TASK-1 CIRCUIT WITH LADDER DIAGRAM 40
2.3.5. TASK-2 DESCRIPTION 41
2.3.6. TASK-2 SIMULATION WITH FLUIDSIM 42
2.3.7. TASK-2 CIRCUIT WITH GRAFCET 44
2.3.8. TASK-2 CIRCUIT WITH LADDER DIAGRAM 45
2.4. BUILDING TASK-2 IN THE REAL WORLD 45
2.4.1. TASK-2 WITH VALVES 46
2.4.2. TASK-2 WITH VALVE TERMINAL 47
2.4.3. TASK-2 WITH PLC 47
3. VISUALISATION 48
3.1. VISUALISATION-1 49
3.2. VISUALISATION-2 50
3.3. VISUALISATION-3 53
4. MEASUREMENTS WITH VTEM 56
4.1. MEASUREMENTS FOR SEMI-ROTARY DRIVE WITH VTEM 58
4.2. MEASUREMENTS FOR LINEAR DRIVE WITH VTEM 59
4.3. CONCLUSION 59

5. CONCLUSION 60
6. REFERENCES 62
7. APPENDIX – A 65
7.1. NORMAL RELAY CIRCUIT OF TASK-1 IN FLUIDSIM 65
7.2. OUTPUT PART OF NORMAL RELAY CIRCUIT OF TASK-1 IN FLUIDSIM 66
7.3. VIRTUAL PLC, SOFTWARE PART, OF TASK-1 67
7.4. VIRTUAL PLC OF HARDWARE PART OF TASK-1 69
7.5. CONTROL PART, LADDER DIAGRAM, OF TASK-1 70
7.6. OUTPUT PART OF CONTROL PART OF TASK-1 72
8. APPENDIX – B 73
8.1. SOFTWARE PART OF TASK-2 73
8.2. LADDER DIAGRAM OF TASK-2 74
8.3. STEP-7 MICRO/WIN PROGRAM IN LD LANGUAGE FOR TASK-2 75
9. APPENDIX – C, SCRIPT PART FOR SIMULATED VISUALISATION OF TASK-2 76

LIST OF FIGURES

Figure 1: Double acting cylinder backward movement [15] 3
Figure 2: Double acting cylinder forward movement [15] 3
Figure 3: Semi-rotary drive [17] 3
Figure 4: Rotary disc [28] 3
Figure 5: Linear drive [21] 4
Figure 6: Vacuum generator [27] 4
Figure 7: Suction cup [20] 5
Figure 8: 3/2-Way normally closed, mono-stable, piloted, spring return valve [27] 5
Figure 9: 5/2-Way mono-stable, piloted, spring return valve [27] 6
Figure 10: 5/2-Way bi-stable, piloted valve [27] 6
Figure 11: Double, adjustable flow control valve [28] 6
Figure 12: Vacuum gauge [22] 7
Figure 13: Magnetic proximity sensor [19] 7
Figure 14: Festo Valve Terminal [7] 8
Figure 15: Siemens S7-200 PLC (CPU222) [16] 8
Figure 16: Working Principle of PLC [8] 8
Figure 17: Festo Motion Terminal [24] (VTEM) [9] 9
Figure 18: Working schema of OPC [11] 10
Figure 19: Simple project for electro-pneumatic circuit [27] 11
Figure 20: Example for GRAFCET Language [12] 12
Figure 21: Example of Ladder Diagram [18] 13
Figure 22: Loads for rotary drive [28] 14
Figure 23: FluidSIM circuit for semi-rotary drive to measure the times between 3 points 14
Figure 24: Semi-Rotary drive circuit for measurements 15
Figure 25: FluidSIM® circuit for linear drive to measure the times between 2 points for both directions 32
Figure 26: Load for linear drive [28] 33
Figure 27: Linear drive circuit for measurements [28] 33
Figure 28: Pneumatic part of the Task-1 37
Figure 29: Functional Diagram of the Task-1 37
Figure 30: A part of the circuit for Task-1 38
Figure 31: State diagram of the circuit for Task-1 38

Figure 32: Task-1 Circuit Built With Using Valves [28] 39
Figure 33: A part of the GRAFCET of Task-1 40
Figure 34: A part of the hardware of GRAFCET for Task-1 40
Figure 35: A part of the ladder diagram for Task-1 41
Figure 36: A part of the ladder diagram output for Task-1 41
Figure 37: Pneumatic part of Task-2 42
Figure 38: Functional Diagram of Task-2 42
Figure 39: Electrical part of Task-2 43
Figure 40: State Diagram of the Circuit for Task-2 43
Figure 41: A part of the GRAFCET of Task-2 44
Figure 42: A part of the hardware solution of GRAFCET for Task-2 44
Figure 43: A part of the electrical part of ladder diagram for Task-2 45
Figure 44: Ladder diagram output of Task-2 45
Figure 45: Task-2 circuit built with using valves [28] 46
Figure 46: Task-2 Circuit Built With Using Valve Terminal [28] 47
Figure 47: A part of the program of the ladder diagram of Task-2 [28] 48
Figure 48: Task-2 with PLC and particular valves [28] 48
Figure 49: Visualisation-1 for Task-2 49
Figure 50: Ethernet Control Block [28] 51
Figure 51: Reliance SCADA Setup-1 51
Figure 52: Reliance SCADA Setup-3 52
Figure 53: Reliance SCADA Setup-2 52
Figure 54: Result of Visualisation-2 project [28] 53
Figure 55: PC Access Tags [28] 54
Figure 56: Tags from OPC Server [28] 55
Figure 57: Result of Visualisation-3 project [28] 55
Figure 58: VTEM interface [29] 56
Figure 59: VTEM directional control valve function [29] 57
Figure 60: Project with VTEM [25] 58

LIST OF TABLES

Table 1: List of hardware components 2
Table 2: Results of movements from position 1 to 2 without load while the rotary disc is parallel to the surface 16
Table 3: Results of movements from position 2 to 3 without load while the rotary disc is parallel to the surface 16
Table 4: Results of Movements from 1 to 2 Without the Load While the Rotary Disc is Perpendicular to the Surface 16
Table 5: Results of Movements from 2 to 3 Without the Load While the Rotary Disc is Perpendicular to the Surface 16
Table 6: Results of Movements from 1 to 2 When the Load is in 1st Position While Rotary Disc is Parallel to the Surface 17
Table 7: Results of Movements from 2 to 3 When the Load is in 1st Position While Rotary Disc is Parallel to the Surface 17
Table 8: Results of Movements from 1 to 2 When the Load is in 2nd Position While Rotary Disc is Parallel to the Surface 17
Table 9: Results of Movements from 2 to 3 When the Load is in 2nd Position While Rotary Disc is Parallel to the Surface 17
Table 10: Results of Movements from 1 to 2 When the Load is in 3rd Position While Rotary Disc is Parallel to the Surface 18
Table 11: Results of Movements from 2 to 3 When the Load is in 3rd Position While Rotary Disc is Parallel to the Surface 18
Table 12: Results of Movements from 1 to 2 When the Load is in 4th Position While Rotary Disc is Parallel to the Surface 18
Table 13: Results of Movements from 2 to 3 When the Load is in 4th Position While Rotary Disc is Parallel to the Surface 18
Table 14: Results of Movements from 1 to 2 When the Load is in 1st Position While Rotary Disc is Perpendicular to the Surface 19
Table 15: Results of Movements from 2 to 3 When the Load is in 1st Position While Rotary Disc is Perpendicular to the Surface 19
Table 16: Results of Movements from 1 to 2 When the Load is in 2nd Position While Rotary Disc is Perpendicular to the Surface 19
Table 17: Results of Movements from 2 to 3 When the Load is in 2nd Position While Rotary Disc is Perpendicular to the Surface 19

Table 18: Results of Movements from 1 to 2 When the Load is in 3rd Position While Rotary Disc is Perpendicular to the Surface 20
Table 19: Results of Movements from 2 to 3 When the Load is in 3rd Position While Rotary Disc is Perpendicular to the Surface 20
Table 20: Results of Movements from 1 to 2 When the Load is in 4th Position While Rotary Disc is Perpendicular to the Surface 20
Table 21: Results of Movements from 2 to 3 When the Load is in 4th Position While Rotary Disc is Perpendicular to the Surface 20
Table 22: Results of Movements from 1 to 2 When both Loads are in 1st Position While Rotary Disc is Parallel to the Surface 21
Table 23: Results of Movements from 2 to 3 When both Loads are in 1st Position While Rotary Disc is Parallel to the Surface 21
Table 24: Results of Movements from 1 to 2 When First Load is in the 1st Position and the Second Load is in the 2nd Position While Rotary Disc is Parallel to the Surface 21
Table 25: Results of Movements from 2 to 3 When First Load is in the 1st Position, and the Second Load is in the 2nd Position While Rotary Disc is Parallel to the Surface 21
Table 26: Results of Movements from 1 to 2 When the First Load is in the 1st Position, and the Second Load is in the 3rd Position While the Rotary Disc is Parallel to the Surface 22
Table 27: Results of Movements from 2 to 3 When the First Load is in 1st Position and the Second Load is in the 3rd Position While the Rotary Disc is Parallel to the Surface 22
Table 28: Results of Movements from 1 to 2 When the First Load is in the 1st Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface 22
Table 29: Results of Movements from 2 to 3 When the First Load is in the 1st Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface 22
Table 30: Results of Movements from 1 to 2 When both Loads are in the 2nd Position While the Rotary Disc is Parallel to the Surface 23
Table 31: Results of Movements from 2 to 3 When both Loads are in the 2nd Position While the Rotary Disc is Parallel to the Surface 23
Table 32: Results of Movements from 1 to 2 When the First Load is in the 2nd Position and the Second Load is in the 3rd Position While the Rotary Disc is Parallel to the Surface 23

Table 33: Results of Movements from 2 to 3 When the First Load is in the 2nd Position and the Second Load is in the 3rd Position While the Rotary Disc is Parallel to the Surface 23
Table 34: Results of Movements from 1 to 2 When the First Load is in the 2nd Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface 24
Table 35: Results of Movements from 2 to 3 When the First Load is in the 2nd Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface 24
Table 36: Results of Movements from 1 to 2 When both Loads are in the 3rd Position While the Rotary Disc is Parallel to the Surface 24
Table 37: Results of Movements from 2 to 3 When both Loads are in the 3rd Position While the Rotary Disc is Parallel to the Surface 24
Table 38: Results of Movements from 1 to 2 When the First Load is in the 3rd Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface 25
Table 39: Results of Movements from 2 to 3 When the First Load is in the 3rd Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface 25
Table 40: Results of Movements from 1 to 2 When both Loads are in the 4th Position While the Rotary Disc is Parallel to the Surface 25
Table 41: Results of Movements from 2 to 3 When both Loads are in the 4th Position While the Rotary Disc is Parallel to the Surface 25
Table 42: Results of Movements from 1 to 2 When both Loads are in 1st Position While Rotary Disc is Perpendicular to the Surface 26
Table 43: Results of Movements from 2 to 3 When both Loads are in 1st Position While Rotary Disc is Perpendicular to the Surface 26
Table 44: Results of Movements from 1 to 2 When First Load is in the 1st Position and the Second Load is in the 2nd Position While Rotary Disc is Perpendicular to the Surface 26
Table 45: Results of Movements from 2 to 3 When First Load is in the 1st Position, and the Second Load is in the 2nd Position While Rotary Disc is Perpendicular to the Surface 26
Table 46: Results of Movements from 1 to 2 When the First Load is in the 1st Position, and the Second Load is in the 3rd Position While the Rotary Disc is Perpendicular to the Surface 27

Table 47: Results of Movements from 2 to 3 When the First Load is in 1st Position and the Second Load is in the 3rd Position While the Rotary Disc is Perpendicular to the Surface 27
Table 48: Results of Movements from 1 to 2 When the First Load is in the 1st Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface 27
Table 49: Results of Movements from 2 to 3 When the First Load is in the 1st Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface 27
Table 50: Results of Movements from 1 to 2 When both Loads are in the 2nd Position While the Rotary Disc is Perpendicular to the Surface..... 28
Table 51: Results of Movements from 2 to 3 When both Loads are in the 2nd Position While the Rotary Disc is Perpendicular to the Surface..... 28
Table 52: Results of Movements from 1 to 2 When the First Load is in the 2nd Position and the Second Load is in the 3rd Position While the Rotary Disc is Perpendicular to the Surface 28
Table 53: Results of Movements from 2 to 3 When the First Load is in the 2nd Position and the Second Load is in the 3rd Position While the Rotary Disc is Perpendicular to the Surface 28
Table 54: Results of Movements from 1 to 2 When the First Load is in the 2nd Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface 29
Table 55: Results of Movements from 2 to 3 When the First Load is in the 2nd Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface 29
Table 56: Results of Movements from 1 to 2 When both Loads are in the 3rd Position While the Rotary Disc is Perpendicular to the Surface..... 29
Table 57: Results of Movements from 2 to 3 When both Loads are in the 3rd Position While the Rotary Disc is Perpendicular to the Surface..... 29
Table 58: Results of Movements from 1 to 2 When the First Load is in the 3rd Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface 30
Table 59: Results of Movements from 2 to 3 When the First Load is in the 3rd Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface 30
Table 60: Results of Movements from 1 to 2 When both Loads are in the 4th Position While the Rotary Disc is Perpendicular to the Surface..... 30

Table 61: Results of Movements from 2 to 3 When both Loads are in the 4th Position While the Rotary Disc is Perpendicular to the Surface.....30
Table 64: Results of Movements from 1 to 2 without Load with using normal valve 34
Table 65: Results of Movements from 2 to 1 without Load with using normal valve 34
Table 66: Results of Movements from 1 to 2 with the Load with using normal valve 35
Table 67: Results of Movements from 2 to 1 with the Load with using normal valve 35
Table 69: Settings for Ethernet Wizard 50
Table 70: Settings for VTEM.....56
Table 68: Results of movements from position 1 to 3 when both loads are in the 3rd position while the rotary disc is parallel to the surface with using VTEM 58
Table 69: Results of movements from 1 to 3 when both loads are in the 3rd position while the rotary disc is parallel to the surface with using normal valve 58
Table 70: Results of Movements from 2 to 1 with the Load using VTEM 59
Table 71: Results of Movements from 2 to 1 with the Load with using normal valve 59

LIST OF ABBREVIATIONS

A: MOTOR_A

B: ROTARY_DRIVE

C: LINEAR_DRIVE

V: VACUUM

V0: Vacuum is off

V1: Vacuum is on

A+, B+, C+ …… Pneumatic motor A, B, C forward movement

A-, B-, C- …… Pneumatic motor A, B, C backward movement

TAU x ……Time delay of x seconds

(B, V) …… Movements of B and V at the same time

MPS1/2/3: Magnetic Proximity Sensor 1/2/3

VTEM: Festo Motion Terminal

PLC: Programmable Logic Controller

SCADA: Supervisory Control And Data Acquisition

PC: Personal Computer

OPC: OLE for Process Control

OLE: Object Linking and Embedding

TSAP: Transport Service Access Point

1. INTRODUCTION

Pneumatics is the discipline that deals with physical properties of gases like pressure, density and applies the principles to use compressed gas as a supply of power to solve engineering problems. The frequent use of compressed gas is air, and so its use has become identical with the term pneumatic. [1]

Most of the necessary property of the air is that the straightforward conversion of pressure to force and translational displacement using a piston in a cylinder. Typically, control is done by a digital computer in the form of a programmable logic controller, PLC, with a different type of sensors for piston position and electrically operated valves. [2]

In this project, a task has been created with a particular sequence given. There are two types of structure to build the project, and for this project, these two structures have been used. These structure types are hardware and software structures. Hardware structure consists of actuators, valves, valve terminal, Festo Motion Terminal (VTEM), sensors, relays and switches. The hardware structure has been used to build the project in the real world. Software structure consists of Ladder Diagram and GRAFCET languages. Software structure has been used to simulate the sequence in computer. For the same project, two tasks have been created. First task's sequence can be seen below;

- A+ A- (B+ V1) C+ C- B- A+ A- B+ TAU 0.5 V0 TAU 1 B-

A more detailed explanation of the first task has been explained in chapter 2.3.1. TASK-1 DESCRIPTION.

The second task has been created after the first task has been tried to built in the real world. Because of not having enough necessary components in the laboratory, the first task has not been built completely. That is why the second task has been created. The second task's sequence can be seen below;

- B+ TAU 3 C+ C- B-

A more detailed explanation of the first task has been explained in chapter 2.3.5. TASK-2 DESCRIPTION.

In both tasks, rotary drive and linear drive have been used. Before creating these tasks, to understand how the rotary drive and linear drive work, some measurements have been done for both of them. For more information about measurements of rotary drive and linear drive have been explained in chapters, respectively, 2.1. and 2.2.

1.1. DRIVES AND COMPONENTS

In this chapter, hardware components have been used and are shown in the table below, and they are described.

NAME OF THE COMPONENTS	QUANTITY
Double Acting Cylinder	1
Semi-Rotary Drive	1
Linear Drive	1
Vacuum Generator	1
Suction Cup	1
3/2 Mono-Stable Valve	1
5/2 Mono-Stable Valve	1
5/2 Bi-Stable Valve	2
Vacuum Gauge	1
Magnetic Proximity Switch (Sensor)	4
Festo Valve Terminal	1
Festo Motion Terminal (VTEM)	1
Siemens PLC S7-200 (CPU222)	1

Table 1: List of hardware components

Some definitions for valve;

- The mono-stable valve means when the power cancelled, it goes back to the normal position by the help of spring.
- The bi-stable valve means the movements for both sides are done with electricity, and even if the pressurised air lost, it will stay in that position until the other side activated.
- The normally closed valve means that when it is in the normal position, the pressurised air is not passing.
- 3/2 means there are three ports and two states.
- 5/2 means there are five ports and two states.

1.1.1. PNEUMATIC DOUBLE ACTING CYLINDER

The pneumatic double acting cylinder works with pressurised air. It has two ports for input and output. According to the movement direction, one port becomes input, and the other port becomes output. When the movement direction changes, input and output ports are also changing their functions respectively. The difference with the single acting cylinder is that this double acting cylinder does not have any spring inside. It moves with pressurised air for both sides.

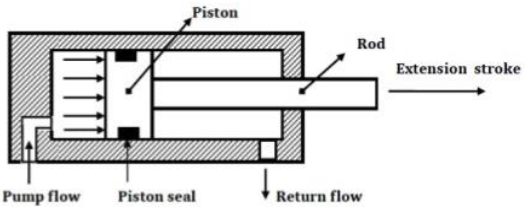


Figure 1: Double acting cylinder backward movement [15]

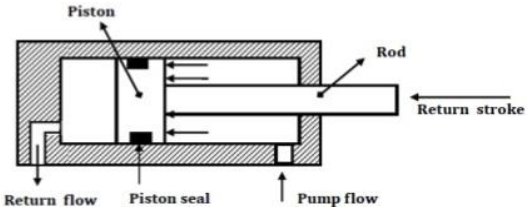


Figure 2: Double acting cylinder forward movement [15]

1.1.2. SEMI-ROTARY DRIVE AND ROTARY DISC

There are too many types of rotary drives. The rotary drive that has been used in this project is vane semi-rotary drive, and it has limited a turning angle with a maximum of 180 degrees, and in total three sensors can be attached with the help of rotary disc's attachments. There are only two stops, at 0 degrees and 180 degrees. The rotary disc is connected with the rotary drive in a unique way that it can stay parallel to the surface or it can stay perpendicular to the surface and can work in both positions.

Figure 3: Semi-rotary drive [17]

Figure 4: Rotary disc [28]

1.1.3. LINEAR DRIVE

Linear drive is a rodless drive. There is a piston inside which is directly connected with the slide outside with a special sealing from inside and outside to prevent the air passing. The working principle is the same as with the double acting cylinder. There are two magnetic proximity switches connected on it, and there is a magnet inside of the piston. Magnetic proximity switches have been positioned at the ends of the linear drive. When slide reaches to one end, the switch on that end is activated.

Figure 5: Linear drive [21]

1.1.4. VACUUM GENERATOR

Vacuum generators are working with the Venturi principle. The pressurised air is entering from the input (1) and exiting from the output (3), and because of choke in the middle, the speed of the air is increasing, and it creates pressure difference, and this pressure difference causes a vacuum at port (2).

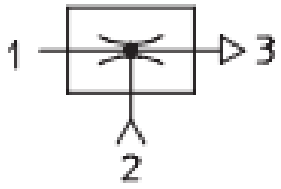


Figure 6: Vacuum generator [27]

1.1.5. VACUUM SUCTION CUPS

There is plenty of type of suction cups. In this project, a small golf ball has been chosen as a material to grip. For this material, bellow suction cup type has been chosen. Suction cups can be easily changed according to the material which will be grip. As a general, suction cups grip the material when there is a vacuum.

Figure 7: Suction cup [20]

1.1.6. 3/2-WAY VALVE

In this project, only one 3/2-Way valve is used. Its properties are; mono-stable, normally closed, piloted, spring return.

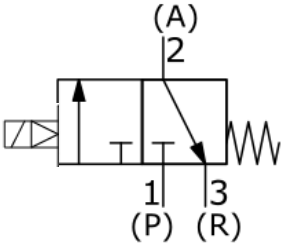


Figure 8: 3/2-Way normally closed, mono-stable, piloted, spring return valve [27]

One of the states of the valve is open, and the other state is closed. When the valve is open, air goes through from the inlet (P, 1) to the outlet (A, 2). When the valve is closed, air goes through from the outlet (A, 2) to the exhaust (R, 3). [3]

1.1.7. 5/2-WAY VALVE

In this project, one 5/2-way mono-stable valve and two 5/2-way bi-stable valves are used.

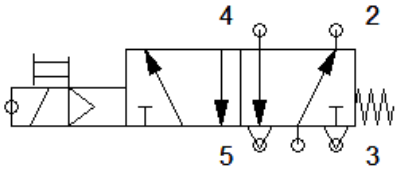


Figure 9: 5/2-Way mono-stable, piloted, spring return valve [27]

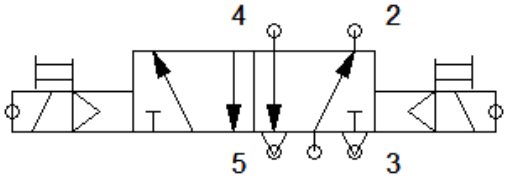


Figure 10: 5/2-Way bi-stable, piloted valve [27]

For both valves, when they are in this position, the air is passing from inlet (1) to the outlet (2). When they are in the second position, the air is passing from inlet (1) to the outlet (4).

1.1.8. DOUBLE ONE WAY FLOW CONTROL VALVE

The double one-way flow control is a unique component which replaces two flow controls in a pneumatic system and allows the adjustment of cylinder for extension and retraction from one location. The adjustment knob closes to the cylinder controls the input or extension speed, the knob furthest from the cylinder controls the exhaust or retraction speed. [4]

Figure 11: Double, adjustable flow control valve [28]

1.1.9. VACUUM GAUGE

A vacuum gauge uses to measure how much vacuum generated in a system.

Figure 12: Vacuum gauge [22]

1.1.10. MAGNETIC PROXIMITY SWITCH (SENSOR)

The presence of a permanent magnet on the piston actuates magnetic proximity switches. Their operating principle is based on the use of reed contacts. The presences of a magnetic field make the thin plates flex and touch each other, causing an electrical contact. There are three cables, the two of them is for power supply, and the third one is for output. [5]

Figure 13: Magnetic proximity sensor [19]

1.1.11. FESTO VALVE TERMINAL

The signal flow from the controller to the valve terminal takes place via a pre-assembled or self-assembled multi-wire cable to the multi-pin plug connection, which substantially reduces installation time. The valve terminal can be equipped with max. 24 coils. [6]

This corresponds to 4 to 24 MPA1 or 2 to 24 MPA2 valves or a combination of both. Valve manifold type MPA with two 5/2-way solenoid valves and two 5/2-way double solenoid valves has been used. The solenoids are connected to power with safety plugs that are labelled with the coil index. [7] In this project, two 5/2-way double solenoid valves have been used on the valve terminal

Figure 14: Festo Valve Terminal [7]

1.1.12. SIEMENS PLC S7-200

The PLC receives information from connected sensors or input devices, processes the data, and triggers outputs based on pre-programmed parameters. Depending on the inputs and outputs, a PLC can control the process, monitor and record run-time data such as machine productivity or operating temperature, automatically start and stop processes, generate alarms if a machine malfunctions, and more. Programmable Logic Controllers are a flexible and robust control solution, adaptable to almost any application. [8]

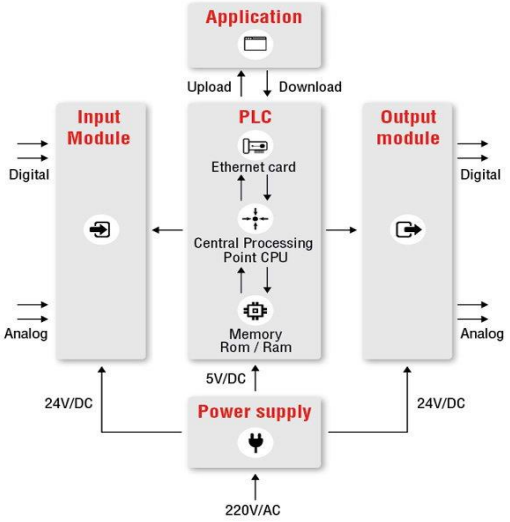


Figure 16: Working Principle of PLC [8]

Figure 15: Siemens S7-200 PLC (CPU222) [16]

1.1.13. FESTO MOTION TERMINAL (VTEM)

VTEM combines numerous functions with the same hardware with the help of software. With the matching Motion App, changing functions at the pressing, whether for a simple change in the directional control valve functions, smooth stop in the end positions, energy-efficient movements. This is the way how the VTEM combines the benefits of both electric and pneumatic automation. [9]

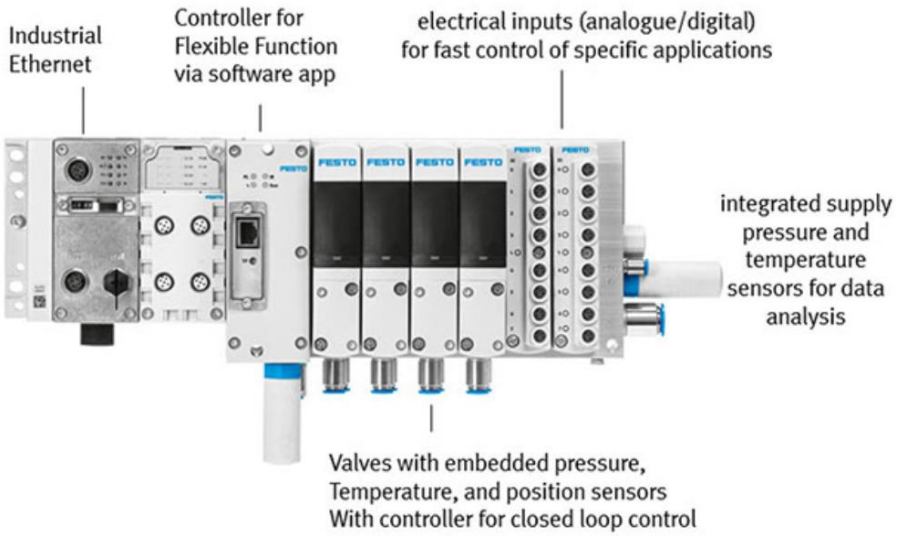


Figure 17: Festo Motion Terminal [24]

1.2. SOFTWARE LIST

1.2.1. FESTO FLUIDSIM®

The principles such as hydraulics and pneumatics are used in the industry very intensely. Designing and implementing such systems is quite troublesome and requires proper design, debugging and testing. In such cases, Festo FluidSIM® is a program that allows testing the system in advance. With this software, there are some advantages, testing the system before installing it in the real world, observing mistakes and making improvements on it. There are three programming languages inside of this software are; FBD, GRAFCET, Ladder Diagram. A project can be created by using any of these languages. For the project that has been created, GRAFCET and Ladder Diagram languages have been used. In the FluidSIM® environment, there is possible to create and debug circuits in the areas of; pneumatics, classical electro-pneumatics, hydraulics, electro-hydraulics.

1.2.2. SCADA

SCADA has been created with the initials of the words Supervisory Control and Data Acquisition. SCADA systems can be used where the widespread facilities can be monitored from a single centre with devices such as computers, mobile phones or tablets. SCADA systems can be used from a single device and can be controlled, monitored with multiple computers or portable devices via network connections. In this project, Reliance SCADA V4 software has been used. [10]

1.2.3. STEP7 - MICRO/WIN

STEP 7 - Micro/WIN programming environment provides possibilities to develop, edit, and monitor and document the functionality of the project. STEP 7 - Micro/WIN provides three program editors for convenience and efficiency in developing the control program.

1.2.4. OPC SERVER

OPC is a software interface standard that allows Windows programs to communicate with industrial hardware devices.

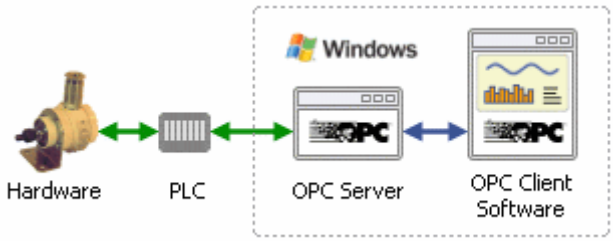


Figure 18: Working schema of OPC [11]

OPC is implemented in server/client pairs. The OPC server is a software program that converts the hardware communication protocol used by a PLC into the OPC protocol. The OPC client software is any program that needs to connect to the hardware, such as an HMI. The OPC client uses the OPC server to get data from or send commands to the hardware.

The value of OPC is that it is an open standard, which means lower costs for manufacturers and more options for users. Hardware manufacturers need only provide a single OPC server for their devices to communicate with any OPC client. Software vendors simply include OPC client capabilities in their

products, and they become instantly compatible with thousands of hardware devices. Users can choose any OPC client software they need, resting assured that it will communicate seamlessly with their OPC-enabled hardware, and vice-versa. The typical OPC connection scenario is a single server-client connection on a single computer, as illustrated in Figure 18. This connection type has been used in this project. Also, as an OPC Server software, PC-Access software from Siemens company has been used. [11]

1.3. STRUCTURES AND LANGUAGES USED

A project can be completed by using virtual environments, such as softwares, and real environments, such as real components. Festo FluidSIM® and Step-7 Micro/WIN softwares have been used to create the same project in different ways. Also, the project has been created by using real components.

1.3.1. ELECTRICAL CIRCUIT

First of all, the electric circuit is not a language, but it is a structure. Using FluidSIM® software and using regular contacts, relays, pushbuttons and using other necessary components, an electro-pneumatic circuit can be programmed, and by the help of FluidSIM software, it can be simulated to see the mistakes or to improve it.

Advantage of programming in this manner is, it can be assembled as physical, in the real world by looking at the electro-pneumatic circuit that has been created in Festo FluidSIM® software. However, the problem is if the circuit is a complex one, building it and debugging it in the real world by using real components, takes plenty of time.

Assembling a project in physical is mostly used to prepare a simple project in the real world to understand the logic of it.

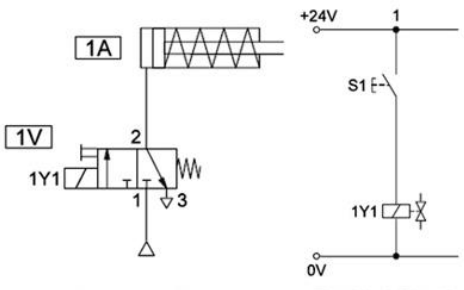


Figure 1 uit [27]

1.3.2. GRAFCET LANGUAGE

GRAFCET language is a graph consisting of two types of nodes, steps and transitions. A step can either be active or inactive. A step represents a state, phase, or mode and has associated actions that are executed when the step is active. There are two main categories of actions: allocation (level) and assignation (impulse).

Allocation actions are modelled by Boolean variables which have the value true as long as the step that the allocation action is associated with remains active. Assignation actions change the values of discrete variables. The change is carried out when the step that the action is associated with changes from inactive to active. A transition generally connects two steps, but also it can connect more than two steps. A receptivity is associated with each transition. The receptivity can either be a Boolean condition or an event or an event together with a condition.

A transition becomes active when the step preceding the transition is activated. While the transition is active, the receptivity is tested. When the receptivity is true, the step preceding the transition is deactivated, and the step connected after the transition is activated. [12]

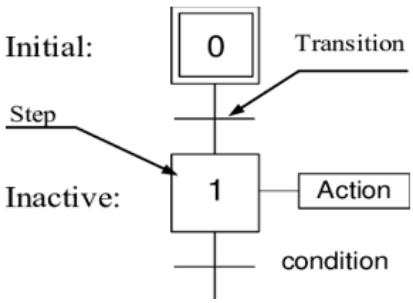


Figure 20: Example for GRAFCET Language [12]

1.3.3. LADDER DIAGRAM

The ladder logic is widely used in industrial environments for programming PLCs, where sequential control of manufacturing processes is required. The programming language is handy for simple programming.

Ladder logic is one form of drawing electrical logic schematics and is a graphical language very popular for programming Programmable Logic Controllers. Ladder logic was originally invented to describe logic made from

relays. The name is based on the observation that programs in this language resemble ladders, with two vertical "rails" and a series of horizontal "rungs" between them. Figure 21 below is a very basic example of ladder logic used in a programmable logic controls program. [13]

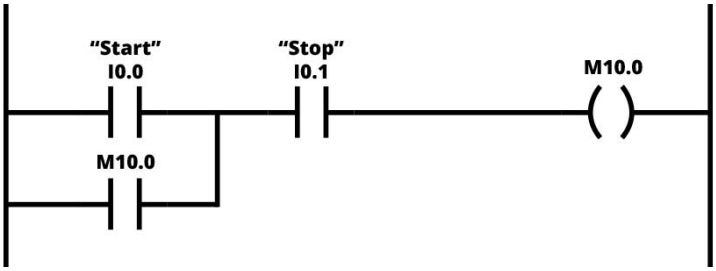


Figure 21: Example of Ladder Diagram [18]

2. SIMULATING, PROGRAMMING AND TESTING

In this part of the thesis, simulation models and circuits that have been built physically are discussed. A circuit has been designed to measure travelling time for the rotary drive and linear drive.

2.1. SIMULATION AND ANALYSING THE OPERATING BEHAVIOUR OF SEMI-ROTARY DRIVE WITH DIFFERENT WEIGHTS

Firstly, the circuit has been built in Festo FluidSIM® software to design the circuits in the real world faster and without any error. The circuit below is for the semi-rotary drive. In Figure 23, the timer on the left side shows the measured time from 1B1 to 1B2 and, the timer on the right side shows the measured time from 1B2 to 1B3. These results are done with 6 Bar input pressure. So the times are different with those measured in the real world because in the real world it has been measured with 4 Bar. However, it is not important because the main idea is to build it in the real world, make measurements and to compare these results with each other. To do this, normal valves and valve terminal have been used. Not to make the same measurements over and over with the valve terminal, only one combination has been chosen, and then, that time has been measured.

The necessary circuit has been built in a simulation, and then it has been built in the real world to understand the working behaviour of the semi-rotary drive. With the circuit that has been built in the real world, have been made

various measurements with the combinations of different weights with different position of those weights, and these combinations combined with the different position of the rotary table like a parallel to surface and perpendicular to the surface. Each weight is 175 gr.

Figure 22: Loads for rotary drive [28]

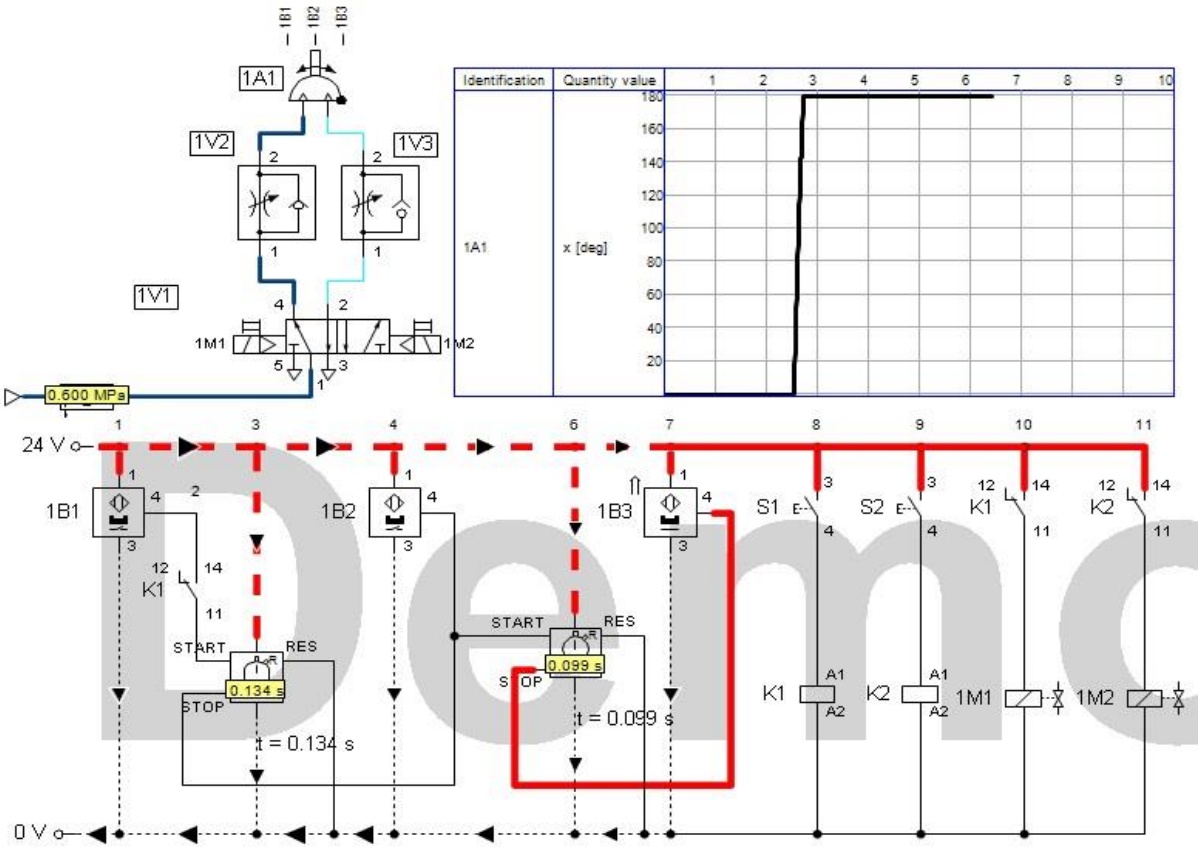


Figure 23: FluidSIM circuit for semi-rotary drive to measure the times between 3 points

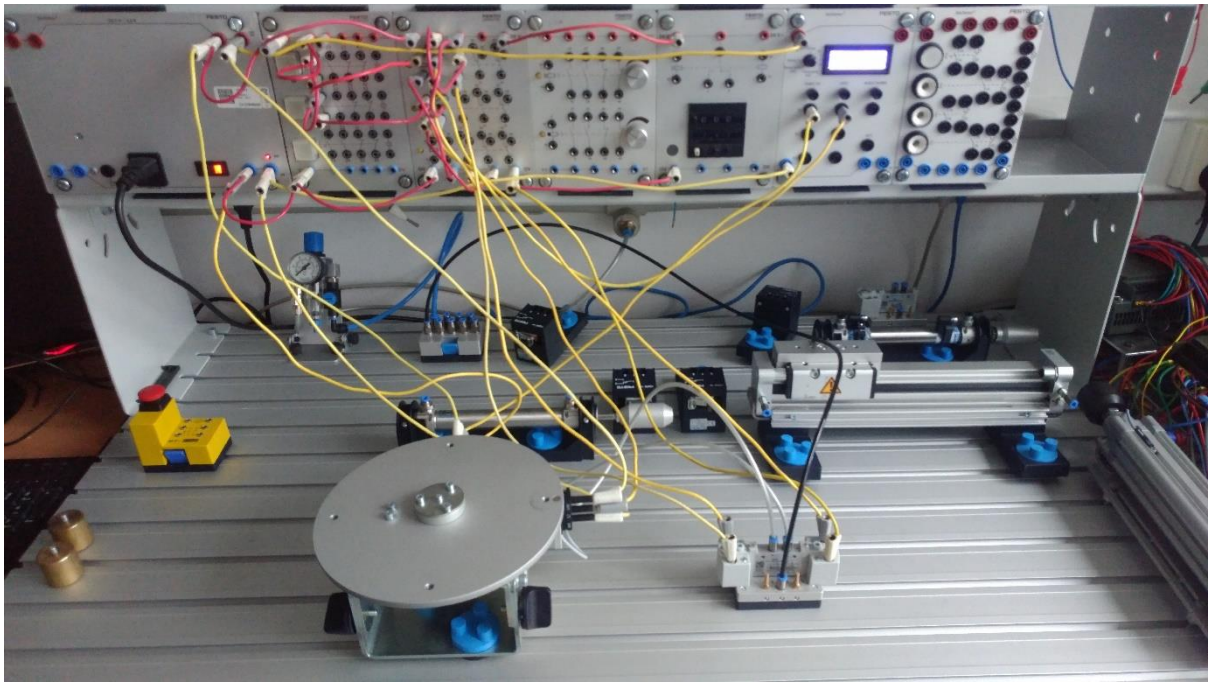


Figure 24: Semi-Rotary drive circuit for measurements

On the Figure 23 is the circuit that has been designed in Festo FluidSIM® software, and that circuit has been built in the real world by using real components. The circuit that has been built in the real world can be seen in Figure 24. The functionality of this circuit is; when pressed to the first button, the semi-rotary drive starts to move from the initial position and simultaneously stopwatch starts to count the time passed in the t1 section until the semi-rotary drive reaches to the end position. When pressed to the second button, the semi-rotary drive starts to move from the end position, and simultaneously stopwatch starts to count the time passed in the t2 section until the semi-rotary drive reaches to the initial position.

2.1.1. FIRST MEASUREMENTS

Time of movements of the semi-rotary drive from position 1 to 2, from beginning position to half, and from position 2 to 3, from half to end position have been measured without load when the rotary disc is parallel to surface and perpendicular to the surface using normal valves. The number 1 represents the first position for the rotary disc, starting position, the number 2 represents the half position, the number 3 represents the end position.

Shown measurements in the Table 2 and Table 3 are when the rotary disc is parallel to the surface.

NUMBER	POSITION 1 TO 2
1	110 ms
2	104 ms
3	104 ms
4	106 ms
5	109 ms
AVERAGE	106.6 ms

Table 2: Results of movements from position 1 to 2 without load while the rotary disc is parallel to the surface

NUMBER	POSITION 2 TO 3
1	48 ms
2	50 ms
3	52 ms
4	50 ms
5	46 ms
AVERAGE	49.2 ms

Table 3: Results of movements from position 2 to 3 without load while the rotary disc is parallel to the surface

Shown measurements in the Table 4 and Table 5 are when the rotary disc is perpendicular to the surface without any load.

NUMBER	POSITION 1 TO 2
1	106 ms
2	109 ms
3	108 ms
4	106 ms
5	107 ms
AVERAGE	107.2 ms

Table 4: Results of Movements from 1 to 2 Without the Load While the Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	48 ms
2	41 ms
3	46 ms
4	43 ms
5	43 ms
AVERAGE	44.2 ms

Table 5: Results of Movements from 2 to 3 Without the Load While the Rotary Disc is Perpendicular to the Surface

2.1.2. SECOND MEASUREMENTS

Movement of the semi-rotary drive from position 1 to 2 and from position 2 to 3 measured with one load with different position of the load while the rotary disc is parallel to surface with using normal valves.

Shown measurements Table 6 and Table 7 are while the rotary disc is parallel to the surface and when the load is in the first position.

NUMBER	POSITION 1 TO 2
1	124 ms
2	120 ms
3	121 ms
4	122 ms
5	122 ms
AVERAGE	121.8 ms

Table 6: Results of Movements from 1 to 2 When the Load is in 1st Position While Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	57 ms
2	60 ms
3	57 ms
4	59 ms
5	58 ms
AVERAGE	58.2 ms

Table 7: Results of Movements from 2 to 3 When the Load is in 1st Position While Rotary Disc is Parallel to the Surface

Shown measurements Table 8 and Table 9 are while the rotary disc is parallel to the surface and when the load is in the second position.

NUMBER	POSITION 1 TO 2
1	124 ms
2	117 ms
3	122 ms
4	122 ms
5	122 ms
AVERAGE	121.4 ms

Table 8: Results of Movements from 1 to 2 When the Load is in 2nd Position While Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	56 ms
2	63 ms
3	56 ms
4	56 ms
5	36 ms
AVERAGE	53.4 ms

Table 9: Results of Movements from 2 to 3 When the Load is in 2nd Position While Rotary Disc is Parallel to the Surface

Shown measurements Table 10 and Table 11 are while the rotary disc is parallel to the surface and when the load is in the third position.

NUMBER	POSITION 1 TO 2
1	124 ms
2	122 ms
3	124 ms
4	122 ms
5	122 ms
AVERAGE	122.8 ms

Table 10: Results of Movements from 1 to 2 When the Load is in 3rd Position While Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	58 ms
2	60 ms
3	57 ms
4	58 ms
5	59 ms
AVERAGE	58.4 ms

Table 11: Results of Movements from 2 to 3 When the Load is in 3rd Position While Rotary Disc is Parallel to the Surface

Shown measurements Table 12 and Table 13 are while the rotary disc is parallel to the surface and when the load is in the fourth position.

NUMBER	POSITION 1 TO 2
1	122 ms
2	122 ms
3	122 ms
4	122 ms
5	123 ms
AVERAGE	122.2 ms

Table 12: Results of Movements from 1 to 2 When the Load is in 4th Position While Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	58 ms
2	58 ms
3	58 ms
4	59 ms
5	57 ms
AVERAGE	58 ms

Table 13: Results of Movements from 2 to 3 When the Load is in 4th Position While Rotary Disc is Parallel to the Surface

2.1.3. THIRD MEASUREMENTS

Time of movements of the semi-rotary drive from position 1 to 2 and from position 2 to 3 has been measured with one load with different position of the load while the rotary disc is perpendicular to surface with using normal valves.

Shown measurements Table 14 and Table 15 are when the load is in the first position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	132 ms
2	132 ms
3	132 ms
4	132 ms
5	132 ms
AVERAGE	132 ms

Table 14: Results of Movements from 1 to 2 When the Load is in 1st Position While Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	54 ms
2	52 ms
3	54 ms
4	51 ms
5	54 ms
AVERAGE	53 ms

Table 15: Results of Movements from 2 to 3 When the Load is in 1st Position While Rotary Disc is Perpendicular to the Surface

Shown measurements Table 16 and Table17 are when the load is in the second position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	126 ms
2	121 ms
3	124 ms
4	122 ms
5	122 ms
AVERAGE	123 ms

Table 16: Results of Movements from 1 to 2 When the Load is in 2nd Position While Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	48 ms
2	51 ms
3	48 ms
4	52 ms
5	52 ms
AVERAGE	50.2 ms

Table 17: Results of Movements from 2 to 3 When the Load is in 2nd Position While Rotary Disc is Perpendicular to the Surface

Shown measurements Table 18 and Table 19 are when the load is in the third position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	123 ms
2	122 ms
3	118 ms
4	118 ms
5	122 ms
AVERAGE	120.6 ms

Table 18: Results of Movements from 1 to 2 When the Load is in 3rd Position While Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	45 ms
2	48 ms
3	49 ms
4	52 ms
5	50 ms
AVERAGE	48.8 ms

Table 19: Results of Movements from 2 to 3 When the Load is in 3rd Position While Rotary Disc is Perpendicular to the Surface

Shown measurements Table 20 and Table 21 are when the load is in the fourth position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	128 ms
2	128 ms
3	126 ms
4	128 ms
5	128 ms
AVERAGE	127.6 ms

Table 20: Results of Movements from 1 to 2 When the Load is in 4th Position While Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	58 ms
2	58 ms
3	58 ms
4	54 ms
5	57 ms
AVERAGE	57 ms

Table 21: Results of Movements from 2 to 3 When the Load is in 4th Position While Rotary Disc is Perpendicular to the Surface

2.1.4. FOURTH MEASUREMENTS

Time of movements of the semi-rotary drive from position 1 to 2 and from position 2 to 3 has been measured with two identical loads with different position of each load while the rotary disc is parallel to surface with using normal valves. Because of the two identical loads, the combinations of them will be like this, 1-1, 1-2, 1-3, 1-4, 2-2, 2-3, 2-4, 3-3, 3-4, 4-4. The first number represents the first load's position on the rotary disc, and the second number, after a dash, represents the second load's position on the rotary disc.

Shown measurements Table 22 and Table23 are when both loads are in the first position while the rotary disc is parallel to the surface.

NUMBER	POSITION 1 TO 2
1	136 ms
2	135 ms
3	136 ms
4	140 ms
5	132 ms
AVERAGE	135.8 ms

Table 22: Results of Movements from 1 to 2 When both Loads are in 1st Position While Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	69 ms
2	65 ms
3	64 ms
4	60 ms
5	69 ms
AVERAGE	65.4 ms

Table 23: Results of Movements from 2 to 3 When both Loads are in 1st Position While Rotary Disc is Parallel to the Surface

Shown measurements Table 24 and Table25 are when the first load is in the first position, and the second load is in the second position while the rotary disc is parallel to the surface.

NUMBER	POSITION 1 TO 2
1	135 ms
2	141 ms
3	134 ms
4	131 ms
5	136 ms
AVERAGE	135.4 ms

Table 24: Results of Movements from 1 to 2 When First Load is in the 1st Position and the Second Load is in the 2nd Position While Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	61 ms
2	59 ms
3	67 ms
4	69 ms
5	64 ms
AVERAGE	64 ms

Table 25: Results of Movements from 2 to 3 When First Load is in the 1st Position, and the Second Load is in the 2nd Position While Rotary Disc is Parallel to the Surface

Shown measurements Table 26 and Table 27 are when the first load is in the first position, and the second load is in the third position while the rotary disc is parallel to the surface.

NUMBER	POSITION 1 TO 2
1	135 ms
2	134 ms
3	136 ms
4	136 ms
5	134 ms
AVERAGE	135 ms

Table 26: Results of Movements from 1 to 2 When the First Load is in the 1st Position, and the Second Load is in the 3rd Position While the Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	64 ms
2	66 ms
3	62 ms
4	69 ms
5	68 ms
AVERAGE	65.8 ms

Table 27: Results of Movements from 2 to 3 When the First Load is in 1st Position and the Second Load is in the 3rd Position While the Rotary Disc is Parallel to the Surface

Shown measurements Table 28 and Table 29 are when the first load is in the first position, and the second load is in the fourth position while the rotary disc is parallel to the surface.

NUMBER	POSITION 1 TO 2
1	136 ms
2	142 ms
3	134 ms
4	135 ms
5	134 ms
AVERAGE	136.2 ms

Table 28: Results of Movements from 1 to 2 When the First Load is in the 1st Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	64 ms
2	58 ms
3	64 ms
4	65 ms
5	67 ms
AVERAGE	63.6 ms

Table 29: Results of Movements from 2 to 3 When the First Load is in the 1st Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface

Shown measurements Table 30 and Table 31 are when both loads are in the second position while the rotary disc is parallel to the surface.

NUMBER	POSITION 1 TO 2
1	137 ms
2	136 ms
3	136 ms
4	136 ms
5	136 ms
AVERAGE	136.2 ms

Table 30: Results of Movements from 1 to 2 When both Loads are in the 2nd Position While the Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	65 ms
2	64 ms
3	64 ms
4	64 ms
5	66 ms
AVERAGE	64.6 ms

Table 31: Results of Movements from 2 to 3 When both Loads are in the 2nd Position While the Rotary Disc is Parallel to the Surface

Shown measurements Table 32 and Table 33 are when the first load is in the second position, and the second load is in the third position while the rotary disc is parallel to the surface.

NUMBER	POSITION 1 TO 2
1	138 ms
2	134 ms
3	130 ms
4	136 ms
5	136 ms
AVERAGE	134.8 ms

Table 32: Results of Movements from 1 to 2 When the First Load is in the 2nd Position and the Second Load is in the 3rd Position While the Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	62 ms
2	66 ms
3	70 ms
4	64 ms
5	64 ms
AVERAGE	65.2 ms

Table 33: Results of Movements from 2 to 3 When the First Load is in the 2nd Position and the Second Load is in the 3rd Position While the Rotary Disc is Parallel to the Surface

Shown measurements Table 34 and Table 35 are when the first load is in the second position, and the second load is in the fourth position while the rotary disc is parallel to the surface.

NUMBER	POSITION 1 TO 2
1	138 ms
2	136 ms
3	136 ms
4	135 ms
5	133 ms
AVERAGE	135.6 ms

Table 34: Results of Movements from 1 to 2 When the First Load is in the 2nd Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	62 ms
2	64 ms
3	64 ms
4	67 ms
5	67 ms
AVERAGE	64.8 ms

Table 35: Results of Movements from 2 to 3 When the First Load is in the 2nd Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface

Shown measurements Table 36 and Table 37 are when both loads are in the third position while the rotary disc is parallel to the surface.

NUMBER	POSITION 1 TO 2
1	134 ms
2	136 ms
3	136 ms
4	140 ms
5	140 ms
AVERAGE	137.2 ms

Table 36: Results of Movements from 1 to 2 When both Loads are in the 3rd Position While the Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	68 ms
2	64 ms
3	66 ms
4	62 ms
5	62 ms
AVERAGE	64.4 ms

Table 37: Results of Movements from 2 to 3 When both Loads are in the 3rd Position While the Rotary Disc is Parallel to the Surface

Shown measurements Table 38 and Table 39 are when the first load is in the third position, and the second load is in the fourth position while the rotary disc is parallel to the surface.

NUMBER	POSITION 1 TO 2
1	138 ms
2	134 ms
3	134 ms
4	134 ms
5	134 ms
AVERAGE	134.8 ms

Table 38: Results of Movements from 1 to 2 When the First Load is in the 3rd Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface

NUMBER	POSITION 2 TO 3
1	64 ms
2	71 ms
3	68 ms
4	66 ms
5	66 ms
AVERAGE	67 ms

Table 39: Results of Movements from 2 to 3 When the First Load is in the 3rd Position and the Second Load is in the 4th Position While the Rotary Disc is Parallel to the Surface

Shown measurements Table 40 and Table 41 are when both loads are in the fourth position while the rotary disc is parallel to the surface.

NUMBER	POSITION 1 TO 2
1	144 ms
2	140 ms
3	141 ms
4	136 ms
5	136 ms
AVERAGE	139.4 ms

Table 40: Results of Movements from 1 to 2 When both Loads are in the 4th Position While the Rotary Disc is Parallel to the Surface

NUMBER	POSITION 1 TO 2
1	58 ms
2	60 ms
3	59 ms
4	64 ms
5	64 ms
AVERAGE	61 ms

Table 41: Results of Movements from 2 to 3 When both Loads are in the 4th Position While the Rotary Disc is Parallel to the Surface

2.1.5. FIFTH MEASUREMENTS

Movement of the semi-rotary drive from position 1 to 2 and from position 2 to 3 has been measured with two identical loads with different position of each load while the rotary disc is perpendicular to surface with using normal valves. Because of the two identical loads, the combinations of them will be like this, 1-1, 1-2, 1-3, 1-4, 2-2, 2-3, 2-4, 3-3, 3-4, 4-4. The first number represents the first load's position on the rotary disc, and the second number, after a dash, represents the second load's position on the rotary disc.

Shown measurements Table 42 and Table 43 are when both loads are in the first position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	160 ms
2	158 ms
3	160 ms
4	160 ms
5	158 ms
AVERAGE	159.2 ms

Table 42: Results of Movements from 1 to 2 When both Loads are in 1st Position While Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	62 ms
2	58 ms
3	58 ms
4	58 ms
5	58 ms
AVERAGE	58.8 ms

Table 43: Results of Movements from 2 to 3 When both Loads are in 1st Position While Rotary Disc is Perpendicular to the Surface

Shown measurements Table 44 and Table 45 are when the first load is in the first position, and the second load is in the second position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	146 ms
2	146 ms
3	148 ms
4	146 ms
5	144 ms
AVERAGE	146 ms

Table 44: Results of Movements from 1 to 2 When First Load is in the 1st Position and the Second Load is in the 2nd Position While Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	52 ms
2	54 ms
3	52 ms
4	54 ms
5	58 ms
AVERAGE	54 ms

Table 45: Results of Movements from 2 to 3 When First Load is in the 1st Position, and the Second Load is in the 2nd Position While Rotary Disc is Perpendicular to the Surface

Shown measurements Table 46 and Table 47 are when the first load is in the first position, and the second load is in the third position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	142 ms
2	142 ms
3	142 ms
4	142 ms
5	141 ms
AVERAGE	141.8 ms

Table 46: Results of Movements from 1 to 2 When the First Load is in the 1st Position, and the Second Load is in the 3rd Position While the Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	56 ms
2	56 ms
3	54 ms
4	56 ms
5	61 ms
AVERAGE	56.6 ms

Table 47: Results of Movements from 2 to 3 When the First Load is in 1st Position and the Second Load is in the 3rd Position While the Rotary Disc is Perpendicular to the Surface

Shown measurements Table 48 and Table 49 are when the first load is in the first position, and the second load is in the fourth position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	152 ms
2	155 ms
3	152 ms
4	150 ms
5	152 ms
AVERAGE	152.2 ms

Table 48: Results of Movements from 1 to 2 When the First Load is in the 1st Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	64 ms
2	57 ms
3	55 ms
4	69 ms
5	60 ms
AVERAGE	61 ms

Table 49: Results of Movements from 2 to 3 When the First Load is in the 1st Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface

Shown measurements Table 50 and Table 51 are when both loads are in the second position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	142 ms
2	138 ms
3	140 ms
4	138 ms
5	140 ms
AVERAGE	139.6 ms

Table 50: Results of Movements from 1 to 2 When both Loads are in the 2nd Position While the Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	46 ms
2	55 ms
3	48 ms
4	50 ms
5	46 ms
AVERAGE	49 ms

Table 51: Results of Movements from 2 to 3 When both Loads are in the 2nd Position While the Rotary Disc is Perpendicular to the Surface

Shown measurements Table 52 and Table53 are when the first load is in the second position, and the second load is in the third position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	132 ms
2	132 ms
3	132 ms
4	132 ms
5	133 ms
AVERAGE	132.2 ms

Table 52: Results of Movements from 1 to 2 When the First Load is in the 2nd Position and the Second Load is in the 3rd Position While the Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	59 ms
2	50 ms
3	52 ms
4	50 ms
5	53 ms
AVERAGE	52.8 ms

Table 53: Results of Movements from 2 to 3 When the First Load is in the 2nd Position and the Second Load is in the 3rd Position While the Rotary Disc is Perpendicular to the Surface

Shown measurements Table 54 and Table 55 are when the first load is in the second position, and the second load is in the fourth position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	142 ms
2	115 ms
3	116 ms
4	112 ms
5	108 ms
AVERAGE	118.6 ms

Table 54: Results of Movements from 1 to 2 When the First Load is in the 2nd Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	58 ms
2	82 ms
3	84 ms
4	84 ms
5	90 ms
AVERAGE	79.6 ms

Table 55: Results of Movements from 2 to 3 When the First Load is in the 2nd Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface

Shown measurements Table 56 and Table 57 are when both loads are in the third position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	160 ms
2	163 ms
3	160 ms
4	159 ms
5	159 ms
AVERAGE	160.2 ms

Table 56: Results of Movements from 1 to 2 When both Loads are in the 3rd Position While the Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	96 ms
2	93 ms
3	96 ms
4	97 ms
5	97 ms
AVERAGE	95.8 ms

Table 57: Results of Movements from 2 to 3 When both Loads are in the 3rd Position While the Rotary Disc is Perpendicular to the Surface

Shown measurements Table 58 and Table 59 are when the first load is in the third position, and the second load is in the fourth position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	155 ms
2	154 ms
3	155 ms
4	153 ms
5	160 ms
AVERAGE	155.4 ms

Table 58: Results of Movements from 1 to 2 When the First Load is in the 3rd Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	41 ms
2	42 ms
3	41 ms
4	43 ms
5	38 ms
AVERAGE	41 ms

Table 59: Results of Movements from 2 to 3 When the First Load is in the 3rd Position and the Second Load is in the 4th Position While the Rotary Disc is Perpendicular to the Surface

Shown measurements Table 60 and Table 61 are when both loads are in the fourth position while the rotary disc is perpendicular to the surface.

NUMBER	POSITION 1 TO 2
1	152 ms
2	152 ms
3	150 ms
4	152 ms
5	152 ms
AVERAGE	151.6 ms

Table 60: Results of Movements from 1 to 2 When both Loads are in the 4th Position While the Rotary Disc is Perpendicular to the Surface

NUMBER	POSITION 2 TO 3
1	62 ms
2	63 ms
3	62 ms
4	60 ms
5	60 ms
AVERAGE	61.4 ms

Table 61: Results of Movements from 2 to 3 When both Loads are in the 4th Position While the Rotary Disc is Perpendicular to the Surface

2.1.6. CONCLUSION

By looking at the results when there is no load, the position of the rotary drive does not influence the time. The time is almost the same when the rotary table is parallel, and when perpendicular to the surface, there is no significant difference.

By looking at the result with one load when the rotary table is parallel to the surface, all times are close to each other like expected. Because gravity is always in the same direction and there is no other force acting on the semi-rotary drive. Therefore, the results are very similar to each other.

By looking at the result with two loads when the rotary table is parallel to the surface, again all times are close to each other like expected. These results are 20ms longer than with one load. Again there is no significant difference between results.

By looking at the result with one load when the rotary table is perpendicular to the surface, there are significant differences between some results and no any result is same with one load when the rotary table is parallel to the surface. The cause of this problem is because of gravity. When the load is perpendicular to the surface when it is on specific positions, there will be the gravity force acting to the negative y-axis, and rotary table needs to move that piece to the positive y-axis. Therefore some times are longer than average results. Also, some times are shorter than usual times because of when the load is on specific positions like when the piece moves the same direction with gravity force. In this position gravity force is helping the rotary table to turn faster. Briefly, because of the gravity, there are significant differences between results, some of them are shorter than average times, some of them are longer than average results.

By looking at the result with two identical loads when the rotary table is perpendicular to the surface, some times are again longer, some times are again shorter. However, this time, some results are very similar, close, with the results of two loads when the rotary table is parallel to the surface. This is happening when loads are at specific positions when they are facing one another. There are two positions for this specific case. One of this position is when one of the load is at position 1, and the other load is at position 3. The other position is when one of the load is at position 2, and the other load is at position 4. The reason is when one of the load is going to the same direction

with gravity, at the same time, the other load is going to the opposite direction with gravity. So, they neutralise each other and acting like two loads when the rotary table is parallel to the surface. That is why these results are very similar to each other. For the other results, there are again some significant differences according to the average results.

There has been a problem when the rotary table is at the vertical position with both loads on the third position. The problem was, because of the gravity semi-rotary drive has not enough power to hold it. So the rotary table was moving freely according to gravity. To fix this problem, normally closed switch added for backward movement to hold the rotary table at the initial position. When pushing the first button to move the system forward, backward movement is disabled.

2.2. SIMULATION AND ANALYSING THE OPERATING BEHAVIOUR OF LINEAR DRIVE WITHOUT LOAD AND WITH LOAD

Circuits have been built in Festo FluidSIM® software to design the circuits in the real world faster and without any error. The circuit below is for the linear drive. On Figure 25 , the timer shows the measured time from 1B1 to 1B2. To measure the time from 1B2 to 1B1, make changes between the start and stop cables with each other, then it can be possible to measure the time for the other direction. These measurements are done with 6 Bar pressure. So

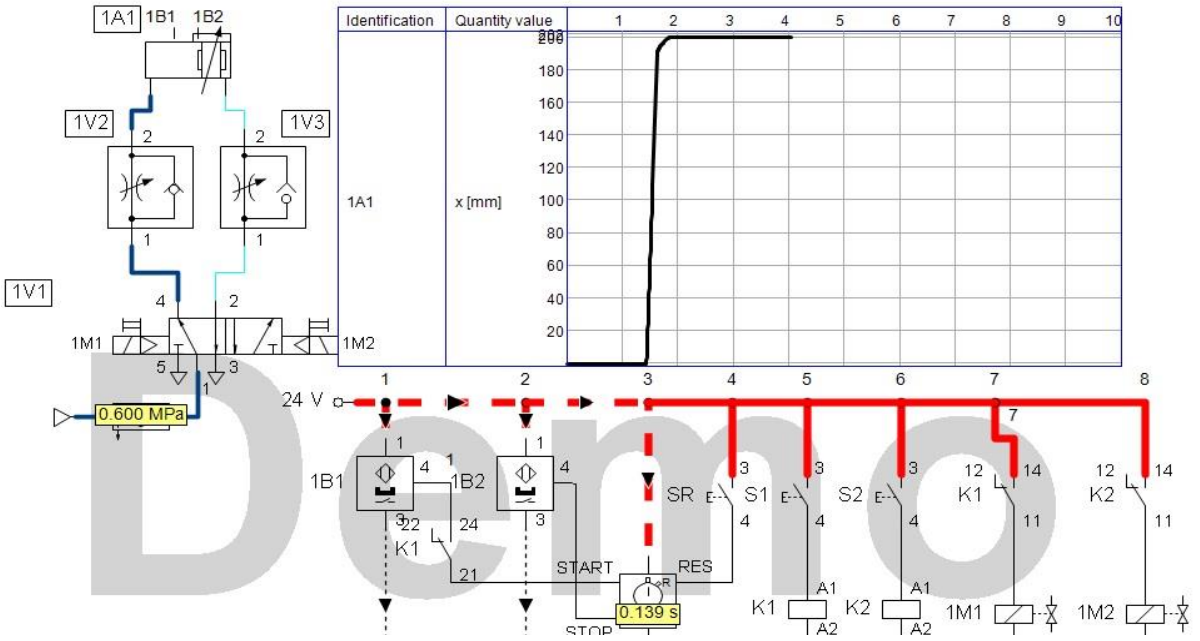


Figure 25: FluidSIM® circuit for linear drive to measure the times between 2 points for both directions

the times are different with the measured in the real world because in the real world it measured with 4 Bar. However, it is not important because the main idea is to build it in the real world and to make measurements and to compare these results with each other. To do this, normal valves and valve terminal have been used. Not to make the same measurements over and over with the valve terminal, only one combination has been chosen, and then that time has been measured.

Movement of a linear drive from position 1 to 2 and from position 2 to 1 has been measured without load and with the load. The number 1 represents the first position, starting position, of the linear drive and, the number 2 represents the ending position. The weight of the load is 2 kg.

Figure 26: Load for linear drive [28]

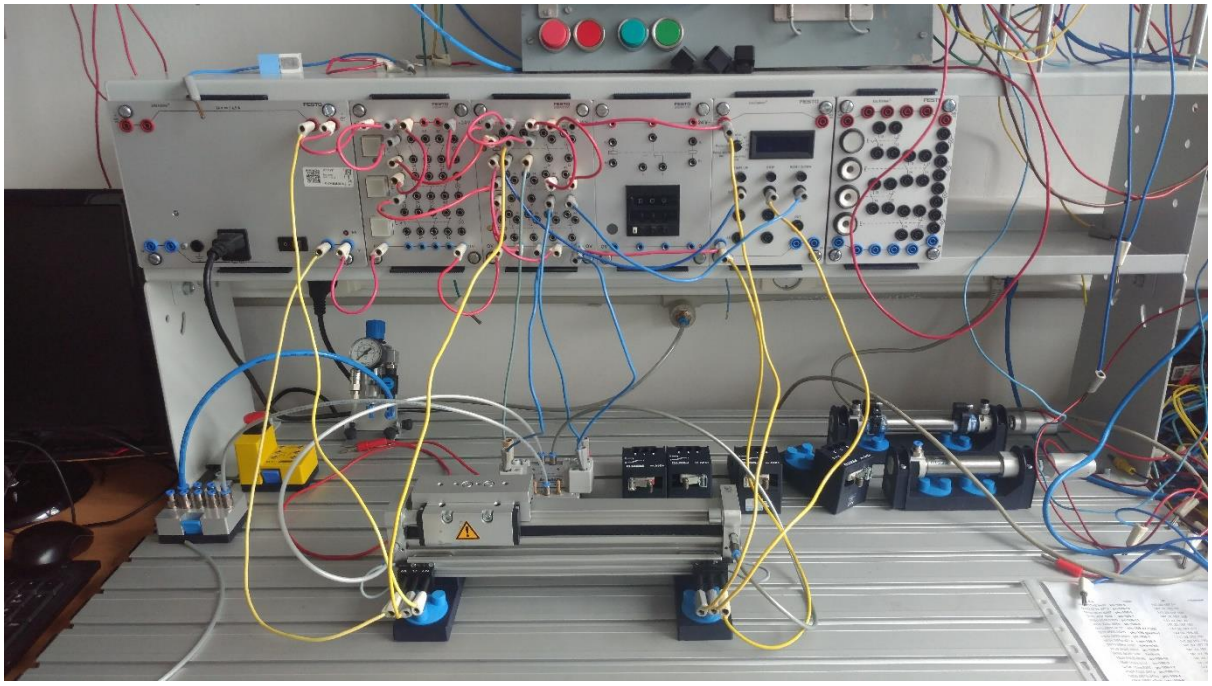


Figure 27: Linear drive circuit for measurements [28]

Figure 25 is the circuit that has been designed in Festo FluidSIM® software, and that circuit has been built in the real world by using real components. The circuit that has been built in the real world can be seen in Figure 27. The functionality of this circuit is; when pressing to the first button, the linear drive starts to move from the initial position and simultaneously stopwatch starts to count the time passed in the t1 section until the linear drive reaches to the end position. After changing the start and stop cables from the stopwatch and then pressing to the second button, the linear drive starts to move from the end position and simultaneously stopwatch starts to count the time passed in the t1 section until the semi-rotary drive reaches to the initial position.

2.2.1. MEASUREMENTS WITHOUT LOAD

Shown measurements Table 64 and Table 65 are movements from 1 to 2 and from 2 to 1 without the load with using normal valves.

NUMBER	POSITION 1 TO 2
1	180 ms
2	181 ms
3	184 ms
4	182 ms
5	180 ms
AVERAGE	181.4 ms

Table 62: Results of Movements from 1 to 2 without Load with using normal valve

NUMBER	POSITION 2 TO 1
1	142 ms
2	136 ms
3	140 ms
4	142 ms
5	138 ms
AVERAGE	139.6 ms

Table 63: Results of Movements from 2 to 1 without Load with using normal valve

2.2.2. MEASUREMENTS WITH LOAD

Shown measurements Table 66 and Table 67 are movements from 1 to 2 and from 2 to 1 with the load with using normal valves.

NUMBER	POSITION 1 TO 2
1	208 ms
2	206 ms
3	206 ms
4	204 ms
5	202 ms
AVERAGE	205.2 ms

Table 64: Results of Movements from 1 to 2 with the Load with using normal valve

NUMBER	POSITION 2 TO 1
1	178 ms
2	174 ms
3	170 ms
4	170 ms
5	170 ms
AVERAGE	172.4 ms

Table 65: Results of Movements from 2 to 1 with the Load with using normal valve

2.2.3. CONCLUSION

By looking at the results that have been measured, moving from one point to another point with load and without load is almost the same. The difference is just 0.0238 ms longer with the load than without the load to move from position 1 to 2. From position 2 to 1, the time passed is longer 0.0328 ms with the load than without the load. As a result, the load is actually not heavy enough for the linear drive with 4 bar input pressure to move it slower.

Moving with load causes a problem. When it moves to the end point, it makes a huge impact. Because of the load and the speed, its momentum is increasing, and when it hits the endpoint, it creates an immense collision. That is why both the linear drive and the load have to be attached tightly.

Also, results show that the movement from position 2 to 1 is always faster, with the load or without the load. The times usually should be the same from one position to another position. The difference is not that big, the time difference is just 0,0418 ms without the load, and with the load, the time difference is 0,0328 ms.

2.3. SIMULATION AND TESTING OF TASKS

In this part, the circuit of Task-1 and Task-2 will be described, and their simulations will be shown with different languages. Task-2 is only a part of

Task-1. Task-2 is designed to be simpler to build it in the real world with standard relay and coils and with PLC.

2.3.1. TASK-1 DESCRIPTION

The Task-1 is decided to be in this sequence:

A+ A- (B+ V1) C+ C- B- A+ A- B+ TAU 0.5 V0 TAU 1 B-

These words are explained in the section of “List of Abbreviation”.

Explanation of the sequence in written is like this:

1. Pressing the “SET” button to set the system to be ready to start the process.

2. If the indicator lamp is green, it means the process can start by pressing the “SB” button.

3. After pressing the “SB” button, “MOTOR_A” brings the first piece to the rotary table by moving forward.

4. When “MOTOR_A” reached to the end position, “MOTOR_A” moves backwards.

5. If “CPS1” is activated, “ROTARY_DRIVE” turns counterclockwise and “VACUUM” turns on at the same time.

6. After turning completed and if “CPS2” is activated, “LINEAR_DRIVE” moves forward and by the help of “VACUUM”, it grabs the piece.

7. After grabbing the piece, “LINEAR_DRIVE” moves backwards and holds the piece.

8. “ROTARY_DRIVE” turns clockwise to its first position.

9. “MOTOR_A” brings the second piece to the rotary table by moving forward.

10. When “MOTOR_A” reached to the end position, “MOTOR_A” moves backwards.

11. If “CPS1” is activated, “ROTARY_DRIVE” turns counterclockwise.

12. If “CPS2” is activated, after waiting for 0.5-second “VACUUM” turns off and first piece, the piece that is grabbed by vacuum before, drops on to the second piece.

13. After “CPS3” is activated, waiting 1 second, half of it passed in step 12 and then “ROTARY_DRIVE” turns clockwise to its first position.

2.3.2. TASK-1 SIMULATION WITH ELECTRO-PNEUMATIC CIRCUIT

Firstly the Task-1 sequence has been built in FluidSIM® software. For that first, the functional diagram and hardware parts have been prepared.

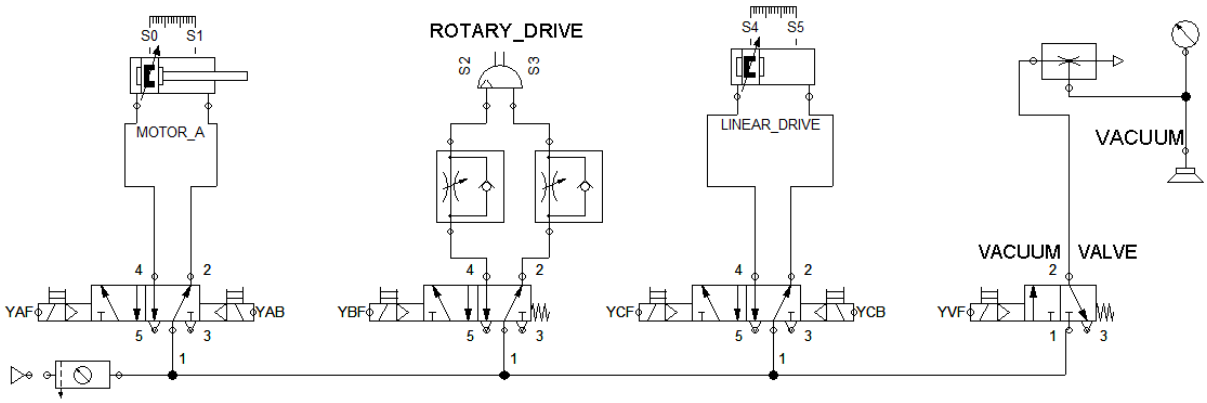


Figure 28: Pneumatic part of the Task-1

The functional diagram can be seen in the Figure 29.

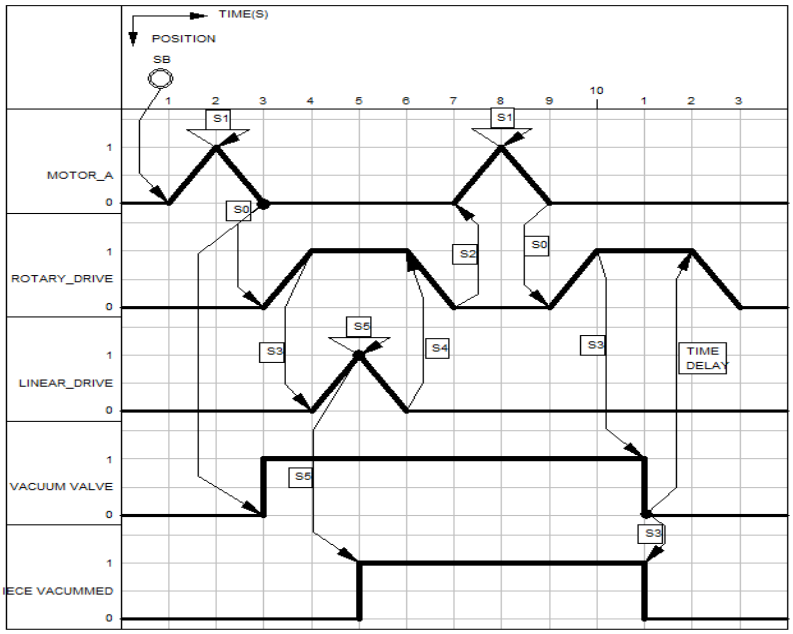


Figure 29: Functional Diagram of the Task-1

Secondly, the circuit has been built in FluidSIM® and tested to see if the result of the circuit is the same as the functional diagram. Rest of the circuit can be seen at appendix 6.1. The output part of the circuit can be seen at appendix 6.2.

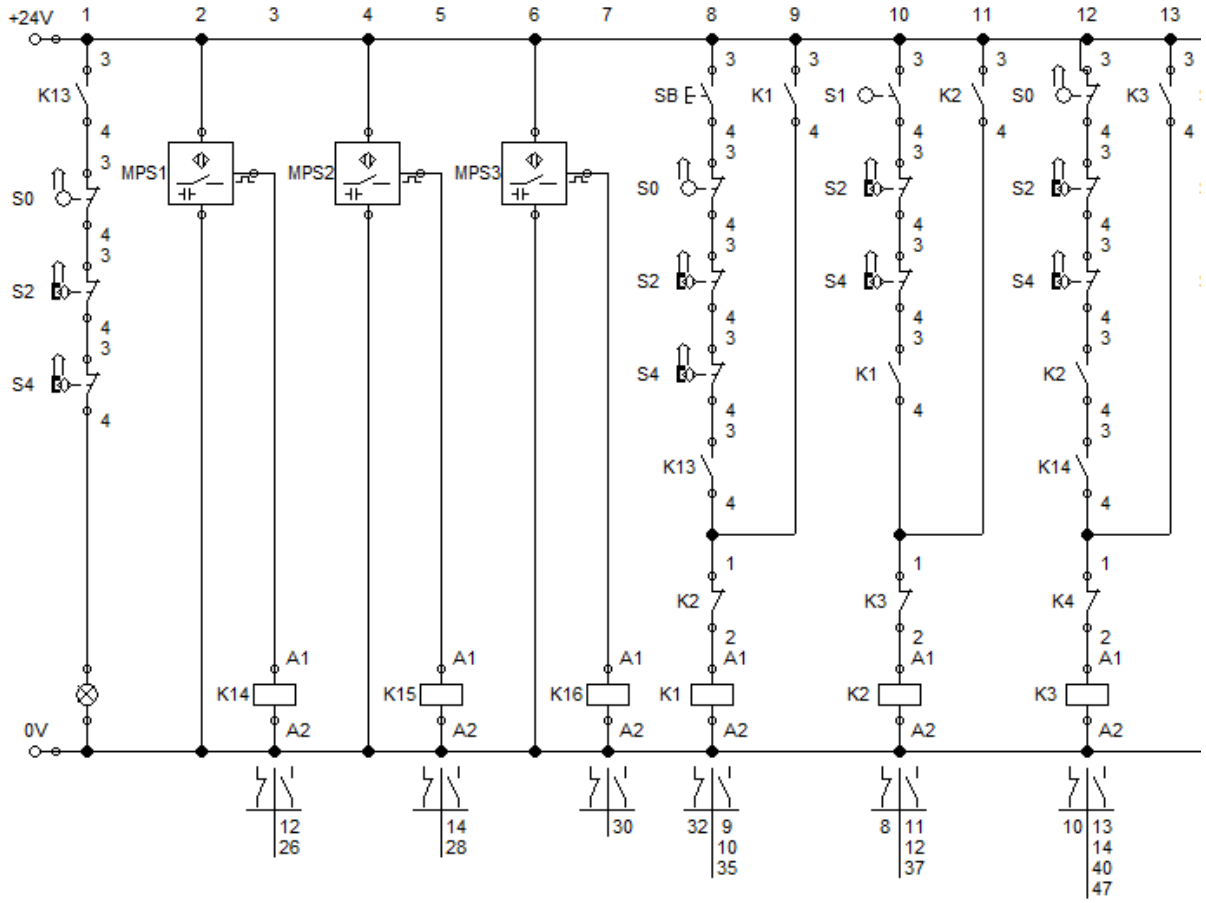


Figure 30: A part of the circuit for Task-1

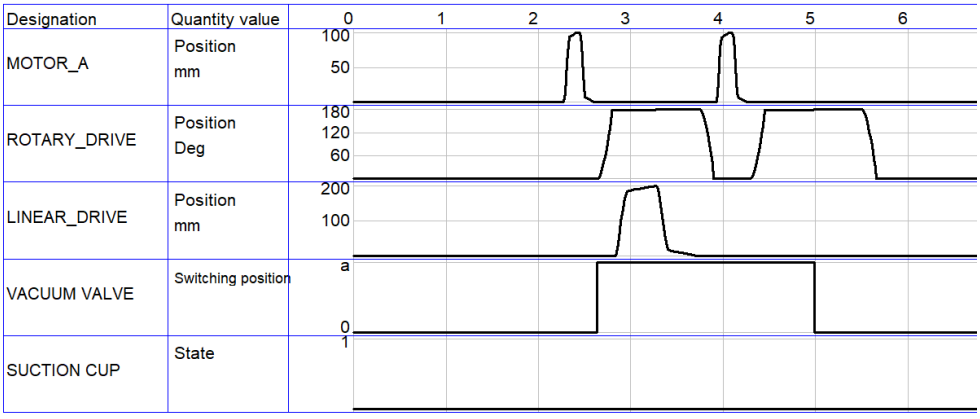


Figure 31: State diagram of the circuit for Task-1

Suction Cup seems like not working. It has to be handled manually and, with the speed of the sequence, it is difficult to use it correctly. It is there only to see if the hardware part of the circuit is done correctly or not. After comparing the results and confirm they are same, this circuit can be written in GRAFCET language and Ladder Diagram. From Figure 32 below can be seen that it is too time-consuming to build it and to debug it. Also, it was not possible to complete it because of the limited components.

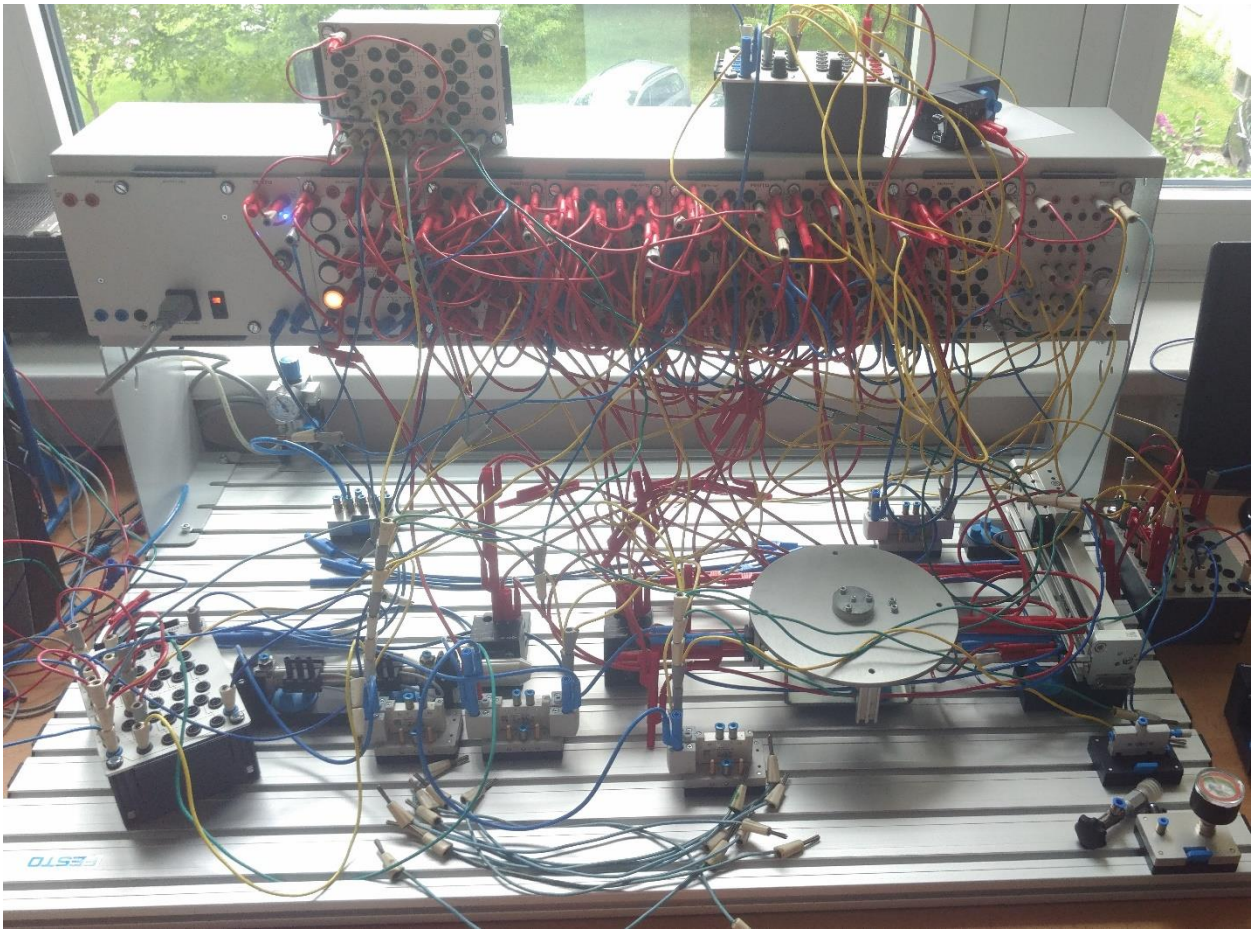


Figure 32: Task-1 Circuit Built With Using Valves [28]

2.3.3. TASK-1 CIRCUIT WITH GRAFCET

In GRAFCET language, instead of using coils and relays, blocks are using with their transitions and actions. However, only the use of blocks and its components is not enough. A hardware part is also necessary to use the GRAFCET completely, pneumatic part of the circuit. That pneumatic part can be seen from Figure 28. For the hardware part a virtual PLC has been used with its inputs and outputs. After completion of the circuit again results are compared to see if this circuit is done correctly. After confirming that it is

correct, this circuit can be written in Ladder Diagram language. Rest of the circuit can be seen at appendix 6.3. and 6.4.

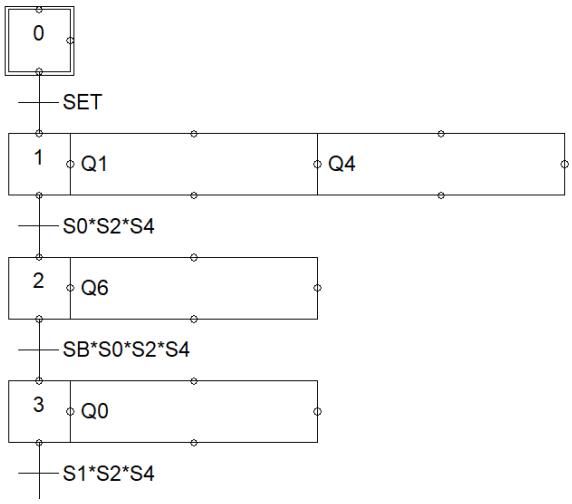


Figure 33: A part of the GRAFCET of Task-1

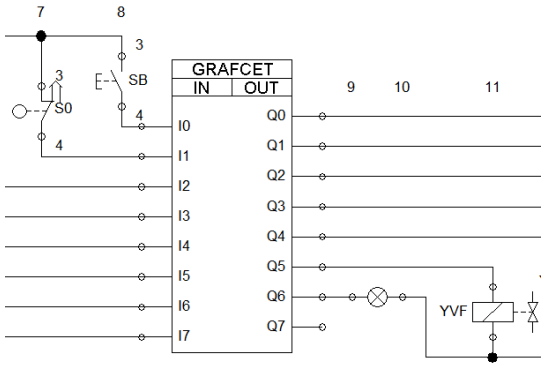


Figure 34: A part of the hardware of GRAFCET for Task-1

2.3.4. TASK-1 CIRCUIT WITH LADDER DIAGRAM

Program in ladder diagram language can be done in FluidSIM® software. Afterwards, it can be implemented to Step-7 Micro/WIN software. After seeing the circuit is working correctly, then it can be implemented to Step-7 Micro/WIN software to build it in the real world with using PLC. Instead of building Task-1, Task-2 has been built with Step-7 Micro/WIN software in the real world. Rest of the circuit can be seen at appendix 6.5. and 6.6.

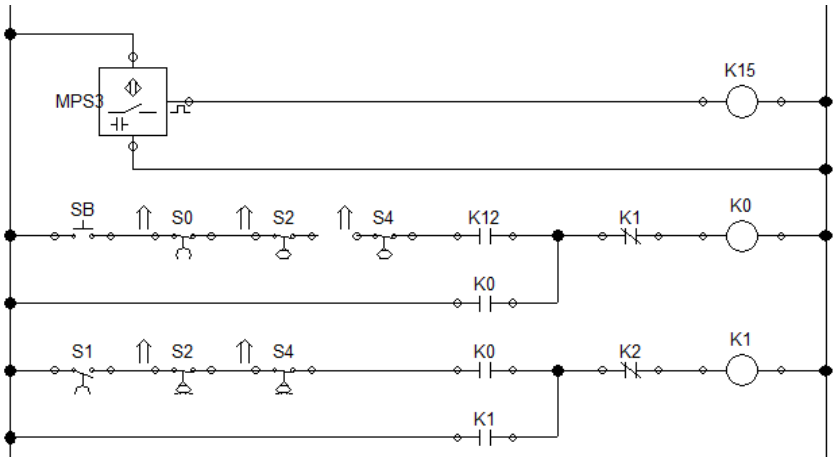


Figure 35: A part of the ladder diagram for Task-1

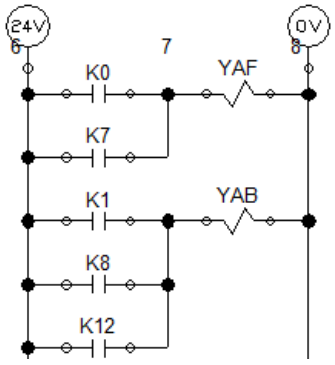


Figure 36: A part of the ladder diagram output for Task-1

2.3.5. TASK-2 DESCRIPTION

The Task-2 is decided to be in this sequence:

- B+ TAU 3 C+ C- B-

These words are explained in the section of “List of Abbreviation”.

Explanation of the sequence in written is like this:

1. Pressing the “SET” button to set the system to be ready to start the process.

2. Pressing the “SB” button to start the process.

3. After pressing the “SB” button, “ROTARY_DRIVE” will turn counter-clockwise.

4. When “ROTARY_DRIVE” reaches the endpoint and waiting for 3 seconds then “LINEAR_DRIVE” will moves forward direction.

5. When “LINEAR_DRIVE” reaches the endpoint, it will start to move backwards direction to its initial position.

6. When “LINEAR_DRIVE” reaches its initial position, “ROTARY_DRIVE” will turn clockwise, its initial position and sequence will be finished.

2.3.6. TASK-2 SIMULATION WITH FLUIDSIM

Firstly the Task-2, sequence, built in FluidSIM software. For that first, the functional diagram and hardware parts prepared.

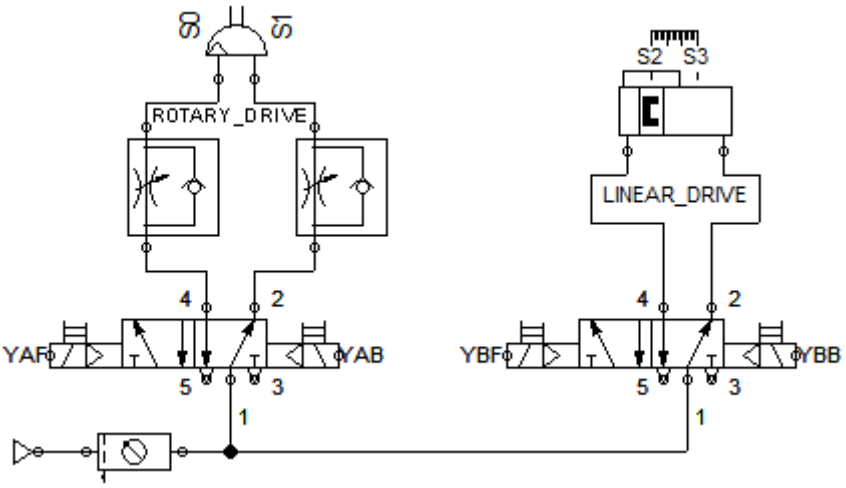


Figure 37: Pneumatic part of Task-2

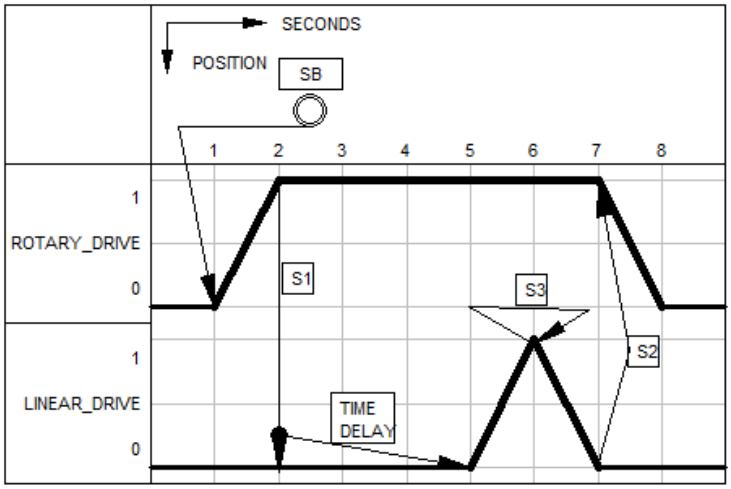


Figure 38: Functional Diagram of Task-2

Secondly, the circuit has been built in FluidSIM and tested to see if the result of the circuit is the same as the functional diagram.

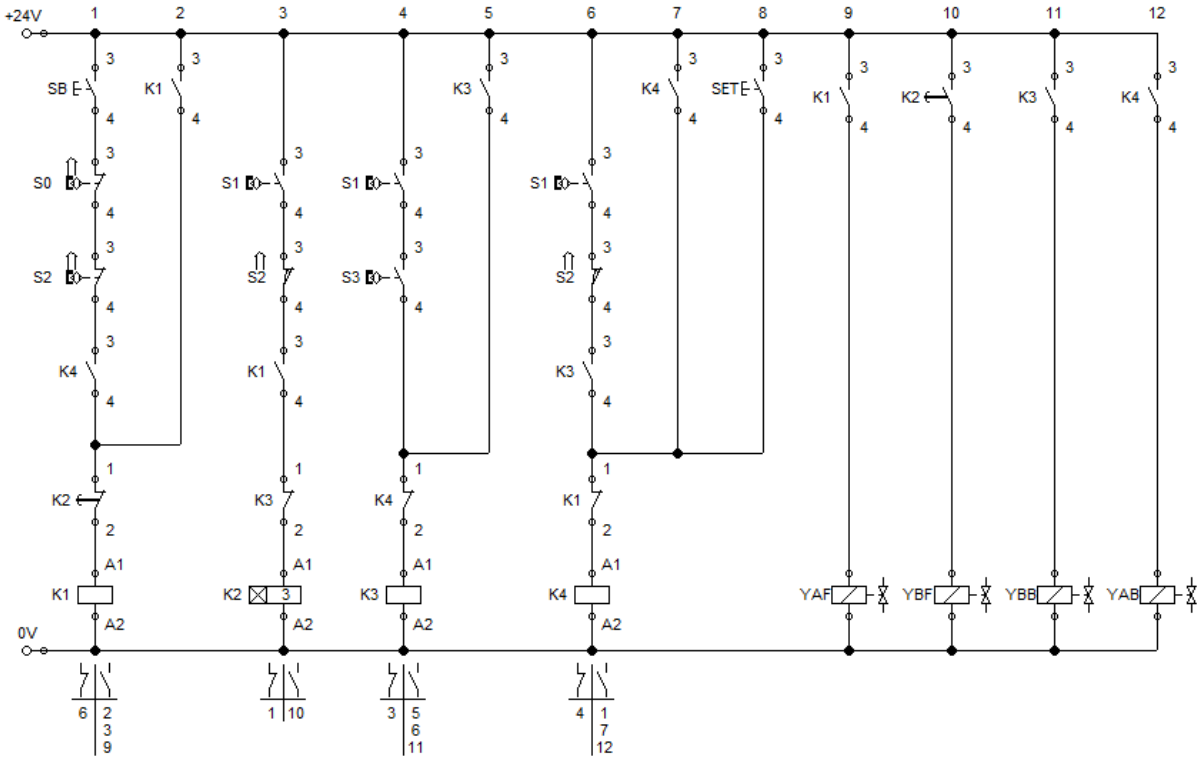


Figure 39: Electrical part of Task-2

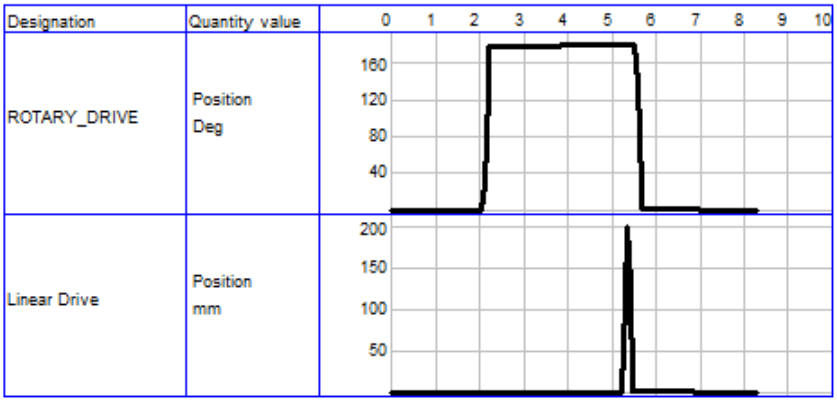


Figure 40: State Diagram of the Circuit for Task-2

After comparing the results and confirming they are same, this circuit can be written in GRAFCET language and ladder diagram language.

2.3.7. TASK-2 CIRCUIT WITH GRAFCET

In GRAFCET, instead of using coils and relays, blocks are used with their transitions and actions. However, only the use of blocks and its components is not enough. A hardware part is also necessary to use the GRAFCET completely. For the hardware part, a virtual PLC is using with its inputs and outputs. After completion of the circuit again results are compared to see if this circuit is done correctly. After confirming that it is correct, this circuit can be written in ladder diagram language. Rest of the circuit can be seen at appendix 7.1.

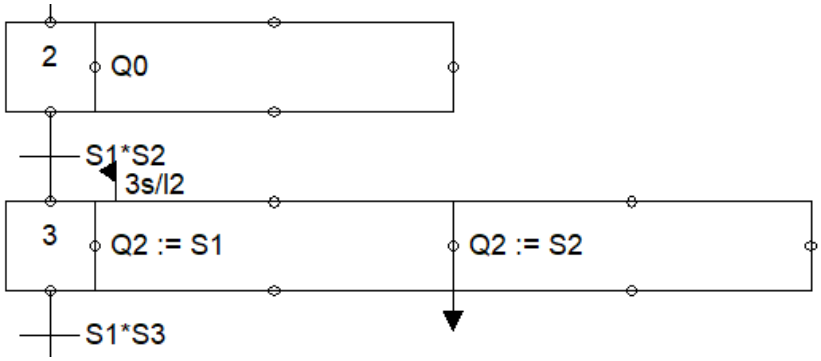


Figure 41: A part of the GRAFCET of Task-2

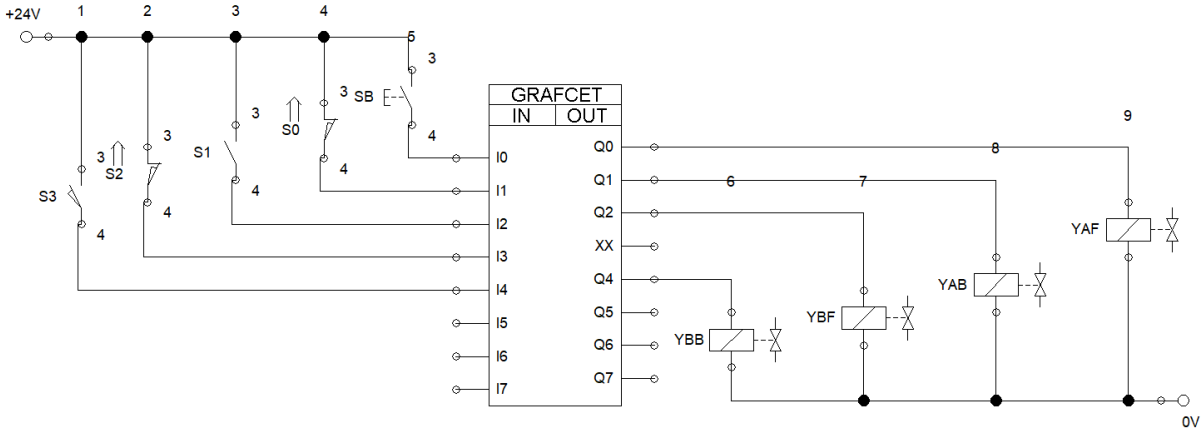


Figure 42: A part of the hardware solution of GRAFCET for Task-2

2.3.8. TASK-2 CIRCUIT WITH LADDER DIAGRAM

Ladder Diagram can be written in FluidSIM® software before writing it in Step-7 Micro/WIN software. After seeing the circuit is working correctly, then it can be written in Step-7 Micro/WIN to built it in the real world. Rest of the circuit can be seen at appendix 7.2.

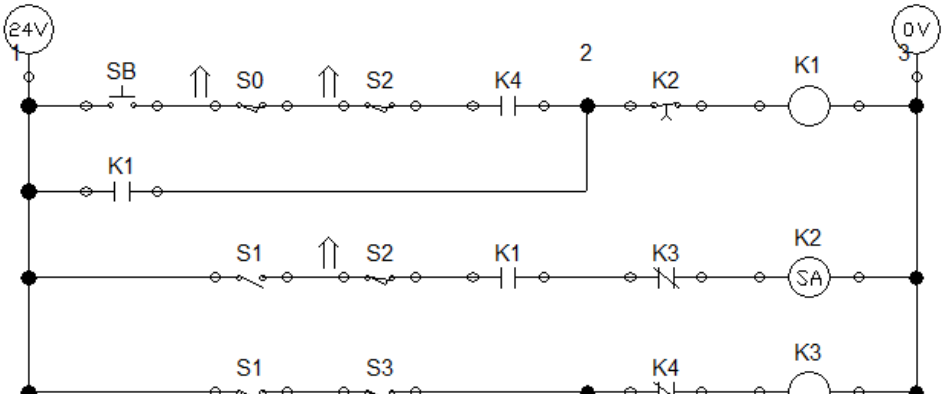


Figure 43: A part of the electrical part of ladder diagram for Task-2

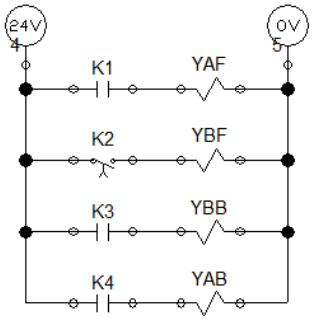


Figure 44: Ladder diagram output of Task-2

2.4. BUILDING TASK-2 IN THE REAL WORLD

Firstly, building and testing the Task-2 circuit by looking at the circuit done in FluidSIM software with standard relays and contacts.

Secondly, building and testing Task-2 with using Festo Valve Terminal, VTEM, by looking at the circuit done in FluidSIM software with standard relays and contacts. The main idea is to build the same circuit by using VTEM, not with using standard valves.

Thirdly, writing the logic in Ladder Diagram in Step-7 Micro/WIN software by taking the Ladder Diagram circuit done in FluidSIM Software and built it by using PLC.

2.4.1. TASK-2 WITH VALVES

The circuit is shown in Figure 39. Valves in Figure 37 are used to build this circuit in the real world. These valves, 5/2-way double solenoid valves, can be seen in Figure 45.

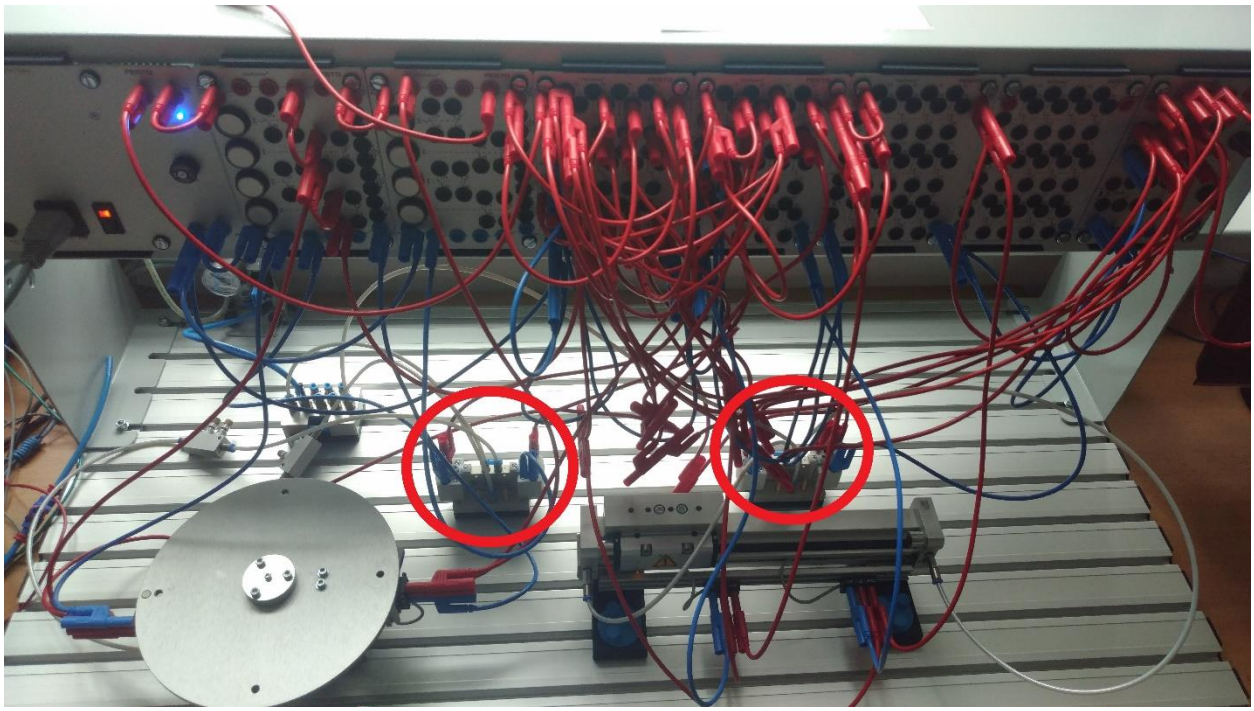


Figure 45: Task-2 circuit built with using valves [28]

2.4.2. TASK-2 WITH VALVE TERMINAL

The circuit is shown in Figure 39. Instead of valves in Figure 37, the valve terminal is used to build this circuit in the real world. Two 5/2 way double solenoid valves have been used. Valve terminal can be seen in Figure 14, and in Figure 46.

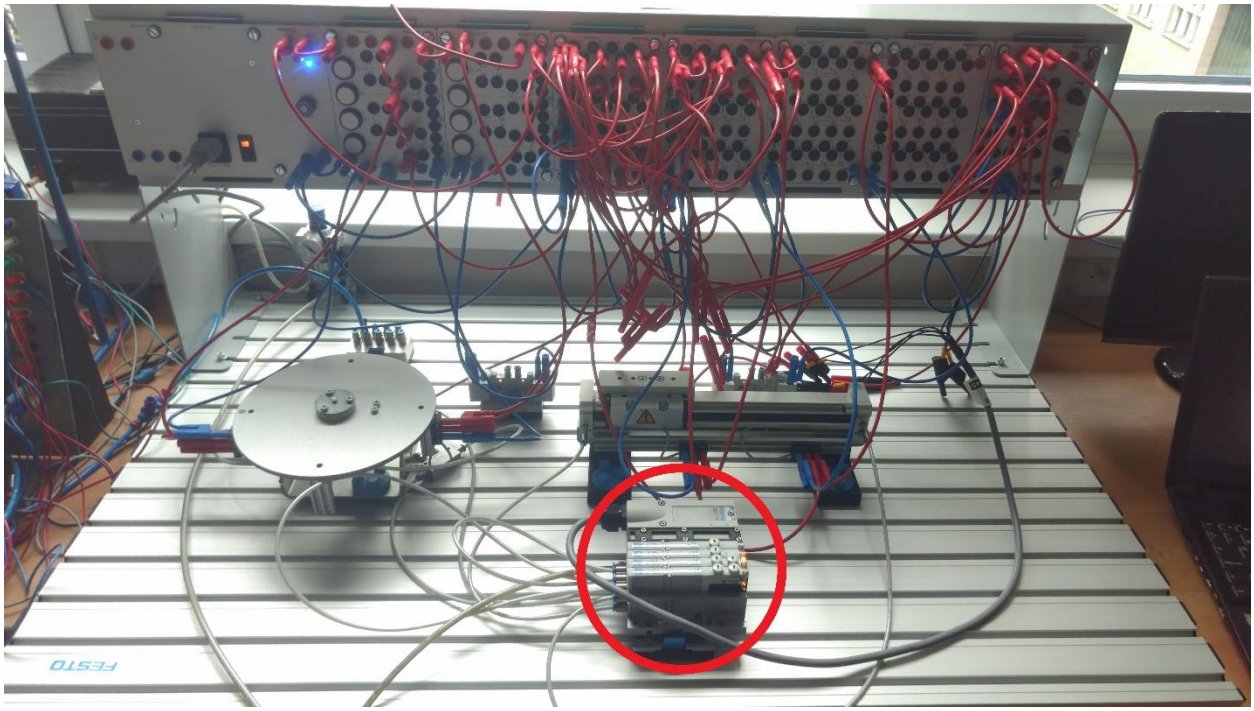
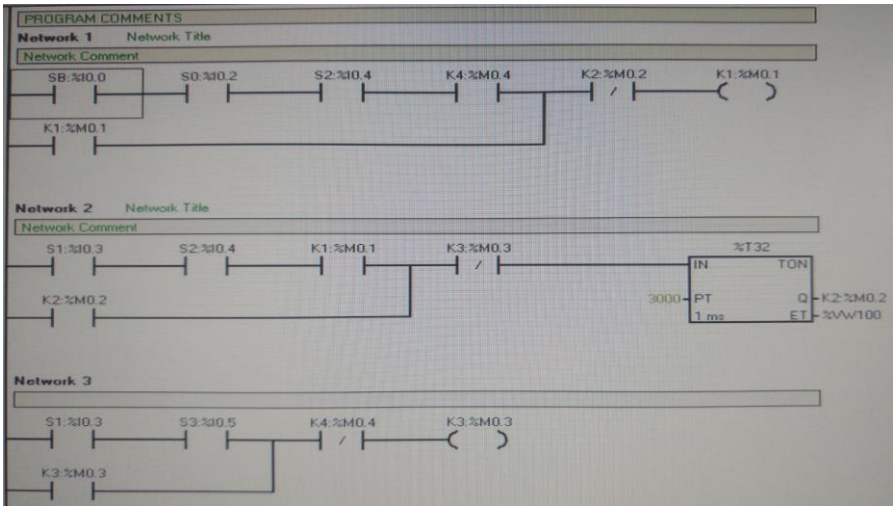


Figure 46: Task-2 Circuit Built With Using Valve Terminal [28]

2.4.3. TASK-2 WITH PLC

The circuit is shown in Figure 38 and in Figure 39. Now the same circuit has been built by using ladder diagram language by using Step-7 Micro/WIN software. Whole program in the ladder diagram can be seen in appendix 7.3.



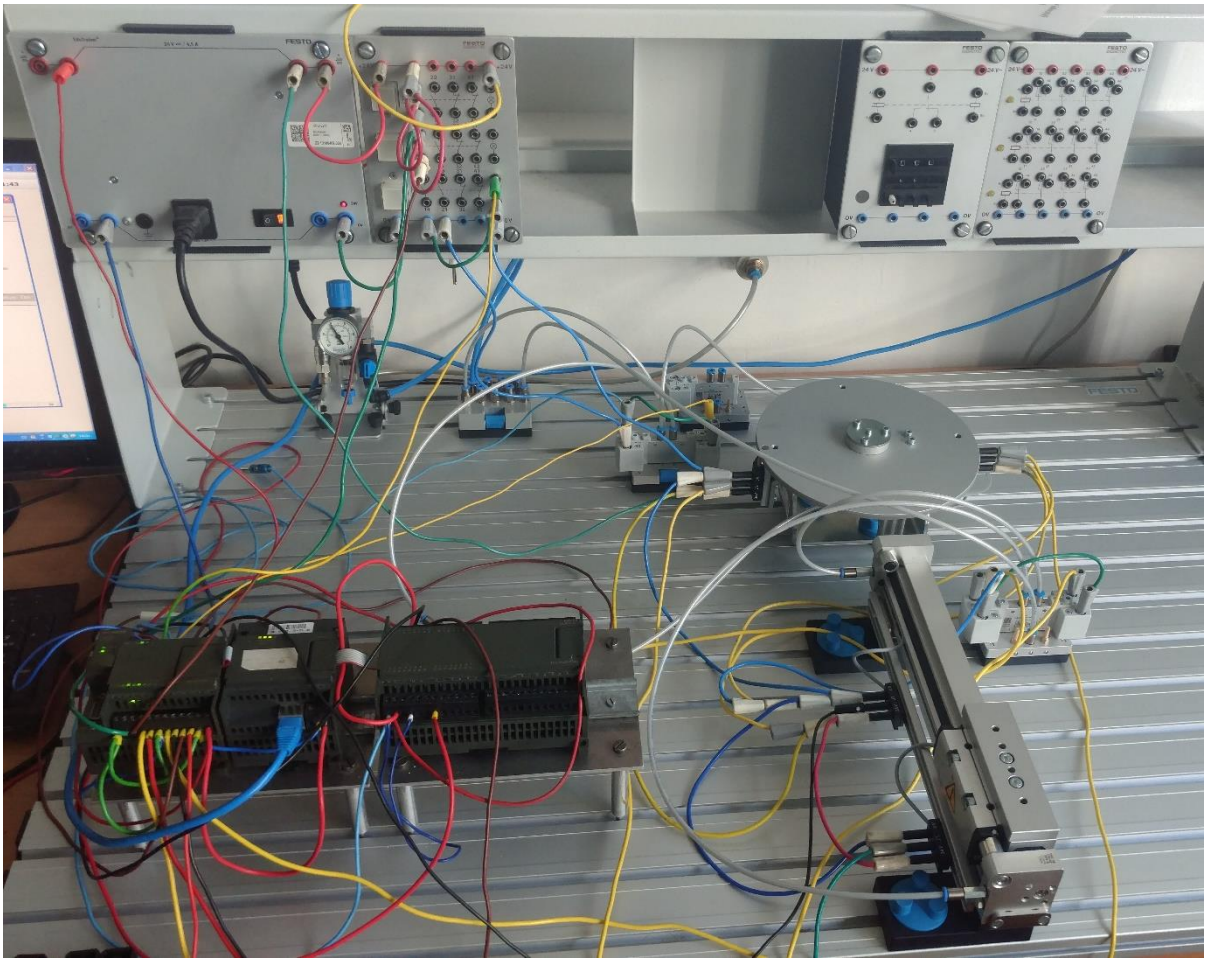


Figure 48: Task-2 with PLC and particular valves [28]

3. VISUALISATION

There have been three visualisation projects created for the Task-2. Each project's sequence is the same, but some necessary components have been added or removed or changed to suit the purpose of that project.

The first one works with the script. This is only to demonstrate the sequence in the computer. The communication is through between scripts and components.

The second one is to make communication between Reliance SCADA and PLC. Values are read from PLC and showed that results in Reliance SCADA. The problem here is that reading the values from PLC and showing them in the Reliance SCADA is slow.

The third one is to make communication between Reliance SCADA and OPC Server and the PLC. The changes can be observed from OPC Server and Reliance SCADA.

3.1. VISUALISATION-1

This visualisation project has been done by scripts. It is working without PLC and OPC Server, just for simulation, demonstrate, to show how the sequence works.

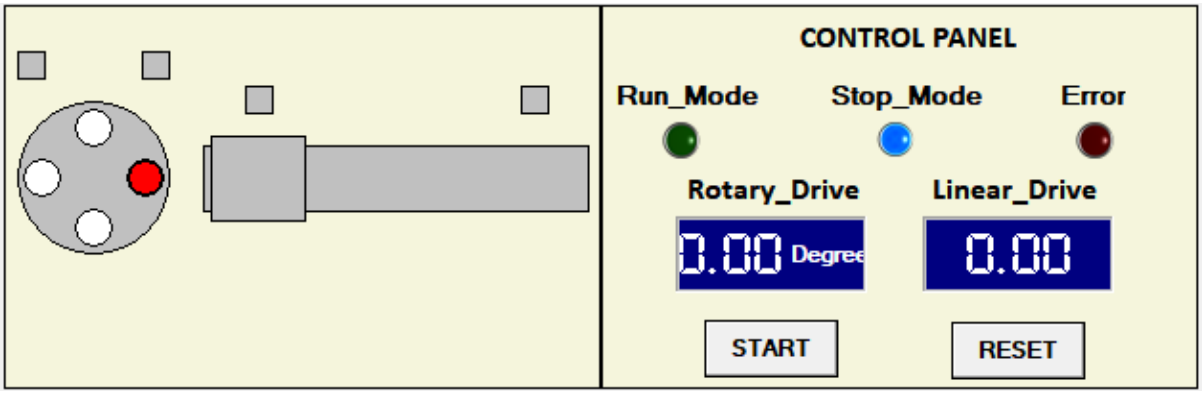


Figure 49: Visualisation-1 for Task-2

According to Task-2, in this visualisation project, on the left side, there is one rotary drive connected to the rotary table to turn it, there is one linear drive and there are sensors. There are totally four sensors. When the start button is pushed, the rotary drive is starting to turn and, to show that it is turning, a red piece is there. The rotary disc is turning by angle tag and scripts. When the rotary drive's angle reached to the 90 degrees, the red piece is moving to the bottom circle and, when the rotary drive reached the 180 degrees, the red piece is moving to the left circle and at the same time, the linear drive is starting to move. The linear drive moves on the x-axis by tag and scripts. When the linear drive reached its endpoint, it starts to moving the other direction and, when it reaches the initial position, the rotary drive starts to run counter-clockwise to its initial position. When the rotary drive reached its initial position, it means sequence is done.

On the right side, there is a control panel for the process on the left side. In the control panel, the rotary drive's turning angle and linear drive's position can be seen. At the bottom, there are two buttons. The left one is to start the process, and the right one is to reset the process at any time. If the blue light is on (Stop_Mode), in the control panel, it means there is no movement, the system is in stop mode. If the green light on (Run_Mode) , in the control panel, it means the system is working, if the red light (Error) is on, in the control panel, it means there is an error, so the system should be reset before starting it again. The script reads the value of the tags that have been created in the

project. Then these tags values can be changed by writing a code, and after that, these values assigning as new values. The script part of the visualisation project can be seen in appendix 8.

3.2. VISUALISATION-2

This project has been created to make communication between Reliance SCADA and PLC. To do that first PLC programming should be done and it is done and tested. This project can be seen at 2.4.3.

As can be seen from Figure 54, there is a total of ten displays. Each one of them has been connected with one input or output to show the change of the value by using tags. Some settings have to be done to make a successful communication.

PLC has communication module in the ethernet wizard settings must be set up correctly from STEP-7 Micro/WIN software. The ethernet wizard can be found at the tab “Tools”. Communication between Reliance SCADA and PLC has been solved in this manner.

NAME	VALUES
IP Address	147.32.167.101
Subnet Mask	255.255.240.0
Number of connections to configure for this module	1
This is a Server Connection	Yes
Local TSAP Value	10.00
Remote TSAP Value	10.00
Accept all connection request	Yes (If there is no any other working PLC at the same time)
Enable the Keep Alive for this connection	Yes
Yes, generate CRC protection for this configuration in the data block	Yes

Table 66: Settings for Ethernet Wizard

After setting up everything correctly, the subroutine must be activated to make communication. A special memory, variable (flag) %SM0.1, that is set to logical 1 only in thr first scan after starting of the PLC. This special memory has to be put as an input for that particular block, “ETH0_CTRL”. The special memory is showed in Figure 50. Also, some values have to be set correctly for that block.

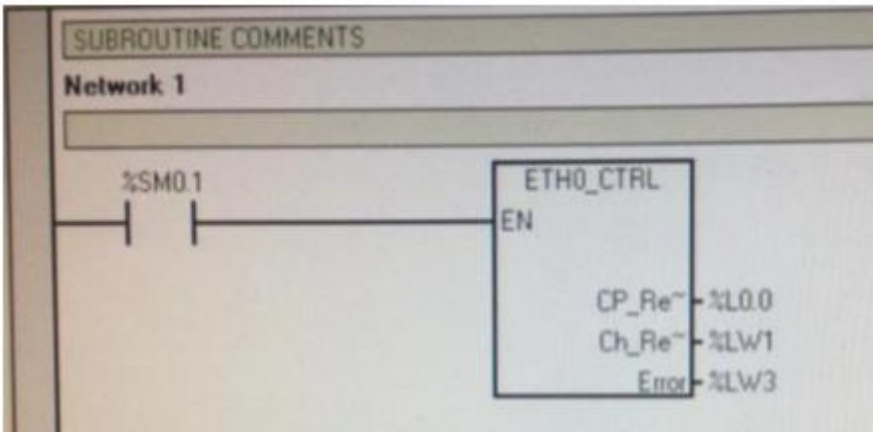


Figure 50: Ethernet Control Block [28]

Second setting is the setting from Reliance SCADA software. In the “TAB” section of the device manager, it is necessary to create a new device and choose the Siemens.

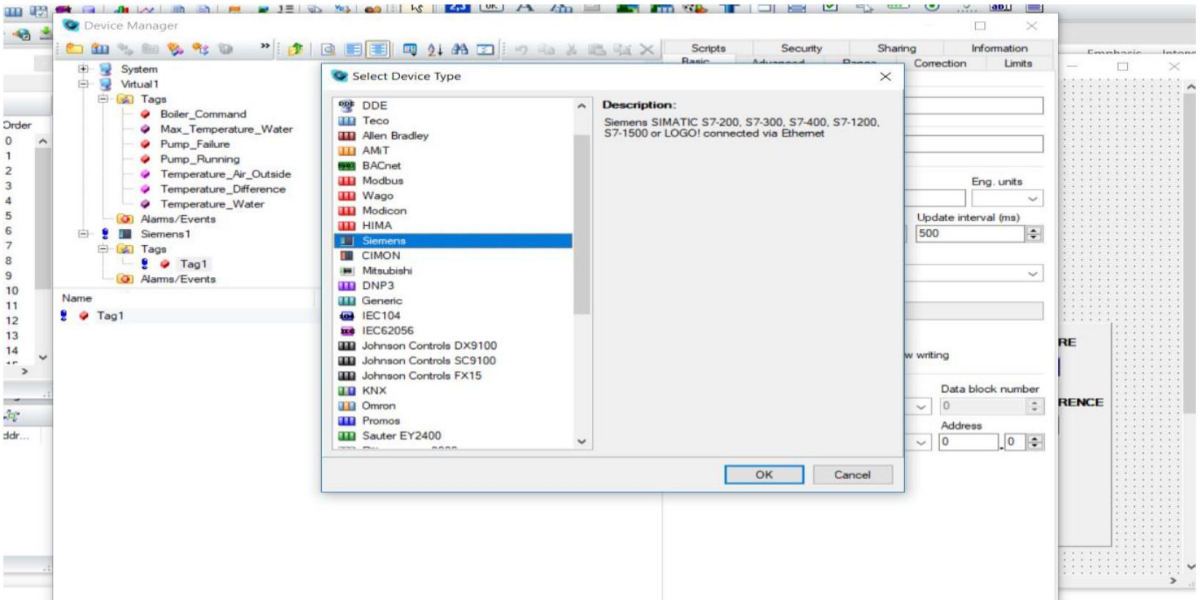


Figure 51: Reliance SCADA Setup-1

After this, the new device has been created. In order to configure it, it is necessary to choose the particular type of the PLC, in this project it is “S7-200,LOGO!” option. From the same place, it is necessary to fill the IP address of the used PLC. Also, “TSAP” values that arranged before in the setup of the “Ethernet Wizard”, needs to be written in the correct places and they have to be the same numbers.

Next step is to create tags under Siemens Device and setup them correctly. Types of Tags have to be Boolean, and they should be chosen as a Discrete Input if it is input in PLC and Discrete Output if it is output in PLC with their particular addresses.

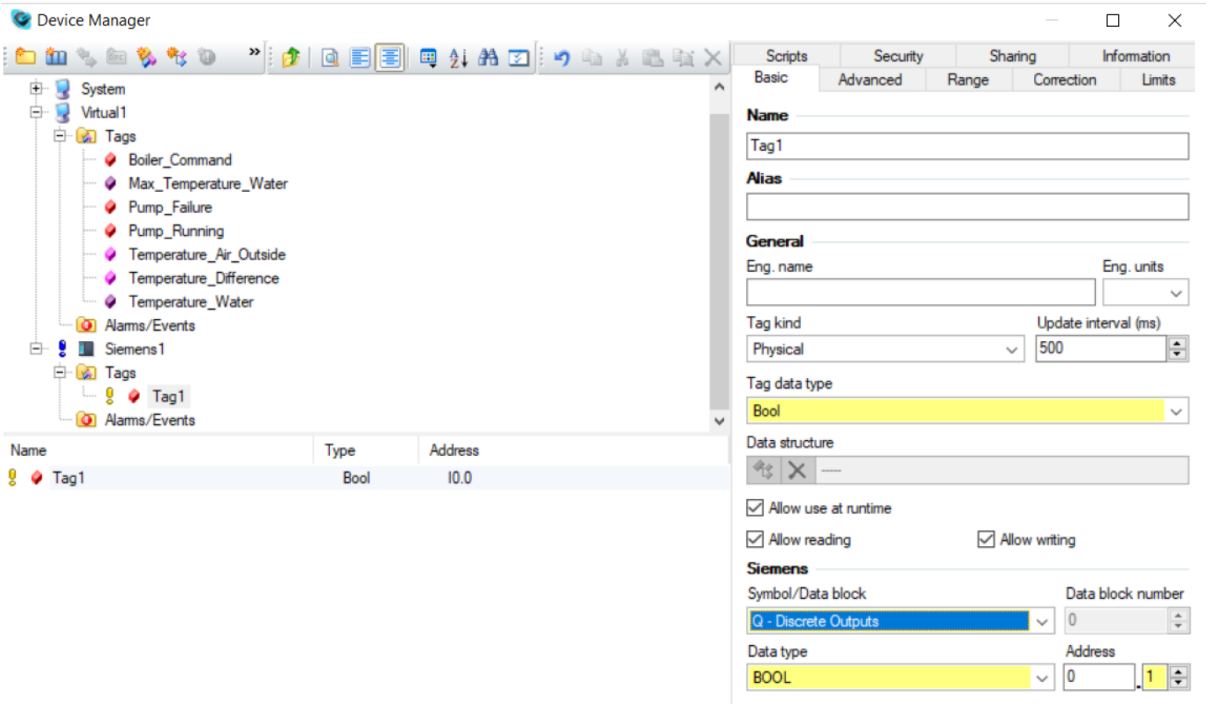


Figure 52: Reliance SCADA Setup-3

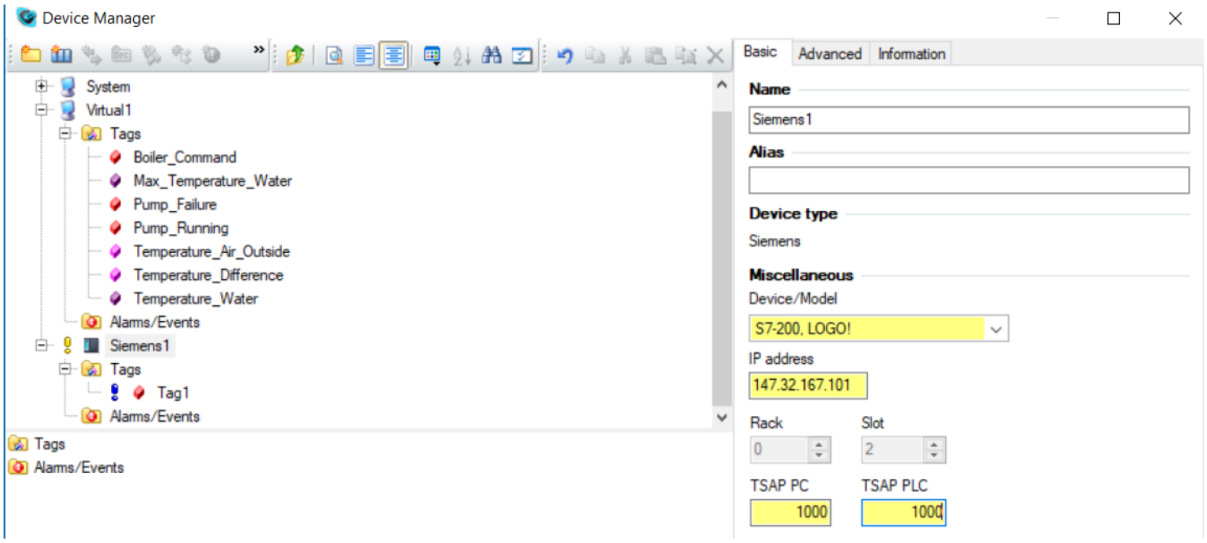


Figure 53: Reliance SCADA Setup-2

After finishing these settings, and putting the necessary tags, the project can be run, and if everything is set up correctly, it is possible to see the values of the tags in Reliance SCADA project in the real time.

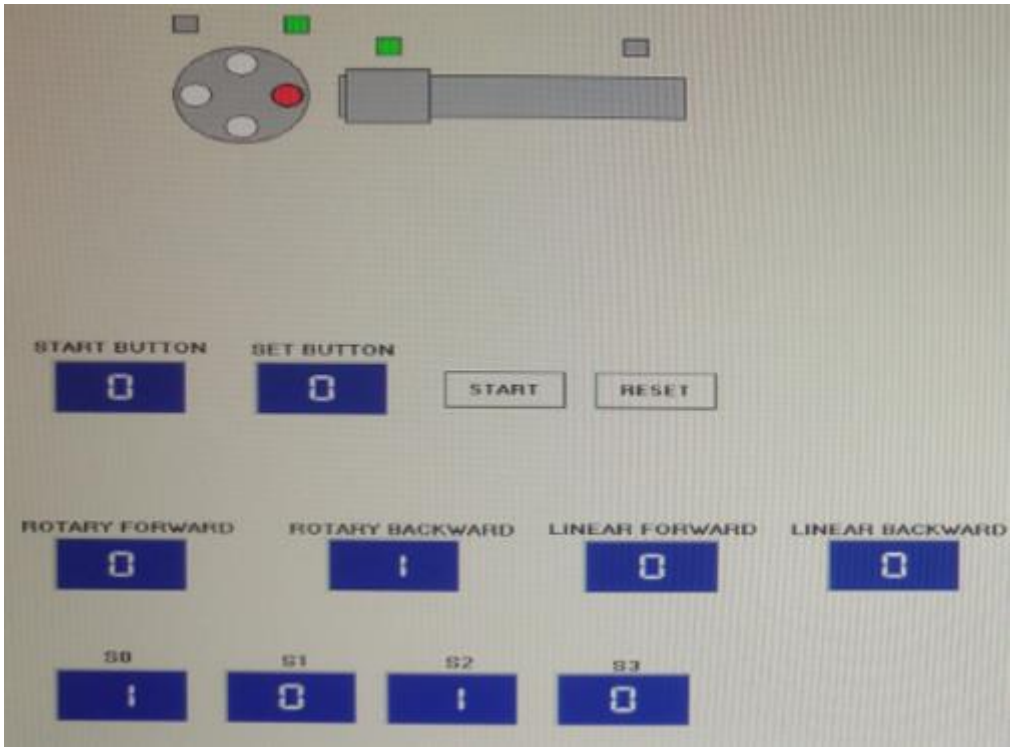


Figure 54: Result of Visualisation-2 project [28]

Result of the communication can be seen from Figure 54. There is no script in this project. Only tags have been used for each component. Sensors outputs can be seen from the little boxes above rotary and linear drive and can be seen from the displays below.

3.3. VISUALISATION-3

This visualisation project has been created to make communication via OPC Server. PC-Access software has been used for this project to make communication between OPC Server and Reliance SCADA softwares. Some settings have to be done to make a successful communication.

There are three parts of settings to make communication between Reliance SCADA and OPC Server.

1. The first setting, setting for ethernet wizard has been done and has been explained in chapter 3.2.
2. PC Access software must be open to create a new project. After creating the project, needs to be clicked to “insert symbols” in PC Access software and choose the project that has been created in STEP-7 Micro/WIN software. After adding the project, by right-clicking it to

select settings and it is necessary to complete the settings by writing the IP Address of the PLC and the “TSAP” values from ethernet wizard configuration.

Now the tags should be seen as in Figure 55. By selecting all tags and moving these tags to “Test Client” part is necessary to see the results. If all the settings have been done correctly, after pressing the simulation button, in the “Test Client”, under the “Quality” section, the word must be “Good”. When the value changed, it should be seen here immediately. If there is an error with communication, then under the “Quality” section, there will be written “Bad”.

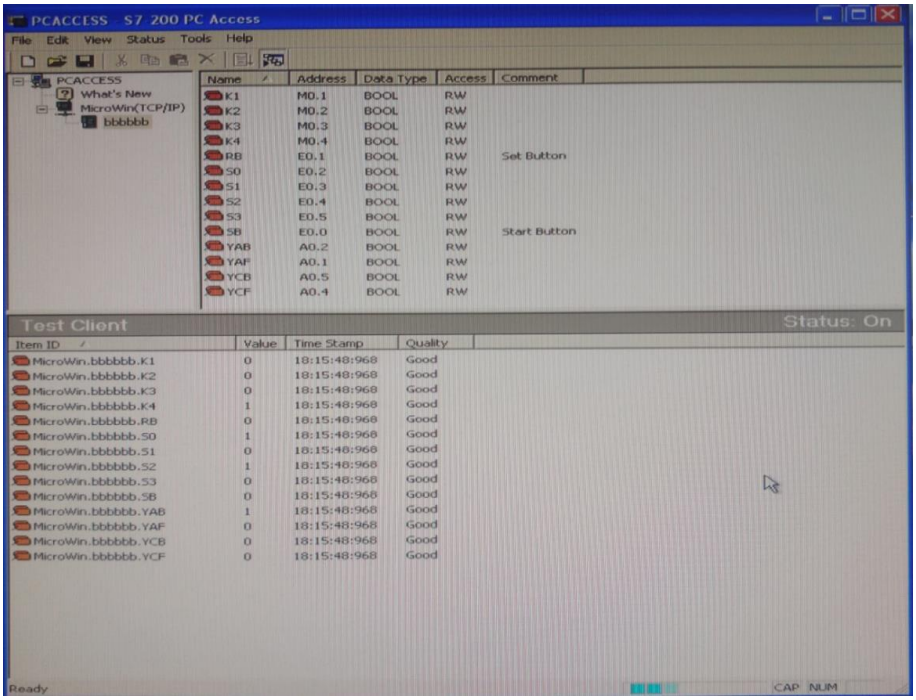


Figure 55: PC Access Tags [28]

3. Next step is to move these tags to the Reliance SCADA. To do that, from Reliance SCADA software, from device manager, OPC device has to be added, and the correct OPC server has to be chosen. After that, it is necessary to click the import tags from OPC Server section to get the tags. Now tags from OPC server should appear like in Figure 56 on the right side. Now choosing all tags from OPC Server and clicking the left top button “Import Selected Items from OPC Server”, all tags have been moved to the Reliance SCADA. Now all tags should be seen in Figure 56 on the left side.

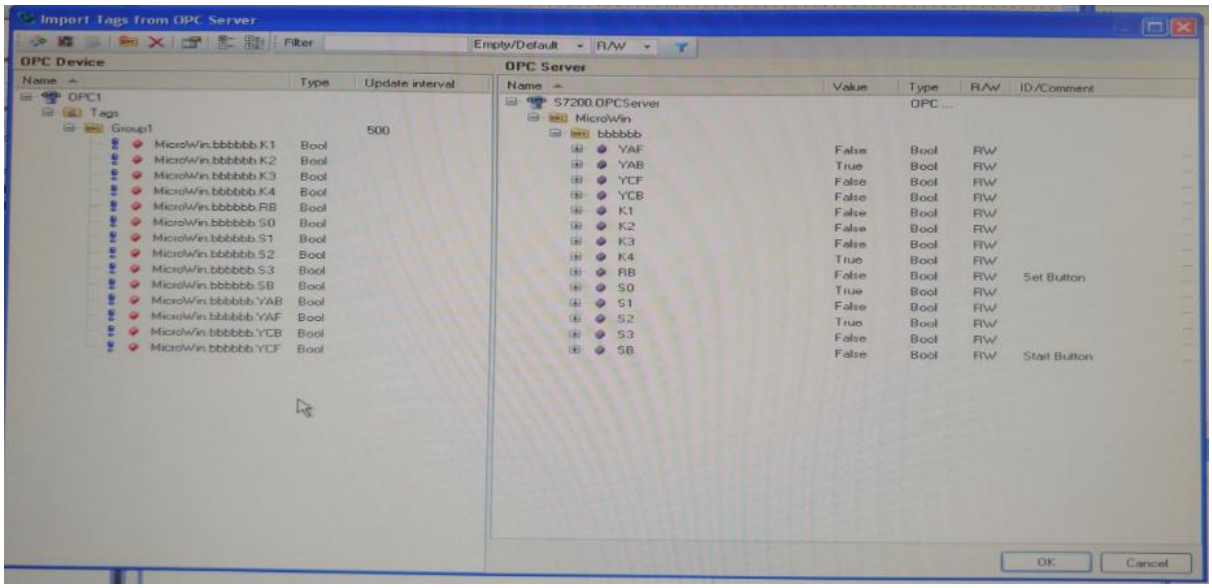


Figure 56: Tags from OPC Server [28]

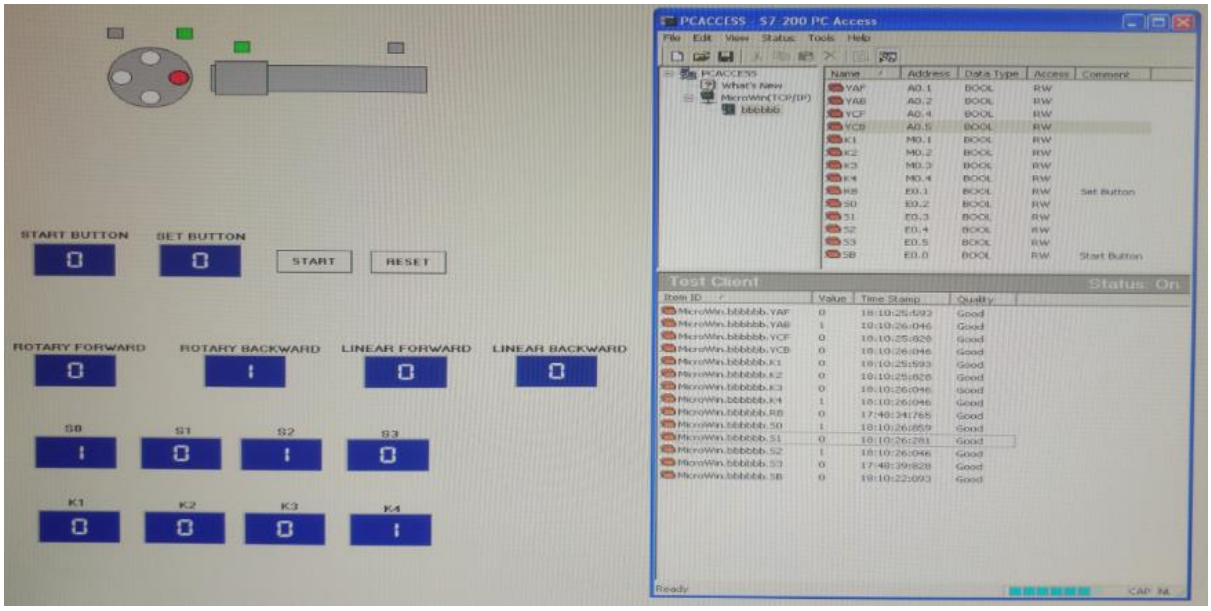


Figure 57: Result of Visualisation-3 project [28]

Communication has been done successfully. This can be proven from comparing the values between Reliance SCADA and PC-Access.

4. MEASUREMENTS WITH VTEM

VTEM is defined at 1.1.13. Two measurements have been done. One of them is with semi-rotary drive and the other one is linear drive. Descriptions can be seen, respectively, at 2.1. and 2.2. The pneumatic part can be seen in Figure 23 and Figure 25.

Firstly, communication has to be made between computer and VTEM via ethernet cable. From the computer, some parameters have to be set correctly to establish communication with VTEM. These parameters are shown in Table 67.

Name	Value
IPv4 Adress	192.168.4.20
Subnet Mask	255.255.0.0
WebConfig Interface	http://192.168.4.2/

Table 67: Settings for VTEM

After setting IPv4 and subnet mask addresses, from the web browser, the specific address (WebConfig Interface) has to be written to address bar. After that, the interface of the VTEM should appear.

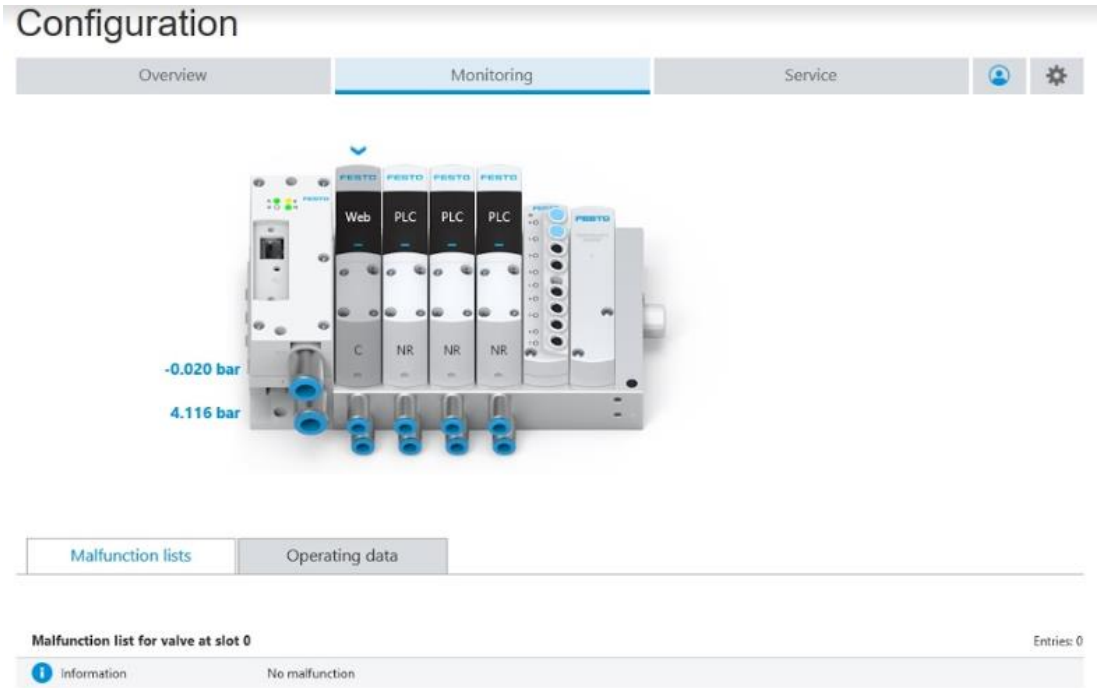


Figure 58: VTEM interface [29]

To change the settings first, login must be done by writing “VTEM”. After the login is completed, now settings of the VTEM can be changed. The module has to be chosen to change the settings. After the module is chosen, proper app has to be chosen. For Task-2, “directional control valve functions” app is chosen. To choose this app “take write permissions from PLC” must be ticked and then assign button can be pressed. From “test mode” section, after pressing “start test run”, extraction and retraction movements can be set by clicking the (2) Pressurised / (4) Exhausted for forward movement and (2) Exhausted / (4) Pressurised for backward movement choices. The project that has been built with VTEM can be seen in Figure 60.

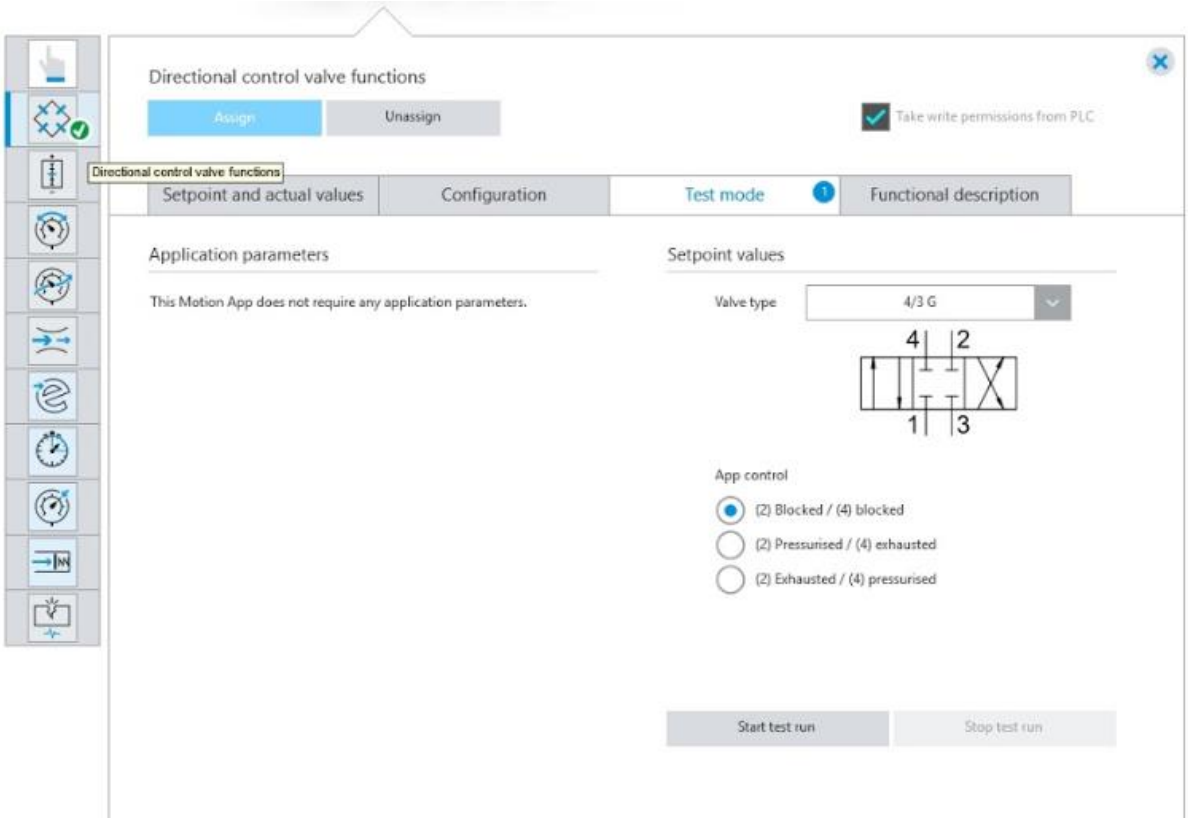


Figure 59: VTEM directional control valve function [29]

4.1. MEASUREMENTS FOR SEMI-ROTARY DRIVE WITH VTEM

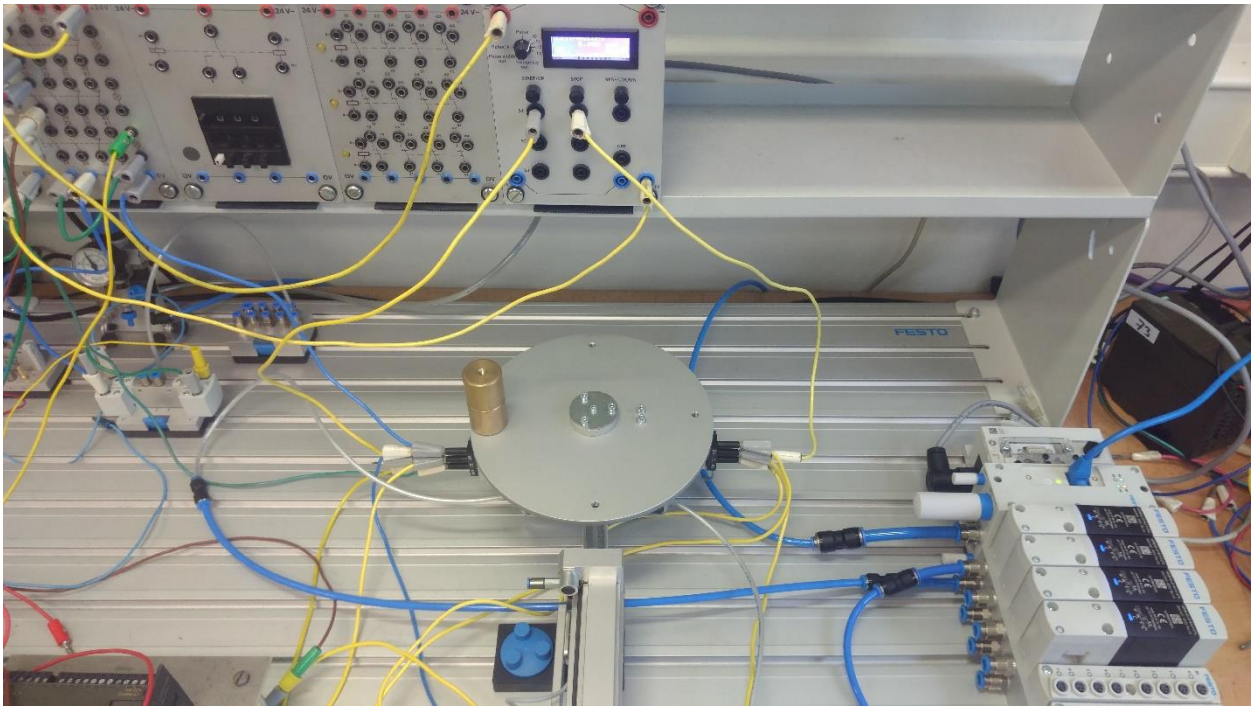


Figure 60: Project with VTEM [25]

Movement of the semi-rotary drive from position 1 to 3 has been measured with using valve terminal with two identical loads while the loads are on the third position, 3-3, while the rotary disc is parallel to the surface with using VTEM. The first number represents the first load's position on the rotary disc, and the second number, after a dash, represents the second load's position on the rotary disc.

NUMBER	POSITION 1 TO 3
1	206 ms
2	208 ms
3	208 ms
4	206 ms
5	206 ms
AVERAGE	206.8 ms

Table 68: Results of movements from position 1 to 3 when both loads are in the 3rd position while the rotary disc is parallel to the surface with using VTEM

NUMBER	POSITION 1 TO 3
1	202 ms
2	200 ms
3	202 ms
4	202 ms
5	202 ms
AVERAGE	201.6 ms

Table 69: Results of movements from 1 to 3 when both loads are in the 3rd position while the rotary disc is parallel to the surface with using normal valve

Table 68, shows that the measurements with using VTEM and Table 69 shows nearly the same measurement values then with using normal valves.

4.2. MEASUREMENTS FOR LINEAR DRIVE WITH VTEM

Movement of the linear drive from position 2 to 1 has been measured using VTEM with the load.

NUMBER	POSITION 2 TO 1
1	181 ms
2	182 ms
3	182 ms
4	182 ms
5	180 ms
AVERAGE	181.4 ms

Table 70: Results of Movements from 2 to 1 with the Load using VTEM

NUMBER	POSITION 2 TO 1
1	178 ms
2	174 ms
3	170 ms
4	170 ms
5	170 ms
AVERAGE	172.4 ms

Table 71: Results of Movements from 2 to 1 with the Load with using normal valve

Table 70, shows that the measurements with using VTEM and Table 71 shows nearly the same measurement values then with using normal valves.

4.3. CONCLUSION

Measurements for semi-rotary drive and linear drive have been done with VTEM and then they have been compared with the measurements that have been done by using normal valves. Only one specific combination of measurement has been chosen to measure it with VTEM for both drives. For semi-rotary drive, when the rotary disc is parallel to the surface and the two identical loads are on the third position has been chosen to measure. After measurements have been done successfully, results can be compared. By looking at the results from Table 68 and Table 69, with the same weights and same position, the time difference is 5.2 ms. The difference is so small, so this shows that the same values can be got by using normal valves and VTEM.

For linear drive, the movement from position 2 to 1 with load has been chosen to measure. By looking at these times from Table 70 and Table 71, with

the same load, the time difference is 9 ms. The difference is so small, so this shows that the same values can be got by using normal valves and VTEM.

5. CONCLUSION

According to the guidelines of the Master thesis, two tasks have been designed with specific sequences to apply the guidelines. The Task-1 is the complex one, and the Task-2 has been created to be a shorter sequence because of the time limitation and because of to apply all steps that have to be done in the real world. In these tasks, specific components have been used. These important components are semi-rotary drive, linear drive and vacuum technology. The first part of the thesis is to do in a software environment Festo FluidSIM® by using virtual PLC in the GRAFCET language and ladder diagram language for both tasks. But to do this, first, another project has been created for the semi-rotary drive and linear drive to understand the working principle of them. The circuit and conclusion for the semi-rotary drive can be seen, respectively, at chapters 2.1. and 2.1.7. The circuit and conclusion for the linear drive can be seen, respectively, at chapters 2.2. and 2.2.3.

After these projects for the semi-rotary drive and the linear drive has been done, both tasks have been done in the software environment Festo FluidSIM®. Both tasks have been built in the real world by using real components. Picture of the Task-1 and the Task-2 that has been built in the real world with valves. The designs can be seen, respectively, in Figure 32 and Figure 45. The Task-2 has also been built with valve terminal. This design can be seen in Figure 46.

Second part of the thesis is to implement the project, Task-2, to the Siemens PLC S7-200 that has been created in Festo FluidSIM software in ladder diagram language by using the Siemens Step-7 Micro/WIN software. The project can be seen in Figure 48.

Third part of the thesis is to create a visualisation project for the Task-2. Total of three visualisation projects have been created according to the type of communications. Actually, there have been used two types of communications. The first one works with scripts and tags, and there is no communication. The first visualisation project has been created to see the sequence of the Task-2. The second one is between Reliance SCADA and PLC, and the third one is between Reliance SCADA and OPC Server.

Forth part of the thesis is to measure times with semi-rotary drive and linear drive using VTEM and compare these times with the times that have been measured with normal valves. Measurements with normal valves have been measured and discussed in chapter 2.1. for the semi-rotary drive and in chapter 2.2. for the linear drive. By looking at the results that have been measured, the same times have been achieved by using VTEM. These results are shown in Table 68 and Table 69 for the semi-rotary drive. For the linear drive, the results are shown in Table 70 and Table 71.

To do the same tasks by using VTEM is simpler. Because there are no pushbuttons are used. The movements are done by interface of the VTEM by using motion apps. If stopwatch will be inside of the VTEM, then there will be no cables outside except for the powering cables.

Times that have been measured with normal valve and VTEM have been measured for helping to improve the next thesis.

Guidelines of the thesis;

1. Prepare the analysis of the application chosen is successfully done. (Chapter 1. and 2.)
2. Design control system in the SW environment FluidSIM® for the virtual PLC in the GRAFCET language is successfully done. (Chapters 2.3.3. and 2.3.7.)
3. Design application of the valve terminals for the special pneumatic motors control is successfully done. (Chapters 2.4.1. and 2.4.2.)
4. Design implementation of the part of the control algorithm for the PLC SIMATIC S7-200 is successfully done. (Chapter 2.4.3.)
5. Design visualisation of the part of the system in the SCADA system Reliance is successfully done in three ways (Chapter 3.)
6. Debug the system in real time has been tried for Task-1 but can not be completed because of the insufficient components, but for Task-2 is successfully done. (Chapters 2.3.2. and 2.4.)
7. Compare solutions designed with respect to the control methods used and the valve terminals used is successfully done. (Chapter 4.)

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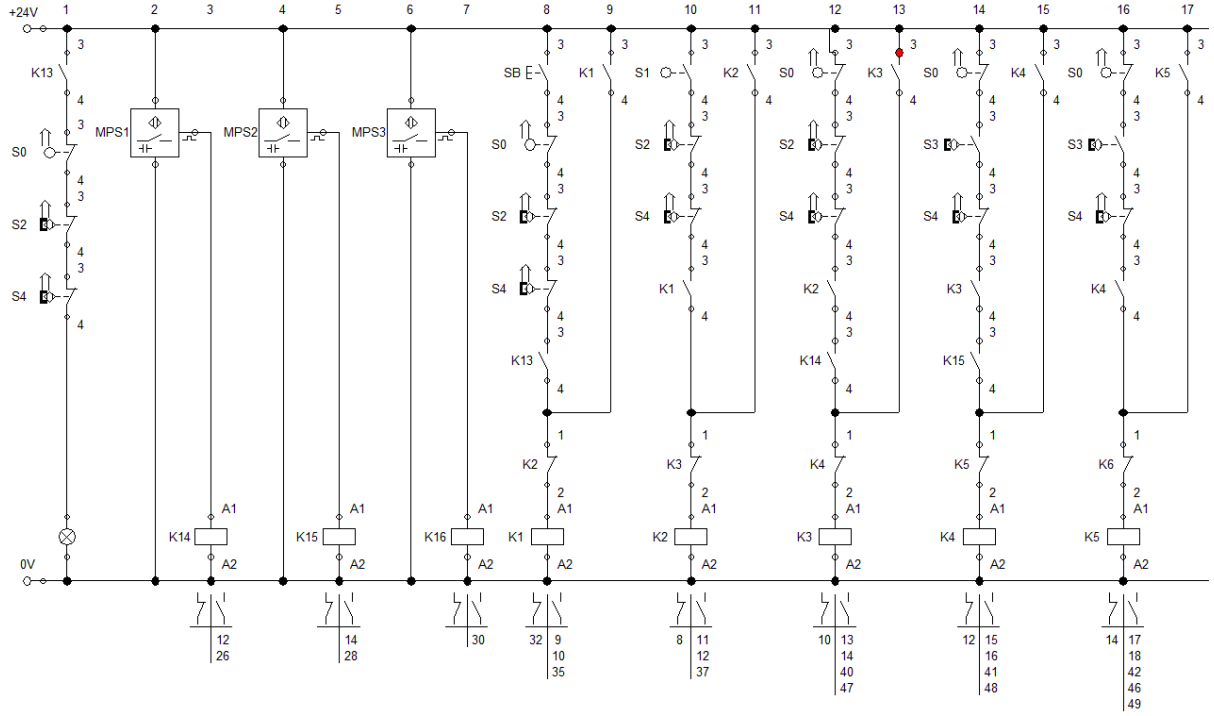
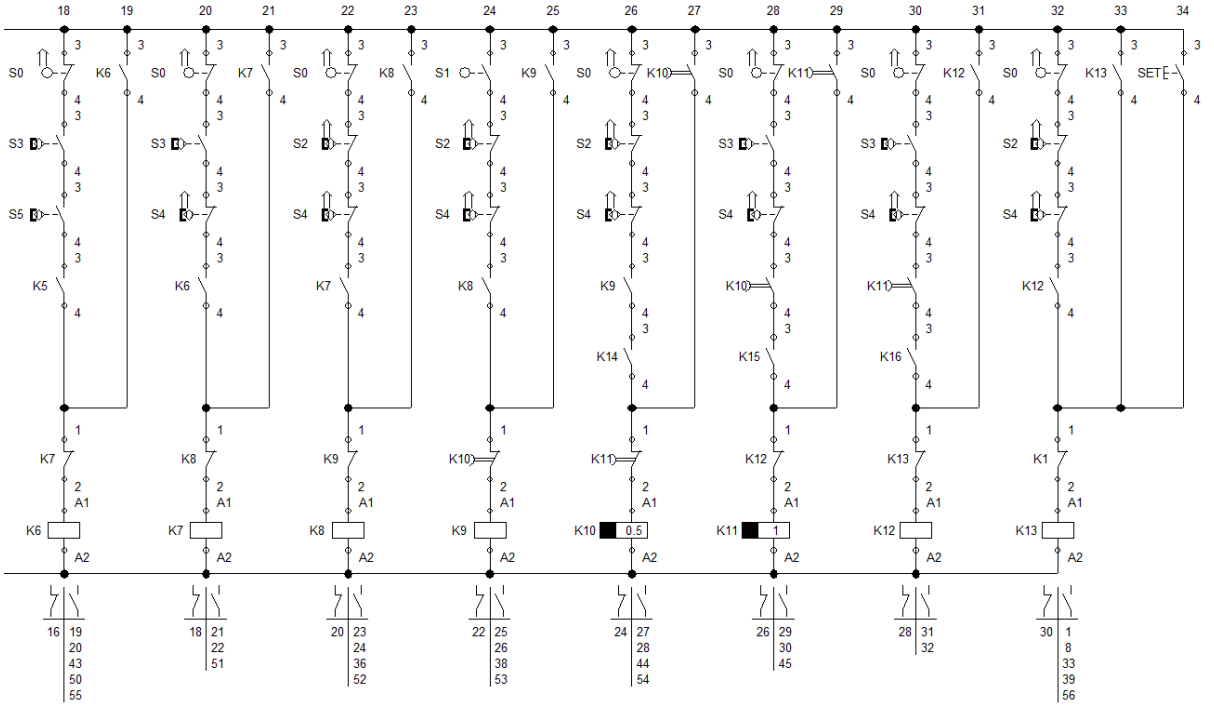
[29] Photo from the interface of the VTEM.

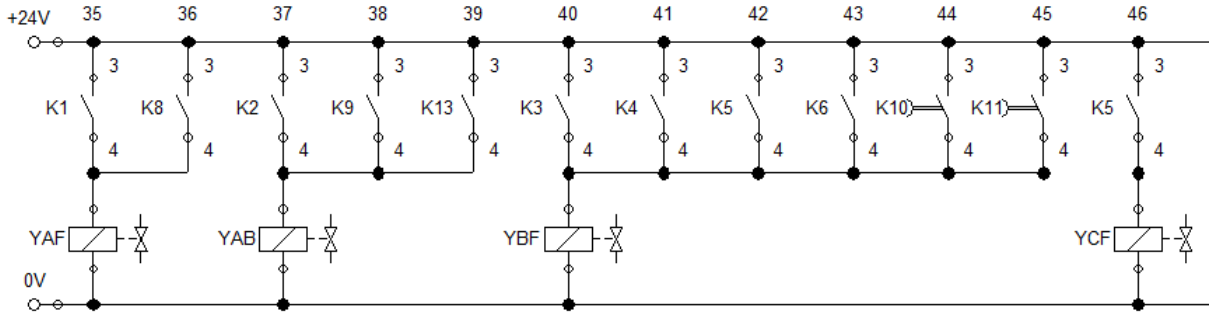
7. APPENDIX – A

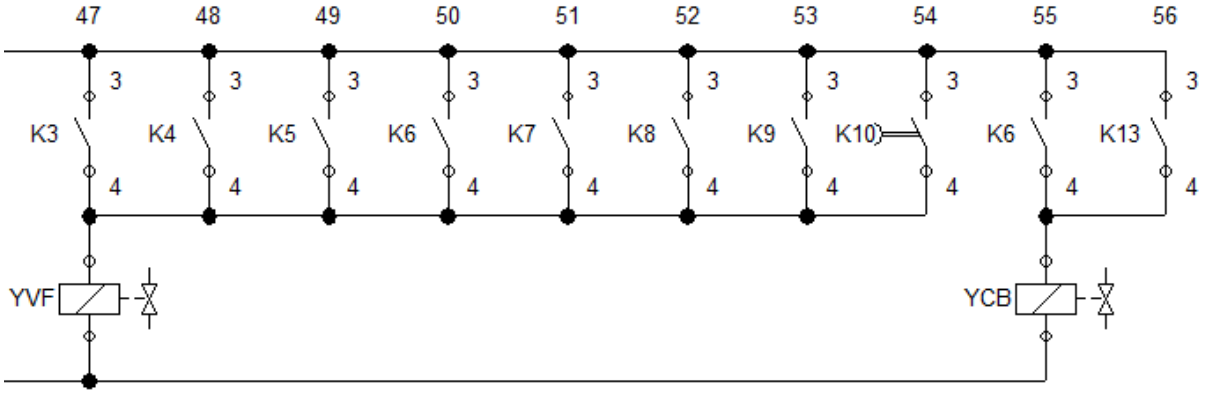
7.1. NORMAL RELAY CIRCUIT OF TASK-1 IN FLUIDSIM



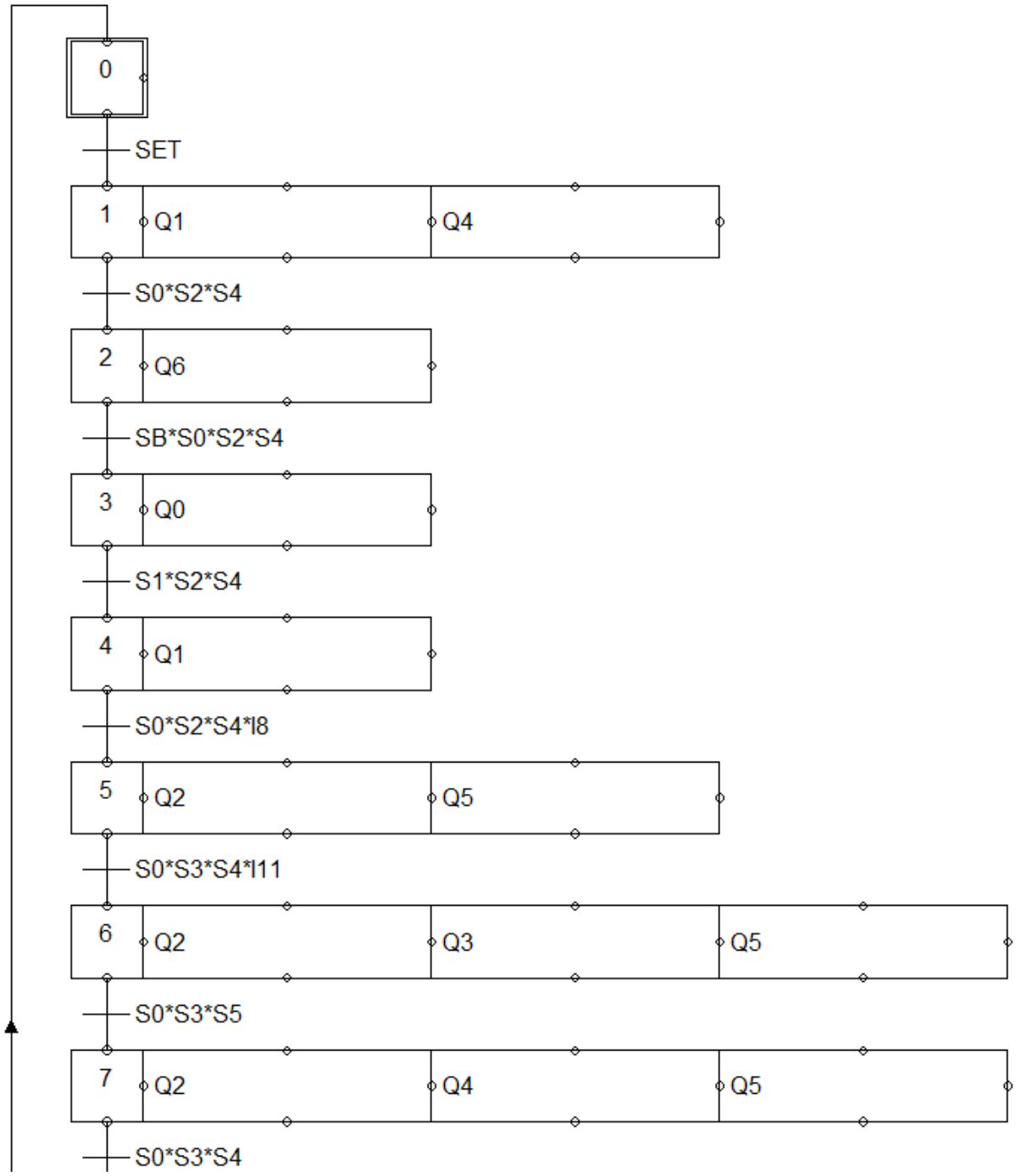


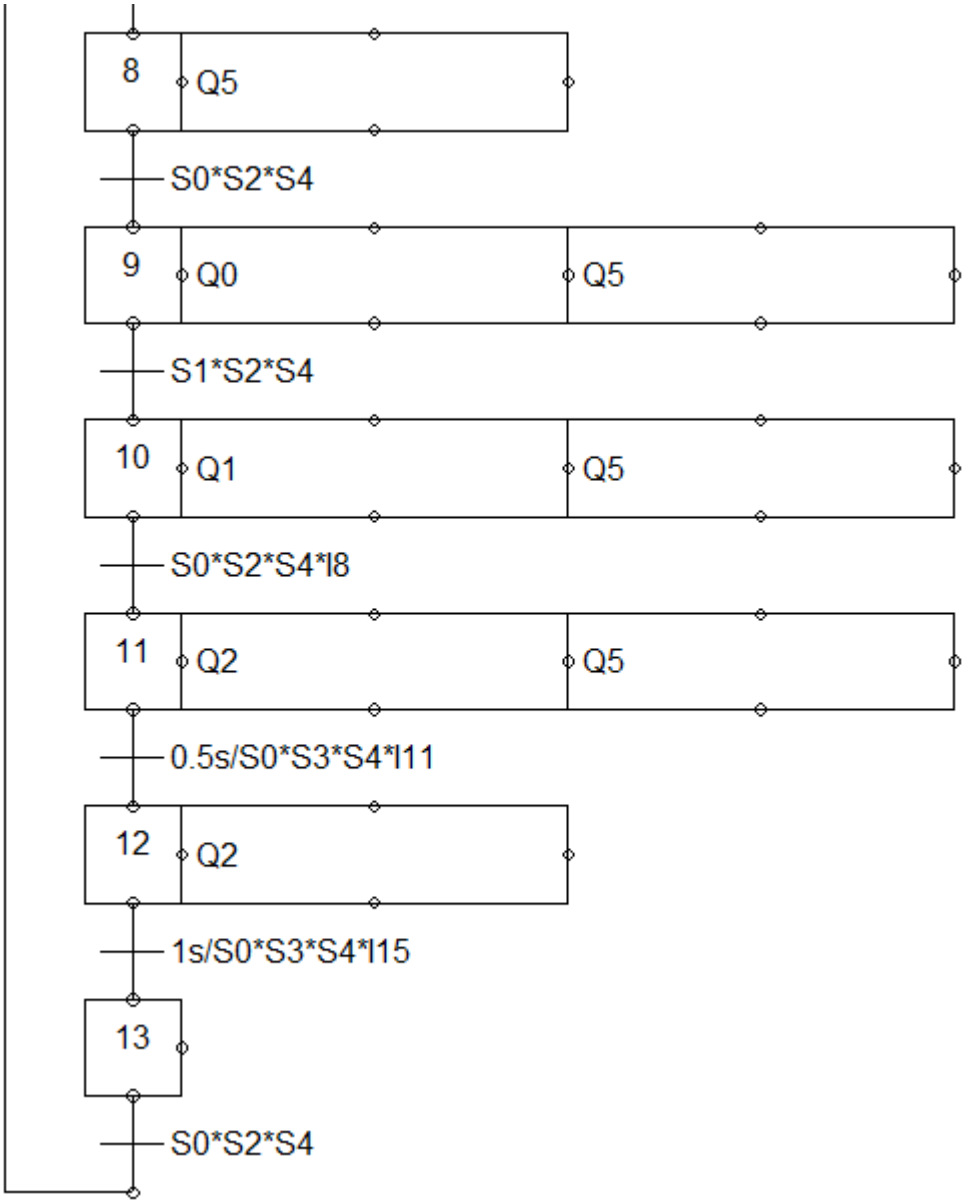
7.2. OUTPUT PART OF NORMAL RELAY CIRCUIT OF TASK-1 IN FLUIDSIM



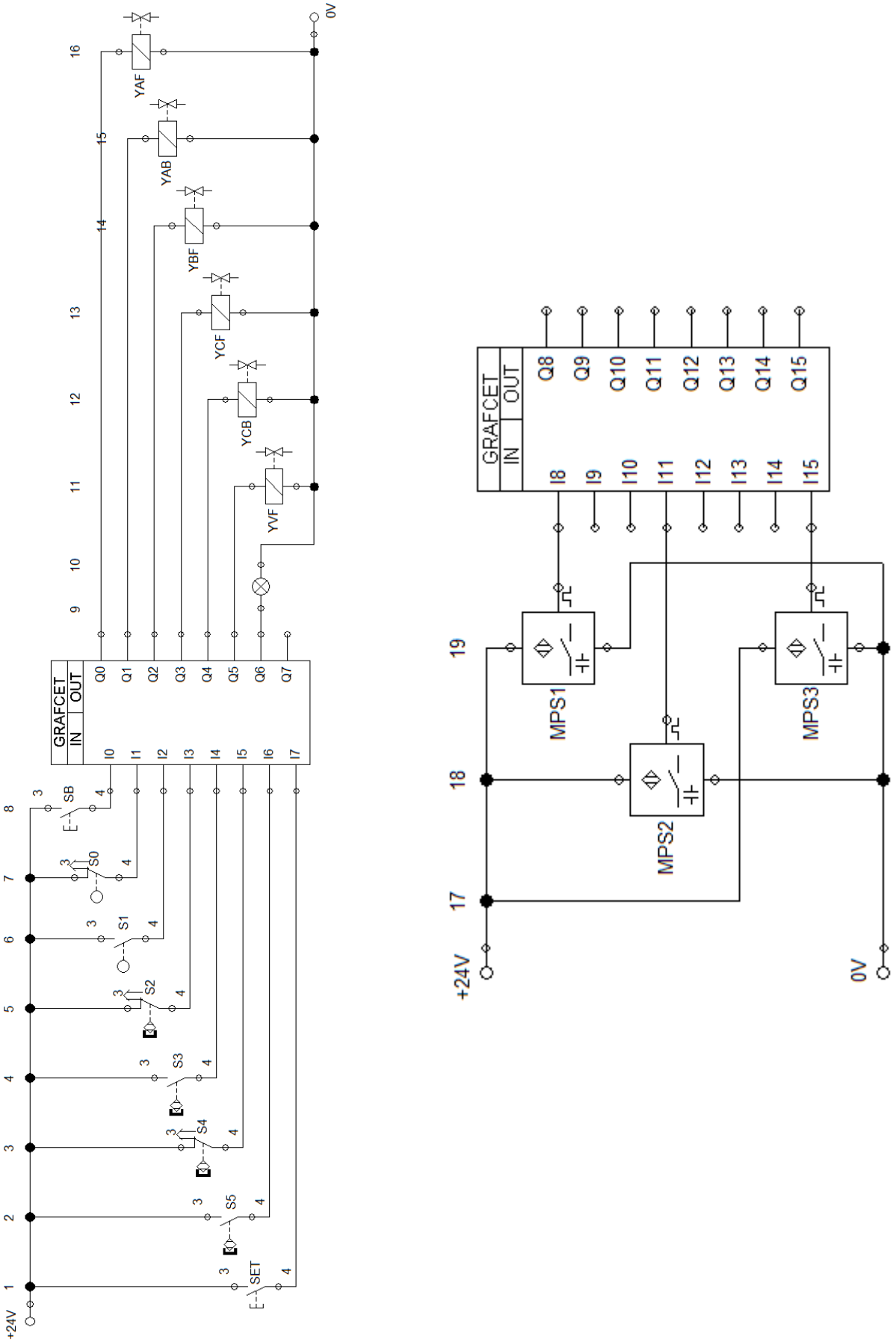


7.3. VIRTUAL PLC, SOFTWARE PART, OF TASK-1

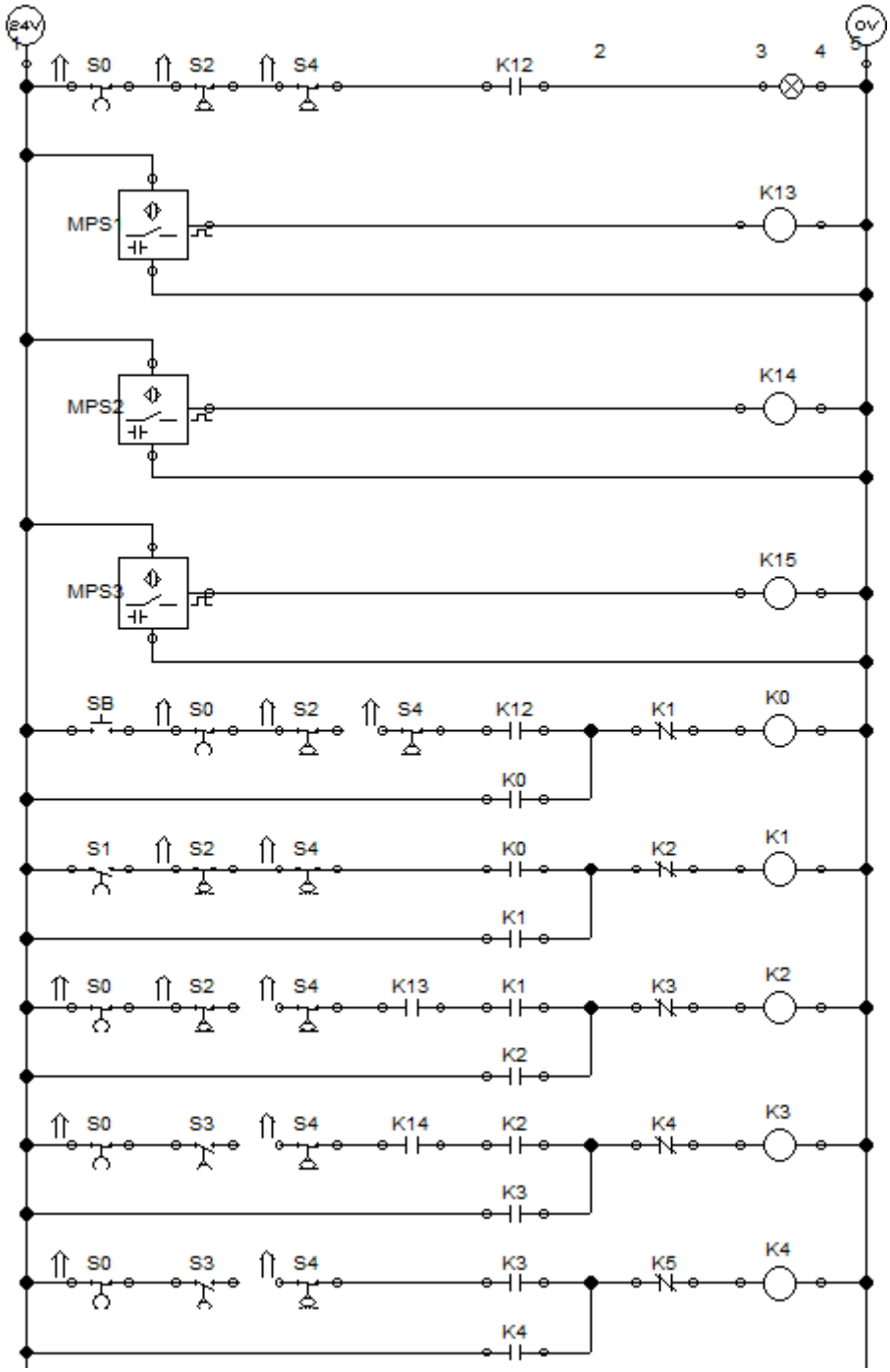


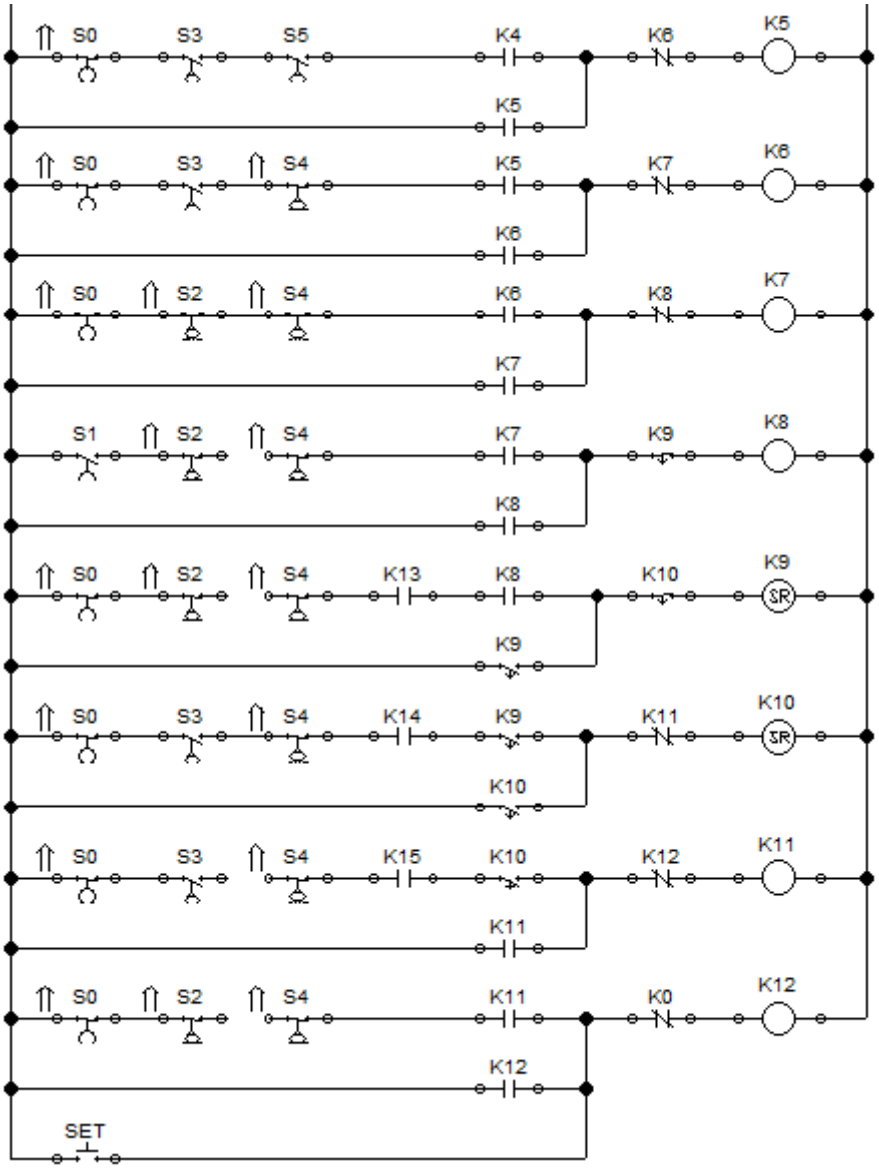

8
Q5
S0*S2*S4
9
Q0
Q5
S1*S2*S4
10
Q1
Q5
S0*S2*S4*I8
11
Q2
Q5
0.5s/S0*S3*S4*I11
12
Q2
1s/S0*S3*S4*I15
13
S0*S2*S4

7.4. VIRTUAL PLC OF HARDWARE PART OF TASK-1

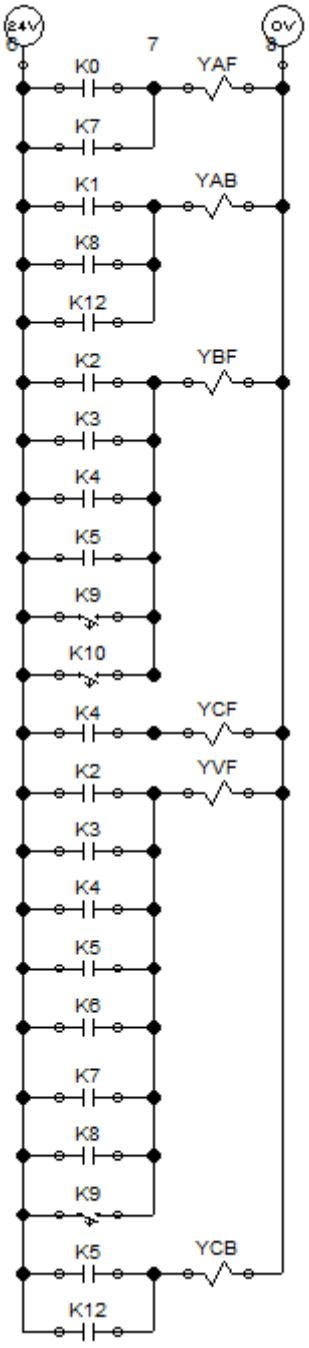


7.5. CONTROL PART, LADDER DIAGRAM, OF TASK-1



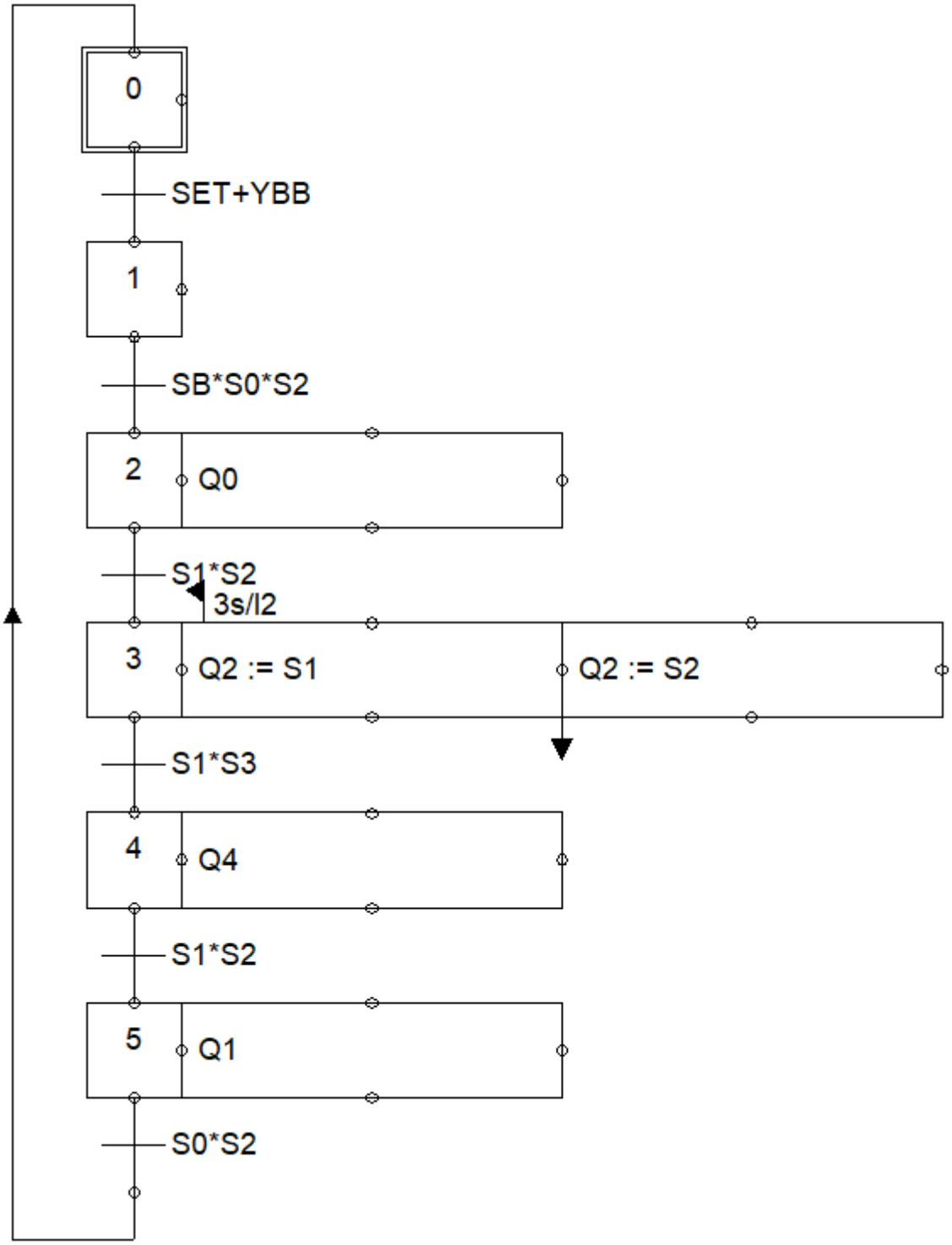

S0
S3
S5
K4
K6
K5
K5
S0
S3
S4
K5
K7
K6
K6
S0
S2
S4
K6
K8
K7
K7
S1
S2
S4
K7
K9
K8
K8
S0
S2
S4
K13
K8
K10
SR
K9
K9
S0
S3
S4
K14
K9
K11
SR
K10
K10
S0
S3
S4
K15
K10
K12
K11
K11
S0
S2
S4
K11
K0
K12
K12
SET

7.6. OUTPUT PART OF CONTROL PART OF TASK-1

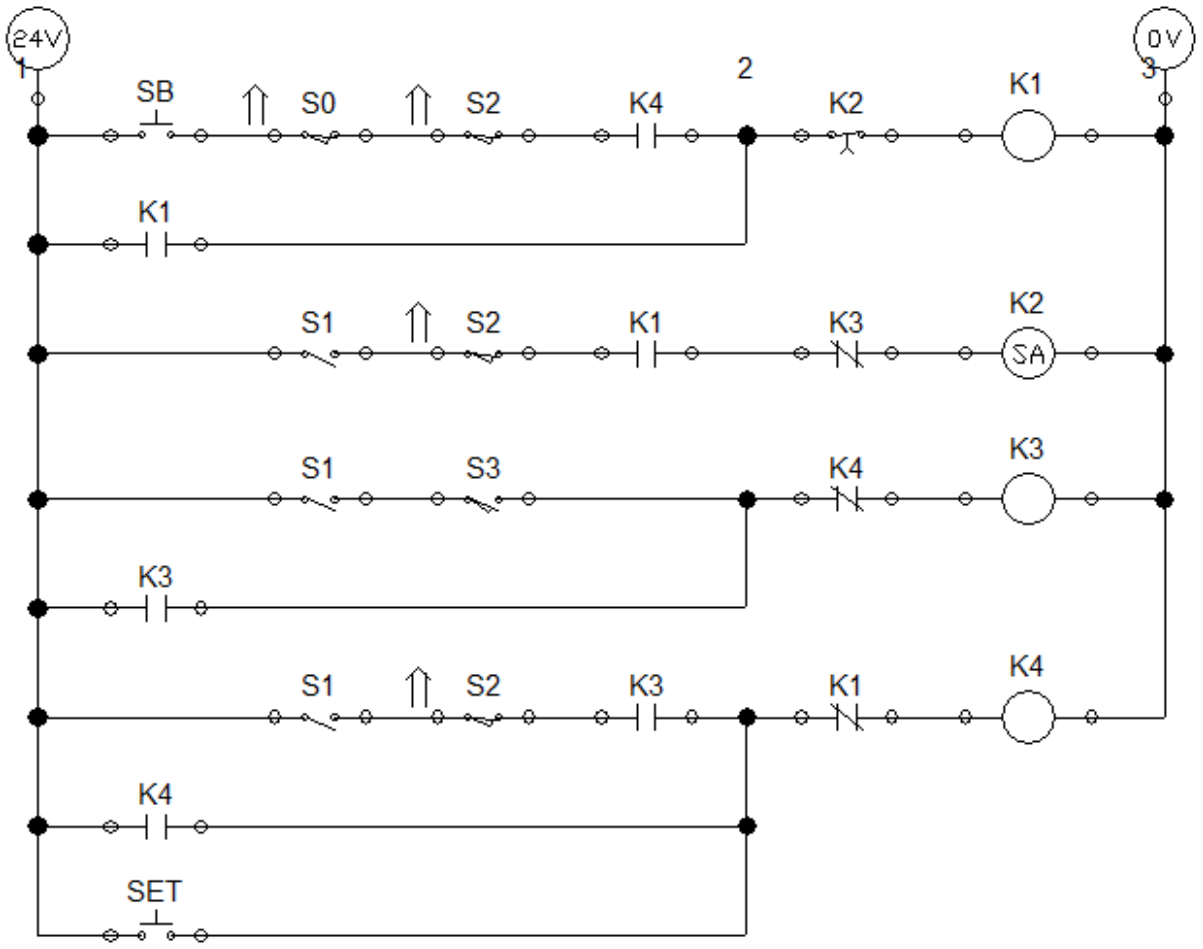


8. APPENDIX – B

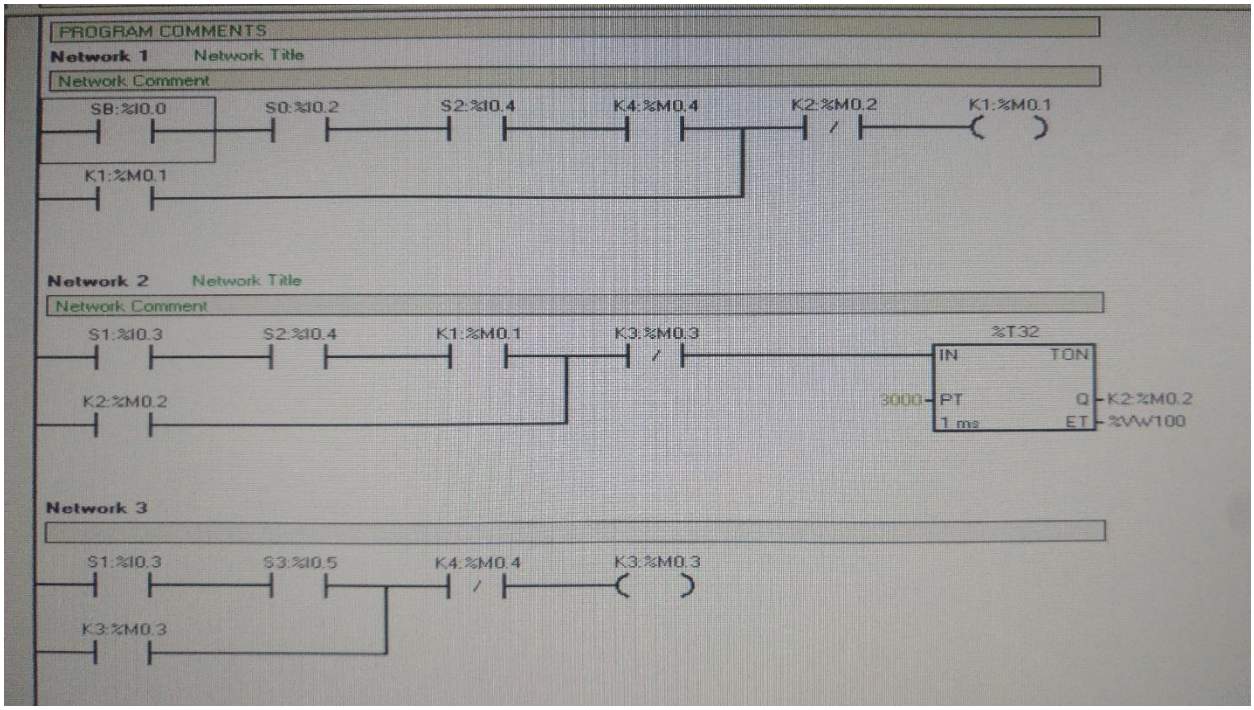
8.1. SOFTWARE PART OF TASK-2

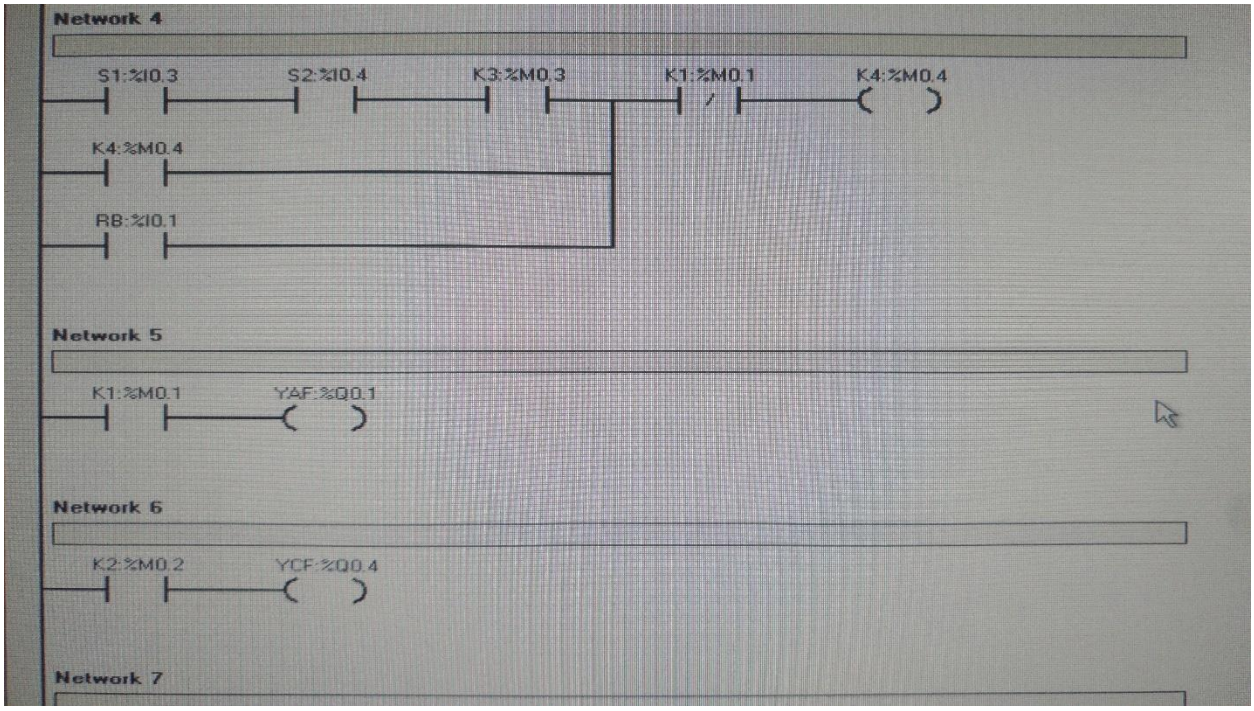


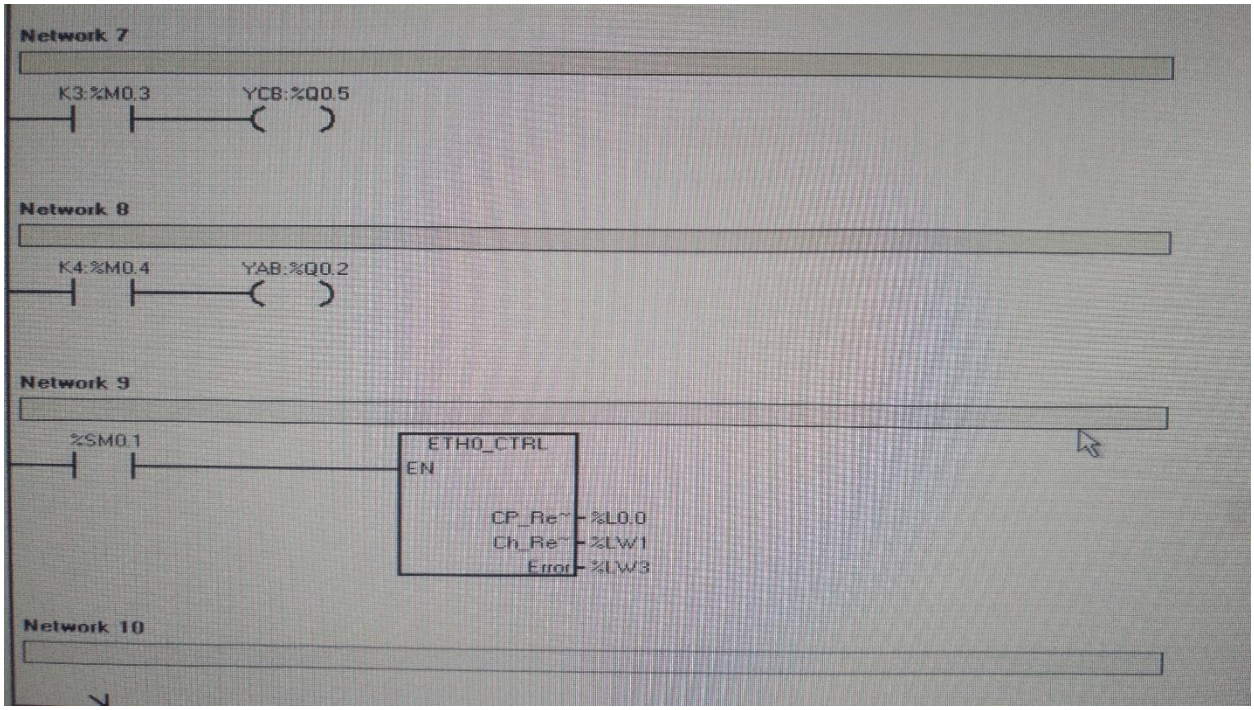
8.2. LADDER DIAGRAM OF TASK-2



8.3. STEP-7 MICRO/WIN PROGRAM IN LD LANGUAGE FOR TASK-2







9. APPENDIX – C, SCRIPT PART FOR SIMULATED VISUALISATION OF TASK-2

Option Explicit

dim LM, LMS0, LMS0L, LMS1, LMS1L, PMX, PMY, PMS, RB, RM, RMS0, RMS0L, RMS1, RMS1L, SB, SBS

LM = RTag.GetTagValue("Virtual1", "LM")

LMS0 = RTag.GetTagValue("Virtual1", "LMS0")

LMS0L = RTag.GetTagValue("Virtual1", "LMS0L")

LMS1 = RTag.GetTagValue("Virtual1", "LMS1")

LMS1L = RTag.GetTagValue("Virtual1", "LMS1L")

PMX = RTag.GetTagValue("Virtual1", "PMX")

PMY = RTag.GetTagValue("Virtual1", "PMY")

PMS = RTag.GetTagValue("Virtual1", "PMS")

```
RB = RTag.GetTagValue("Virtual1", "RB")
RM = RTag.GetTagValue("Virtual1", "RM")
RMS0 = RTag.GetTagValue("Virtual1", "RMS0")
RMS0L = RTag.GetTagValue("Virtual1", "RMS0L")
RMS1 = RTag.GetTagValue("Virtual1", "RMS1")
RMS1L = RTag.GetTagValue("Virtual1", "RMS1L")
SB = RTag.GetTagValue("Virtual1", "SB")
SBS = RTag.GetTagValue("Virtual1", "SBS")

If LM <= 0 and RM <= 0 and PMX <= 0 and PMY <= 0 then
  SBS = true
  Else
  SBS = false
End if

If SBS = true then
  LMS0L = true
  LMS1L = false
  RMS0L = true
  RMS1L = false
End if

If SB = true then
  LMS0 = false
  LMS1 = false
  RMS0 = true
```

```
  RMS1 = false
  PMX = 0
  PMY = 0
End if

If RB = true then
  LMS0 = false
  LMS1 = false
  RMS0 = false
  RMS1 = false
  SB = false
  SBS = false
  LM = 0
  PMX = 0
  PMY = 0
  RM = 0
End if

If RM = 5 and LM = 0 and RMS0 = true then
  LMS0L = true
  LMS1L = false
  RMS0L = false
  RMS1L = false
End if

If RM = 90 and LM = 0 and RMS0 = true then
```

```
  LMS0 = false
  LMS1 = false
  RMS0 = true
  RMS1 = false
  PMX = -27
  PMY = 26
  LMS0L = true
  LMS1L = false
  RMS0L = false
  RMS1L = false
End if

If RM = 180 and LM = 0 and RMS0 = true then
  LMS0 = true
  LMS1 = false
  RMS0 = false
  RMS1 = false
  PMX = -54
  PMY = 0
  LMS0L = true
  LMS1L = false
  RMS0L = false
  RMS1L = true
End if

If RM = 180 and LM = 5 and LMS0 = true then
```

```
  LMS0L = false
  LMS1L = false
  RMS0L = false
  RMS1L = true
End if

If RM = 180 and LM = 148 and LMS0 = true then
  LMS0 = false
  LMS1 = true
  RMS0 = false
  RMS1 = false
  LMS0L = false
  LMS1L = true
  RMS0L = false
  RMS1L = true
End if

If RM = 180 and LM = 143 and LMS1 = true then
  LMS0L = false
  LMS1L = false
  RMS0L = false
  RMS1L = true
End if

If RM = 180 and LM = 0 and LMS1 = true then
  LMS0 = false
```

```
  LMS1 = false
  RMS0 = false
  RMS1 = true
  LMS0L = true
  LMS1L = false
  RMS0L = false
  RMS1L = true
End if

If RM = 175 and LM = 0 and RMS1 = true then
  LMS0L = true
  LMS1L = false
  RMS0L = false
  RMS1L = false
End if

If RM = 90 and LM = 0 and RMS1 = true then
  LMS0 = false
  LMS1 = false
  RMS0 = false
  RMS1 = true
  PMX = -27
  PMY = 26
End if

If RM = 0 and LM = 0 and RMS1 = true then
```

```
  LMS0 = false
  LMS1 = false
  RMS0 = false
  RMS1 = false
  PMX = 0
  PMY = 0
  LMS0L = true
  LMS1L = false
  RMS0L = true
  RMS1L = false
End if

If RMS0 = true then
  RM = RM + 1
End if

If LMS0 = true then
  LM = LM + 1
End if

If RMS1 = true then
  RM = RM - 1
End if

If LMS1 = true then
  LM = LM - 1
```

```
End if


RTag.SetTagValue "Virtual1", "LM", LM
RTag.SetTagValue "Virtual1", "LMS0", LMS0
RTag.SetTagValue "Virtual1", "LMS0L", LMS0L
RTag.SetTagValue "Virtual1", "LMS1", LMS1
RTag.SetTagValue "Virtual1", "LMS1L", LMS1L
RTag.SetTagValue "Virtual1", "PMX", PMX
RTag.SetTagValue "Virtual1", "PMY", PMY
RTag.SetTagValue "Virtual1", "PMS", PMS
RTag.SetTagValue "Virtual1", "RB", RB
RTag.SetTagValue "Virtual1", "RM", RM
RTag.SetTagValue "Virtual1", "RMS0", RMS0
RTag.SetTagValue "Virtual1", "RMS0L", RMS0L
RTag.SetTagValue "Virtual1", "RMS1", RMS1
RTag.SetTagValue "Virtual1", "RMS1L", RMS1L
RTag.SetTagValue "Virtual1", "SB", SB
RTag.SetTagValue "Virtual1", "SBS", SBS
```