

CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of Mechanical Engineering

MASTERS THESIS

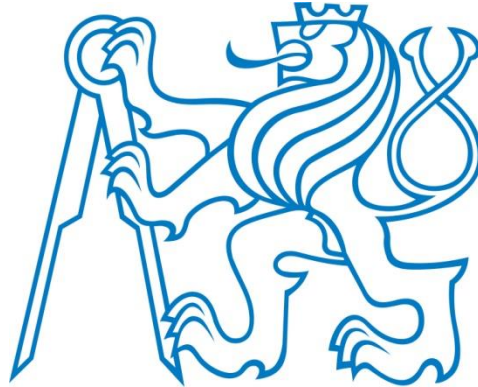
2017

Surya Rengarajan

CZECH TECHNICAL UNIVERSITY IN PRAGUE

FACULTY OF MECHANICAL ENGINEERING

Department of Instrumentation and Control Engineering



MASTERS THESIS

Control and Visualization of the experiments in the Vacuum technology

Surya Rengarajan

2017

Supervisor: Ing. Marie Martinaskova, Ph.D.

Declaration 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 potential publication of the results of the thesis or of its substantial part, provided I will be listed as the co-author.

In Prague,

..... Signature



MASTER THESIS ASSIGNMENT

I. PERSONAL AND STUDY INFORMATION

Surname:	Rengarajan	First name:	Surya	Personal no.:	453194
Faculty:	Faculty of Mechanical Engineering Department of Instrumentation and Control Engineering				
Study program:	Mechanical Engineering				
Study field:	Instrumentation and Control Engineering				

II. MASTER THESIS SPECIFICATION

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3. Design visualization of the particular experiments in the SCADA system
4. Evaluate data from the measurements

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Name and affiliation of the thesis supervisor:

Ing. Marie Martinásková Ph.D., Dpt. of Instrumentation and Control Engineering, FME

Consultant:

-

Assignment issue date: **19th April 2017** Thesis due date: **16th June 2017**


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Thesis Supervisor Head of the Department Dean of the Faculty

III. THESIS ASSIGNMENT RECEIVED

The student is aware that the thesis has to be accomplished through an independent and unassisted student's work, supported only by recognized consultations. Literature and other information resources as well as consultants' names have to be acknowledged in the thesis.

19/04/2017
Date


Student

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2017

ABSTRACT

This master thesis deals with the Vacuum Technology used in industrial handling technology to analyze and measure the data by performing experiments on vacuum technology with Festo equipment kit (TP 230). The main aim of this thesis is to perform experiments to understand the principle of vacuum in handling technology, designing control by PLC SIMATIC S7 -200 for reducing the compressed air consumption and for controlled release of work pieces retained by a vacuum air. And to design visualization for the both process in the SACDA software.

This involves communication between the field level elements and upper levels of automation. The automation process is monitored by the Reliance 4 Design software. Evaluation of the data from the PLC is processed in Reliance 4 Design software.

Scope of thesis work

- Study and understand the concept of Vacuum Technology.
- Perform experiments with the kit TP-230 and design solutions of basic electro-pneumatic circuit using FluidSIM® V 5.0 software.
- Design control by PLC using STEP 7-Micro/WIN software for the PLC SIMATIC S7 -200 for the two experiments.
- Design visualization of the two experiments using SCADA Reliance 4 software.
- Evaluate the measurements and results.

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CHAPTER 1 INTRODUCTION

1.1 Vacuum Technology

Vacuum technology is used in enormous field in industries around the world. Even the tungsten filament needs vacuum to operate. Vacuum is environment friendly and it can be used as major source for all the chemical, food industries and medical industries.

Vacuum handling applications are used in a wide range of industries. The increase in growth of industrial automation, vacuum plays a key role in transportation work pieces from one place to another. The vacuum is used to lift all kinds of materials ranging from few grams to even tons in weight.

Though vacuum technology has enormous applications this project concerns about the handling technology used in industries. The vacuum lifting is useful in following fields:

1. Plastic Manufacturing
2. Packaging
3. Transportation
4. Medical Fields
5. Electronics
6. Metal Manufacturing
7. Glass Manufacturing
8. Automotive and Aero space engineering.



Figure 1: Vacuum handling technology^[11]

1.2 Basic terminology

1.21 Pressure

According to ISO 80000, pressure p is defined as the quotient of normal force on a surface and the area of that surface (surface-related force). The official unit of measure for pressure is the Pascal (Pa)^[11]

$$P = \frac{F_N}{A}$$

$$1Pa = \frac{N}{m^2}$$



1.22 Vacuum

Definition according to ISO 3529, part 1:

“Vacuum is the state of a gas with a density of molecules that is less than that of the atmosphere at the surface of the earth. The state of a gas can be designated a vacuum if its pressure is less than atmospheric pressure.”^[11]

1.23 Ideal vacuum

Ideal vacuum in the sense of vacuum technology is the condition within a given space, within which a gas's number density of molecules is equal to zero. This state was previously designated “absolute vacuum”.^[11]

1.24 Units of vacuum in handling technology

The unit of measure usually used in vacuum technology is millibar (mbar). However, the Pascal (Pa) is used in scientific circles. In handling technology, in which low vacuum predominates, the unit of measure bar is used with a preceding minus sign for the degree of partial vacuum achieved, or it's expressed as % vacuum (where 0% vacuum is defined as ambient atmospheric pressure). Vacuum range for handling technology is low vacuum ranging from $10^5 - 10^2$ p (Pa).

1.3 Programmable logic controller

1.3.1 Motivation

PLC's or programmable logic controllers are one of the most widely used industrial control systems applied today to enhance the functionality of a production line or machine functions. Their flexibility in controlling a wide range of inputs and outputs and changing their operation based on requirements have made them a favorite control system in recent times.^[4]



The typical PLC system is like any other computer system that consists of various hardware components such as the CPU, Input/Outputs (I/O) and power supply. The CPU system is microprocessor based that allows all arithmetic operations as well as logic operations, blocks memory moves, handles the computer interface etc. Typical systems have 4 buses: a data bus to share information between different elements, address bus for the respective addresses, control bus for internal actions that need to be monitored and lastly a system bus which allows the communication between the various ports and Input/output unit. Inputs are usually sensors or switches are used for controlling outputs such as motors and valves etc.

Thus, like other computerized devices, the PLC unit has a memory storage as well as power supply thus making it a very small integrated unit that can be used in various industries for a wide variety of applications.

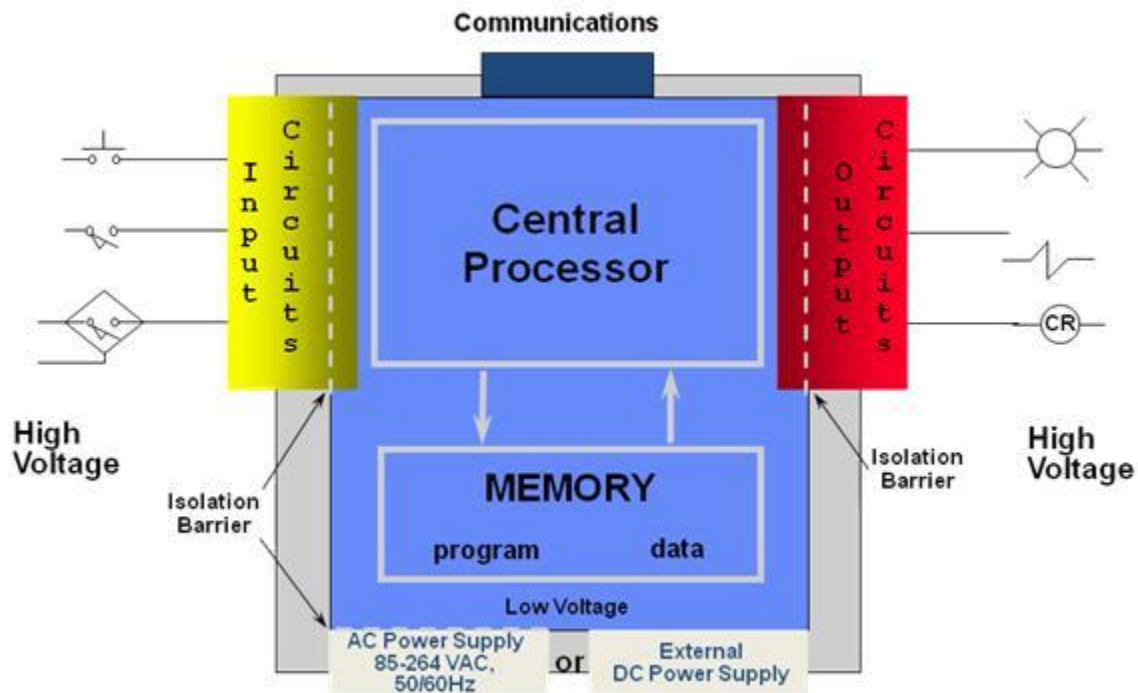


Figure 2: Typical PLC system interface between inputs and outputs ^[4]



The criteria for selection of an appropriate PLC varies from system requirements and application requirements to physical environments. For any application, it is extremely crucial to determine that the PLC can handle the application in the appropriate way. After the goals of the application are determined, the inputs and outputs need to be identified that are required by the system. Once these factors are considered, the electrical requirements come into play and the input power, device voltage and currents need to be calculated. This is followed by the communication protocol that will be used by the PLC which can be of several types. In an automation and control systems, theoretical information along with constraints and specifications play a key role in solving diverse types of control problems. It is critical that none of these factors are ignored and the most efficient process is developed.

1.3.5 S7-200 Operation & Execution

In this thesis work, SIMATIC S7-200 PLC is chosen to automate the process.

The basic operation of the S7-200 is very simple as shown in figure 3

- The S7-200 reads the status of the inputs.
- The program that is stored in the S7-200 uses these inputs to evaluate the control logic. As the program runs, the S7-200 updates the data.
- The S7-200 writes the data to the outputs.

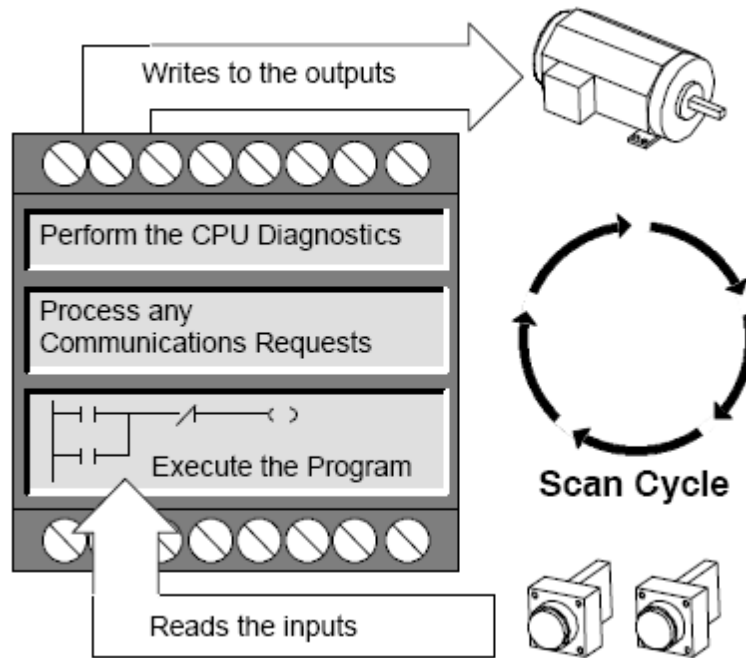


Figure 3 : Scan Cycle ^[4]

The S7-200 executes a series of tasks repetitively. This cyclical execution of tasks is called the scan cycle. As shown in Figure 3, the S7-200 performs most or all the following tasks during a scan cycle.

1.3.6 Reading the inputs

The S7-200 copies the state of the physical inputs to the process image input register. If the inputs are digital inputs, each scan cycle begins by reading the current value of the digital inputs and then writing these values to the process-image input register. If analog, the S7-200 does not update analog inputs from expansion modules as part of the normal scan cycle unless filtering of analog inputs is enabled. An analog filter is provided to have a more stable signal. You can enable the analog filter for each analog input point. When analog input filtering is enabled for an analog input, the S7-200 updates that analog input once per scan cycle,



performs the filtering function, and stores the filtered value internally. The filtered value is then supplied each time user program accesses the analog input. When analog filtering is not enabled, the S7-200 reads the value of the analog input from expansion modules each time user program accesses the analog input.

Executing the control logic in the program: The S7-200 executes the instructions of the program and stores the values in the various memory areas.

During the execution phase of the scan cycle, the S7-200 executes program, starting with the first instruction and proceeding to the end instruction. The immediate I/O instructions give user immediate access to inputs and outputs during the execution of either the program or an interrupt routine. ^[4]

1.3.7 Processing any communications requests

The S7-200 performs any tasks required for communications. During the message-processing phase of the scan cycle, the S7-200 processes any messages that were received from the communications port or intelligent I/O modules. ^[4]

1.3.8 Executing the CPU self-test diagnostics

The S7-200 ensures that the firmware, the program memory, and any expansion modules are working properly. During this phase of the scan cycle, the S7-200 checks for proper operation of the CPU and for the status of any expansion modules.

1.3.9 Writing to the outputs

The values stored in the process-image output register are written to the physical outputs. At the end of every scan cycle, the S7-200 writes the values stored in the process-image output register to the digital outputs. (Analog outputs are updated immediately, independently from the scan cycles). ^[4]



The execution of the user program is dependent upon whether the S7-200 is in STOP mode or in RUN mode. In RUN mode, user program is executed; in STOP mode, user program is not executed. ^[4]

1.3.10 Operating mode

The S7-200 has two modes of operation:

1. STOP mode and
2. RUN mode.

The status LED's on the front of the CPU indicates the current mode of operation. In STOP mode, the S7-200 is not executing the program, and user can download a program or the CPU configuration from PC. In RUN mode, the S7-200 is running the user program.

1.4 Supervisory Control and Data Acquisition (SCADA)

Using powerful technologies, based on experience of qualified personal, SCADA (Supervisory Control and Data Acquisition) applications are created as a main tool for performing management, required by technical reengineering of an industrial company. In modern manufacturing and industrial processes, mining industries, public and private utilities and security industries, control systems are often needed to connect equipment and systems which are separated by large distances. These systems are used to send commands, programs and receives monitoring information from these remote locations. SCADA refers to the combination of control systems and data acquisition.

Supervisory control and data acquisition (SCADA) is a system of software and hardware elements that allows industrial organizations to:

- Control industrial processes locally or at remote locations
- Monitor, gather and process real-time data



- Directly interact with devices such as sensors, valves, pumps, motors, and more through human-machine interface (HMI) software
- Record events into a log file

SCADA systems are essential for industrial organizations since they help to maintain efficiency, process data for all smarter decisions, and communicate system issues to helping in finding errors. ^[6]

1.4.1 Basic architecture of SCADA

The basic SCADA architecture begins with programmable logic controllers (PLCs) or remote terminal units (RTUs). PLCs and RTUs are microcomputers that communicate with an array of objects such as factory machines, HMIs, sensors, and end devices, and then send the information from those objects to computers with SCADA software. The SCADA software processes, distributes, and displays the data, helping operators and other employees analyze the data and make important decisions. ^[6]

SCADA will have the communication between the PLC and the RTUs. For example, consider a beer manufacturing company, all the process is automatic and supervised by SCADA system, the SCADA will give the overview of the entire industry through visual windows and it can transfer information between the PLC's and RTU's.

If some of the batch in industry is continuously showing error values in the SCADA system, the operator can pause the operation and view the SCADA system data via an HMI to determine the cause of the issue. The operator reviews the data and discovers the error in the industry. The SCADA system's ability to notify the operator of an issue helps him to resolve it and prevent further loss of product.



The SCADA can generally viewed in two ways:

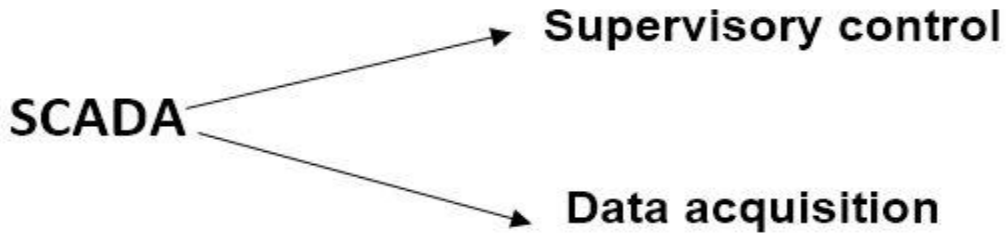


Figure 4: SCADA

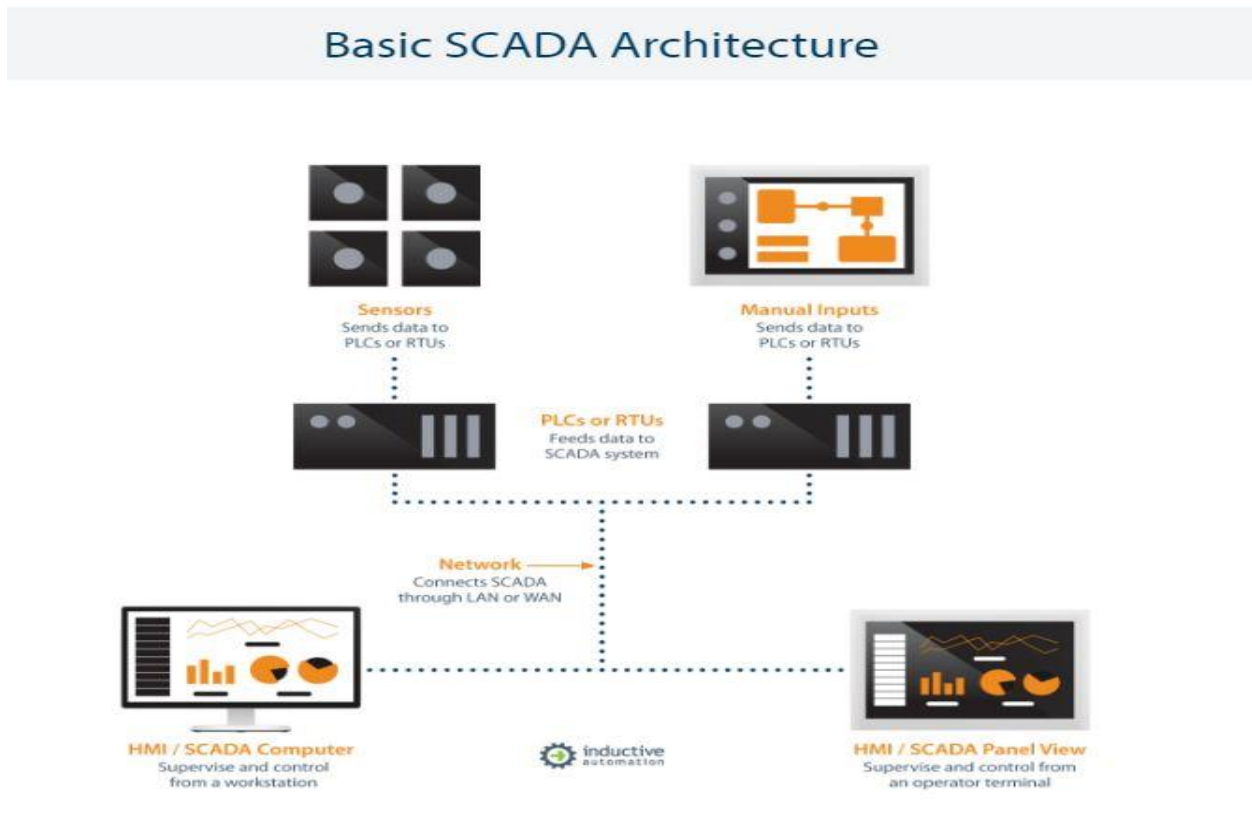


Figure 5: Basic architecture of SCADA [5]



1.4.2 Applications of SCADA

SCADA systems are used by industrial organizations and companies in the public and private sectors to control and maintain efficiency, distribute data for smarter decisions, and communicate system issues. SCADA systems are the backbone of many modern industries, including:

- Energy
- Food and beverage
- Manufacturing
- Power
- Recycling
- Transportation
- And many more

1.5 Communication in control systems

There are lot ways to communicate between the devices within a network in an industry. The communication used for transferring the data from PLC to SCADA is OPC sever.

1.5.1 OPC server

OPC is a published industrial standard for system inter-connectivity. Its purpose is to provide a standards-based infrastructure for the exchange of process control data. It uses Microsoft 's COM and DCOM technology to enable applications to exchange data on one or more computers using a client/server architecture

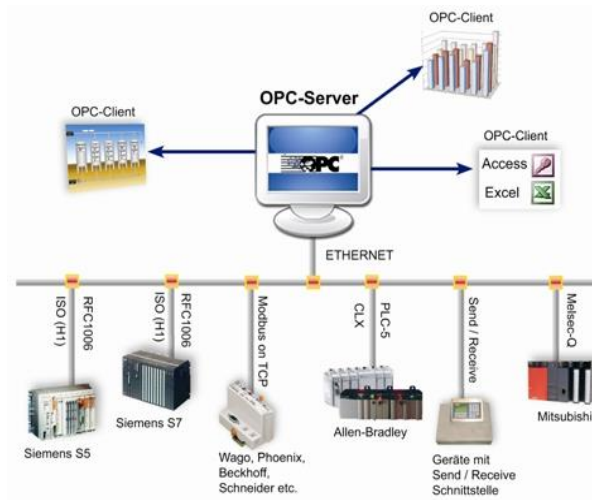


Figure 6: OPC Server [2]

The OPC server is a software program specifically for windows operating system and performs communication between the PLC and the SCADA software or HMI. The OPC program 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. [6]

OPC means OLE for Process Control, OLE is a technology that serves for linking (embedding) of the objects into some applications and their modifying (e.g. inserting of the trend from MS Excel to MS Word with the possibility to modify it with the help of the Excel tools). [6]



CHAPTER 2 COMPONENT DESCRIPTION

There are lot of components used in handling technology in industries, in this thesis the following table contains the components that have been used to achieve the required solution.

Table 1: Components of handling technology for Task 5 and Task 6 from the TP-230 set

Serial number	Name of the component
1	Vacuum generator
2	3/2-way solenoid valve
3	5/2-way solenoid valve
4	Pressure sensor
5	Air reservoir
6	Vacuum switch
7	Non-return valve
8	Flow control valve
9	Suction cup
10	Non-return valve, de-lockable
11	Air Service unit
12	PC & PLC



2.1 Siemens SIMATIC S7-200 PLC

The S7-200 series of micro-programmable logic controllers (Micro PLCs) can control a wide variety of devices to support automation needs. It monitors inputs and changes outputs as controlled by the user program, which can include Boolean logic, counting, timing, complex math operations, and communications with other intelligent devices. The compact design, flexible configuration, and powerful instruction set combine to make the S7-200 a perfect solution for controlling a wide variety of applications. ^[4]

2.1.2 S7-200 CPU module

The S7-200 CPU module combines a microprocessor, an integrated power supply, input circuits, and output circuits in a compact housing to create a powerful Micro PLC.



Figure 7: PLC S7-200



The PLC consists of two modules, CPU module and communication module. The CPU communication module is used to transfer the files ladder program from PC to PLC.

2.2 Vacuum generator

The vacuum generator is used to create the vacuum in the handling technology. The industries are also using vacuum pumps for generating vacuum. The goal of both processes is to reduce ambient pressure in a suction gripper to a lower level.

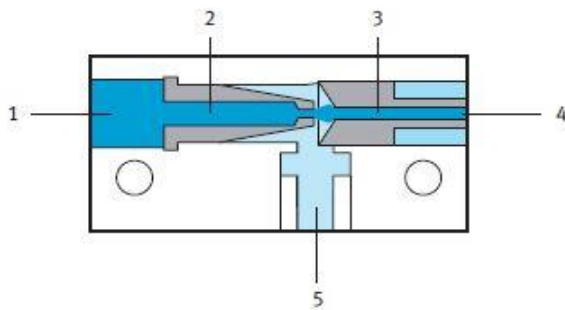


Figure 8: Ejector – cutaway View^[11]

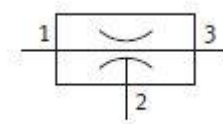


Figure 9: Ejector symbol^[11]

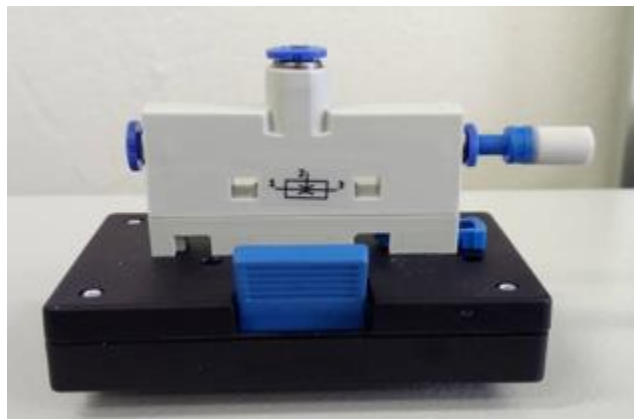


Figure 10: Ejector



In the figure 8, 1 means supply port, 2 means jet nozzle, 3 means collector nozzle, 4 means exhaust air, 5 means vacuum port.

There are two types of Ejectors in the TP 230 at disposal:

- Type – H (high performance ejector)
- Type – L (low performance ejector)

2.2.1 Vacuum generation

The main principle of vacuum generation is "Venturi principle". Compressed air flows through a cross-section contraction – the ejector's so-called jet nozzle. At this point air flow velocity is increased to ultrasonic speeds. After the air exits the jet nozzle, it expands and flows through the collector nozzle with downstream silencer. During this process, a vacuum occurs in the chamber around the jet nozzle. As a result, air is drawn in through the vacuum port.

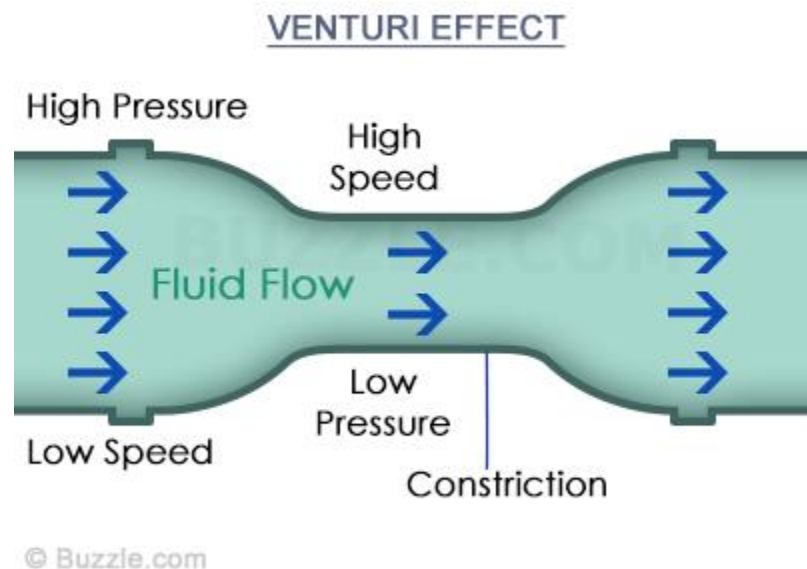


Figure 11: Venturi Principle ^[1]



By the figure it is clear that the pressure and speed are inversely proportional to each other. On the constriction area of the speed is high due to small cross section area and the pressure is low, here the vacuum will generate due to change sudden change in speed. From the constructive point of view there are two types of ejectors single stage ejector and multi stage ejectors. Ejectors reach negative pressures of down to approximately -0.9 bar. In some cases, negative pressures of down to - 0.99 bar can be generated with multi-stage ejectors.

2.2.2 Single-stage ejector with repulsion function

2.2.2.1 Function

The vacuum generator unit has the same function as the vacuum generator. However, simultaneous to the suction process, an integrated reservoir is filled with air. When the input line is deactivated, the stored compressed air is vented abruptly as a pulse via the port (quick exhaust), and reliably repels the suction gripped work piece from the suction cup.

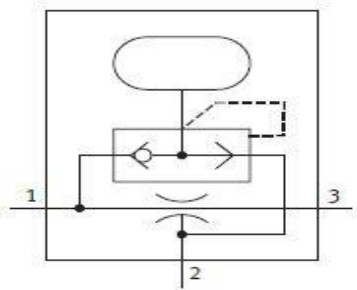


Figure 12: Symbol ^[11]

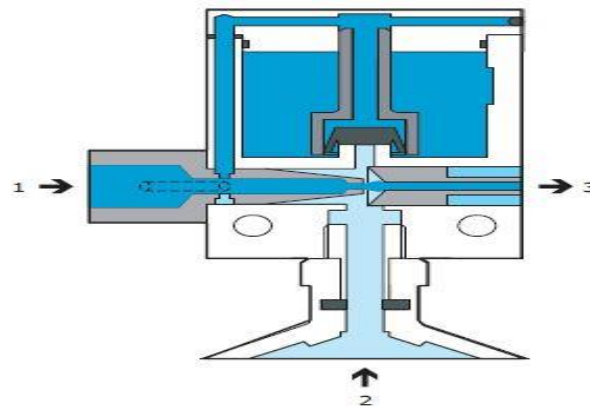


Figure 13: Single stage ejector with repulsive function cut way ^[11]



2.3 Valves

There are two types of valves can be used for all the experiments. They are 3/2 value and 5/2 valve. These valves have the following characteristics:

- Mono-stable valve
- Solenoidal valve
- Pivoted by air

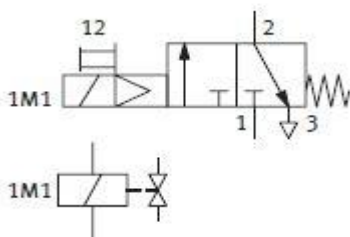


Figure 14: 3/2 Mono-stable Solenoidal Valve ^[11]

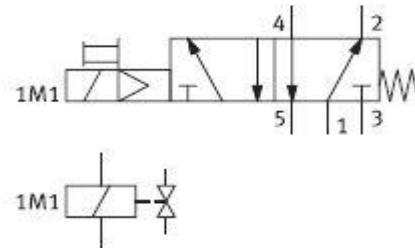


Figure 15: 5/2 Mono-stable Solenoidal Value ^[11]



Figure 16: 5/2 Mono-stable solenoidal value

During implementation of the overall design of the process, it is important to know the essential specifications of the components provided by the manufacturer in the data sheets to reliability of the vacuum generation.



2.4 Pressure switch

The pressure switch has been used to sense the pressure and indicate the operator if the required level of partial vacuum has been achieved or not during the current suction process.

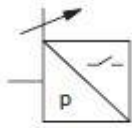


Figure 17: Symbol Vacuum Switch ^[11]



Figure 18: Vacuum Switch ^[11]

2.4.1 Function

The pressure switch is used for indication purpose, it has memory to register the value of the pressure. This can be done by setting a particular pressure in the vacuum gauge and holding a small button present in the pressure switch to capture the new value of vacuum.



1st Step

2nd Step

3rd Step

Figure 19: Steps to reset the pressure switch ^[11]



In the Task 5,6 it is used to set the correct level of vacuum achieved when catching a work piece and to monitor the degree of vacuum achieved.

2.5 Vacuum gauge

The vacuum gauge is used to indicate the partial vacuum pressure. It is placed in between the vacuum generator and the suction cup. The gauge has the range of measuring the vacuum from 0.00 – 1.00 bar.



Figure 20: Vacuum gauge Symbol



Figure 21: Vacuum gauge photo

2.6 One-way flow control valve

The one-way flow control valve is a combination of a flow control valve and a nonreturn valve. The cross-section of the restrictor can be set by means of a knurled screw. It is used to adjust the flow of pressurized air. ^[3]

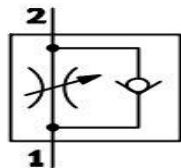


Figure 22: One way flow control valve symbol



Figure 23: One way flow control valve photo ^[3]



2.7 Vacuum reservoir

Vacuum reservoirs are used for assorted reasons in the field of handling technology. When installed downstream from a vacuum pump, they often function as vacuum storage containers, thus reducing pump operating time with the help of so-called on/off regulation. Another application area involves protection circuits. For safety purpose, the suspended work piece must remain gripped during the emergency situations even when the supply air is turned off during partial transportation. ^[11]



Figure 24: Vacuum reservoir symbol ^[11]





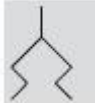

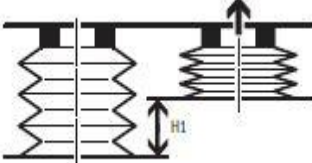

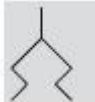

Figure 25: Vacuum reservoir photo ^[11]

2.8 Suction cups

Suction cups are used mainly in handling technology to hold the work piece and to transport it from one place to another. Suction cups make it possible to handle various work pieces with weights ranging from just a few grams, right up to several hundred kilograms. They're available in a vast variety of types. Depending on our requirements we can choose from various materials such as polyurethane (PUR), nitrile rubber (NBR), fluor elastomer (FPM) and silicone (SI). ^[11]



Table 2: Types of suction cups

Name of the suction cup	Symbol	Picture
Standard round		
Bellows, round 1.5convolutions		
Bellows, round 3.5 convolutions		
oval		



Selection cups play vital role in handling technology. The material and type of suction cup is selected to make sure that no leakage of vacuum is present and holds the work piece.

2.8 Non-return valve

A non-return valve allows a medium to flow in only one direction. A non-return valve is fitted to ensure that medium flows through a pipe in the right direction, where pressure conditions may otherwise cause reversed flow.



Figure 26: Symbol Non-Return Valve ^[11]



Figure 27: Non-Return Valve photo

There are diverse types of non-return valves. These valves are used to prevent backflow in Task 5 or Task 6.

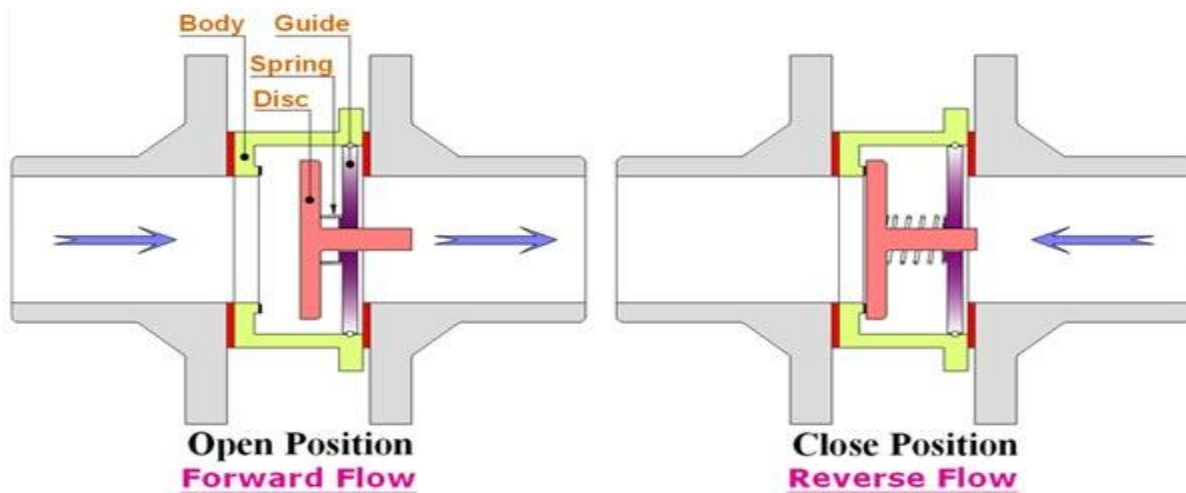


Figure 28: Working principle of non- return valve ^[12]



It is evident that the forward flow increases the pressure, the spring then contracts and allows the air or liquid to flow from right to left. From the right to left the spring retracts and does not allow flow of air or liquid.

2.9 Non-return valve, de-lockable

If a pilot signal is applied to the non-return valve, compressed air should flow to valve is opened. When the pilot signal is cancelled, the non-return valve should shut off the air, thereby stopping pressure air flow is closed. The valve should be suitable for use for positioning and braking functions. [3]

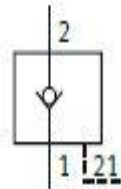


Figure 29: Non-return valve symbol ^[1]



Figure 30: Non-Return Valve, de – lockable
photo ^[3]



CHAPTER 3 SOTWARE DESCRIPTION

3.1 FluidSIM® V 5.0

For more than 20 years FluidSIM® has been the world's leading circuit diagram design and simulation program for pneumatics, hydraulics and now also for electrical engineering. Being able to freely design control systems is motivating, and promotes creativity and focus. Beyond that FluidSIM® provides teachers and students with a wealth of text, images and videos for multimedia-based lesson planning. ^[3]

Table 3: FluidSIM® - features

Libraries for new technologies	GRAFCET in various modes
<ul style="list-style-type: none">• Libraries for the pneumatics and hydraulics training packages at all levels including control technology and proportional technology• New: drives in pneumatics• Vacuum technology• Sensors in pneumatics• Safety in pneumatic systems• Electrical engineering, electronics• Circuits with contacts^[3]	GrafEdit: create GRAFCETs in compliance with the standard GrafView: visualize the control sequence represented as a GRAFCET GrafControl: control the process with the GRAFCET, including error simulation and process monitoring GrafPLC ^[3]

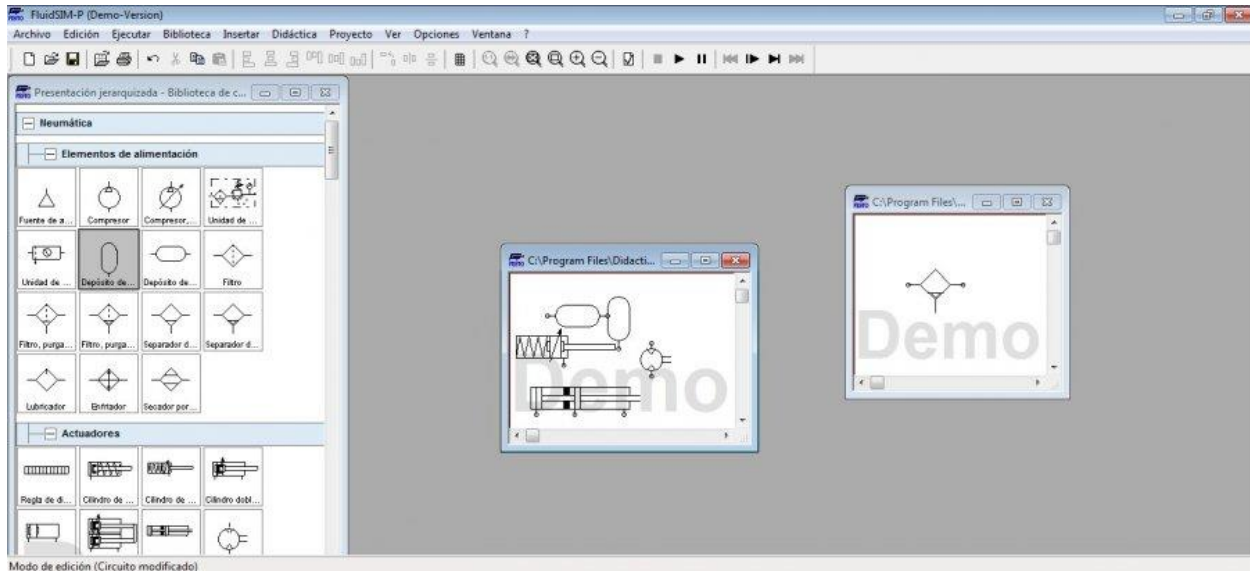


Figure 31 : FluidSim® 5 - components library [3]

The FluidSim® 5 environment has an improved component library than the FluidSim® 4. It is easy to design the Task 5 and Task 6 with FluidSim® 5. Hence all the tasks are done in the FluidSim® 5.

3.2 STEP 7-Micro/WIN Programming Package

The STEP 7-Micro/WIN programming package is a computer software. It provides a user-friendly environment to develop, edit, debug, download and upload the logic program into the PLC. [7]

Form the figure 32, the Micro/Win program is based on three convenient working spaces for crating the control program:

- 1) Navigation bar Presents groups of icons for accessing different programming features of STEP7- Micro/Win.
- 2) Instruction tree displays all the project objects and the instructions for creating the program.



- 3) Program editor contains the program logic and a local variable table where you can assign symbolic names for temporary local variables. Subroutines and interrupt routines appear as tabs at the bottom of the program editor window.

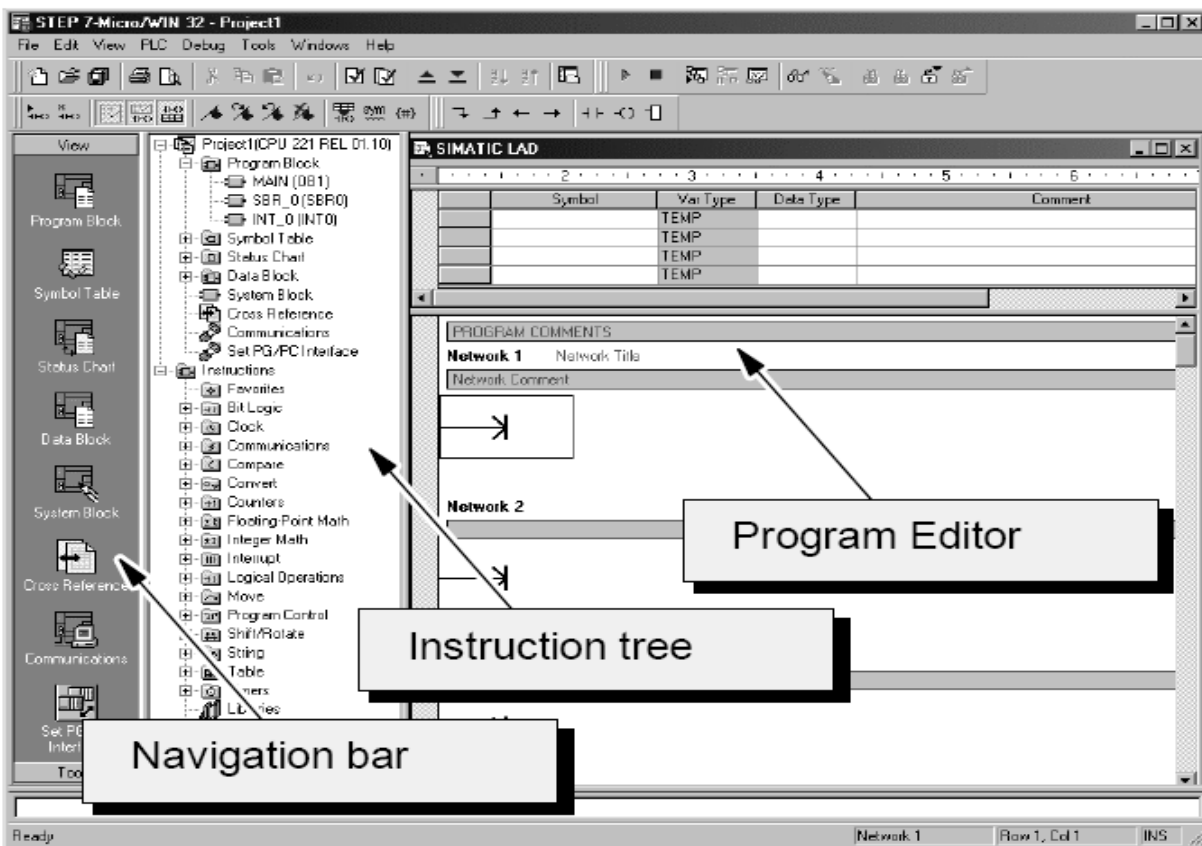


Figure 32: STEP 7-Micro/WIN Programming environment ^[7]

STEP 7-Micro/WIN provides three editors for creating user program:

1. Ladder Logic (LAD)
2. Statement List (STL)
3. Function Block Diagram (FBD)

The STL editor displays the program as a text-based language, where The LAD editor displays the program as a graphical representation like electrical wiring diagrams and the FBD editor displays the program as a graphical representation that resembles common logic gate diagrams. ^[7]



Figure 33 : Steps to running the user code on PLC ^[4]

3.3 S7-200 PC Access

PC Access is an OPC server dedicated to Microsoft which can be used as source of connecting and creating communication between the one or more devices with PC.

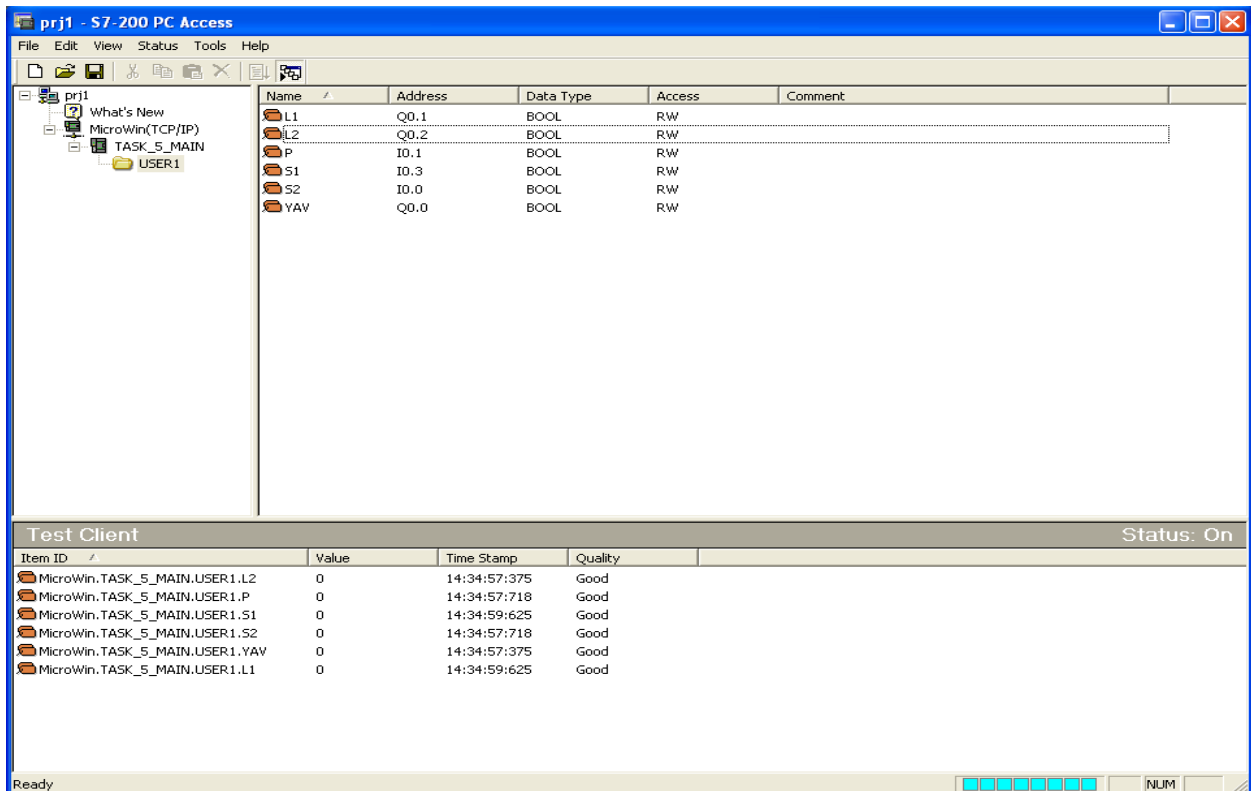


Figure 34: PC Access



This S7-200 PC Access is used to connect the PC and PLC. It gets the symbols (inputs, outputs and flag etc.) from the STEP 7-Micro/WIN to PC Access and make available for the OPC clients e.g. SCADA Reliance.

3.4 Reliance 4 design

The Reliance 4 Design environment is intended for creating and editing visualization projects (applications). It is available in two versions, Desktop and Enterprise. The Desktop version allows for creating local applications for one computer. The Enterprise version is designed for creating network applications and displaying a visualization application in a Web browser, on a smartphone, or on a tablet. [9]

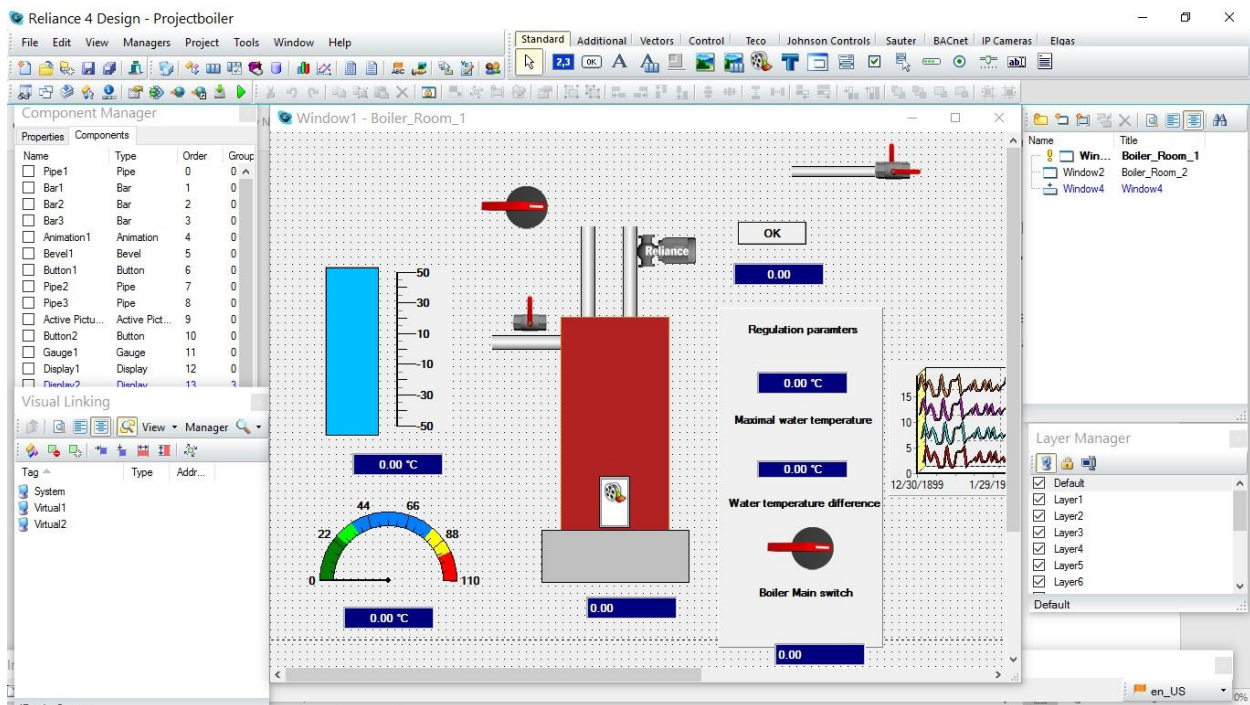


Figure 35: Reliance SCADA with an example

The Reliance 4 SCADA is a powerful tool using this software visualization of the task related to monitoring of vacuum. It has design window to create design of



the project, device manager to add the several types of devices, OPC etc. The run time module is used as HMI system.

In the reliance 4 design, we can design the technology process using the design window and can monitor values from the PLC in the run time. The application of boiler room project is shown in figure 35.

The Reliance 4 Design have managers like Device manager, Data table manger, Trend manager, Picture manager, String manager and Project structure manager. These managers are used to create the tags, data tables, data in graphical form, pictures etc. The detailed working procedure is explained in the chapter 6.

This software can control the process of by scripts. The data can be viewed in terms graphics and reports. We can evaluate the data by calculations using this software. Alarms and events are the one of the best features of this software.

We can add Siemens, Modbus , OPC, Teco etc. to the user project and we can import the OPC tags to the project .Using the Reliance 4 SCADA many industrial applications are automated. It is helpful in creating a HMI which shows the overall working of the industry by visual design.



CHAPTER 4 EXPERIMENTAL TASK

4.1 Necessary condition for all the tasks

All the tasks are prepared as classical electro pneumatics circuits.

1. Design the circuit in FluidSIM® 5 and understand the working process.
2. All the tasks have one pneumatic circuit and controlled electrically by electro-pneumatic circuit.
3. Implementation of the real-time hardware of the required task
4. The pressure unit needs to be maintained at 6 bar.
5. All the required measurements need to be tabulated.
6. Make conclusion.

4.2 Task 1 – Generating Vacuum

This task involves creation of partial vacuum using the components in the kit TP – 230. A handling unit for different work pieces needs to be developed. This task will include learning of various components used in vacuum generation.

4.21 Operation

The Vacuum can be generated by two vacuum generators type H and type L with different performance. The operation is simple, all the tasks have one pneumatic circuit and controlled electrically by electro-pneumatic circuit.

When S1 switch is pressed the K1 relay will activate which in turn activates its contacts K1. The first contact K1 activates coil valve 1M1 thus the 3/2 Mono-stable solenoidal valve changes its position. Now the pressure will flow to vacuum ejector as the position of the valve has changed. This will generate the partial



vacuum. From the figure: 37, it is evident that the partial vacuum has been generated and it can be measured by the vacuum gauge.

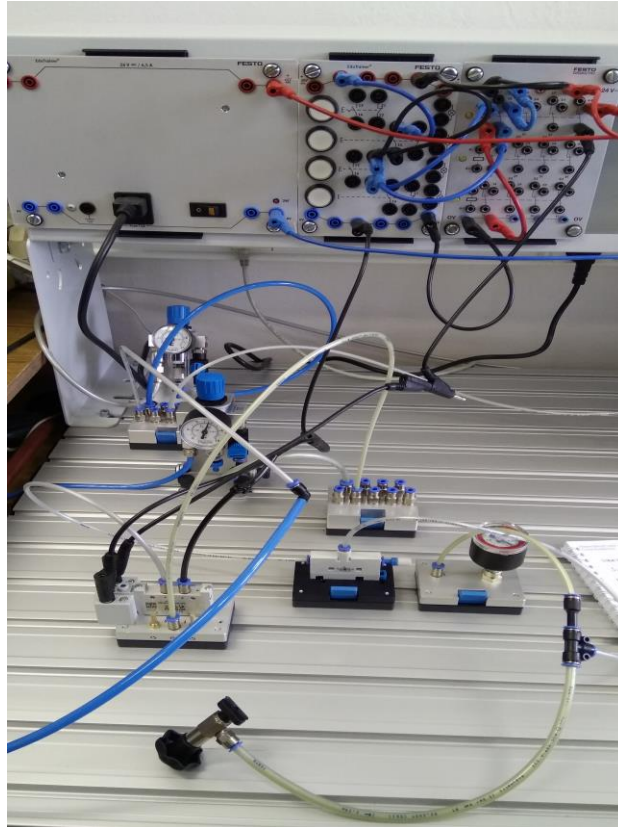


Figure 36: Implementation of Task 1

4.21 Work done

1. The design circuit for vacuum generation has been implemented in the FluidSIM® 5.
2. The practical implementation has been done with the TP-230 kit in the lab 109.



4.2.2 Problems faced

- Tubing is the main problem because there are several types of tubing and the diameter of tubing varies from one component to another. One should consider the tubing diameter to connect all the components.
- During the process, we did not have the 3/2 Mono-stable normally opened valve so it is replaced the 3/2 valve with 5/2 mono stable valve with port 2 terminated.

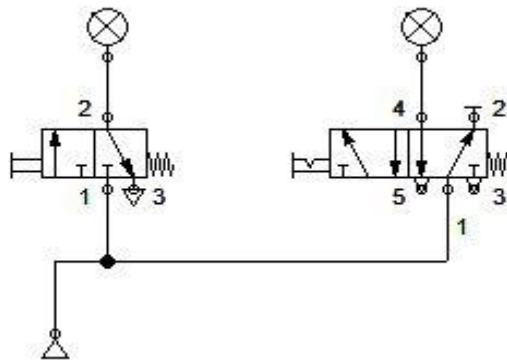


Figure 37: Equivalent Diagram

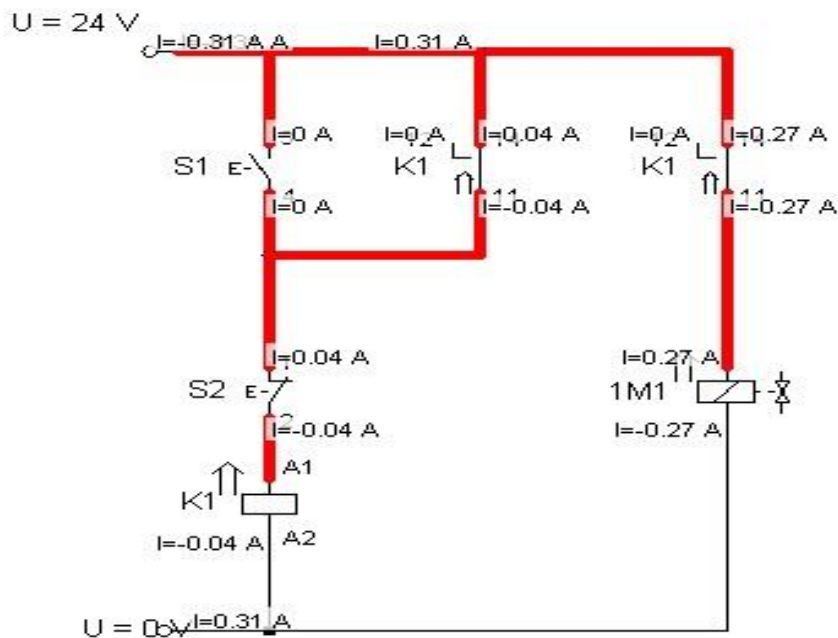
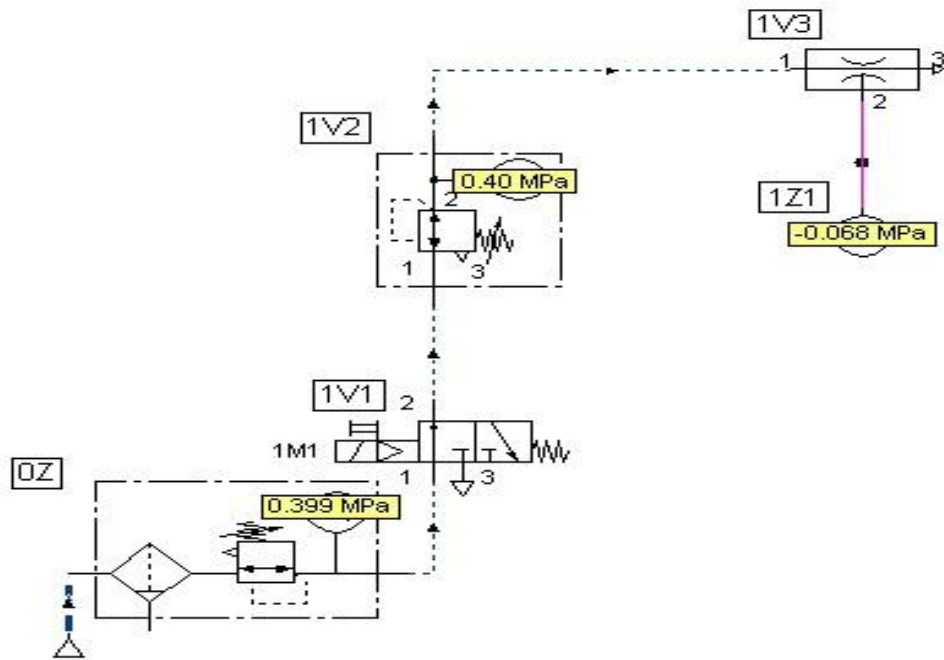


Figure 38: Pneumatic and electro Pneumatic circuit for Task 1



4.3 Task 2 - Selecting suction cups for various work pieces

This task involves selection of suction cups for different work pieces. Different work pieces will have variant surface, structure, finishes, size and shape. These parameters have to be taken into consideration when designing a handling unit. The main aim of this experiment is to check the suction cups and pick the right one for particular material.

The circuit for this task is similar to the previous one, only the suction cups is added to vacuum port of the ejector. There are several types of the suction cups available which can be seen from the table – 2.

The various suction cups can be compared related to shape and type.



Figure 39: Suction cups

The electro-pneumatic circuit is similar as the figure 38. Here each suction cups needs to be tested with various work pieces and both generators have to be used.

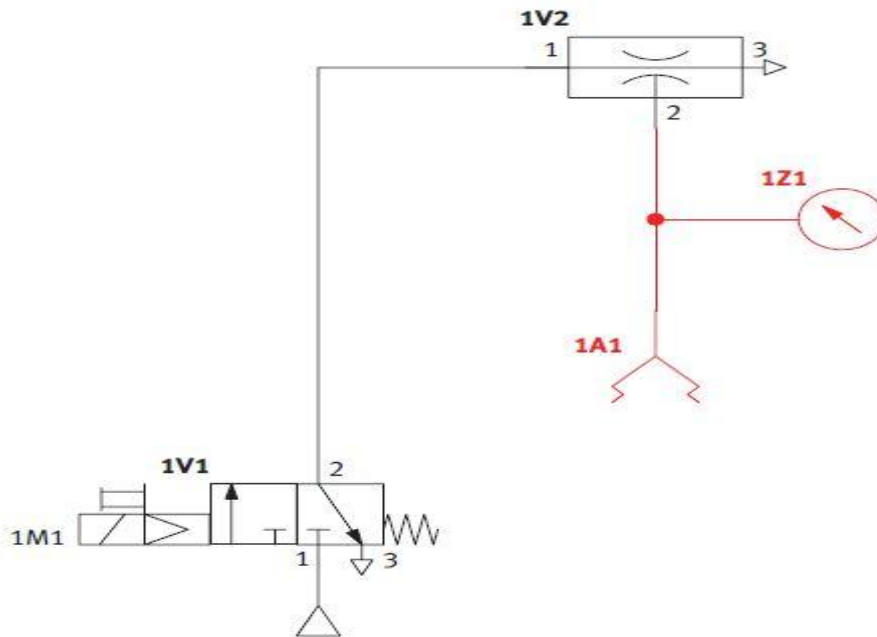


Figure 40: Pneumatic circuit of Task 2

4.3.1 Work done

- Designed circuit in the FluidSIM® software and implemented the real-time application with electro-pneumatics.
- Tested various suction cups with different work pieces.
- The results are tabulated and compared.

The vacuum generation relies on work piece's surface finish and shape, suction cup diameter and flexibility of the suction cup material. In this experiment, the values are compared with the standard value, but there is more deviation from the standard values due to leakage. The suction cup has to be chosen in a manner that the degree of the partial fraction must be higher.

*Table 4: Measurement results for type H vacuum generator*

Suction cup/work piece	Suction cup 30mm transparency	Suction cup 30 mm black	Suction cup 20mm black	Bellows 20 mm	Suction cup oval
Sand paper, 120 grit	-	-	-	0.001	-
Sand paper, 100 grit	0.19	0.01	-	0.58	-
Plastic can	0.84	0.8	0.8	0.8	0.8
Ball (Golf)	-	-	-	0.82	-
Pen	-	-	-	-	0.8

Table 5: Measurement results for type L vacuum generator

Suction cup/work piece	Suction cup 30mm transparency	Suction cup 30 mm black	Suction cup 20mm black	Bellows 20 mm	Suction cup oval
Sand paper, 120 grit	-	-	-	-	-
Sand paper, 100 grit	0.23	0.01	-	0.14	-
Plastic can	0.32	0.3	0.32	0.32	0.32
Ball (Golf)	-	-	-	0.32	-
Pen	-	-	-	-	0.32



The table 4 and 5 gives the readings of the vacuum level achieved when using type H and type L vacuum generators respectively. This will give the idea to choose the suitable suction cup.

4.3.2 Calculation and comparison

Table 6: Selection criteria

Suction cup/work piece	Selection suction cup
Sand paper :120 grit	Suction cup, transparent, 20 mm. Together with the type L vacuum generator, this suction cup reaches maximum possible vacuum with this work piece.
Sandpaper :180 grit	All the suction cups can be used and all will acquire partial fraction
Plastic can	Maximum possible vacuum is achieved with all suction cups and all vacuum generators
Golf Ball	Only below had achieved higher level of partial vacuum
Ball point Pen	Only oval suction cups reached higher degree of vacuum

4.4 Task 3 Maintaining vacuum when using more than one suction cup

A work piece will be gripped using two suction cups. It is possible that only one of the two suction cups grips the work piece and the other doesn't, for example because it isn't placed squarely onto the surface. As a result, no partial vacuum is generated at the first suction cup either.



The circuit for this task is shown in the figure: 42 and the interesting point here is to notice the suction grippers have security valves so that if there are number of suction cups holds work piece the degree of pressure will be maintained high.

4.4.1 Function security valve

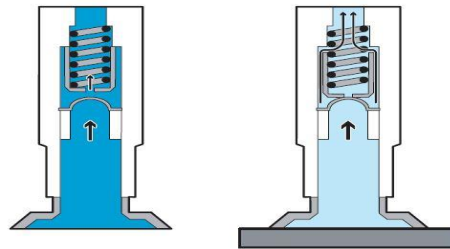


Figure 41: Function of security valve ^[11]

Vacuum security valves are installed between the vacuum generator and the suction cup. If, during vacuum generation, a suction cup is uncovered, or only partly covered, the vacuum security valve automatically stops the influx of air almost entirely. As soon as the suction cup is once again fitted tightly against the surface, vacuum is regenerated.

Removal of the work piece from the suction cup also causes the vacuum security valve to immediately close almost entirely. If the suction cup is open to the environment, a float in the vacuum security valve is pressed up against the housing. In this position, flow is only possible through a small hole in the float. When a work piece is in contact with the suction cup, air flow is reduced and the spring forces the float forward. The vacuum security valve is thus opened and full vacuum is generated within the suction cup. ^[11]

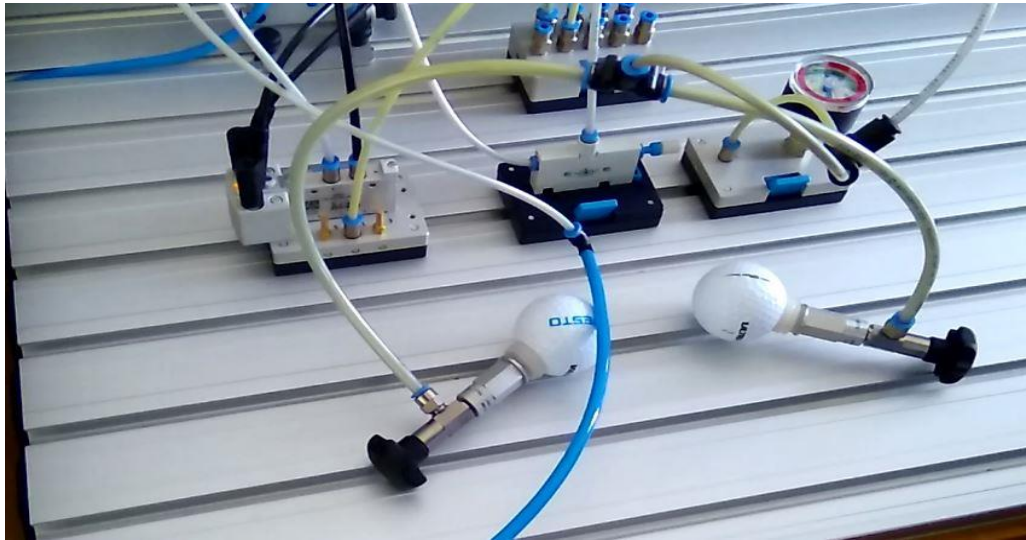


Figure 42: Implementation of Task3

This experiment is repeated, with and without security valve for both vacuum generators. Calculations are done and compared.

Table 7: Vacuum generation on, none of the suction cups grips the workpiece

Vacuum generator (type)	Partial vacuum achieved without vacuum security valve	Partial vacuum achieved with vacuum security valve
Type H	0	0.1
Type L	0	0.1

Table 8: Vacuum generation on, one of the suction cups grips the workpiece

Vacuum generator (type)	Partial vacuum achieved without vacuum security valve	Partial vacuum achieved with vacuum security valve
Type H	0	0.26
Type L	0	0.1

*Table 9: Vacuum generation on, both suction cups grips the workpiece*

Vacuum generator (type)	Partial vacuum achieved without vacuum security valve	Partial vacuum achieved with vacuum security valve
Type H	0.78	0.82
Type L	0.4	0.44

4.5 Task 4 Monitoring partial vacuum

This task will monitor the vacuum generated and tell the operator that the required degree of partial vacuum is reached, for example, a handling unit needs to move work pieces from a conveyor belt to a roller container. It must be ensured that none of the work pieces is dropped during transport due to inadequate partial vacuum. The handling unit should not be started until enough partial vacuum has been built up. The vacuum level therefore has to be checked to determine whether or not the required level has been reached. This should be done automatically. When the required degree of partial vacuum has been reached, a signal lamp indicates that he is handling device can be started manually. ^[11]

4..5.1 Function

To adjust the vacuum switch, the required degree of partial vacuum must first of all be generated. This is done by setting system pressure such that the required degree of partial vacuum is reached.

Once the required degree of partial vacuum has been reached, the EDIT key on the vacuum switch is pressed and held until the integrated LED blinks. When the key is released, the vacuum switch saves the momentary partial vacuum value to memory as a switching pressure. The vacuum switch has three wires (positive, negative and output) needs to be connected correctly by using the following table:10. ^[11]

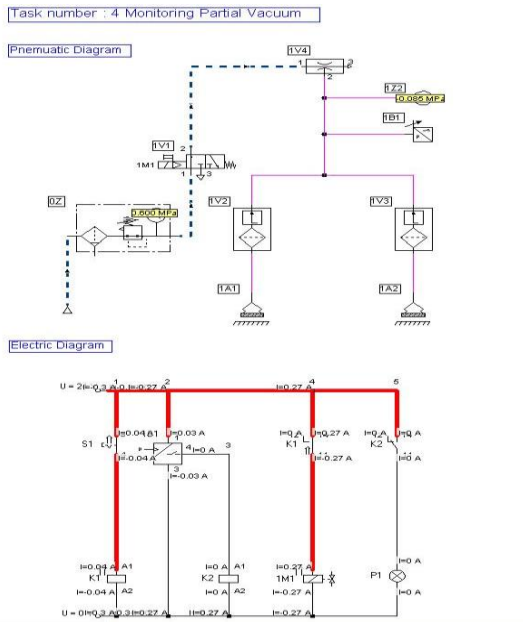


Figure 43: Task 4



Figure 44: Changing the value of pressure sensor

Table 10: Vacuum Switch wire connection ^[11]

Connection	Colour abbreviation
Operating voltage, positive terminal	BN (RD)
Operating voltage, negative terminal	BU
Switching output	BK

Sensors with 3 connecting cables

BN represents red colour, BU represents blue and BK represents black.



4.6 Task 5 Reducing compressed air consumption in a vacuum system

This task is the main task of the thesis. Energy savings is biggest challenge in all fields of technology. Energy should be saved and conserved. The energy savings problem can be done with lot of innovative ideas and experiments. For example, in Germany, 30 % of overall energy is consumed for industrial purpose. In vacuum technology reducing the compressed air consumption will give efficient results and save lot of money.

4.6.1 Ways to Save Energy Consumption

1. Use low-friction components
2. Use air-switching circuits
3. Efficient open and closed loop control
4. Reduce leakages
5. Switch off power (Task 5)
6. Reduce tubing lengths
7. Reduce pressure loss

4.6.2 Problem description

The work pieces should be transferred from one place to another, design an air consumption unit which gives reduced vacuum consumption. The main of this experiment is to design a compressed air economy circuit unit.



4.6.3 Operation

When partial pressure at the suction cup reaches the specified value, vacuum generation must be stopped, i.e. no more compressed air can be fed to the ejector.

When partial pressure at the suction cup falls below a specified value, vacuum is generated again until the required vacuum level has been reached.

4.6.4 Selecting Suitable Components

Table 11:Components of Task 5

Name	Quantity
3/2-way solenoid valve, normally closed (from TP 201)	1
Non-return valve	1
Vacuum generator (H)	1
Vacuum switch	1
Signal input, electrical (from TP 201)	1
Relay, 3-way (from TP 201)	1
On-off valve with filter-regulator	1
Compressed air source	1
Tubbing's	Few



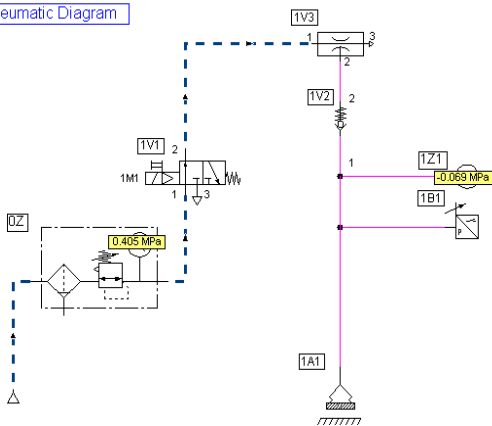
4.6.5 Problems faced

In order to save compressed air, the compressed air supply to the vacuum generator is stopped as long as the vacuum doesn't fall below a specified value. But the vacuum drops very quickly when it reached the capture value of the vacuum switch. The frequency of the switching ON and OFF is comparatively high.

This problem is solved by using the non -return valve between the suction cup and the vacuum generator. The tubing connection is also challenging during this experiment.

Task Number :5 Reducing Compressed air consumption in a vacuum system

Pneumatic Diagram



Electric Diagram

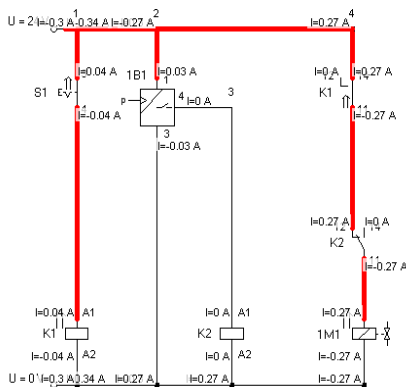
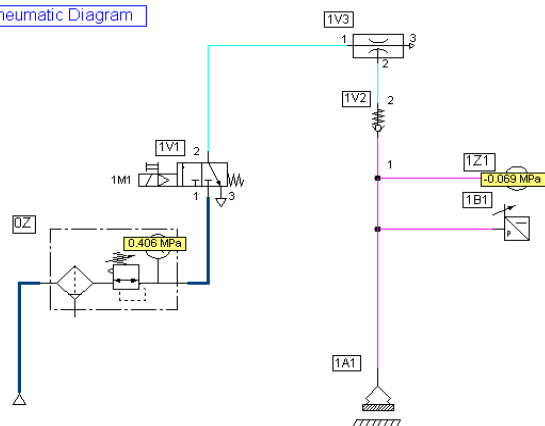


Figure 45: Task 5 initial

Task Number :5 Reducing Compressed air consumption in a vacuum system

Pneumatic Diagram



Electric Diagram

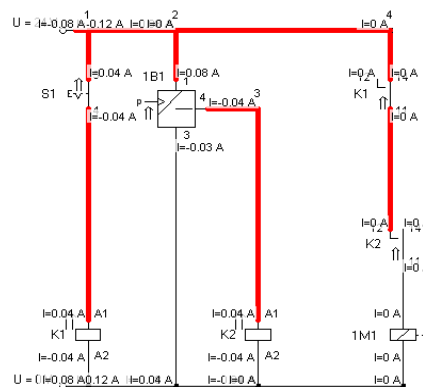


Figure 46: Task 5 reduces consumption



4.6.6 Process explanation

The figures 45 and 46 show the overall functioning of this experiment. Initially the vacuum is generated to catch the work piece and when the vacuum level reached the captured level of a vacuum switch it turns off pressure to the valve but the partial vacuum level is still maintained due to presence of non-return valve. When the vacuum generated is reduced below the registered value of the vacuum switch the valve is again given the air pressure thus the vacuum is generated again. Thus, saves the pressure air.



Figure 47: Step displacement diagram

4.7 Task 6 Controlled release of work pieces retained by a vacuum

This task is complete real-time task which can be used in transportation units. This task involves ejection of work piece from the suction gripper in a controlled fashion after the transportation is done.



4.7.1 Problem description

Use the compressed air economy circuit from exercise 5. Vacuum generation must be stopped when the transport process is finished. The work piece needs then to be ejected in a controlled fashion.

4.7.2 Problems faced

If a work piece has been gripped using a compressed air economy circuit, and if there's no leak between the suction cup and the work piece, the work piece is retained due to confined vacuum pressure. The vacuum must thus be evened out in a controlled fashion in order to ensure that the work piece is released from the suction cup. ^[11]

This can be done by including another circuit to Task 5. This new circuit contains another 3/2 mono-stable solenoid valve and non – return valve, delocakble valve. This new circuit stops the leakage of air when vacuum is generated and provide the pressure for ejection.

4.7.3 Selecting suitable components

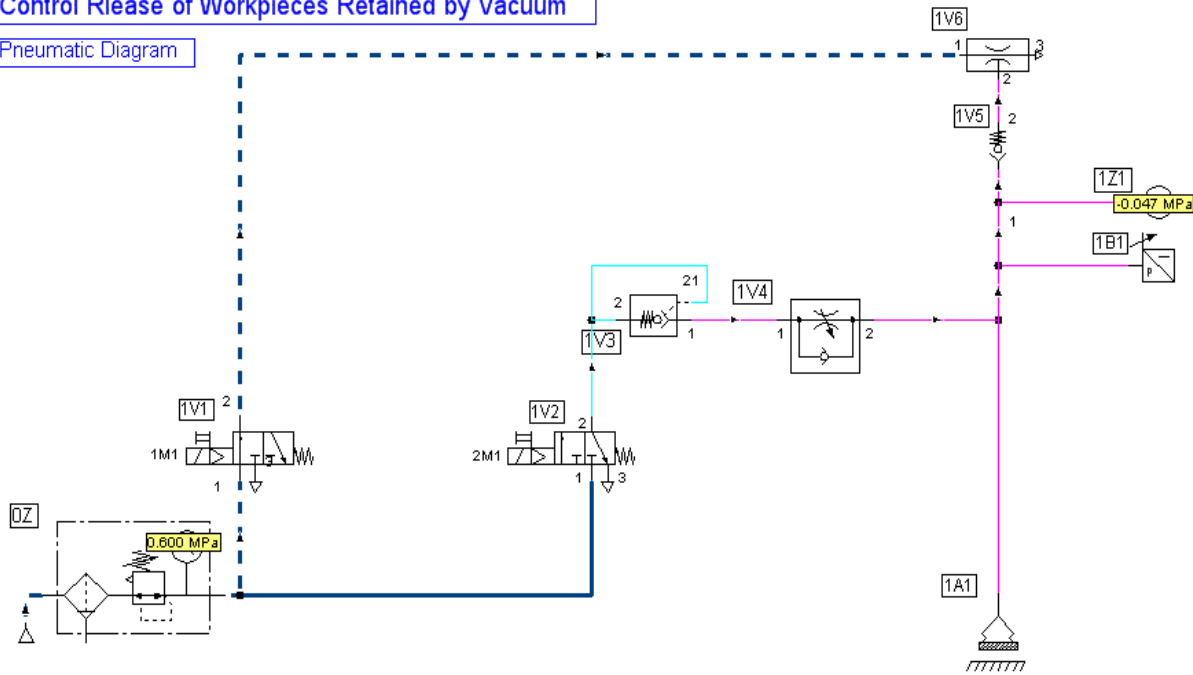
The Non – return delocakble valve, one more 3/2 Mono-stable valve and one-way flow control is added in this experiment.

In Task 6, the ejection of the work piece can be controlled by the throttle valve. High the throttling ejection force is lower. This is useful when glass type materials are transported from one place to another the ejection of the glass work piece should be done in a controlled manner.



Task Number : 6
Control Release of Workpieces Retained by Vacuum

Pneumatic Diagram



Electric Diagram

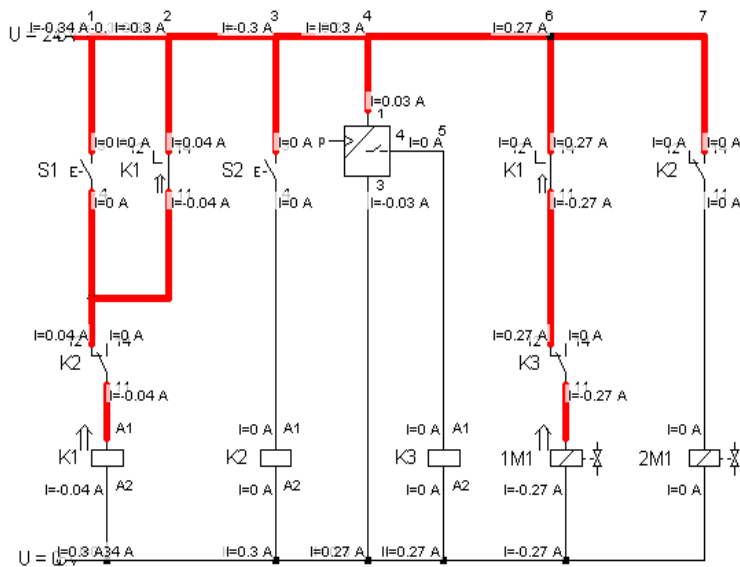


Figure 48: Task 6

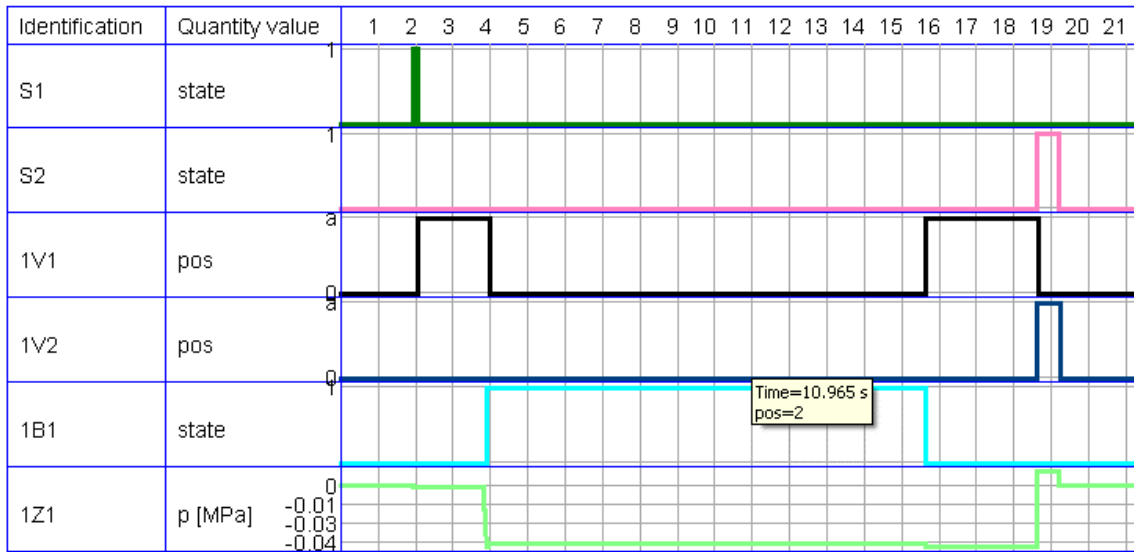


Figure 49: State diagram of task 6

When S1 is ON state then circuit will act as vacuum generator and when S2 is ON state this circuit will eject the work piece. when both are on it is an error state. It is seen from the figure – 50 that the partial vacuum is generated when S1 changes its state. We can read the level of the partial vacuum in the vacuum gauge. Then the function of the air economy circuit will take place. S2 is used to stop the vacuum generation and start the ejection. When S2 is ON state the pressure will increase.

Table 12: State level of Task 6

S1	S2	1V1 valve used for suction	1V2 valve used for ejection
0	0	0	0
0	1	0	1
1	0	1	0
1	1	Not defined	Not defined



4.8 Deciding the suitable task for automating

4.8.1 Basic Tasks

There are six tasks they can be given by:

- Exercise 1: Generating vacuum
- Exercise 2: Selecting suction cups for various work pieces
- Exercise 3: Maintaining vacuum when using more than one suction cup
- Exercise 4: Monitoring partial vacuum
- Exercise 5: Reducing compressed air consumption in a vacuum system
- Exercise 6: Controlled release of work pieces retained by a vacuum

Depending on the experience we had with all the basic tasks, the Task 5 (Monitoring partial vacuum) and Task 6 (Control release of work piece by vacuum) is suitable for the automating with PLC and these tasks can be monitored by SCADA software.

These two tasks have vacuum switch as a sensor and it can be applied directly in practical applications in handling technologies.



CHAPTER 5 IMPLEMENTATION OF PLC FOR TASK 5 AND TASK 6

5.1 Programming languages

EN 61131-3 (IEC 61131-3) defines five programming languages. Although the functionality and structure of these languages is very different, these are treated as one language family by EN 61131-3 (IEC 61131-3) with overlapping structure elements (variable declaration, organization parts such as function and function block, etc.) and configuration elements. The five programming languages includes:

1. Ladder diagram
2. Function block diagram (FBD)
3. Instruction list (IL)
4. Structured text (ST)
5. Sequential function chart (SFC) ^[8]

For the PLC coding Ladder language (LD) have been chosen and for the analysis and simulation in the FluidSIM® GRAPHCET language have been chosen.

5.1.2 Ladder diagram (LD)

Ladder diagram is a graphic programming language derived from the circuit diagram of directly wired relay controls. The ladder diagram contains contact rails to the left and the right of the diagram; these contact rails are connected to switching elements (normally open/normally closed contacts) via current paths and coil elements. ^[8]

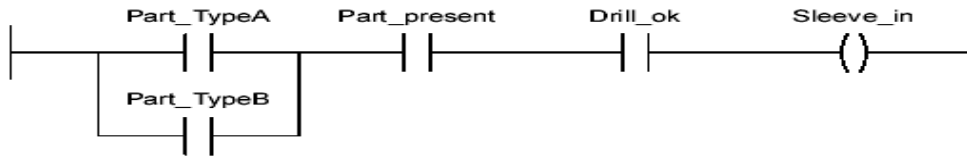


Figure 50: Ladder diagram ^[8]

5.1.3 GRAFCET language

The GRAFCET (Functional Graph of Control Step Transition) or SFC (Sequential Function Charts) is a formal model being used to specify and also to control reactive systems of the type "all or nothing" (Boolean inputs and outputs). ^[13]

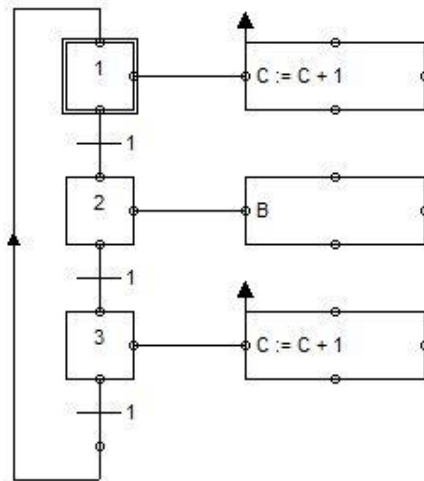


Figure 51: GRAFCET language

A GRAFCET is graph which is composed of steps and transitions, connected between them by connections or directed arcs. If we define in terms of PLC coding, Step will define the states of the PLC. The transition will give the information about the next sensor value. And the action block which executed the outputs of the PLC.



The GRAFCET is similar to the petri nets. Petri nets have place, transitions, tokens. GRAFCET have step, transitions and actions.

5.2 PLC coding for Task 5

5.2.1 Block diagram for Task 5

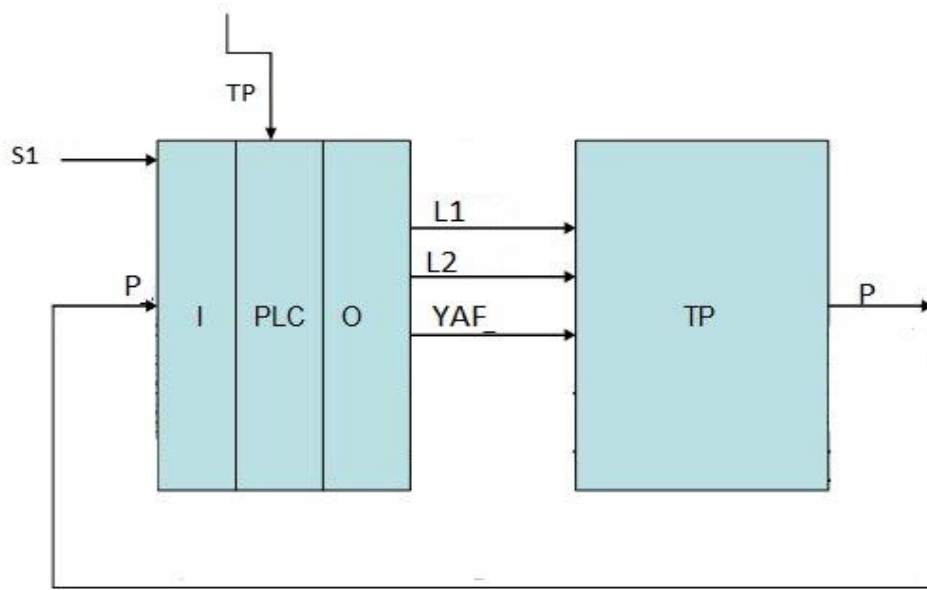


Figure 52:Block diagram for Task 5

The block diagram represents the technological process of the Task 5. It consists of two inputs S1 and P. The TP is signal coming from the previous technological process. The PLC have three outputs L1, L2 and YAF. The explanation the symbols are given in the table- 13.

The standing chain method is suitable for the ladder programming because using of this monostable valve. The mono stable valve does not have memory.



5.2.2 Explanation of symbols

Table 13: Explanation symbols

Symbols	Signals	Description
TP	Input	Previous technological process
S1	Input	Starting of the process using S1 switch
L1	Output	Indication of the situation that technological process is over
L2	Output	Indication that the situation that the current process is running
YAF	Output	Output valve
P	Input	Sensor signal vacuum high enough to catch the work piece

5.2.3 Process explanation

The Task 5 overall control has been controlled by one switch S1. The switch used in this task is detent switch. The next input is the vacuum switch, this will turn off the air supply entering the circuit when it is ON state. Depending on the vacuum switch the circuit turn ON and turn OFF the value in a loop. This circuit has been done with virtual PLC using GRAFCET language. The ladder program for the same task has been implemented in STEP 7-Micro/WIN. The SIMATIC S7– 200 is used for the implantation of the task.

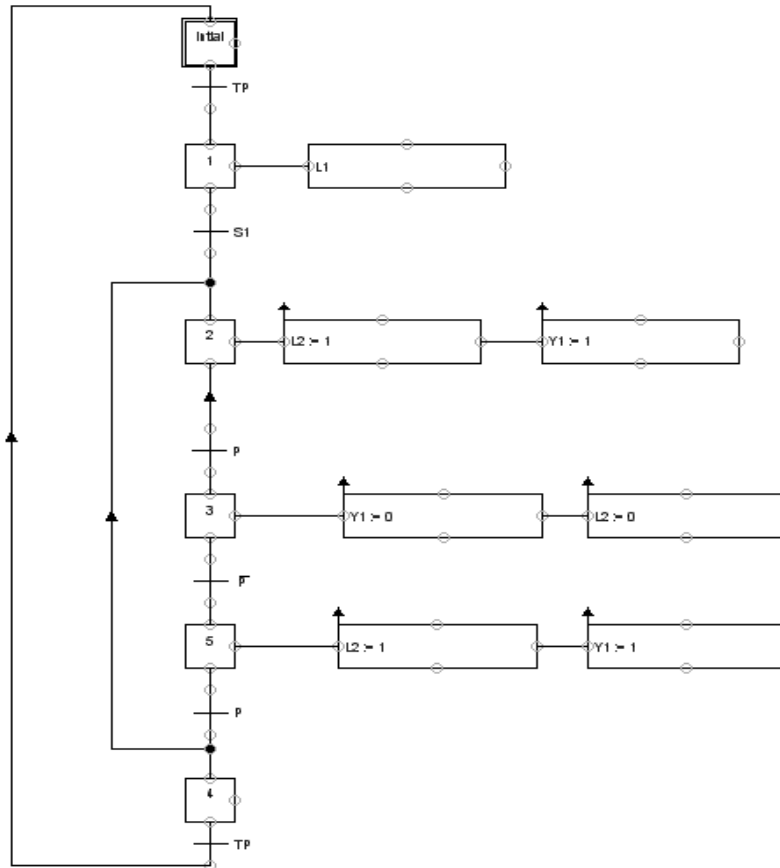


Figure 53: Program in GRAFCET language for Task 5

The initial state is represented by the double brackets. Here TP and S1 both switches are detent switch. The GRAFCET represents the operation of Task 5, when the switch S1 is pressed, the vacuum is generated. Once the signal from P is high that means the vacuum is high enough to catch the piece so the output valve will have turned off now. the vacuum created will getting decreased. At some point the value of the P is zero again the output valve is turned ON. The ON and OFF the output valve depends on the value of vacuum switch P. The loop will continue infinitely until the switch S1 is opened.



5.2.4 PLC coding

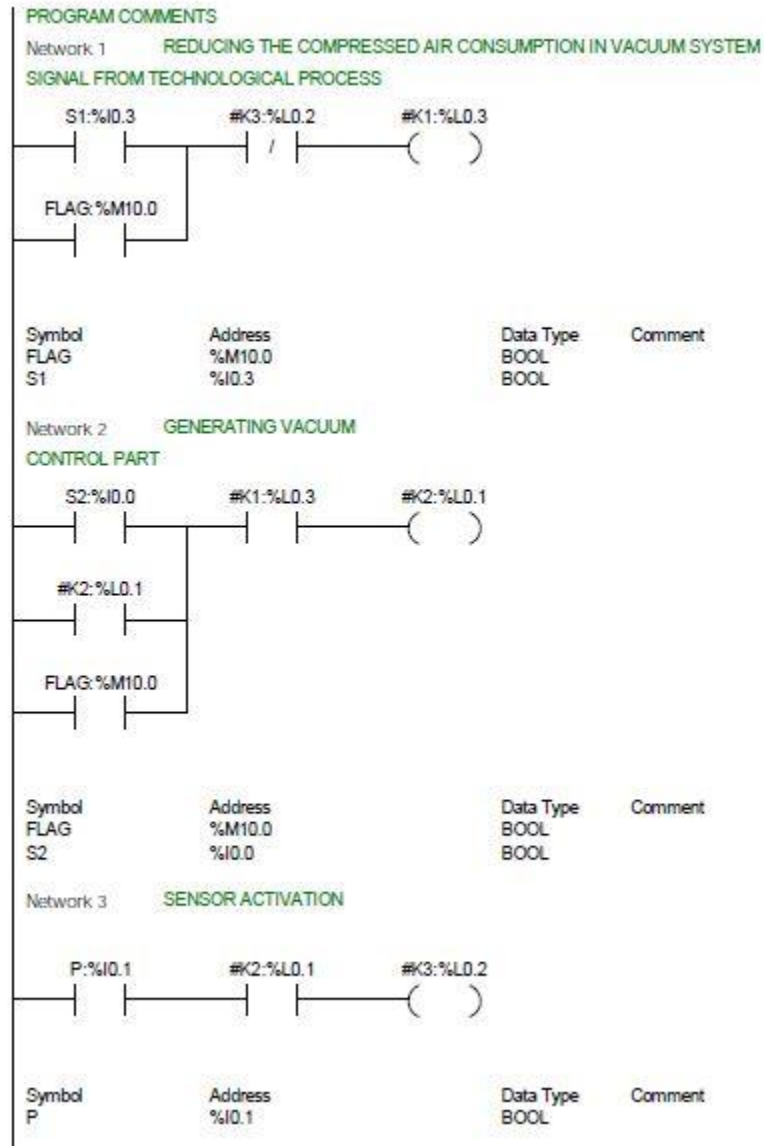


Figure 54: PLC coding for Task 5- part 1



TASK_522_MAIN / MAIN (OB1)

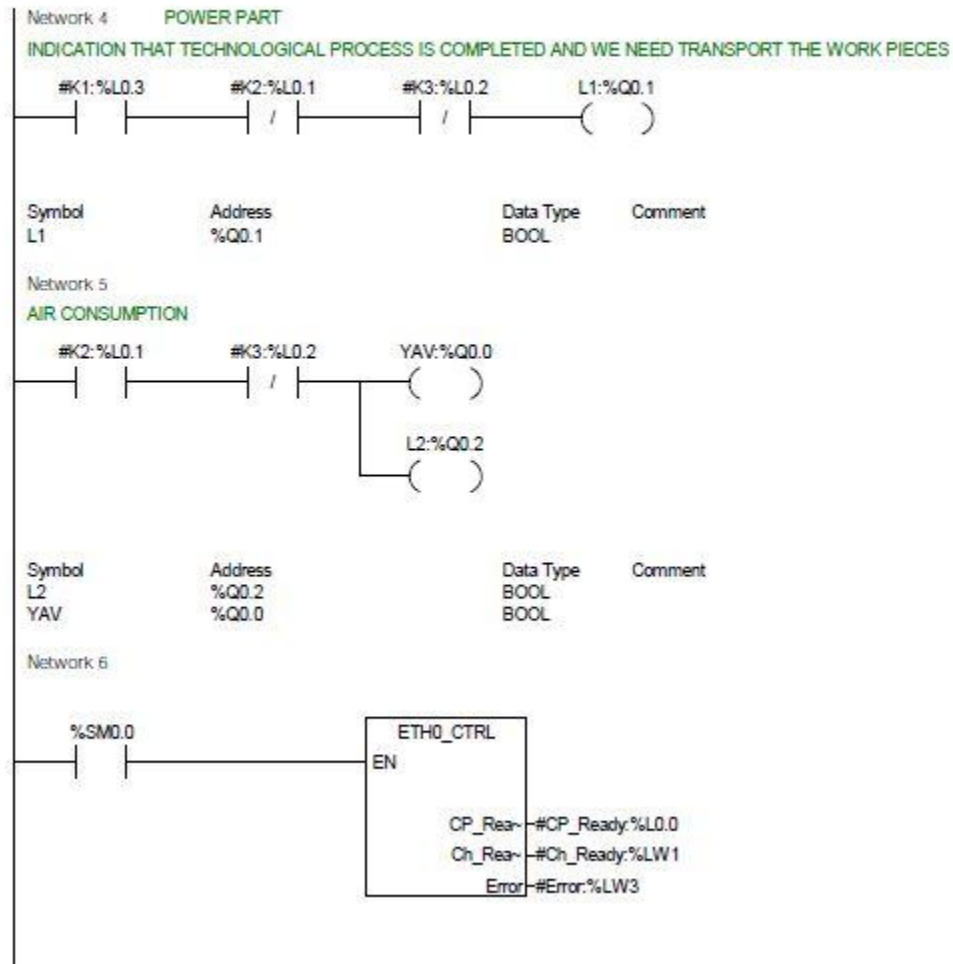


Figure 55: PLC coding for Task 5- part 2

5.2.5 Explanation of PLC coding

There are diverse types of methods used for ladder program we have used standing chain method for the Task 5 coding. The standing chain is suitable because of using monostable valve.



5.2.6 ETHx_CTRL (CP243-1 Module Control Subroutine)

ETHO_CTRL are available in the call subroutines which is used to make communication between the MICRO/Win S7-200 software to PC Access. If one needs to access the symbols created by the PLC in the PC Access ETHO_CTRL should be included and the ethernet wizard should be configured correctly [10].

The ETHx_CTRL subroutine initializes and performs error checking for the Ethernet module. The subroutine should be called at the beginning of every scan and should only be used once per module. This instruction commands the CP243-1 Ethernet module to check the V memory area for a new configuration each time the CPU changes to RUN mode. If the configuration is different or the CRC protection is disabled, then the module is reset with the new configuration. CP_Ready becomes active when the Ethernet module is ready to receive commands from the other instructions. Ch_Ready has a bit assigned to each channel to show the status of the connection for that particular channel. For example, bit 0 is ON when channel 0 has established a connection. [10]

5.2.7 Flag creation

In the PLC coding the flag is created to write values during run time. The problem we faced is that we could not write the values from the SCADA to PLC. This is solved by creating internal variables (flags) in PLC coding.



5.3 PLC coding for Task 6

5.3.1 Block diagram

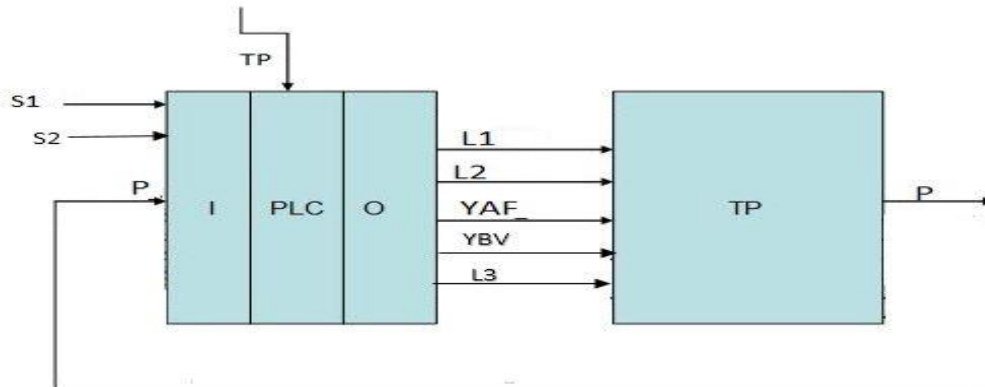


Figure 56: Block diagram for Task 6

The block diagram represents the technological process of the Task 6. It consists of two inputs S1, S2, P. The TP is signal coming from the previous technological process. The PLC have three outputs L1, L2, L3 and YAF. The explanation the symbols are given in the table- 14.

The standing chain method is suitable for the ladder programming because using of this monostable valve. The mono stable valve does not have memory.



5.3.2 Explanation of symbols

Table 14: Explanation of symbols

Symbols	signals	Description
TP	Input	Previous technological process
S1	Input	Starting of the process using S1 switch
S2	Input	Ejecting the work piece
L1	output	Indication of the situation that technological process is over
L2	output	Indication of the situation that the current process is running
L3	output	Indication that ejection is on
YAF	output	valve for suction
YBV	output	valve for ejection



5.3.4 PLC coding

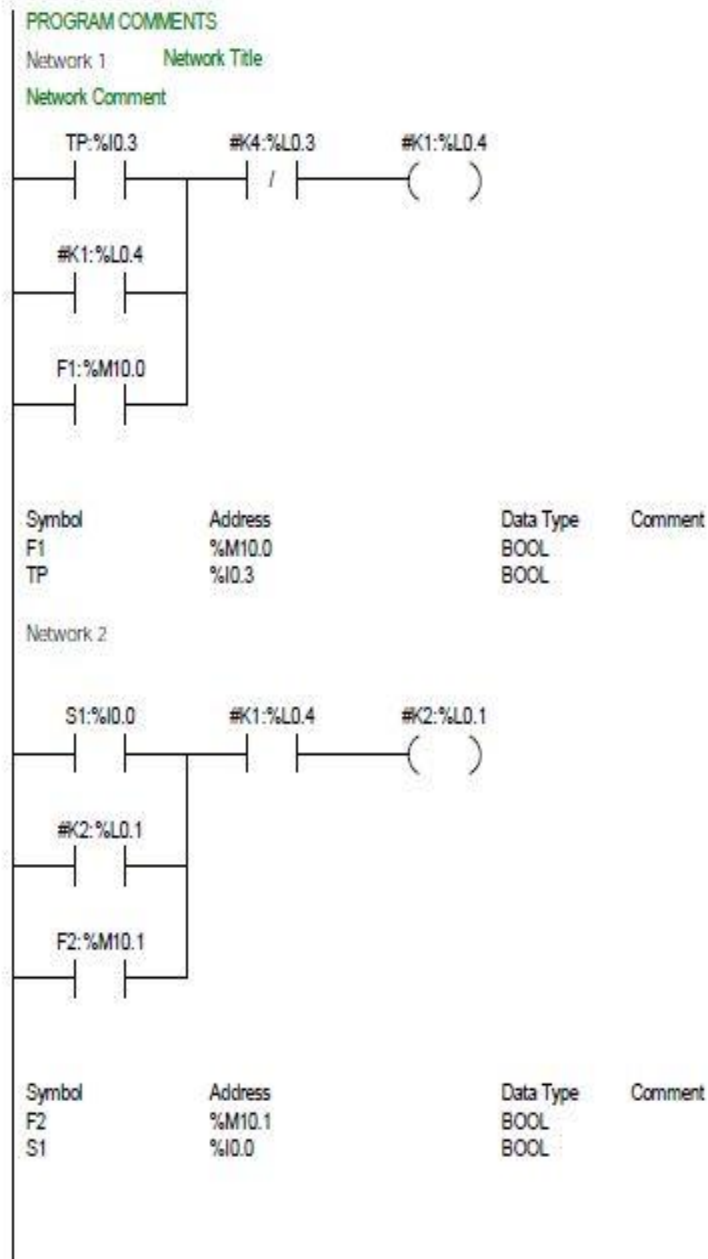


Figure 57: PLC coding for Task 6- part 1

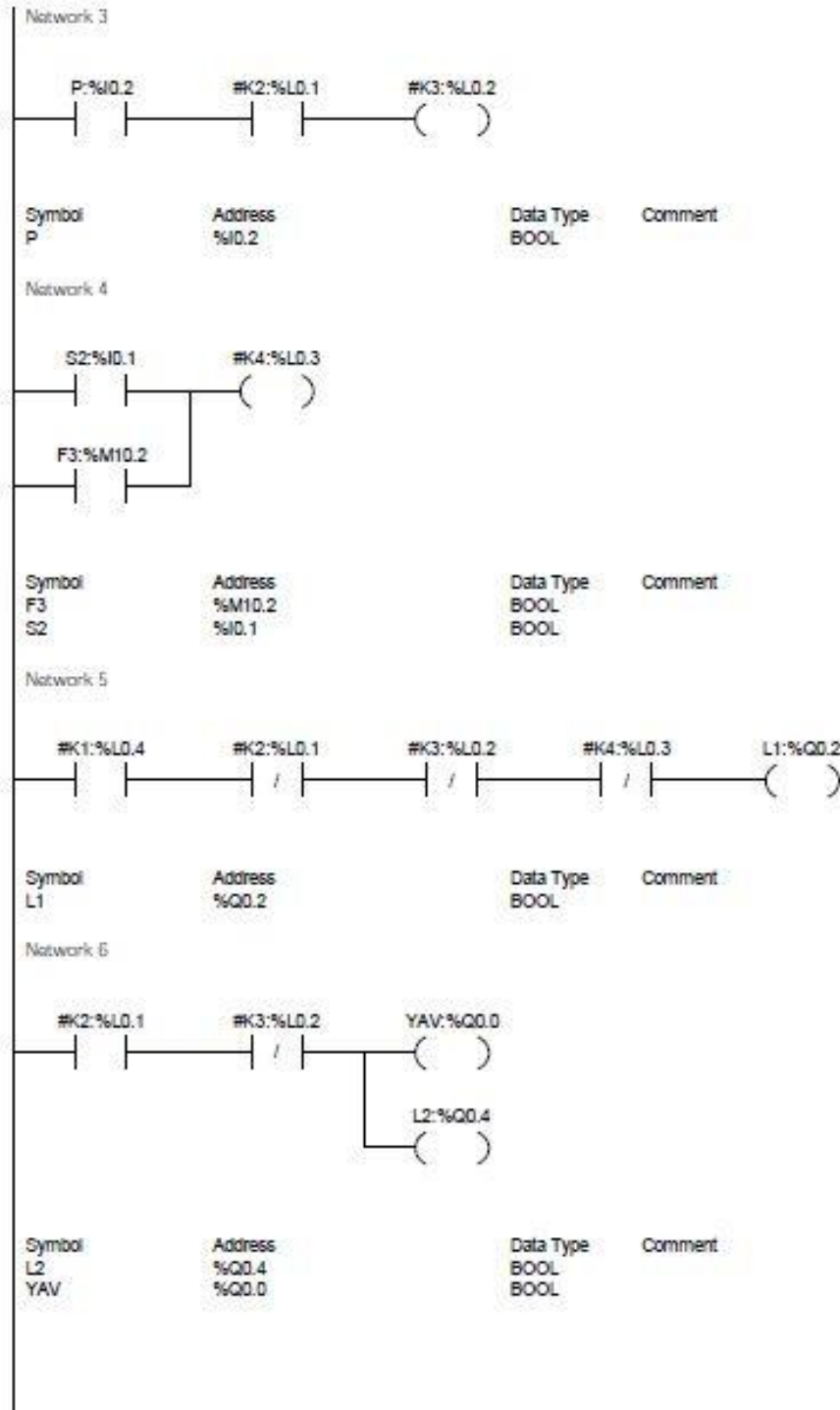


Figure 58: PLC coding for Task 6- part 2

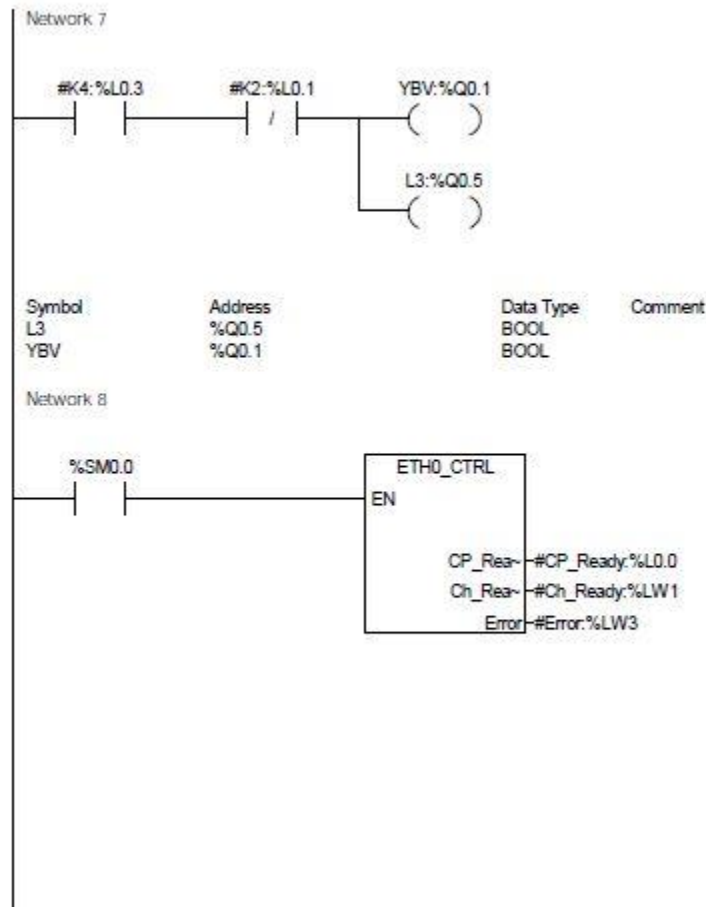


Figure 59: PLC coding for Task 6- part 3


5.5 Ethernet wizard

The Ethernet wizard is used to connect the CP243-1 to an Industrial Ethernet network. The Ethernet module uses the configuration information that is stored in the V memory of the S7-200 to generate the connections required for Ethernet communication. [10]



The ethernet wizard set communication between the PLC and PC. The setting of parameters is important that the correct IP address of the PLC and communication link of the CP243-1 should be configured correctly.

Module Address
Please select the address to assign to this CP 243-1 module. If your network provides a BOOTP server (a service that will automatically assign IP addresses at startup), you may choose to have an IP address automatically assigned.


IP Address: 147 . 32 . 167 . 106 

Subnet Mask: 255 . 255 . 240 . 0

Gateway Address: 0 . 0 . 0 . 0

Allow the BOOTP server to automatically assign an IP address for the module.

Module Connection Type
Specify the communications connection type for this module.

Auto Detect Communications 

<Prev Next> Cancel

Figure 60: Ethernet wizard part 1

The setting of TSAP properties is important that it will give information about the CP243-1 module. it is shown in the figure 58.

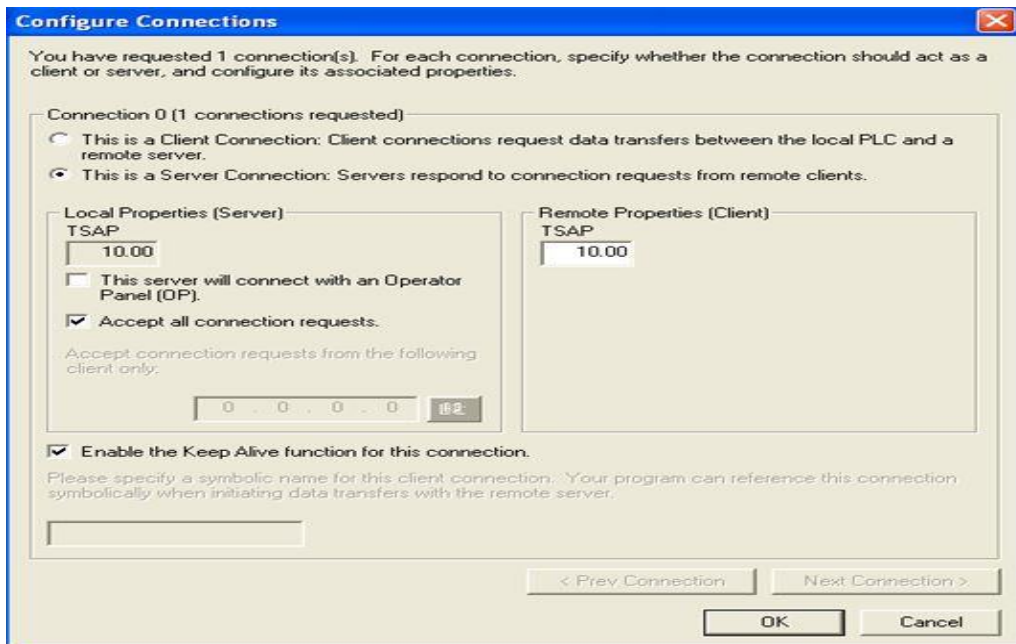


Figure 61: Ethernet wizard part 2

The above steps need to be carefully done to achieve the communication between PLC and PC Access. these are the only important steps and there are three steps more but these steps are very important.



Chapter 6 SCADA design for Task 5 and Task 6

6.1 SCADA design for task 5

The SCADA design for the Task 5 has been done its run time and design window environment is shown in figure. This SCADA environment is used to check the functionality of the process.

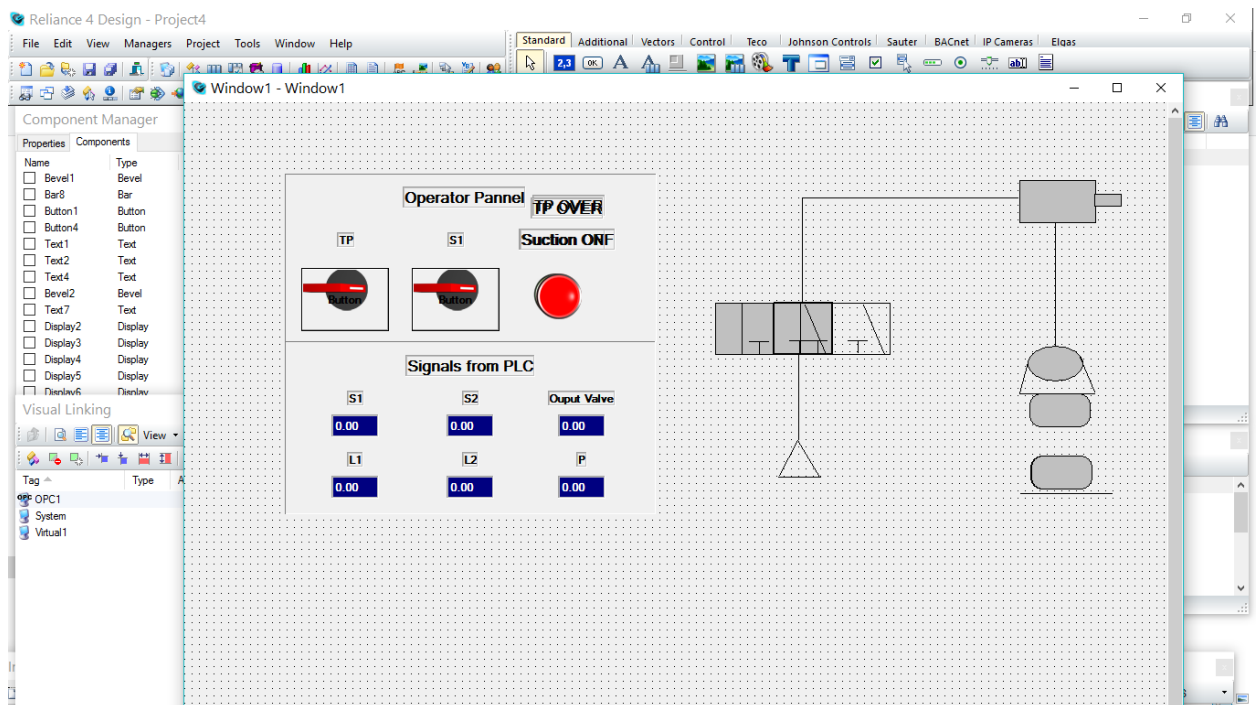


Figure 62: SCADA design for the Task 5

6.2 Steps to design a project in Reliance 4 design

- Select the Reliance 4 SCADA, select Create the new project and the give name of the project and select the required window to work on.
- Now create the window for the project, after clicking perform it automatically ask you for activating the window click next and choose the window type and click perform.



The SCADA software contains two modes:

1. Design mode
2. Run time mode

In the design mode, the technological process can be visualized. Tags can be created and based on the tags values it is possible the control the visualization.

In the run mode, we can see the real-time output of the process linked with SCADA software.

There most important thing in SCADA design is Managers. They are used for tag creation, adding devices, pictures and viewing the data in terms of text, graphical etc.

6.2.1 Device manager

The device manager gives information about the all the devices and tags which is used in the project. If you need to add OPC server and Siemens S7-200 to the project you can add the in the device manager. For example, the OPC server is added to the project by device manager.

6.2.2 Scripts

To control anything, we need code, in the visualization, the most often used code is VB scripts. The important thing here to understand is to know what to control and to design an algorithm that suits the required task to do. We haven't use any scripts for the tasks but for perform calculations we can write the scripts.



6.2.3 Data tables

All historical data are stored into the databases in the Reliance for the purposes of their displaying in the form of the Trends (graphical form) or Reports (textual and numerical form) or for their processing and evaluations according to the criteria given.^[5] We can save the data in the excel format and we also use the data for the future use. Every day at midnight there is an archive daily file created from the actual data and it is copied into another directory under another name, related to the year.

In data tables two things are important they are data sampling and data logging. The data sampling is rate is the rate at which the new record is created from the actual tag value to store in the Reliance data table. The data logging is the rate how often the data from the RDT memory are stored into the physical table on the disk. When user needs to create reports, trends and real time trends the data table has to be created first.

6.2.4 User manager

User manager is important feature in Reliance design which is used to define different kind of users. The user's rights can set according to their purpose like to view, changes parameters and design changes and control. Password can set for different user. And, can customize run time module for each user differently. Different user can log on the run time environment and the can change the parameters accordingly.

There are lot more features available for in the SCADA 4 design software like reports, alarms and events, duplications, string manager. These all the managers will be used for the visualization process as per the user requirements.



6.3 Work done

- The SCADA design for the Task 5 and Task 6 is designed.
- The users are created by user managers and given them priorities.
- The data tables are created to store the values.

6.3.1 Difficulties faced

The tag allocation and design of the technological process is a big challenge and time consuming. Improvements can be done in the design

6.4 Run time environment of SCADA

In the figure 60 and 61, the basic operation of the Task 5 is visualized.

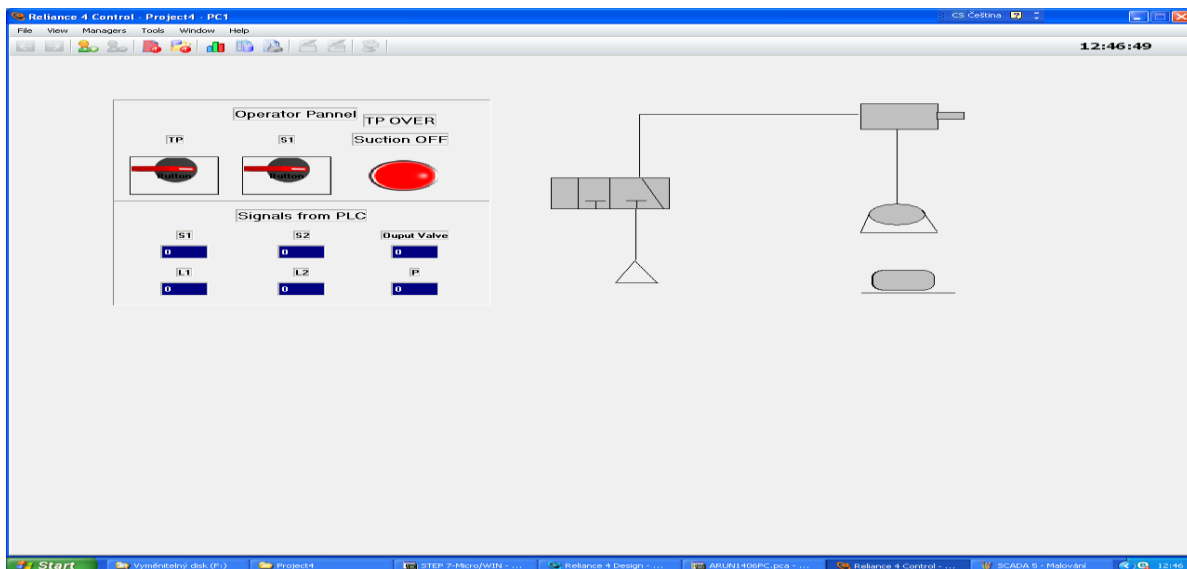


Figure 63: Run time environment of Task 5- part 1

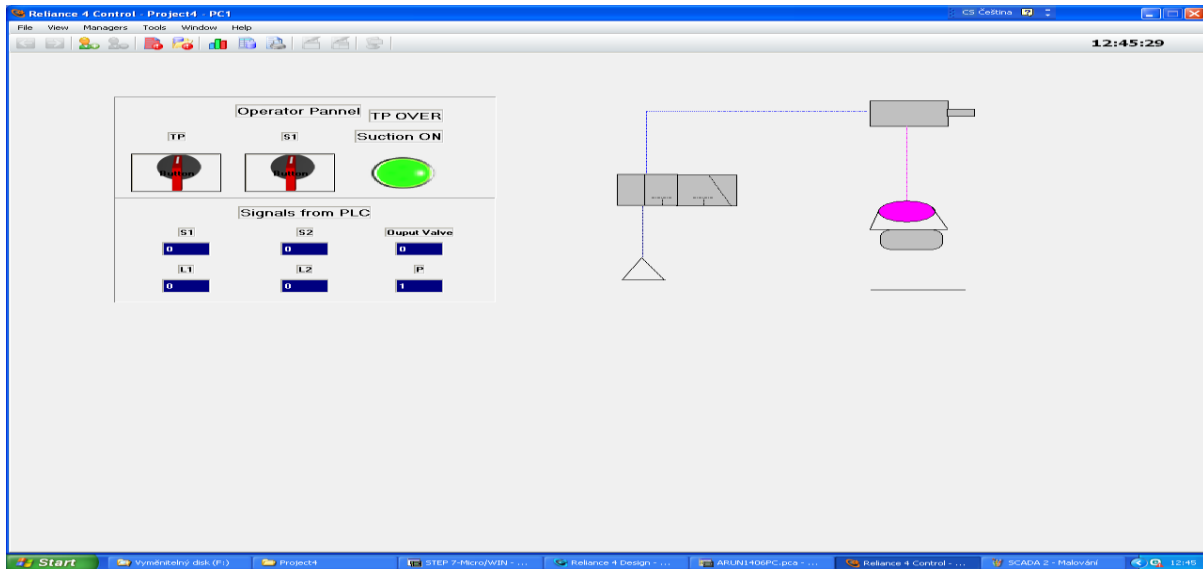


Figure 64: Run time environment of Task 5- part 2

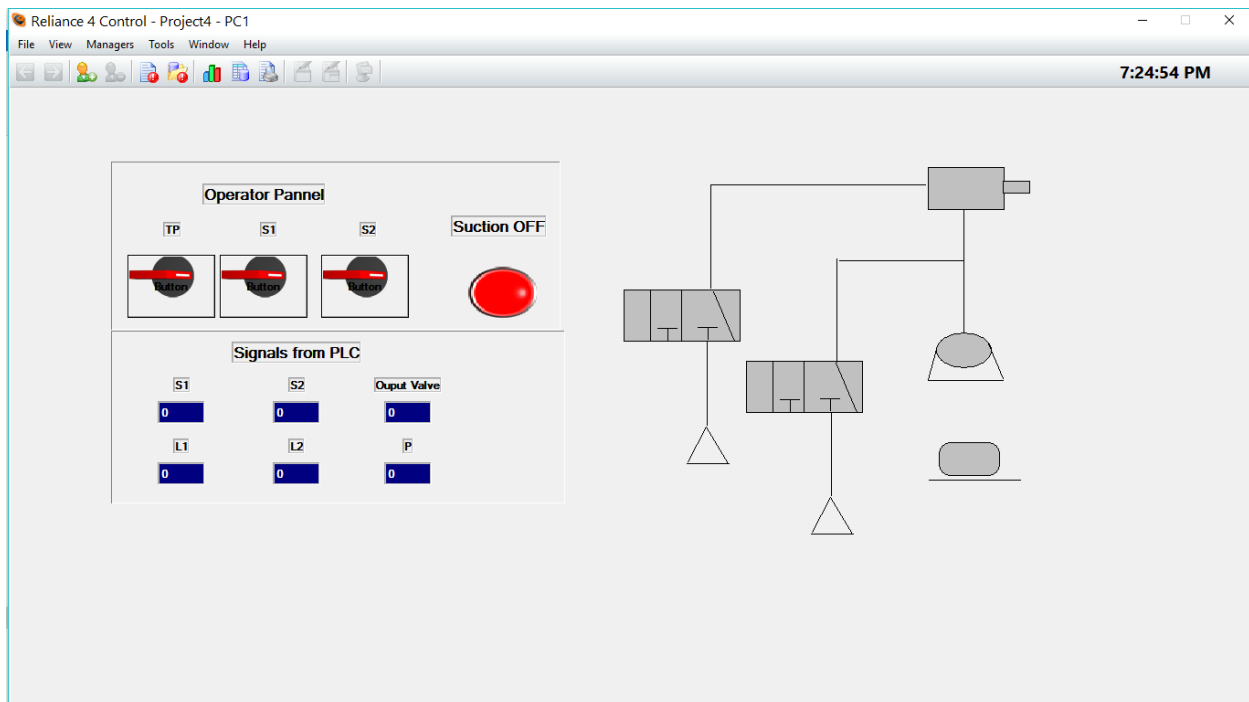


Figure 65: Run time environment of Task 6



The run time environment of Task 6 has some limitations but the basic concept was working one switch is for ejection and other switch is for suction. Once the control by PLC and design of SCADA is done now the PLC and SCADA have to communicate with each. The following chapters will give the detailed information communication between PLC to PC and SCADA.

CHAPTER 7 COMMUNICATION BETWEEN PLC – PC – SCADA.

7.1 Steps for communication

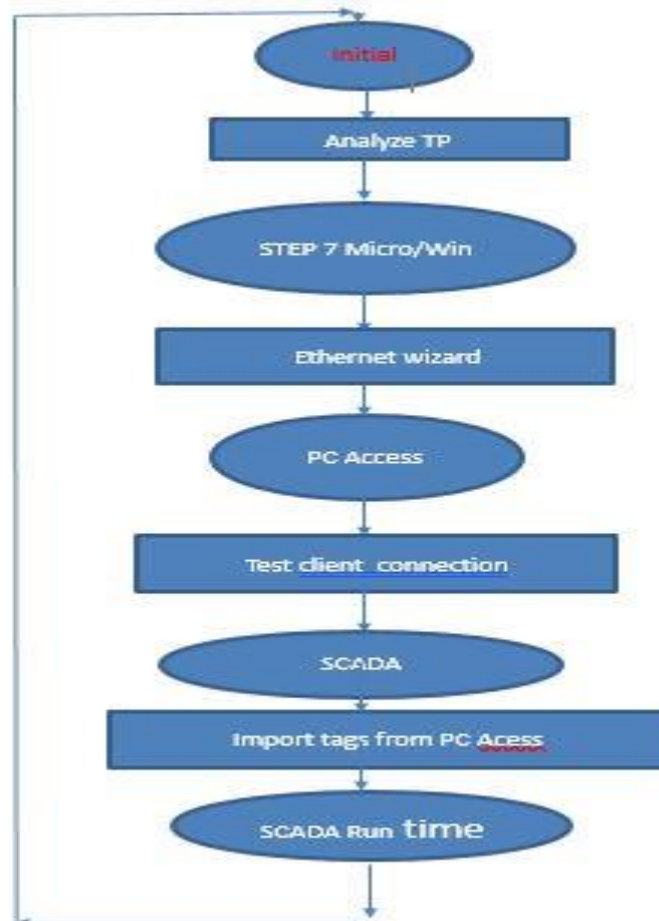


Figure 66: Steps for communication



These steps are useful in debugging error in the communication. If one requires to communicate from field level actuators to SCADA HMI, these steps has to be followed in a given sequential manner to get the desirable communication.

7.2 OPC server

OPC server is an application created specifically for the devices to communicate between the OPC clients. This is used in I/O problems due to driver issues, each software and each PLC have different driver to communicate but OPC provides common platform for all the clients and server which is connected in a network. SCADA is also a client of OPC server.

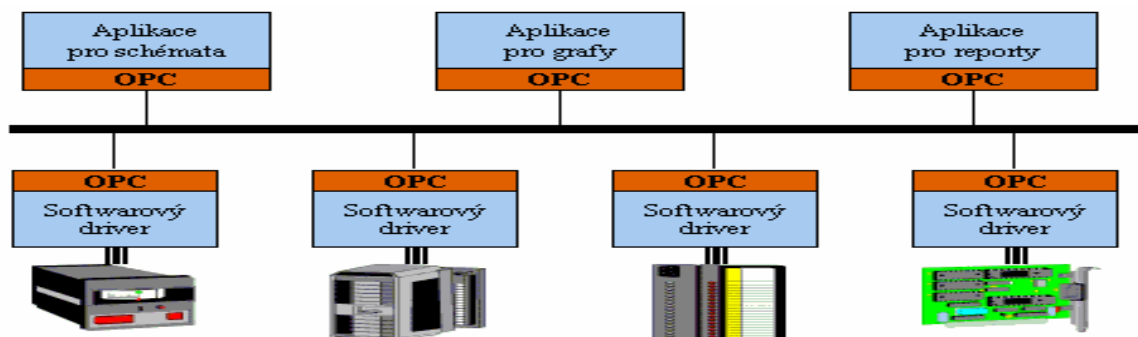


Figure 67: OPC Server^[6]

7.3 PC Access

The PC Access is bridge between the physical field levels devices to upper levels of automation. The PC Access is OPC client which provides the common platform to communicate in the network.

7.4 Setting of parameters

The communication has certain parameters that needs to be satisfied to function properly. After configuring the ethernet wizard the configuration of PC Access should be set with correct parameters. This section will guide us to set the



correct configuration of the PC Access correctly and too achieve proper communication.

7.4.1 Reading the symbols from the PLC projects

From the window of PC Access, it is necessary follow the below instructions to get the symbols from PLC and make available for the SCADA.

Step 1: Files → Import symbols → Choose the project → Get the tags on the PC Access window → Click drag them to the test client space → Run the test client.

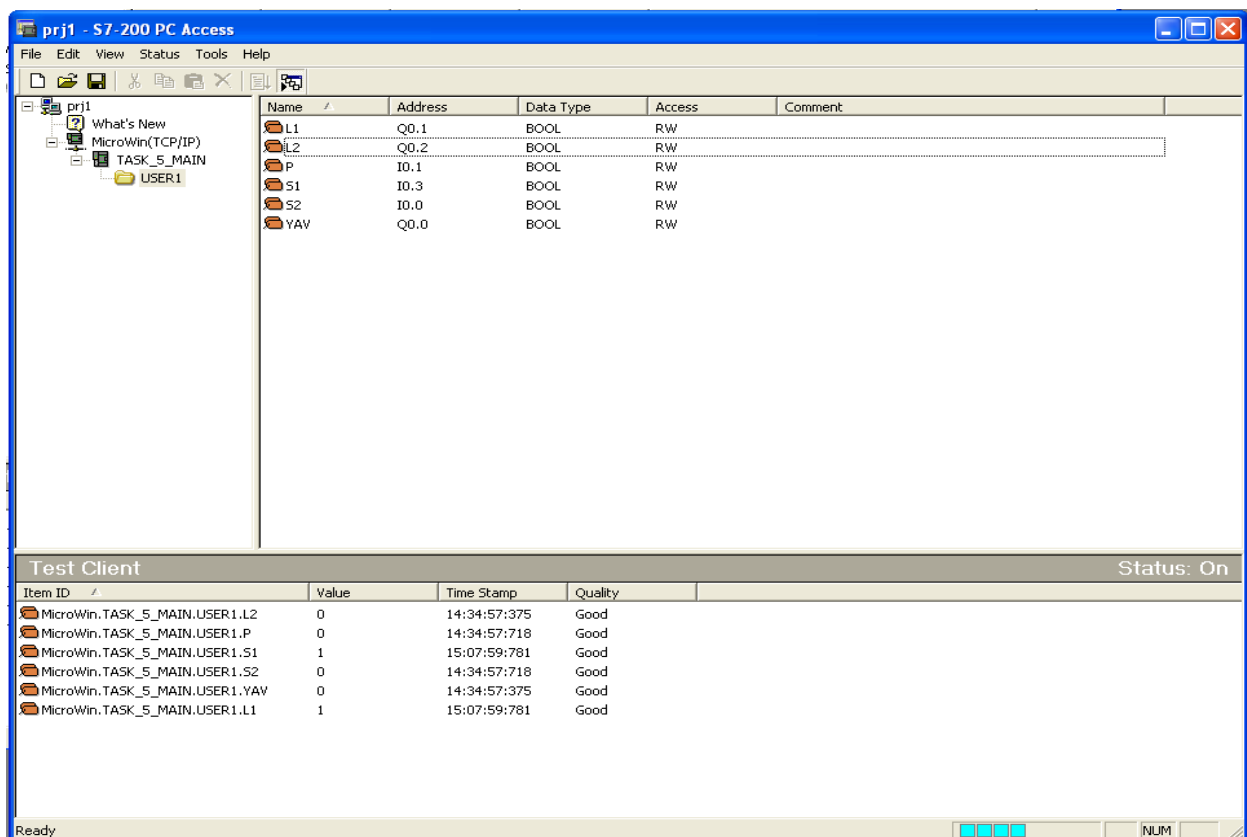


Figure 68: PC Access



7.5 Problems and solutions

- The main problem faced in the S7- 200 PC Access is each time when the server is in active, it is impossible to save the configurations. The configurations must be save so that the tags can be imported successfully in the SCADA software.
- Errors were made during configuring the Ethernet wizard which changes the IP address of the PLC's in an Ethernet network. In this step, the exact IP address of the PLC should be assigned to IP address space which is shown in the figure 69.

Module Address

Please select the address to assign to this CP 243-1 module. If your network provides a BOOTP server (a service that will automatically assign IP addresses at startup), you may choose to have an IP address automatically assigned.

IP Address: 147 . 32 . 167 . 106

Subnet Mask: 255 . 255 . 240 . 0

Gateway Address: 0 . 0 . 0 . 0

Allow the BOOTP server to automatically assign an IP address for the module.

Module Connection Type

Specify the communications connection type for this module.

Auto Detect Communications

<Prev Next> Cancel

Figure 69: Important configuration setting

- Another problem is when importing symbols from Micro/WIN projects, each time in the properties of the project the TSAP value should match with value at the 5th step of the Ethernet wizard that is shown in figure.

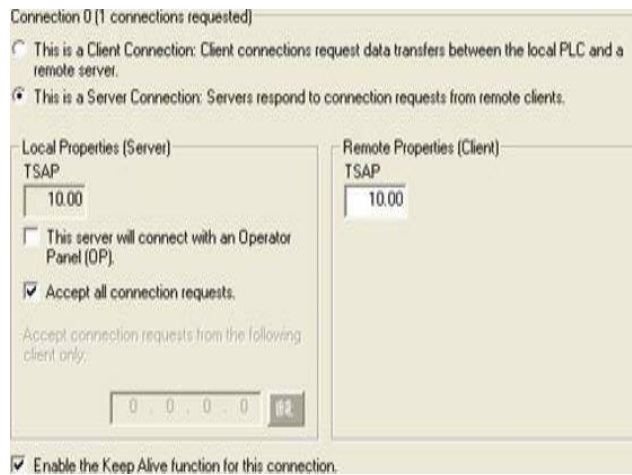


Figure 70: TSAP properties

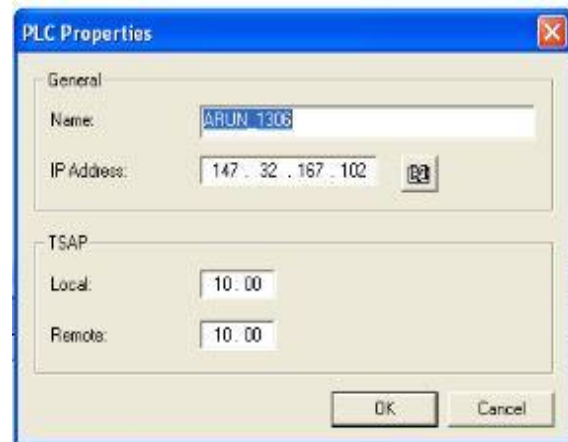


Figure 71: PC Access properties

7.5.1 TSAP

A Transport Services Access Point (TSAP) is an end-point for communication between the Transport layer (layer 4) and the Session layer in the OSI (Open Systems Interconnection) reference model. Each TSAP is an address that uniquely identifies a specific instantiation of a service. TSAPs are created by concatenating the node's Network Service Access Point (NSAP) with a transport identifier, and sometimes a packet and/or protocol type.^[10]

The TSAP (Transport Service Access Point) addresses the channel you use for an Ethernet based communication. Basically, it gives the information about the PLC and its communication panel location which is connected in a network.

The TSAP contains two locations that is given below:

TSAP: 10.00 - It mean that

- 10 - Ethernet or IT module is connected next to the PLC
- 00 - use the first of the 8 communication channels.



CHAPTER 8 COMMUNICATION BETWEEN PC ACCESS AND SCADA

Once the communication between the PLC and PC Access is achieved and PC Access can read values from the PLC. Now it's time import this OPC tags to Reliance 4 SCADA.

8.1 Procedure for importing Tags from PC Access

1. After creating the project in the Reliance Design development environment and confirming the settings, it is suitable to choose what we are going to connect to, i.e., the type of PLC, driver, etc. In our case it is OPC. So, go to the Managers menu and bring up the Device Manager. Because an OPC server is used for the SIMATIC PLC, choose OPC and confirm.

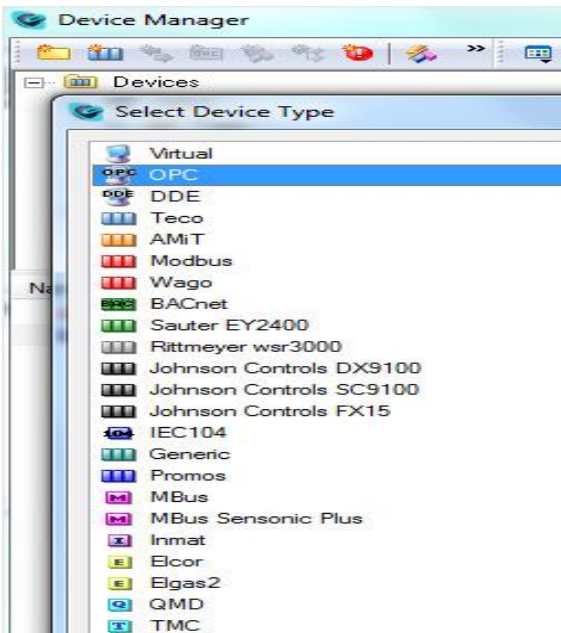


Figure 72: Adding OPC to project

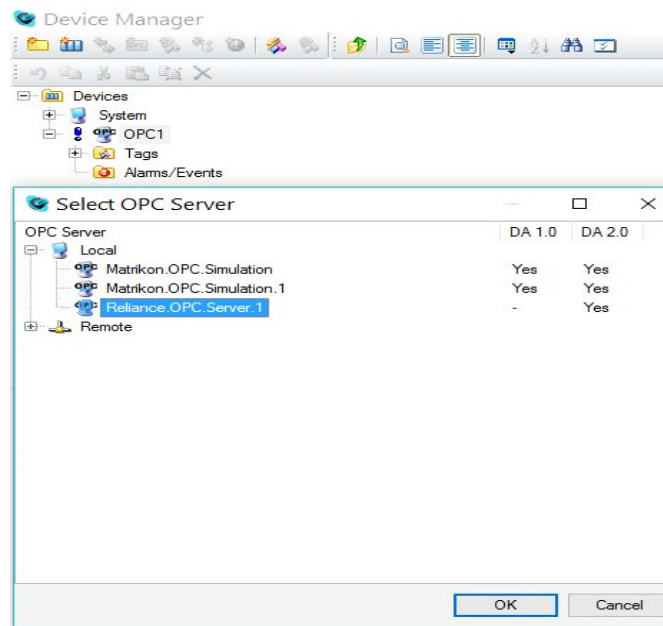


Figure 73: Selecting OPC server



2. On the left side of the manager window, click on OPC1. Then, click on the OPC icon next to the red cross in the basic tag of the OPC1. And Select OPC Server then Select the Reliance OPC server and confirm. Then, in the Tags folder, create the OPC Group subfolder into which tags from the OPC server.
3. Next step is the crucial step to import the tags from the OPC clients, and it is done by pressing the Import from OPC Server button.
4. Once the above step is done. you will have the window as shown figure-77 in that expand the type of the tags you need to get into the folder and simply move them by dragging with the mouse into the OPC Group 1 folder. Now, the tags are imported and ready to be used in the project. Save the changes and one pop window will come click yes. It allows you to connect the OPC server (OPC1) to the computer.

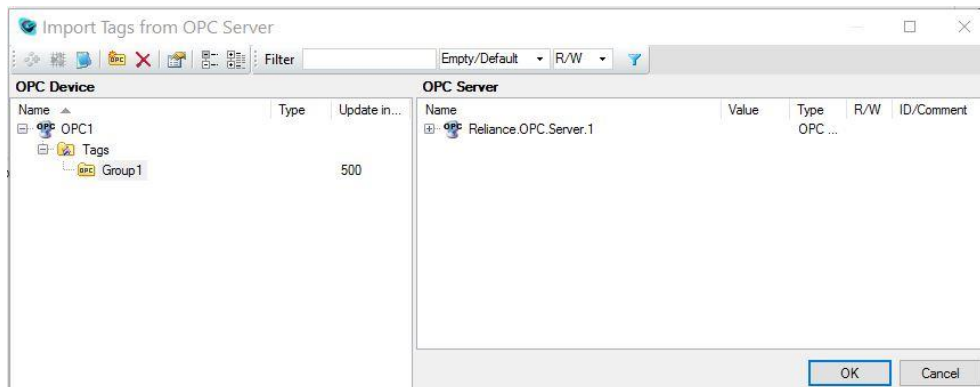


Figure 74: Importing from OPC server 1



8.2 Problems and solutions

1. The main problem is the order of opening the software, it should be in sequence of order.
 - a. Micro/Win S7-200
 - b. PC Access
 - c. Reliance 4 Design
2. At starting I opened the software randomly so I didn't achieve the desired output. And I faced difficulties in importing the tags from OPC this is solved by the proper setting the proper configuration in the PC access.
3. The next main problem is from SCADA design, the tags cannot write the values to the PLC, this is solved by creating the internal flags in the PLC coding.
4. Priorities should be set in the SCADA because there are two possibilities to start the process. One is through the switch and another is from SCADA itself. This kind of problems can be solved by giving priorities to the inputs to avoid the malfunctions in a complex control design.



CHAPTER 9 DATA EVALUATION

9.1 Calculating cost savings which result from the compressed air economy circuit

The data evaluation can be done in two methods:

1. Manual
2. Automatic

The manual calculations are calculated from the experiments results. The data are directly measured from the system and using mathematical calculations we can get required data.

To automate the calculation, we can get the data from the process using SCADA software. The field level elements give raw data. The SCADA can convert raw data into information. This can be done through scripts and also through introducing new filters in the SCADA software.

9.2 Manual evaluation

Consider the following conditions:

- Compressed air costs: €0.15 per m³ at 6 bar.
- Flow rate of a type H vacuum generator with an operating pressure of 6 bar: 12 l/min
- The lifting device is operated 8 hours a day.

In these conditions if we use air economy circuit which is the task 5, the air consumption will be reduced significantly.

From experimenting the Task 5 it is seen that the ON time range is faster than the OFF time of the vacuum generation. If the circuit is operated normally for 8 hours



a day without the air economy circuit it will consume more than with air economy circuit.

Without air economy circuit:

Compressed air consumption per day in minutes: 8 hours x 60 = 480 minutes

Vacuum generator operating time without air economy unit = 480 minutes

Consumed compressed air = 480 minutes x 12 liters per minute = 5760 liters

Costs for consumed compressed air = 5.76 m³ x €0.15 = €0.864

With air economy circuit:

Compressed air consumption per day in minutes: 8 hours x 60 = 480 minutes

Vacuum generator operating time = 480 ÷ 2 = 240 minutes

Consumed compressed air = 240 minutes x 12 liters per minute = 2880 liters

Costs for consumed compressed air = 2.88 m³ x €0.15 = €0.43

From the above calculations, it is clear that the cost is reduced to 50 %.

9.3 Automatic evaluation

The evaluation can be computed for the Task 5 in the SCADA by reading the switching frequency and the ratio between ON/OFF. With the help of scripts, we can get the required data.

In SCADA, it is also possible to use summary of computing the data gathered from PLC. For example, the great advantage of SCADA is to evaluate the data within the given requirements. For example, using filters.

To do these, first is to create data table to store the values from PLC in SCADA design. In the report manager add the created data table to create the data table



for the project. The reports for the project must be created. And from the created report from the data table, user can create a filter to get the required data at the run time environment of the SCADA.

The screenshot shows the 'Create Filter' dialog box. The 'Name' field is set to 'Filter5' and the 'Active' checkbox is unchecked. The 'Columns' tab is selected, displaying a list of columns with checkboxes. The column 'கேசி' is selected. The 'Range limits' section shows 'Minimum' and 'Maximum' values with 'Including limit' checked for both. The 'Value position' section has 'Inside range' selected. The 'OK' and 'Cancel' buttons are visible at the bottom right.

Figure 75: Creating filter in SCADA

By selecting the required data with help of filter, we formulate formulas in scripts and we get the required results. The important step is to select the required tag value. Once these steps are done, user can monitor and control the entire process.



CHAPTER 10 CONCLUSION

The control algorithm and visualization of the two tasks has been done and it is working successfully. The PLC hardware solution is implemented for the task-5 is shown in figure.

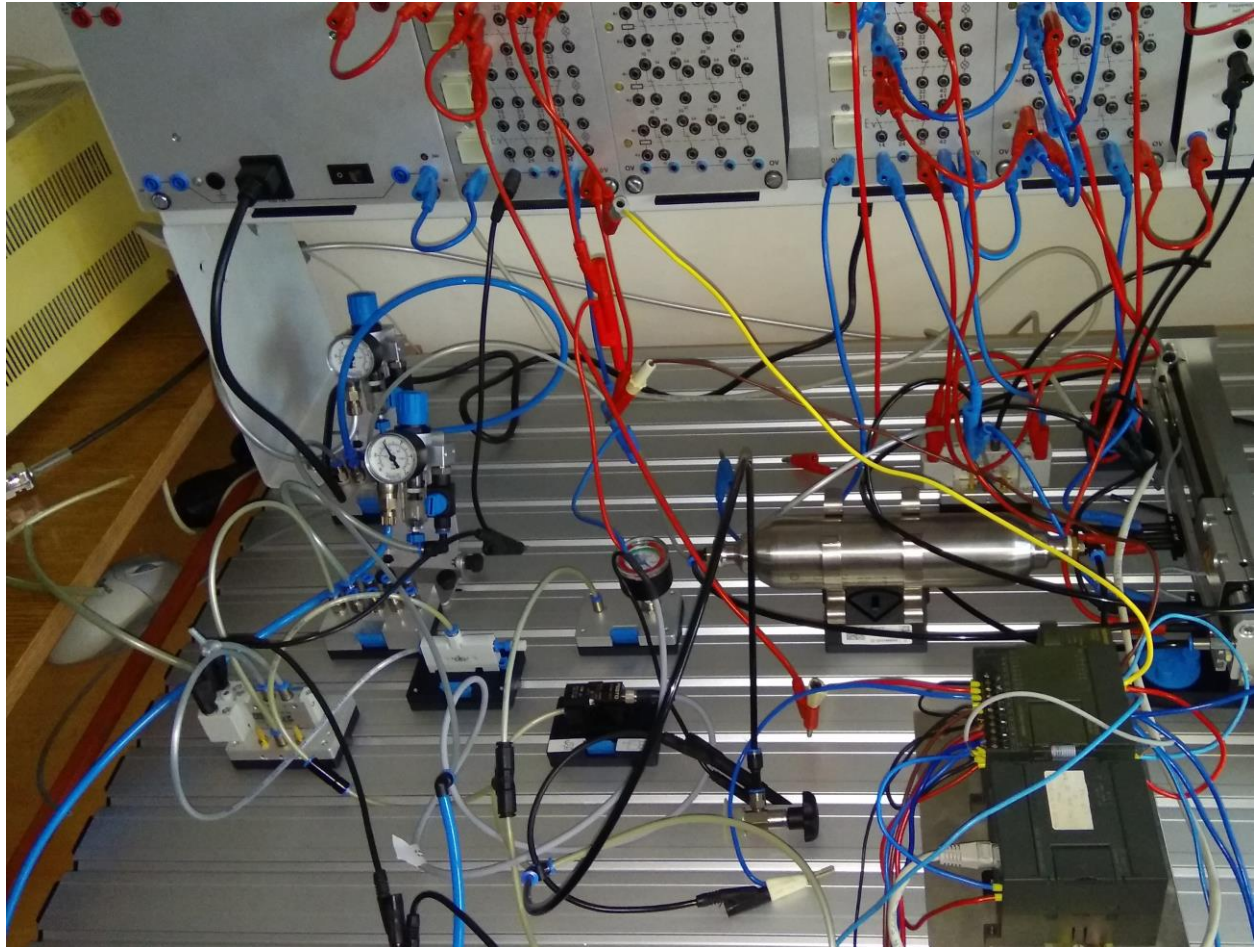


Figure 76: PLC hardware solution for Task 5

This thesis attempts to understand and test the vacuum handling applications by using automation principles. The basic terminologies of the Vacuum technologies are discussed and six experiments related to the vacuum technology TP230 were experimented.



In the six experiments, suitable two tasks are chosen. The control algorithm by PLC and design visualization by SCADA has been done and the results were successful. The vacuum technology has greater advantages in industrial applications specially in handling and transportation applications. The energy savings concept is truly fascinating and helps in the energy crisis faced by the industries.

It was a really personal challenge and great joy to learn vacuum technology with aid of real time equipment's like TP 230 kit from FESTO company. I am really glad and thankful to FESTO company to make learning easier with these types of study modules. Typical areas such as industrial handling equipment, vacuum generation, vacuum switch, several types of suction cups, ejection of work piece and energy savings in vacuum technology has been clearly understood. Throughout the thesis I had faced lot problems related with connections, tubing's, communication but all these elements make this thesis work interesting.

1. My first task was to study was to study the materials related to TP 230 set vacuum technology. I have done it and it is described in chapter 1 and 2.
2. Second task was to understand the basic six tasks of the vacuum technology and choose an experiment which is suitable to automate. I have done it with FluidSIM® V5.0 and described in the chapter 4.
3. Third task was to design the control algorithm by PLC SIMATIC S7 - 200 for the experiment 5 and 6. It has been done and I have described it in the chapter 5. Resulting state diagram corresponds to the desired functionality of the process.
4. Fourth task was to design a visualization for the selected experiment in the SCADA system. I have done it and it is described in the chapter 6.



5. The next task is to make the communication between the field level component to upper levels of automation such as SCADA software. The communication is successfully achieved and I have described it in the chapter 7 and 8.
6. My last task was to evaluate data from the measurements, I have done this and it is described in the chapter 9. Thus, all the specified tasks for this thesis work was fulfilled.

This thesis can be extended to evaluate the data by using SCADA, for that scripts should be used to calculate the necessary calculations. For the experiment 5, Due to time limitations I evaluated the data in hand but it is possible to calculate the time difference for the ON and OFF switching. By using scripts, we can have the data evaluated automatically in SCADA.

In conclusion, through this thesis work I have understood the concept of vacuum technology used in handling applications and learned how the communication works from field level to upper levels of automation.

Vacuum technology is vast area and I hope that this work can help as a guidance to the other students who would like to work on the vacuum technology in future.



CHAPTER 11 REFERENCES

11.1 List of Abbreviations used

PLC	Programmable Logic Controllers
SCADA	Supervisory Control And Data Acquisition
HMI	Human Machine Interface
LED	Light Emitting Diode
PC	Personal Computer
OPC	OLE for Process Control
RTU	Remote Terminal Unit
GUI	Graphic User Interface
LD	Ladder Diagram
SFC	Sequential Flow Chart
FBD	Functional Block Diagram
CPU	Central Processing Unit
TSAP	Transport Service Access Point



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