Sudan University of Science and Technology

College of Graduate Studies

PLC Based Pump Hydraulic Outlet Valve Automation

أتمتة الصمام الهايدروليكي للمضخة إعتماداً علي متحكمة المنطق المبرمجة

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in Mechatronics Engineering

Prepared by:

Talal Haydar Diab Mohammed

Supervisor:

Dr. Awadalla Taifour Ali Ismail

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Dedication

I dedicate this work to my father's memory who taught me this way to be life, to beloved mother

Who has strong and gentle soul who taught me to trust in Allah and to my family and friends for always supporting, helping and standing by me.

It is also dedicated to my wife who has been a source of encouragement and inspiration to me throughout my life.

Acknowledgements

Thanks to Allah almighty who give me the ability to conduct this research. Then

i would like to express my sincere gratitude to my supervisor Dr. Awadalla Taifour Ali for the continuous support of my research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. Besides my advisor, I would like to thank my colleagues Eng. Mohammed Abd Elrahman and Eng Mohammed Elmoatism for helping in implementation of this research and for encourage me. My sincere thanks also goes to Eng Bushar Musa and Eng. Abdelwahab Ismail and Eng. Ahmed Abd Elwahab and Eng Wegdan Hamid for giving me the required information to complete my research .Last but not the least, I would like to thank my family, my mother and my wife for encourage me, provide me support and help me throughout the research period.

Abstract

Automation becomes very essential in industrial field so as to protect the industrial equipments from human errors and to make the industrial process works in an efficient manner by selecting an accurate operating parameters with reduce the production and maintenance cost. The outlet hydraulic valve of raw water pump operated manually by using hand pump and this causes many problems such as putting the raw water pump in danger besides a great efforts from operator is needed and the operation process takes long time. The main goals of this research is finding the solution for these problems by making this valve working automatically and that will be fulfilled by designing and implementing a new control system includes Programmable Logic Controller (PLC). So to accomplish this design the hydraulic valve system is well understood and then the controller is designed accordingly after that this design is simulated in order to check the control system design which has been implemented in the next stage and the whole system is tested and the hydraulic valve is working automatically.

المستخلص

تعتبر الاتمتة (التشغيل الآلي)عاملا أساسيا في المجال الصناعي وذلك لحماية المعدات الصناعية من الأخطاء البشرية وجعل العملية الصناعية تعمل بطريقة فعالة عن طريق اختيار معايير دقيقة للتشغيل وبالتالي خفض تكلفة الإنتاج والصيانة. الصمام الهيدروليكي لخرج مضخة المياه يعمل يدويا باستخدام مضخة يدوية بواسطة المشغل و تسبب هذا الوضع في العديد من المشاكل مثل تعريض مضخة المياه لخطر التلف بسبب عدم تشغيل البلف مع المضخة علي حسب توصيات المصنع إلى جانب ذلك يبذل المشغل جهود كبيرة اثناء عملية التشغيل وذلك يستغرق المزيد من الوقت. الأهداف الرئيسية لإجراء هذا البحث هو إيجاد حل لهذه المشاكل مما يجعل هذا الصمام يعمل تلقائيا والتي سيتم الوفاء بها من خلال تصميم وتنفيذ نظام تحكم جديد يتضمن المتحكمة القابلة للبرمجة (PLC). لإنجاز هذا التصميم تمت دراسة نظام الصمام الهيدروليكي وذلك لاجل تحديد كيفية التحكم به وتحديد مدخلات ومخرجات هذا النظام ومن ثم تم تصميم وحدة تحكم وفقا لذلك بعد ذلك تمت محاكاة هذا التصميم من أجل التحقق من تصميم نظام التحكم التي تم تنفيذها. في المرحلة التالية تم اختبار النظام بأكمله ووجد ان الصمام الهيدروليكي يعمل تلقائيا بصورة جيدة .

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List of Abbreviations

CPU	Central processing unit
CP	Communication Processor
DC/AC	Direct Current / Alternative Current
FBD	Function Block Diagram
HAWL	Hydraulic Actuators Weight-Loaded
I/O	Input/Output
LAD	Ladder Logic Diagram
LED	Light Emitting Diode
MOV	Metal Oxide Varistor
PG	Programming Device
PPI	Point to Point Interface
RAM	Random Access Memory
SCR	Silicon controlled Rectifier
STL	Statement List

Chapter one
Introduction

1.1 General Overview

Riverside water treatment system is one of essential systems in power plant because it prevents problems such as carryover to the turbine components, as well as corrosion and scale formation/deposition in the boiler and turbine systems The most appropriate raw water treatment system will help the facility avoid costly plant downtime, expensive maintenance fees . An efficient and well-designed raw water treatment system should be able to handle seasonal variations in turbidity and flow variations in water chemistry needs and required chemical volumes adjustments beside changes in water quality requirements (such as the quality of feed water required for a new boiler).

Raw water treatment system supplies the plant with raw water that needed in many systems such as Cooling water system to provide the condenser with cold water and also in demineralised water treatment plant which uses the raw water to produce the demineralised water that been used to fill the boiler and later to be converted to steam. In Khartoum North power station the system that responsible for supplying the power plant with raw water in riverside water treatment system is riverside forwarding system; it consists of four forwarding pumps and their outlet hydraulic valves. The old hydraulic valves are replaced by new type due to mechanical failure and lack of spare parts but this replacement generates new problems which I will try to find out solutions for it by conducting this research.

1.2 Problem Statement

The hydraulic valve is working manually only by using hand which needs a great effort and the operators get tired and this makes the system response is too slow when a raw water is requested for power plant .

Also the forwarding pump is started manually only without pump protection (should be working with outlet hydraulic valve as group) which is not recommended according to pump design specifications. In addition to that a new control panel is ordered from the supplier but his offer founded very expensive.

1.3 Research aims and objectives

The major objectives of the research are:

(a) To make new hydraulic valve work automatically.

(b) To reduce human intervention.

(c) To start forwarding pump and hydraulic valve as specified by the system designer.

(d) To reduce the cost of new control system for the hydraulic valve.

(e) To improve system response.

(f) To decrease human error by automating the system.

(g) To build a new controller for a new hydraulic valve using PLC.

(h) To Design a related control and power circuit

(i) To test the PLC and its control and power circuit then test the valve operations locally and remotely to ensure that the project goals are achieve.

1.4 Methodology

(a) Study the system hydraulic diagram and principle of operation to determine the control sequence and opening and closing interlocks and parameters

(b) List out the controller inputs and outputs variables

(c) Select a PLC controller that compatible with the inputs/outputs of the system which is Siemens step 7 -200 (CPU 224).

(d) Configure the PLC using ladder logic diagram language.

(e) To design new control circuit of hydraulic valve so it can be controlled remotely or locally and to allow hydraulic valve to be controlled automatically from main control system.

(f) To design new power circuit for hydraulic pump taking new hydraulic pump specification into consideration.

1.5 Thesis Layout

Chapter one is an introduction for research including the research problem identification. And the problem proposed solutions besides the research objectives and goals are clarified and the method that been used so as to solve the problem and achieve the objectives. In chapter two which is literature review the basic information about hydraulic system that been used in hydraulic valve and its components and its advantages over other systems has been discussed. In addition to this a control system that been used to control a hydraulic system is reviewed .In chapter three the system is fully described including the system hardware which consist of two parts hydraulic valve hardware and control system hardware then the software that been used for configuration purpose after that the system control philosophy is been simulated .In chapter four the control system for hydraulic valve is designed and implemented and tested to confirm the system objectives have been achieved .In chapter five the research conclusion and recommendations are listed.

Chapter Two

Theoretical Background and Literature Review

2.1 Introduction

In this chapter will discuss a basic information about hydraulic system that been used in hydraulic valve and its components and its advantages over other systems. Hydraulics has been defined as a study of the physical behavior of water at rest and in motion [1]. This term has expanded in meaning to include the physical behavior of all liquids. This includes the oils used in present day hydraulic systems and it is one of drives system to control machinery and equipments. It is extremely important to the operation of heavy equipment. In addition to this a control system that been used to control a hydraulic system and their types and we will focus on sequence logic control and its relation with hydraulic circuit. Finally the controller that been selected as system controller is discussed which is programmable logic controller.

2.2 Hydraulic Systems

It is an enclosed fluid system that can provide both linear as well as rotary motion. The high magnitude controlled force can also be applied by using these systems. This kind of enclosed fluid based systems using pressurized incompressible liquids as transmission media are called as hydraulic systems and it is part of fluid power system. In hydraulic systems, forces that are applied by the liquid are transmitted to a mechanical mechanism. To understand how hydraulic systems operate, it is necessary to understand the principles of hydraulics.

2.2.1 Hydraulic system principles

Fluid power system is defined as a technology that deals with generation, control and transmission of power using pressurized fluid which is divided into pneumatic and hydraulic system [2]. Hydraulic system uses liquids such as oil and water as fluid medium and transmitting power using pressure and flow of liquid.

The hydraulic system works on the principle of Pascal's law which says that the pressure in an enclosed fluid is uniform in all the directions [3]. The Pascal's law is illustrated in Figure 2.1. The force given by fluid is given by the multiplication of pressure and area of cross section. As the pressure is same in all the direction, the smaller piston feels a smaller force and a large piston feels a large force. Therefore, a large force can be generated with smaller force input by using hydraulic systems.

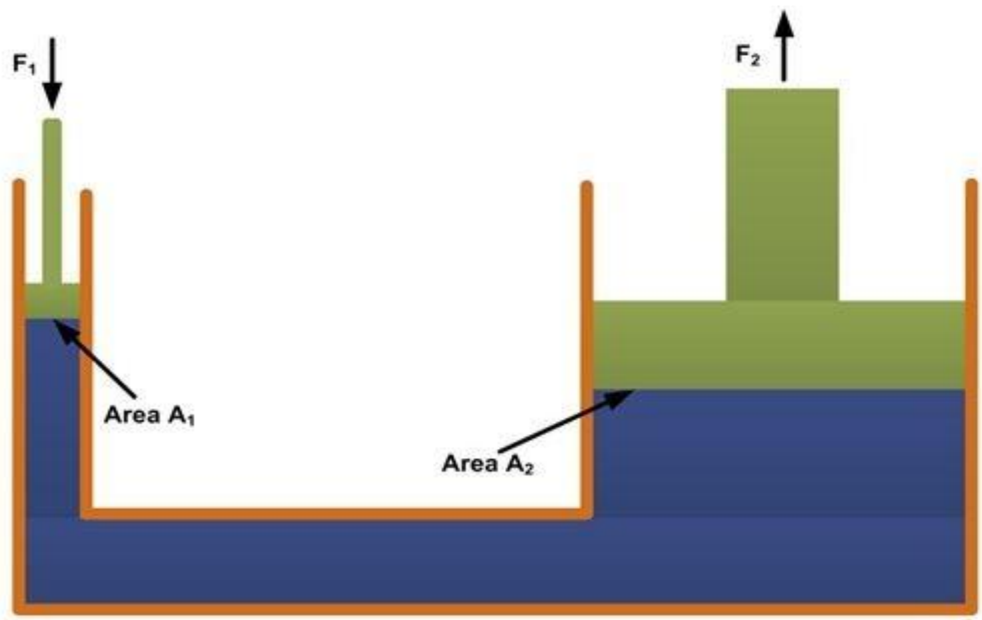


Figure 2.1: Pascal law

Where $F2 \times A1 = F1 \times A2$ or $F2 = F1 \times \frac{A1}{A2}$ F1and F2 represent the force on area A1 and A2 respectively . The use of hydraulic fluids to generate and transmit power is based upon physical laws which govern the mechanics` of liquids

2.2.2 Hydraulic system components

Although hydraulic circuit layouts may vary significantly in different applications, many of the components are similar in design or function. All hydraulic circuits are essentially the same regardless of the application. There are four basic components required; a reservoir (tank) to hold the fluid; a pump to force the fluid through the system; valves to control the flow; and an actuator to convert the fluid energy into mechanical force to do the work so the main components of hydraulic system are :

A. Hydraulic Pump

The combined pumping and driving motor unit is known as hydraulic pump. The hydraulic pump takes hydraulic fluid (mostly some oil) from the storage tank and delivers it to the rest of the hydraulic circuit. In general, the speed of pump is constant and the pump delivers an equal volume of oil in each revolution and the hydraulic pumps are characterized by its flow rate capacity, power consumption, drive speed, pressure delivered at the outlet and efficiency of the pump.

The hydraulic pumps can be classified to multiple types so we will concentrate on positive displacement type including major pumps types.

i. Gear pump

Gear pumps are the most widely used pumps for hydraulic systems. They are available in a wide range of flow and pressure ratings. The drive and gears are the only moving parts gear pump is a robust and simple positive displacement pump. It has two meshed gears revolving about their respective axes. They are compact, relatively inexpensive and have few moving parts. The rigid design of the gears and houses allow for very high pressures and the ability to pump highly viscous fluids. One of typical type of gear pump is external gear pump which externally meshed two gears housed in a pump case as shown in Figure 2.2. One of the gears is coupled with a prime mover and is called as driving gear and another is called as driven gear. The rotating gear carries the fluid from the tank to the outlet pipe. The suction side is towards the portion whereas the gear teeth come out of the mesh. When the gears rotate, volume of the chamber expands leading to pressure drop below atmospheric value. Therefore the vacuum is created and the fluid is pushed into the void due to atmospheric pressure. The fluid is trapped between housing and rotating teeth of the gears [4]. The discharge side of pump is towards the portion where the gear teeth run into the mesh and the volume decreases between meshing teeth. The pump has a positive internal seal against leakage; therefore, the fluid is forced into the outlet port.

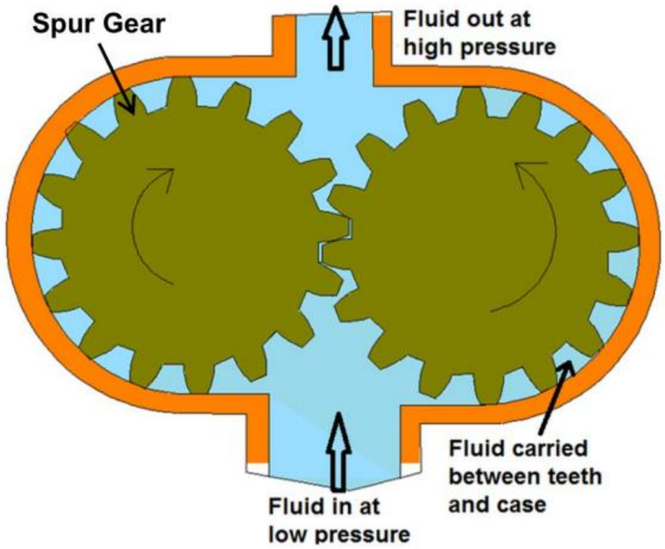


Figure 2.2: External gear pump

ii. Vane pump

This pump intake and discharge fluid according to the change of space enclosed by the vane and the cam ring that rotates by means of rotor. The schematic of vane pump working principle is shown in Figure 2.3. Vane pumps generate a pumping action by tracking of vanes along the casing wall. The vane pumps generally consist of a rotor, vanes, ring and a port plate with inlet and outlet ports. The rotor in a vane pump is connected to the prime mover through a shaft.

The vanes are located on the slotted rotor. The rotor is eccentrically placed inside a cam ring as shown in the figure. The rotor is sealed into the cam by two side plates. When the prime mover rotates the rotor, the vanes are thrown outward due to centrifugal force. The vanes track along the ring. It provides a tight hydraulic seal to the fluid which is more at the higher rotation speed due to higher centrifugal force. This produces a suction cavity in the ring as the rotor rotates. It creates vacuum at the inlet and therefore, the fluid is pushed into the pump through the inlet. The fluid is carried around to the outlet by the vanes whose retraction causes the fluid to be expelled. The capacity of the pump depends upon the eccentricity, expansion of vanes, and width of vanes and speed of the rotor.

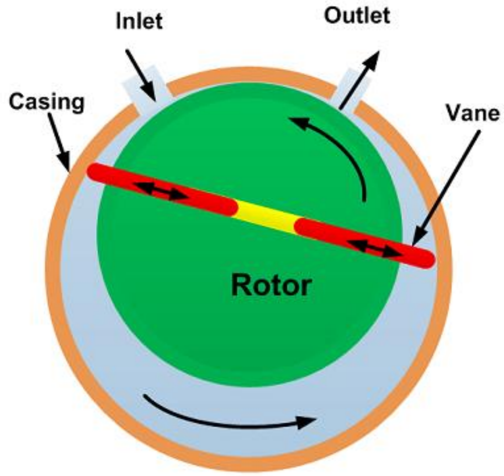


Figure 2.3: Vane pump working principle

iii. Piston pump

Piston pumps are meant for the high-pressure applications. These pumps have high efficiency and simple design and needs lower maintenance. These pumps convert the rotary motion of the input shaft to the reciprocating motion of the piston. These pumps work similar to the four stroke engines. They work on the principle that a reciprocating piston draws fluid inside the cylinder when the piston retracts in a cylinder bore and discharge the fluid when it extends. Generally, these pumps have fixed inclined plate or variable degree of angle plate known as swash plate as shown in Figure 2.4 .When the piston barrel assembly rotates, the swash plate in contact with the piston slippers slides along its surface. The stroke length (axial displacement) depends on the inclination angle of the swash plate. When the swash plate is vertical, the reciprocating motion does not occur and hence pumping of the fluid does not take place. As the swash plate angle increases, the piston reciprocates inside the cylinder barrel. The stroke length increases with increase in the swash plate angle and therefore volume of pumping fluid increases. During one half of the rotation cycle, the pistons move out of the cylinder barrel and the volume of the barrel increases. During another half of the rotation, the pistons move into the cylinder barrel and the barrel volume decreases. This phenomenon is responsible for drawing the fluid in and pumping it out. These pumps are positive displacement pump and can be used for both liquids and gases.

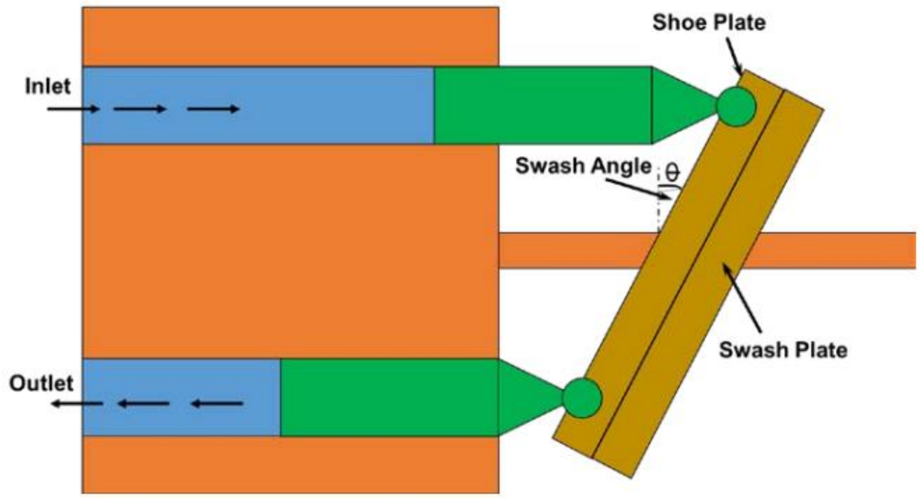


Figure 2.4: Swash plate piston pump

This type of piston pump in Figure 2.4 called swash plate piston pump which translates the rotary motion of a shaft into the reciprocating motion. It consists of a disk attached to a shaft as shown in Figure 2.4. If the disk is aligned perpendicular to the shaft; the disk will turn along with the rotating shaft without any reciprocating effect. Similarly, the edge of the inclined shaft will appear to oscillate along the shaft's length. This apparent linear motion increases with increase in the angle between disk and the shaft [5] (offset angle). The apparent linear motion can be converted into an actual reciprocating motion by means of a follower that does not turn with the swash plate. Another type of axial piston pump is called bent-axis piston pump as shown in Figure 2.5 .In these pumps; the reciprocating action of the pistons is obtained by bending the axis of the cylinder block. The cylinder block rotates at an angle which is inclined to the drive shaft. The cylinder block is turned by the drive shaft through a universal link. The cylinder block is set at an offset angle with the drive shaft.

The cylinder block contains a number of pistons along its periphery [5]. These piston rods are connected with the drive shaft flange by ball-and socket joints. These pistons are forced in and out of their bores as the distance between the drive shaft flange and the cylinder block changes. A universal link connects the block to the drive shaft, to provide alignment and a positive drive.

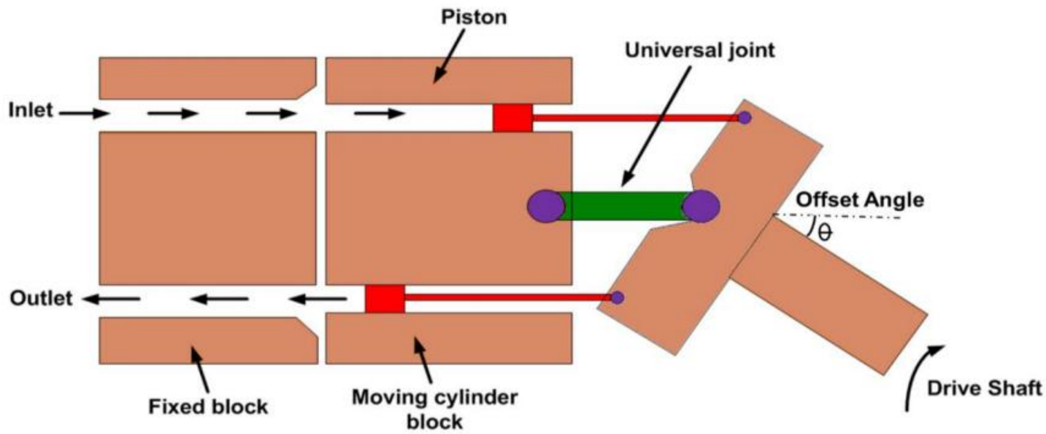


Figure 2.5: Bent axis piston pump

iv. Screw pump

A screw pump is an axial-flow gear pump. Figure 2.6 shows a two-rotor screw pump with helical gears. Liquid is introduced at the two ends and discharged at the center. The seal is formed by the contact of the two gears at the intersection of their addenda and by the small clearance between the gears and the pump housing. In pumps employing double helical gears, as shown in Figure 2.5, the thrust loads are balanced. This design is frequently employed in large pumps. Screw pumps are especially applicable where quiet operation is essential. In screw pumps, the gears must be in contact at the intersection of their addenda. This contact plus the minimum clearance at the outside diameter of the gears, provides a series of sealed chambers along the length of the screws. Screw pumps can also be arranged with three rotors. The center gear is the driver, and no timing gears are necessary [6].

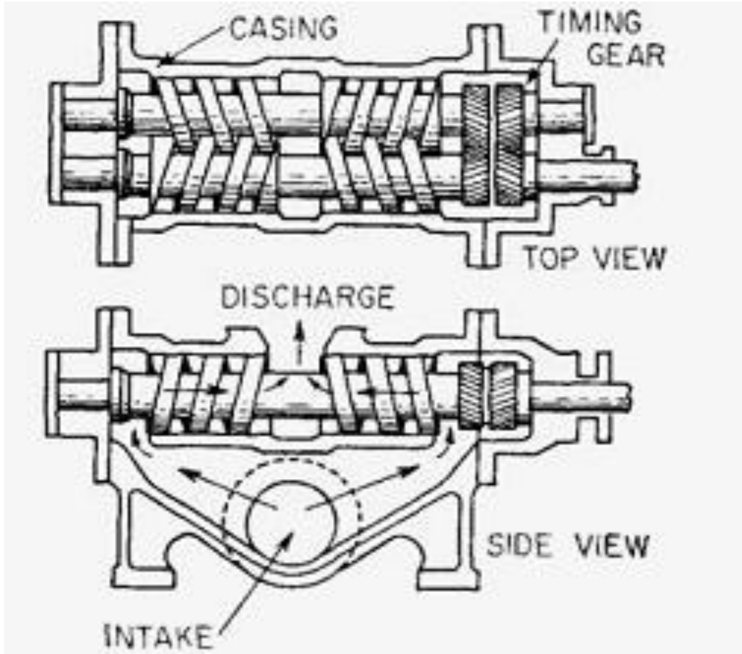


Figure 2.6: Screw pump

B. **Hydraulic control valves**

Hydraulic control valves are devices that use mechanical motion to control a source of hydraulic power .They varied in design and complexity depending on their function .They play as interface between fluid power and mechanical in hydraulic system. They classified to many types according to their function and design so here are some types of them.

a. Pressure control valve

Used to control hydraulic fluid pressure in hydraulic system and it consists of different types according to its function in hydraulic circuit [7].

i. Relief valve

These relief valves protect pumps and other control valves from excessive pressure in hydraulic systems and maintain a constant system pressure. The variations are the direct, pilot operated, and solenoid controlled types for example direct type relief valve which used to relief hydraulic pressure when getting high. Figure 2.7 shows the relief valve.

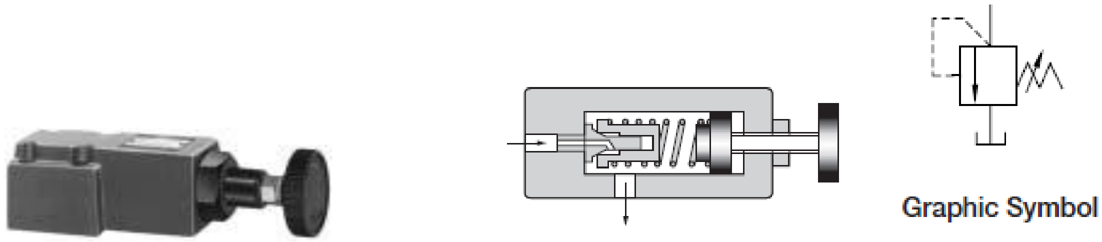


Figure 2.7: Relief valve

ii. Sequence valve

It is used in a fluid system where a set of operations are to controlled in a pressure related sequence for example, with the normal pressure, one operation is performed when the pressure exceed the preset limit in sequence valve it will open to let the second operation to be performed. Figure 2.8 shows the sequence valve.

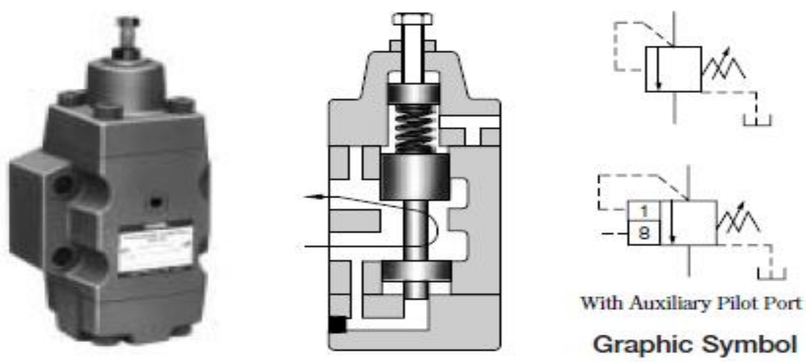


Figure 2.8: Sequence valve

iii. Counterbalance valve

It maintains hydraulic pressure in a hydraulic system or load backpressure on a cylinder. If the inlet pressure exceeds a preset level, flow is released to keep the pressure constant. They are accompanied with a check valve that allows the flow for lifting a cylinder up to freely pass to control the cylinder speed [6].Figure 2.9

shows the unloading valve.

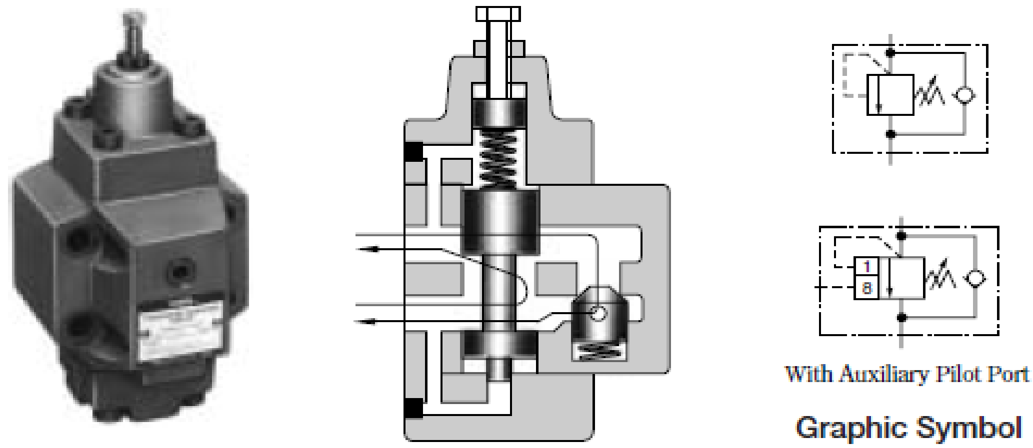


Figure 2.9: Counterbalance valve

iv. Unloading valve

In many hydraulic system, the hydraulic pump is kept running continuously. It is not advisable to switch the pump ON and OFF frequently to meet the load requirements so in no load situation an unloading valve will relief the pump pressure to the tank.

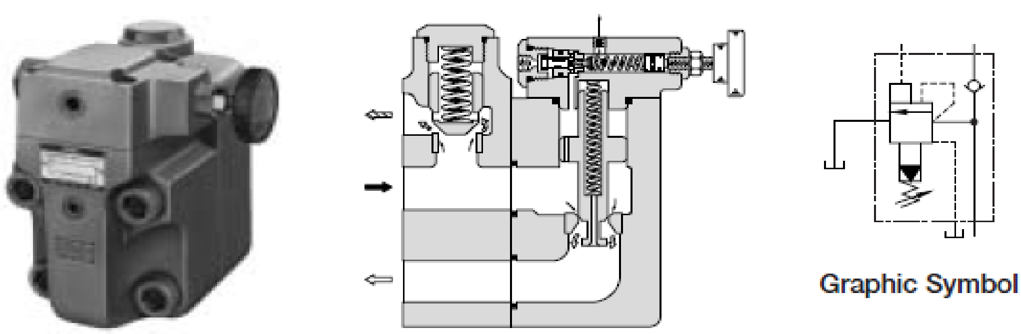


Figure 2.10: Unloading valve

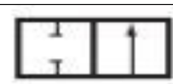
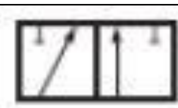
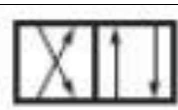
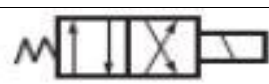
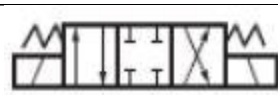
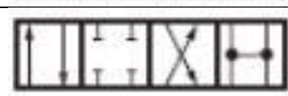
b. Directional control valve

A directional control valve is a device that uses mechanical motion to source of fluid power [8]. It used to control start/stop, directions, and acceleration/deceleration of hydraulic cylinders and motors. They can be used in a various applications, and a wide range of products is available. They can be categorized into three types: spool, poppet, and ball. The spool type can be either a sliding type or a rotary type. The former is the most popular for pressure balancing and high capacity. The poppet type offers excellent leak-tight capability (zero leak) for its poppet-seat contact. The ball type is an alternative for the poppet; a ball is used instead of a poppet.

- Ports and positions in directional valve

  The port (way) count indicates the number of connectable lines, and the position count indicates the number of changeovers in the directional control valves. The four ports include: pump port (P), tank port (T), and cylinder ports (A and B). The Table 2.1 shows the control valves ports and position symbols.

Table 2.1: Control valve ports and positions

Classification		**Graphic symbol**	**Remarks**
No of Ports	Two Ports		This valve has two ports to open /close a hydraulic line
	Three Ports		This valve has three ports for changeover from the pump port to two ways only
	Four Ports		This valve has four ports for a wide variety of purposes ,including moving the actuator forward and backward or stopping it
	Multiple Ports		This valve has five or more ports for special purposes
No of positions	Two Positions		This valve has two positions
	Three Positions		This valve has three positions
	Multiple Positions		This valve has four or more positions for special purposes

- Directional control valve actuation

  The control valve can be actuated by various methods and the method of actuation depends on the valve design and requirements of the application.

- Manual actuation

  This most common method of actuation that require action by operator who must make control action based on system requirements. Levers pushbutton and pedal could be used

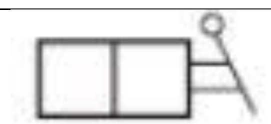
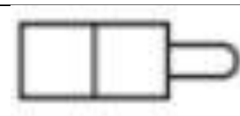
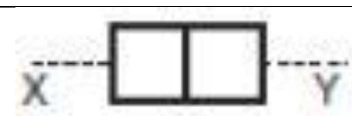
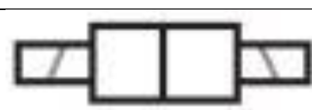
- Mechanical actuation

  It includes springs and plungers rollers, and cams but the spring and plunger are most commonly used to provide force of several of valve operations

- Electrical actuation

  Usually uses solenoid which is an electromagnetic coil when it is energized it creates a magnetic force that pulls the armature. The armature is connected to the spool of the valve and the valve is actuated. Solenoids are available in AC or DC and it provides flexibility in hydraulic system design because system command can be obtained from signal in any port of circuit. Table 2.2 shows the control valve actuation types.

Table 2.2 Control valve actuation types

Manual		Operated manually with lever
Mechanical		Operated mechanical components ,including cam flower
Pilot Operated-Hydraulic		Operated by pilot
Solenoid Operated		Operated by electromagnetic force

A. Accumulator

Accumulators are devices that store energy in the form of fluid under pressure. Because of their ability to store excess energy and release it when needed, accumulators are useful Tools for improving hydraulic efficiency. Industrial hydraulic accumulators are typically classified as hydro pneumatic. This type of accumulator applies a force to a liquid by using compressed gas the purpose of a hydraulic accumulator is to store hydraulic fluid under pressure. It may be used to:

- Dampen hydraulic shocks which may develop when pressure surges occur in hydraulic systems.
- Add to the output of a pump during peak load operation of the system, making it possible to use a pump of much smaller capacity than would otherwise be required.
- Absorb the increases in fluid volume caused by increases in temperature

2.3 Control System Theory

Control system design must start with a precise analysis of the movements which must be performed, normally using a distance-time diagram. It is then necessary to allocate power components (e.g. cylinders) to achieve these movements and select suitable control Components (e.g. robots). The major problem is then to plot the circuit to achieve correct Working with no possibility of lock-up and, preferably, elimination of all redundancies. This can demand considerable skill and experience in circuit design and is normally best done on a logic basis .The combination of hydraulic actuation n and electrical control has often been seen as an ideal partnership [9]. Many control applications do not involve analog process variables, that is, the ones which can assume a continuous range of values, but instead variables that are set valued, that are they only assume values belonging to a finite set [9]. The simplest examples of such variables are binary variables that can have either of two possible values, (such as 1 or 0, on or off, open or closed etc.). These control systems operate by turning on and off switches, motors, valves, and other devices in response to operating conditions and as a function of time. Such systems are referred to as sequence/logic control systems. For example, in the operation of transfer lines and automated assembly machines, sequence control is used to coordinate the various actions of the production system (e.g., transfer of parts, changing of the tool, feeding of the metal cutting tool, etc.).Note that some of these can also be operated using analog control methods. However, in specific applications they may be viewed as discrete control or sensing devices for two reasons, namely:-

A. The inputs to these devices only belong to two specific sets. For example in the control of a reciprocating conveyor system, analog motor control is not applied. Simple on-off control is adequate. Therefore for this application, the motor-starter actuation system may be considered as discrete.

B. Often the control problem considered is supervisory in nature, where the problem is provide different types of supervisory commands to automatic control systems, which in turn carry out analog control tasks, such that overall system operating modes can be maintained and coordinated to achieve system objectives. The simplest control level is the logic controller which carries out a sequence of predefined operations, using a PLC. The majority of these are general purpose devices but there are some hydraulic specific controllers which can be used in this way generally giving much more than the basic features. PLCs usually work with digital inputs and outputs requiring various actions to be completed before the next step in the sequence.

2.4 Programmable Logic Controllers

A modern controller device used extensively for sequence control today in transfer lines, Robotics, process control, and many other automated systems is the PLC. In essence, a PLC is a special purpose industrial microprocessor based real-time computing system, which performs the following functions in the context of industrial operations.

PLC is a special form of microprocessor-based controller that uses programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting, and arithmetic in order to control machines and processes [10].

The Hydramatic Division of the General Motors Corporation specified the design criteria for the first programmable controller in 1968 and their primary goal is to eliminate the high costs associated with inflexible, relay-controlled systems. The controller had to be designed in modular form, so that sub-assemblies could be removed easily for replacement or repair in case of failure of any part of the system so the system had to be reusable and the method used to program the controller had to be simple, so that it could be easily understood by plant personnel. Typically a PLC system has the basic functional components of processor unit, memory, power supply unit, input/output interface section, communications interface and the programming device. Figure 2.11 shows the basic components.

- The processor unit or Central Processing Unit (CPU) is the unit containing the microprocessor and this interprets the input signals and carries out the control actions, according to the program stored in its memory, communicating the decisions as action signals to the outputs.
- The power supply unit is needed to convert the mains AC. voltage to the low DC voltage (5V) necessary for the processor and the circuits in the input and output interface modules.
- And the programming device that is used to enter the required program into the memory of the processor. The program is developed in the device and then transferred to the memory unit of the PLC.
- The memory unit is where the program is stored that is to be used for the control actions to be exercised by the microprocessor and data stored from the input for processing and for the output for outputting

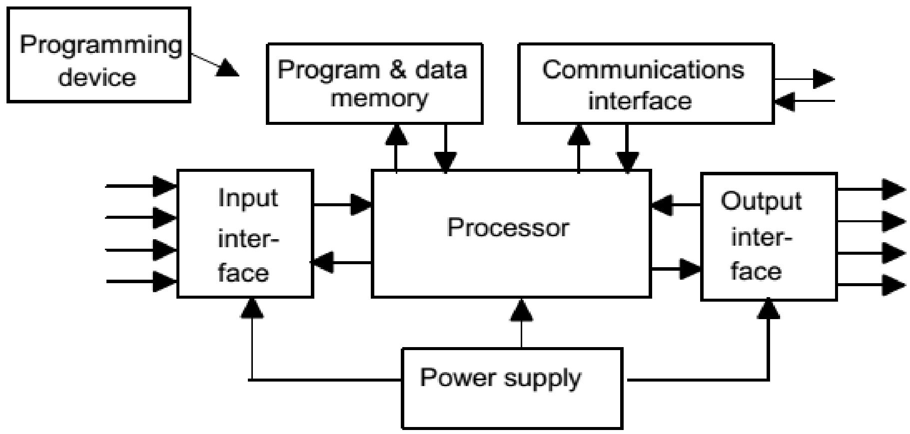


Figure 2.11: PLC architecture

2.4.1 PLC inputs and outputs modules

It provides signal conversion and conditioning and isolation between the internal logic- level signals inside the PLC and the field's high level signal and connects it to external field devices. The main purpose of the I/O interface modules is to condition the various signals received from or sent to the external input and output devices. So input modules convert signals from discrete or analog input devices to logic levels acceptable to PLC's processor whereas output modules converts signal from the processor to levels capable of driving the connected discrete or analog output devices [11].

a. AC/DC Inputs

Figure 2.12 shows a block diagram of a typical AC/DC input interface circuit. Input Circuits vary widely among PLC manufacturers, but in general, AC/DC interfaces operate similarly to the circuit in the diagram. An AC/DC input circuit has two Primary Parts: the power section and the logic section. These sections are normally, but not always, coupled through a circuit that electrically separates them, providing isolation.

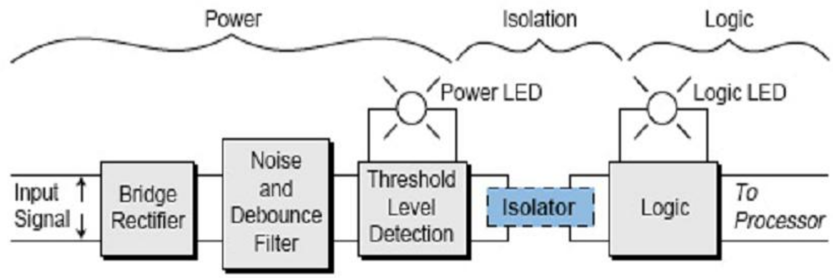


Figure 2.12: AC/DC input block diagram

The power section of an AC/DC input interface converts the incoming AC voltage from an input-sensing device to a DC, logic-level signal that the processor can use during the read input section of its scan. During this process, the bridge rectifier circuit of the interface's power section converts the incoming AC signal to a DC-level signal. It then passes the signal through a filter circuit, which protects the signal against bouncing and electrical noise on the input power line. This filter causes a signal delay of typically 9–25 msec. The power section's threshold circuit detects whether the signal has reached the proper voltage level for the specified input rating. If the input signal exceeds and remains above the threshold voltage for a duration equal to the filter delay, the signal is recognized as a valid input.

Figure 2.13 shows a typical AC/DC input circuit. After the interface detects a valid signal, it passes the signal through an isolation circuit, which completes the electrically isolated transition from an AC signal to a DC, logic-level signal. The logic circuit then makes the DC signal available to the processor through the rack's back plane data bus, a pathway along which data moves. The signal is electrically isolated so that there is no electrical connection between the field device (power) and the controller (logic). This electrical separation helps prevent large voltage spikes from damaging either the logic side of the interface or the PLC. An optical coupler or a pulse transformer provides the coupling between the power and logic sections[11].

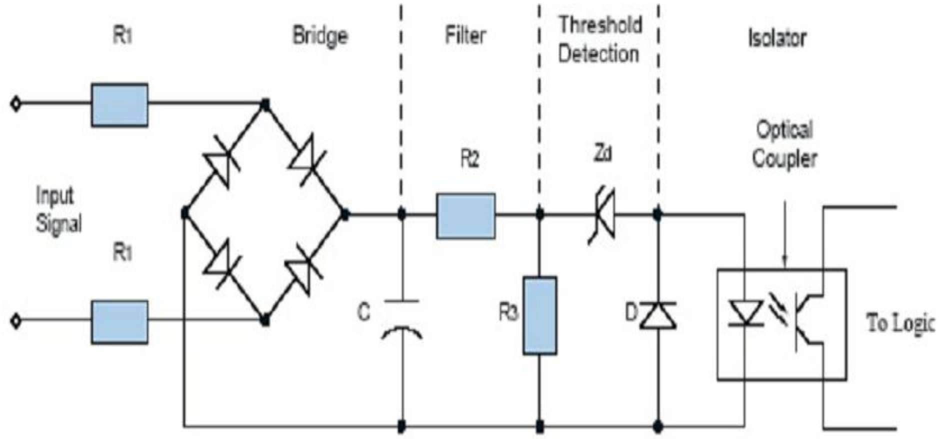


Figure 2.13: AC/DC input circuit

Most AC/DC input circuits have an LED (power) indicator to signal that the proper input voltage level is present. In addition to the power indicator, the circuit may also have an LED to indicate the presence of a logic 1 signal in the logic section. If an input voltage is present and the logic circuit is functioning properly, the logic LED will be lit. When the circuit has both voltage and logic indicators and the input signal is ON, both LEDs must be lit to indicate that the power and logic sections of the module are operating correctly. Figure 2.14 shows AC/DC device connection diagrams[11].

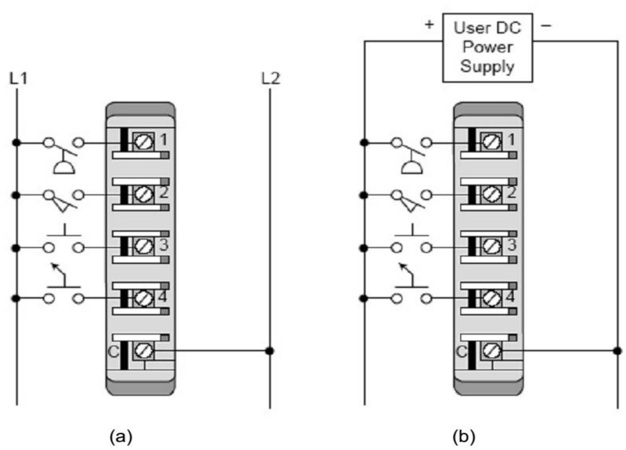


Figure 2.14: Device connection for (a) AC input circuit (b) DC input

i. DC inputs

A DC input module interfaces with field input devices that provide a DC output voltage. The difference between a DC input interface and an AC/DC input interface is that the DC input does not contain a bridge circuit, since it does not convert an AC signal to a DC signal. The input voltage range of a DC input module varies between 5 and 30 VDC. The module recognizes an input signal as being ON if the input voltage level is at 40% (or another manufacturer-specified percentage) of the supplied reference voltage. The module detects an OFF condition when the input voltage falls under 20% (or another manufacturer specified percentage) of the reference DC voltage.

b. Discrete outputs

Discrete output modules receive their necessary voltage and current from their enclosure's back plane. The field devices with which discrete output modules interface may differ in their voltage requirements; therefore, several types and magnitudes of voltage are provided to control them (e.g., 120 VAC, 12 VDC). Following tables illustrate some typical output field devices and the standard output ratings found in discrete output applications [11].

Table 2.3: Output devices and standard output ratings

Output Devices
Alarms
Control relays
Fans
Horns
Lights
Motor starters
Solenoids
Valves

Output Ratings
12-48 volts AC/DC
120 volts AC/DC
230 volts AC/DC
Contact (relay)
Isolated output
TTL level
5-50 volts DC (sink/source)

i. AC Outputs

AC output circuits, like input circuits, vary widely among PLC manufacturers, but the block diagram shown in Figure 2.15 depicts their general configuration. This block configuration shows the main sections of an AC output module, along with how it operates. The circuit consists primarily of the logic and power sections, coupled by an isolation circuit. An output interface can be thought of as a simple switch (see Figure 2.16) through which power can be provided to control an output device [11].

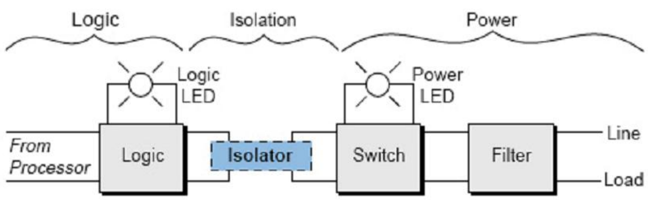


Figure 2.15: AC output block diagram

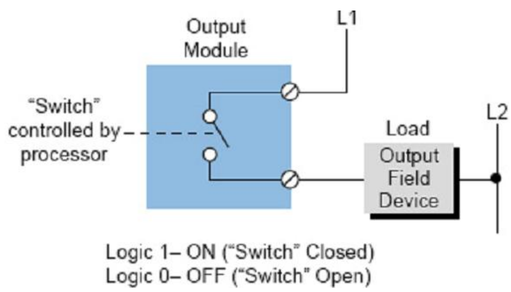


Figure 2.16: Switch function of an output interface

During normal operation, the processor sends an output's status, according to the logic program, to the module's logic circuit. If the output is to be energized (reflecting the presence of a 1 in the output table), the logic section of the module will latch, or maintain, a 1. This sends an ON signal through the isolation circuit, which in turn, switches the voltage to the field device through the power section of the module. This condition will remain ON as long as the output table's corresponding image bit remains a 1. When the signal turns OFF, the 1 that was latched in the logic section unlatches, and the OFF signal passed through the isolation circuit provides no voltage to the power section, thus de-energizing the output device. Figure 2.17 illustrates a typical AC output circuit.

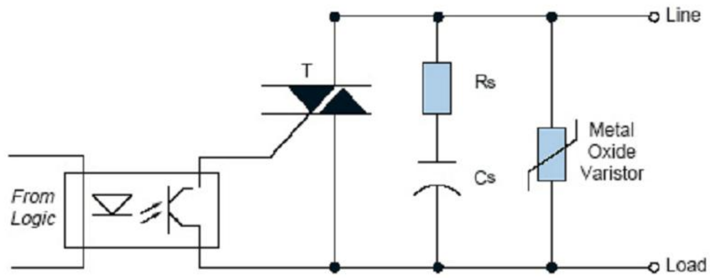


Figure 2.17: AC output circuit

The switching circuit in the power section of an AC output module uses either a triac or a Silicon Controlled Rectifier (SCR) to switch power. The AC switch is normally protected by an RC snubber and/or a Metal Oxide Varistor (MOV), which limits the peak voltage to some value below the maximum rating. Snubber and MOV circuits also prevent electrical noise from affecting the circuit operation. Furthermore, an AC output circuit may contain a fuse that prevents excessive current from damaging the switch. If the circuit does not contain a fuse, the user should install one that complies with the manufacturer's specifications. As with input circuits, AC output interfaces may have LEDs to indicate operating logic signals and power circuit voltages. If the output circuit contains a fuse, it may also have a fuse status indicator. Figure 2.18 illustrates an AC output connection diagram. Note that power from the field (L1) supplies the voltage that the module uses to turn ON the output devices [11].

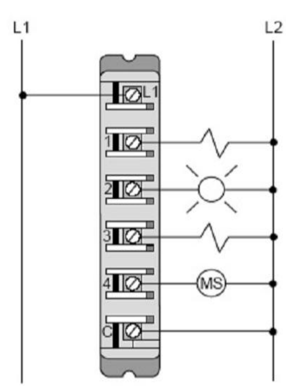


Figure 2.18: AC output connection diagram

DC output interfaces control discrete DC loads by switching them ON and OFF. The functional operation of a DC output is similar to that of an AC output; however, the DC output's power circuit employs a power transistor to switch the load. Like triacs, transistors are also susceptible to excessive applied voltages and large surge currents, which can cause over dissipation and short-circuit conditions. To prevent these conditions, a power transistor is usually protected by a freewheeling diode placed across the load (field output device). DC outputs may also incorporate a fuse to protect the transistor during moderate overloads. These fuses are capable of opening, or breaking continuity, quickly before excessive heat due to over currents occurs. As in DC inputs, DC output modules may have either sinking or sourcing configurations. If a module has a sinking configuration, current flows from the load into the module's terminal, switching the negative (return or common) voltage to the load. The positive current flows from the load to the common via the module's power transistor. In a sourcing module configuration, current flows from the module into the load, switching the positive voltage to the load. Figure 2.19 illustrates a typical sourcing DC output circuit. Note that in sinking output devices, current flows into the device's terminal from the module (the module provides, or sources, the current). Conversely, the current in sourcing output devices flows out of the device's terminal into the module (the module receives, or sinks, the current).

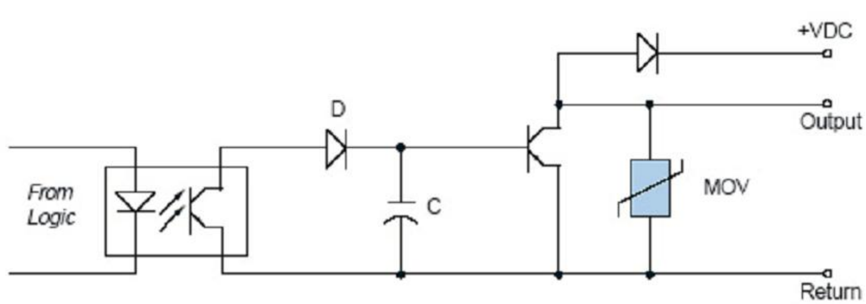


Figure 2.19: Typical sourcing DC output circuit

ii. Contact Outputs

Contact output interfaces allow output devices to be switched by normally open or normally closed relay contacts. Contact interfaces provide electrical isolation between the power output signal and the logic signal through separation between contacts and between the coil and contacts. These outputs also include filtering, suppression, and fuses. The basic operation of contact output modules is the same as that of standard AC or DC output modules. When the processor sends status data (1 or 0) to the module during the output update, the state of the contacts changes. If the processor sends a 1 to the module, normally open contacts close and normally closed contacts open. If the processor sends a 0, no change occurs to the normal state of the contacts. Contact outputs can be used to switch either AC or DC loads, but they are normally used in applications such as multiplexing analog signals, switching small currents at low voltages, and interfacing with DC drives to control different voltage levels. High-power contact outputs are also available for applications that require the switching of high currents. Figure 2.20 shows a contact output circuit. The device connection for this output module is similar to an AC output module. In this circuit, one side (1A) goes to L1, while the other (1B) goes to the load.

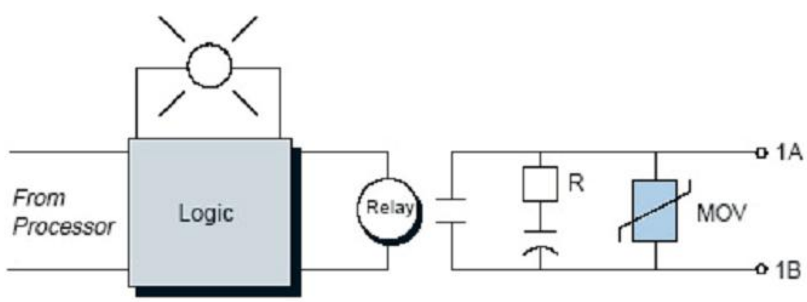


Figure 2.20: Contact output circuit

2.4.2 Sourcing and sinking concept of PLC

A DC input module can interface with field devices in both sinking and sourcing Operations, a capability that AC/DC input modules do not have. Sinking and sourcing operations refer to the electrical configuration of the circuits in the module and field input devices. If a device provides current when it is ON, it is said to be sourcing current. Conversely, if a device receives current when it is ON, it is said to be sinking current. There are both sinking and sourcing field devices, as well as sinking and sourcing input modules. The most common, however, are sourcing field input devices and sinking input modules. Rocker switches inside a DC input module may be used to select sink or source capability. Figure 2.21 and Figure 2.22 depict sinking and sourcing operations and current direction.

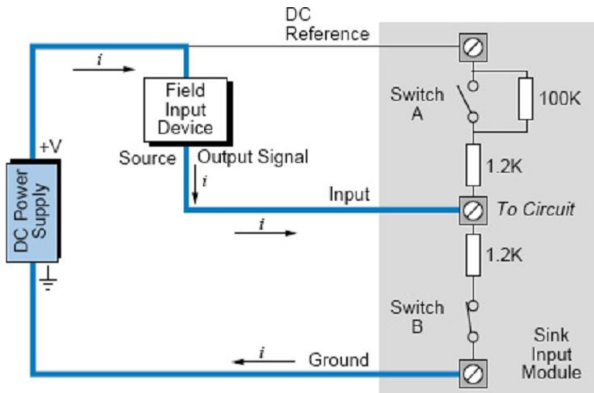


Figure 2.21: Sink input module

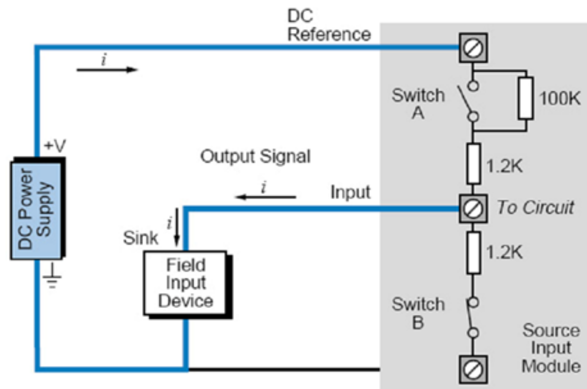


Figure 2.22: Source output module

During interfacing, the user must keep in mind the minimum and maximum specified currents that the input devices and module are capable of sinking or sourcing. Also, if the module allows selection of a sink or source operation via selector switches, the user must assign them properly. A potential interface problem could arise, for instance, if an 8-input module was set for a sink operation and all input devices except one were operating in a source configuration. The source input devices would be ON, but the module would not properly detect the ON signal, even though a voltmeter would detect a voltage across the module's terminals. Figure 2.23 illustrates three field device connections to a DC input module with both sinking and sourcing input device capabilities

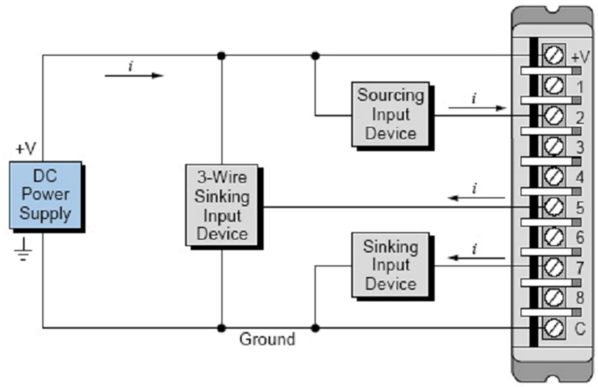


Figure 2.23: Field device connections for source/sink DC input

2.4.3 PLC Operation

The operation of a programmable controller is relatively simple. The input/ output (I/O) system is physically connected to the field devices that are encountered in the machine or that are used in the control of a process. These field devices may be discrete or analog input/output devices, such as limit switches, pressure transducers, push buttons, motor starters, solenoids, etc. The I/O interfaces provide the connection between the CPU and the information providers (inputs) and controllable devices (outputs). During its operation, the CPU completes three processes: (1) it reads, or accepts, the input data from the field devices via the input interfaces, (2) it executes, or performs, the control program stored in the memory system, and (3) it writes, or updates, the output devices via the output interfaces. This process of sequentially reading the inputs, executing the program in memory, and updating the outputs is known as scanning. Figure 2.24 illustrates a graphic representation of a scan.

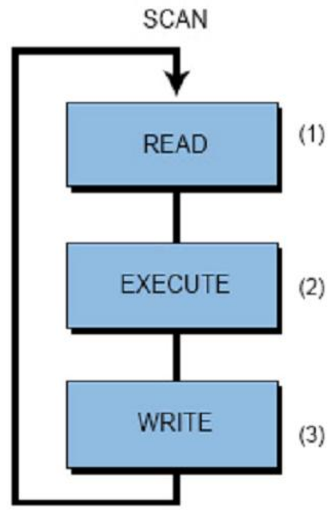


Figure 2.24: PLC scan cycle

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Chapter Three

System Hardware and Software Considerations

3.1 System Description

River side forwarding system is the system that responsible for forwarding raw water that been treated at river side plant to power plant and it consists of forwarding pumps and their hydraulic outlet valve. The forwarding pumps and their outlet valves are working as a group to protect the forwarding pump from water hammering phenomenon that could occur if the pump starts in a wrong way. Since the starting procedure of the forwarding pump depends on the hydraulic valve position so it is essential to open the hydraulic valve automatically when starting the forwarding pump. The pump starting procedure is as follows:

a- Open the hydraulic outlet valve partially to 15 degree

b- Start the pump automatically. In other hand the stopping procedure should following steps:

a- Close the hydraulic outlet valve to 75 degree

b- Then stop the pup immediately.

In the system block diagram that shown in Figure 3.1 which clarify that the main control system which control the entire system including the forwarding system so it controls the forwarding pump needs to exchange the data with the hydraulic outlet valve control system that been implemented in this research so as to operate the pump remotely. The data that to be exchanges comprise valve opened and closed and 15 degree positions which will be sent from hydraulic valve control system to main control system.

Furthermore, there are remote commands for opening and closing the hydraulic valve remotely and these signals will be sent to hydraulic valve control system from main control system. The hydraulic valve control system contains the programmable logic controller type Simatic step 7- 200 and their related hardware control and power circuits. This control system is used to control open and close the valve and also to preserve the hydraulic pressure to keep the valve open by starting the oil pump of hydraulic valve when the hydraulic pressure become low beside this to act as an interface to main control system and exchange the data that been needed for pump starting .

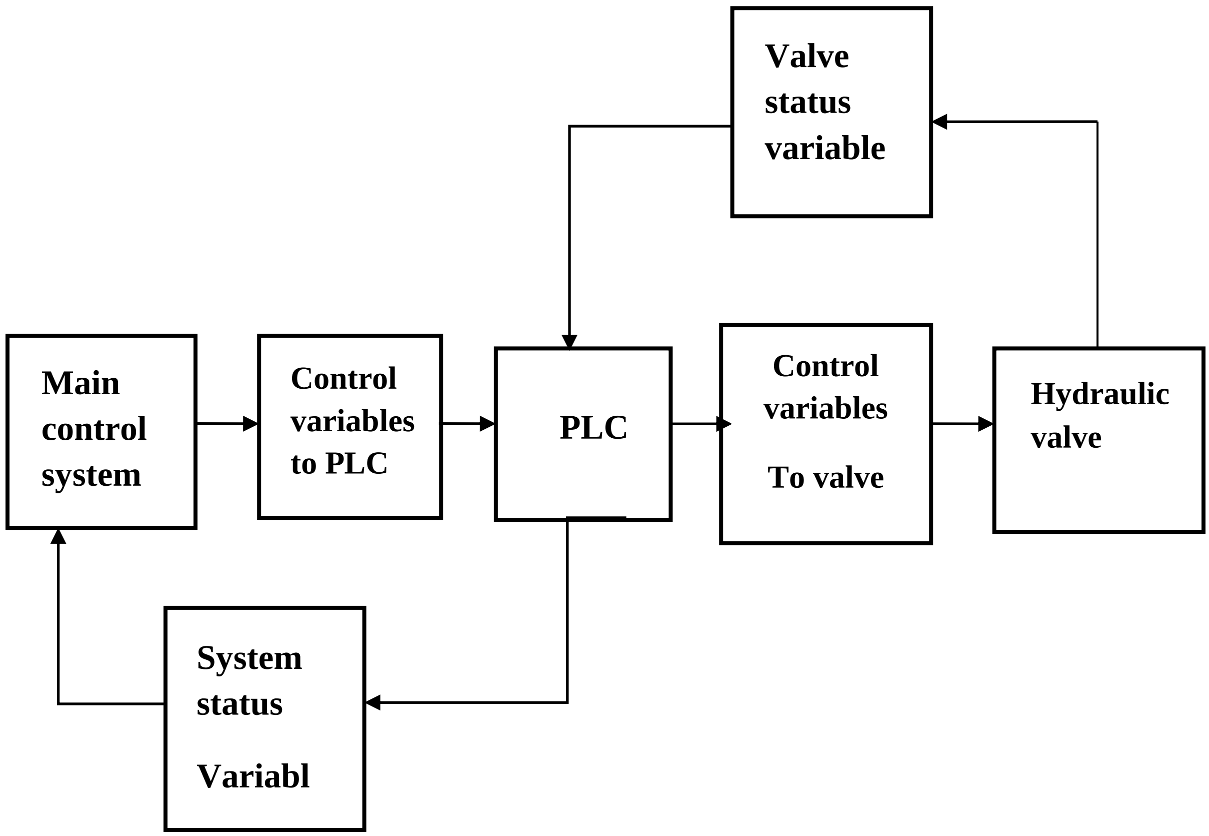


Figure 3.1: System block diagram

3.2 System Hardware

The hardware system consists of two major components which is hydraulic valve hardware and its control system hardware

The Hydraulic Actuators Weight-Loaded type (HAWL) type from hydromat are used wherever valves installed at crucial points of pipe networks have to close or to open in a secure and reliable manner even on failure of external operating energy.

Thus, they have to meet the most stringent requirements in terms of functional safety. Thanks to their solid and state-of-the-art design, HAWL are optimized and economical solution.

The compact electro hydraulic equipment brake and lift cylinder are complete unit. All operating, regulating and controlling devices are combined in one assembly. HAWL are used for operating valves with a drive shaft rotating by maximum 90 degree. The weight-loaded hydraulic actuator is equipped with an energy accumulator. The weight loaded lever provides the energy required for a single closing or opening operation of the valve. Depending on the particular application and service required the HAWL may be incorporated in ball Valves, butterfly Valves. A range of sizes and standardized interfaces combined with a perfected modular concept enable us to supply the best solution for valves of all sizes and pressure ratings.

A. Hydraulic valve Design

HAWL excels by their compact design. The weight loaded hydraulic actuator incorporated in the valve includes not only the mechanical components as weight loaded lever, bracket, and support plate (for cylinder attachment) but also the hydraulic damping and opening cylinder

a. The hydraulic diagram and description of performance

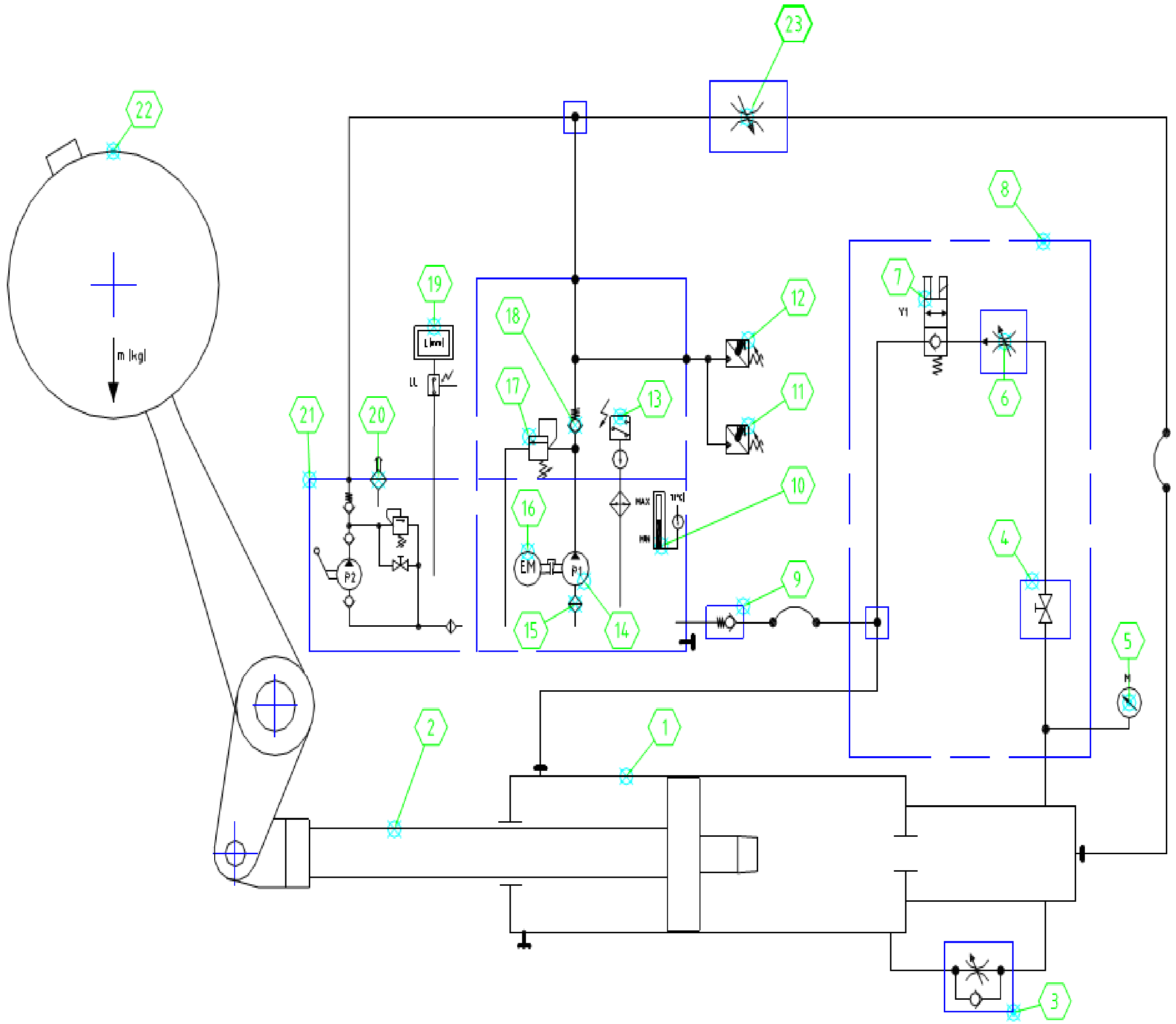
HAWL - standard design and performance is shown in Figure 3.2.

i. Open-circuit concept

Solenoid valve (no7) or pilot valve de-energized. Weight drops when energizing the solenoid valve.

i. Hydraulic valve opening

The pumps (motor or manual pump) suck up the oil from the cylinder chamber on the rod side or from the oil tank and produce a pressure on the piston side of the cylinder which raises the weight loaded lever.



No.	Name [EN]	No	Name [EN]	No.	Name [EN]	No	Name [EN]	No.	Name [EN]
1	Hydraulik Cylinder	6	Flow control valve	11	Pressure switch LP	16	Electric motor	20	Oil filing filter
2	Piston rod	7	Solenoid seat valve	12	Pressure switch HP	17	Pressure limitng valve	21	Hand pump
3	Flow control valve	8	Valveblock	13	El. heater with thermostat	18	Check valve	22	Drop weight
4	Block ball valve	9	Check valve	14	Pump	19	Level switch	23	Throttle valve
5	Pressure gauge	10	Ol level indicator	15	Oil filter				

Figure 3.2: Hydraulic circuit for hydraulic valve

Electrically and mechanically operated solenoid valve (no 7) which isolates or releases oil flow from the cylinder. The actuator is hydraulically maintained in "working position" (weight loaded lever raised). This brings about the advantage that the lowering of the weight loaded lever immediately shows the oil losses due to internal leakage.

ii. Manually opening

In case of total power failure or control block burst, weight loaded lever will always move to closed position. In such an event it's possible to open the valve with a hand oil pump. For this operation block ball valve (no.4) must be in closed position.

iii. Electrification and tripping movement to closing

Closing process the HAWL in standard design hydromat offer in two stages that shown in Figure3.3. The two stages are:

1. Stage: Open 100 % - 30 %.

2. Stage: 30 %- 0 % Open (Closed) .

The lowering velocity for the first damping stage (about 70% of the cylinder stroke or open valve) can be adjusted at flow control valve (no.6), the velocity for the second damping stage at the flow control valve (no.3). Flow control valves keep the flow rate constant irrespective of the differential pressure. This principle permits phase operating laws for the lowering weight-loaded lever. These phases are necessary in order to keep the pressure increase (water hammer, backflow) in the pipeline within an admissible range, with the closing times being as short as possible. For detecting and signaling the different positions of the valve, several limit switches are mounted on the cover plate or angle transducer on the valve shaft. Apart from signaling, this limit switches also serve for controlling the electric components at the actuator. The basic standard design provides three limit switches for open and close and 15 degree positions. With the electrical solenoid valves or pilot valves, the closing movement is tripped by energizing (open-circuit concept) or de-energizing (closed-circuit concept) the solenoid valve (no 7). Thus, lowering of the weight-loaded lever is started.

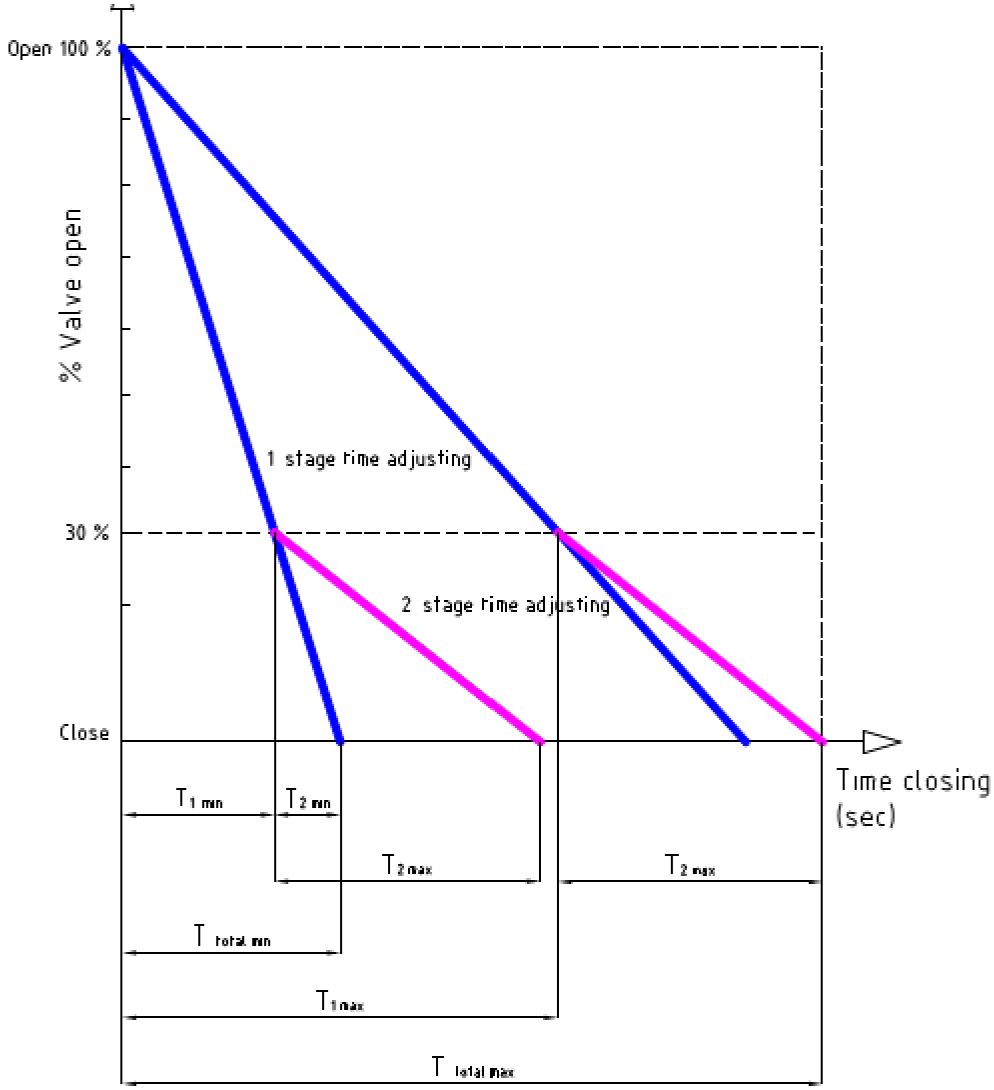


Figure 3.3: Hydraulic valve closing stage

The components (motor pump no. 17), thermal switch and limit switches) must be controlled electrically. Each damping is adjustable individually, allowing damping performance to be matched in the application and technical characteristics of the size each hydromat HAWL. Second stage damping is made like a security device for dangerous lowering situation.

Compact design with incorporated hydraulic unit (motor pump and manual pump) as well as thermal switch pressure limiting valve, pressure low and high switches, heater, oil low level switch - control by means of solenoid valve (open-circuit/closed-circuit concept), emergency lowering with manually push button of solenoid valve.

iv. Modular concept

Among others, the following types are available within the modular concept: - HAWL without hydraulic unit, i.e., equipped only with weight-loaded lever and cylinder assembly for connecting to hydraulic unit supplied by customer, - one or three stages operating laws, depending on the requirement and application of the plant, - mechanical control of the main valve (if there is no external energy available on site) - hydraulic unit equipped with hydro accumulator.

Limit switches the limit switches required for controlling electromotor pump. The limit switches must be connected according with electric circuit diagrams on, respectively. The basic design provides 2 limit switches as follows: Limit switch Open 2. Limit switch close.

v. Sizing and dimensioning

HAWL is designed according to the case of application and the hydraulic conditions. The required parameters are given in below check list. The HAWL are sized and designed to the modular concept. Essential data for determining, dimensioning and assigning the actuators to the valves:

- Max. actual dynamic opening/closing torque (depending on the case of application as well as pressure and flow rate conditions).
- Max. operating torque for seating and off-seating the closed valve.
- Case of application and existing specifications.

3.2.2 Control system hardware

The S7-200 series of Micro-Programmable Logic Controllers (Micro PLCs) can control a wide variety of devices to support your automation needs. The S7-200 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.

A. S7-200 CPU

It combines a microprocessor, an integrated power supply, input circuits, and output circuits in a compact housing to create a powerful Micro PLC. See Figure 3.4. After you have downloaded your program, the S7-200 contains the logic required to monitor and control the input and output devices in your application .All S7-200 CPUs have an internal power supply that provides power for the CPU, the inputs and outputs modules, and other 24 VDC user power requirements also provide a 24 VDC sensor supply that can supply 24 VDC for input points, for relay coil power on the expansion modules[12].

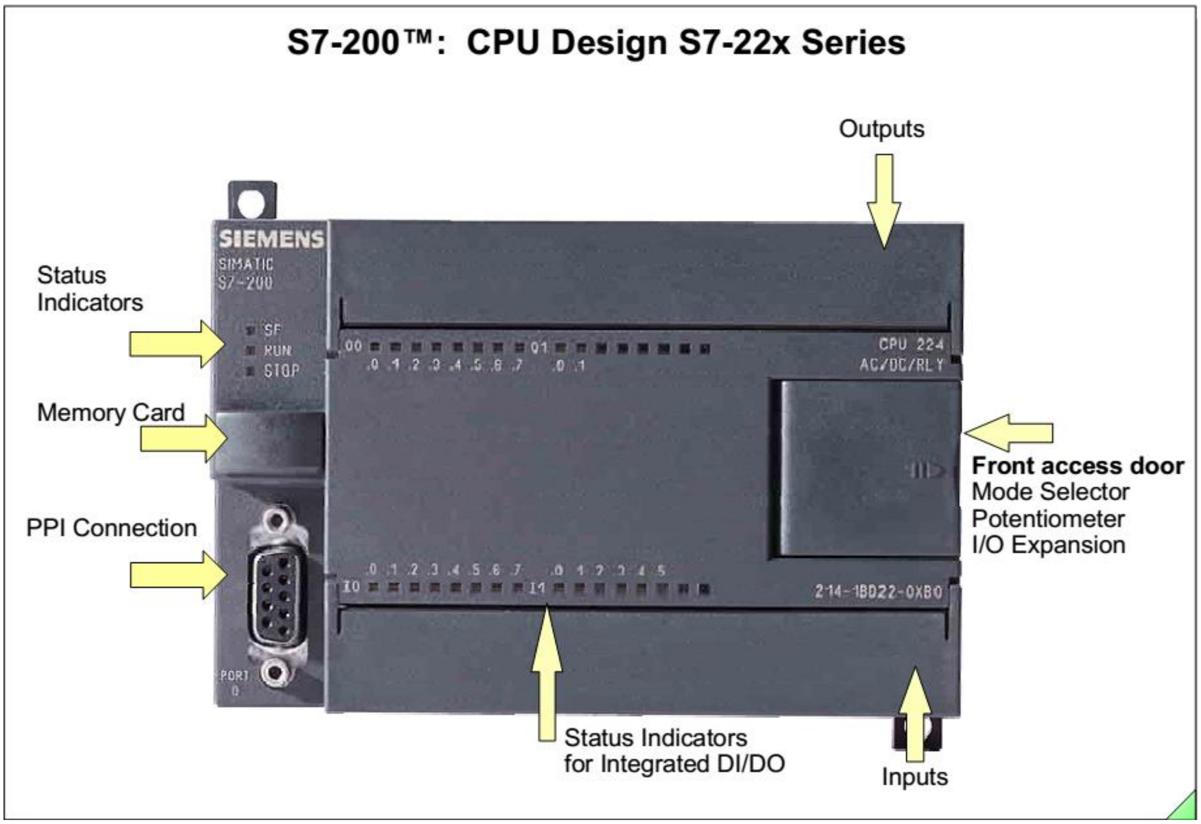


Figure 3.4: S7-200 PLC compact controller

B. S7-200 models

There are four S7-200 CPU types: S7-221, S7-222, S7-224, S7-226, and S7-226XM and three power supply configurations for each type as shown in Table 3.1

Table 3.1: S7-200 PLC models

Model Description	Power Supply	Input Types	Output Types
221 DC/DC/DC	20.4-28.8 VDC	6 DC Inputs	4 DC Outputs
221 AC/DC/Relay	85-264 VAC, 47-63 Hz	6 DC Inputs	4 Relay Outputs
222 DC/DC/DC	20.4-28.8 VDC	8 DC Inputs	6 DC Outputs
222 AC/DC/Relay	85-264 VAC, 47-63 Hz	8 DC Inputs	6 Relay Outputs
224 DC/DC/DC	20.4-28.8 VDC	14 DC Inputs	10 DC Outputs
224 AC/DC/Relay	85-264 VAC, 47-63 Hz	14 DC Inputs	10 Relay Outputs
226/226XM DC/DC/DC	20.4-28.8 VDC	24 DC Inputs	16 DC Outputs
226/226XM AC/DC/Relay	85-264 VAC, 47-63 Hz	24 DC Inputs	16 Relay Outputs

The model description indicates the type of CPU, the power supply, the type of input, and the type of output for example CPU 224 DC/DC/DC means that power supply is DC and output voltage is DC and input voltage is DC.

C. S7-200 Features

The S7-200 family includes a wide variety of CPUs and features. This variety provides a range of features to aid in designing a cost-effective automation solution. The following Table 3.2 provides a summary of the major features.

Table 3.2: Summary of major features

Feature	CPU221	CPU222	CPU224	CPU226
Memory				
Program	2048 words	2048 words	4096 words	4096 words
User Data	1024 words	1024 words	2560 words	2560 words
Memory Type	EEPROM	EEPROM	EEPROM	EEPROM
Memory Cartridge	EEPROM	EEPROM	EEPROM	EEPROM
Data Backup	50 Hours	50 Hours	50 Hours	50 Hours
I/O				
Local Digital I/O	6 IN/4OUT	8 IN/6OUT	14 IN/10OUT	24 IN/16OUT
Max no of Expansion module	None	2	7	7
Max Digital I/O with Expansion	6 IN/4OUT	40 IN/38OUT	94 IN/74OUT	128IN/120OUT
Max Analogue I/O with Expansion	None	8 IN/2OUT	28 IN/7OUT	28 IN/7OUT
Instructions				
Boolean Execution Speed	0.37 μs/inst	0.37 μs/inst	0.37 μs/inst	0.37 μs/inst
Internal Relays	256	256	256	256
Counters	256	256	256	256
Timers	256	256	256	256
Communication				
Number of Ports	1(RS-485)	1(RS-485)	1(RS-485)	2(RS-485)
Protocols Supported port0	PPI,MPI slave ,free port	PPI,MPI slave ,free port	PPI,MPI slave ,free port	PPI,MPI slave ,free port
Built in High Speed counters	4(30KHz)	4(30KHz)	6(30KHz)	6(30KHz)

D. Mode switch and analogue adjustment

When the mode switch is in the RUN position the CPU is in the run mode and executing the program. When the mode switch is in the STOP position the CPU is stopped. When the mode switch is in the TERM position the programming device can select the operating mode. The analog adjustment is used to increase or decrease values stored in special memory. These values can be used to update the value of a timer or counter, or can be used to set limits. Figure 3.5 shows mode switch for PLC type S7-200.

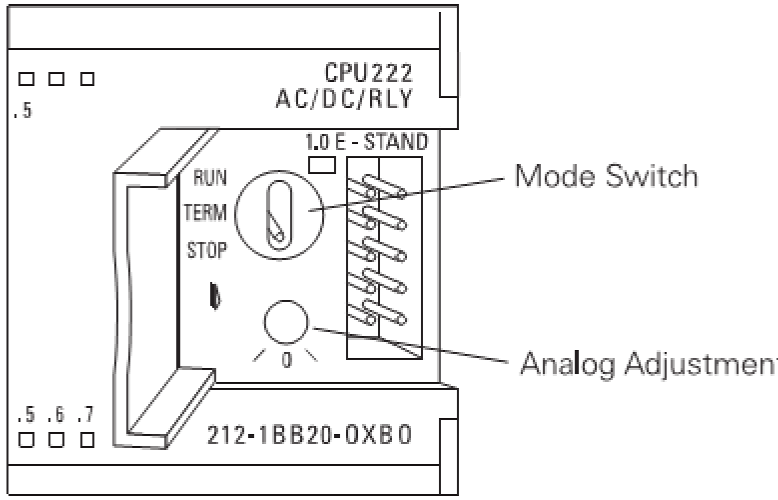


Figure 3.5: S7-200 mode switch

E. PLC Status indicators

The CPU status indicators reflect the current mode of CPU operation. If, for example, the mode switch is set to the RUN position, the green RUN indicator is lit. When the mode switch is set to the STOP position, the yellow STOP indicator is lit. The I/O status indicators represent the On or Off status of corresponding inputs and outputs. When the CPU senses an input is on, the corresponding green indicator is lit. External power supply an S7-200 can be connected to either a 24 VDC or a 120/230 Sources VAC power supply depending on the CPU. An S7-200 DC/DC/DC would be connected to a 24 VDC power supply. An S7-200 AC/DC/Relay would be connected to a 120 or 230 VAC power supply. Figure 3.6 shows the wiring diagram of power supply and inputs and outputs supply for PLC S7224 AC/DC/Relay.

F. PLC I/O Numbering

S7-200 inputs and outputs are labeled at the wiring terminations and next to the status indicators. These alphanumeric symbols identify the I/O address to which a device is connected. This address is used by the CPU to determine which input is present and which output needs to be turned on or off. I designates a discrete input and Q designates a discrete output. The first number identifies the byte; the second number identifies the bit. Input I0.0, for example, is byte 0, bit 0.

I0.0 = Byte 0, Bit 0, I0.1 = Byte 0, Bit 1 I1.0 = Byte 1, Bit 0 I1.1 = Byte 1, Bit 1.

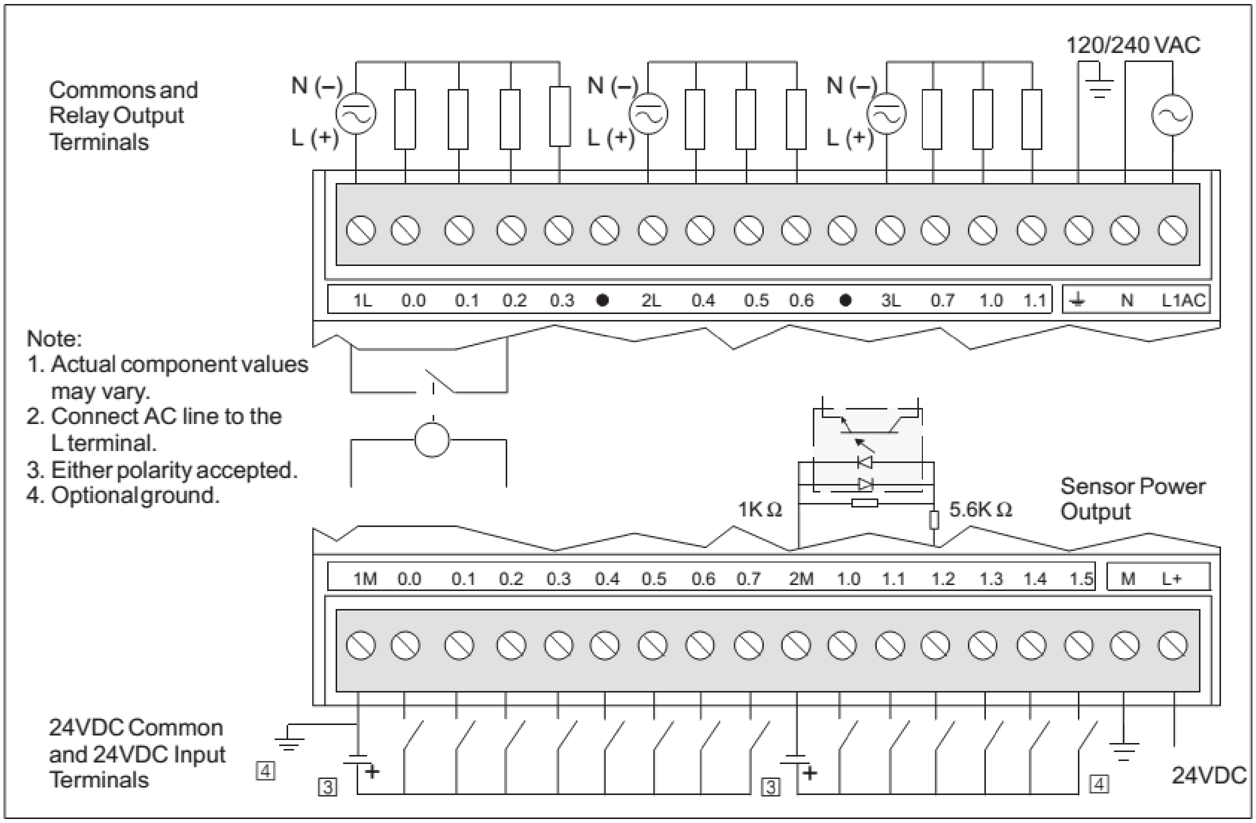


Figure 3.6: S7-200 connections and wiring diagram

G. Super Capacitor

A super capacitor that shown in Figure:3.7 , so it is named because of its ability to maintain a charge for a long period of time, protects data stored in RAM in the event of a power loss. The RAM memory is typically backed up on the S7-221 and 222 for 50 hours, and on the S7-224 and 226 for 190 hours

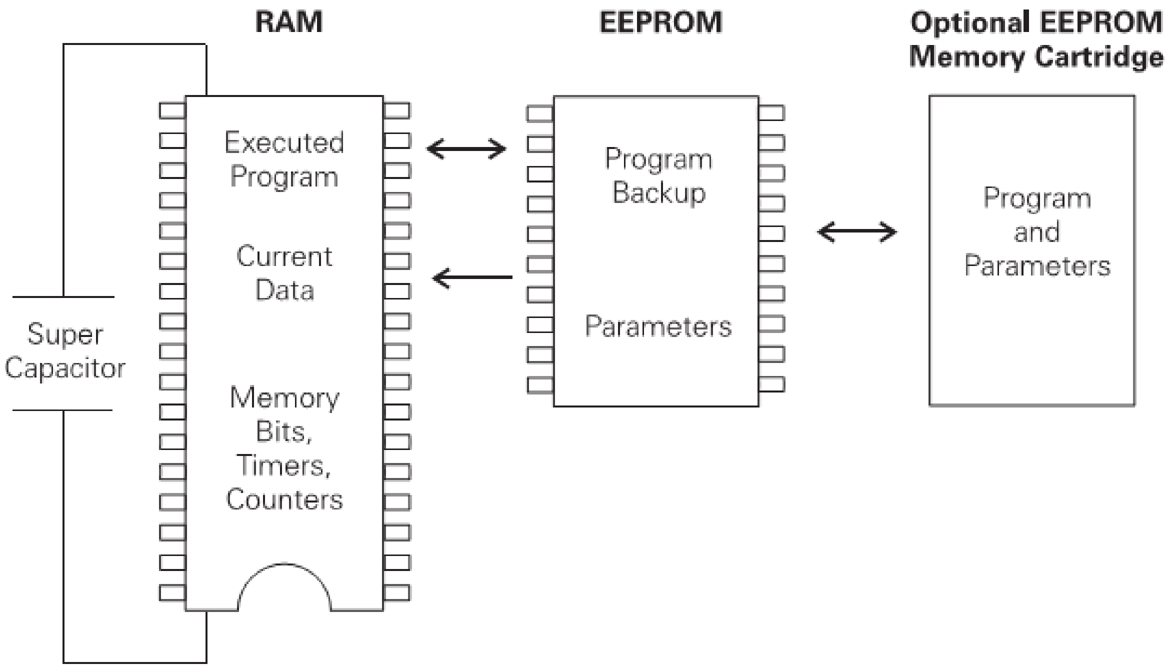


Figure: 3.7: Super capacitor

3.3 System Software

The software programming package that used in system as software programming tool is STEP 7-Micro/WIN Programming Package which The STEP 7--Micro/WIN programming package provides a user-friendly environment to develop, edit, and monitor the logic needed to control your application. STEP 7--Micro/WIN provides three program editors for convenience and efficiency in developing the control program for your application. To help you find the information you need, STEP 7--Micro/WIN provides an extensive online help system and a documentation CD that contains an electronic version of this manual, application tips, and other useful information.

3.3.1 Computer requirements for software

STEP 7--Micro/WIN runs on either a personal computer or a Siemens programming device, such as a PG 760. Your computer or programming device should meet the following minimum requirements:

Operating system: Windows 2000, Windows XP (Professional or Home) with at least 100M bytes of free hard disk space and Mouse (recommended).To link your computer to PLC S7-200Siemens provides two programming options for connecting your computer to your S7-200: a direct connection with a PPI multi-master cable, or a Communications Processor (CP) card with an MPI cable. The PPI multi-master programming cable is the most common and economical method of connecting your computer to the S7-200. This cable connects the communications port of the S7-200 to the serial communications of your computer. The PPI multi-master programming cable can also be used to connect other communications devices to the S7-200. STEP 7--Micro/WIN makes it easy for you to program your S7-200. In just a few short steps using a simple example, you can learn how to connect, program, and run your S7-200. All you need for this example is a PPI multi-master cable, an S7-200 CPU, and a programming device running the STEP 7-Micro/WIN programming software.

3.3.2 Hydraulic valve control program simulation

Simatic manager simulator has been used as simulator tools .through this simulator all hydraulic valve control process is simulated which includes the opening valve process and closing valve process beside other interlocking process such as hydraulic oil pressure interlock .To start simulator first create a new project then hardware of plc should be configured by selecting the type of controller and inputs and outputs modules as shown in Figure: 3.8

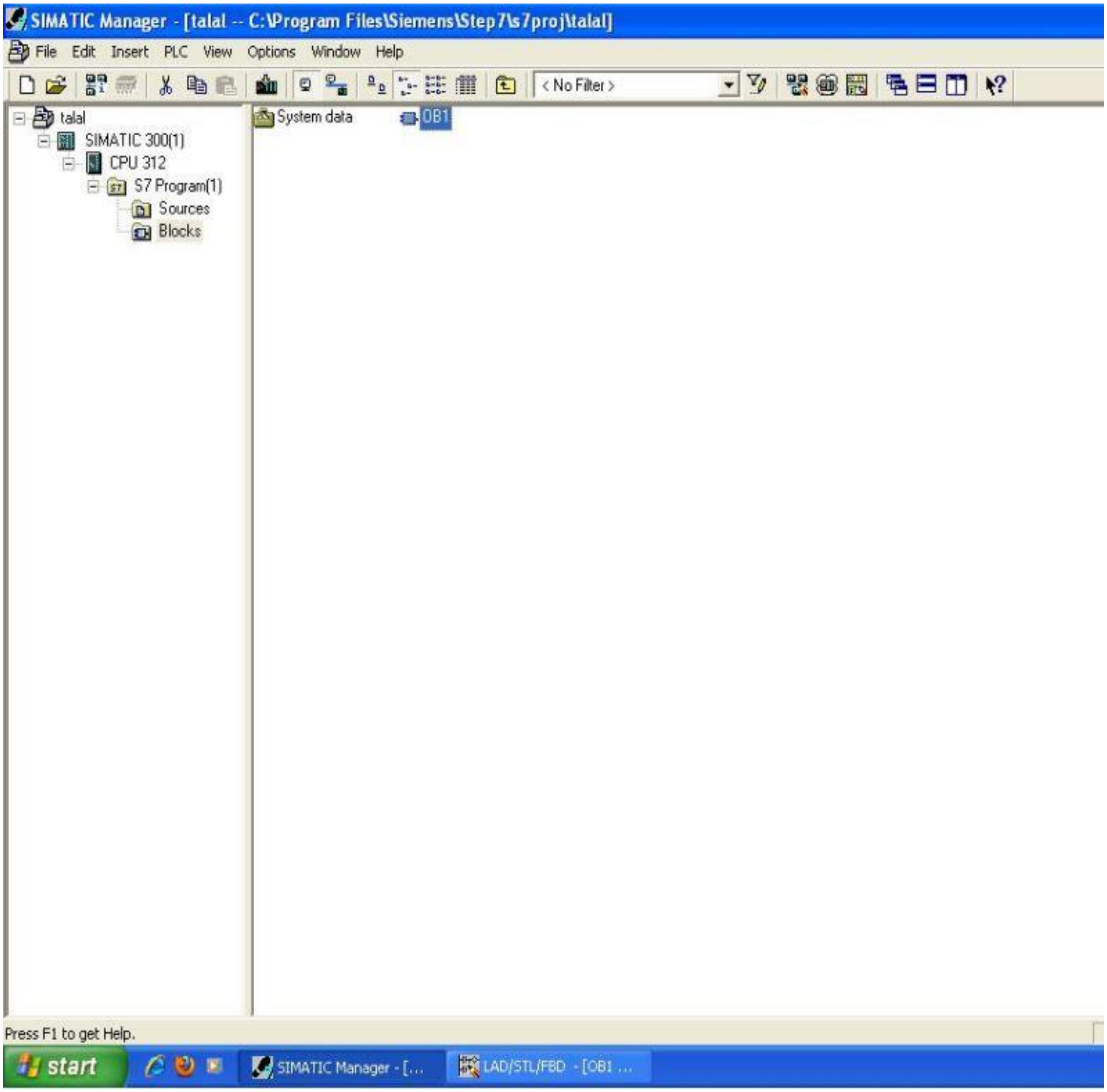


Figure 3.8 Simatic S7 project creating

After the new project has been created turn on the the simulator by clicking on the Simulation On/Off button located on the SIMATIC Manager toolbar, a PLC simulation view that comprises all PLC simulated hardware such as inputs and outputs .By means if this window that shown in Figure 3.9 all inputs could be simulated and all outputs can be monitored.

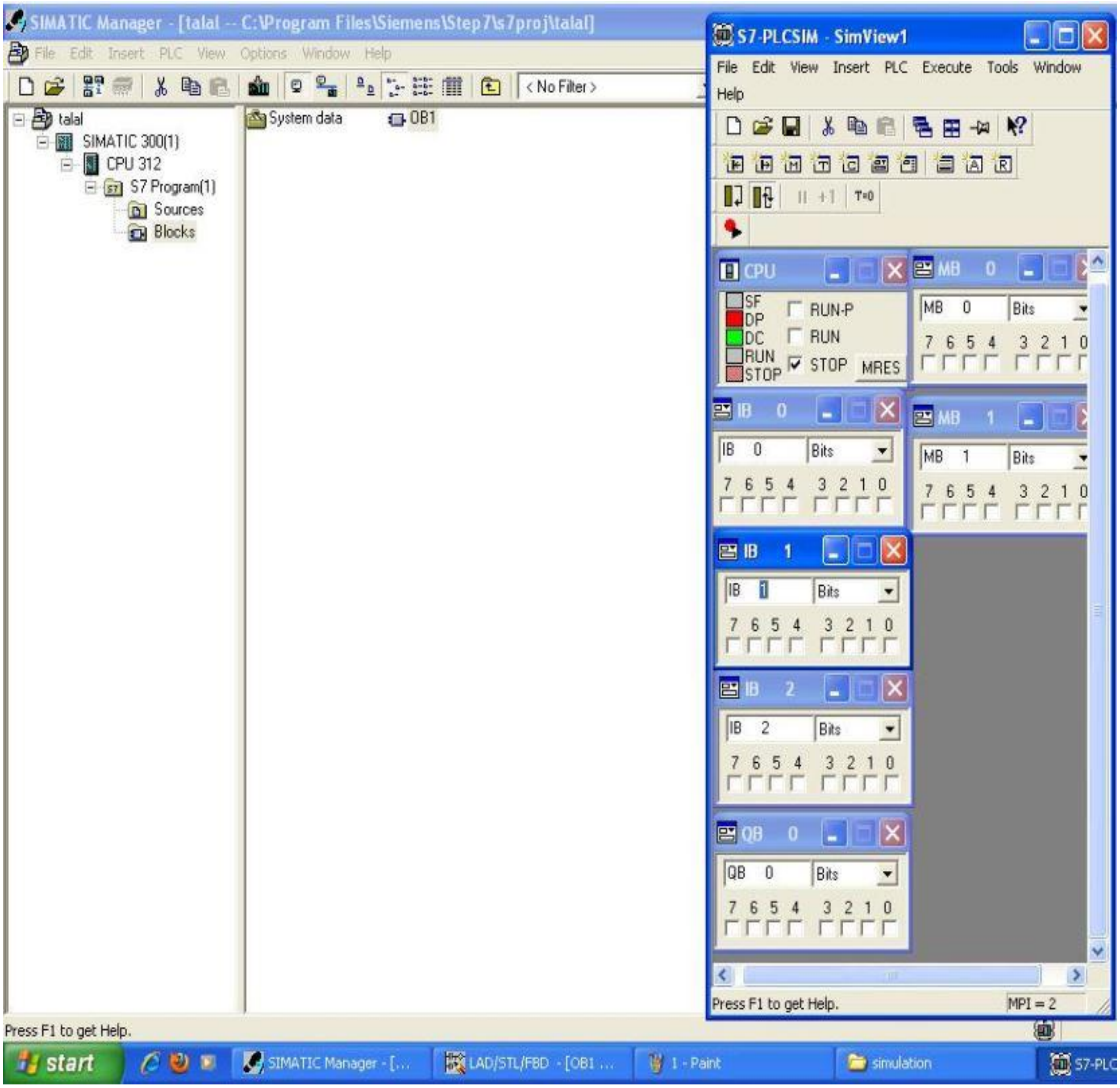


Figure 3.9: Simatic S7 simulator starting

After starting the simulator the simulated PLC will be in stop mode by default and should be switched to running program mode (RUN-P) as shown in Figure 3.10

In RUN-P mode, the CPU runs the program and allows you to change the program and its parameters. In order to use the STEP 7 tools for modifying any of the parameters of the program while the program is running, you must put the CPU in RUN-P mode.

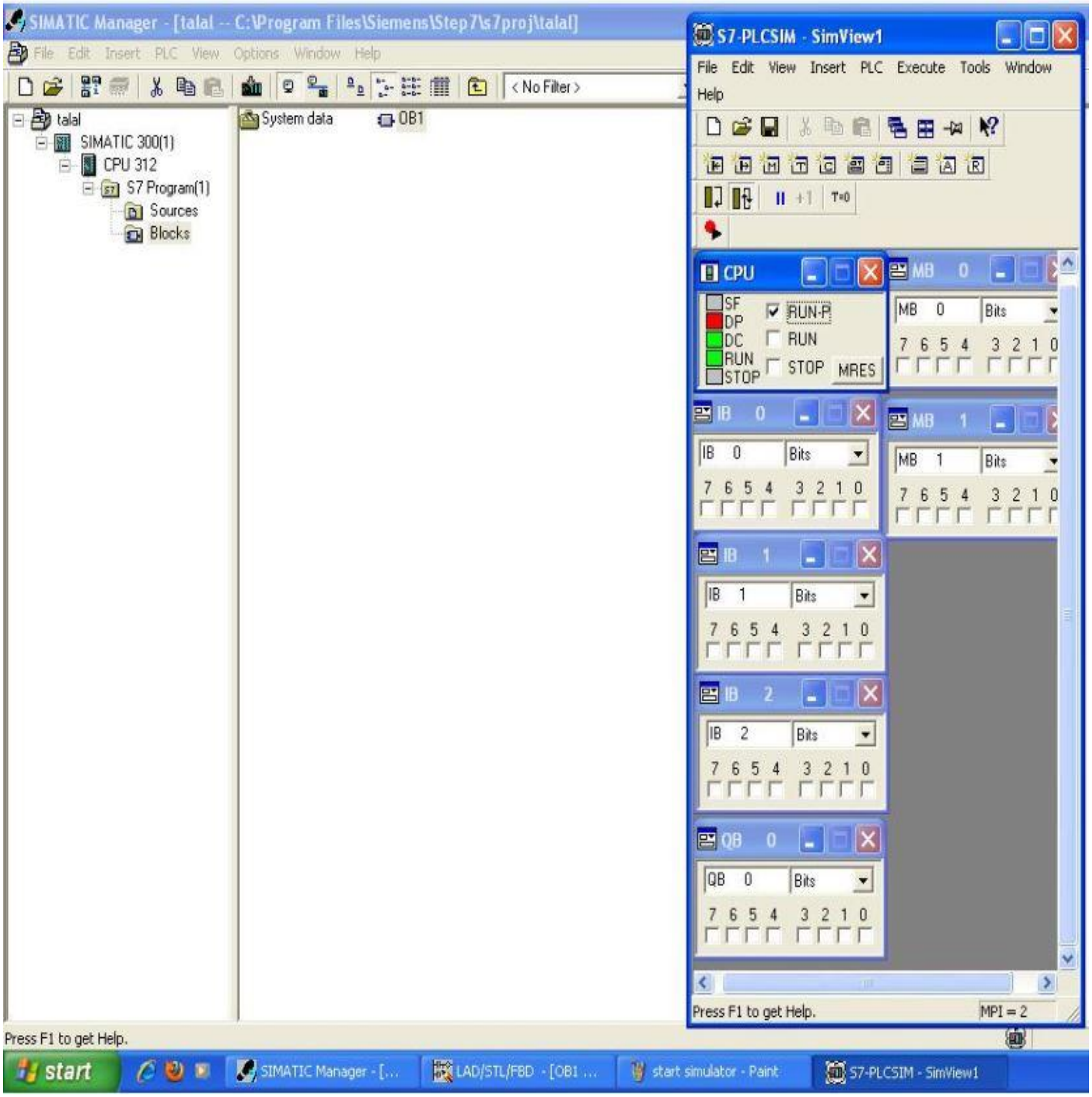


Figure 3.10 Simulated PLC running in RUN-P mode

In Organizing Block number one (OB1) that contains the main program cycle the hydraulic valve control logic is configured .You can create S7 programs in the standard languages Ladder Logic (LAD), Statement List (STL), or Function Block Diagram (FBD). In this OB1 window the ladder logic language is selected and the program is configured as shown in Figure 3.11.After configuration click on the download button to download the program logic to the simulated CPU.

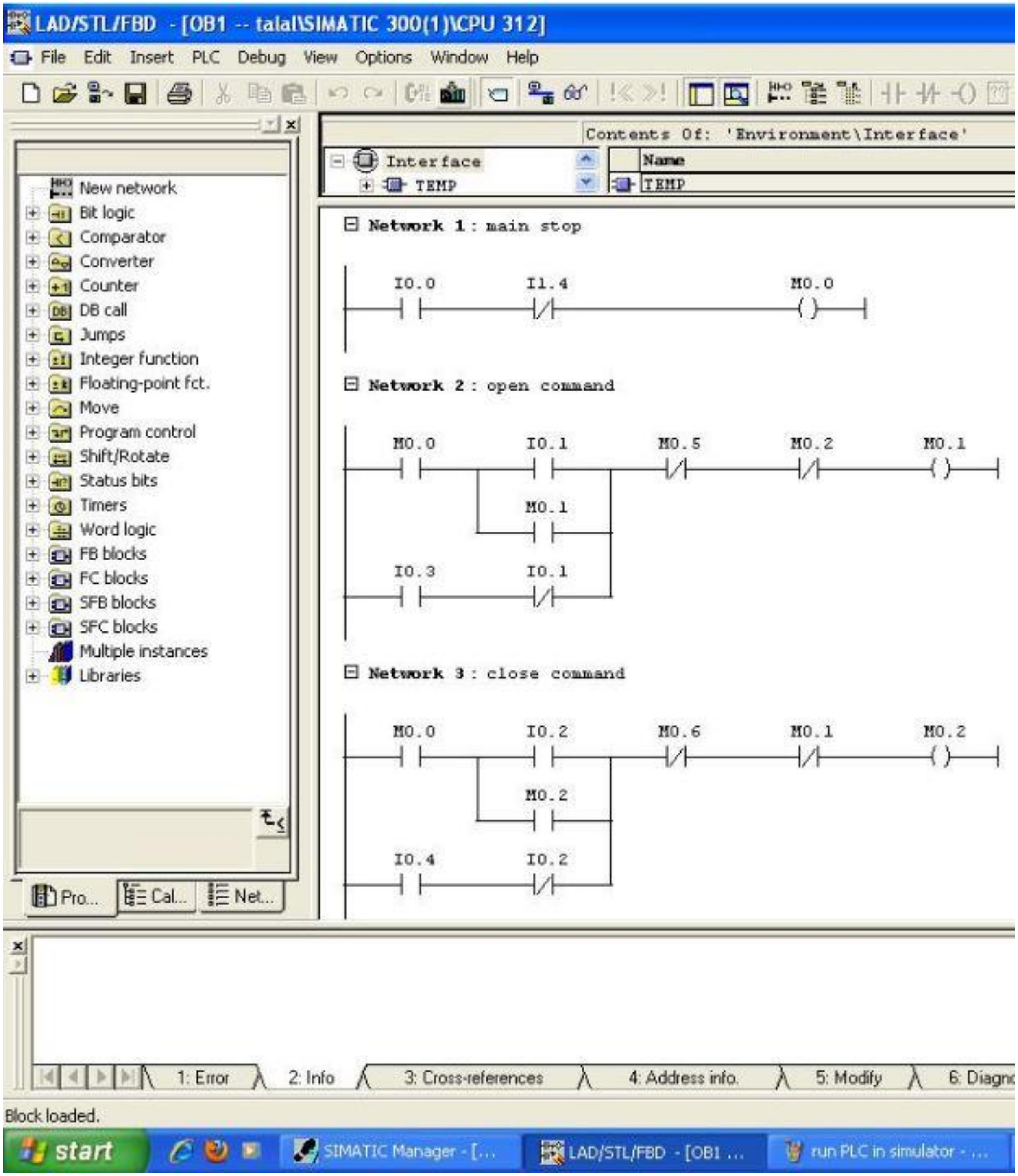


Figure 3.11: Logic program creation in OB1

The program in main program window will be as Figure 3.12 after clicks on online monitor button. At this stage your simulation is ready to be tested so as to ensure that the PLC controller will act as specified in process description.

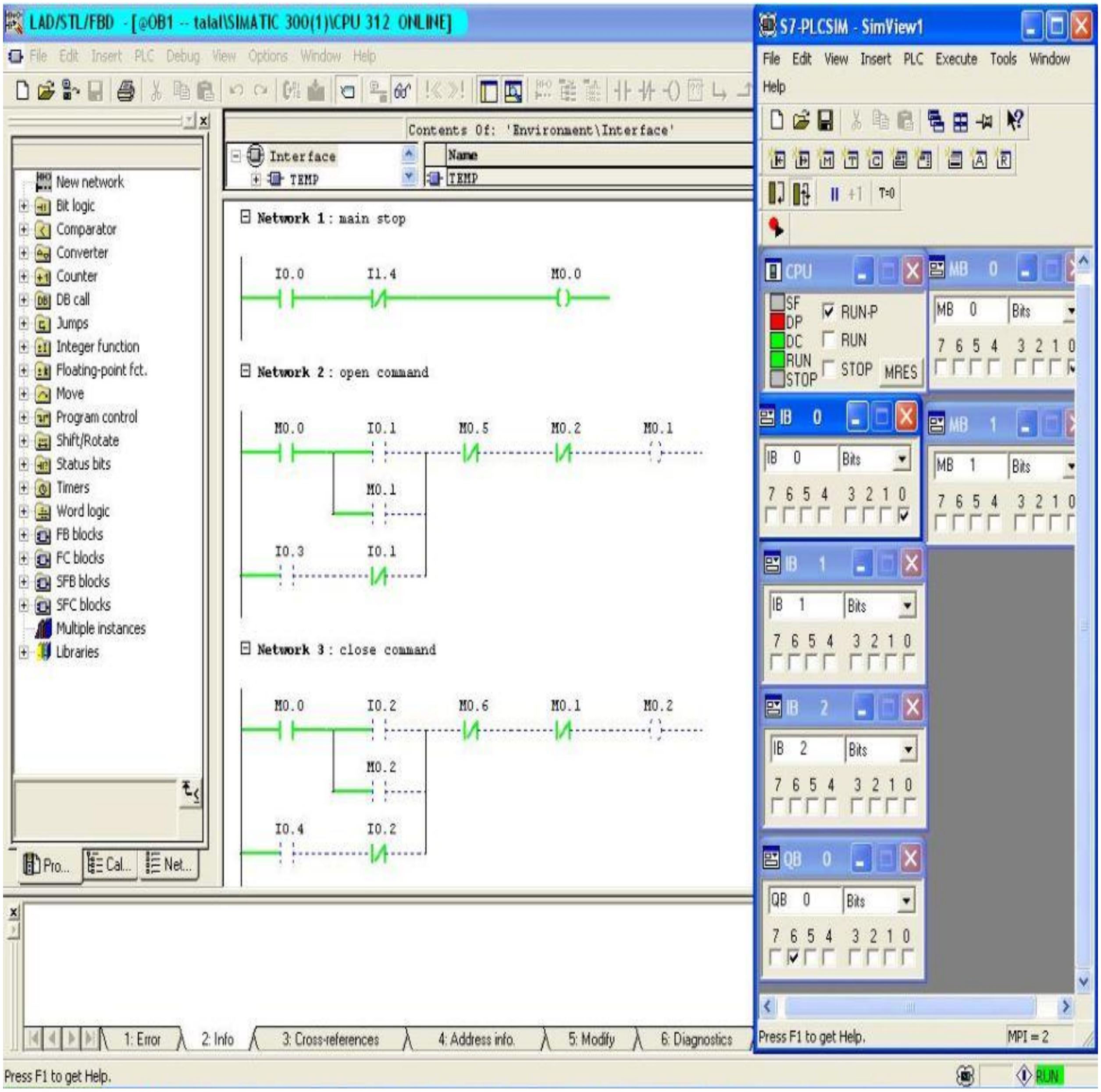


Figure: 3.12 S7 Simulator online monitoring

Then the tick on input variable I0.1 in simulation view to open the valve by energizing the memory bit M0.1 as shown in Figure 3.13.

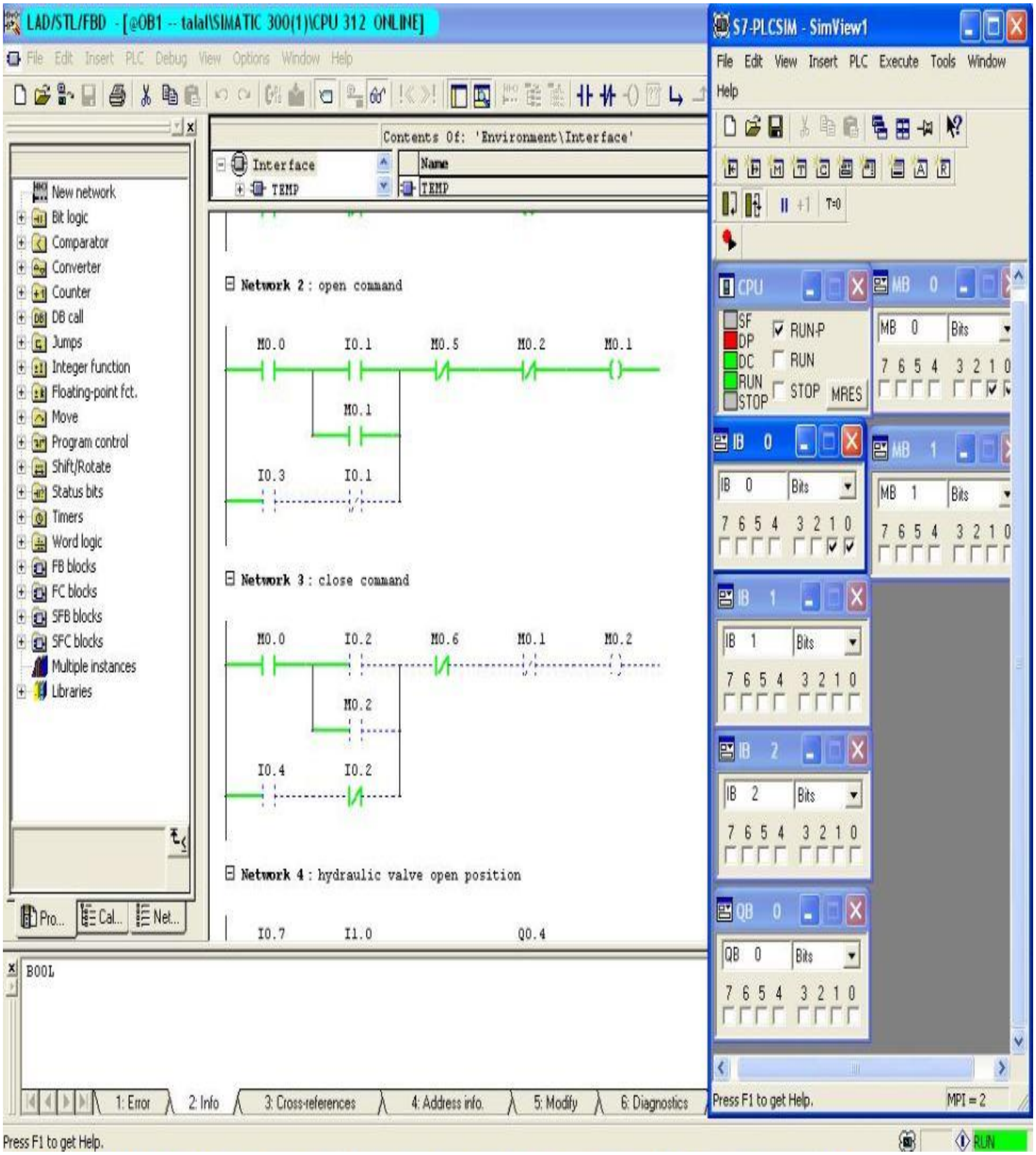


Figure 3.13: Open valve command simulation

Figure 3.14 illustrates that when tick open command the hydraulic pump will start automatically by energizing the output coil Q0.0 .When the pump start the hydraulic pressure will increase which lead to move the piston of the valve and the valve begin to open.

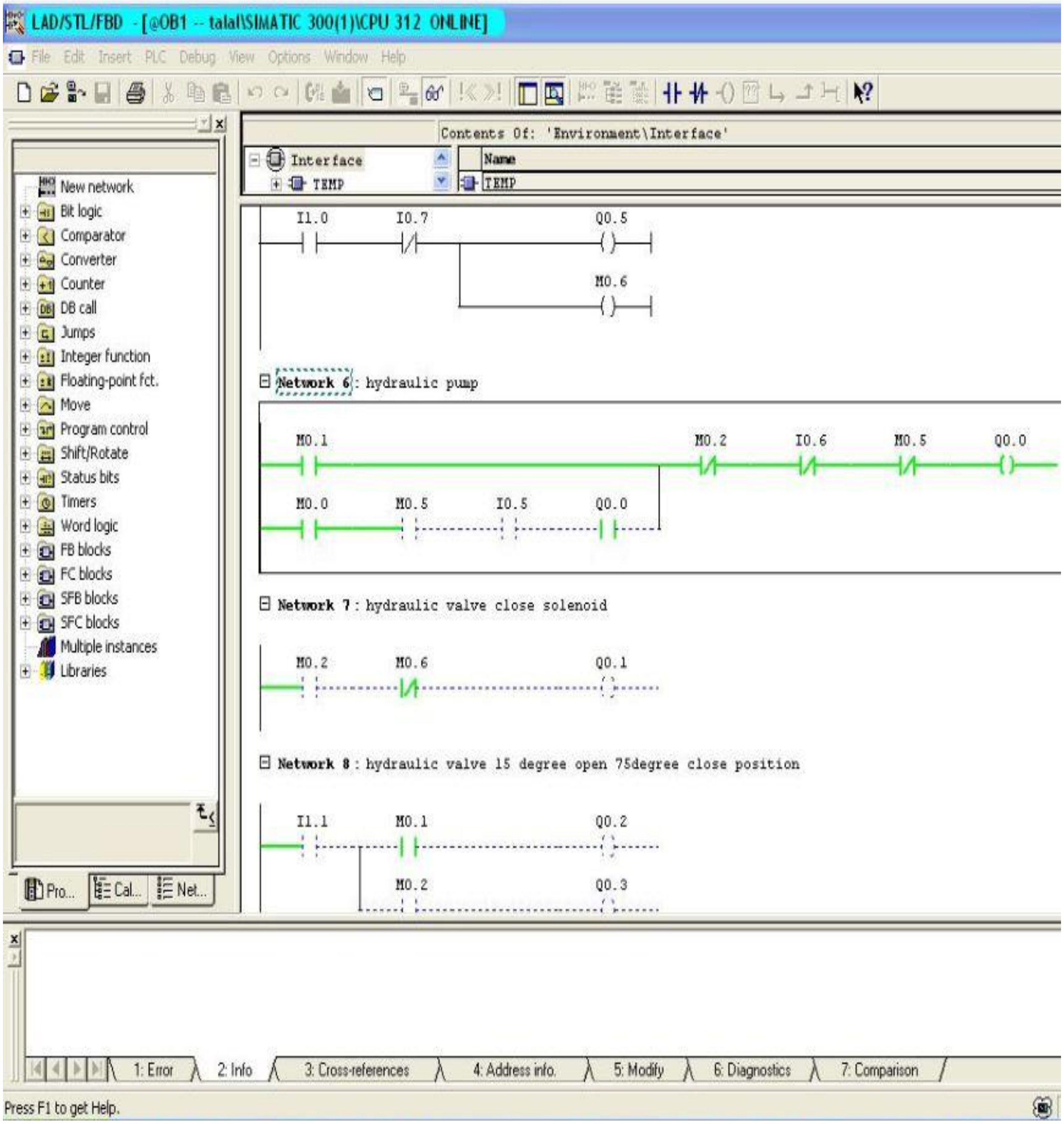


Figure 3.14: Hydraulic pump starting

The hydraulic pump will continue running until the valve is fully open then the pump will stop automatically. Figure 3.15 illustrates how the pump stop by de-energizing the output coil Q0.0 when the valve is fully open (memory bit M0.1) de-energized.

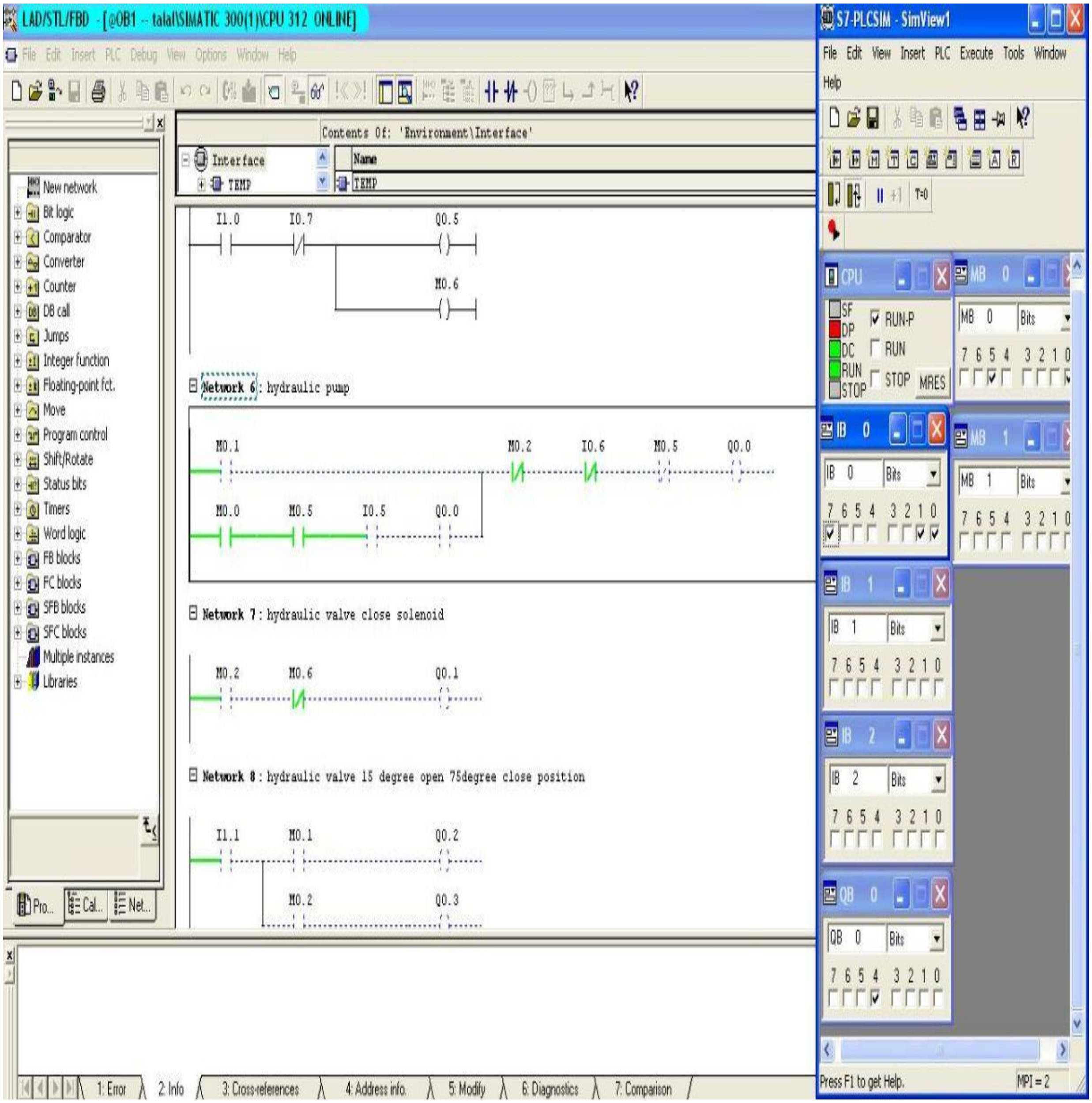


Figure 3.15: Valve fully open position simulation

To close the hydraulic valve energizes the close solenoid valve. Therefore the input I0.2 is ticked which energized the memory bit M0.2 hence energizes the output relay Q0.1 Figure 3.16 clarify the valve close process by open solenoid valve that drain the hydraulic oil inside the valve piston and the valve will close by weighted load.

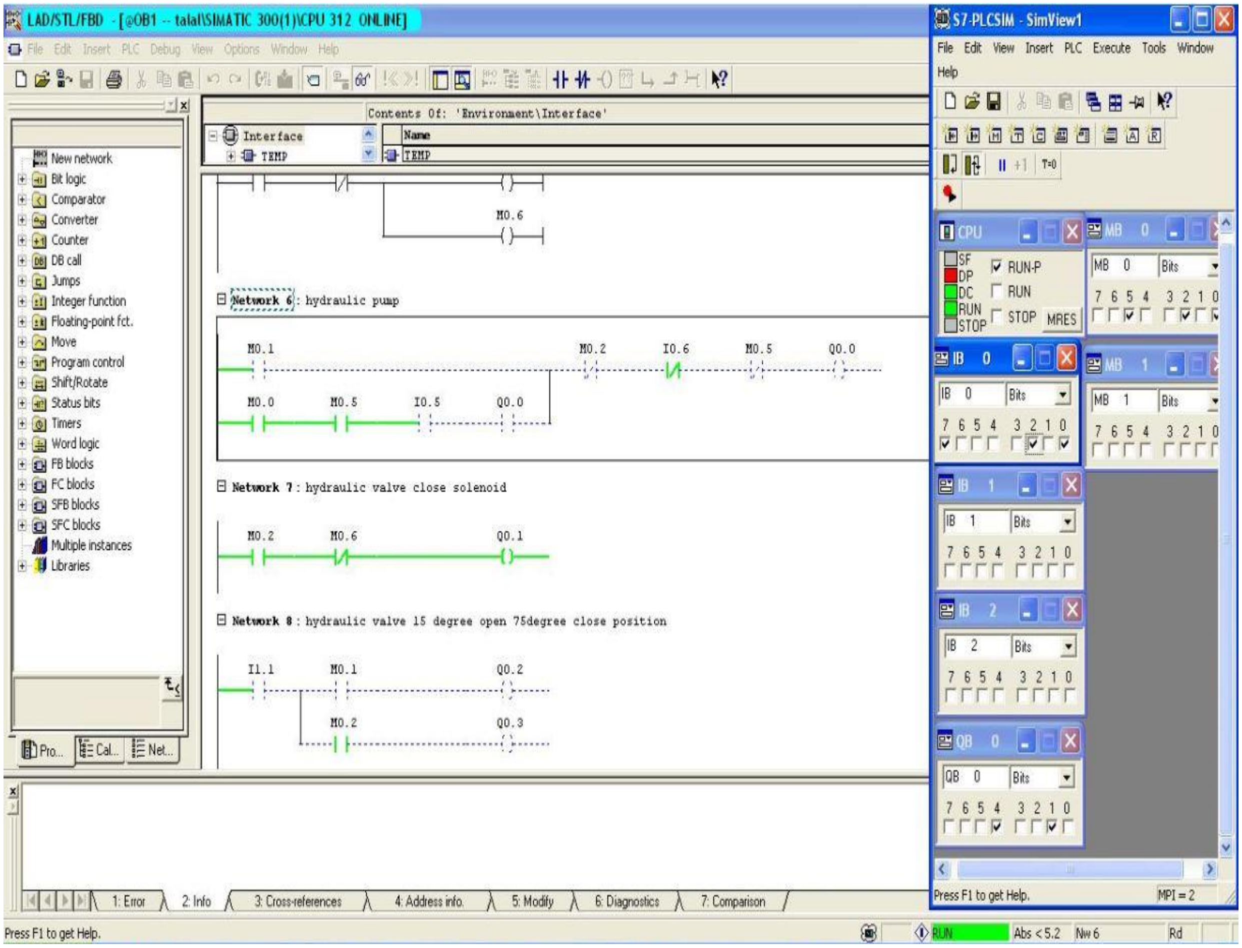


Figure 3.16: Valve close command simulation

Chapter Four

System Implementation and Testing

4.1 System Implementation

After studying the system in the previous chapters the system hardware components and the process variables of the system have been identified furthermore the control philosophy and the type of control and hence the controller has been defined. The hydraulic valve system process variables are illustrated in the Table 4.1 that contains the digital inputs and outputs variables.

Table 4.1: hydraulic valve inputs and outputs variables

Process variable description	PLC address code
Hydraulic valve fully open position	I0.7
Hydraulic valve fully close position	I1.0
Hydraulic valve 15 degree position	I1.1
Hydraulic oil pressure high	I0.6
Hydraulic oil pressure low	I0.5
Hydraulic valve local open command pushbutton	I0.1
Hydraulic valve local close command pushbutton	I0.2
Hydraulic valve remote open command from main controller	I0.3
Hydraulic valve remote close command from main controller	I0.4
Hydraulic oil level low alarm	I1.3
Hydraulic valve local stop command	I0.0
Hydraulic valve remote stop command from main controller	I1.4
Hydraulic oil pump start command	Q0.0
Solenoid valve open command	Q0.1
Hydraulic valve 15 degree position to main controller	Q0.2
Hydraulic valve75 degree position to main controller	Q0.3
Hydraulic valve fully open position to main controller	Q0.4
Hydraulic valve fully close position to main controller	Q0.5
Hydraulic oil valve stop indication	Q0.6
Hydraulic oil level low	Q0.7

4.1.1 Control circuit design and implementation

The control system type depends on system process variables types whether it is analogue or digital and the total numbers of these variables, therefore, the controller has been selected to satisfy these parameters specifications. Since the hydraulic valve system process variable are all digital as shown in Table 4.1 besides the total numbers of these parameters are almost are 14 inputs and 6 outputs the controller that compatible with these design requirements is Siemens step7 -200 type cpu 224 which has 14 inputs and 10 outputs. Furthermore, the power supply type for process variables is very crucial for selecting controller type for instance; the power supply for inputs variables for hydraulic valve system is DC as selected by the system designer. Whereas the supply power output variable is AC so as to start the hydraulic equipment through relay outputs so the relay output is selected to be a PLC output. In addition to this the AC power is selected to feed the PLC itself. Figure 4.1 illustrates the control circuit of hydraulic valve system including the programmable logic controller.

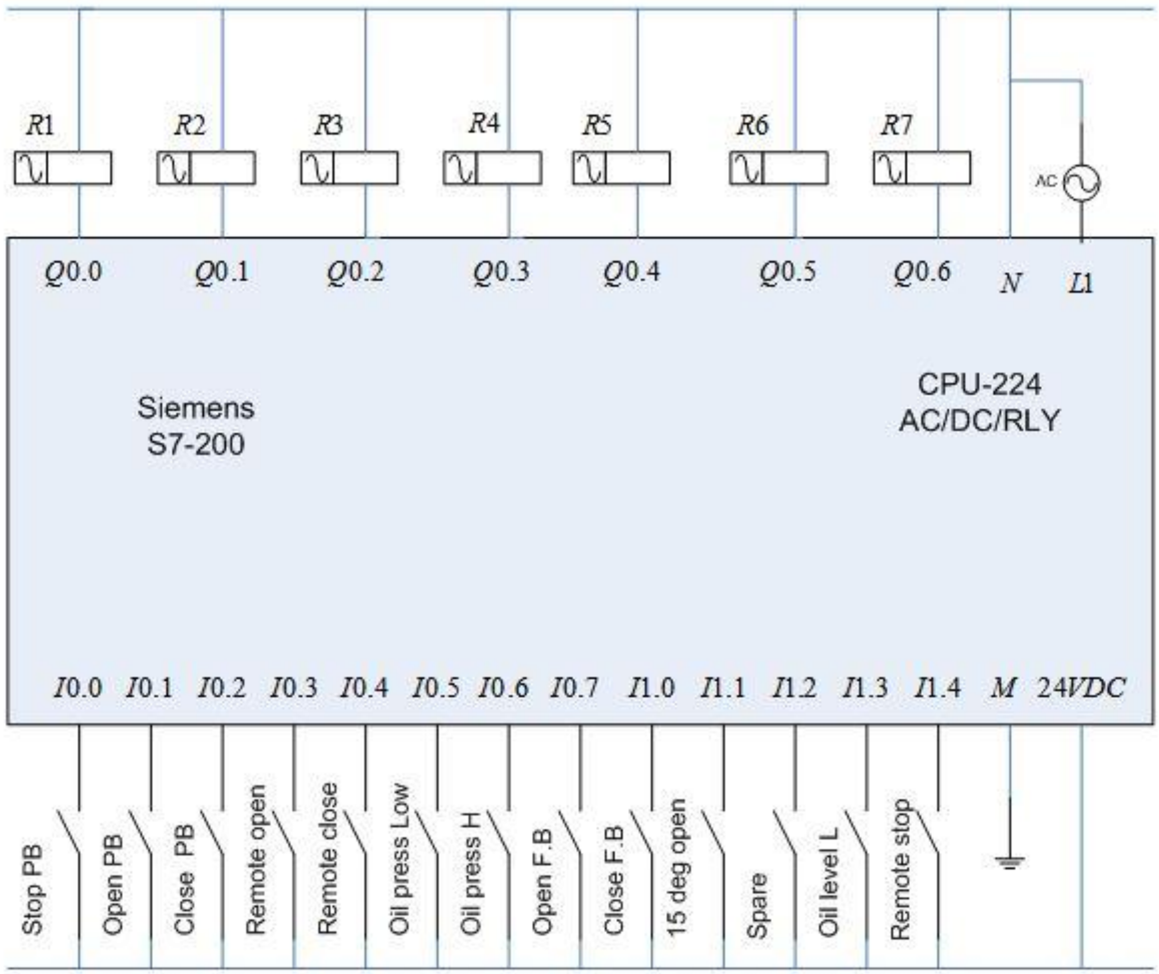


Figure 4.1: System control circuit No. (1)

At the bottom of the figure there are inputs variables that include all inputs that mentioned in table 4.1 and fed by 24 VDC. At the top the output relays is existed to work as interface between the controller and hydraulic components of the valve such as hydraulic pump and solenoids valves besides this there is power supply which is used as power supply for programmable logic controller. Also there is control circuit no (2) that depict the hardware circuit and comprises the inputs pushbuttons and indication lamps. This hardware control circuit is shown in Figure 4.2.

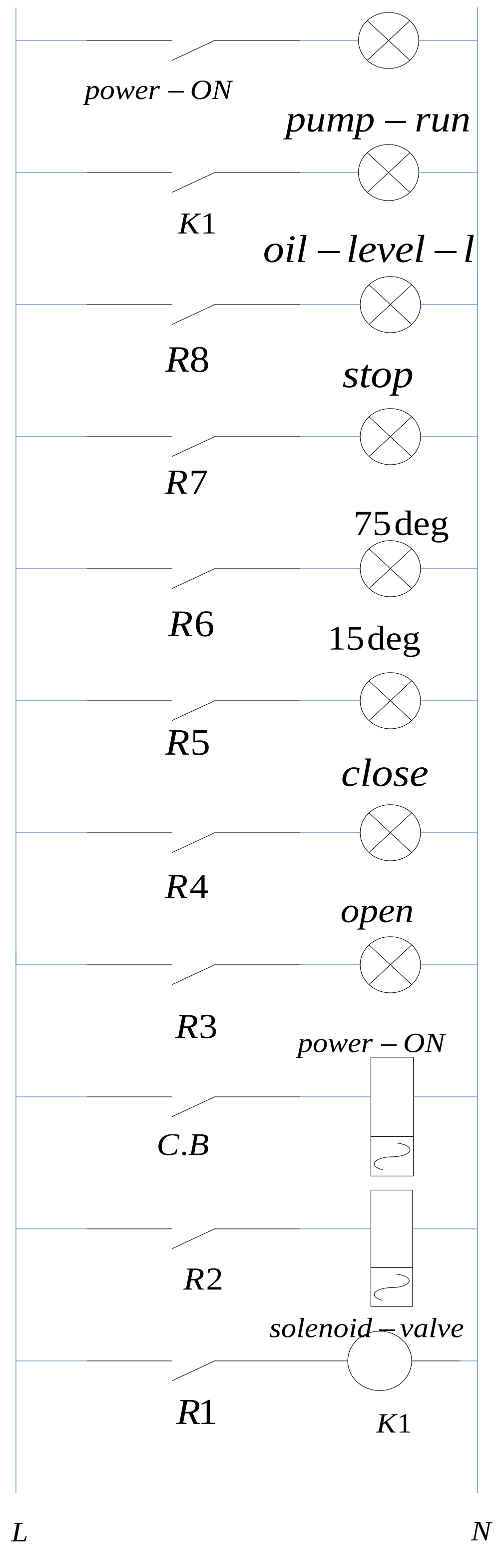


Figure 4.2: Control circuit No. (2)

4.1.2 Hydraulic valve control system program configuration

To configure programmable logic controller first the connection between the Programming Device (PG) and PLC is established via Point to Point Interface (PPI) using PPI to USB adapter then start STEP 7-Micro/WIN icon that shown in Figure 4.3 to open a new project.

Figure 4.3: Programming tools (MicroWIN SP4)

Figure 4.4 shows a new project. At the left side of window the navigation bar is noticed. You can use the icons on the navigation bar to open elements of the STEP 7-Micro/WIN project. Click on the communications icon in the navigation bar to display the Communications dialog box that shown in Figure 4.4. Dialog box can be used to set up and verify the communications parameters for STEP 7-Micro/WIN so as to verify that the address of the PC/PPI cable in the communications dialog box is set to 0 and the interface for the network parameter is set for PC/PPI cable (COM1, and the transmission rate is set to 9.6 kbps).

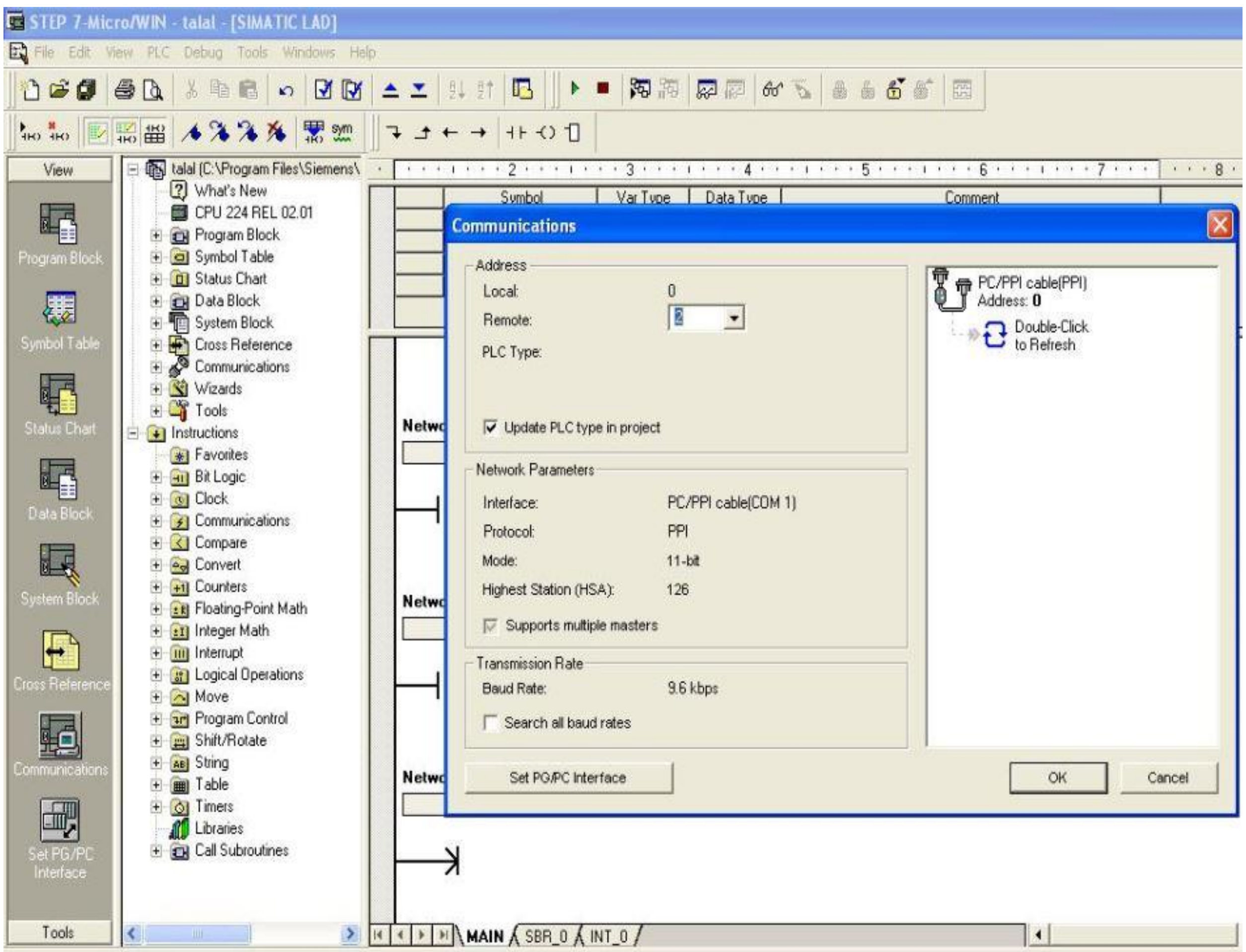


Figure 4.4: New project communication dialogue window

Then the programming device commutation is configured by clicking on set PG/PC interface icon and tick on point to point interface for PC as illustrates in Figure 4.5.

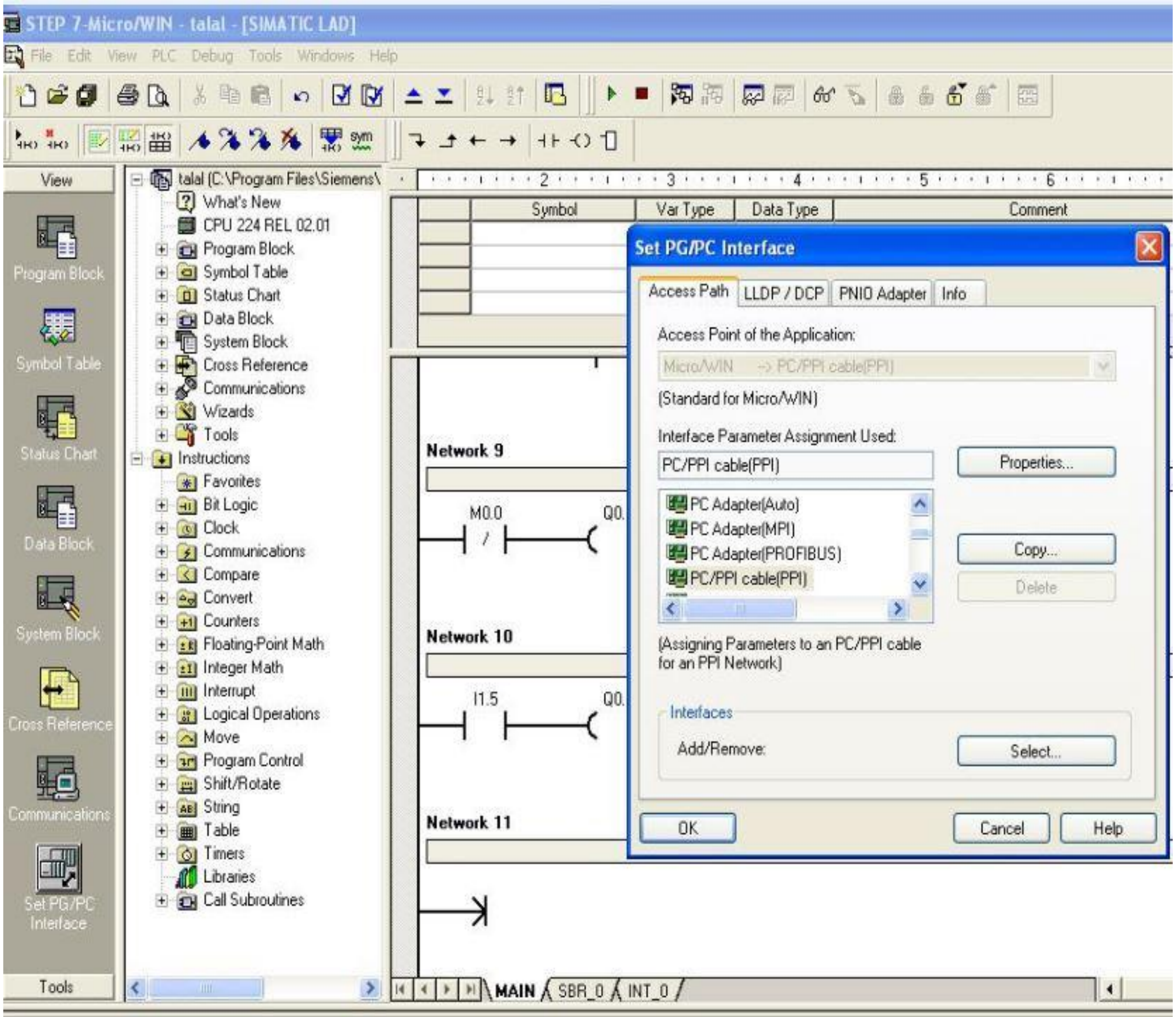


Figure 4.5: Programming device communication setting window

Then click on the refresh icon in the communications dialog box.STEP 7-Micro/WIN to search for the S7-200 station and displays a CPU icon for the connected S7-200 station as shown in Figure 4.6. After Communications have been established with the S7-200, the PLC is ready to create and download the system program.

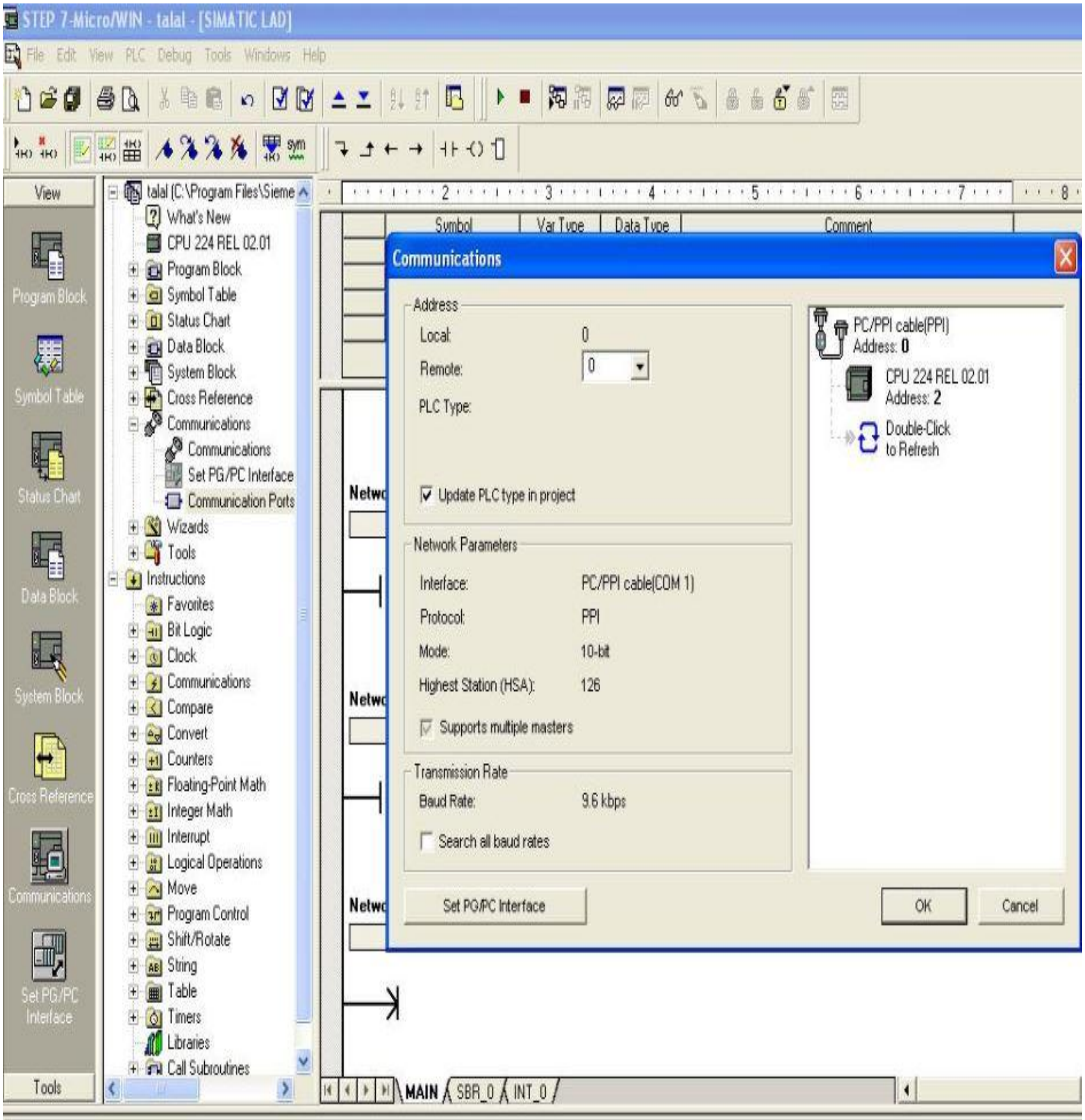


Figure 4.6: Connected PLC window

Then the program has been created as shown in Figure 4.7 according to hydraulic valve principle of operation and design requirements. The program includes all valve opening and closing procedure besides all protections interlocks for forwarding pump. In addition to this all alarms and warning that should displayed when there is any failure occurs in valve equipments.

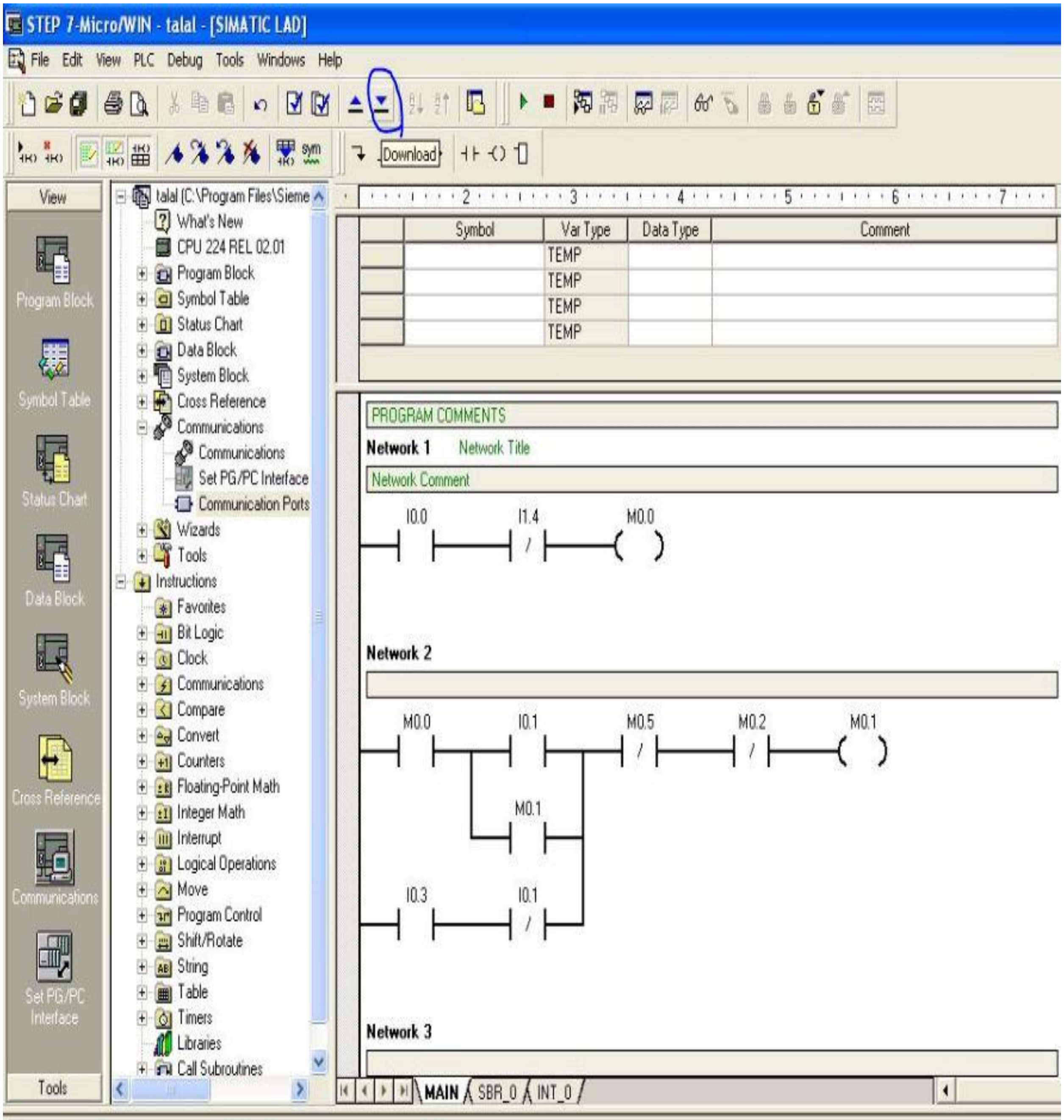


Figure 4.7: Project program block window

After the program is reviewed to guarantee that it is built successfully to satisfy the system operation requirements it is downloaded to programmable logic controller from our programming device as shown in Figure 4.8.

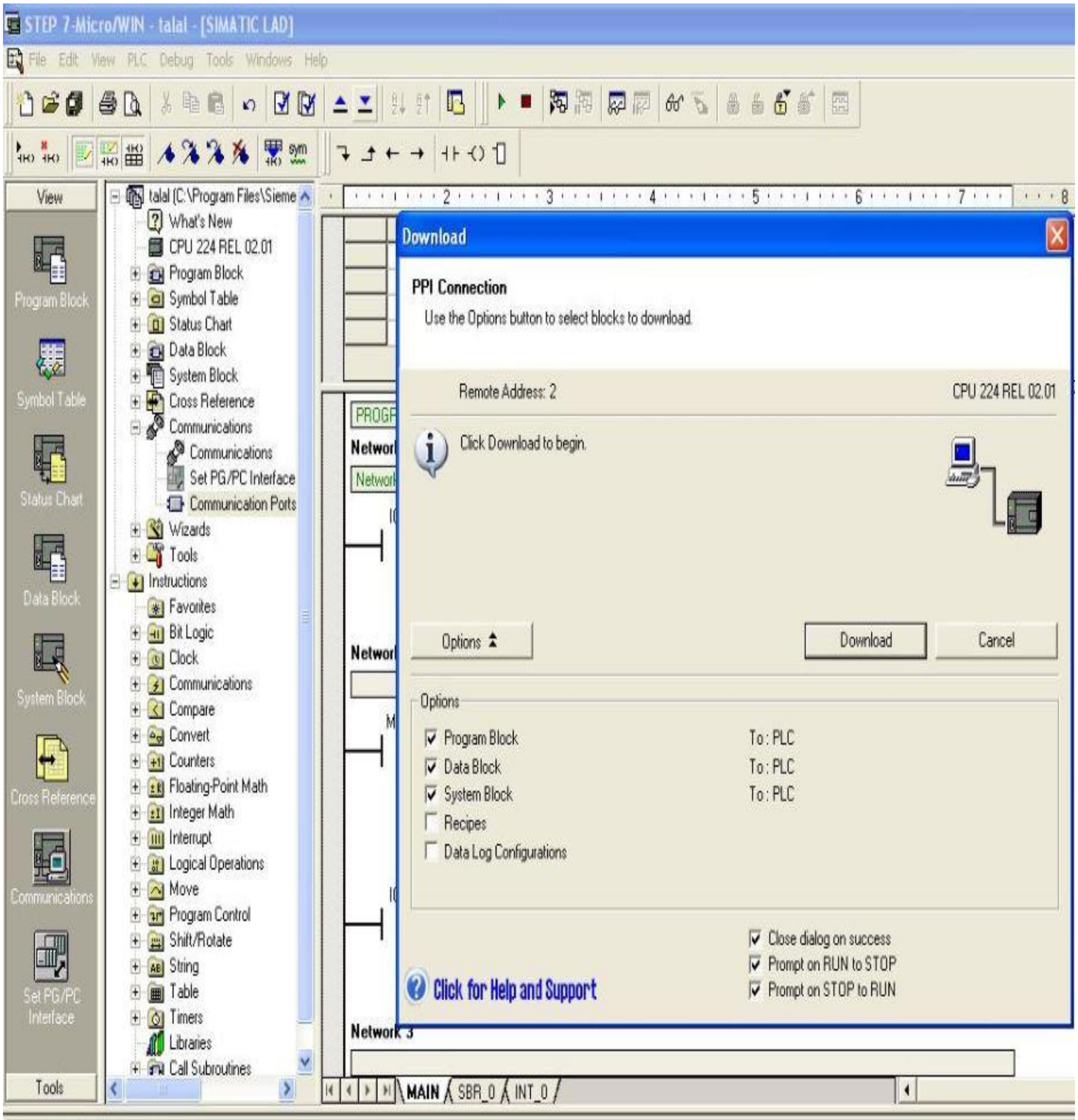


Figure 4.8: The project download to PLC window

So now the PLC is ready to control the hydraulic valve and when make it online it will be as illustrate in Figure 4.9.

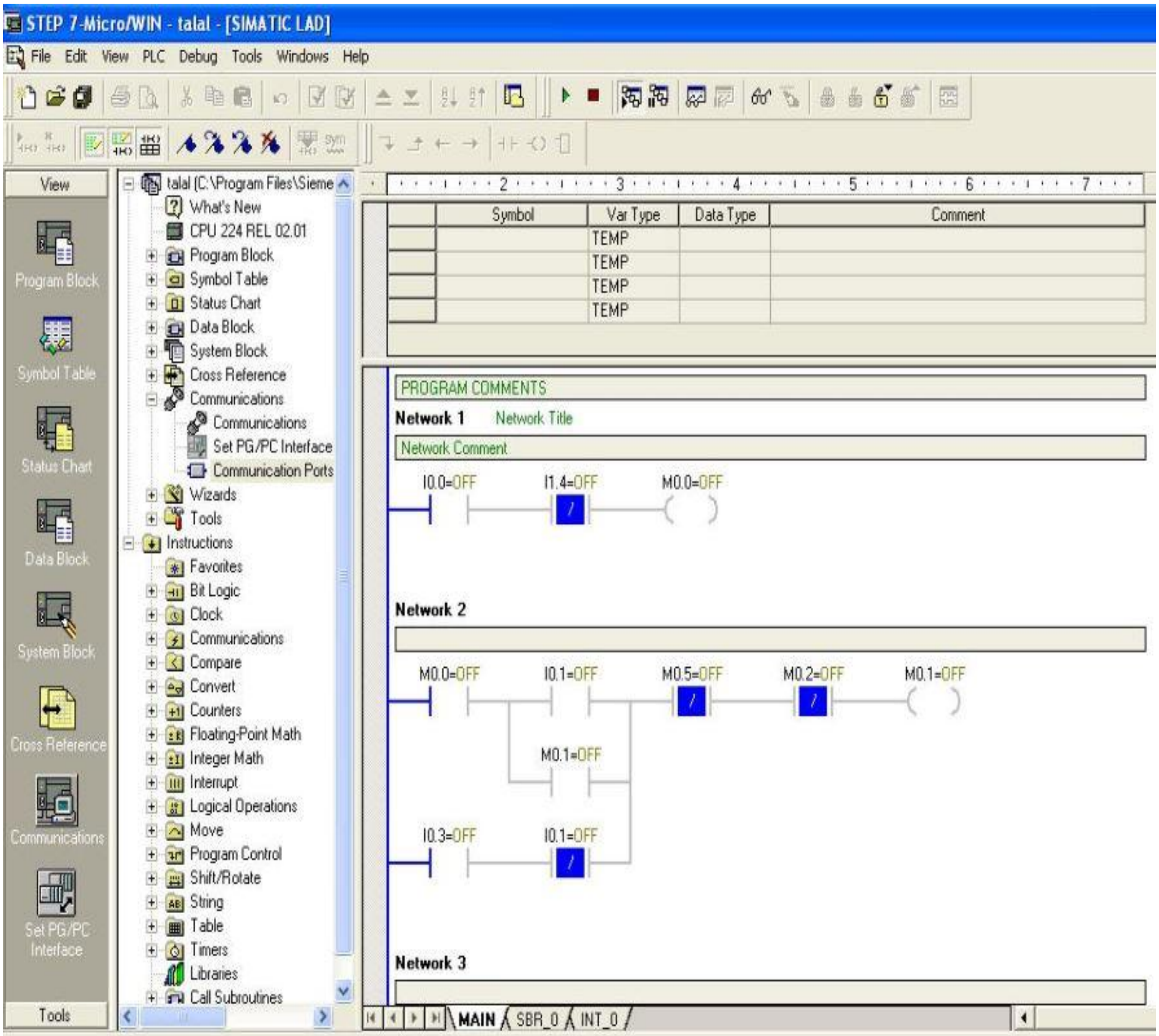


Figure 4.9: Project online window after program downloaded

4.1.3 Power circuit design and implementation

The main criteria that govern the power circuit design is motor design specification which has been used to calculate the power system components capacity and materials .in power circuit that shown in Figure 4.10 a precise calculations for this circuit is essential so as to protect the motor and to avoid high rate of motor trip besides increase motor reliability.

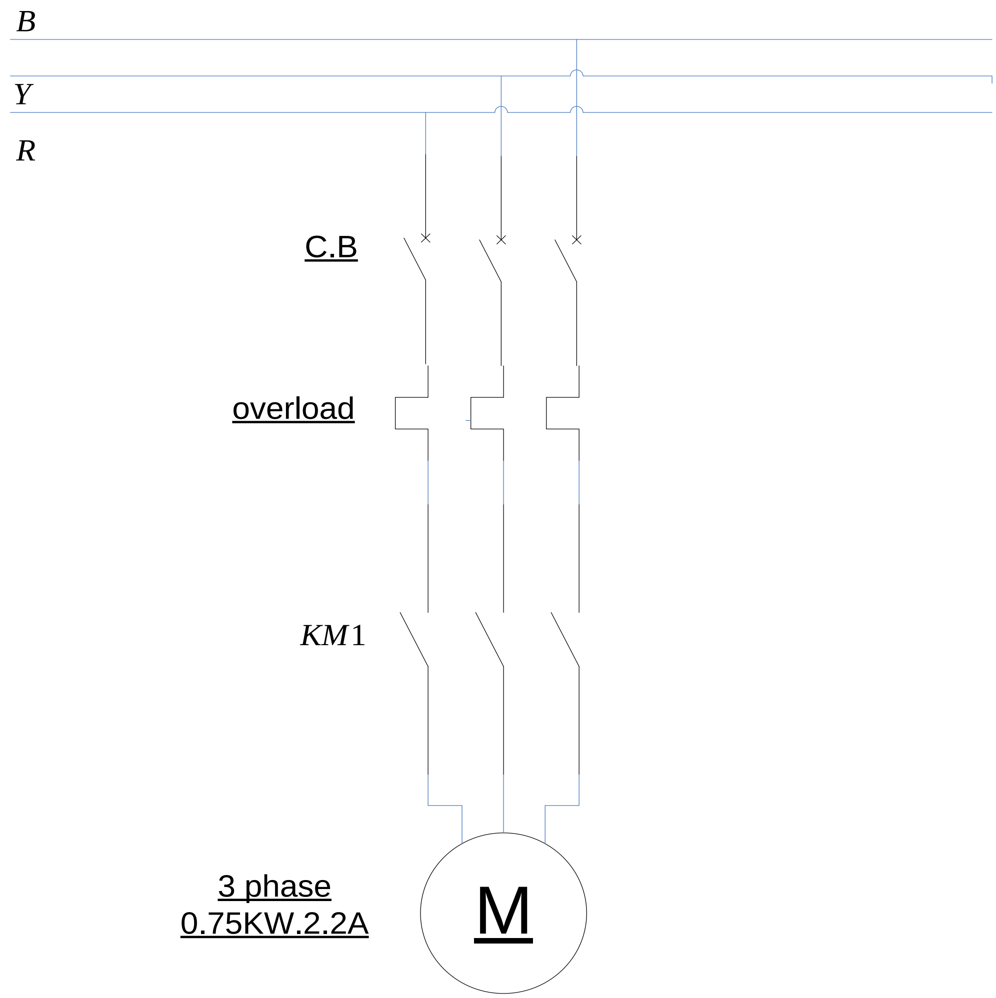


Figure 4.10: System power circuit

- Circuit breaker size calculations:

First to calculate the size of circuit breaker as per NEC 430-52 for motor has a current 2.2 A is Maximum Size of Instantaneous trip Circuit Breaker = 800%x2.2 = 17.6 A , And Maximum Size of Inverse trip Circuit Breaker = 250%x2.2 = 5.5 .

- Thermal overload size calculations:

Amp and for thermal overload calculation for same motor is minimum thermal overload relay setting = 70%x full load current (Phase) so it is 0.7 x 2.2 = 1.54 A and maximum thermal overload relay setting = 120%x2.2 = 2.64A so the overload setting should be in between 1.54A to 2.64 A. finally contactor type selection is AC3 for Squirrel Cage induction Motor .

The final implemented control and power circuit for hydraulic valve is shown in Figure 4.11.

Figure 4.11: Final implemented power and control circuits for the valve

4.2 Hydraulic Valve Control System Testing

System testing of software or hardware is testing conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements. System testing is performed on the entire system in the context of a functional requirement specification and/or a system requirement specification. System testing tests not only the design, but also the behaviour and even the believed expectations of the customer. It is also intended to test up to and beyond the bounds defined in the software/hardware requirements specification. So after the hydraulic valve control system has been designed and implemented the system is tested to ensure that the system is implemented correctly also to confirm that the valve operation function is designed as specified.

4.2.1 Hydraulic valve open testing

First the hydraulic valve open operation is tested as illustrate in Figure 4.12

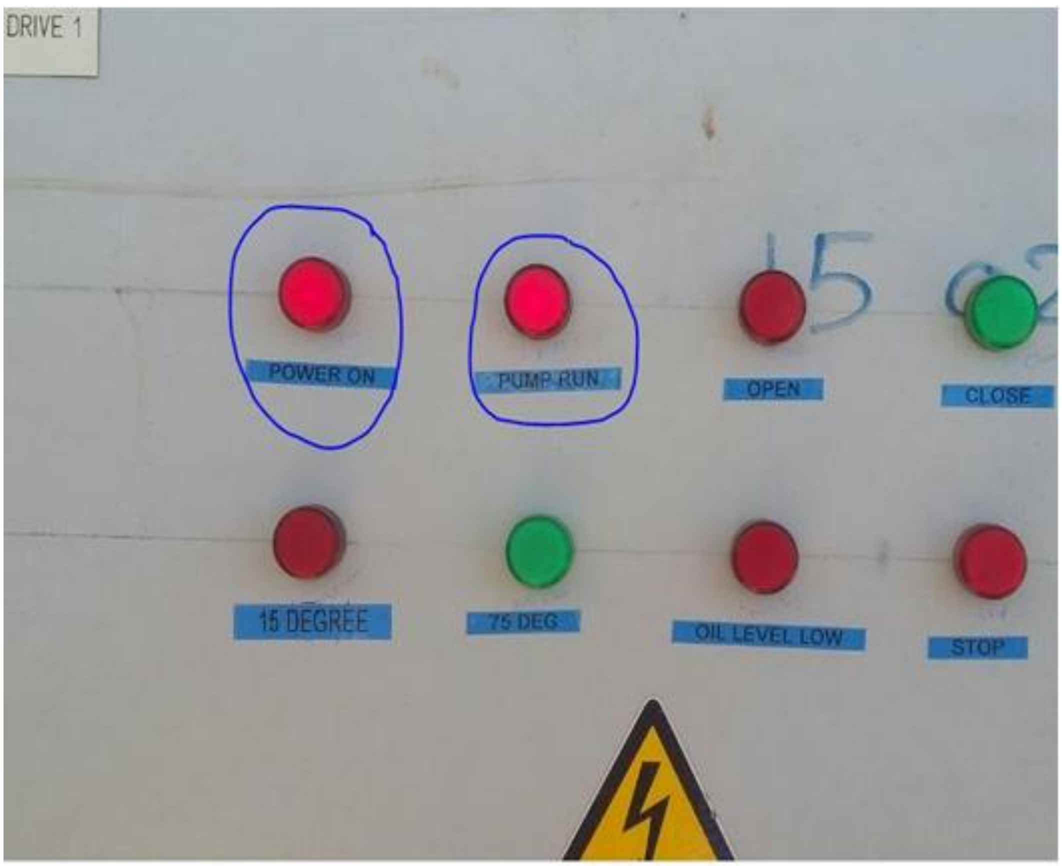


Figure 4.12: Hydraulic valve opening process

The above Figure 4.12 shows the valve locally and remotely opening process which starts by running the hydraulic pump to build up the pressure inside the valve piston to increase the hydraulic force. The opening time as shown in Figure 4.13 became very short approximately 29 seconds compare to manual opening process before designing the control system.

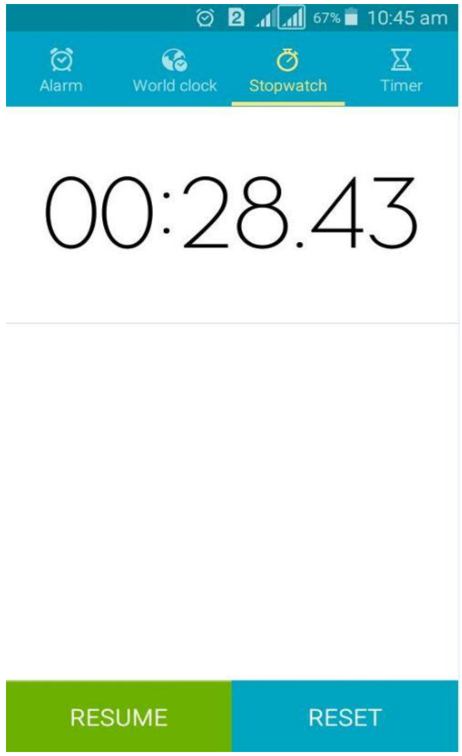


Figure 4.13: Hydraulic valve opening time

Figure 4.14 shows the control system status and alarms at opening process the local indication showing the valve opening status besides the programmable logic control sent this status to main control unit.

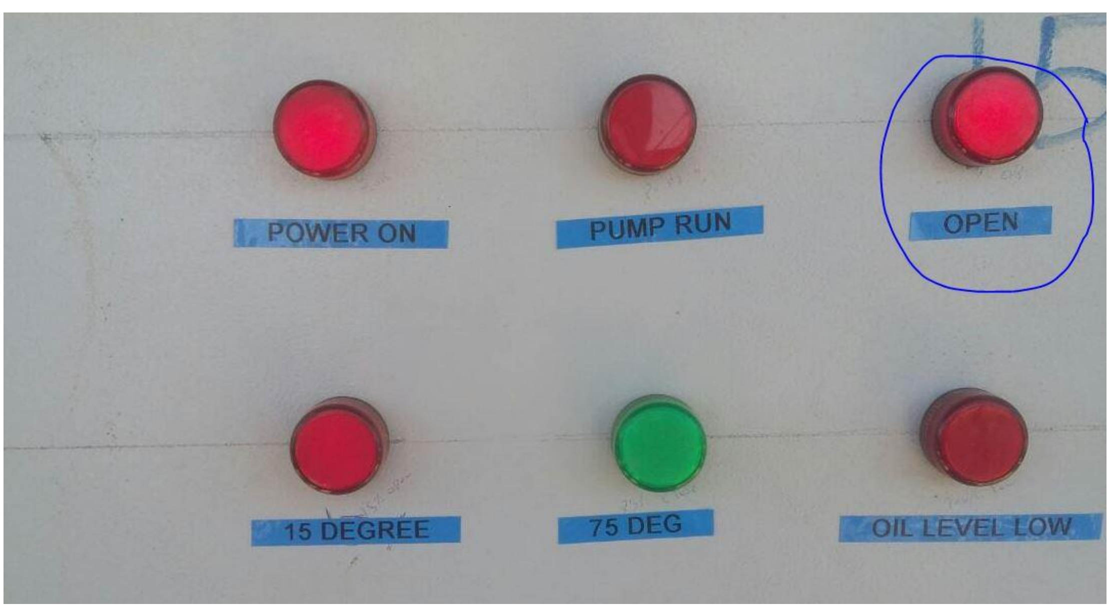


Figure 4.14: Hydraulic valve fully open position

4.2.2 Hydraulic valve close testing

In other hand the hydraulic valve closing process is shown in Figure 4.15 the valve is closed either locally or remotely then after the valve has been closed the limit switch latched to indicate the valve is closed then the close indication lamp illuminated and the close status is sent to main control unit also the closing time is counted and it is approximately 16 seconds which illustrates in Figure 4.16.

Figure 4.15: Hydraulic valve fully close position

Figure 4.16: Hydraulic valve closing time

4.2.3 Hydraulic system protection and indications testing

Furthermore, how the control system will react to hydraulic oil pressure changing is tested .When hydraulic oil pressure get high and the valve does not reach fully open position the hydraulic pump is forced to stop so as to protect hydraulic system equipments and hydraulic oil system should be checked. Figure 4.17 illustrates the hydraulic pump is forced to stop at high pressure.

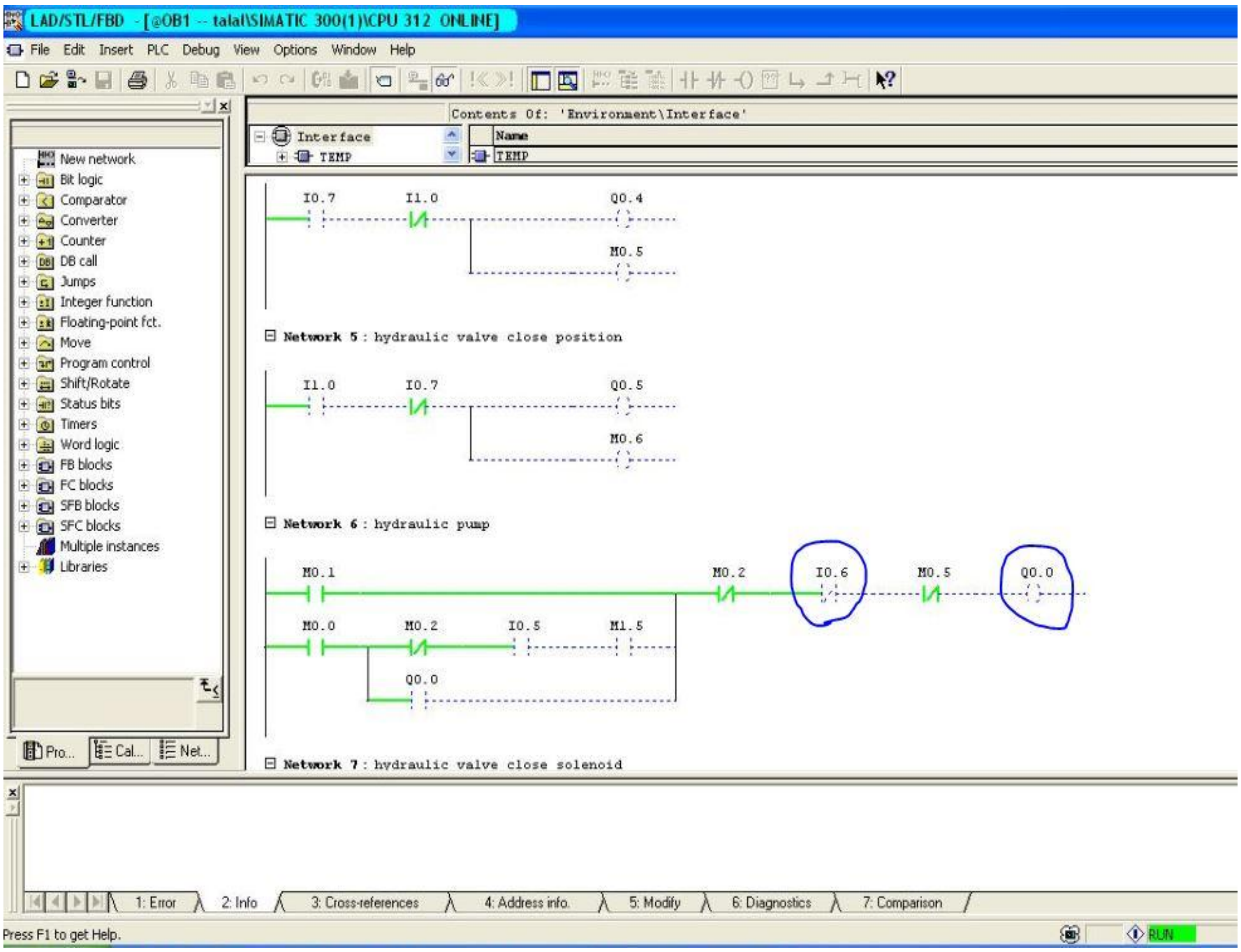


Figure 4.17: Hydraulic pump force to stop due to pressure high

When the oil pressure get low and there is an open order the hydraulic pump will start automatically to compensate the pressure drop .Figure 4.18 shows the automatic start of hydraulic oil pump at low pressure.

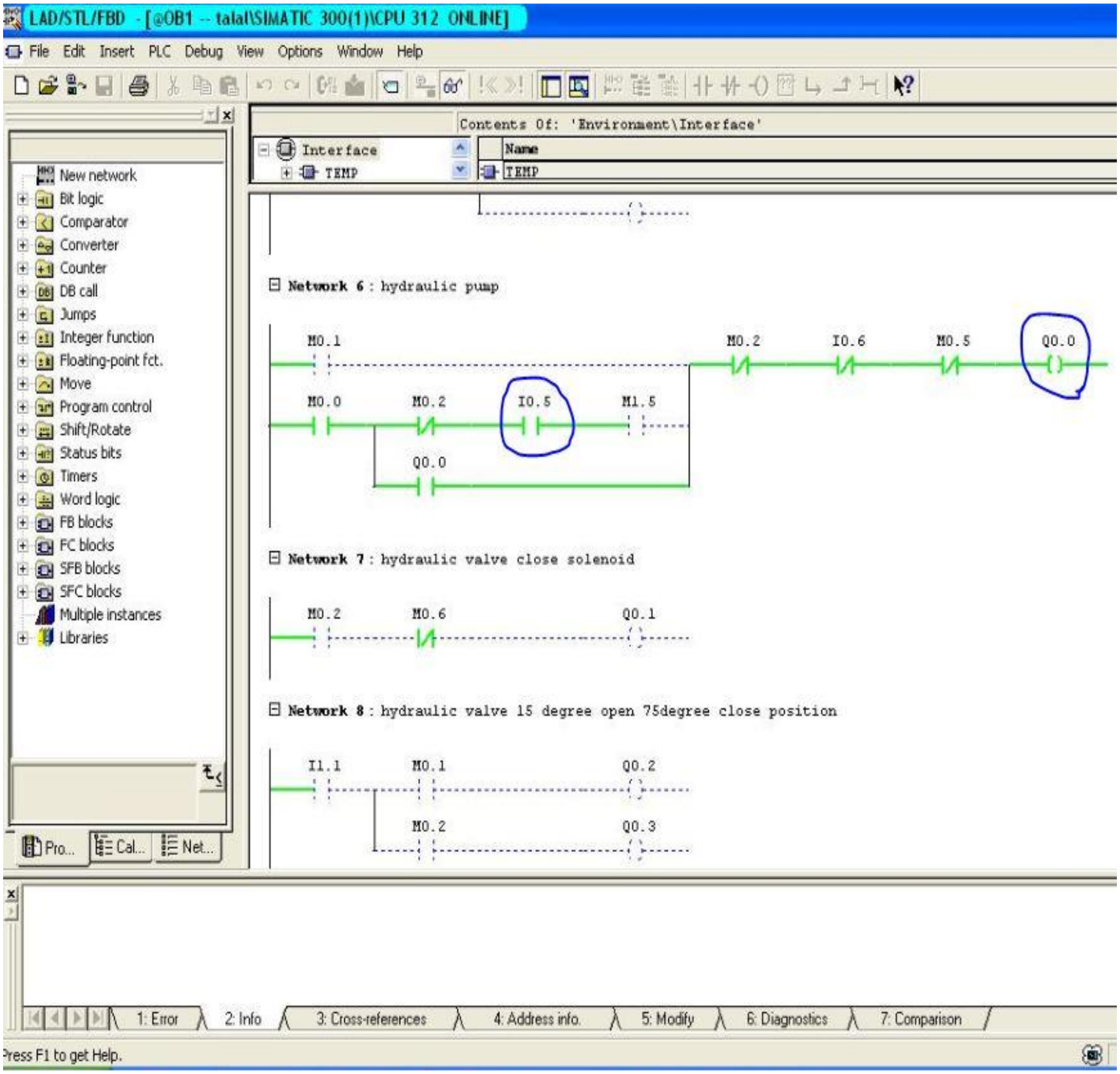


Figure 4.18: Hydraulic pump force to start due to pressure low

Also the alarms of oil tank level low is tested as shown in Figure 4.19 besides the other indications such as power on to indicate that there is an power in control cabinet and 15degree open and 75 degree close that shown in Figures 4.20 and Figure 4.21.

Figure 4.19: Hydraulic oil level low alarm

Figure 4.20: 15 degree open position to automatic start make up pump

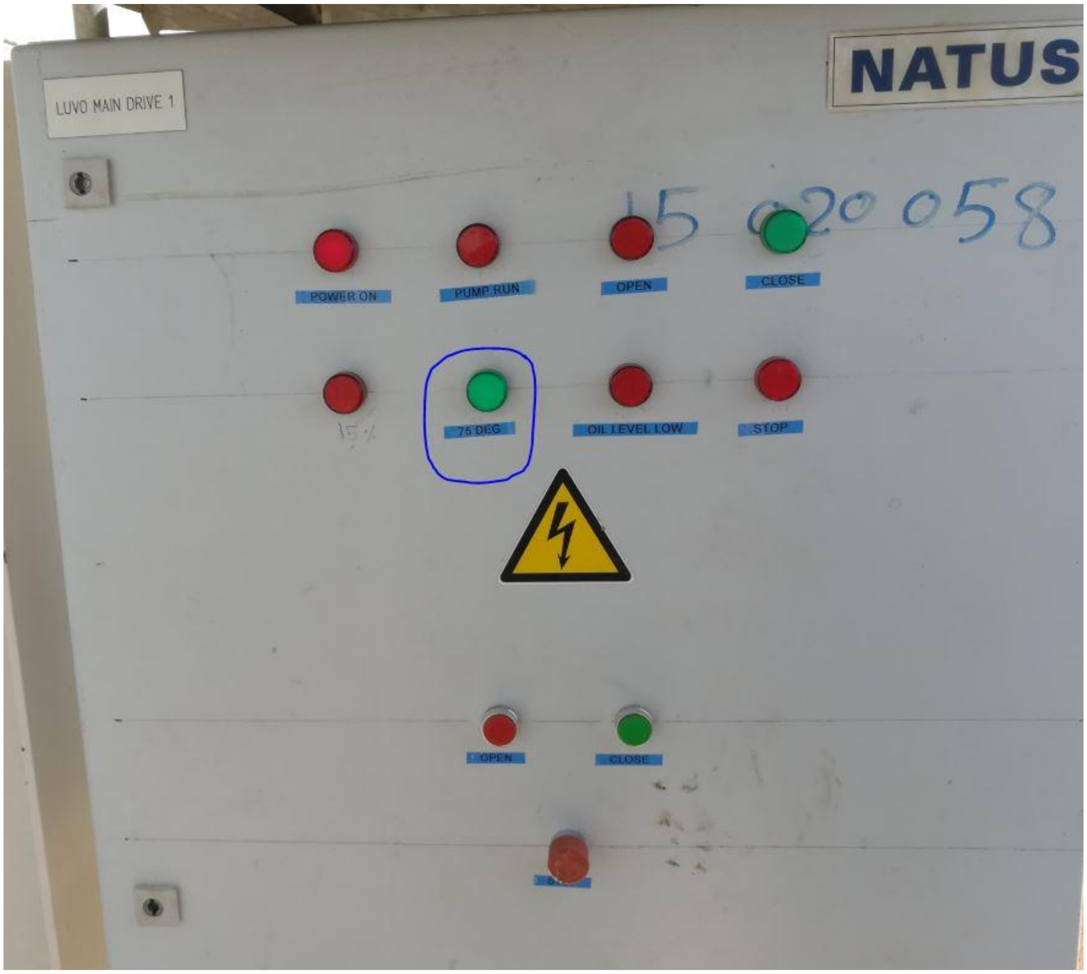


Figure 4.21: 75 Degree open position to automatic stop make up pump

Chapter five

Conclusion and Recommendations

5.1 Conclusion

The hydraulic valve control system has been designed according to hydraulic valve operating parameters and open/close design requirements and this increases the hydraulic system lifetime and reduce maintenance cost and efforts.

Then the system has been implemented in such way that could eliminate the problems that produced by manual operation. The designed control system after has been implemented is tested to guarantee that all objectives are achieved and the results of these test were satisfied.

5.2 Recommendations

It is better to observe the hydraulic valve open position as long as the valve is kept fully open. This can be done by installing a position sensor to indicate when the valve is fall from fully open position and the hydraulic pressure is not getting low at this position this position sensor will latch to start the hydraulic pump automatically to increase hydraulic pressure hence , the valve will return to fully open position again.

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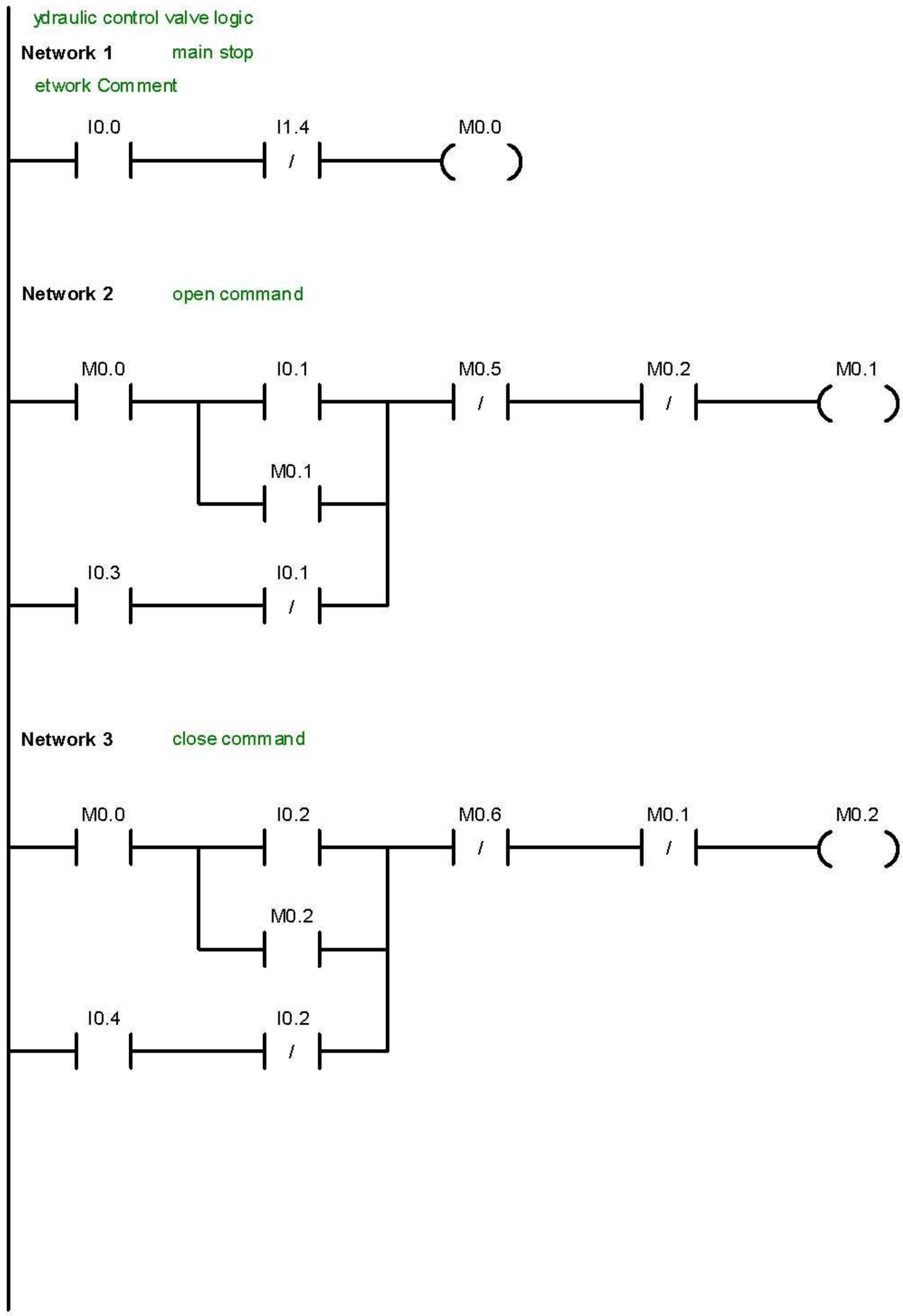
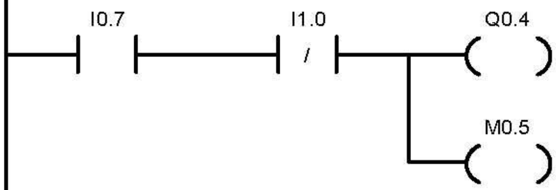
Appendix

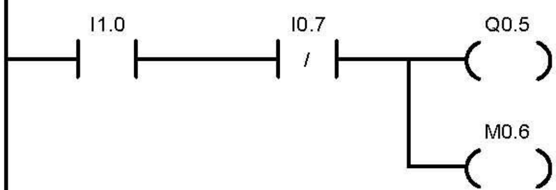
Hydraulic valve control logic



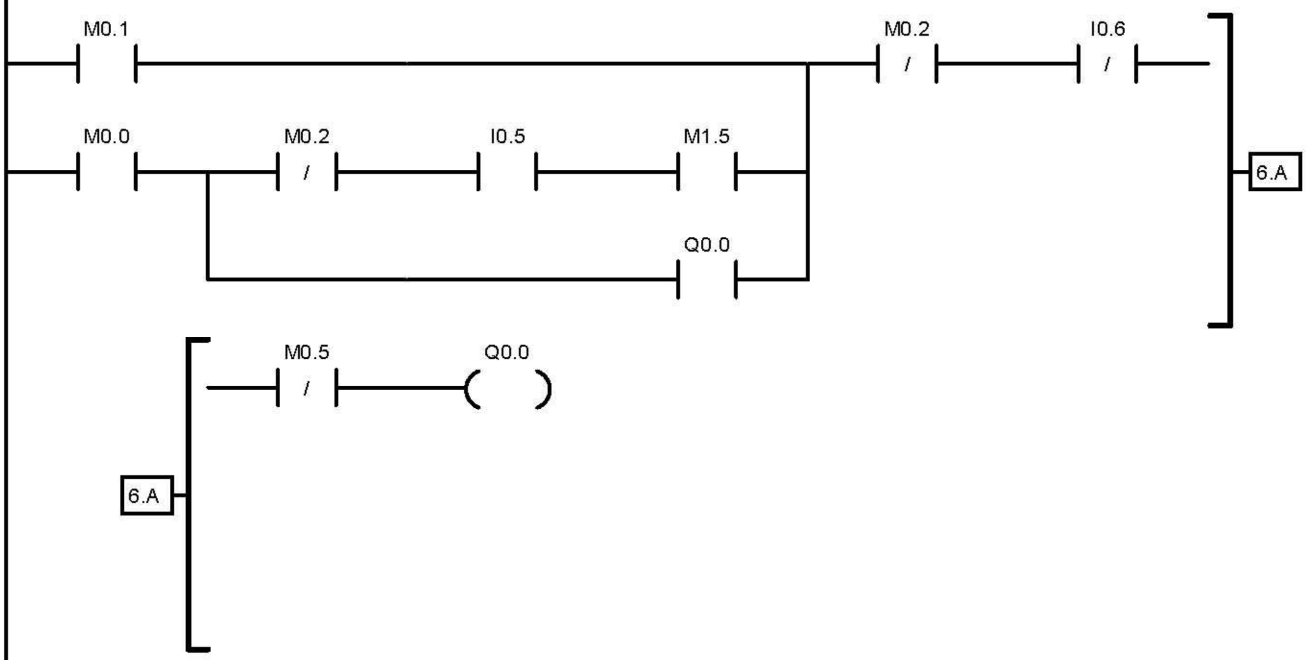
Network 4 valve open position

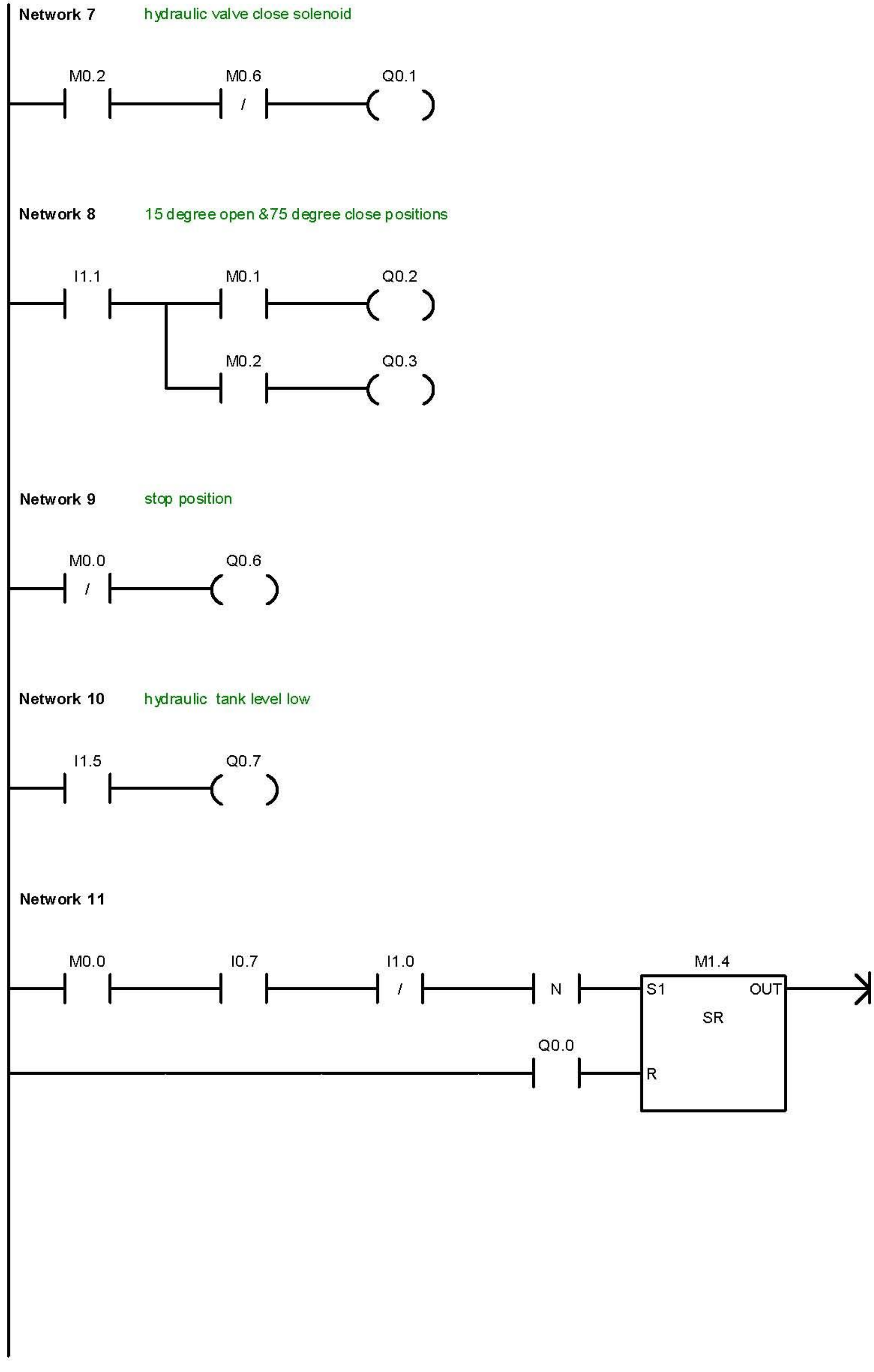


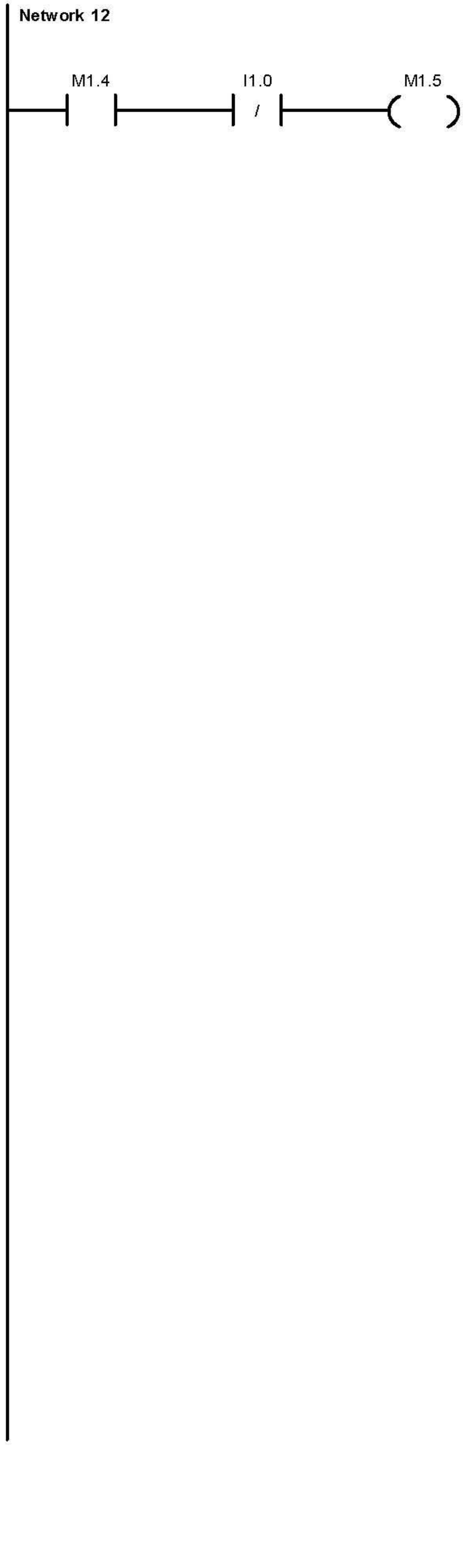
Network 5 close position



Network 6 hydraulic pump




Network 7
hydraulic valve close solenoid
M0.2
M0.6
/
Q0.1
Network 8
15 degree open &75 degree close positions
I1.1
M0.1
Q0.2
M0.2
Q0.3
Network 9
stop position
M0.0
/
Q0.6
Network 10
hydraulic tank level low
I1.5
Q0.7
Network 11
M0.0
I0.7
I1.0
/
N
M1.4
S1
OUT
SR
Q0.0
R


Network 12
M1.4
I1.0
/
M1.5