PLC BASED CONTACTOR TESTING MACHINE

A Project Report

Submitted by

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BONAFIDE CERTIFICATE

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LECS

LAKSHMI ELECTRICAL CONTROL SYSTEMS LIMITED

April 7, 2008

TO WHOMSOEVER IT MAY CONCERN

This is to certify that the following Final year B.E (Electrical & Electronics Engineering) students from Kumaraguru College of Technology, Saravanampatti, Coimbatore – 641 006, have done the project on **"PLC BASED CONTACTOR TESTING MACHINE"**.

We found their performance and conduct were highly commendable.

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28th MARCH, 2008

CERTIFICATE

...is to acclaim that Ms / ~~Mrs~~ / ~~Mr~~ / ~~Dr.~~ ... R. JANANI ...
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... *at "RETEEICOM - '08" held on 28th March 2008,*
...d by the departments of EEE, ECE & EIE.

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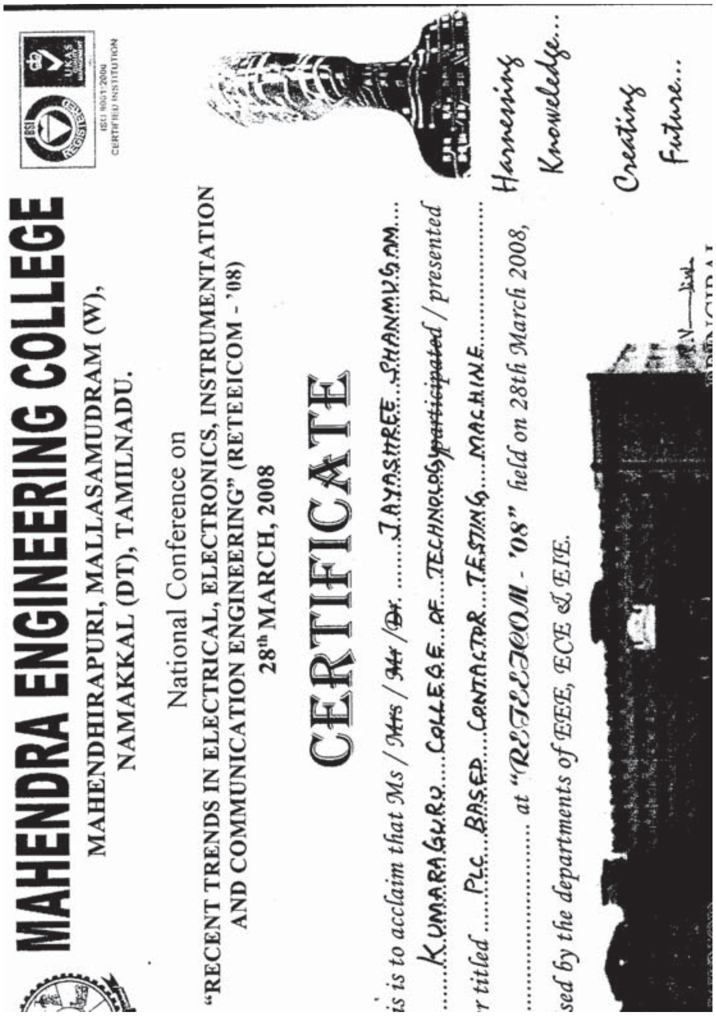
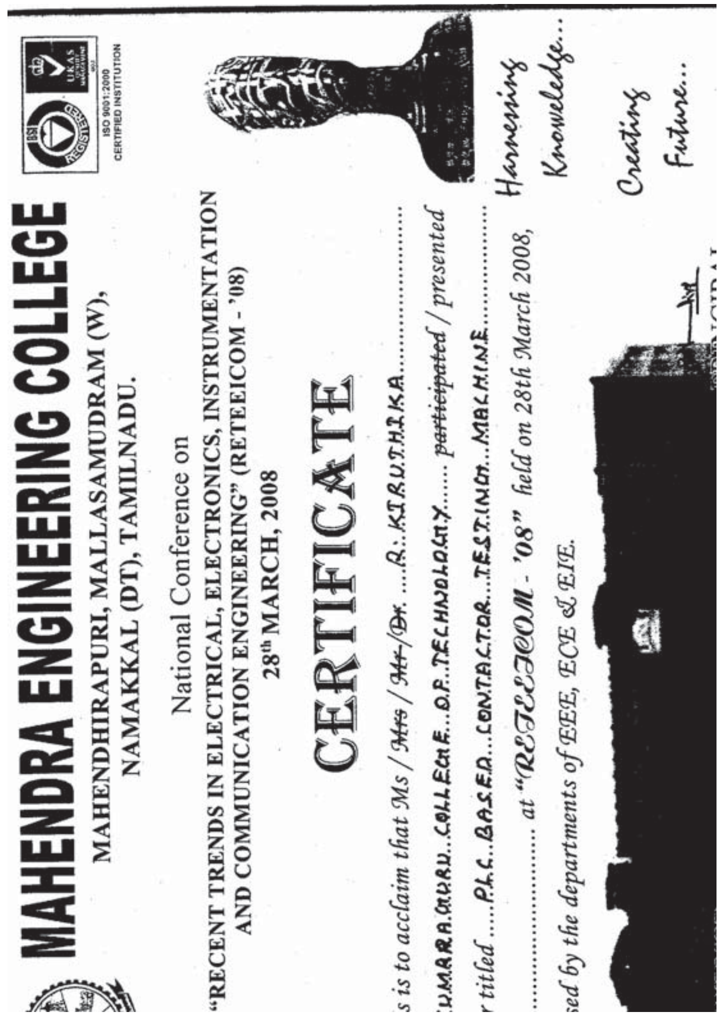
PRINCIPAL





ABSTRACT

All the contactor manufacturers give vital importance to marketing of their product. So, it is essential to test the contactors before marketing. A series of tests have to be conducted on the contactor and it requires more man power if done manually. This not only gives way to human errors but at times it proves to be less efficient and not reliable.

The control of the testing of contactors, using automation is done with the help of Programmable Logic Controller(PLC). The ladder logic is used for programming the PLC. Automation reduces testing time ,manpower and increases reliability.

ACKNOWLEDGEMENT

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LIST OF SYMBOLS AND ABBREVIATIONS

NO.	SYMBOLS	ABBREVIATIONS
01	PLC	Programmable Logic Controller
02	NO	Normally Open
03	NC	Normally Closed
04	PIR	Passive Infrared
05	SAC	Single Acting Cylinder
06	DAC	Double Acting Cylinder
07	PBU	Push Button Up
08	I/O	Input/Output
09	PPI	Point to point interface
10	LAD	Ladder Logic
11	STL	Statement List
12	FBD	Function Block Diagram
13	C	Counter
14	AC	Accumulator
15	T_{on}	On-Delay Timer
16	CV	Current Value

1. INTRODUCTION

1.1 OBJECTIVE

The main objective of this project is to simplify the test bench for testing contactors which will give results with higher accuracy and faster rate when compared with a semi-automatic test bench. It should increase the production rate of contactors and reduce the involvement of the skilled operator.

1.2 CONTACTOR

A contactor is an electrically controlled switch (relay) used for switching a power circuit. A contactor is activated by a control input which is a lower voltage / current than that which the contactor is switching. Contactors come in many forms with varying capacities and features. Unlike a circuit breaker a contactor is not intended to interrupt a short circuit current. Contactors range from having a breaking current of several amps and 110 volts to thousands of amps and many kilovolts. The physical size of contactors ranges from a few inches to the size of a small car. Contactors are used to control electric motors, lighting, heating, capacitor banks, and other electrical loads.

1.3 CONSTRUCTION

A contactor is composed of three different systems. The contact system is the current carrying part of the contactor. This includes Power Contacts, Auxiliary Contacts, and Contact Springs. The electromagnet system provides the driving force to close the contacts. The enclosure system is a frame housing the contact and the electromagnet. Enclosures are made of insulating materials like Bakelite, Nylon 6, and thermosetting plastics to protect and insulate the contacts and to provide some measure of protection against personnel touching the contacts. Open-frame contactors may have a further enclosure to protect against dust, oil, explosion hazards and weather.

Contactors used for starting electric motors are commonly fitted with overload protection to prevent damage to their loads. When an overload is detected the

Some contactors are motor driven rather than relay driven and high voltage contactors (greater than 1000 volts) often have arc suppression systems fitted (such as a vacuum or an inert gas surrounding the contacts). *Magnetic blowouts* are sometimes used to increase the amount of current a contactor can successfully break. The magnetic field produced by the blowout coils force the electric arc to lengthen and move away from the contacts. The magnetic blowouts in the pictured Albright contactor more than double the current it can break from 600 Amps to 1500 Amps.

Sometimes an *Economizer* circuit is also installed to reduce the power required to keep a contactor closed. A somewhat greater amount of power is required to initially close a contactor than is required to keep it closed thereafter. Such a circuit can save a substantial amount of power and allow the energized coil to stay cooler. Economizer circuits are nearly always applied on direct-current contactor coils and on large alternating current contactor coils.

Contactors are often used to provide central control of large lighting installations, such as an office building or retail building. To reduce power consumption in the contactor coils, two coil latching contactors are used. One coil, momentarily energized, closes the power circuit contacts; the second opens the contacts.

A basic contactor will have a coil input (which may be driven by either an AC or DC supply depending on the contactor design) and generally a minimum of two poles, which are controlled.

1.4 OPERATING PRINCIPLE

Unlike general-purpose relays, contactors are designed to be directly connected to high-current load devices, not other control devices. Relays tend to be of much lower capacity and are usually designed for both Normally Closed and Normally Open applications. Devices switching more than 15 amperes or in circuits rated more than a few kilowatts are usually called contactors. Apart from optional auxiliary low current contacts, a contactor normally only has Normally Open contacts fitted.

When current passes through the electromagnet, a magnetic field is produced which attracts ferrous objects; in this case the moving core of the contactor is attracted to the stationary core. Since there is an air gap initially, the electromagnet coil draws more current initially until the cores meet and reduce the gap, increasing the inductive impedance of the circuit.

For contactors energized with alternating current, a small part of the core is surrounded with a shading coil, which slightly delays the magnetic flux in the core. The effect is to average out the alternating pull of the magnetic field and so prevent the core from buzzing at twice line frequency.

Most motor control contactors at low voltages (600 volts and less) are "air break" contactors, since ordinary air surrounds the contacts and extinguishes the arc when interrupting the circuit. Modern medium-voltage motor controllers use vacuum contactors.

Motor controls contactors can be fitted with short-circuit protection (fuses or circuit breakers), disconnecting means, overload relays and an enclosure to make a combination starter. In large industrial plants many contactors may be assembled in motor control centers.

1.5 RATINGS

Contactors are rated by designed load current, maximum fault withstand current, duty cycle, voltage, and coil voltage. A general-purpose motor control contactor may be suitable for heavy starting duty on large motors; so-called "definite purpose" contactors are carefully adapted to such applications as air-conditioning compressor motor starting. North American and European ratings for contactors follow different philosophies, with North American contactors generally emphasizing simplicity of application while European rating philosophy emphasizes design for the intended life cycle of the application.

2.CONTACTOR TESTING PROCESS

2.1 TESTS CONDUCTED ON CONTACTORS

Different types of tests conducted on contactors are the following

1. High Voltage Test
2. Low Voltage Test
3. Coil Burden Test
4. Stroke Value Test
5. Humming Level Test
6. Holding Current Test

In this project, the tests 3, 4 and 5 are automated.

2.2 COIL BURDEN TEST

In this test, ability of the contactor's coil to energize and de-energize for maximum voltages applied to it is tested. The minimum voltage to switch OFF the contactor (Drop out Voltage Test) and the minimum voltage to switch ON the contactor (Pickup Voltage Test) is tested. Various coil voltages are applied continuously and checked for its tolerance. If the parameters are within the tolerance limits the contactor is accepted else it is rejected.

Normally for all contactors 65% of its maximum coil voltage will be its pickup voltage and 35% of its maximum coil voltage will be its drop out voltage.

Specification:

Type of test: Coil burden test for AC & DC Coils

Product: Control relays or Contactors

Mounting Position: Vertical mount without auxiliary block for routine test

Procedure: It is to be verified that the control relay / contactors opens & closes clearly within a particular voltage, when the coil circuits are rapidly opened or closed. Test shall be performed with no current flowing through the main circuit.

COIL BURDEN TEST BLOCK DIAGRAM

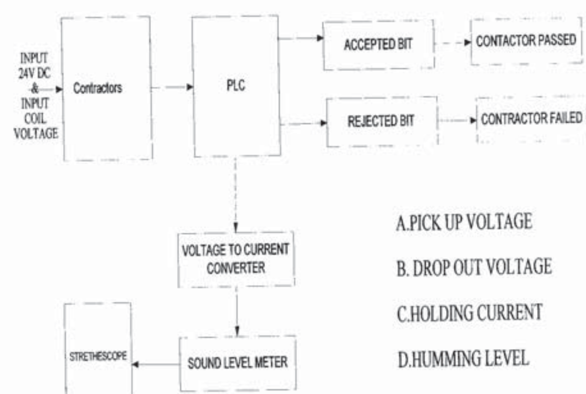


Fig 2.1 Coil Burden Test Block Diagram

2.3 HUMMING LEVEL TEST

In this test, the humming level during coil burden test is measured with the help of a stethoscope. The humming level should not be greater than 80db (decibels). The output of the stethoscope is given to the sound level meter. The output of the sound level meter will be 0 – 1V AC (or) 0 – 1V DC. In this project, we are using 0 – 1V AC. The output of the sound level meter is given to the Voltage – Current converter. The output of the voltage to current converter (4- 20mA) is given to the PLC Unit. The humming level is an analog measurement, the input to the PLC must be 4 – 20mA. If the humming level is within the tolerance level 4mA is given as input to the PLC else 20mA is given as input to the PLC.

2.4 STROKE VALUE TEST

The contactor consists of a coil and a moving armature. Energizing the coil causes the armature to move. The maximum distance moved is called a stroke.

To measure the stroke length, the armature of the contactor is moved to its maximum travel length by a stepper motor. Then the armature is slowly released and the distance at which the closed contact opens or opened contact closes is measured by infrared sensor. This distance is measured with respect to the maximum travel length and then compared with the standard limits.

Specification:

Type of test: Stroke value test for AC & DC Coils

Product: Control relays or Contactors

Mounting Position: Vertical mount without auxiliary block for routine test

Procedure: Perfect contact making is verified in this test. The stroke measurement is taken in the ON position. The maximum stroke, minimum stroke and total stroke length are measured.

3.AUTOMATION PROCESS

3.1 COIL BURDEN TEST MODULE

Initially, the presence of the contactor is sensed by an inductive sensor, which is given as input to the PLC. If the sensor is ON, the feeding cylinder is activated till the inductive sensor of coil burden test is ON. If the coil burden test sensor is ON, the PLC will switch ON the contact point cylinders. This cylinder will push the contact lead through which coil voltage and the NO/NC point's voltage is applied. Parallelly a relay is switched on through which a 24-volt supply is provided to the NO/NC points of the contactor.

All the NO/NC points are given a 24-volt supply. If the supply reaches the opposite lead of the contactor while the contactor is not energized, then the set of lead under consideration is a NC point or vice versa.

Now the contactor is switched ON and OFF for 10 times by the application of 100% voltage to its coil. This is done in order to remove the dust and other blockages, if any. After completion of 10 on & off, 65% of the coil rated voltage (pick up voltage) is applied to the coil of the contactor. Then the contact leads are checked, state of NO/NC must be opposite to the previous state.

Keeping the 65% voltage applied, 35% voltage (drop out voltage) is applied to the contactor. After some few milliseconds, the 65% voltage is withdrawn. This is done to maintain the contactor in ON position while applying drop out voltage. Now at this instant the contact leads are checked, state of NO/NC must be opposite to the previous state, now the contactor must be in switch OFF state, which means that contactor has passed the drop out voltage test. If the above conditions are ok, the contactor is accepted for pickup voltage test else rejected.

3.2 STROKE VALUE TEST MODULE

If the contactor is accepted during coil burden test, it is passed to perform stroke value test. The presence of the contactor is sensed by an inductive sensor, which is given as input to the PLC. If the sensor is ON, then the PLC will activate the ... Stepper motor moves the piston step by step till the IR Sensor is ON.

piston. The sensor detects the movement of the contact. Initial position of the contact is measured and this is taken as reference point. Then the piston has been fully pushed down till it closes / open the contacts. After the cylinder has been fully pushed down, it is then made to move upwards. As it moves upwards there will be change over of contacts. The reading of the sensor is noted at this instance. If any one of the measured readings falls out of the standard range, then the contactor is rejected and reworked. Else it is passed on to the next stage.

4.PROCESS ELEMENTS

4.1 STETHOSCOPE

The **stethoscope** is an acoustic medical device for auscultation, or listening to, internal sounds in a human or animal body. It is most often used to listen to heart sounds and breathing. It is also used to listen to intestines and blood flow in arteries and veins. Less commonly, "mechanic's stethoscopes" are used to listen to internal sounds made by machines, such as diagnosing a malfunctioning automobile engine by listening to the sounds of its internal parts. It can also be used to leak check vacuum chambers for scientific purposes. In this project, we are using stethoscope to measure the humming level of the contactor in decibels.

4.2 SOUND LEVEL METER:

Sound level meters measure **sound pressure level** and are commonly used in noise pollution studies for the quantification of almost any noise, but especially for industrial, environmental and aircraft noise. In this project, sound level meter is used to convert the humming level in decibels to required 0 –1V AC / 0 – 1V DC. The output of the sound level meter (0 –1V AC) is given to the voltage / current converter.

4.3 INFRA RED SENSOR

A **Passive InfraRed sensor (PIR sensor)** is an electronic device which measures infrared light radiating from objects in its field of view. PIRs are often used in the construction of *PIR-based motion detectors* . All objects emit what is known as black body radiation. This energy is invisible to the human eye but can be detected by electronic devices designed for such a purpose. The term 'passive' in this instance means the PIR does not emit energy of any type but merely accepts incoming infrared radiation. In this project, IR Sensor is used to detect the displacement of the contacts of the contactor.

4.4 REED SWITCH

The **reed switch** is an electrical switch operated by an applied magnetic field. It consists of a pair of contacts on ferrous metal reeds in a hermetically sealed glass envelope. The contacts may be normally open, closing when a magnetic field is present, or normally closed and opening when a magnetic field is applied. The reed relay is a type of relay, in which a reed switch is mounted inside a coil.

4.5 CYLINDERS

Pneumatic cylinders (sometimes known as **air cylinders**) are mechanical devices which produce force, often in combination with movement, and are powered by compressed gas (typically air). To perform their function, pneumatic cylinders impart a force by converting the potential energy of compressed gas into kinetic energy. This is achieved by the compressed gas being able to expand, without external energy input, which itself occurs due to the pressure gradient established by the compressed gas being at a greater pressure than the atmospheric pressure. This air expansion forces a piston to move in the desired direction.

4.5.1 Single acting cylinders

Single acting cylinders (SAC) use the force imparted by air to move in one direction (usually out), and a spring to return to the "home" position.

4.5.2 Double acting cylinders

Double Acting Cylinders (DAC) use the force of air to move in both extend and retract strokes. They have two ports to allow air in, one for outstroke and one for instroke.

4.5.3 Magnetically Coupled Rod less air cylinders

Actuators that use a mechanical or magnetic coupling to impart force, typically to a

5.PROGRAMMABLE LOGIC CONTROLLERS(PLC)

5.1 INTRODUCTION

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

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

There is a constant need for process control systems in the manufacturing industries to produce a better quality product more efficiently and at a low cost. This has led to the evolution of the automated systems.

Since the mid 1975 advances in electronics and especially microelectronics have made a revolution in industry from small to large system. To ensure that the plant or machinery operates within the tolerances and the correct speed etc., It must be programmed and controlled.

The programmable logic controller (PLC) has become a standard for control. It now not only replaces the earlier relay controls but has also taken over any additional control functions. The development of the programmable logic controller resulted in a paradigm change in control engineering. The first PLC was an extremely high voltage oriented design be connected over the same wire and using the same tools as contactor controls. It main benefit was its hardware-

independent ability to permit changes. Now, it was possible to implement control tasks in the form of software programs.

During the further evolution of the PLC, the offering was extended with a number of controllers with scalable performance and configuration, along with appropriate signal converters for different input and output voltages and output currents, respectively. An associated development was that short response times required the use of fast processors.

Programmable Logic Controllers (PLCs), also referred to as programmable controllers, are in the computer family. They are used in commercial and industrial applications. A PLC monitors inputs, makes decisions based on its program, and controls outputs to automate a process or machine.

The PLC used to be a dedicated device communicating only with the machine it controlled. Today's PLC has the ability to control several machines at one time, has extensive man – machine interfaces and can communicate with other PLC's through its own data high way system to create a distributed control Network.

5.2 BASIC PLC OPERATIONS

PLCs consist of input modules or points, a Central Processing Unit (CPU), and Output modules or points. An input accepts a variety of digital or analog signals from various field devices (sensors) and converts them into a logic signals that can be used by the CPU. The CPU makes decisions and executes control instructions based on program instructions in memory. Output modules convert control instructions from the CPU into a digital or analog signal that can be used to control various field devices (actuators). A programming device is used to input the desired instructions. These instructions determine what the PLC will do for a specific input. An operator interface device allows process information to be displayed and new control parameters to be entered.

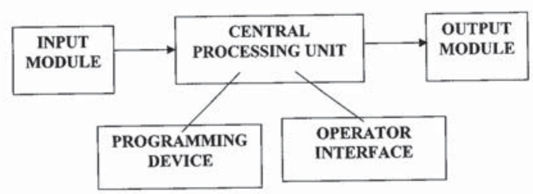


Fig 5.1 Basic PLC Unit

5.3 ELECTRONIC CONTROL WITH LOGIC GATES

In this contactor and relays together with timers and counters were replaced with logic gates and electronic timers in the control circuits.

Major benefits:

- Reduced space requirements
- Energy saving
- Less maintenance and hence greater reliability

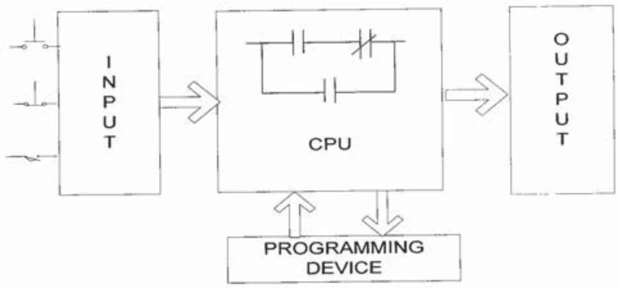
Implementation of changes in the control logic as well as reducing the project lead time was not possible.

Hard Wired Control:

Prior to PLCs, many of these control tasks were solved with contactor or relay controls. This is often referred to as hard-wired control. Circuit diagrams had to be designed, electrical components specified and installed, and wiring lists created. Electricians would then wire the components necessary to perform a specific task. If an error was made the wires had to be reconnected correctly. A change in function or system expansion required extensive component changes and rewiring.

5.4 PLC

The same, as well as more complex tasks can be done with a PLC. Wiring between devices and relay contacts is done in the PLC program. Hard wiring, though still required to connect field devices, is less intensive. Modifying the application and correcting errors are easier to handle. It is easier to create and change a program in a PLC than it is to wire and rewire a circuit.



PLC BLOCK DIAGRAM

Fig 5.2 Basic PLC Block Diagram

Sensor

A sensor is device that converts a physical condition into an electrical signal for use by the PLC. Sensors are connected to the input of a PLC. A pushbutton is one example of a sensor that is connected to the PLC input. An electrical signal is sent from the pushbutton to the PLC indicating the condition (open/closed) of the pushbutton contacts.

Actuators

actuator that is connected to the PLC output. Depending on the output PLC signal the motor starter will either start or stop the motor.

5.4.1 Discrete Input

A discrete input also referred to as a digital input, is an input that is either in an ON or OFF condition. Pushbuttons, toggle switches, limit switches, proximity switches, and contact closures are examples of discrete sensors, which are connected to the PLCs discrete or digital inputs. In the ON condition a discrete input may be referred to as logic 1 or logic high. In the OFF condition a discrete input may be referred to as logic O or logic low.

A normally open (NO) pushbutton is used in the following example. One side of the pushbutton is connected to the first PLC input. The other side of the pushbutton is connected to an internal 24 VDC power supply. Many PLCs require a separate power supply to power the inputs. In the open state, no voltage is present at the PLC input. This is OFF condition. When the pushbutton is depressed, 24 VDC is applied to the PLC input. This is the ON condition.

5.4.2 Analog Inputs

An analog input is an input signal that has a continuous signal. Typical analog inputs may vary from 0 to 20 milliamps, 4 to 20 milliams, or 0 to 10 volts. In the following example, a level transmitter monitors the level of liquid in a tank. Depending on the level transmitter, the signal to the PLC can either increase or decrease as the level increases or decreases.

5.4.3 Discrete Outputs

A discrete output is an output that is either in an On or Of condition. Solenoids, contactor coils, and lamps are examples of actuator devices connected to discrete outputs. Discrete outputs may also be referred to as digital outputs. In the following example, a lamp can be turned on or off by the PLC output it is connected to.

5.4.4 Analog Outputs

An analog output is an output signal that has a continuous signal. The output may be as simple as a 0-10 VDC level that drives an analog meter; Examples of analog meter outputs are speed, weight, and temperature. The output signal may also be used on more complex applications such as a current-to pneumatic transducer that controls an air-operated flow-control valve.

5.4.5 CPU

The central processor unit (CPU) is a microprocessor system that contains the system memory and is the PLC decision-making unit. The CPU monitors the inputs and makes decisions based on instructions held in the program memory. The CPU performs relay, counting, timing, data comparison, and sequential operations.

5.5 MAJOR BENEFITS

- Reduced Space
- Energy saving
- Ease of maintenance
- Economical
- Greater life and reliability
- Tremendous Flexibility
- Short project time
- Easier storage archiving and documentation
- Modular replacement, easy trouble shooting, error diagnostics programming.

Capabilities of PLCs

- Logic Control
- PID Control
- Co-ordination and communication
- Operator Control
- Signaling-and listing etc.,

5.6 GENERAL APPLICATION AREAS OF PLC

- Sequence control applications
- Individual machines
- Conveyors
- Packaging machineries
- Modern control applications
- Motion control applications
- Linear motion
- Rotary motion'
- Single / multiple axes control
- Servo drives
- Steeper drives
- Hydraulic drives
- Metal cutting machineries
- Computer numerical control machines
- Process control applications
- Temperature/Pressure/Flow controls
- P, PI, PID controls
- Plastic injection Moulding machines
- Heat treatment furnace
- Data Management applications
- Data acquisition systems
- Data manipulation
- Unmanned FMS/FMC
- Large material handling

5.7 LADDER DIAGRAM CONSTRUCTION

Some of the steps in planning for a ladder diagram are:

1. Define the process to be controlled.
2. Make a sketch of the process operation.

5. Add manual controls as needed for process setup or operational and checking.
6. Consider the safety of the operating personnel and make additions and adjustments as needed.
7. Add master stop switches as required for safe shutdown.
8. Create-the ladder logic diagram that will be used as a basis for the PLC program.
9. Consider the process sequence may go astray. Some other steps needed in program planning that we will not cover are troubleshooting of process malfunctions, parts list of sensors, relay, and so on, and wiring diagrams, including terminals, conduit runs, and so on.

We then go through the creative process to illustrate [each of the steps of the planning process].

Step 1

Define the problem?.

We wish to set up a system for spray-painting parts. A part is to be placed on a mandrel. (A mandrel is a shaft or bar whose end is inserted into a work piece to hold it during an operation.) When the parts are in place, two pushbuttons are pressed and the mandrel rises. After the part rises to the top and is in the hood, it is to have spray paint applied for a period of 6 seconds. At the end of the 6 seconds, the mandrel returns to the original position. The painted part is then removed from the mandrel by hand.

Step 2

List the sequence of operational steps in as much detail as possible. The sequence steps should be double or triple spaced so that any omitted steps discovered later may be added.

The following is a step sequence for this process.

1 Turn on the paint pump and pneumatic air supply.
2 Turn the system on. This requires pushbuttons other than the system buttons.
3 Put the part on the mandrel. A sensor indicates that the part is in place.

hands being injured by the rising mandrel.

5 A pneumatic cylinder energized by the opening of an electrically actuated air valve when the system start buttons are pressed raises the mandrel. (The mandrel will return by gravity and downward spring action when the valve is re- opened.) When the mandrel rises, the part-in-place sensor at the bottom becomes de-energized. (Note: The part-in-place sensor does not rise with the mandrel.)
6 When the part reaches the top and is under the hood, it is held against a stop by air pressure. A sensor has indicated that the part has reached the top.
7 During the timing period of 6 seconds, the sprayer applies paint.
8 At the end of 6 seconds, painting stops and the mandrel, with the part on it, lowers.
9 The up sensor is de-energized when the mandrel with the part on descends.
10 The part arrives at the bottom, reenergizing the part-in-place sensor.
11 The part is removed from the mandrel.
12 The system resets so that we may start at step 3 again.

Step 3

Add sensors as required. Once we list the sequence, we find that sensors are needed in the machine to indicate process status. We need a sensor (a limit switch placement) to show that the part has been placed on the mandrel initially. We also need a sensor (limit switch up) to indicate when the mandrel is fully extended upward. Among other possible sensors that a process such as this might need is one to make sure the paint sprayer has paint and one to make sure the inserter's hand is out of the way. Depending on the process and the detail of control, other sensors could be required as well.

Step 4

Add manual controls as needed. We may need a manual pushbutton to raise the mandrel to the top for setup purposes. The manual up position is needed when we set the spray-gun pressure for optimum paint coverage. We include pushbutton up (PBU) on our ladder diagram to accomplish this manual control.

Step 5

Consider the safety of the machine operator. One basic way to keep hands out of a process is to have two start buttons. Then both hands must be away from the work to depress both buttons (which works until the operator figures out how to use one knee and one hand).

Other considerations, which we do not cover in detail here, might be operating a fan to disperse fumes during spraying, or perhaps a photocell proximiity-personnel-system-stop device.

Step 6

Add emergency and master stop switches as needed for operator safety. This may seem to be part of step 6 because both steps deal with operator safety. It is a continuation of the safety issue, but emergency stop switches are so important that they need special consideration as an additional step.

Step 7

Create the ladder logic diagram. The diagram created is to include the steps and considerations of the first six steps.

Step 8

Determine the potential problem areas. After the ladder diagram is completed,

- What if no part is in place when the start buttons are pushed?
- What if the power fails during the cycle when the part is rising, during painting or at any other time?
- What if the sprayer runs of paint?
- What if the same part is left in for a double coat?
- What if the master stop button is pushed? Does the stop button really stop the entire process, or can the mandrel move and create a safety problem after the stop button is depressed.

All of these types of questions should be considered in the final sequence and ladder diagram. Further modifications would be needed for a more complete consideration of contingencies.

6.SIMATIC S7 200 PLC'S

6.1 S7 – 200 MICRO PLC'S

The S7-200 Micro PLC is the smallest member of the SIMATIC S7 family of programmable controllers. The central processing unit (CPU) is internal to the PLC. Inputs and outputs (I/O) are the system control points. Inputs monitor field devices, such as switches and sensors. Outputs control other devices, such as motors and pumps. The programming port is the connection to the programming device.

S7-200 MODELS

There are four S7-200 CPU types: S7-221, S7-222, S7-224, and S7-226 and three power supply configurations for each type.

Model Description	Power Supply	Input Types	Output Types
221 DC/DC/DC 221 AC/DC/Relay	20.4-28.8 VDC 85-264 VAC 47-63 Hz	6 DC Inputs 6 DC Inputs	4 DC Outputs 4 Relay Outputs
222 DC/DC/DC 222AC/DC/Relay	20.4-28.8 VDC 85-264 VAC 47-63 Hz	8 DC Inputs 8 DC Inputs	6 DC Outputs 6 Relay Outputs
224 DC/DC/DC 224 AC/DC/Relay	20.4-28.8 VDC 85-264 VAC 47-63 Hz	14 DC Inputs 14 DC Inputs	10 DC Outputs 10 Relay Outputs
226 DC/DC/DC 226 AC/DC/Relay	20.4-28.8 VDC 85-264 VAC 47-63 Hz	24 DC Inputs 24 DC Inputs	16 DC Outputs 15 Relay Outputs

Table 6.1 S7-200 Models

6.2 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 provides a summary of the major features. This variety provides a range of features to aid in designing a cost effective automation solution. The following table provides a summary of the major features.

Features	CPU 221	CPU 222
Integrated Inputs/Outputs	6DE/4DA	8DE/6DA
Max Expansion Modules	-	2
Max.# of Dig. I/O Channels	10	78
Analogue Points In/Out/Max	-	8/4/10
Program/Data Memory	4KB/2KB	4KB/2KB
Boolean Execution Time	0.22	0.22
Bit Relays/Counters/Timers	256/2/56/256	256/2/56/256
High Speed Counters	4x30kHz	4x30kHz
Real Time Clock	Optional	Optional
Pulse Outputs	2x20 kHz	2x20kHz
Communication Interface	1xRs-485	1xRS-485
Analogue Potentiometers	1	1

Features	CPU 224	CPU 224XP	CPU 226
Integrated Inputs/Outputs	14DE/10 DA	14DE/10 DA	24DE/16DA
Integrated Analogue In/Out	-	2AE/1AA	-
Max. Expansion	7	7	7
Max. # of Dig. I/O Channels	168	168	248
Analogue Points In/Out/Max	28/14/35	30/15/38	28/14/35
Program/	8/12 KB	12/16 KB	16/24 KB
Data Memory	8KB	10KB	10KB
Boolean Execution Time	0.22		
Bit Relays /counter/ timers	256/256/256	256/256/256	256/256/256
High Speed Counters	6 x 30 kHZ	4x30 kHz 2 x 200 KHz	6x30 kHz
Real time clock	Integrated	Integrated	Integrated
Pulse outputs	2 x 20 kHz	2 x 100 k Hz	2 x 100 k Hz
Communication interface	1x RS-485	2x RS-485	1x RS-485
Analogue potentiometers	2	2	2

Table 6.2 S7-200 Features

6.3 MODE SWITCH AND ANALOG 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.

Installing The S7-200 can be installed in one of two ways. A DIN clip allows installation on a standard DIN rail. The DIN clip snaps open to allow installation and snaps closed to secure the unit c the rail, The S7-2OO can also be panel

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 S7-2O0 DC/DC/ DC would be connected to a 24 VDC power supply. The power supply terminals are located on the far right side of the top terminal strip.

I/O Numbering S7-2OO 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. The CPU to determine which input is present and which output needs to be turned on or off uses this address. It designates a discrete input and Q designates a discrete output. The first number Identifies the byte, the second number identifies the bit. Input 10.0, for example, is byte 0, bit 0.

The following table Identifies the Input and output designations.

I0.0	1st Input	I1.0	9th Input	Q0.0	1st Output	Q1.0	9th output
I 0.1	2nd Input	I1.1	10th Input	Q0.1	2nd Output	Q1.1	10th Output
I 0.2	3rd Input	I1.2	11th Input	Q0.2	3rd Output		
I 0.3	4th Input	I1.3	12th Input	Q0.3	4th Output		
I 0.4	5th Input	I1.4	13th Input	Q0.4	5th Output		
I 0.5	6th Input	I1.5	14th Input	Q0.5	6th Output		
I 0.6	7th Input			Q0.6	7th Output		
I 0.7	8th Input			Q0.7	8th Output		

Table 6.3 I/O designations

Inputs

Input Devices, such as switches, pushbuttons, and other sensor devices are connected to the terminal strip under the bottom cover of the PLC.

	strips under the top cover of the PLC. When testing a program it is not necessary to connect output devices. The LED stay indicators signal if an output is active.
Optional Connector	An optional fan-out connector allows for field wiring connections to remain fixed when removing or replacing an S7-221 or 222. The appropriate- connector slides into the Input, output, or expansion modulo terminals.
Removable Terminal Strip	The S7-224 and S7-226 do not have an optional fan-out connector. Instead, the terminal strips are removable. This allows the field wiring connections to remain fixed when removing or replacing the S7-224 and S7-226.
Super Capacitor	A super capacitor, so 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 72 hours.

6.4 PROGRAMMING OF SIEMENS S7 200 PLC

In order to create or change a program, the following items are needed:

- PLC
- Programming Device
- Programming Software
- Connector Cable

The program is created in a programming device (PG) and then transferred to the PLC. The program for the S7-200 can be created using a dedicated Siemens SIMATIC S7 programming device, such as a PG 720 (not shown) or PG 740, if STEP 7 Micro/WIN software
is installed. A personal computer (PC), with STEP 7 Micro/WIN installed, can also be used as a programming device with the S7-200.

Software

A software program is required in order to tell the PLC what instructions it must follow. Programming software is typically PLC specific. A software package for one PLC, or one family of PLCs, such as the S7 family, would not be useful on other PLCs. The S7-200 uses a Windows based software program called STEP 7-Micro/WIN32. The PG 720 and PG 740 have STEP 7 software pre-installed. Micro/WIN32 is installed on a personal computer in a similar manner to any other computer software.

Connector Cables

PPI Connector cables are required to transfer data from the (Point-to-Point Interface) programming device to the PLC. Communication can only take place when the two devices speak the same language or protocol. Communication between a Siemens programming device and the S7-200 is referred to as PPI protocol (point-to point interface). An appropriate cable is required for a programming device such as a PG 720 or PG 740. The S7-200 uses a 9-pin, D-connector. This is a straight-through serial device that is compatible with Siemens programming devices (MPI port) and is a standard connector for other serial interfaces.

Programming Device Cable

A special cable, referred to as a PC/PPI cable, is needed when a personal computer is used as a programming device. This cable allows the serial interface of the PLC to communicate with the RS-232 serial interface of a personal computer. DIP switches on the PC/PPI cable are used to select an appropriate speed (baud rate) at which information is passed between the PLC and the computer.

Programming Methods

Programming a PLC is simply constructing a set of instructions. There are several ways to look at a program such as ladder logic, statement lists, or function block diagrams.

Ladder Logic

Ladder logic (LAD) is one programming language used with PLCs. Ladder logic uses components that resemble elements used in a line diagram format to describe hardwired control. Ladder Logic Diagram The left vertical line of a ladder logic diagram represents the power or energized conductor. The output element or instruction represents the neutral or return path of the circuit. The right vertical line, which represents the return path on a hard-wired control line diagram, is omitted. Ladder logic diagrams are read from left-to-right, top-to-bottom. Rungs are sometimes referred to as networks. A network may have several control elements, but only one output coil.

Statement list

A statement list (STL) provides another view of a set of instructions. The operation, what is to be done, is shown on the left. The operand, the item to be operated on by the operation, is shown on the right. A comparison between the statement list shown below, and the ladder logic shown on the previous page, reveals a similar structure.

Function Block Diagram

Function Block Diagrams (FBD) provide another view of a set of instructions. Each function has a name to designate its specific task. Functions are indicated by a rectangle. Inputs are shown on the left-hand side of the rectangle and outputs are shown on the right-hand side.

Using the Memory Address to Access Data

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Using the Memory Address to Access Data

To access a bit in a memory area, you specify the address, which includes the memory area Identifier. The byte address and the bit number. Figure 14.3 shows an example of addressing a bit (which is also called 'byte, bit1 addressing). In this example, the memory area and byte address (1=input, and 3=byte 3) are followed by a period (".") to separate the bit address. By using the byte address format, you can access data In many CPU memory areas (I.O. M, and SM) as bytes, words, or double words. To access B byte, word, or double word of data in the CPU memory, you must specify the address in a similar way to the address for a bit. This includes an area identifier, data size designation, and the starting byte address of the byte, word, or double word value, as shown in Figure 10-4. Data in other CPU memory areas (such as T, C, HC, and the accumulators) are accessed by using an address format that includes identifier and a device number.

Table shows the range of integer values that can be represented by the different size of data. Real (or floating-point) numbers are represented as 32-bd, single-precision number, whose format is described in the ANSI/IEEE 754- 1995 standard. Real number values are accessed in double - word lengths.

Data Size and Associated integer ranges

Data Size	Unsigned Integer Range		Signed integer range	
	Decimal	Hexadecimal	Decimal	Hexadecimal
B (Byte): 8-bit value	0 to 255	O to FF	- 128 to 127	80 to 7F
W(Word): 16-bil value	0 to 65,535	0 to FFFF	- 32, 768 to 32, 767 / '	8000 to 7FFF
D (Double word, Dword): 32-bil value	O to 4,294,967,295	0 to FFFF FFFF	-2,147,483,648 to 2,147,483,647	8000 0000 7FFF FFFF

Table 6.4 Data size and associated integer ranges

Addressing the Variable (V) Memory Area

You can use V memory to store intermediate results of operations being performed by the control logic in your program. You can also use V memory to store other data pertaining to your process or task. You can access the V memory area in bits, bytes, words; or double word.

Format: Bit V (bytes address), [bit address] VIO.2

Byte, Word, Double Word V (Size) (starting byte address) VW100

Addressing the Bit Memory (M) Area

You can use the internal memory bits (M memory) as control relays to stored intermediate status of an operation or other control Information. While the name 'bit memory area" implies that this information is stored in bit-length units, you can access the bit memory area not only in bits, but also in bytes, words, or double words.

Byte, Word, Double Word M (size) [starting byte address] MD20

Addressing Sequence Control Relay (S) Memory Area

Sequence Control relay bits (S) are used to organize machine operations or stops into equivalent program segments. SCRs allow logical segmentation of the control program. You can access the S bits as bits, bytes, wards, or double words.

Format: Bit 5[byte address], [bit address] 53.1

Byte. Word, 1 Double Word 5(size) (starting byte address] 5B4

Addressing the Special Memory (SM) Bits

The SM bits provide a means for communicating information between the CPU and your program. You can use these bits to select and control some of the special functions of the S7-200 CPU, such as:

- A bit that turns on for the first scan
- Bits that toggle at fixed rates
- Bits that show the status of math or operational instructions

Format: Bit SM [byte address), (bit address] SMO.1

Byte. Word, Double Word SM [size)(starting byte address] SMB86

Addressing the Timer (T) Memory Area

In the S7-200 CPU, timers are devices that count Increments of time. The S7-200 timers have resolutions (time-base Increments) of 1 ms, 10 ms, or 100 ms. There are two variables that are associated with a timer:

Current value this 16 bit signed integer stores the amount of time counted by the timer. Liner bit this bit turns on (is set to 1) when the current value of the timer is greater than or equal to the preset value. (The preset value in entered a. part of the timer instruction. You access both of these variables by using the timer address (T + timer number). Access to either the timer hit or the current value is dependent on the

with word operands access the current value. The Normally Open Contact instruction accesses the timer bit, while the Move Word (MOV-M instruction accesses the current Value of the timer.

Addressing the Counter (C) Memory Area

In the S7-200 CPU, counters are devices that count each low-to-high transition event on the counter input(s). The CPU provides two types of counters: one type counts up only, and the other counts both up and down. There are two variables that are associated with a counter:

Current value: this 16-bit signed integer stores the accumulated Counter bit, this bit turns on (is sat to 1) when the current value of the counter is greater than or equal to the preset value. (The preset value is entered as part of the timer instruction.) You access both of these variables by using the counter address (C + counter number). Access to either the counter bit or the current, value is dependent on the instruction used: instructions with bit operands access the

counter bit, while instructions with word operands access the current value. The normally open Contact instruction accesses the counter bit while the Move Word (MOV_W) instruction accesses the current value of the counter. For more information about the S7-200 instruction set

Format: C [counter number] C20

Addressing the Analog Inputs (A)

The S7-200 converts a real-world, analog value (such as temperature or voltage) into a word-length (16-bit) digital value. You access these values by the area identifier (Al), size of the data (W), and the starting byte address. Since analog inputs are words and always start on even-number bytes (such as 0, 2, or 4), you access them with even-number byte addresses (such as AIWO, AIW2, or AIW4. Analog input values are read only values.

Format: AIW[Starting by-to address) AIW4

Addressing the Analog Outputs (AQ)

The S7-200 converts a word-length (1 6-bd) digital value into a current or voltage, proportional to the digital value (such as for a current or voltage). You write these values by the area identifier (AO), size of the data (M, and the starting byte address. Since analog outputs are words and always start on even-number bytes (such as 0, 2, or 4), you write them with even-number byte addresses (such as ACWO, AOW2, or AOW4). Your program cannot read the values of the analog outputs.

Format AQW (Startling byte address] AQW4

Addressing the Accumulators (AC)

Accumulators are read / time devices that can be used like memory. For example, you can use accumulators to pass parameters to and from subroutines and to store intermediate values used in a calculation. The CPU provides four 32-bh accumulators (ACO, ACI, AC2, and AC3). You can access the data in the accumulators as bytes, words, or double words. Accessing the

accumulator as bytes, or words, uses the least significant L3 or 16 bits of the value that Is stored In the accumulator. Accessing the accumulator as a double word uses all 32 bits. The size of the data being accessed is determined by the instruction that is used to access the accumulator.

Symbols

In order to understand the instructions a PLC is to carry out, an understanding of the language is necessary. The language of PLC ladder logic consists of a commonly used set of symbols that represent control components and instructions. Contacts One of the most confusing aspects of PLC programming for first-time users is the relationship between the device that controls a status bit and the programming function that uses a status bit. Two of the most common programming functions are power flows through these contacts when they are closed. The normally open contact (NO) is true (closed) when the input or output status bit controlling the contact is 1. The normally closed contact (NC) is true (closed) when the input or output status bit controlling the contact is 0.

Coils: Coils represent relays that are energized when power flows to them. When a coil is energized, it causes a corresponding output to turn on by changing the state of the status bit controlling that output to 1. That same output status bit may be used to control normally open and normally closed contacts elsewhere in the program.

Boxes: Boxes represent various instructions or functions that are executed when power flows to the box. Typical box functions are timers, counters, and math operations.

Entering Elements: Control elements are entered in the ladder diagram by positioning the cursor and selecting the element from lists. In the following example the cursor has been placed in the position to the right of 10.2. A coil was sheeted from a pull-down list and inserted in this position.

6.5 TIMERS AND COUNTERS

Timers are devices that count increments of time. Traffic lights are one example where timers are used. In this example timers are used to control the length of time between signal changes. Boxes in ladder logic represent timers. When a timer receives an enable, the timer starts to time. The timer compares its current time with the preset time. The output of the timer is logic 0 as long as the current time is less than the preset time. When the current time is greater than the preset time the timer output is a logic 1. S7-200 uses three types of timers: On-Delay (TON), Retentive On-Delay (TONR), and Off-Delay (TOF).

S7-200 Timers are provided with resolutions of 1 millisecond, 10 milliseconds, and 100 milliseconds. The maximum value of these timers is 32.767 seconds, 327.67 seconds, and 3276.7 seconds, respectively. By adding program elements, logic can be programmed for much greater time intervals.

On-Delay (TON) When the On-Delay timer (TON) receives an enable (logic

the timer bit (T-bit) turns on. The T-bit is a logic function internal to the timer and is not shown on the symbol. The timer resets to the starting time when the enabling input goes to logic 0.

Retentive On-Delay Timer (TONR) This timer (TONR) functions in a similar manner to the On-Delay timer (TON). There is one difference. The Retentive On-Delay timer times as long as the enabling input is on, but does not reset when the input goes off. The timer must be reset with a RESET (R) instruction.

Off-Delay (TOF) This timer is used to delay an output off for a fixed period of time after the input turns off. When the enabling bit turns on the timer bit turns on immediately and the value is set to 0. When the input turns off, the timer counts until the preset time has elapsed before the timer bit turns off.

Counters

Counters used in PLCs serve the same function as mechanical counters. Counters compare an accumulated value to a preset value to control circuit functions. Control applications that commonly use counters include the following:

- Count to a preset value and cause an event to occur
- Cause an event to occur until the count reaches a preset value

Counters used in PLCs serve the same function as mechanical counters. Counters compare an accumulated value to a preset value to control circuit functions.

There are 256 counters in the S7-200, numbered CO through C255. The same number cannot be assigned to more than one counter. For example, if an up counter is assigned number 45, a down counter cannot also be assigned number 45. The maximum count value of a counter is ±32,767.

The **up counter** counts up from a current value to a preset value (PV). Input CU is the count input. Each time CU transitions from logic 0 to logic 1 the counter increments by a count of 1. Input R is the reset. A preset count value is stored in PV input. If the current count is equal to or greater than the preset value stored in PV.

The **down counter** counts down from the preset value (PV) each time CD transitions from logic 0 to logic 1. When the current value is equal to zero the counter output bit (Q) turns on (not shown). The counter resets and loads the current value

The **up/down counter** counts up or down from the reset value each time either CD or CU transitions from logic 0 to logic 1. When the current value is equal to the preset value, the output QU turns on. When the current value (CV) is equal to zero, the output QD turns on. The counter loads the current value (CV) with the preset value (PV) when the load input (LD) is enabled. Similarly, the counter resets and loads the current value (CV) with zero when the reset (R) is enabled. The counter stops counting when it reaches preset or zero.

6.6 TESTING A PROGRAM

Once a program has been written it needs to be tested and debugged. One way this can be done is to simulate the field inputs with an input simulator, such as the one made for the S7-200. The program is first downloaded from the programming device to the CPU. The selector switch is placed in the RUN position. The simulator switches are operated and the resulting indication is observed on the output status indicator lamps.

Status Functions After a program has been loaded and is running in the PLC, the actual status of ladder elements can be monitored using STEP 7 Micro WIN32 software. The standard method of showing a ladder element is by indicating the circuit condition it produces when the device is in the reenergized or on operated state. In the following illustration input 1 (I0.0) is programmed as a normally open (NO) contact. In this condition, power will not flow through the contacts to the output (Q0.0). When viewing the ladder diagram in the status mode, control elements that are active, or true (logic 1), are highlighted. In the example shown the toggle switch connected to input 1 has been closed. Power can now flow through the control element associated with input 1 (I0.0) and activate the output (Q0.0).

Forcing: Forcing is another useful tool in the commissioning of an application. It can be used to temporarily override the input or output status of the application in order to test and debug the program. The force function can also be used to override discrete output points. The force function can be used to skip portions of a program by enabling a jump instruction with a forced memory bit. Under normal circumstances

input 1 (I0.0) and turn on the output light. Forcing enables input 1 even though the input toggle switch is open. With input 1 forced high the output light will illuminate. When a function is forced the control bit identifier is highlighted. The element is also highlighted because it is on.

8. CONCLUSION

The advantages of Advanced Contactor Testing Machine using PLC are that it is fully automatic, economical, compact, accurate, efficient and more reliable in operation. By this contactor-testing machine, intervention of skilled labor is not required and increases production rate. In general, PLC's are more robust and require less maintenance, thus making the things they control work better, in spite of the environment. Overall PLC's appear to be a better solution for many problems. The contactor testing devices used in this project are very sensitive and the percentage of error is negligible. An average output of 34sec is achieved to test a contactor in this advanced contactor-testing machine. Further, it is planned to reduce the time to 25sec by modifying the design of the contactor-testing machine.

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APPENDIX A DATASHEET

Symbol	Address	Description
CYC_ON_PB	I0.0	CYCLE ON PUSH BUTTON
CYC_OFF_PB	I0.1	CYCLE OFF PUSH BUTTON
AUTO_MAN	I0.2	AUTO MANUAL SELECTOR SWITCH
COIL_BUR_CYC_F_SEN	I0.3	COIL BURDEN CYCLINDER FORWARD SENSOR
COIL_BUR_CYC_B_SEN	I0.4	COIL BURDEN CYCLINDER BACKWARD SENSOR
COIL_BUR_SELECTOR	I0.5	COIL BURDEN SELECTOR
STR_TEST_SELECTOR	I0.6	STROKE TEST SELECTOR
HUM_CYC_U_SEN	I0.7	HUMMING CYLINDER UPWARD SENSOR
FEEDING_SEN	I1.0	FEEDING SENSOR
HUM_CYC_D_SEN	I1.1	HUMMING CYLINDER DOWNWARD SENSOR
COIL_BUR_SEN	I1.2	COIL BURDEN TEST SENSOR
C_B_IP_CON1	I1.3	COIL BURDEN TEST INPUT CONTACT1
C_B_IP_CON2	I1.4	COIL BURDEN TEST INPUT CONTACT2
C_B_IP_CON3	I1.5	COIL BURDEN TEST INPUT CONTACT3
C_B_IP_CON4	I1.6	COIL BURDEN TEST INPUT CONTACT4
S_TEST_SEN	I1.7	STROKE TEST SENSOR
S_TEST_IP_CON1	I2.0	STROKE TEST INPUT CONTACT1
S_TEST_IP_CON2	I2.1	STROKE TEST INPUT CONTACT2
S_TEST_IP_CON3	I2.2	STROKE TEST INPUT CONTACT3
S_TEST_IP_CON4	I2.3	STROKE TEST INPUT CONTACT4
PRESENCE_OF_CONT	I2.4	PRESENCE OF CONTACTOR
C_REJ_CYC_F_SEN	I2.5	COIL BURDEN REJECTION CYCLINDER FORWARD SENSOR
C_REJ_CYC_B_SEN	I2.6	COIL BURDEN REJECTION CYCLINDER BACKWARD SENSO
S_CYC_F_SEN	I2.7	STROKE TEST CYCLINDER FORWARD SENSOR
S_CYC_B_SEN	I3.0	STROKE TEST CYCLINDER BACKWARD SENSOR
S_REJ_CYC_F_SEN	I3.1	STROKE TEST REJECTION CYCLINDER FORWARD SENSOR
MIC_SWITCH_S_T	I3.3	MICRO SWITCH STROKE TEST

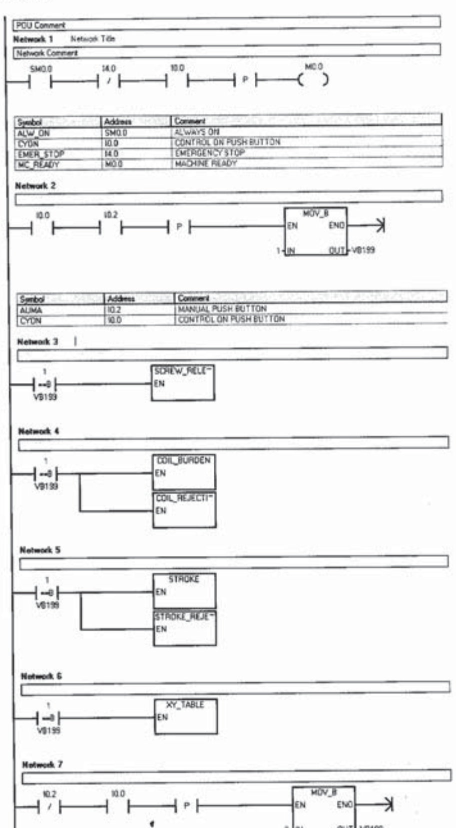
Symbol	Address	Description
CLMP_CYC_U_SEN	I3.4	CLAMP CYCLINDER UPWARD SENSOR
CLMP_CYC_D_SEN	I3.5	CLAMP CYCLINDER DOWNWARD SENSOR
STP_MOT_U_SEN	I3.6	STEPPER MOTOR UPWARD SENSOR
STP_MOT_D_SEN	I3.7	STEPPER MOTOR DOWNWARD SENSOR
EMG	I4.0	EMERGENCY
FEED_CYC_F_SEN	I4.1	FEEDING CYLCE FORWARD SENSOR
FEED_CYC_B_SEN	I4.2	FEEDING CYLCE BACKWARD SENSOR
ALM_PIK_VOL_REJ	M21.0	ALARM FOR PICK UP VOLTAGE REJECTION
ALM_DRP_VOL_REJ	M21.1	ALARM FOR DROP OUT VOLTAGE REJECTION
ALM_HLD_CUR_REJ	M22.2	ALARM FOR HOLDING CURRENT REJECTION
FEED_CYC_FRD	Q0.0	FEED CYCLINDER FORWARD
FEED_CYC_BKD	Q0.1	FEED CYCLINDER BACKWARD
C_B_CYC_FRD	Q0.2	COIL BURDEN CYCLINDER FORWARD
C_B_CYC_BKD	Q0.3	COIL BURDEN CYCLINDER BACKWARD
C_B_REJ_CYC_FRD	Q0.4	COIL BURDEN REJECTION CYCLINDER FORWARD
C_B_REJ_CYC_BKD	Q0.5	COIL BURDEN REJECTION CYCLINDER BACKWARD
C_B_REJ_CYC_PUSH	Q0.6	COIL BURDEN REJECTION CYCLINDER PUSH UP
S_TEST_CYC_FRD	Q0.7	STROKE TEST CYCLINDER FORWARD
S_TEST_CYC_BKD	Q1.0	STROKE TEST CYCLINDER BACKWARD
S_TEST_REJ_CYC_FRD	Q1.1	STROKE TEST REJECTION CYCLINDER FORWARD
S_TEST_REJ_CYC_BKD	Q1.2	STROKE TEST REJECTION CYCLINDER BACKWARD
S_TEST_REJ_CYC_PUSH	Q1.3	STROKE TEST REJECTION CYCLINDER PUSH UP
RELAY_24V	Q1.4	24V RELAY ON
RELAY_100P_V	Q1.5	100% PICKUP VOLTAGE RELAY ON
RELAY_65P_V	Q1.6	65% PICKUP VOLTAGE RELAY ON
RELAY_35P_V	Q1.7	35% PICKUP VOLTAGE RELAY ON
S_T_CON_ON	Q2.0	STROKE TEST CONTACT ON

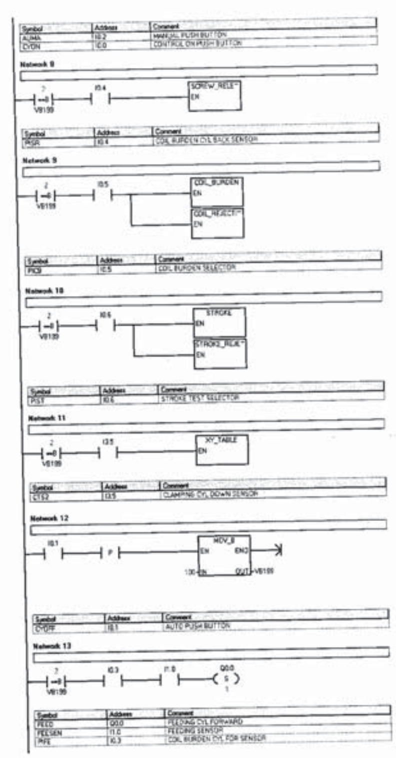
Symbol	Address	Description
S_T_NONC_SEN_OP	Q2.1	STROKE TEST NO&NC SENSING OUTPUT
S_T_CYC_CURSEN_EN	Q2.2	STROKE TEST CYCLINDER CURRENT SENSOR ENABLE
CLMP_CYC_DWD	Q2.3	CLAMP CYCLINDER DOWNWARD
CLMP_CYC_UWD	Q2.4	CLAMP CYCLINDER UPWARD
STP_MOT_OP1	Q2.5	STEPPER MOTOR OUTPUT1
STP_MOT_OP2	Q2.6	STEPPER MOTOR OUTPUT2
HUM_CYC_DWD	Q2.7	HUMMING CYCLINDER DOWNWARD
HUM_CYC_UWD	Q3.0	HUMMING CYCLINDER UPWARD
C_B_MAN_BIT	V0.4	COIL BURDEN MANUAL BIT
S_T_MAN_BIT	V0.5	STROKE TEDT MANUAL BIT
C_B_TEST_ACPT	V0.7	COIL BURDEN TEST ACCEPTED MESSAGE
C_B_TEST_REJT	V1.2	COIL BURDEN TEST REJECTED MESSAGE
PICK_UP_VOL_ACPT	V1.3	PICKUP VOLTAGE ACCEPTED
DROP_OUT_VOL_ACPT	V1.4	DROP OUT VOLTAGE ACCEPTED
HLD_CUR_ACPT	V1.5	HOLDING CURRENT ACCEPTED
PICK_UP_VOL_REJT	V34.0	PICKUP VOLTAGE REJECTED
DROP_OUT_VOL_REJT	V34.1	DROP OUT VOLTAGE REJECTED
HLD_CUR_REJT	V34.2	HOLDING CURRENT REJECTED
AUTO_CYCLE	V100.0	AUTO CYCLE RUNNING
FEED_FRW_ALLOW	V100.1	FEEDING CYLINDER FORWARD ALLOW IN AUTO CYCLE
CONT_MOVED_C_B	V100.2	CONTACTOR MOVED TO COIL BURDEN STATION
CB_IN_FORWARD	V101.0	COIL BURDEN CYLINDER FORWARD
HOLDING_CUR_FINISH	V101.1	HOLDING CURRENT CYCLE FINISHED
HUM_RATED_FINISH	V101.2	RATED HUMMING TEST FINISHED
HUM_PICK_FINISH	V101.3	HUMMING TEST DURING PICKUP FINISHED
NO_NC_FINISH	V101.4	NO/NC TEST FINISHED
A65_FINISH	V101.5	65% VOLTAGE TEST FINISHED
A35_FINISH	V101.6	35% VOLTAGE TEST FINISHED
FEED_FRD	V110.0	FEEDING CYCLINDER FORWARD BIT

Symbol	Address	description
COIL_BUR_FRD	V110.2	COIL BURDEN CYLINDER FORWARD
COIL_BUR_BKD	V110.3	COIL BURDEN CYLINDER BACKWARD
HUM_DOWN	V110.4	HUMMING CYLINDER DOWN
HUM_UP	V110.5	HUMMING CYLINDER UP
RES1	VD2012	TOTAL STROKE VALUE
RES2	VD2028	LINE 1 TO 2 STROKE VALUE
RES3	VD2044	LINE 3 TO 4 STROKE VALUE
RES4	VD2060	LINE 5 TO 6 STROKE VALUE
RES5	VD2077	LINE 13 TO 14 STROKE VALUE
MAXST	VW1000	MAXIMUM STROKE
MINST	VW1002	MINIMUM STROKE
AM1	VW1202	LINE 1 TO 2 STROKE VALUE FROM AIW0
AM2	VW1204	LINE 3 TO 4 STROKE VALUE FROM AIW0
AM3	VW1206	LINE 5 TO 6 STROKE VALUE FROM AIW0
AM4	VW1220	LINE 13 TO 14 STROKE VALUE FROM AIW0
DIFF1	VW1500	DIFFERENCE WORD - MAXIMUM & MINIMUM STROKE
DIFF2	VW1510	DIFFERENCE WORD - MAXIMUM STROKE & AM1
DIFF3	VW1520	DIFFERENCE WORD - MAXIMUM STROKE & AM2
DIFF4	VW1530	DIFFERENCE WORD - MAXIMUM STROKE & AM3
DIFF5	VW1540	DIFFERENCE WORD - MAXIMUM STROKE & AM4
STROKE_VAL_ANALOG	AIW0	ANALOG OUTPUT FOR STROKE VALUE
CURRENT_VAL_ANALOG	AIW2	ANALOG OUTPUT FOR HOLD CURRENT
HUMMING_VAL_ANALOG	AIW4	ANALOG OUTPUT FOR HUMMING LEVEL

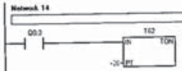
APPENDIX B LADDER LOGIC

MAIN



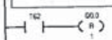


Network 14



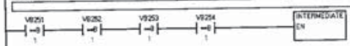
Symbol	Address	Comment
FEED	Q0.0	FEEDING CYL FORWARD

Network 15

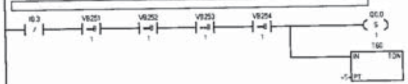


Symbol	Address	Comment
FEED	Q0.0	FEEDING CYL FORWARD

Network 16

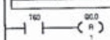


Network 17



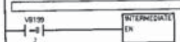
Symbol	Address	Comment
FEED	Q0.0	FEEDING CYL FORWARD
PFE	I0.3	COIL BURDEN CYL FOR SENSOR

Network 18

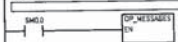


Symbol	Address	Comment
FEED	Q0.0	FEEDING CYL FORWARD

Network 19

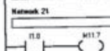


Network 20



Symbol	Address	Comment
ALW_ON	SM0.0	ALWAYS ON

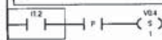
Network 21



Symbol	Address	Comment
FEESEN	I1.0	FEEDING SENSOR

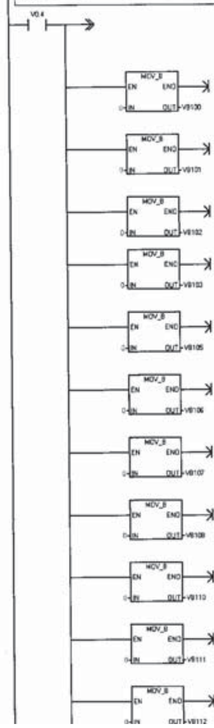
COIL BURDEN

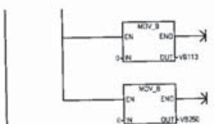
Network 1



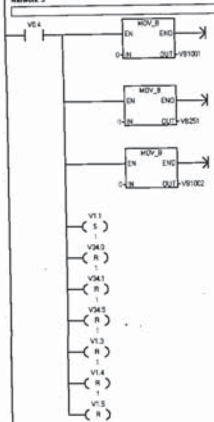
Symbol	Address	Comment
CBTS	I1.2	COIL BURDEN TEST SENSOR

Network 2



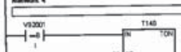


Network 3

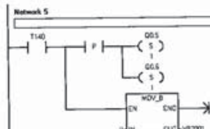


Symbol	Address	Comment
ABDV	V1.4	ACCEPTED BIT FOR DROP OUT VOLTAGE
ABHC	V1.5	ACCEPTED BIT FOR HOLDING CURRENT
ABPV	V1.3	ACCEPTED BIT FOR PICK UP VOLTAGE
DOVR	V34.1	ERROR BIT FOR DROP OUT VOLTAGE REJECTION
HCR	V34.5	ERROR BIT FOR HOLDING CURRENT REJECTION
PUVR	V34.0	ERROR BIT FOR PICK UP VOLTAGE REJECTION

Network 4



Network 5

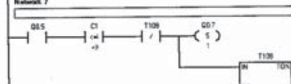


Symbol	Address	Comment
CBCON	Q0.5	COIL BURDEN REJ CYL BACK
REGN	Q0.6	COIL BURDEN REJ CYL PUSHUP

Network 6

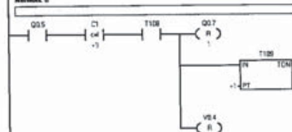
Symbol	Address	Comment
CBTS	I1.2	COIL BURDEN TEST SENSOR
PUR	Q0.7	STROKE TEST CYL FOR

Network 7



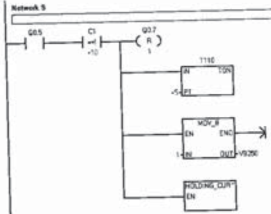
Symbol	Address	Comment
CBCON	Q0.5	COIL BURDEN REJ CYL BACK
PUR	Q0.7	STROKE TEST CYL FOR

Network 8



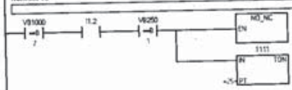
Symbol	Address	Comment
CBCON	Q0.5	COIL BURDEN REJ CYL BACK
PUR	Q0.7	STROKE TEST CYL FOR

Network 9



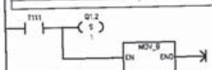
Symbol	Address	Comment
CBCON	Q0.5	COIL BURDEN REJ CYL BACK
FUR	Q0.7	STROKE TEST CYL FOR

Network 10



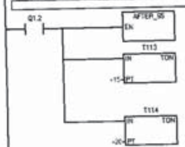
Symbol	Address	Comment
CBTS	I1.2	COIL BURDEN TEST SENSOR

Network 11



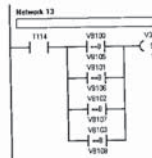
Symbol	Address	Comment
HUR	Q1.2	STROKE TEST REJ CYL BACK

Network 12



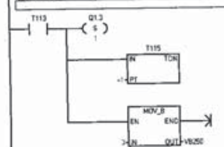
Symbol	Address	Comment
HUR	Q1.2	STROKE TEST REJ CYL BACK

Network 13



Symbol	Address	Comment
PUVR	V34.0	ERROR BIT FOR PICK UP VOLTAGE REJECTION

Network 14

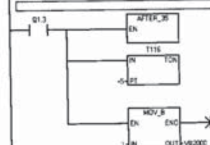


Symbol	Address	Comment
QUR	Q1.3	STROKE TEST REJ CYL PUSHUP

Network 15

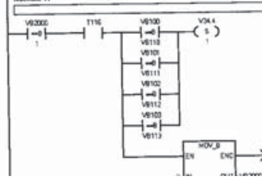
Symbol	Address	Comment
HUR	Q1.2	STROKE TEST REJ CYL BACK

Network 16

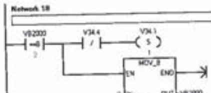


Symbol	Address	Comment
QUR	Q1.3	STROKE TEST REJ CYL PUSHUP

Network 17

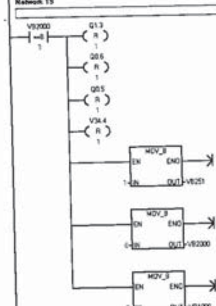


Network 18



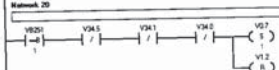
Symbol	Address	Comment
DOVR	V34.1	ERROR BIT FOR DROP OUT VOLTAGE REJECTION

Network 19



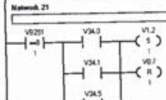
Symbol	Address	Comment
CBCON	Q0.5	COIL BURDEN REJ CYL BACK
QUR	Q1.3	STROKE TEST REJ CYL PUSHUP
REON	Q0.6	COIL BURDEN REJ CYL PUSHUP

Network 20



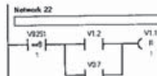
Symbol	Address	Comment
BSAMCT	V0.7	BIT TO SET ACCEPTED MSG FOR COIL TEST
BSRMCT	V1.2	BIT TO SET REJECTED MSG FOR COIL TEST
DOVR	V34.1	ERROR BIT FOR DROP OUT VOLTAGE REJECTION
HCR	V34.5	ERROR BIT FOR HOLDING CUURENT REJECTION
PUVR	V34.0	ERROR BIT FOR PICK UP VOLTAGE REJECTION

Network 21



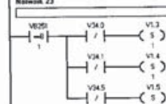
Symbol	Address	Comment
BSAMCT	V0.7	BIT TO SET ACCEPTED MSG FOR COIL TEST
BSRMCT	V1.2	BIT TO SET REJECTED MSG FOR COIL TEST
DOVR	V34.1	ERROR BIT FOR DROP OUT VOLTAGE REJECTION
HCR	V34.5	ERROR BIT FOR HOLDING CUURENT REJECTION
PUVR	V34.0	ERROR BIT FOR PICK UP VOLTAGE REJECTION

Network 22



Symbol	Address	Comment
BSAMCT	V0.7	BIT TO SET ACCEPTED MSG FOR COIL TEST
BSRMCT	V1.2	BIT TO SET REJECTED MSG FOR COIL TEST

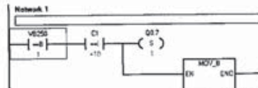
Network 23



Symbol	Address	Comment
ABOV	V1.4	ACCEPTED BIT FOR DROP OUT VOLTAGE
ABHC	V1.5	ACCEPTED BIT FOR HOLDING CURRENT
ABPV	V1.3	ACCEPTED BIT FOR PICK UP VOLTAGE
DOVR	V34.1	ERROR BIT FOR DROP OUT VOLTAGE REJECTION
HCR	V34.5	ERROR BIT FOR HOLDING CUURENT REJECTION
PUVR	V34.0	ERROR BIT FOR PICK UP VOLTAGE REJECTION

HUMMING LEVEL AND HOLDING CURRENT TEST

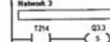
Network 1



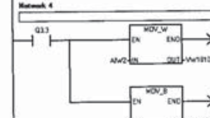
Symbol	Address	Comment
FUR	Q0.7	STROKE TEST CYL FOR

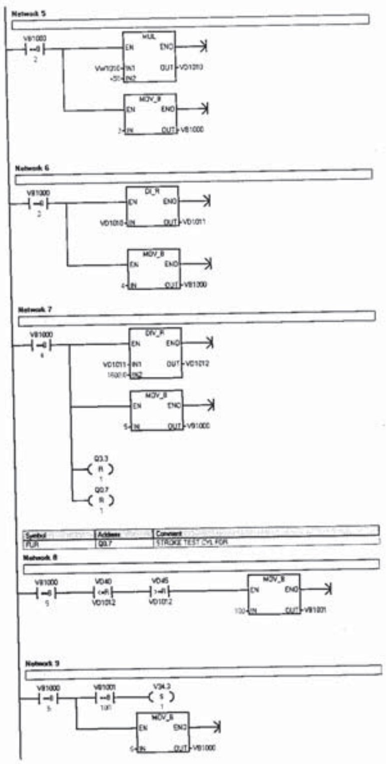
Network 2

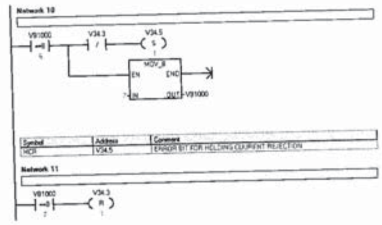
Network 3



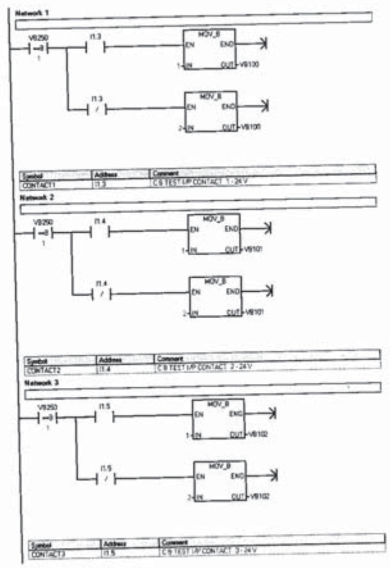
Network 4

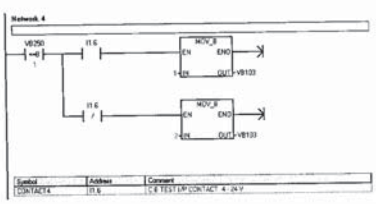




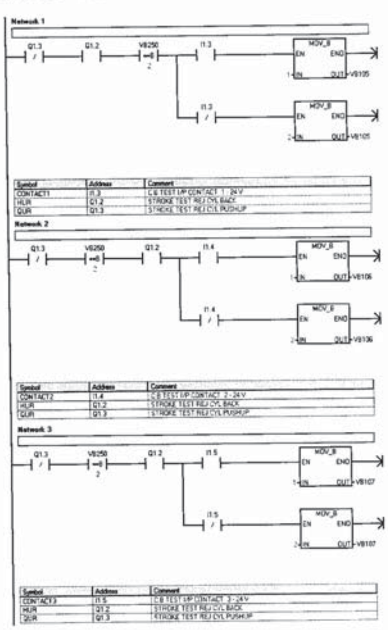


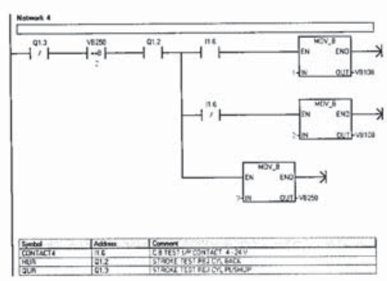
NO NC



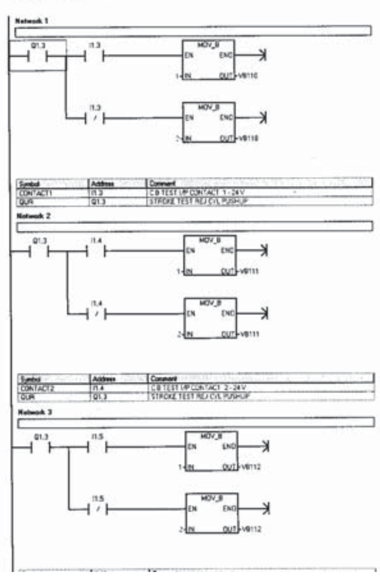


PICK UP VOLTAGE - 65% OF RATED VOLTAGE

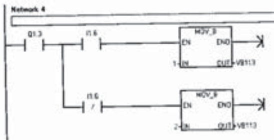




DROP OUT VOLTAGE - 35% OF RATED VOLTAGE



Network 4

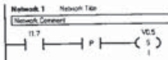


Symbol	Address	Comment
CONTACT4	I1.6	CB TEST UP CONTACT 4 - 24V
QUPL	Q1.3	STROKE TEST REJ CYL PUSHUP

STROKE TEST

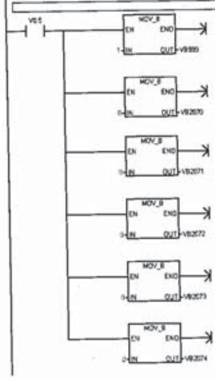
Network 1 Network Title

Network Comment

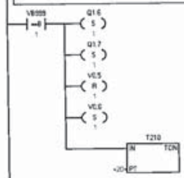


Symbol	Address	Comment
STS	I1.7	STROKE TEST SENSOR

Network 2

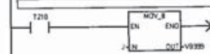


Network 3

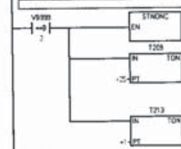


Symbol	Address	Comment
POINTS	Q1.5	65% VOLTAGE RELAY
RELAY	Q1.7	35% VOLTAGE RELAY

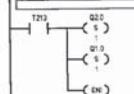
Network 4



Network 5

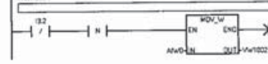


Network 6



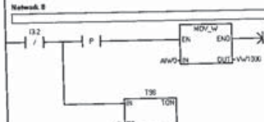
Symbol	Address	Comment
STCY	Q2.0	HUMMING CYL DOWNWARD

Network 7



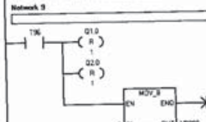
Symbol	Address	Comment
MINSEN	I3.2	STROKE REJECTION CYL BACK SENSOR
MINST	VW1002	MINIMUM STROKE

Network 8



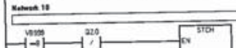
Symbol	Address	Comment
MAXST	VW1000	MAXIMUM STROKE
MINSEN	I3.2	STROKE REJECTION CYL BACK SENSOR

Network 9



Symbol	Address	Comment
STCY	Q2.0	HUMMING CYL DOWNWARD

Network 10

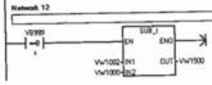


Symbol	Address	Comment
STCY	Q2.0	HUMMING CYL DOWNWARD

Network 11

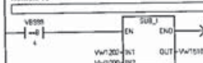
Symbol	Address	Comment
MINSEN	I3.2	STROKE REJECTION CYL BACK SENSOR

Network 12



Symbol	Address	Comment
DIFF1	VW1500	DIFFERENCE WORD - MAXIMUM_MINIMUM STROKE
MAXST	VW1000	MAXIMUM STROKE
MINST	VW1002	MINIMUM STROKE

Network 13



Symbol	Address	Comment
AM1	VW1202	LINE 1 TO 2 STROKE VALUE FROM AIW0
DIFF2	VW1510	DIFFERENCE WORD - MAXIMUM STROKE_AM1
MAXST	VW1000	MAXIMUM STROKE

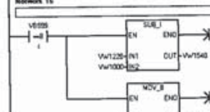
Network 14

Symbol	Address	Comment
AM2	VW1204	LINE 3 TO 4 STROKE VALUE FROM AIW0
DIFF3	VW1520	DIFFERENCE WORD - MAXIMUM STROKE_AM2
MAXST	VW1000	MAXIMUM STROKE

Network 15

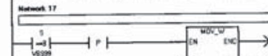
Symbol	Address	Comment
AM3	VW1206	LINE 5 TO 6 STROKE VALUE FROM AIW0
DIFF4	VW1530	DIFFERENCE WORD - MAXIMUM STROKE_AM3
MAXST	VW1000	MAXIMUM STROKE

Network 16

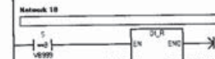


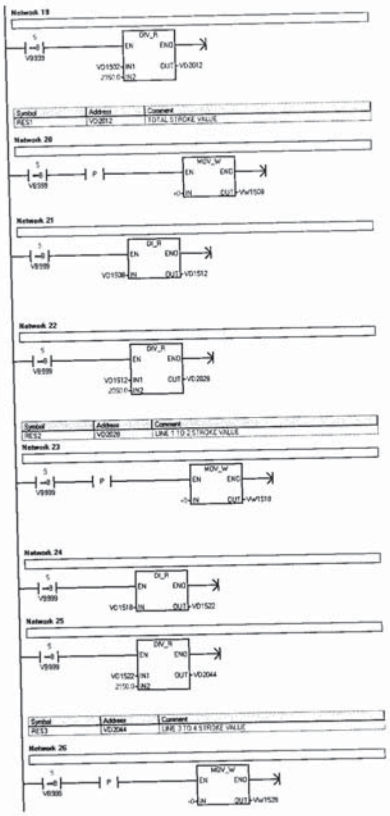
Symbol	Address	Comment
AM4	VW1220	LINE 13 TO 14 STROKE VALUE FROM AIW0
DIFF5	VW1540	DIFFERENCE WORD - MAXIMUM STROKE_AM4
MAXST	VW1000	MAXIMUM STROKE

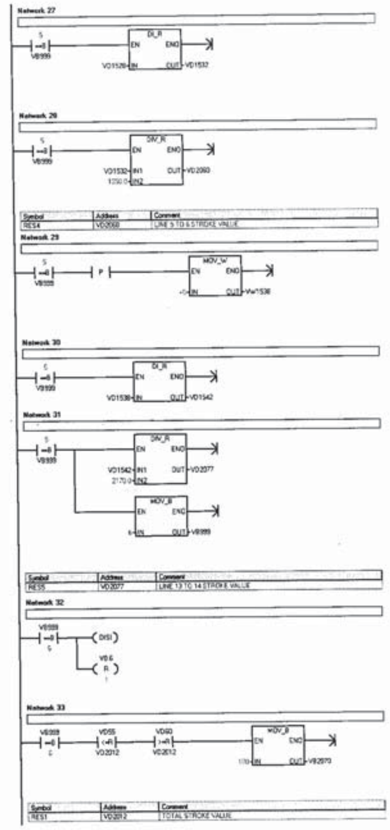
Network 17

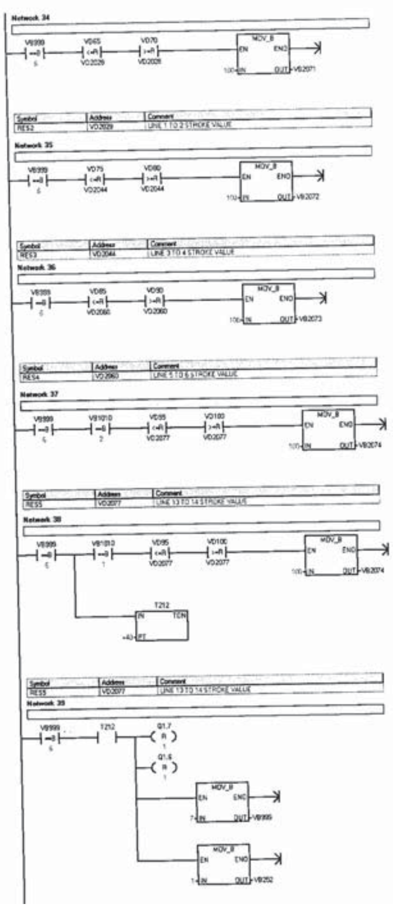


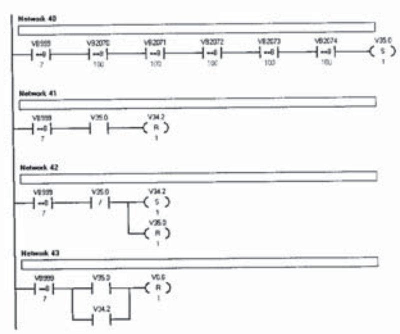
Network 18



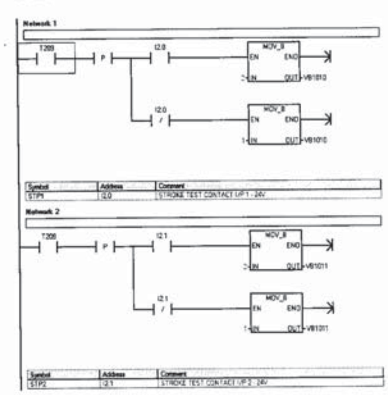




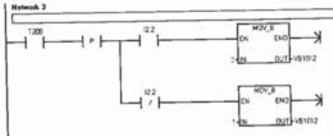




STROKE TEST – NO NC

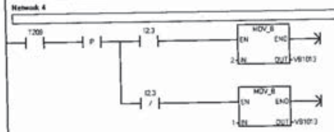


Network 3



Symbol	Address	Comment
STP3	I2.2	STROKE TEST CONTACT UP 3 - 24V

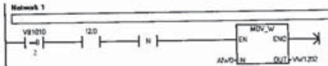
Network 4



Symbol	Address	Comment
STP4	I2.3	STROKE TEST CONTACT UP 4 - 24V

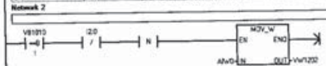
STROKE CHECK

Network 1



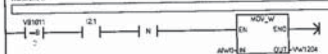
Symbol	Address	Comment
AM1	VW1202	LINE 1 TO 2 STROKE VALUE FROM AIW0
STP1	I2.0	STROKE TEST CONTACT UP 1 - 24V

Network 2



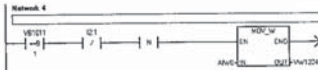
Symbol	Address	Comment
AM1	VW1202	LINE 1 TO 2 STROKE VALUE FROM AIW0
STP1	I2.0	STROKE TEST CONTACT UP 1 - 24V

Network 3



Symbol	Address	Comment
AM2	VW1204	LINE 3 TO 4 STROKE VALUE FROM AIW0
STP2	I2.1	STROKE TEST CONTACT UP 2 - 24V

Network 4

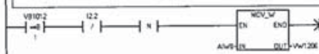


Symbol	Address	Comment
AM2	VW1204	LINE 3 TO 4 STROKE VALUE FROM AIW0
STP2	I2.1	STROKE TEST CONTACT UP 2 - 24V

Network 5

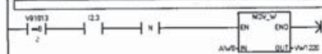
Symbol	Address	Comment
AM3	VW1206	LINE 5 TO 6 STROKE VALUE FROM AIW0
STP3	I2.2	STROKE TEST CONTACT UP 3 - 24V

Network 6



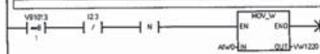
Symbol	Address	Comment
AM3	VW1206	LINE 5 TO 6 STROKE VALUE FROM AIW0
STP3	I2.2	STROKE TEST CONTACT UP 3 - 24V

Network 7



Symbol	Address	Comment
AM4	VW1220	LINE 13 TO 14 STROKE VALUE FROM AIW0
STP4	I2.3	STROKE TEST CONTACT UP 4 - 24V

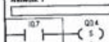
Network 8



Symbol	Address	Comment
AM4	VW1220	LINE 13 TO 14 STROKE VALUE FROM AIW0
STP4	I2.3	STROKE TEST CONTACT UP 4 - 24V

INTERMEDIATE

Network 1

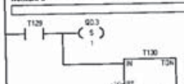


Symbol	Address	Comment
INTER2	Q0.4	COIL BURDEN REJ CYL FOR
INTSEN	I0.7	HUMMING CYLINDER UP SENSOR

Network 2

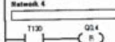
Symbol	Address	Comment
INTER2	Q0.4	COIL BURDEN REJ CYL FOR

Network 3



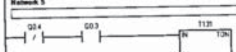
Symbol	Address	Comment
INTER1	Q0.3	COIL BURDEN CYL BACK

Network 4



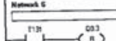
Symbol	Address	Comment
INTER2	Q0.4	COIL BURDEN REJ CYL FOR

Network 5



Symbol	Address	Comment
INTER1	Q0.3	COIL BURDEN CYL BACK
INTER2	Q0.4	COIL BURDEN REJ CYL FOR

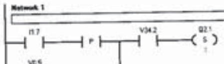
Network 6



Symbol	Address	Comment
INTER1	Q0.3	COIL BURDEN CYL BACK

STROKE REJECTION

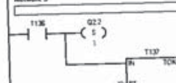
Network 1



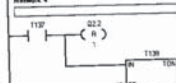
Network 2

Symbol	Address	Comment
SRC	Q2.1	HUMMING CYL UPWARD

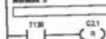
Network 3



Network 4



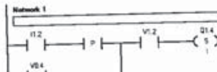
Network 5



Symbol	Address	Comment
SRC	Q2.1	HUMMING CYL UPWARD

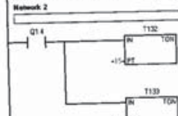
COIL REJECTION

Network 1



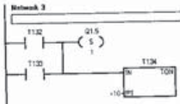
Symbol	Address	Comment
RSRMCT	V1.2	BIT TO SET REJECTED MSG FOR COIL TEST
CBRFC	Q1.4	24V RELAY
CBTS	I1.2	COIL BURDEN TEST SENSOR

Network 2



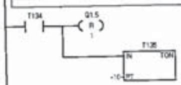
Symbol	Address	Comment
CBRFC	Q1.4	24V RELAY

Network 3



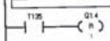
Symbol	Address	Comment
CBRC	Q1.5	100% VOLTAGE RELAY

Network 4



Symbol	Address	Comment
CBRC	Q1.5	100% VOLTAGE RELAY

Network 5



Symbol	Address	Comment
CBRFC	Q1.4	24V RELAY

APPENDIX C : PHOTOGRAPHS