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JAWAHARLAL NEHRU ENGINEERING COLLEGE
AURANGABAD

Name of the Laboratory: Industrial Automation

Class: BE Electrical Electronics and Power

HOD/EEP

Principal

Table of Contents

| Do's and Don'ts Guidelines For Laboratory Notebook | | |
|---|--|----------|
| Sr.No | Name of Experiment | Page No. |
| 1 | PLC supply, input, output wiring scheme development & testing | 4 |
| 2 | Study of digital inputs, outputs, Analog Inputs, outputs | 7 |
| 3 | Ladder Diagram logic programming | 9 |
| 4 | Timer function application:Study | 12 |
| 5 | Counter function application, for Standard Digital Input: Study | 14 |
| 6 | Study of function blocks & their applications in logic programming | 15 |
| 7 | Temperature measurement using analog input | 18 |
| 8 | Case study of Industrial DCS | 21 |

Do's and Don'ts in laboratory:

- Do not handle kits without reading the instructions from manual.
- Strictly observe the instructions given by the teacher lab instructor.

Instruction for laboratory teacher:

- Lab work completed during prior session should be corrected during the next lab session.
- Students should be guided and helped whenever they face difficulties.
- The promptness of submission should be encouraged by way of marking and evaluation patterns that will benefit the sincere students.

Guidelines for Laboratory Notebook:

The laboratory notebook is a record of all work pertaining to the experiment. This record should be sufficiently complete so that you or anyone else of similar technical background can duplicate the experiment and data by simply following your laboratory notebook. Descriptive headings should be used to separate and identify the various parts of the experiment. A neat, organized and complete record of an experiment is just as important as the experimental work.

Experiment No.: 1

Aim: To study PLC supply, input, output wiring scheme development & testing.

Objectives:

- how to provide ac power to a PLC
- various types of PLC input configurations.
- how to connect external components to PLC inputs.
- various types of PLC output configurations.
- how to connect PLC outputs to external components.

Appratus:

Allen Bradley micrologix-1400 PLC or Siemens S7-1200 PLC
PLC Trainer kit

Theory:

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. This course is meant to supply you with basic information on the functions and configurations of PLCs.

Basic PLC Operation

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 signal 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.

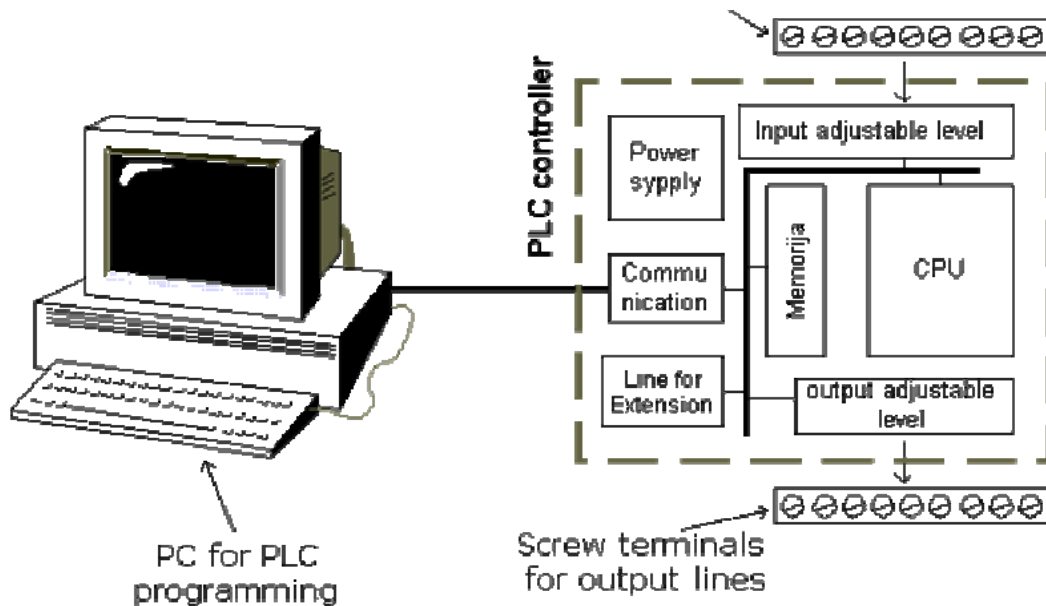


Figure 1. PLC main components

Power Supply

Electrical supply is used in bringing electrical energy to central processing unit. Most PLC controllers work either at 24 VDC or 220 VAC. On some PLC controllers you'll find electrical supply as a separate module. Those are usually bigger PLC controllers, while small and medium series already contain the supply module. User has to determine how much current to take from I/O module to ensure that electrical supply provides appropriate amount of current. Different types of modules use different amounts of electrical current. This electrical supply is usually not used to start external inputs or outputs. User has to provide separate supplies in starting PLC controller inputs or outputs because then you can ensure so called "pure" supply for the PLC controller. With pure supply we mean supply where industrial environment can not affect it damagingly. Some of the smaller PLC controllers supply their inputs with voltage from a small supply source already incorporated into a PLC.

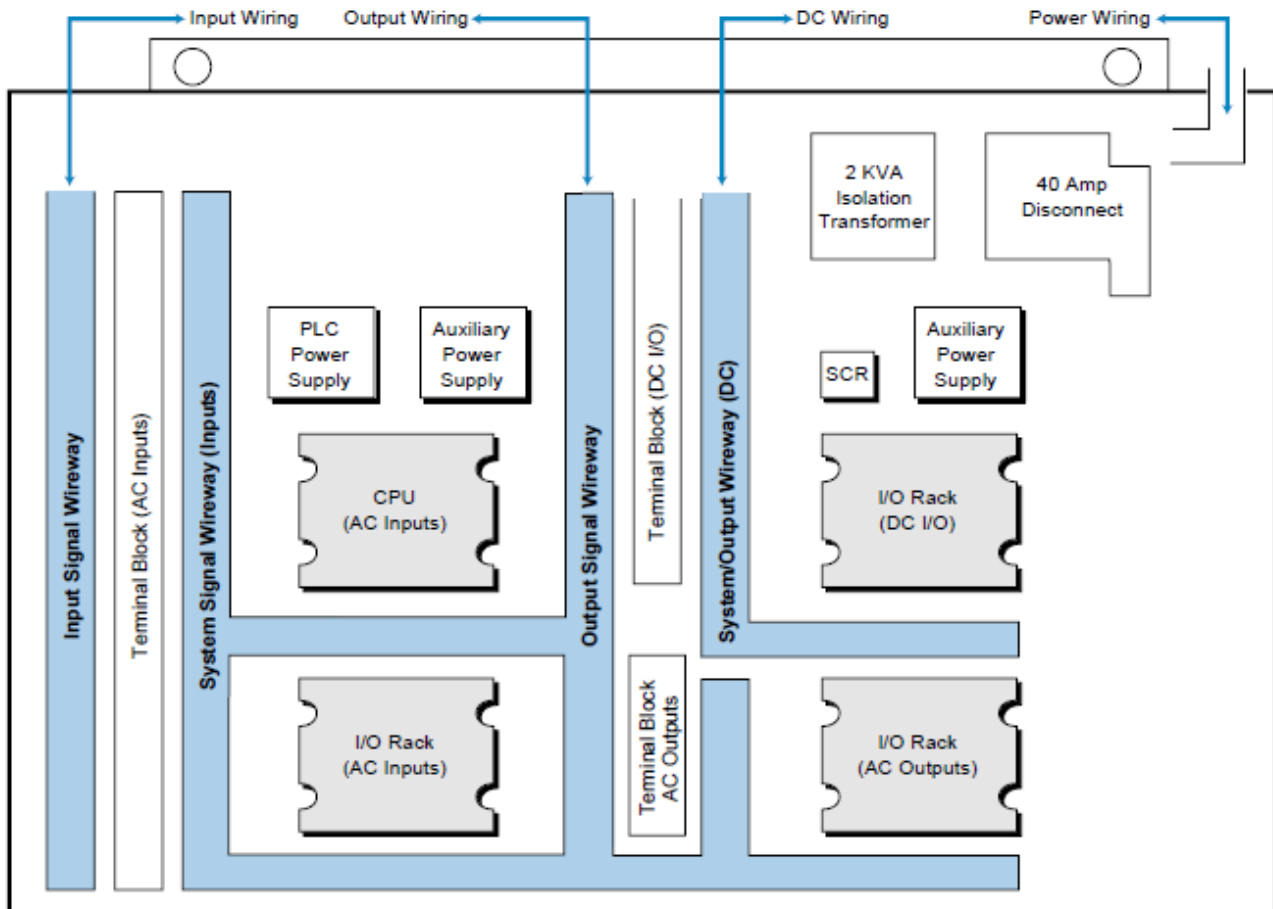


Figure 2. Enclosure Layout

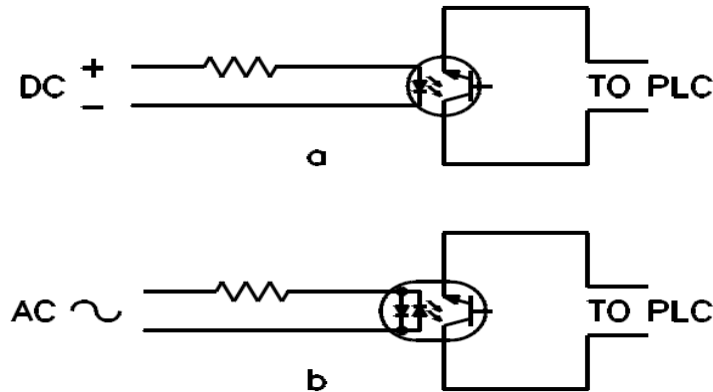
Duct and Wiring Layout. The duct and wiring layout defines the physical location of wireways and the routing of field I/O signals, power, and controller interconnections within the enclosure shown in figure 2. The enclosure's duct and wiring layout depends on the placement of I/O modules within each I/O rack. The placement of these modules occurs during the design stage, when the I/O assignment takes place.

Input Wiring

The inputs of modern PLCs are generally opto-isolators. An opto-isolator is a device consisting of a light producing element such as an LED and a light sensing element such as a phototransistor. When a voltage is applied to the LED, light is produced which strikes the photo-detector. The photo-detector then provides an output; in the case of a phototransistor, it saturates. The separation of the sensing and output devices in the optoisolator provide the input to the PLC with a high voltage isolation since the

only connection between the input terminal and the input to the PLC is a light beam. The light producing element and any current limiting device and protection components determine the input voltage for the opto-isolator. For instance, an LED with a series current limiting resistor could be sized to accept 5 VDC, 24 VDC or 120 VDC. To accept an AC signal, two back to back LED's with a series current limiting resistor are used. The resistor could be sized to allow the LED to light with 5 VAC, 24 VAC, 120 VAC or 240 VAC or any voltage we desire.

Figure 4 shows two types of opto-isolators which are utilized. The DC unit is shown in (a) and the AC unit in (b). The wires from the switch or sensor are connected to the left side of the drawing. The right side of the device is connected internally to the actual PLC input. Notice that each opto-isolator has a series resistor to limit the device current. Also notice that the AC unit has back-to-back LED's inside the device so light is produced on both half cycles of the input voltage.



Output Wiring

PLC outputs are of two general types: (1) relay (2) solid state. Relay outputs are mechanical contacts and solid state outputs may take the form of transistor or TTL logic (DC) and triac (AC). Relay outputs are usually used to control up to 2 amps or when a very low resistance is required. Transistor outputs are open collector common emitter or emitter follower. This type of output can control lamps and low power DC circuitry such as small DC relays. TTL logic outputs are available to drive logic circuitry. Triac outputs are used to control low power AC loads such as lighting, motor starters and contactors. As with input units, output units are available with a common terminal and isolated from each other. The type of output unit selected will depend upon the outputs being controlled and the power available for controlling those devices. Typically, power for driving output devices must be separately provided since there can be a wide range of requirements depending upon the device.

Conclusion:

Experiment No.: 2

Aim: Study of digital inputs, outputs, Analog Inputs, outputs.

Objective:

- the operations performed by analog-to-digital (A/D) and digital-to-analog (D/A) converters.
- some of the terminology used to describe analog converter performance parameters.
- the difference between a unipolar and bipolar converter.

Appratus:

Allen Bradley micrologix-1400 PLC or Siemens S7-1200 PLC
PLC Trainer kit

Theory:

Although most of the operations performed by a PLC are either discrete I/O or register I/O operations, there are some situations that require the PLC to either monitor an analog voltage or produce an analog voltage. As example of an analog monitoring function, consider a PLC that is monitoring the wind speed in a wind tunnel. In this situation, an air flow sensor is used that outputs a DC voltage that is proportional to wind speed. This voltage is then connected to an analog input (also called A/D input) on the PLC. As an example of an analog control function, consider an AC variable frequency motor drive (called a VFD). This is an electronic unit that produces an AC voltage with a variable frequency. When connected to a 3-phase AC induction motor, it can operate the motor at speeds other than rated speed. VFD's are generally controlled by a 0-10 volt DC analog input with zero volts corresponding to zero speed and 10 volts corresponding to rated speed. PLCs can be used to operate a VFD by connecting the analog output (also called D/A output) of the PLC to the control input of the VFD.

Analog input and output values are generally handled by the PLC as register operations. Input and output transfers are usually done at update time. Internally, the values can be manipulated mathematically and logically under ladder program control.

Analog (A/D) Input

Analog inputs to PLCs are generally done using add-on modules which are extra cost items. Few PLCs have analog input as a standard feature. Analog inputs are available in unipolar (positive input voltage capability) or bipolar (plus and minus input voltage capability). Standard off-the-shelf unipolar analog input modules have ranges of 0-5 VDC and 0-10 VDC, while standard bipolar units have ranges of -5 to +5 VDC and -10 to +10 VDC.

Specifying an Analog Input

There are basically three characteristics that need to be considered when selecting an analog input. They are as follows.

Unipolar (positive only) or bipolar (plus and minus)

This is a simple decision. If the voltage being measured cannot be negative, then a unipolar input is the best choice. It is not economical to purchase a bipolar input to measure a unipolar signal.

Input range

This is relatively simple also. For this specification, you will need to know the type of output from the sensor, system, or transducer being measured. If you expect a signal greater than 10 volts, purchase a 10 volt input and divide the voltage to be measured using a simple resistive voltage divider (keep in mind that, if necessary, you can restore the value in software by a simple multiplication operation). If you know the measured voltage will never exceed 5 volts, avoid purchasing a 10 volt converter because you will be paying extra for the unused additional range.

Number of Bits of Resolution

The resolution of an A/D operation determines the number of digital values that the converter is capable of discerning over its range. As an example, consider an analog input with 4 bits of resolution and a 0-10 volt range. With 4 bits, we will have 16 voltage steps, including zero. Therefore, zero volts will convert to binary 0000 and the converter will divide the 10 volt range into 16 increments.

Analog (D/A) Output

When selecting an analog output for a PLC, most of the same design considerations are used as is done with the analog input. Most analog outputs are available in unipolar 0 to 5 V and 0 to 10 V, and in bipolar -5 to +5 V and -10 to +10 V systems. The methods for calculating bit resolution and voltage resolution is the same as for analog inputs, so the selection process is very similar.

However, one additional design consideration that must be investigated when applying an analog output is load impedance. Most D/A converters use operational amplifiers as their output amplifiers. Therefore, the maximum current capability of the converter is the same as the output current capability of the operational amplifier, typically about 25 mA. In most cases, a simple ohm's law calculation will indicate the lowest impedance value that the D/A converter is capable of accurately driving.

Logical inputs and outputs

Inputs to, and outputs from, a PLC are necessary to monitor and control a process. Both inputs and outputs can be categorized into two basic types: logical or continuous. Consider the example of a light bulb. If it can only be turned on or off, it is logical control. If the light can be dimmed to different levels, it is continuous. Continuous values seem more intuitive, but logical values are preferred because they allow more certainty, and simplify control. As a result most controls applications (and PLCs) use logical inputs and outputs for most applications.

Outputs to actuators allow a PLC to cause something to happen in a process. A short list of popular actuators is given below in order of relative popularity.

- i. Solenoid Valves - logical outputs that can switch a hydraulic or pneumatic flow.
- ii. Lights - logical outputs that can often be powered directly from PLC output boards.
- iii. Motor Starters - motors often draw a large amount of current when started, so they require motor starters, which are basically large relays.
- iv. Servo Motors - a continuous output from the PLC can command a variable speed or position.

Outputs from PLCs are often relays, but they can also be solid state electronics such as transistors for DC outputs or Triacs for AC outputs. Continuous outputs require special output cards with digital to analog converters.

Inputs come from sensors that translate physical phenomena into electrical signals. Typical examples of sensors are listed below in relative order of popularity.

- i. Proximity Switches - use inductance, capacitance or light to detect an object logically.
- ii. Switches - mechanical mechanisms will open or close electrical contacts for a logical signal.
- iii. Potentiometer - measures angular positions continuously, using resistance.
- iv. LVDT (linear variable differential transformer) - measures linear displacement continuously using magnetic coupling.

Inputs for a PLC come in a few basic varieties, the simplest are AC and DC inputs. Sourcing and sinking inputs are also popular. This output method dictates that a device does not supply any power. Instead, the device only switches current on or off, like a simple switch.

Sinking - When active the output allows current to flow to a common ground. This is best selected when different voltages are supplied.

Sourcing - When active, current flows from a supply, through the output device and to ground. This method is best used when all devices use a single supply voltage.

Conclusion:

Experiment No.: 3

Aim: Ladder Diagram logic programming.

Objectives:

- how to convert a simple electrical ladder diagram to a PLC program.
- the difference between physical components and program components.

Appratus:

Allen Bradley micrologix-1400 PLC or Siemens S7-1200 PLC
PLC Trainer kit

Theory:

Machine Control Components And Their Symbols In Ladder Diagram:

1. SWITCHES : There are two fundamental uses for switches. First, switches are used for operator input to send instructions to the control circuit. Second, switches may be installed on the moving parts of a machine to provide automatic feedback to the control system.

2. PUSH BUTTON : The most common switch is the push button. It is widely used in automotive and electronic equipment applications. There are two types of the push button-the momentary and maintained. The momentary push button switch is activated when the button is pressed and deactivated when the button is released. The deactivation is done using an internal spring. The maintained push button switch activates when pressed, but remains activated when it is released. To deactivate it, it must be pressed second time. For this reason, this type of switch is sometimes called a push-push switch. The ON/OFF switches on desktop computers and laboratory oscilloscopes are maintained push buttons. The contacts on switches can be of two types. These are normally open (N/O) and normally closed (N/C).whenever a switch is in its deactivated position, the N/O contacts will be open (non-conducting) and the N/C contacts will be closed (conducting).There are no internal electrical connection between different contact pairs on the same switch.

3. SELECTOR SWITCHES : A selector switch is also known as a rotary switch. An automobile ignition switch and an oscilloscopes vertical gain and horizontal time base switches are examples of selector switches. The top contacts are closed when the switch selector is turned to the left position and open when the switch selector is turned to the right. The bottom set of contacts works exactly opposite. There is no electrical connection between top and bottom pairs of contacts. In most cases, we label the selector positions same as the labeling on the panel where the switch is located.

4. LIMIT SWITCHES: Normally, limit switches are not operator accessible. They are activated by moving parts on the machine. They are usually mechanical switches but can also be light activated (such as the automatic door openers used by stores and supermarkets) or magnetically operated (such as the magnetic by stores and home security system that sense window has been opened).

5. INDICATOR LAMPS: All the control panels include indicator lamps. They tell the operator when power is applied to the machine and indicate the present operating status of the machine. The light bulbs used in indicators are generally incandescent (white), they are usually covered with colored lenses.

The **ladder diagram** has and continues to be the traditional way of representing electrical sequences of operations. These diagrams represent the interconnection of field devices in such a way that the activation, or turning ON, of one device will turn ON another device according to a predetermined sequence of events. Figure 1 illustrates a simple electrical ladder diagram.

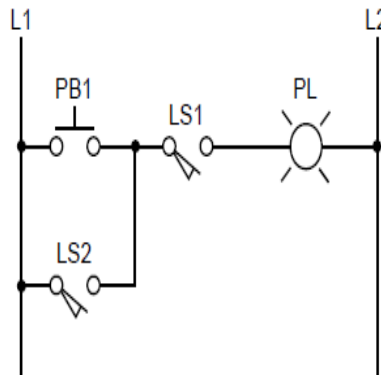


Figure 1 Simple electrical ladder diagram

The original ladder diagrams were established to represent hardwired logic circuits used to control machines or equipment. Due to wide industry use, they became a standard way of communicating control information from the designers to the users of equipment. As programmable controllers were introduced, this type of circuit representation was also desirable because it was easy to use and interpret and was widely accepted in industry.

Programmable controllers can implement all of the “old” ladder diagram conditions and much more. Their purpose is to perform these control operations in a more reliable manner at a lower cost. A PLC implements, in its CPU, all of the old hardwired interconnections using its software instructions. This is accomplished using familiar ladder diagrams in a manner that is transparent to the engineer or programmer.

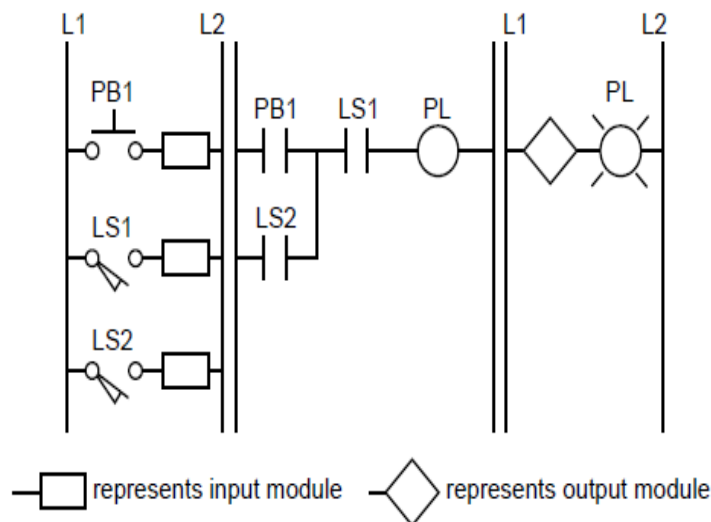


Figure 2 PLC implementation of Figure 1

Figure 2 illustrates the PLC transformation of the simple diagram shown in Figure 1 to a PLC

format. Note that the “real” I/O field devices are connected to input and output interfaces, while the ladder program is implemented in a manner, similar to hardwiring, inside the programmable controller (i.e., *softwired* inside the PLC’s CPU instead of *hardwired* in a panel). As previously mentioned, the CPU reads the status of inputs, energizes the corresponding circuit element according to the program, and controls a real output device via the output interfaces.

Each instruction is represented inside the PLC by a reference **address**, an alphanumeric value by which each device is known in the PLC program. For example, the push button PB1 is represented inside the PLC by the name PB1 (indicated on top of the instruction symbol) and likewise for the other devices shown in Figure 2. These instructions are represented here, for simplicity, with the same device and instruction names.

Conclusion:

Experiment No.: 4

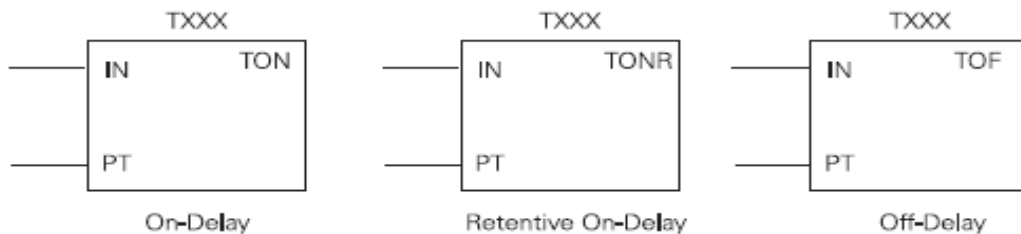
Aim: Timer function application Study.

Appratus:

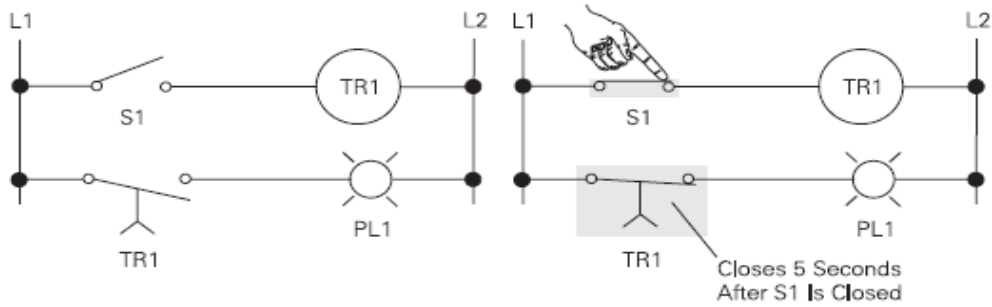
Allen Bradley micrologix-1400 PLC or Siemens S7-1200 PLC
PLC Trainer kit

Theory:

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. Timers are represented by boxes in ladder logic. 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 a 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. PLC uses three types of timers: On- Delay (TON), Retentive On-Delay (TONR), and Off-Delay (TOF).



Hard-Wired Timing Circuit Timers used with PLCs can be compared to timing circuits used in hard-wired control line diagrams. In the following example, a normally open (NO) switch (S1) is used with a timer (TR1). For this example the timer has been set for 5 seconds. When S1 is closed, TR1 begins timing. When 5 seconds have elapsed, TR1 will close its associated normally open TR1 contacts, illuminating pilot light PL1. When S1 is open, deenergizing TR1, the TR1 contacts open, immediately extinguishing PL1. This type of timer is referred to as ON delay. ON delay indicates that once a timer receives an enable signal, a predetermined amount of time (set by the timer) must pass before the timer's contacts change state.



1.ON Delay Timer :

It is used to program a time delay before instruction becomes true. ON delay timer is used when an action is to begin a specified time after i /p becomes true. For e.g.- Certain stages in manufacturing processes is expected to begin 30 sec after i/p is received from limit switch, here 30 sec is nothing but the present value of ON delay timer.

2.OFF Delay Timer: It is used to program a time to begin after the i/p goes false. For e.g. – external cooling fan or a motor which has to run all the time & it is expected to turn off the fan or motor after 5 min when i/p is sensed by them. The 5 min is nothing but off delay time.

3.Retentive timer: It is used to reset accumulated value through power loss, process change state or in rung from true to false. For e.g. RTO is used to true running time OR motor for maintenance. The time is used to track accumulated value time the motor has run. For e.g. motor need maintenance 8hrs (28800 sec). Each time the motor is turned off, the timer needs to remember motor's total elapse time, next time when the motor is turned ON the timer will increased accumulated running time where it left off. When total accumulated running time has been reached, maintenance reminder time will be off, same procedure repeats. RESET instruction is used to reset accumulated value of a timer. It is used only in retentive timer & not in 'ON' or 'OFF' delay timer.

Figure 1 is a PLC ladder logic program that uses timer instructions to alternately turn-on two output devices. A start button is connected to the input terminal I:2/1 and a stop button is connected to the input terminal I:2/2. When the start button is pushed, it energizes the instruction B3:1/1 in the first rung. This instruction latches itself by using the Exam-if-Closed instruction B3:1/1 in the same rung. That allows the push button to be released and the B3:1/1 stays in HIGH status. When B3:1/1 is HIGH, it enables the timer instruction T4:1 in the second rung. Timer T4:1 is preset to 2 minutes (120 seconds). When this timer is timing, the T4:1/TT instruction in rung 4 is true. It energizes the output

O:3/4. When this timer reaches 2 minutes, T4:1/TT goes to false and de-energizes O:3/4. However, the T4:1/DN bit goes to HIGH at this moment. That enables the timer T4:2 that is preset to 3 minutes. When T4:2 is timing, the T4:2/TT instruction in rung 5 turns on the output O:3/5. When timer T4:2 reaches 3 minutes, T4:2/TT goes to LOW and O:3/5 is de-energized. Meantime, the T4:2/DN bit goes to HIGH. That causes the second rung's condition to be false and the timer T4:1 to be reset. When timer T4:1 is reset, the T4:1/DN bit goes to low and timer T4:2 in the third rung is reset. This causes T4:2/DN to be low. In the next scan cycle, the second rung turns to true and the timer T4:1 is timing again. This starts another cycle of energizing the outputs. These two outputs alternate between ON and OFF until the stop button is pushed. Pushing the stop button de-energizes B3:1/1 in the first rung. That breaks the latch in the first rung. It also stops and resets the timers T4:1 and T4:2.

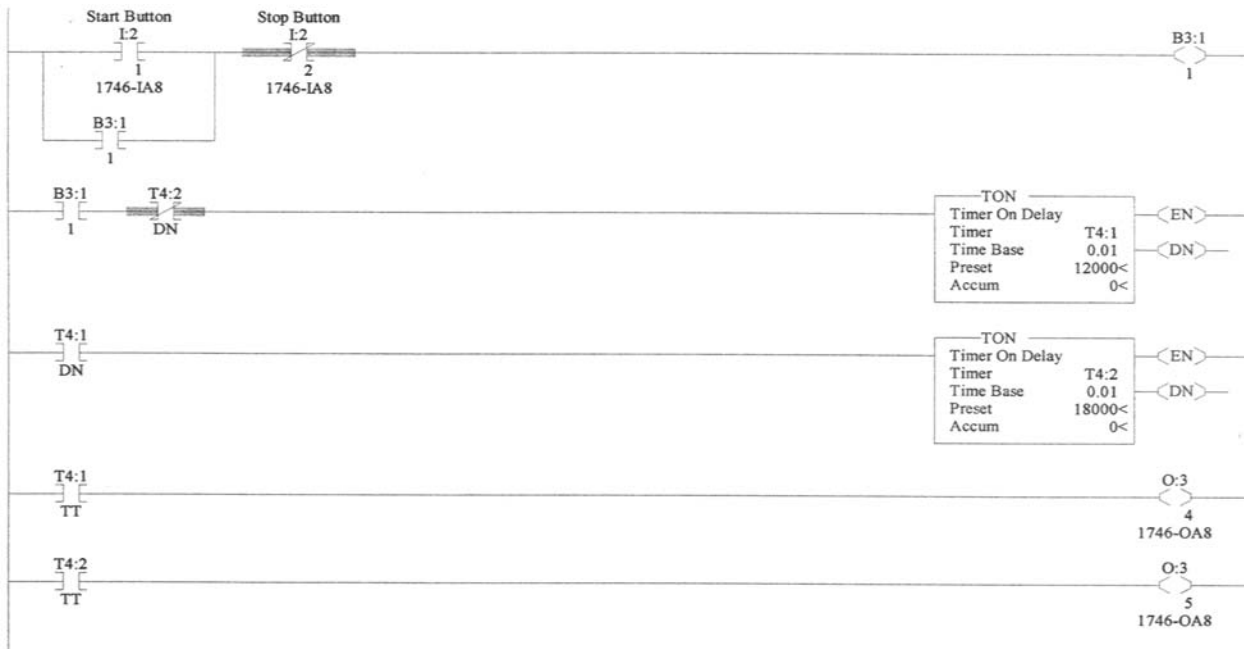


Figure 1 A Program Using Timers to Control Outputs

Conclusion:

Experiment No.: 5

Aim: Study counter function application, for Standard Digital Input.

Appratus:

Allen Bradley micrologix-1400 PLC or Siemens S7-1200 PLC
PLC Trainer kit

Theory:

Counters are represented by boxes in ladder logic. Counters increment/decrement one count each time the input transitions from off (logic 0) to on (logic 1). The counters are reset when a RESET instruction is executed. This PLC uses three types of counters: up counter (CTU), down counter (CTD), and up/down counter (CTUD).

A PLC counter instruction can be a count-up instruction or a count-down instruction. These are shown in Figure 1 and Figure 2. When a counter instruction is used in a program, the programmer must specify the counter address. A counter address has the format of C5:N, where N is a positive integer to distinguish it from other counters. The programmer must also specify the Preset value, which is a signed (positive or negative) integer.

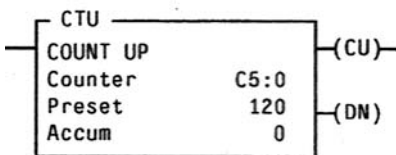


Figure 1 Count-up Counter Instruction

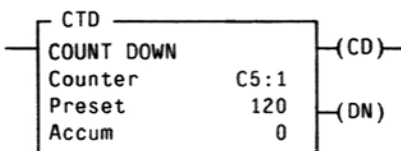


Figure 2 Count-down Counter Instruction

A counter instruction counts false-to-true rung transitions. These rung transitions could be caused by events monitored by the program or by something else. Each time a rung condition is changing from false to true, a count-up instruction in the rung increases its Accumulate value by 1 and a count-down instruction in the rung decreases its Accumulate value by 1.

There are several status bits associated with each counter instruction. Three of these bits are used frequently in PLC ladder logic programs. These bits are the counter-up enable bit (CU), the counter-down enable bit (CD), and the done bit (DN).

- When a count-up counter is counting, its CU bit is high.
- When a count-down counter is counting, its CD bit is high.

- A DN bit is high when its counter's Accumulate value is greater or equal to the counter's Preset value.

A counter retains its Accumulate value when its rung condition is true, false, or changing from true to false. A counter's Accumulate value can be reset to zero by using a reset instruction that has the same counter address. The counter is reset when the reset instruction is enabled.

The program in Figure 3 is used for counting parts and controlling box packaging in a manufacturing company. One hundred parts are packed into a box. A sensor, which is connected to input terminal I:2/1, detects the parts coming down from a conveyer. When a part passes in front of it, the sensor has a high output. This high output causes counter C5:1 to count. When this counter is counting up to 100, its DN bit goes to high. That causes the output O:3/1 in rung 2 to be energized, which initiates a box packaging process that is not included in this example program. The switching of DN bit of counter C5:1 to high also causes the counter C5:2 in rung 3 to count. This counter counts the number of boxes packed. When C5:2 is counting, its CU bit is high. That enables the reset instruction in rung 4 to reset counter C5:1's Accumulate value to 0. The C5:1 will count up from 0 again.

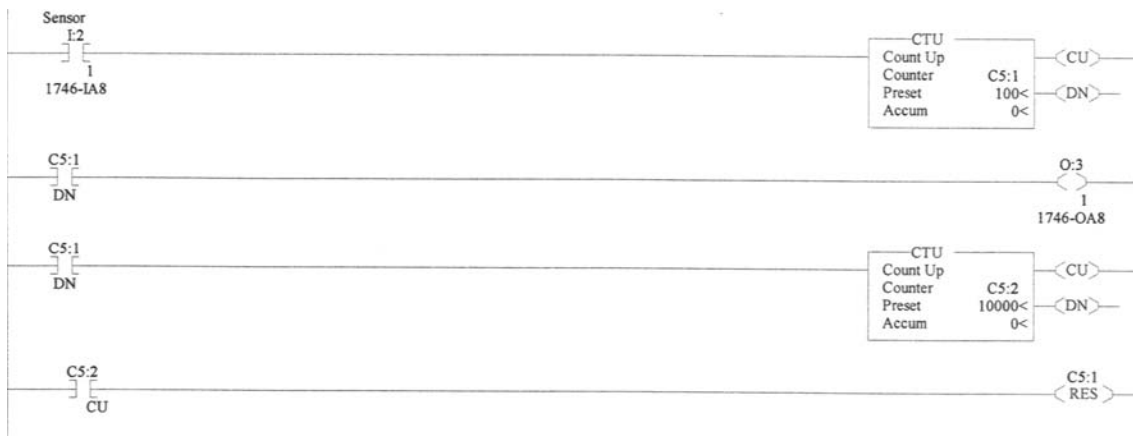


Figure 3 A Program Using Counters to Count Parts

Conclusion:

Experiment No.: 6

Aim: Study of function blocks & their applications in logic programming.

Objectives:

- To be able to write simple FBD programs

Apparatus:

Allen Bradley micrologix-1400 PLC or Siemens S7-1200 PLC
PLC Trainer kit

Theory:

Function Block Diagrams (FBDs) are part of the IEC 61131-3 standard. The primary concept behind a FBD is data flow. In these types of programs the values flow from the inputs to the outputs, through function blocks. A sample FBD is shown in Figure 21.1. In this program the inputs $N7:0$ and $N7:1$ are used to calculate a value $\sin(N7:0) * \ln(N7:1)$. The result of this calculation is compared to $N7:2$. If the calculated value is less than $N7:2$ then the output $O:000/01$ is turned on, otherwise it is turned off. Many readers will note the similarity of the program to block diagrams for control systems.

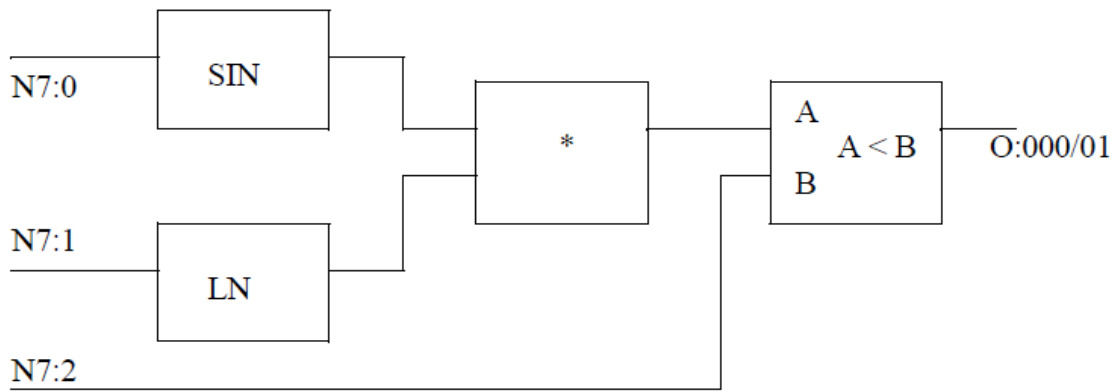


Figure 1 A Simple Comparison Program

A FBD program is constructed using function blocks that are connected together to define the data exchange. The connecting lines will have a data type that must be compatible on both ends. The inputs and outputs of function blocks can be inverted. This is normally shown with a small circle at the point where the line touches the function block, as shown in Figure 2.

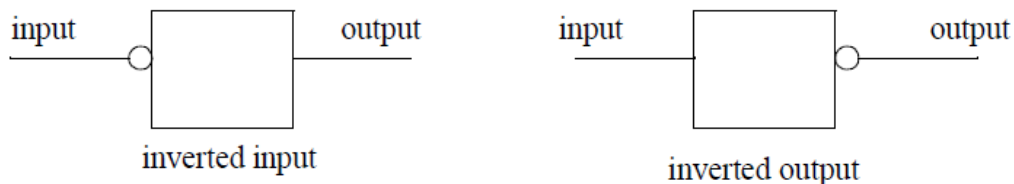


Figure .2 Inverting Inputs and Outputs on Function Blocks

The basic functions used in FBD programs are equivalent to the basic set used in Structured Text (ST) programs. Consider the basic addition function shown in Figure 3. The ST function on the left adds *A* and *B*, and stores the result in *O*. The function block on the right is equivalent. By convention the inputs are on the left of the function blocks, and the outputs on the right.

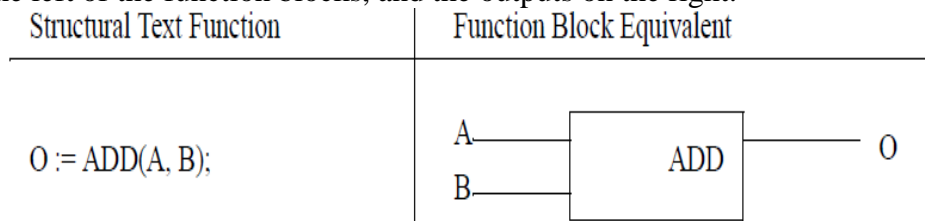


Figure 3 Simple Function Block

Some functions allow a variable number of arguments. In Figure 4 there is a third value input to the *ADD* block. This is known as overloading.

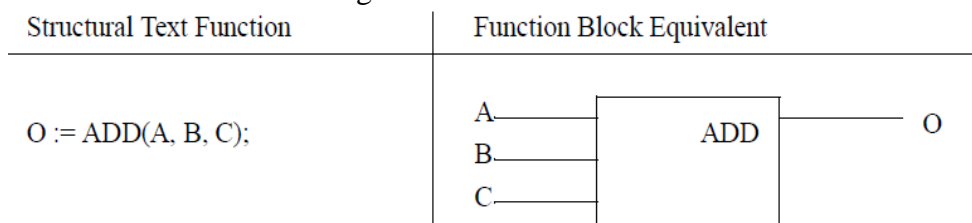


Figure 4 A Function with A Variable Argument List

The *ADD* function in the previous example will add all of the arguments in any order and get the same result, but other functions are more particular. Consider the circular limit function shown in Figure 5. In the first ST function the maximum *MX*, minimum *MN* and test *IN* values are all used. In the second function the *MX* value is not defined and will default to 0. Both of the ST functions relate directly to the function blocks on the right side of the figure.

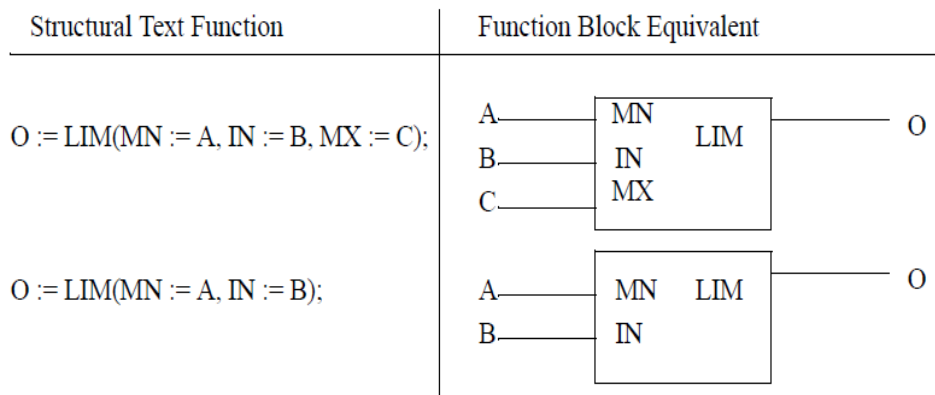


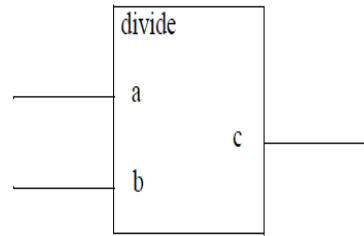
Figure 5 Function Argument Lists

CREATING FUNCTION BLOCKS

When developing a complex system it is desirable to create additional function blocks. This can be done with other FBDs, or using other IEC 61131-3 program types.

Figure 6 shows a divide function block created using ST. In this example the first statement declares it as a *FUNCTION_BLOCK* called *divide*. The input variables *a* and *b*, and the output variable *c* are declared. In the function the denominator is checked to make sure it is not 0. If not, the division will be

performed, otherwise the output will be zero.



```
FUNCTION_BLOCK divide
VAR_INPUT
    a: INT;
    b: INT;
END_VAR
VAR_OUTPUT
    c: INT;
END_VAR
IF b <> 0 THEN
    c := a / b;
ELSE
    c := 0;
END_IF;
END_FUNCTION_BLOCK
```

Figure 6 Function Block Equivalencies

Conclusion:

Experiment No.: 7

Aim: Temperature measurement using analog input.

Theory:

Special function I/O interfaces provide the link between programmable controllers and devices that require special types of signals. These special signals, which differ from standard analog and digital signals, are not very common, occurring in only 5–10% of PLC applications. However, without special interfaces, processors would not be able to interpret these signals and implement control programs.

Special I/O interfaces can be divided into two categories:

- direct action interfaces
- intelligent interfaces

Direct action I/O interfaces are modules that connect directly to input and output field devices. These modules preprocess input and output signals and provide this preprocessed information directly to the PLC's processor. Special direct action I/O interfaces include modules that preprocess low-level and fast-input signals, which standard I/O modules can not read. Special function **intelligent I/O interfaces** incorporate on-board microprocessors to add intelligence to the interface. These intelligent modules can

perform complete processing tasks independent of the PLC's processor and program scan. They can also have digital, as well as analog, control inputs and outputs. Figure 8-2 illustrates an application of intelligent I/O interfaces. The method of allocating various control tasks to intelligent I/O interfaces is known as **distributed I/O processing**.

THERMOCOUPLE INPUT MODULES

In addition to standard analog voltage/current input interfaces that can receive signals directly from transmitters, special analog input interfaces can also accept signals directly from sensing field devices. **Thermocouple input modules**, which accept millivolt signals from thermocouple transducers, are an example of this type of special preprocessing interface. Different types of thermocouple input modules are available, depending on the thermocouple used. These modules can interface with several types of

thermocouples by selecting jumpers or rocker switches in the module. For example, an input module may be capable of interfacing with thermocouples of (ISA standard) type E, J, and K. The operation of a thermocouple module is very similar to that of a standard analog input interface. The module amplifies, digitizes, and converts the input signal (in millivolts) into a digital signal. Depending on the manufacturer, the converted number will represent, in binary or BCD, the degrees Celsius or Fahrenheit being measured by the selected thermocouple. Thermocouple modules do not provide a range of counts proportional to the measured temperature because thermocouples exhibit nonlinearities along their range. These nonlinearities usually occur between 0 °C and the thermocouple's upper temperature limit. To determine the digital value of the incoming signal, the thermocouple input module's on-board microprocessor calculates the temperature (in °C or °F) that corresponds to the voltage reading. The microprocessor does this by referencing a thermocouple table (millivolts versus °C or °F) and performing a linear interpolation.

Thermocouple interfaces usually provide **cold junction compensation** for thermocouple (device) readings. This compensation allows the thermocouple to operate as though there were an ice-point reference (0 °C), since all of the thermocouple's tables depicting the generation of electromotive force (emf) are referenced at this point.

In addition to cold junction compensation, thermocouple modules provide **lead resistance compensation** for a determined resistance value. Lead resistance deals with the loss of signal due to

resistance in the wires. Thermocouple manufacturers can provide resistance values for given wire size lengths at known temperatures. Depending on the PLC manufacturer, thermocouple interfaces may provide different lead resistance compensations. One manufacturer may provide 200 ohms of compensation, while another may provide 100 ohms. If the lead resistance is greater than the available compensation, a calculation in the control program can add degrees Celsius to compensate for the resistance. When possible, it is a good practice to use the same type of material for the lead wire as is used in the thermocouple. Smaller gauge wire provides a slightly faster response, but heavier gauge wire tends to last longer and resist contamination and deterioration at high temperatures. Figure 1 shows a typical thermocouple interface connection.

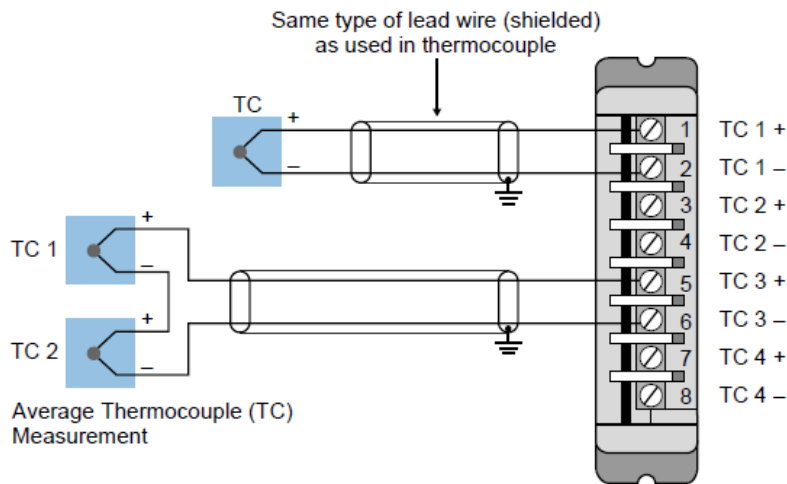


Figure 1. Thermocouple interface connection diagram.

RTD INPUT MODULE

Resistance temperature detector (RTD) interfaces receive temperature information from RTD devices. RTDs are temperature sensors that have a wire-wound element whose resistance changes with temperature in a known and repeatable manner. An RTD in its most common form consists of a small coil of platinum, nickel, or copper protected by a sheath of stainless steel. These devices are frequently used for temperature sensing because of their accuracy, repeatability, and long-term stability.

The operation of RTD modules is similar to that of other analog input interfaces. These modules send a small (mA) current through the RTD and read the resistance to the current flow. In this manner, the module can measure changes in temperature, since the RTD changes resistance with changes in temperature. An RTD module converts changes in resistance into temperature values, available to the processor in either C or F. Some interfaces are able to provide the processor with the resistance value in ohms in addition to temperature measurements. Depending on the manufacturer, the module may also be able to sense more than one type of RTD. Table 1 lists some of the most common RTD devices and their resistance ratings. RTD devices are available in 2-, 3-, and 4-wire connections.

| RTD Type | Resistance Rating (ohms) | Temperature Range | |
|----------|--------------------------|-------------------|----------------|
| Platinum | 100 | -200 to 850°C | -328 to 1562°F |
| Nickel | 120 | -80 to 300°C | -112 to 572°F |
| Copper | 10 | -200 to 260°C | -328 to 500°F |

Table 1. Common RTD types and their specifications.

Devices with a 2-wire scheme do not compensate for lead resistance; however, 3- and 4-wire RTDs do allow for lead resistance compensation. The most commonly used RTD device is the 3-wire RTD. This type of device is used in applications requiring long lead wires, where wire resistance is significant in comparison to the ohms/°C sensitivity of the RTD element. It is a good practice to try to match the resistance of the lead wires by using quality cabling and heavy gauge wires (16–18 gauge). Figure 2 illustrates typical connections for an RTD module with 2-, 3-, and 4-wire RTDs.

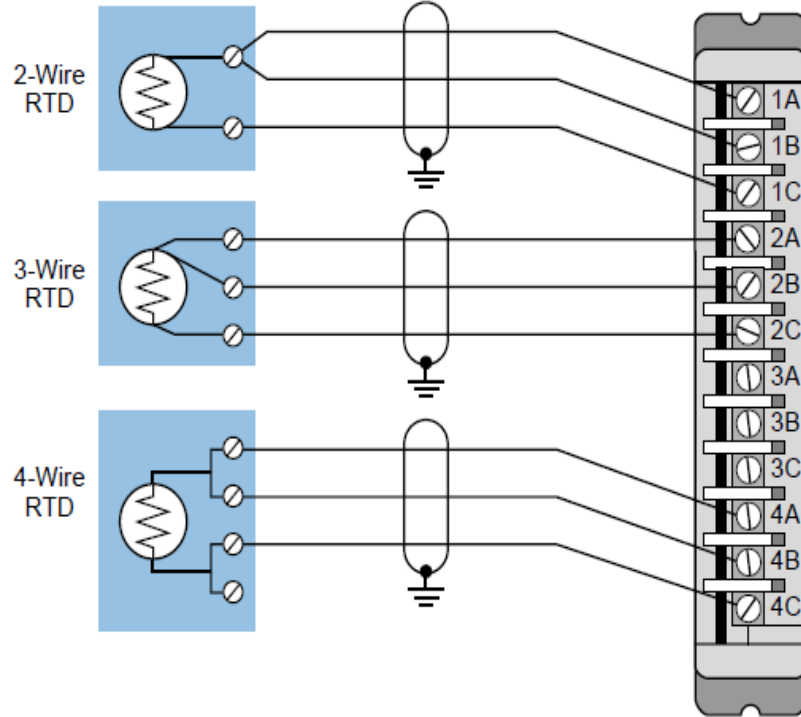


Figure 2. RTD connection diagram.

Conclusion:

Experiment No.:8

Aim: Case study on Industrial DCS.

Theory:

Process Control of Captive Power Plant:

The power plant is an industrial facility for the generation of electricity. At the centre of nearly all power stations is a generator, a rotating machine that converts mechanical energy into electrical energy by creating relative motion between a magnetic field and a conductor. The energy source harnessed to turn the generator varies widely. It depends on what fuels are easily available and the types of technology that Power Company has accessed to. In automating the captive power plant processes the use of equipment and software, which have not been designed specifically for the industry, can land the user with headaches.

Working of Captive Power Plant:

Steam is generated in the boiler of the thermal power plant using heat of the fuel burnt in the combustion chamber. The steam generated is passed through steam turbine where part of its thermal energy is converted into mechanical energy which is further used for generating electric power. The steam coming out of the steam turbine is condensed in the condenser and the condensate is supplied back to the boiler with the help of the feed pump and the cycle is repeated.

The function of the boiler is to generate steam. The function of the condenser is to condense the steam coming out of the low pressure turbine. The function of the steam turbine is to convert heat energy into mechanical energy. The function of the condenser is to increase the pressure of the condensate from the condenser pressure to the boiler pressure. The other components like economizer, super heater, air heater and feed waters are used in the primary circuit to increase the overall efficiency of the plant.

Captive Power Plant Process Controlled through DCS:

The process variables are controlled by DCS through valves, pumps or other motors. A motor has a provision to be either run locally (from field) or from DCS (remote). Once it is in remote mode; the message flashes in the operator screen and further option is available to operate either in auto mode or manual mode. When it is manual mode, it can be made to start or stop by pressing the on-off buttons in Digivis. When in auto mode, the command is issued from DCS, based on the logic of the process station. An example, of process control logic is a set point control loop consisting of a pressure sensor, controller, and valves. Some of the areas of control are:

a) Drum Level Control:

The aim of this control loop is to maintain the drum level at normal operating level of the boiler. Middle value of three transmitters (LT1, LT2 and LT3) is selected for drum level control through Level indicator (L1) block.

If reading of any two transmitters deviates by 10% then the controller should be forced to manual mode. If greater than 10% deviation is observed in all the three transmitters then the boiler should be tripped. In case of failure of one transmitter, average of the other two transmitters should be referred for control and in case of failure of two transmitters, the boiler should be tripped.

The level signal acts as a Process variable (PV) to the controller block LIC. The controller block will vary the percentage opening of the valve LV and hence level control is achieved.

b) Steam Temperature Control:

The main aim of this control loop is to maintain the steam temperature at a certain set point. The final steam temperature is measured with the transmitter TT. The output is compared with a fixed set point in the controller TIC. The resultant control signal instructs the spray control valve TV to control flow of

water to the attemperator.

c) Furnace Pressure Control:

The furnace pressure is measured with the Pressure transmitter PT. This is used as a Process variable (PV) and is then compared with a fixed set point in the controller PIC. The resultant control varies the speed of the motor that controls the pressure (ID fan).

d) Combustion Control:

The aim of the combustion control loop is to maintain rated steam pressure during fixed and varying conditions. This is achieved by controlling the firing rate and the air flow rate to have a proper combustion in the furnace.

The main steam pressure is measured by the pressure transmitter PT and is used as a process variable for the controller PIC. This controller generates an output signal based on the difference between the local set point and the process variable. The output of this controller is then passed on to the boiler lading stations HIC-M1, M2, M3, M4 which act as an auto/manual station for rotary feeder for coal.

The air flow controller is a slave controller with the airflow as the Process variable (FI) and total heat demand as remote set point. This remote set point is total combustion air requirement. The air flow controller generates an output signal comparing the remote set point and the process variable. The output is fed to the FD fan to control the net air flow.

e) CBD Tank Level Control :

This control loop is used to [3] control the CBD tank level. The CBD tank level is measured by the transmitter LT. this level is fed to a level indicating controller LIC as a measured variable. This measured variable is compared with the fixed set point in the Level indicating controller. The controller then operates the CBD level control valve.

Acceptable limit then the corresponding alarm is generated as Low (LAL), Low-Low (LALL), High (LAH) and High-High (LAHH).

f) Deaerator Level Control:

This control loop is used to control the deaerator storage tank level. The Deaerator level transmitter (LT) senses deaerator tank level and level is fed to a Level indicating controller (LIC) as a measured variable. The measured signal is compared with the fixed set point in the level indicating controller. The resultant control signal operates the deaerator control valve (LV) which controls the deaerator level.

g) Deaerator Pressure Control

This control loop is [4] used to control deaerator pressure. The deaerator Pressure transmitter (PT) senses the deaerator tank pressure and pressure signal is fed to a Pressure indicating controller (PIC) as a measured variable. The measured variable signal is compared with fixed set point in pressure indicating controller. The resultant control signal operates the Deaerator pressure control valve (PV) to control the deaerator pressure.

h) PRDS Control:

This loop is used to control the pressure and temperature of the steam going to deaerator and steam header.

For Deaerator steam, the [3] Pressure transmitter (PT) senses the pressure of the steam and Temperature transmitter (TT) senses the temperature of the steam going to deaerator. These signals are given to Pressure indicating controller (PIC) and Temperature indicating controller (TIC) as process

variable respectively.

The output of the Pressure indicating controller (PIC) is used to provide to operate the Pressure control valve (PV) to control the pressure of steam. Output of the Temperature indicating controller (TIC) is provided to operate the Temperature control valve (TV) to control the temperature of steam.

Similarly for steam header pressure transmitter, the Pressure transmitter (PT) senses the pressure of the steam and the Temperature transmitter (TT) senses the temperature of the steam going into the header. These signals are given to the Pressure indicating controller (PIC) and Temperature indicating controller (TIC) and act as process variables respectively.

The output of the Pressure indicating controller (PIC) is used to operate the pressure control valve to control the pressure of steam.

These are provisions to view the valve position through the Position transmitter (ZT) in the DCS.

D. System configuration of DCS:

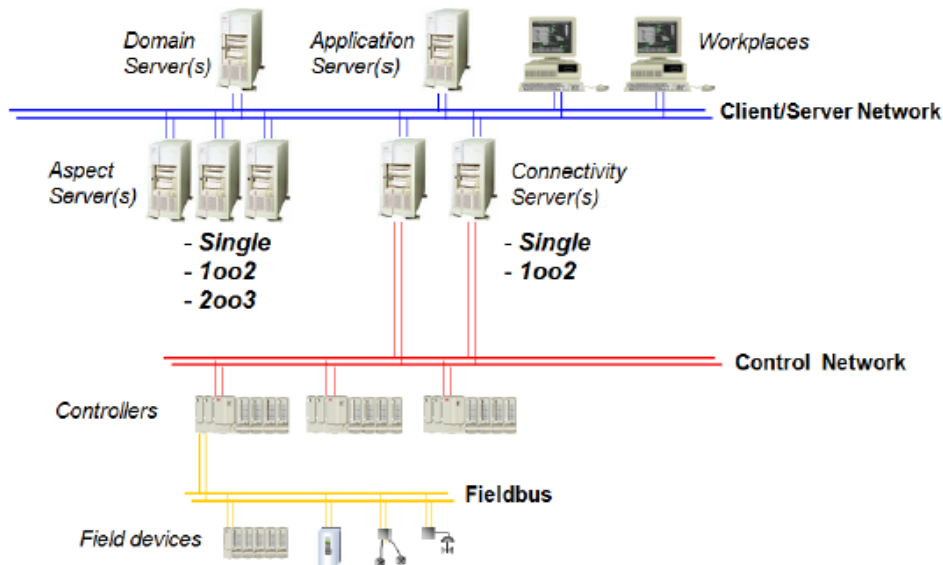


Figure: System Configuration Drawing

All connected to plant server and all controllers are connected connectivity server to It has two redundant servers where both the servers are connected to switch 1 and switch 2. Switch 1 and switch 2 helps to communicated between the server, client and controllers. DCSs may employ one or several workstations and can be configured at the workstation or by an off-line personal computer. Local communication is handled by a control network with transmission over twisted pair, coaxial, or fiber optic cable. A server and/or applications processor may be included in the system for extra computational, data collection, and reporting capability.

A typical DCS consists of functionally and/or geographically distributed digital controllers capable of executing from 1 to 256 or more regulatory control loops in one control box. The input/output devices (I/O) can be integral with the controller or located remotely via a field network. Today's controllers have extensive computational capabilities and, in addition to proportional, integral, and derivative (PID) control, can generally perform logic and sequential control.

E. Human Machine Interface:

A DCS typically uses custom designed processors as controllers and uses both proprietary interconnections and Communications protocol for communication. Input & output modules form component parts of the DCS. The processor receives information from input modules and sends information to output modules. The input modules receive information from input instruments in the

process and transmit instructions to the output instruments in the field. Computer buses or electrical buses connect the processor and modules through multiplexer or demultiplexers. Buses also connect the distributed controllers with the central controller and finally to the Human Machine Interface (HMI) or control consoles. The figure shows the simulation of the drum level control.

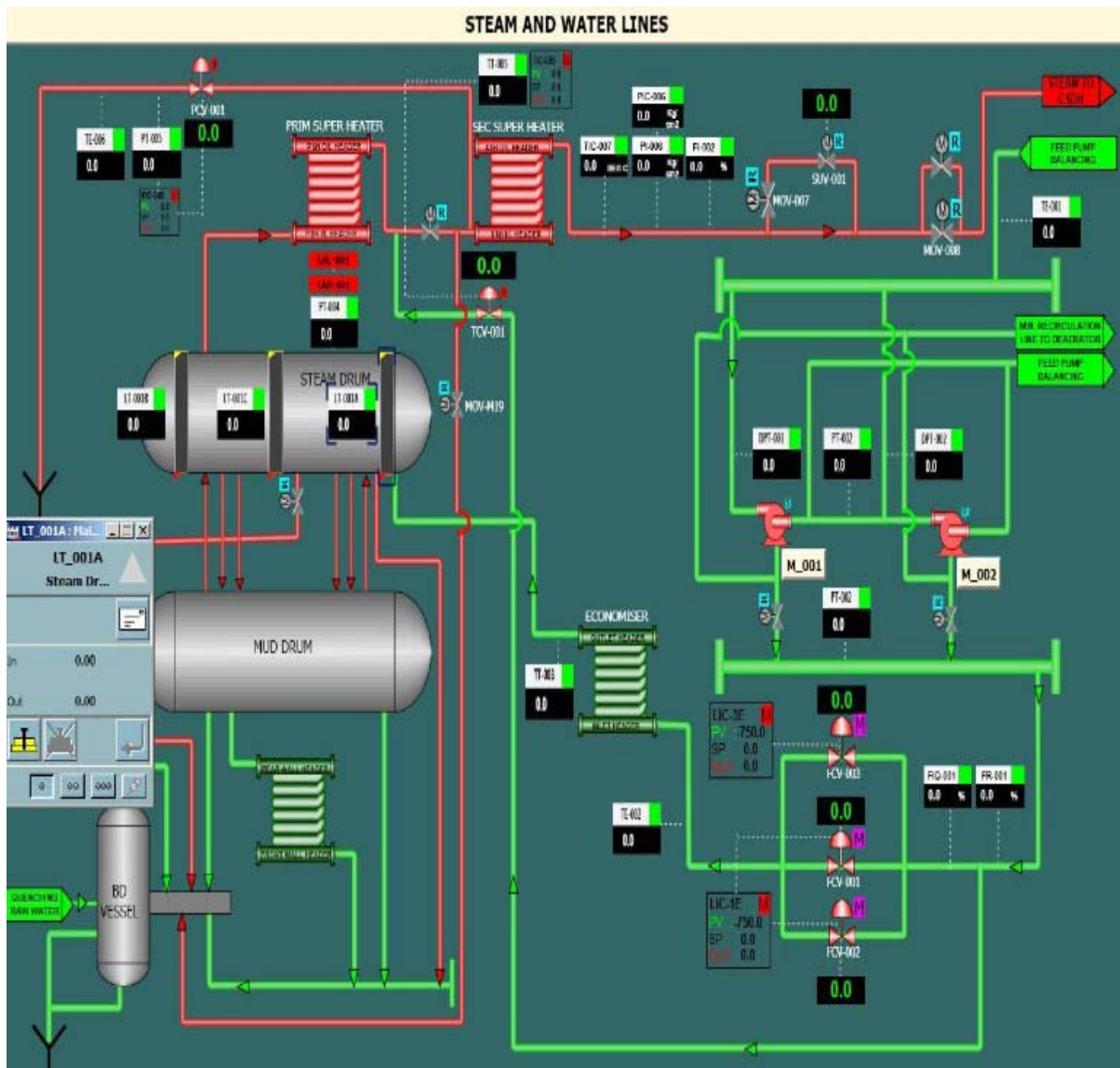


Figure: Simulation of the Water and Steam Lines

Conclusion: