

A Typical PLC Application in Automation

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Abstract:-This document describes the need of Programmable Logic Controller (PLC) in Industrial Automation and Process control, the basic PLC hardware and software architecture very briefly. And then it tells about a typical PLC application in a walking beam furnace for calculating the length of a steel tubular pipe while entering into the furnace, and placing the pipe centrally inside the furnace.

PLC, SCADA, VVVF, Process Control, Automation

I. INTRODUCTION

A. What is Process Control?

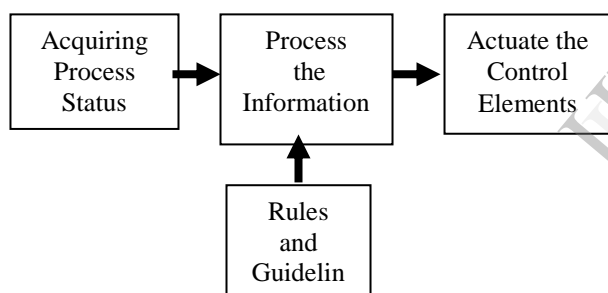


Fig. 1 Block Diagram of Process Control

The method of acquiring the state of the process all the times, process the information according to the set rules and guidelines, and accordingly actuate the control elements is referred to as Process Control.

In the control of process, above actions can be implemented manually by human intervention; or it can be done semi automatically by incorporating Relay Logic, or fully automatically by introducing PLC.

II. PLC and AUTOMATION

A. What is Automation?

Automation is basically delegation of human control functions to technical equipments aimed towards achieving

1. Higher Productivity
2. Superior quality of End Product

3. Efficient usage of Energy & Raw materials
4. Improved safety in working condition

B. Now what is PLC?

In very simple language a PLC is a type of computer. But the computers that most people are familiar with use a keyboard as an input device and a screen for an output device. PLC's don't have a keyboard. So for an input device, we use an "input module" which is basically a little box with a row of screws on the front of it. We wire up a bunch of pushbuttons, sensors, switches, etc. to the little screws ... and this will serve as the input device for our PLC "computer". We do something similar for an output device. Instead of using a screen for an output device, we use an "output module" which is basically another little box with a row of screws on the front of it. We wire up a bunch of solenoid valves, indicator lamps, motor starters, etc. to the little screws; and this will serve as the output device for PLC "computer".

C. What Constitutes a PLC?

The PLC is basically a programmed interface between the field Input elements like limit switches, sensors, transducers, push buttons etc. and the final control elements like actuators, solenoid valves, dampers, drives, hooters etc.

This interface called as programmable Logic Controller (PLC) consists of the following:

- 1- Input Modules (Signal Modules)
- 2-CPU with processor and program and Data memory
- 3-Output Modules (Signal Modules)
- 4-Bus System
- 5-Power Supply

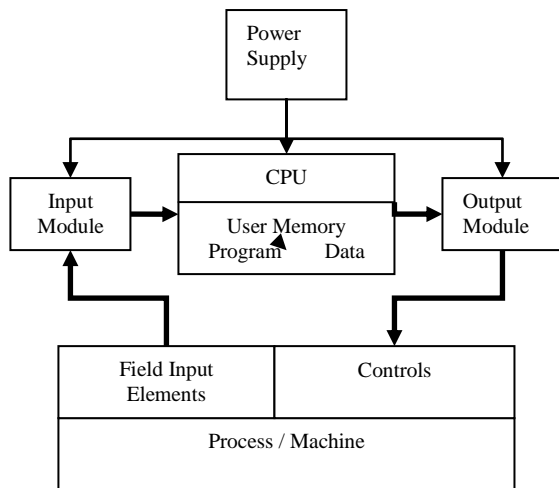


Fig. 2 Block Schematic of a PLC in a minimum system.

The Power Supply, CPU, Input and Output modules are inserted in a channel/Rail. They are interconnected by a backplane bus on the Channel. The CPU also has at least one communication port (PG/PC interface) which can be connected to a programming device or PC for downloading user program and for testing the PLC logic and troubleshooting with the help of manufacture specific software tools.

In addition to the above listed modules, the other frequently used modules for special functions, such as, Interface Module, Communication Processor or Function Modules can also be inserted into the Channel.

Interface modules interconnect modules in different channels. Communication processors facilitate use of communication network like Profibus, Modbus or Ethernet etc. Function modules are used for time-critical and memory intensive signal processing, for example, high speed counting, positioning or closed-loop control.

Some CPUs, in addition to PG/PC interface, have one or two communication port like Profibus, Modbus or Ethernet as in-built ports.

Though not shown in Fig. 2, CPU has also system memory for storing operating system, inherent system functions, Timers, counters, Flags etc.

D. What is User Program?

User program tells the CPU how to manipulate the acquired process status and accordingly how to actuate the output control elements. All PLC manufacturers have their own program development tools. User writes the program using these tools in a PC or programming device and downloads it to the CPU. The most common method of writing a user program is Ladder Diagram. Siemens provides alternate methods like Statement List (An Assembly language like), Function Block Diagram etc. Now let's consider an electric circuit as below:

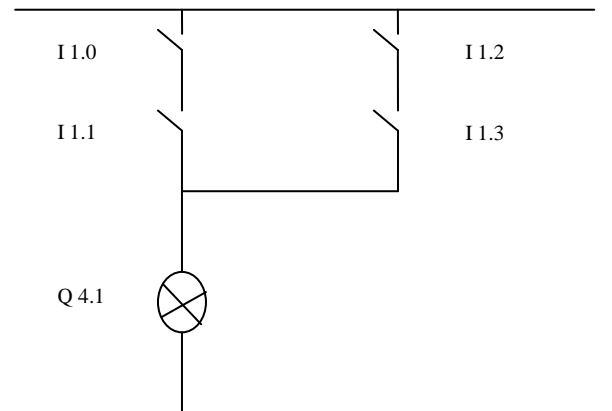


Fig. 3 Electrical Circuit Diagram

The equivalent program in Ladder diagram is as follows:

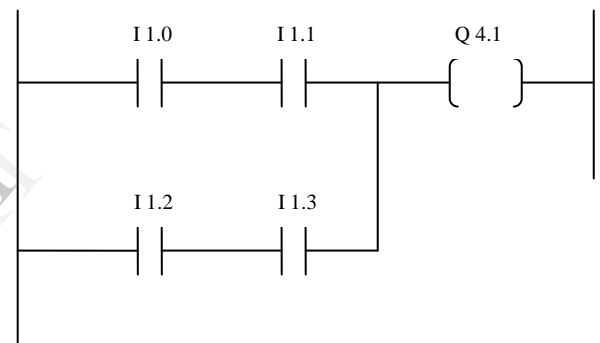


Fig. 4 Equivalent Program in Ladder Diagram (LAD)

The equivalent program in Statement list is as under:

```
A I 1.0
A I 1.1
O
A I 1.2
A I 1.3
= Q 4.1
```

The detailed PLC programming technique and language is not the intention of this paper. That may be learned with the help of PLC programming manuals; more important is analyzing process needs and deriving proper logic. Better we will see how the PLC CPU handles the user program.

E. How PLC scan user program?

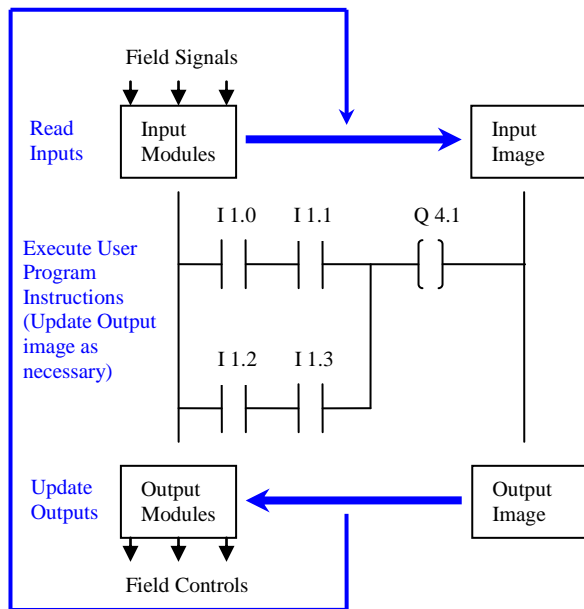


Fig. 5 PLC Scan Cycle

The field signals are connected to input modules.

At the output of the input modules, the field status converted into voltage or current level required by the CPU is always available.

- At the beginning of each cycle, the CPU brings in all the field input signals from input modules and stores into its internal memory as process image Input.
- When the Input process image is ready, the execution of user program, statement by statement begins from start to end.
- The results of user program execution are stored in the internal memory as process image Output.
- After the execution of the last instruction of user program, the CPU transfers the process image output to the output modules and further to field controls.
- The programmable controller operates cyclically, i.e., when complete program is scanned to end, it starts again at the beginning of the program.

III. EXAMPLE of a REAL-LIFE APPLICATION

A. Functioning of the Furnace

We will discuss one application area of Process Control of a Walking Beam Furnace. The figure below will give an idea of what is a Walking Beam Furnace.

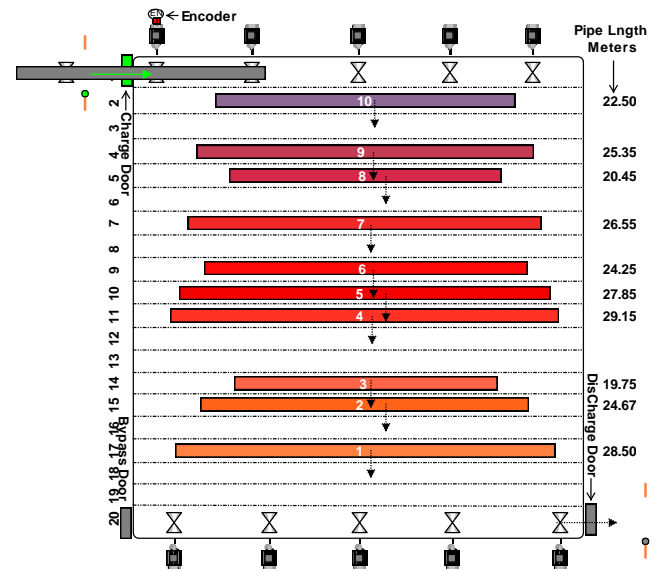


Fig. 6 Overview of a Walking Beam Furnace

Tubular pipe to be heated is entered into the furnace through the open charge door as shown in fig. 6; a series of hourglass shaped roller driven by motors brings the tube inside the furnace. An encoder is fixed to the motor shaft of the first roller from the charge door. An infra-ray light barrier sensor (IRLB) is placed outside the furnace left to the charge door. All the charge side Motors rotating the charge side rollers are driven by a single variable voltage variable frequency motor drive (VVVF). As the tube entered inside the furnace and placed centrally, the charge door closes. All the tubes in the furnace are then moved to the next position (from position 1 to 2, 2 to 3 etc.) of the furnace by a hydro-mechanical walking beam. In this way, when a tube is placed in the last position, i.e. on discharge roller, the discharge door opens, another VVVF driving the discharge side motors start running and the tube is driven out of the furnace. Gas fired burners are fixed on both side of the walls. As the tubes move from charge side to discharge side, they got more heated. Burner fires are controlled by controlling the aperture of the solenoid valves for gas and air, by user program. Inlet roller table outside the furnace help the tube entering into the furnace. Outlet roller table help the tube to bring out of the furnace. The speeds of the charge side and discharge side rollers are synchronized respectively with inlet & outlet roller table speeds through user program. Different zone temperatures in the furnace are controlled to be near respective set points by controlling burner fire through PID control. Tracking details of the tubes inside the furnace is also implemented in the user program. It is obvious by now, that there are many details of this automation project require discussions and clarification. But for now, we will only limit our goal to find how to know the length of the tube entered into the furnace and how to place it centrally inside the furnace.

B. Calculate the length of entered tube and positioning it centrally inside the furnace

As the roller rotates while tube is entering the furnace, encoder generates pulses to its output which is wired to the input of a FM frequency counter module. This counter can be controlled through user program to start or stop counting. When the tube, during entry into the furnace, reaches the infra-ray light barrier (IRLB), user program tells the counter to start counting. When the tube, during entry into the furnace, just passes away the IRLB sensor, the counted pulses are stored in some memory location, and from this pulse count, the length of the tube can be calculated as will be shown in following discussion. But

When the tube moves into the furnace over the hour-glass shaped roller, its surface touches the roller where diameter of the roller is in between the roller outer diameter and the roller central diameter as shown in fig. 8. This diameter is the contact diameter from which, contact circumference can be obtained. For one rotation of the roller, the tube moves a distance equal to this contact circumference.

If a line is drawn from the centre of the tube to the contact point, it will be perpendicular to roller surface. Let's assume the radius of the tube is r , roller outer diameter is d , roller central diameter is c and the roller length is l . Let contact diameter be k and contact circumference be s .

$$\tan \alpha = ((d-c) \div 2) / (l \div 2)$$

$$h \div r = \tan \alpha$$

$$p \div h = \sin \alpha$$

$$\text{So, } p = h \times \sin \alpha$$

Replacing h , we get $p = r \times \sin \alpha \times \tan \alpha$

Now the contact diameter $k = c + 2 \times p$

Contact circumference $s = \Pi \times k$

2) *Calculate length of the tube:* As mentioned earlier, an encoder is connected to the motor driving the first roller. Pulses per rotation (PPR) are specific to the encoder.

Let's say PPR is n .

Then distance traversed by the tube for one encoder pulse is $(\Pi \times k \div n)$.

If the total pulse count during the period from the moment the tube sensed by the IRLB and the moment when the tube just move away from IRLB is m , then the length of the tube $L = (\Pi \times k \div n) \times m$.

3) *Placing the tube centrally inside the furnace:* As soon as the tube passes away the IRLB, we know the length of the tube L . To place the tube centrally inside the furnace, it is required to know the distance between the centre line of the furnace and the IRLB. Let's assume it to be X . To place the tube centrally, the distance moved by the tube from the IRLB should be $X + L \div 2$. For the tubular pipe

before that, roller contact diameter, where the tube touches the roller, is to be calculated.

1) *Calculate Contact diameter of the Roller where tube touches the Roller:* The Roller is hourglass shaped and tube is round. So to calculate the contact diameter, some basic knowledge in trigonometry will be required. Though redundant to all who matters in this seminar, I am still putting these equations.

$$\begin{aligned} \sin \alpha &= p \div h \\ \cos \alpha &= b \div h \\ \tan \alpha &= p \div b \end{aligned}$$

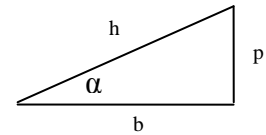


Fig. 7 Triangl

movement for the distance X , equivalent encoder pulses will be $X \div (\Pi \times k \div n)$. For distance $(L \div 2)$, equivalent encoder pulses will be $(m \div 2)$. So counting should be stopped when the pulse count equals to $X \div (\Pi \times k \div n) + (m \div 2)$. The driving motor should also be stopped at this point to place the tube in centre position of the furnace. We hope the following figure will further clear the discussion.

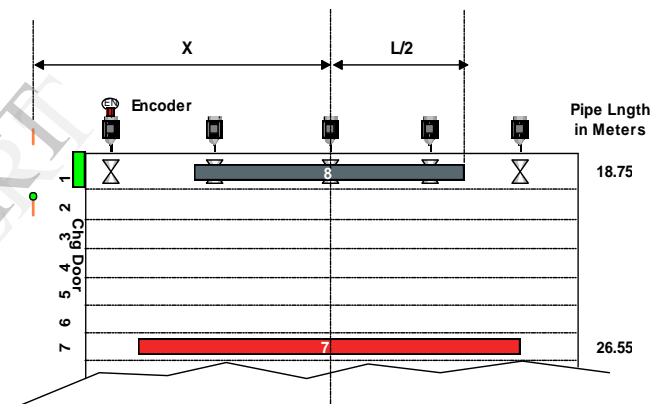


Fig. 8-Positioning the tubular pipe centrally in furnace

To keep it simple, it is assumed that the motor will instantaneously be stopped when the stop command is given to the drive (VVVF) driving all the charge side motors. But in real situation, it takes few seconds to stop. So actually, stop command is given a few seconds earlier, computing the time the drive will take to stop the motor from the running speed to stop. But that computation and many other automation aspects might be discussed in some future occasions.

IV. CONCLUSION

The above discussion points out that not only knowledge in PLC hardware & programming language but also proper analysis of the process requirements to find a logical solution makes a successful automation project. The author of this paper, solely designed, developed and commissioned both PLC & SCADA (Supervisory Control and Data Acquisition) software for this project.

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