1. Object

The experiment is designed to provide experience in programming a modern IEC-compliant PLC system for sequence control of typical industrial processes.

2. Introduction

A sequence control system is one that performs a set of operations in a prescribed manner. The automatic washing machine is a familiar example of sequence control: the control system performs the operations of filling the tub, washing the clothes, draining the tub, rinsing the clothes, and spin drying the clothes.

Before 1970, large relay panels were used to control sequential operations. In 1968, General Motors Corporation specified the design criteria for the first programmable logic controller (PLC). The purpose was to replace the inflexible relay panels with a computer-controlled solid-state system. The project succeeded beyond anyone's dreams. Programmable logic controllers have gone beyond replacement of relay panels to include PID modules for process control and communications interfaces that make it possible to link programmable controllers into an integrated manufacturing operations. PLCs have since become an indispensable portion of industrial automation and by the 80s, there were already a very wide range of PLC and programming languages in the market, many of which were proprietary. Having so many languages often result in misunderstandings which may have disastrous results. In 1993, a working group within the International Electro-technical Commission (IEC) was formed to look into setting up a PLC language standard, otherwise known as the IEC 1131-3. The major players in the market like Siemens, Allen-Bradley, Modicons etc. have since adopted the standard.

The experiment will be based on the S7/300 IEC-compliant PLC system of Siemens. Students will be trained on various aspects of sequence control as in control analysis, logic operations and use of standard function blocks like the Up/Down counter and the Set/Reset (SR) block.
3. Apparatus

The equipment set up required for this experiment consists of:

- Pentium workstation
- Siemens S7/300 PLC with I/O modules
- STEP7 programming software running on Windows 95
- Technology simulators of industrial processes

4. Technology Simulators

Each set of PLC system will be equipped with two technology simulators

*Simulator #1 (Reaction Vessel)*

![Process Schematic of Reaction Vessel](image)

*Figure 1: Process Schematic of Reaction Vessel*
The process schematic of the reaction vessel is as shown in Figure 1. The pin assignment for the connection between the PLC and the simulator is shown in Figure 2. A chemical process is to take place in a reaction vessel at a specific temperature and at a specific pressure. The reaction vessel has a thermal detector for measuring the temperature and a pressure gauge for the pressure. Temperature and pressure are regulated via the following three actuators:

- Heater H
- Cooling-water inlet K and
- Safety valve S

The enabling conditions for the actuators are given as follows:

Safety valve S is activated when
- pressure P is too high and
- temperature δ is too high or normal
Cooling-water inlet K is activated when
- temperature \( \delta \) is too high and
- pressure P is too high or normal

Heater H is activated when
- temperature \( \delta \) is too low and
- pressure P is not too high
or
- pressure P is too low and
- temperature \( \delta \) is normal

If actuator K (cooling-water inlet) or H (heater) has been activated, agitator U must also be activated.

The reaction states must also be correctly shown on the indicator lamps as follows:

- Starting state : Pressure P too low
- Normal state : Pressure P is normal
- Alarm : Pressure P too high
Simulator #2 (Automatic Pill Filling Machine)

Figure 3: Process Schematic for Automatic Pill Filling Machine

Figure 4: Pin Assignment
The schematic for the Automatic Tablet Filling Machine is shown in Figure 3 and the pin assignment is given in Figure 4. The functional sequence for the machine is described as follows:

1. After the control system has been put into operation, the operator must select the number of pills to be filled into each tube. The filling procedure is switched on with I0.1.
2. Valve Y then opens the supply container; light barrier B1 counts the pills.
3. When the tube has been filled with the prescribed number of pills, valve Y closes and the conveyor motor M is started. Opening and closing I0.2 acknowledges the positioning of the pill container. The above procedure (1-3) is repeated.
4. If a different number of pills is selected by actuating the relevant pushbutton, the tube that is at the filling position is to be filled with the old number of tablets.
5. When the control system is shut down, the filling procedure currently in process is terminated before all actuators are switched off.

5. Experiment

5.1 Preparation

At the Windows 95 environment, double click the SIMATIC Manager icon. The project window for the SIMATIC Manager will then be opened.

5.1.1 Create Project structure

Select the CPU model as “CPU 313” and keep other items as the defaults values. Click on the menu command File→New→Project in the SIMATIC Manager. In the filename field, type the project name of your choice, say “reactor”, “pill”, etc. Click on OK (or Save) to create the project.

Next, add a station to the opened project with the menu command:

Insert→Station→SIMATIC 300 Station.
5.1.2 Reset PLC

Before loading any data into the CPU of the S7-300, perform memory reset of the CPU to make sure that it does not contain any old data.

Select SIMATIC 300 Station which you have added and click on the third icon on the toolbar (Accessible Nodes) in the SIMATIC Manager. Select the MPI address (default) of the CPU in the dialogue box so as to establish an on-line connection.

Set the switch of the S7-300 to STOP position. This switch is situated on the PLC itself.

Clear the PLC with the menu command: PLC→Clear/Reset and confirm it. The STOP light on the PLC will flash several times.

5.1.3 Configure and parameterize hardware

Select SIMATIC S7-300 Station 1 which you have created and double click on the Hardware icon.

At the Hardware Configuration window, click on the menu command: PLC→Upload.

Next, change the name of project to your project name. Click OK and click Upload on the subsequent window.

Save and Compile the hardware configuration (default).

5.1.4 Procedure for programming blocks

Open your project in the SIMATIC Manager by clicking:
SIMATIC S7-300 Station 2→CPU313(1)→S7Program(1)→Blocks.

Insert a function with the name FC1 using the menu command:
Insert→S7 Block→Function.
5.2 Programming the PLC

Double click on the FC1 block, you can choose to enter your program in Ladder logic by clicking the command: View → LAD.

Write a ladder program to fulfill the sequence control required of the simulators as stipulated in Section 5. To maximize the benefits from the experiment, it is advisable for you to do some preparation homework and have a draft program with you prior to the experiment.

Define the symbols you use in the ladder program by clicking Options → Symbol Table in the FC1. Refer to Figure 2 and Figure 4 for the pin assignments (addresses). Save the symbol table.

After the program is ready, double click on the OB1 block to open it. Type Call FC1 and then save it.

Now the program is ready to be downloaded. Select SIMATIC S7-300 Station 2 → CPU313(1) → S7Program(1) → Blocks and download it to CPU by clicking PLC → Download.

6. Report

You should ask the laboratory assistant to verify the results after your program is running correctly. The program and results of each stage of the experiment should be logged and adequate comments and explanation on the logic of the program should be provided where necessary.

7. References


S7-300 Programming Controllers, Quick Start- Primer, 1996.