An Interactive PLC Programming Application on Unloading and Handling Systems with Undergraduate Engineering Students

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Abstract: *This article describes an experimental setup for the practical teaching of process control in an undergraduate mechanical engineering curriculum. The system is practice-oriented and is based on developing students' skills in control system application of real process systems. A PLC (Programming Logic Controllers) program is proposed to introduce simulation aspects and final control design practices in scale processes (Unloading and Handling Station). It is based on the principle of introducing a PLC-supported, Siemens Simatic S7-200 PLC controller-controlled production system with the help of SIMATIC Step 7 Programming Software, presenting the scenario for the system and writing the PLC program accordingly. This algorithm prepared for the Unloading and Handling Station operation is not unique and without alternatives. The aim here is to enable students to get to know the system and program the system with different approaches according to the algorithm they have developed.*

Keywords*: S-200 PLC, SIMATIC STEP 7 PROGRAM, PLC ALGORITHM, UNLOADING AND HANDLING SYSTEM, EDUCATIONAL TRAINING*

1. Introduction

The advent of the PLC began in the 1970s and has become the most common choice for manufacturing controls [1]. PLCs are an important part of the electric-electronic technology field, which is the locomotive of technology [2]. PLCs are ubiquitous in automation practice and 74% of process controls job advertisements seek applicant familiarity with this equipment [3].

In traditional engineering courses, the theoretically taught concepts of control systems, usually a physical simulation of production facilities, are reinforced by the participation of students in experiments carried out in a laboratory setting. Today's schools must equip students with the knowledge and skills they need to succeed in an uncertain, constantly changing tomorrow [4]. It is very important in the control and automation curriculum to gain practical experience in monitoring, supervising, and controlling the industrial process, especially before stepping into working life [5].

In process control, experimentation helps students observe dynamic phenomena that are often difficult to display in a classroom by traditional means [6]. The continuous development of science and technology has promoted the continuous development of enterprise units, and the corresponding equipment applications and technical fields have been upgraded and broadened [7].

Relays, contactors, timers, and counters are conventionally used as elements in control circuits [8]. Using PLC is gradually increasing instead of these elements. The use of PLC equipment has been increasing day by day being parallel to progress in the systems of controls nowadays [9]. Changing the PLC programming is enough if any modification is demanded in the control function.

PLC has a wide area of use in the industrial sector, defense industry, agriculture, and the energy sector, where you can think of automation [10]. Some of these are elevator systems, automated packaging, oil wells, unloading and transport systems, conveyor belt systems, filling systems, automobile industry systems, vacuum systems, gate control systems, electrical installations, storage systems, etc.

In this study, the PLC-based unloading and handling system which is used actively in Trakya University Mechanical Theory and Dynamics Laboratory will be experimentally run with the students, so they will be experienced in the system parameters and the program before being involved in the industry.

The content of this paper is organized as follows. Section 2 introduces the components required to develop the physical demonstration setup introduced as the proposed PLC, and experimental materials and devices are illustrated. In section 3, the recommended scenario is included. In addition, detailed information is given on the PLC program and some of our student observations and feedback. Finally, the paper is concluded in section 4.

2. Materials and Methods for PLC-based Uploading and Handling System Experiment

2.1 Uploading and Handling Experiment Set and Its Components

In this experiment, we, therefore, concentrate on comparative observation. Yıldırım Elektronik Y-0044A unloading and handling experiment set is illustrated in Figure 1. The unloading and handling station components, which consist of two parts, are shown in detail in Figure 2.

Fig.1 *Uploading and handling system experiment set*

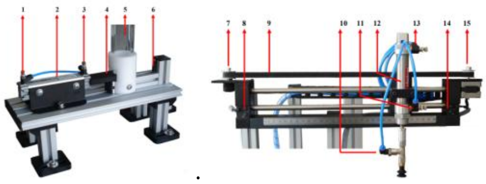

Fig 2. *Component of Unloading and Handling Station*

The components of the system are in numerical order below as shown in Figure 2.

1. Uploading LeverForwardSpeed Adjustment, **2**.Uploading Lever Forward/Reverse Double Acting Piston,**3.** Uploading Arm Reverse Speed Adjustment, **4**. Unloading Arm, **5.** Magazine **6**.Unloading Lever Forward Limit Switch, **7**.Trigger Belt Tension Adjustment Screw, **8**. Handling Left Limit Switch**, 9.** Timing Belt, **10.** Vacuum (Suction) Air inlet, **11.** Handling Arm Up Speed Adjustment, **12**. Handling Arm Up/Down Double Acting Piston, **13.** Handle Down Speed Adjustment, **14.** Handling Right Limit Switch, **15**. Handling Unit Right/Left Motion Motor (Step Motor)[11].

2.2 PLC

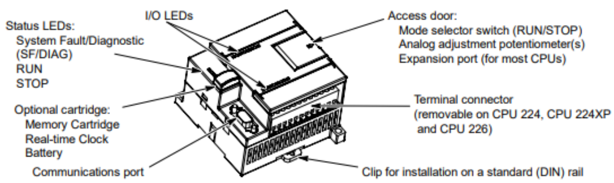

Fig.3 *S7-200 PLC*

This type of device is a microprocessor, an integrated power supply, input circuits, and output circuits in a compact housing to create a powerful PLC [12]. The PLC used in the system; is a 10-bit digital output, and 14-bit has a numeric input. Digital outputs with semiconductor elements (MOSFET) are driven. Digital input/output signals use voltage levels of 0/+24V. There are 4096-word user program memory, 2560 word data memory that can be stored permanently. PLC is supplied with 24 VDC voltage and draws a maximum current of 700 mA depending on the load situation. PLC has one serial port for programming. PLC is programmed by connecting the programming cable to port 0.

2.3 Limit Switch

Generally speaking, a limit switch is often used for controlling machinery as a part of its control system, as a safety interlock, or to count objects passing a point [13]. A mechanical state is converted into an electrical signal with a limit switch. When a moving part collides with a limit switch, the limit switch becomes closed. At the same time, the controller can detect the voltage change of the corresponding I/O port. And then, the follow-up actions could be taken by PLC. This switch has three ends. Common end (COM: Common), normally closed end (NC: Normally Close), and normally open end (NO: Normally Open) and illustrated in fig4. It is used to learn the forward position of the material feeding arm and the right or left side of the transport.

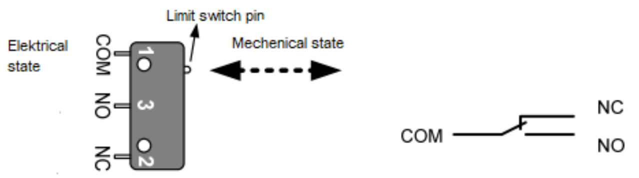

Fig. 4 *Limit Switch Schema*

2.4 Solenoid Valve Group

The solenoid valve group, which can be controlled by an electrical signal, takes the filtered (dried, cleaned) compressed air at 5-6 bar level required for the operation of the system from a single point and transmits it to different points.

The points controlled by the valves used in the system are shown in Figure 5.

Fig. 5 *Selenoid valves group*

2.5 Vacuum Switch

It is an electronic device that measures the reverse air pressure at the inlet of the vacuum switch. With this device, information is obtained on whether the material is retained as a result of the vacuum. When the transport piston does not hold the material, the vacuum switch will not be able to generate a signal because there is more than enough air suction. When the transport piston is requested to move after holding the material, the PLC program flow will be executed accordingly with the signal generated by the vacuum switch.

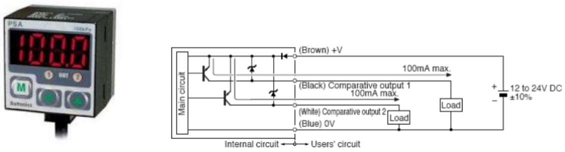

Fig. 6 *Vacuum Swıtch and Electrical Circuıt Shema*

2.6 PLC Software (Step 7-Micro/WIN)

It is the original software used to develop/edit the PLC program for the Unloading and Handling Station and to monitor the system's inputs/outputs in the computer environment. The interface of the Step7-Micro/WIN program is illustrated in Fig7.

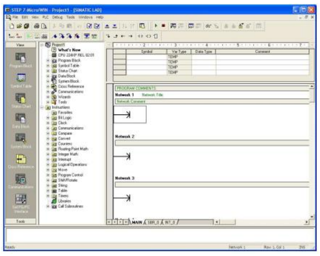

Fig. 7 *Step7-Micro/WIN program*

3. Scenario and Students' Feedback

3.1 Scenario

If we briefly summarize the operation of the system, it consists of the process of unloading and handling the materials filled into the magazine. To put it more broadly, the materials loaded in the magazine are advanced with the magazine piston until a signal is received from the limit switch. When the signal is received from the limit switch, the magazine piston waits for the holding piston to come down to receive the material. When the material is held by the vacuum effect, the vacuum switch generates a signal. Then the magazine plunger retracts to release the material. The handling piston moves the material upwards when the vacuum switch signals. The material unloading process continues until the material runs out. When the material runs out, the magazine piston cannot press the limit switch, so it concludes that the piston is retracted after a certain period of time and the system stops by going to the stop position.

After the material taken from the magazine is pulled up for handling, the conveyor mechanism which is connected to the step motor moves to the right until the right limit switch generates a signal and then stops the step motor. Then handling piston is lowered. The vacuum effect is cut off and the material is released and the piston is retracted. Then the system is brought to the starting position.

In order to operate the unloading and handling station in accordance with the scenario and algorithm (flowchart in fig.9) software above, the PLC inputs/outputs and system inputs/outputs were determined by the students, and a table was created. The system is ready for operation after connecting the intermediate cables between the input and output points given according to the values in Table 1.

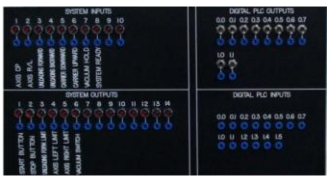

Fig. 8 *Unloading and Handling Station in/out ports*

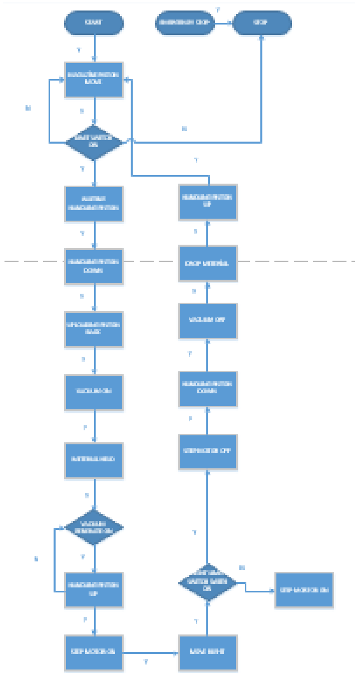

Fig. 9 *Flowchart of Algorithm*

Table 1: *PLC System Input/Output Connections.*

PLC System Input/Output Connections.					
System Inputs	PLC Outputs		System Outputs	PLC Inputs	
Axis CP	Q 0.0	Digital Outputs	Start Button	I 0.0	Digital Inputs
Axis R/L	Q 0.1		Stop Button	I 0.1	
Unloading Forward	Q 0.2		Unloading Forward Limit	I 0.2	
Unloading Backward	Q 0.3		Axis left limit	I 0.3	
Carrier Downward	Q 0.4		Axis right limit	I 0.4	
Carrier Upward	Q 0.5		Vacuum Switch	I 0.5	
Vacuum Hold	Q 0.6				
System Ready	Q 0.7				

3.2 System Diagram

The unloading and handling system diagram is shown in Fig.10.

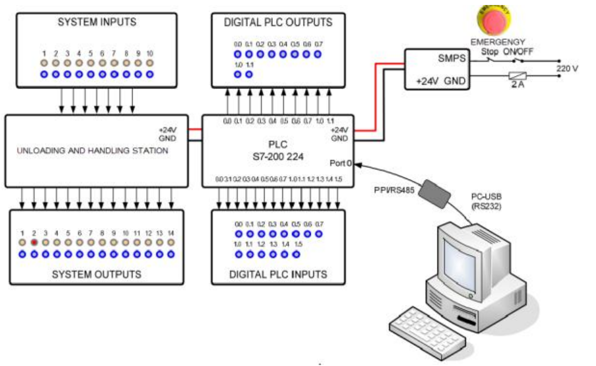

Fig. 10 *Uploading and Handling System Diagram*

3.3 Uploading and Handling Operations

While preparing a program for PLC, students created a very useful method by assigning symbolic addresses to the symbol table for all input/output, memory, counters, and timers in Table 2 and in Fig.11. Thus, the program writing speed increased and the probability of making mistakes decreased.

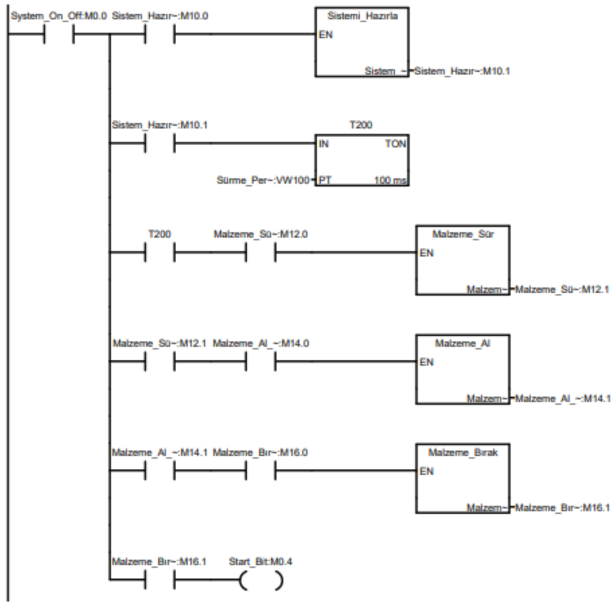

Fig. 11 *A Sample of the Ladder Diagram part of the Uploading And Handling System Software*

Table2: *Description of Symbols Contacts and Comments for Uploading and Handling System*

Symbol	**Address**	**Comment**
Malzeme_Al_Bitti	M14.0	Internal Contact to take material
Malzeme_Al_Ok	M14.1	It is set when the material-taking process is completed
Malzeme_Bırak_Bitti	M16.0	Internal contact used to drop material
Malzeme_Bırak_Ok	M16.1	It is set when the material-dropping process is completed.
Malzeme_Sür_Bitti	M12.0	Internal contact discharging material
Malzeme_Sür_Ok	M12.1	It is set when the material-discharging process is completed.
Sistem_Hazırla_Bitti	M10.0	The contact used to enable the system to switch to its initial setup
Sistem_Hazırla_Ok	M10.1	When the system is ready it is set.
Start_Bit	M0.4	Contact uses in software
System_On_Off	M0.0	System On-off initial contact
Sürme_Peryodu	VW100	Timer variable for the material feeding period

4. Conclusion

The PLC-based unloading and handling system which is used actively in Trakya University Mechanical Theory and Dynamics Laboratory was experimentally run with the students, thus providing to develop their talents and gained experience in system parameters and PLC program before being applied to the industry.

Students got to know the system and programmed the system with different approaches and possibilities, and by developing codes based on feedback, they achieved the same results. Thus, it will open a door for them to solve problems related to the difficulties they realized to encounter and may face in the future.

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