

Design of Industrial Oriented PLC Training Media for Vocational School

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Abstract—This paper describes a training media based on a Programmable Logic Controller (PLC) which is intended to train vocational school students to have competencies that are oriented to the needs of work competencies in the industry. The design of training media was created based on the results Front End Analysis (FEA) consisted of: 1) task analysis, 2) technology analysis, 3) audience analysis, 4) objective analysis and 5) media analysis. Data were obtained from questionnaires and interview with industry practitioners and the conclusions of the Forum Group Discussion (FGD) followed by five vocational schools (SMK) that have Electronics Engineering Study Programs in Yogyakarta. The result was a PLC training media that met specifications: 1) the trainer media was designed to train the competence of a PLC technician, which includes competency in PLC programming, PLC input output wiring and troubleshooting on PLC systems; 2) PLC training media was equipped with sensors, electro pneumatic components and a Human Machine Interface (HMI) in one system that could be a description of the production process; 3) PLC training media could be used to practice in group consisting of two students.

Keywords: PLC, training media

I. INTRODUCTION

Programmable Logic Controllers (PLC) is still an important part of industrial production processes [1]. Many industries still need employees related to the PLC field. Vocational school (SMK) play an important role in providing employees for industry. However, there are still many SMK graduates who are not ready to work. One of contributing factors is competency gap between industry needs and students' competencies. An effort to minimize competency gap is to provide learning facilities including learning media that support the achievement of competencies expected by the industry.

Currently various media for learning PLC have been developed. Akparibo has developed a PLC-based training media with switch input and lamp output. The strength of the training media developed is that the training media can be moved/portable so that it can be used anywhere, not necessarily in the workshop [2]. Burhan tried to overcome the many problems of input output needs in the PLC by developing a PLC training media that have a number of I/O ports and compatible with various types of PLC [3]. The development of PLC training media for vocational school students especially in electrical engineering has also carried out by Sukir where training media made emphasize on simple programming for electric motor control [4]. PLC learning

media in the form of application software has also developed, as did Sang Kim. He conducted research focusing on the development of PLC learning media in the form of application software with Augmented Reality for learning PLC wiring [5]. Navrapescu also answered the needs of e-learning by presenting PLC learning media that combines real hardware with video and simulation [6]. There are some limitations of the developed training media or application software. Software applications as learning media do have good practicality and effectiveness to be used in learning PLC cognitively especially in terms of programming. However, application softwares are certainly not sufficient to train student skills in components wiring and troubleshooting the PLC system. Likewise, the developed PLC training medias above still have limitations where training medias are more focused on programming aspect, they are not emphasized the troubleshooting competencies. The developed PLC training medias are not integrated with pneumatic systems as well as production systems in the industry. A compact and portable industrial automation media has made by Maarif, but the components in the training media were not integrated in a single process system [7].

This paper describes a PLC-based training media design to meet competency needs in the industry, especially on tasks that must be performed by a PLC technician from vocational school graduate. The design of the training media is not only focused on PLC programming but also emphasized on the component wiring and troubleshooting of the PLC system. The PLC training media is integrated with sensors, electro pneumatic components and Human Machine Interface (HMI) as well as production systems in the industry This is in line with the basic characteristics of XXI century vocational learning, namely work oriented learning [8].

II. METHDOLOGY

The data in this study were obtained from pre-survey, Front-End Analysis (FEA) and Focus Group Discussion (FGD). Pre-survey data were used to investigate the opinions of respondents about the need of PLC based training media for vocational school (SMK). The pre-survey was conducted without validated instrument, by giving questions to two types of respondents, namely industrial employee and teacher. There were five industrial employees from four companies in Indonesia and five electronics engineering teachers who taught at five vocational schools in Yogyakarta. Pre-survey results showed that all respondents agreed that industrial

oriented PLC training media was needed to support practicum in vocational school.

Results of pre-survey were followed up by conducting FEA. FEA was carried out through five analyses, namely 1) task analysis, 2) technology analysis, 3) audience analysis, 4) objective analysis and 5) media analysis. Task analysis aimed to get information about tasks in the industry related to PLC field work. Technology analysis aimed to obtain information about technology that is applied in the industry. Data collection related to task analysis and technology analysis was done by giving questionnaire to Human Resources Department (HRD) Manager in one of the manufacturing industries in Batam. To confirm and complete the data from the questionnaire, researchers interviewed one of the technician in this company who graduated from vocational school. Results of the questionnaire and interview in the form of data about qualifications, positions, tasks and competencies needed in the industry related to the field of PLC and data about technology used in industry.

After that, audience analysis, objective analysis and media analysis were conducted. Audience analysis aimed to get the appropriate users of PLC training media. Objective analysis aimed to get the basic competencies that are the objectives of the PLC training media. Media analysis aimed to get the appropriate learning media to be applied at school. Three analyses were carried out in the Focus Group Discussion (FGD). The FGD was attended by teachers who taught Electronics Engineering and Industrial Automation in five vocational schools in Yogyakarta. Results of the FEA from industry were also delivered to be discussed. The results of FGD were: 1) provisions for students using PLC training media, 2) competencies that are the objectives of the training media and 3) training media specifications that are oriented to industry needs and suitable for learning in vocational schools. The results of FGD were the basis of the researchers to develop PLC based training media design.

III. RESULTS

Based on the task analysis carried out in one of the industries in Batam, it is known that job positions for secondary school graduates are operator and technician. The position of operator is filled by graduates from general high school (SMA), while for vocational school graduates (SMK) fill the position of technician. Technician position can be divided into three groups based on the scope of work responsibilities and types of duties.

- Technicians who are responsible for the production process in certain production lines. The technicians in this group are tasked with carrying out inspection and maintenance of the equipment used in the production system, it is also possible to make minor repairs on certain production lines.
- Technicians responsible for repairing machinery and production equipment. Technicians in this group are tasked with repairing equipment or machines used for the production process if there are errors or damage.
- Technicians who are responsible for the entire system that supports the project being carried out in accordance with requests from customers. Technicians in this group are tasked with designing PLC systems according to customer requests, determining the input devices and other peripherals used, installing devices,

creating PLC programs and modifying the PLC program.

Thus vocational students must have work competencies that support the implementation of technician tasks. The competency of technician jobs can be summarized in three main competencies, namely installing (wiring) PLC input output devices, PLC programming and PLC based systems troubleshooting.

The results of technology analysis showed that the industry applied various types of PLC (Omron, Scheider, Siemens) with programming languages namely Ladder Diagram and Instruction List. The input devices used are in the form of various sensors according to system requirements, such as proximity switches, trubeam sensors and others. The output devices used are AC motors, DC motors, solenoid valves, pneumatic devices and hydraulic devices. The system is equipped with monitoring devices in the form of HMI, PC or seven segment. Industry implements a stand-alone PLC system for certain parts of production, there is also a PLC system connected in the network.

Forum Group Discussion (FGD) produced several conclusions related to audience analysis, objective analysis and media analysis, i.e:

- Students who use PLC training media must have learned about basic electricity and electronics, basic programming, sensors, actuators and PLC. Students are also able to operate the Windows operating system and the CX-Programmer application program.
- PLC training media is intended to meet the competencies needed by technicians in the industry, namely installing (wiring) PLC input output devices, PLC programming and PLC based systems troubleshooting. This PLC training media is also intended to fulfill the basic competencies in the vocational curriculum, i.e apply PLC as a system controller, analyze control circuits consisting of PLC and pneumatics and perform control circuit testing of PLC and pneumatics system.
- PLC training medias as a medium for learning vocational students should be able to represent part of the production process in the industry, using devices that have characteristics such as devices used in industry, can motivate students, can be used to practice in small groups. The hardware specifications of training media are specified as shown in the table below.

TABLE I. HARDWARE SPECIFICATIONS

No	Aspect	Specification
1	Type of PLC	Brand : Omron Minimum I/O : 30 , Interface port : USB, RS 232
2	Input components	Push button, Proximity (capacitive, inductive), Photoelectric/Thrubeam sensor, Reed switch
3	Output components	Relay, Motor DC, Solenoid Valve, Lamp
4	Type of HMI	Size: 7 inch, Interface: RS232
5	Programming	Programming language : Ladder diagram, Software application: CX-Programmer
6	Interface	PLC to PC : USB PLC to HMI : RS 232
7	Power supply	220 VAC, 24 VDC, 12 VDC, 5 VDC
8	Form of training media	Consisting of 2 panels: horizontal and vertical
9	Size	Horizontal panel : 50 cm x120 cm, Vertical panel: 50 cm x120 cm, Overall: 120 cm x 70 cm x 70 cm
10	Material	Alumunium, Acrylic
11	Dominant Colour	White, silver
12	Label	Arial, black
13	Other provisions	Sensor components, pneumatic components and HMI are integrated in one system that can describe a production process Training media is equipped with terminals to wiring and troubleshooting practice Training media can be used for practice in groups consisting of 2 students can be used for practice in groups consisting of 2 students

IV. DESIGN AND FABRICATION

PLC-based training media design made in accordance with these specifications. In general, PLC-based training media block diagram is shown in the figure below.

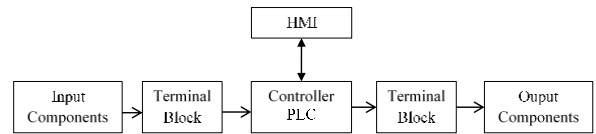


Figure 1. Block Diagram System

PLC training media consists of four main components, namely input components, controller, output components and HMI. The input components consist of a push button, proximity switches, trubeam sensors and reed switches. The output components consist of relays, DC motors and solenoid valves. Terminal blocks are used to place cable connections between input components and input terminals in the PLC as well as between the output components and the output terminals on the PLC. The terminals are used for the purpose of students being able to connect the input and output components to the PLC terminal using cables and screwdrivers.

In more detail, PLC training media consists of two boards, namely input output (I/O) board and control board. The I/O board contains input output components that are integrated to form a production process simulation. The control board contains the control device for its production process. The design of the training media I/O board is shown in the figure below.

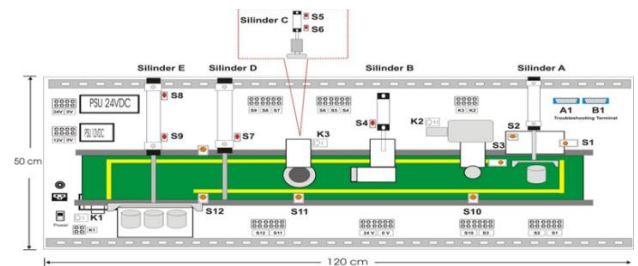


Figure 2. Design of Training media I/O Board

The simulation of the production process used in this training media refers to the process in industry, which is bottle filling. This process involves 12 sensors (S1 to S12), five pneumatic cylinders (cylinder A to E), and three relays (K1, K2, K3). In brief, the production process begins with the Start button on the control board and the activation of the bottle presence sensor (S1). If S1 is active then the bottle is pushed to the conveyor then the conveyor is running. If the bottle is detected by the sensor (S10), conveyor stops and the bottle is filled for the specified time. After filling process, the bottle runs again and the bottle cap will be placed on top of the bottle automatically. When the bottle is detected by sensor (S11), the bottle cap will be tightened. The sensor S12 will count the number of bottles that have passed. If the specified number of bottles has been met, the bottle barrier (cylinder D) will extend. Finally, the bottles are pushed into the packing area by cylinder E.

The control board consists of a PLC and five solenoid valves. The PLC will read the inputs from the buttons and

sensors then control the existing solenoid valves in accordance with the program. The solenoid valves will control the movement of the cylinders on the I/O board. The controller board has two terminals (A2-B2) and five fault switches (F1 until F5) for troubleshooting practices. If one of the fault switches is activated, the system will fault, students can analyze the error and correct it. Control board is equipped with a HMI. HMI will show what components are active during the process. HMI can also be used to enter commands such as start or stop by touching the start-stop button icons that were created on the HMI screen. The design of the controller board is shown in the figure below.

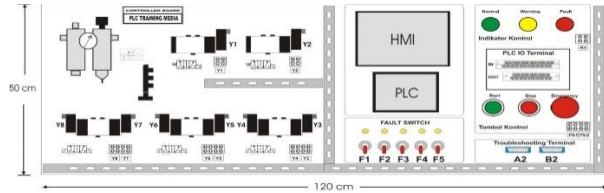


Figure 3. Design of Training media Controller Board

According to specifications, the PLC training media is designed with a horizontal and vertical board with a size of 120 cm x 70 cm x 70 cm. With this size the training media can be used to train students independently or in groups of 2 students. The training media is placed on a table so students will practice easily because of the appropriate height of the training media. The design of the PLC training media is shown in the figure below.

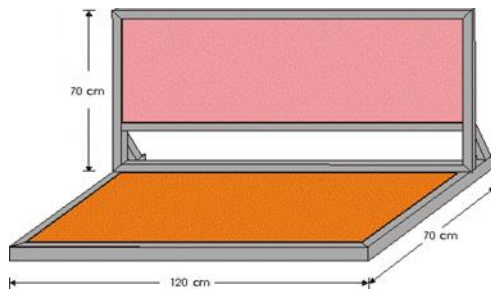


Figure 4. Design of Training Media Frame

This PLC training media uses components of various types and sizes. The aim is students can learn several supporting competencies, namely identifying each component of I/O, reading the circuit and reading the component datasheet. The components used in the PLC training media are detailed in the table below.

TABLE II. COMPONENT LIST

No	Group	Component	Specification	Quantity
1	Controller	PLC	Omron CP1E-N30SDR-A	1 unit
2	Input	Push Button	22mm, NO NC	2 pcs
		Reed switch	CS1-G Airtac	5 pcs
		Inductive proximity sensor	LJ12A3-4-Z/BX	3 pcs
		Capacitive proximity sensor	LJC18A3-B-Z/BX	1 pcs
		Thru-beam sensor	Keyence PQ-01	1 pcs
		Photo electric sensor	Omron E3Z-D61	2 pcs
3	Output	Pilot lamp	22 mm, R-G-Y, 12-48 DC/AC	3 pcs

4	Pneumatic	Relay	DC 12 V	3 pcs
		DC Motor	Gearbox, DC 24 V	1 pcs
		DC Motor	DC 3-6 V	1 pcs
		Solenoid valve	Airtac 4V210-08 (5/2 single)	2 pcs
		Solenoid valve	Airtac 4V220-08 (5/2 double)	3 pcs
		Solenoid valve	SF4200-IP (5/2 double)	1 pcs
		Electric water valve	12VDC, 1/2" to 12mm	1 pcs
		Mini water pump	12 VDC	1 pcs
		Pneumatic cylinder	AirTac MA20x100	2 pcs
		Pneumatic cylinder	SMC CDJ2B 10 40	2 pcs
5	Supply	Pneumatic cylinder	Double acting, port 6mm	1 pcs
		Air Supply Unit	EL 2000-02	1 pcs
		DC Power supply	Omron 24VDC 4,5A	1 pcs
		DC Power supply	12VDC 3 A	1 pcs
		DC Power supply	5VDC 3 A	1 pcs
6	Terminal	Power socket	240V 10A	1 pcs
		Switch	240V 10A	1 pcs
		Terminal blok	TB1503	2 pcs
		Terminal blok	TB1504	8 pcs
7	Miscellaneous	Terminal blok	TB1506	6 pcs
		Terminal	DB25 Female	4 pcs
		HMI	WienView MT6071-IP	1 pcs
		Fault switch	Toggle switch, DPDT	5 pcs
		Fault switch indicator	LED 5mm, yellow	5 pcs
		Emergency switch	22mm, NO NC	1 pcs
		Socket	DB25 Male	4 pcs
		Cable duct	Slotted, 32x32mm	4 mtrs

The figure 5 shows the components that have been assembled into a PLC training media. The specificity of the training media is that there are fault switches as shown in the picture by the red rectangle which can be used to practice finding faults. Each I/O component in this training media is equipped with an auxiliary terminal for component wiring practice. The training media frame is made of aluminium and acrylic so it is light enough to be moved.

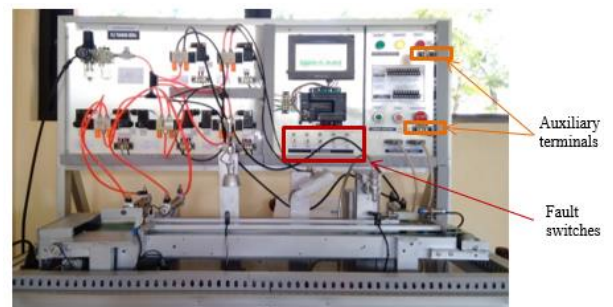


Figure 5. PLC Training Media

The developed training media can be used by students to practice some of the competencies as shown in the table below.

TABLE III. SUPPORTED COMPETENCIES OF TRAINING MEDIA

Competencies		Performance criteria
Skills	Identify PLC input and output components	Identify the switch types (NO and NC contact)
		Identify the sensor type (2 wires and 3 wires)
		Identify the sensor types (NPN and PNP)
		Identify contacts on the relay
		Identify pneumatic valve types
		Identify pneumatic cylinders
	Install PLC with other devices	Connect the push button to the input terminal
		Connect a 2 wire sensors to the input terminal
		Connect the 3 wire sensors to the input terminal
		Connect the relays to the output terminal
		Connect the solenoid valves to the output terminal
		Connect pneumatic valves to cylinders
	Create PLC program	Create ladder diagram using the CX Programmer
		Create timer program using the CX Programmer
		Create counter program using CX Programmer
		Create instruction list using programming console
	Download the PLC program	Download program using computer
		Download program using programming console
	Operate PLC	Operate PLC system with push button
		Operate PLC system with HMI
	Repair the PLC-based system	Test the performance of the PLC system
		Identify the symptoms of the existing PLC errors
		Perform PLC system troubleshooting
Attitude and other skills	Careful	Use component datasheet information appropriately
		Measure the component voltage correctly

Discipline	Conduct practicum in accordance with established procedures
Creative	Make some alternative ways to program PLC
Collaborate with others	Practice with others in a group
Communication skill	Make a practicum report
Critical thinking	Find the causes of the existing PLC errors

V. CONCLUSION

The PLC training media has made by integrating sensor components, electropneumatic components and HMI in one system as simulation of a production system in industry. Through this training media students can practice the competencies needed i.e. identify components in the PLC system, install the PLC with other components, create PLC program and perform PLC-based system troubleshooting. These competencies are in accordance with the needs of the industry, especially for the tasks of a technician from a vocational school graduate.

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