

Compact Portable Industrial Automation Kit for Vocational School and Industrial Training

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Abstract. This Paper presents a compact and portable kit for learning on industrial automation practice for vocational schools and training industry. The kit is compactly designed with reference to basic of standard competences in industrial automation areas. They are PLC programming, PLC input and output wiring, motor control and pneumatic cylinder control. The components used are standard part in industry field. In addition to compact design, the second concept is portable, so the selection of components and layout should be done carefully so that the dimensions of the kit can be maintained at a certain size. This kit has 41 x 23 x 11.8 cm and weight 6.76 kg weight that can be easily carried or to be stored in the cabin of the aircraft during the training trip.

1. Introduction

Industry is always innovating in an effort to provide cost reduction. In this cost conscious environment, industry is looking for employees that can fill numerous roles within their manufacturing facility [1]. On the other hand, many production lines originally operated by current employees have been replaced with automation systems where PLC (Programmable Logic Controller) becomes one of the main controllers. This will also be followed by increasing the need for human resources that can operate PLCs and industrial automation systems. Vocational school students who will later enter industrial field as an automation technician should be equipped with competencies related to PLC and automation. Likewise with the workers who have entered and worked in the industry, their skills about to be improved in order to be able to work with PLC-based automation system.

PLC control programming is a complex cognitive skill that requires hands-on experience to develop proficiency. Successful automation/control engineers must know how to write PLC programs to control and troubleshoot the process being automated [2]. Unfortunately, it is difficult to find suitable devices or training kit to perform hands-on skills aspect during the practical session in executing the syllabus for several courses such as Industrial Automation & Programmable Logic Controller. But, the existing training kits are usually large and difficult to move if the training location is to be carried out in an industrial area.

PLC learning can be done by using industrial standard PLC, microcontroller or just by using personal computer. B.K Rana has worked with C ++ software and for creating a PLC program [3] and PLC with microcontroller and LabView software ever done by K.Bhise that can run program logic well [4]. But PLC learning with this tool is not enough to give enough skill to work in the industry.



Al Mashhanday had designed and implemented PLC for classical control laboratory. He has developed a PLC training kit using LG PLCs equipped with digital IO (input / output), analog IO, seven segment and other simulation devices [5]. So, trainee can learn about programming and wiring but not yet equipped with pneumatic system. Burhan has also built a PLC kit with a variety of IOs as a learning tool. He has been using electric motors and solenoid as output, but does not have a pneumatic cylinder [6]. Training kit with a more complete component with induction motor and Variable Drive Frequency has also been made by P. Chakraborty, but with a size large enough [7].

This paper describes an effort to design and build a compact portable automation kit teaching basic I/O devices and to evaluate the developed kit and instructional support materials. The kit consists of (1) controller module, (2) plug and play I/O interface, (3) DC motor module, (4) electro-pneumatic module—all integrated in a portable box for easy transport. The controller module contains an industrial programmable logic controller (PLC) and power supply unit.

2. Methodology

Astra Manufacturing Polytechnic has Industrial Automation Laboratory that concern on teaching and development technology in the automation field. In this Lab, students should experience hands-on skills in PLC as it is a major component in engineering courses. Theoretical knowledge and hands-on skills experience in PLC control principles provide more career opportunities besides meeting the emerging of workforce and education need for global industries.

The detailed competence of industrial automation in Indonesia is regulated by the Decree of Ministry of Manpower No. 631 of 2016. Where the outline covers the competence of operating electrical system including relay and electric motor, operates electronics system, operates PLC, and operates pneumatic system. The following is a description of the need for such competence.

2.1. *Electrical Device Operation*

Electrical competence covers:

- Operate electrical device, this competence deals with the operation of electrical equipment of industrial automation systems according to the operating procedures.
- Operate the electrical system, this competency unit is related to the work of preparation, installation, testing and operation of electrical system for industrial automation system in accordance with the operating procedure of electrical system.
- Assemble equipment and electrical system, this competence unit is related to the implementation of assembly work of equipment and electrical system of industrial automation on network of production system according to work procedure of equipment and electrical system of industrial automation.

To meet the above competency requirements, the kit should have some features of electrical components. The main electrical component is the lamp. The lamp serves as a marker of the condition of an output / indicator. The next electric component is the electric motor, especially the 3 phase electric motor which is the most actuator type in the industry such as for conveyor actuator [8]. Another electric component is a solenoid valve for controlling the direction of the pneumatic cylinder movement. With the solenoid valve student can learn to regulate the valve condition through electrical signal.

2.2. *Electronics Device Operation*

Electronics competence covers:

- Operate electronic equipment, this unit deals with the operation of any electronic equipment of industrial automation systems in accordance with the manufacturer's operating procedures and in accordance with standard procedures.
- Operates an electronic system, this competency unit deals with preparatory work, set-up of operating parameters, start-up and operation of electronic systems in industrial automation systems in accordance with manufacturer's standard procedures and / or standard procedures.
- Assemble electronic equipment and system, this competency unit is concerned with the execution of assembly work of electronic equipment and industrial automation systems on the network of

production systems in accordance with the procedure of assembling equipment and industrial automation systems.

Electronic devices contained in automation systems include power supply, input devices for PLCs such as push buttons, sensors and relays. This kit should be able to facilitate the Student to get training on how to organize the power supply to meet the power requirements of the control system, connecting the electronic components to the PLC.

2.3. PLC Operation

Competence of PLC field covers:

- Operating PLC, this competency unit is related to PLC operation work including selection of PLC type and peripheral, initialization, program download and testing according to operating work procedure.
- Writing software program, this competency unit is concerned with the design of control program (software) industrial automation system based on the program flow diagram and testing of programming results according to the required specifications and implemented according to programming procedures.

PLC selection hardware is considered on the basis of size, completeness of input and output, ease of getting power supply and ease of programming connection. PLC with programming access via USB is preferred over Serial port because it has high flexibility to all programming devices. Especially nowadays Laptops are more widely used than Personal Computer, while very difficult to find a laptop with serial port.

In software, PLC programming language should be selected the most basic and commonly used in the industry. As per IEC 6-1131 standards, PLC has several languages such as Ladder Diagram (LD), Instruction List (IL), Structure Text (ST) and Sequential Function Chart (SFC) languages [6]. In this kit is limited to Ladder Diagram only. This language is most commonly used by technicians in the image-based installation industry and is logically easy to understand.

2.4. Pneumatic Cylinder Control

Pneumatic competencies covers:

- Operate pneumatic equipment, this competency unit is concerned with the operation of electro-pneumatic equipment and components, including preparatory work, checking, air pressure set-up, performance testing and operation according to operating procedures.
- Operates a pneumatic system, this competency unit is concerned with the operation of the pneumatic / electro-pneumatic system, including preparatory work, checking, air pressure set-up, performance testing and operation of the pneumatic system in accordance with the operating procedures of the pneumatic system.
- Assemble equipment and pneumatic system, this competency unit is concerned with the implementation of assembly work of pneumatic equipment and industrial automation system on the network of production system as per the working procedure of pneumatic equipment and industrial automation system.

The kit must have a pneumatic cylindrical actuator component as one means to train pneumatic cylinder control competence. Student or training participants can learn how to connect a pressurized air hose to the valve, in order to control the movement of the cylinder [9], [10].

3. Design and Fabrication

From the description of competence in chapter II can be drawn a summary that the competencies targeted are operational devices, device assembly or wiring and PLC programming. Therefore, students need to be familiar with functions and general characteristics of hardware devices, to understand how PLC controllers process programs, to be able to understand the control requirements of an Application and write control programs accordingly. Hands-on experience with PLCs and I / O devices is needed to develop these skills. So the automation kits must be able to meet and use with industry needs.

3.1. General Scheme

The kit provides digital input/output that can be used to control the output components. Figure 1 shows the block diagram of the industrial automation kit. It consists of PLC as controller, Input Module, Output Module, 24VDC Power Supply unit and common connection for Input/Output.

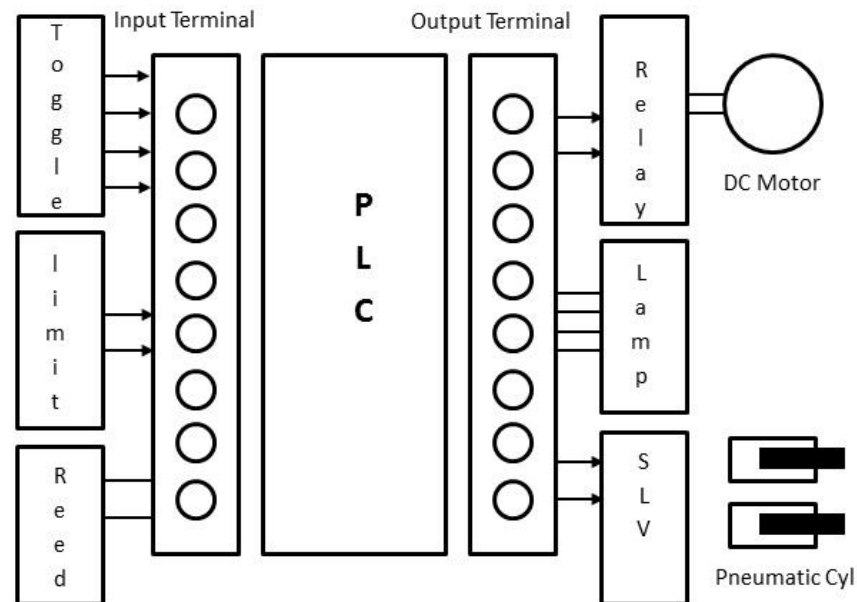


Figure 1. Block Diagram of Industrial Automation Kit

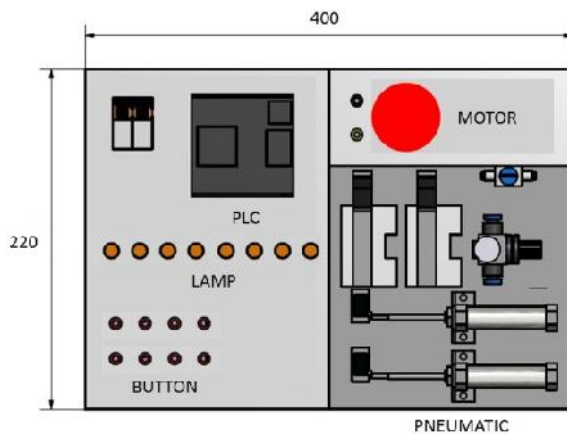
Connection with straight line is permanent wiring and connection with arrow is cable to be wire by student or trainee.

3.2. Portable Concept

Portable concept can be limited by taking the standard size and weight of the kit. To be brought by car transport or shipping in general, no special standards are applied. However, kits containing electrical and electronic components must be carried with special care and caution so as not to damage the working function of the apparatus. The concept of a portable PLC kit has been studied by S.H Hsieh [1] and M.Barret [11] that has the idea of placing control components such as PLCs, push buttons and contactors in one panel. But unfortunately it is not packaged in that is safe and easy to carry.

When traveling by airplane, there is a strict standard on the goods to be brought into the cabin of the aircraft. The size of the suitcase should not exceed 41 x 34 x 17 cm, and with maximum total weight is 7 kg. This standard that is applied as a kit reference can be considered portable. Therefore, the suitcase that is used as the main casing of the kit has size 41 x 23 x 11.8 cm.

Portable concept has given the limit with the size of a rigid suitcase. Thus all the components to be used in the kit should take into account that dimension. Figure 2 and Figure 3 are component layout and kit dimension.

**Figure 2.** Kit Design Top View**Figure 3.** Kit Design Side View

Another requirement to be compiled with portable concept is the weight of the kit. Therefore components selection is important step. Table 1 shows the selected components taking into consideration the available space.

Table 1. Component List

No	Group	Component	Spesification	Quantity
1	Controllor	PLC Omron CP1E-N20R	Supply 220V AC 24V DC input (12 bit) Relay Output (8 bit) USB terminal	1 Unit
2	Input	Toggle switch	15 mm	4 pcs
		Reed switch	D-C73	2 pcs
		Limit Switch	-	2 pcs
3	Output	DC lamp	24 V	8 pcs
		Solenoid valve (5/2 single)	SY5120-5D-01	2 pcs
		Relay	Omron MY4	2 pcs
		DC Motor	24 V	1 pcs
4	Terminal	Banana hole	-	28 pcs
5	Supply	Power supply	Omorn 24 V	1 pcs
		Power Socket	240 V 10 A	1 pcs
		Switch	240V 10 A	1 pcs
6	Pneumatic	Pneumatic Cylinder	CDJ2B16-45Z-B	2 pcs
		Pressure gauge	AR4000-04	1 pcs

3.3. Fabrication

The Figure 4 shows the view of the kit that has been designed. In order to keep the box light, it is made from acrylic 3 mm and the main base is acrylic 5 mm.

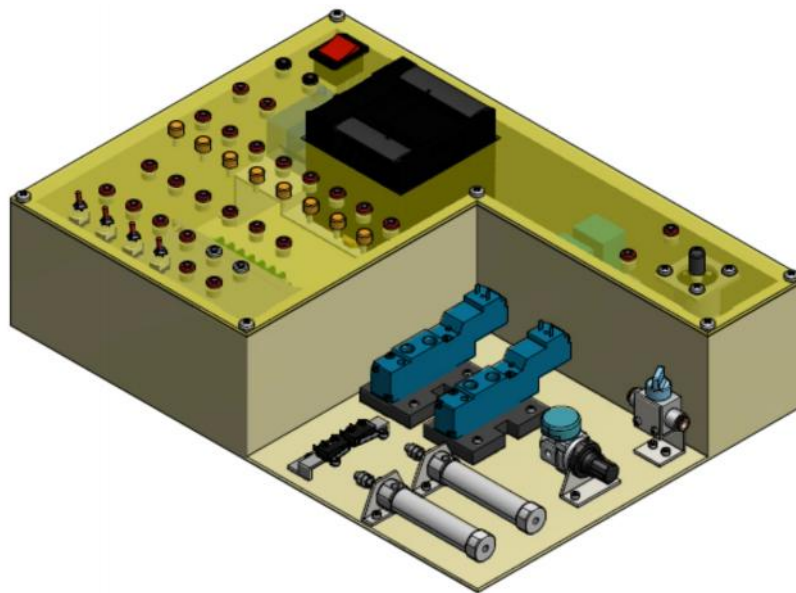


Figure 4. Kit Top View

3.3.1 Output Component and Terminal. The lamp as an input component is selected which has a medium size with a commonly rated 24V, voltage commonly used in the PLC output. But 3 phase electric motor is too big to be placed on kit. Therefore, the motor control simulation can be replaced by setting the direction of DC motor rotation. Clockwise (CW) or Counter clockwise (CCW) adjustments can be done with the help of 2 relays through electrical signals. Each relay replaces of contactor that controls 3 phase electric motor, Figure 6.

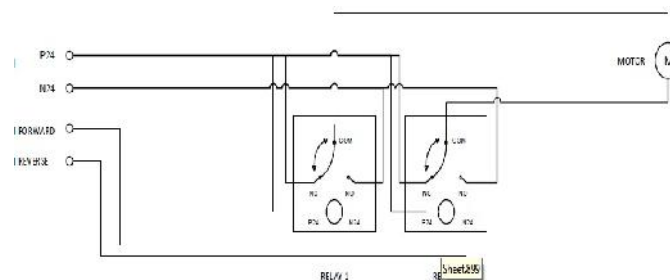


Figure 5. DC Motor Control using Relay

The pneumatic cylinder is selected on a double acting type with a 10 cm stroke dimension controlled by a single solenoid valve 5/2 with spring. They are 2 pneumatic cylinders that controlled by 2 single solenoid valves.

3.3.2 Input Components. Toggle switches are preferred over push buttons with consideration of smaller size and functional flexibility. The toggle switch can be used as a switch or alternate switch. Other input components are the limit switch and reed switches as the front and rear bounds of the pneumatic cylinder movement.

4. Results and Discussion

A series of manufacturing and testing processes have been undertaken to ensure the condition of the kit is safe to use. The main frame is made using acrylic 3 mm instead of metal. In addition to facilitate the

process of making and lightweight, acrylic is also useful to avoid the occurrence of short circuit on the main panel. The overall weight of the kit is 6.76 kg, Figure 6. Thus still within the maximum weight standard.



Figure 6. Overall Weight

The Figure 7 shows internal component and Figure 8 is the kit along with the completeness of the power cable, USB cable and connection cable.

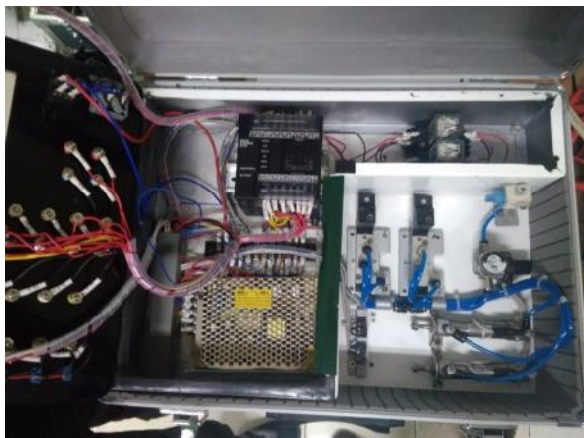


Figure 7. Internal Components



Figure 8. Kit with Cable Connection

5. Conclusion

Through this newly designed, developed and fabricated compact portable kit, training equipment needs and learning in accordance with the target of competence can be met. Trainee can enhance the theoretical knowledge and hands-on skills aspect through ladder diagram design, programming execution, component operational and wiring. The fabrication of compact portable kits has been designed and built

with dimension size 41 x 23 x 11.8 cm and weight 6.76 kg, which means it can be considered portable. All the tools needed for teaching and training have been provided by this kit.

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