

# Development of a Programmable Logic Controller Training Platform for the Industrial Control of Processes

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## Abstract

This paper presents an interactive, less expensive and more portable Programmable Logic Controller (PLC) training platform for the industrial control of processes. The proposed system employs Delta DVP14SS2 PLC, WPLSoft software, a programming device, switches as inputs and pilot lamps as outputs. The training system gives one the flexibility to wire and program any type of inputs and outputs of one's choice and can be easily carried in one's laptop bag giving one the freedom to learn the PLC anywhere at one's own comfort. The paper is also meant to enlighten beginners and experienced PLC users to build themselves PLC trainers which can enhance their understanding of the theoretical knowledge gained from school. Traffic light automation application is set up to train the Electrical and Electronic Engineering students to measure the applicability of the system. Pre-test and post test are conducted for participating students as a way of measuring the understanding level of the student before and after training. Cost analysis indicates that the individual can build the trainer on one's own at a cost of \$ 214.

**Keywords:** PLC trainer; interactive; less expensive; portable.

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## 1. Introduction

Increasing developments in the automation and manufacturing industries has caused much demand for Programmable Logic Controller (PLC) training for the execution of factory automation systems [1, 2]. Since the inception of PLCs for industrial automation and control, plant technicians, engineers and engineering students are challenged by lack of thorough understanding of the PLC system. Moreover, due to the high cost associated with PLC training courses and the continuous changing demand of the automation industries, companies and institutions find it difficult to provide the needed training on the PLC [3].

A PLC is an industrial computer consisting mainly of hardware and software that is used to control a machine or a process [4-7]. It is designed for multiple input/output (I/O) arrangements, extended temperature ranges, immunity to electrical noise, and resistant to vibration and impact [6]. A PLC is an example of a real-time system since the output of the system controlled by the PLC depends on the input conditions. It has become the heart of industrial automation and control systems since 1968 [6, 8]. A PLC trainer is a designed prototype that allows beginners such as students and experienced PLC users to wire, program and simulate real-time control processes. The PLC trainer is a very useful tool for learning PLC hardware, software and programming on one's own.

Research so far presented expensive, less portable, less interactive PLC trainers in the form of prebuilt hardwired kits and simulators [4, 9]; expensive and less portable PLC trainers are however not affordable to the masses of PLC users. Prebuilt hardwired kits in particular do not provide a more interactive system for the novice PLC user who needs it most. This is because they are pre-fabricated in a casing making it inaccessible to observe the interfacing between the controller and the I/O modules. These reasons contribute to the rising gap between the industry endowed graduates and the industries.

## 2. Materials and Methods

The proposed research paper employed the following materials and methods to address the problem.

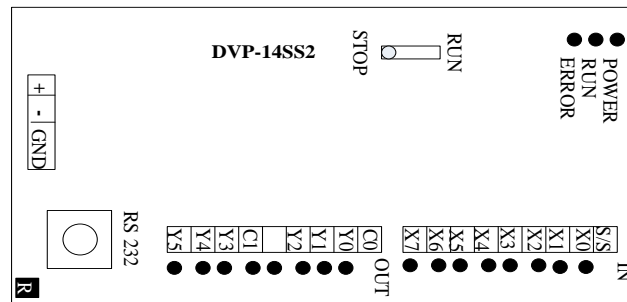
### 2.1. Materials Used

The following materials were used to achieve the hardware design of the PLC trainer:

- DVP14SS2 Delta PLC
- Power Supply Unit (PSU)
- Delta DVPACAB2A30 programming cable
- Toggle switches
- Pilot lamps
- Contactors
- Terminal blocks
- WPLSoft

### 2.1.1. Delta DVP14SS2 PLC

Delta DVP14SS2 PLC is used in this design to achieve the desired control using a written ladder diagram program. The selected PLC uses WPLSoft for programming. The software is user friendly and available for free download. Figure 1 shows the pin layout diagram of the PLC and Table 1 shows the specifications of DVP14SS2 PLC. We selected this type of PLC because it is relatively cheap, small in size, flexible and easy to use.



**Figure 1:** Pin layout diagram of DVP-14SS2 PLC

**Table 1:** Specifications of delta DVP14SS2

Description	Specification
Model	DVP14SS2R
Number of I/O	14 (discrete, I=8, O= 6)
Input signal	24 VDC
Output type	Relay and Transistor
Power supply	24 DC

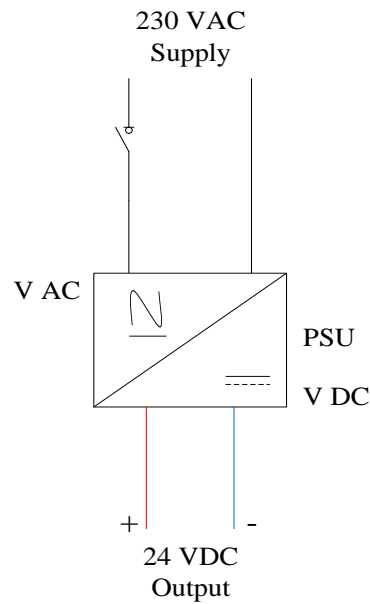
### 2.1.2. Power supply unit

The main power supply line to the controller is 24 VDC. This power supply line is distributed to the central processing unit (CPU), the input module through the input devices and the output module through the output devices. The 24 VDC supply is a converted power from a 230 VAC source as shown in figure 2.

### 2.1.3. Programming device

This is a personal computer or handheld device with appropriate installed programming software that is used to create, edit, monitor, download or upload a control program into or from the PLC [6, 8]. Dell latitude E5430, core i5 laptop with windows 8.1 operating system is used as a programming device in this paper. We downloaded and installed WPLSoft software on the windows operating system for the PLC programming. We

also interfaced the PLC with the laptop using an RS-232 communication cable.



**Figure 2:** Power supply unit

#### **2.1.4. I/O module**

The I/O module provides an interface between the process I/O devices and the CPU of the PLC [6, 8]. The DVP14SS2 input module has 8 discrete input connections that accept 24 VDC signals. The output module has 6 discrete connections; 3 are relay output while the other 3 are transistor output. The relay output switches both 24 VDC and 230 VAC output signals while the transistor output switches only 24 VDC output signals.

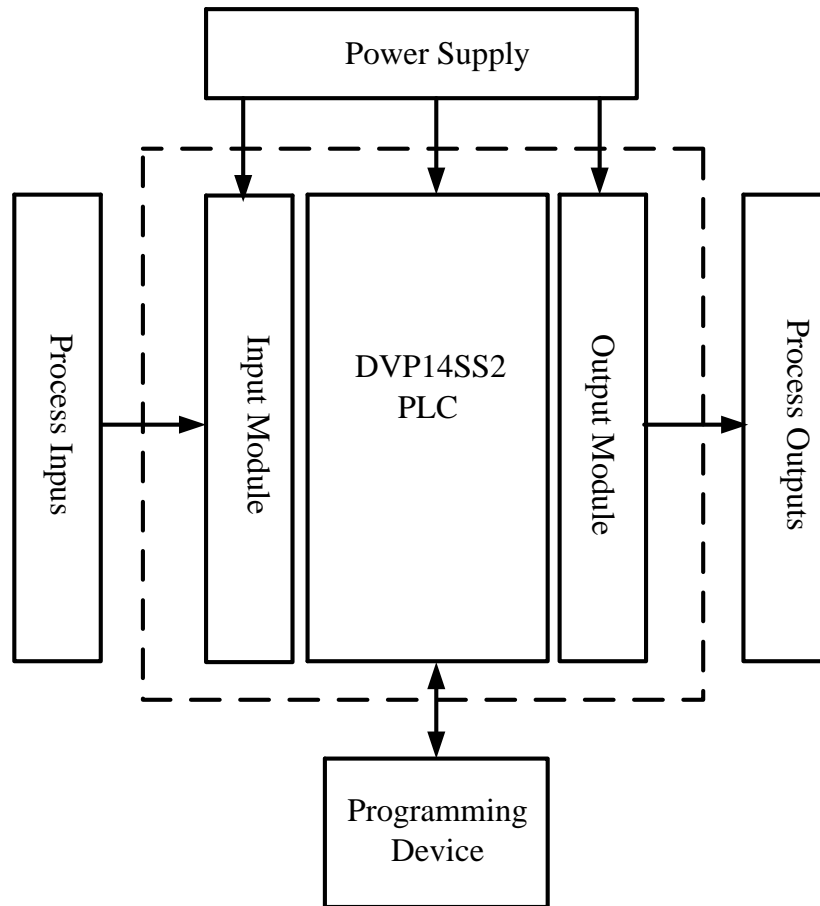
#### **2.1.5. Process I/O**

The process input refers to the input devices that send electrical signals to the input module when they are turned on [6, 8]. Examples of input devices include; proximity switches, push buttons, limit switches, temperature switches and pressure switches. The process inputs can either be discrete (example, proximity switches) or analog (example, temperature switches). In this paper, 8 discrete inputs (6 toggle switches and two push buttons) are used as process inputs to simulate any form of inputs.

The process outputs are the controlled devices. They receive electrical signals from the output module based on the input conditions [6, 8]. Examples of process outputs or output devices include; relay/contactors coil, motor, fan, solenoid coil, indicator lamps and actuators. The process outputs may be discrete (example, contactor coil) or analog (example, actuators). 4 pilot lamps and 2 contactors are used in this design to represent any form of discrete outputs.

### **2.2. Hardware Design Methodology**

The hardware design is centred on the proposed block diagram shown in figure 3 [6, 8].



**Figure 3:** Block diagram of proposed plc trainer

### ***2.2.1. Schematic circuit diagram of proposed PLC trainer***

The layout and schematic wiring diagram of the PLC trainer is as given in figure 4.

### **3. Testing and Validation of PLC Trainer**

To test and validate the PLC trainer, pretest and posttest were conducted during a training session for 20 students from the Electrical and Electronic Engineering Department at Tamale Polytechnic using the following industrial application:

Wire and program a PLC based ladder logic of a traffic lighting control system. The control program should conform to the following conditions:

- Red light on for 10s
- Green light on for 15s
- Amber light on for 4s
- The sequence must repeat itself
- Note only one light can be on at a time (red or green or amber)

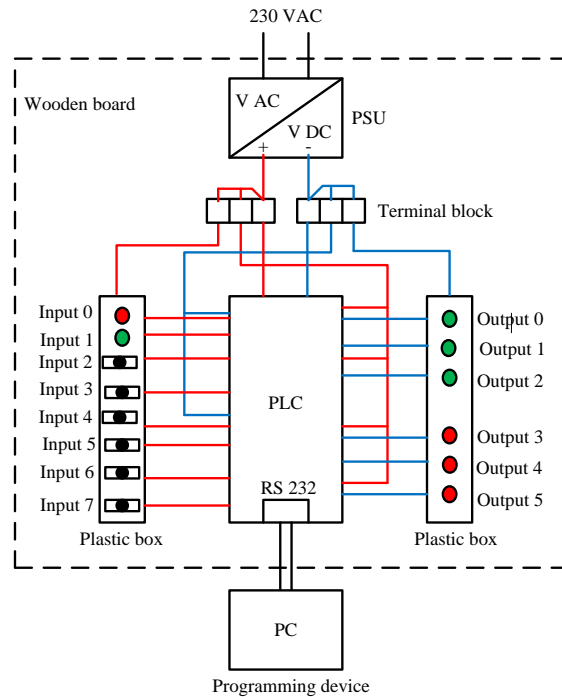
#### 4. Results and Discussions

The results of marks obtained from pretest and posttest conducted during the training session are given in table

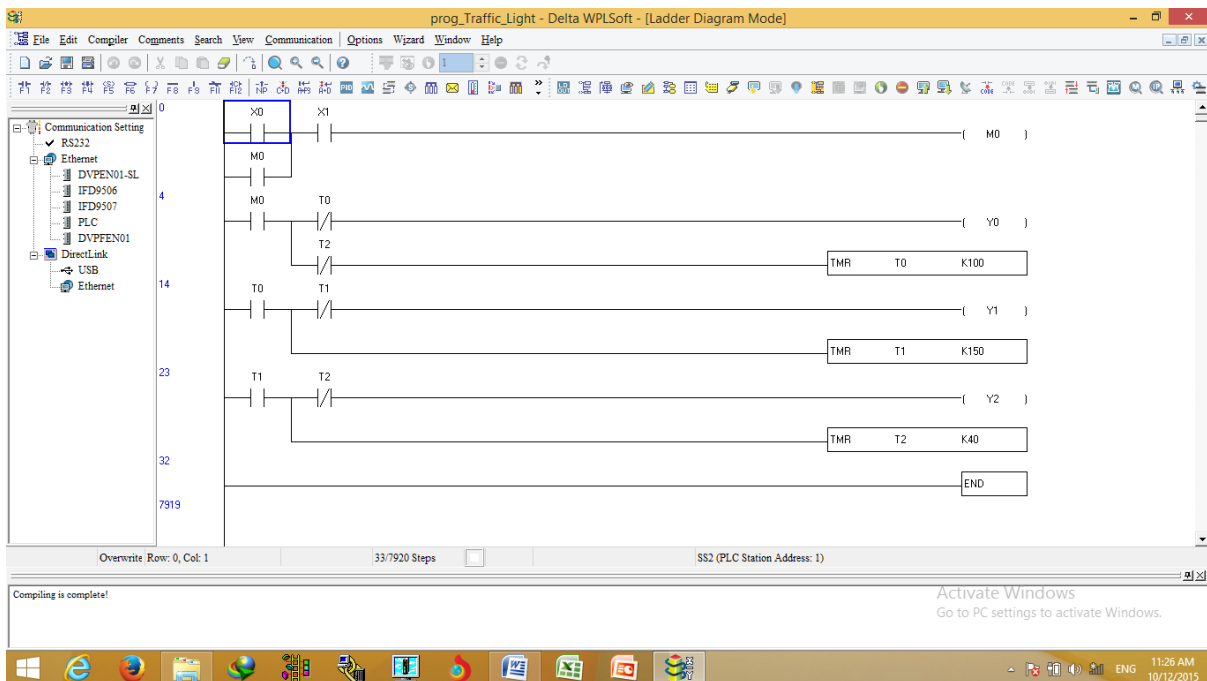
**Table 2:** Marks of students obtained before and after training

Student No.	Pretest Mark (%)		Posttest Mark (%)	
PLC01	25		75	
PLC02	20		76	
PLC03	35		75	
PLC04	40		80	
PLC05	13		72	
PLC06	15		65	
PLC07	16		65	
PLC08	30		78	
PLC09	45		85	
PLC10	11		67	
PLC11	14		58	
PLC12	20		79	
PLC13	22		65	
PLC14	34		73	
PLC15	35		80	
PLC16	40		79	
PLC17	45		81	
PLC18	29		77	
PLC19	34		73	
PLC20	23		59	
	Minimum	11	Minimum	58
	Maximum	45	Maximum	85
	Average	27.3	Average	73.1

Figure 5 gives the traffic light program designed by one of the students. The program was compiled and downloaded to the PLC memory to run the traffic light automation. Figure 6 also gives a screen shot of the program after the start pushbutton was pressed and the PLC in run mode.



**Figure 4:** Layout diagram of the proposed plc trainer



**Figure 5:** Traffic light automation control program designed by a student

Students were able to develop their own PLC training platform and used it for the industrial control of processes with ease as marks obtained by students before and after test showed that there was an average performance improvement of students by 45.8%. Cost analysis also suggested that the training platform is relatively low cost (\$ 214) and affordable. Size of the training platform had relatively reduced by careful space management during the mounting of components on the wooden board and the selected PLC used was small too.

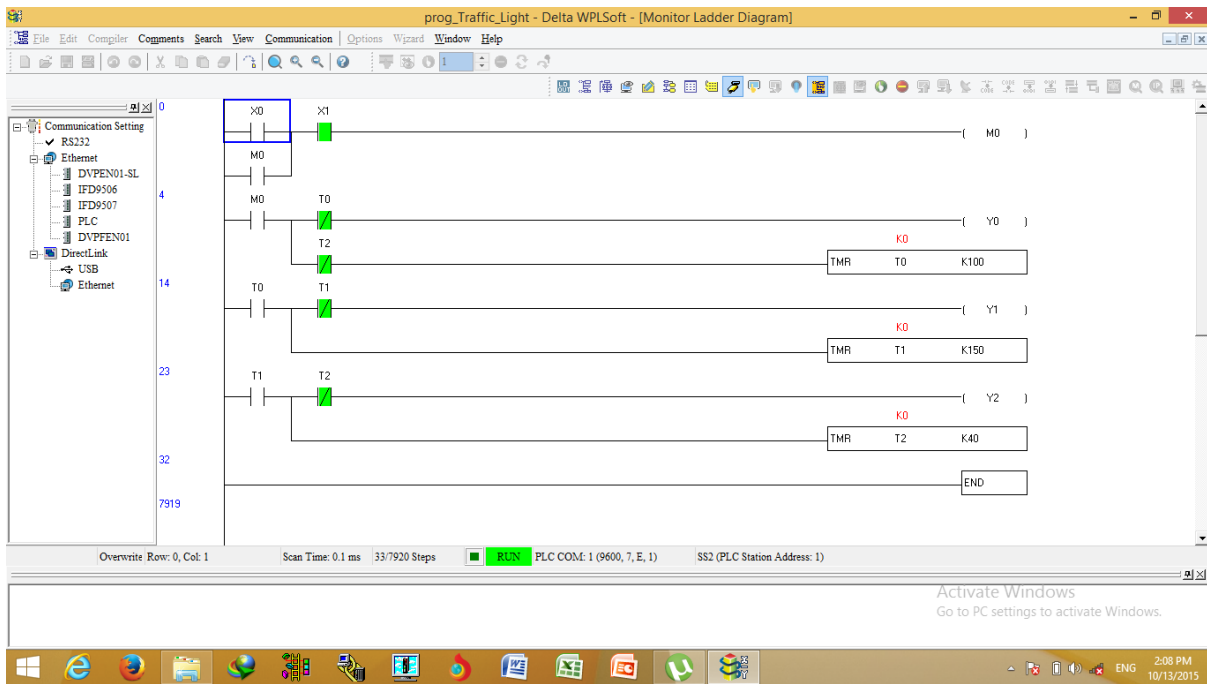


Figure 6: Screen shot of the control program in online and run mode before the start pushbutton was pressed

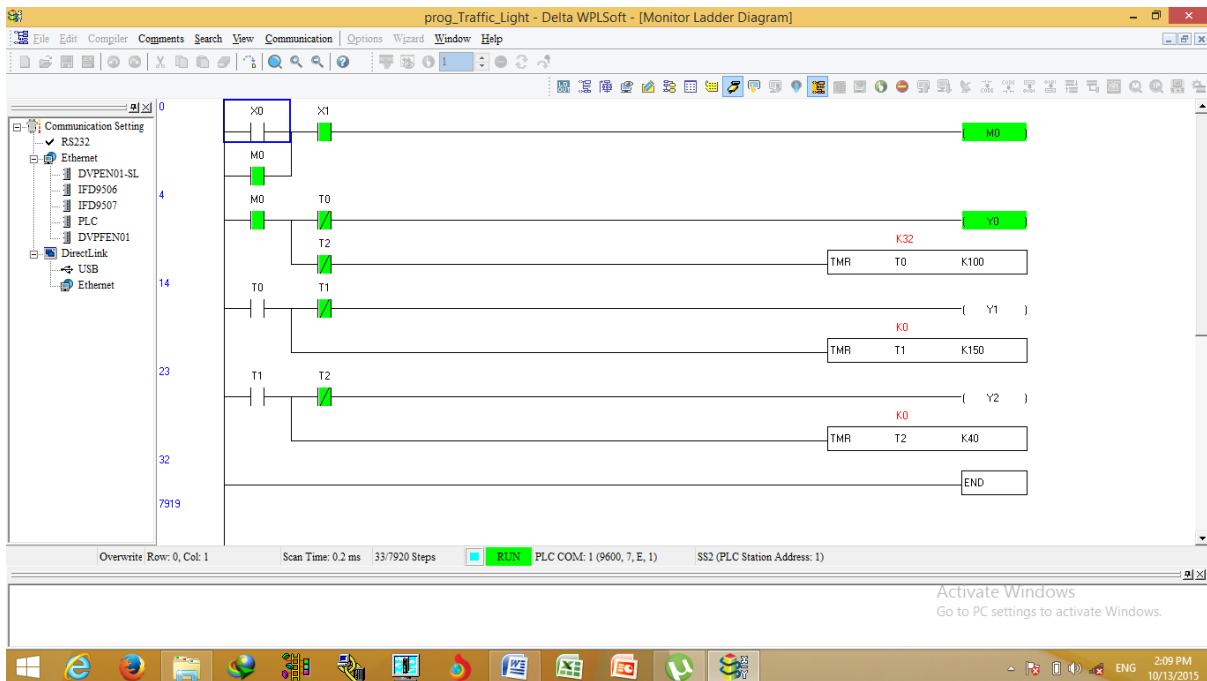


Figure 7: Screen shot of the control program in online and run mode after the start (X0) pushbutton was pressed



**Table 3:** Device list of traffic light control program

Device	Function
X0	Start pushbutton
X1	Stop pushbutton
M0	Internal relay
T0	10 s timer. Time base: 100 ms
T1	15 s timer. Time base: 100 ms
T2	4 s timer. Time base: 100 ms
Y0	Red lamp
Y1	Green lamp
Y2	Amber lamp

Cost analysis of building the PLC training platform is given in table 4.

**Table 4:** Cost of items purchased for the training platform

Item	Description	Quantity	Unit	Rate	Cost US \$
PLC	Delta DVP14SS211R PLC	1	Pieces	100	100
PSU	Delta DVPPS01/DVPPS02 power supply unit	1	Pieces	50	50
Programming Cable	Delta DVPACAB2A30 programming cable	1	Pieces	25	25
Toggle Switch	5 Amps toggle switch	6	Pieces	1.5	9
Pushbutton	5 Amps pushbutton	2	Pieces	2	4
Pilot Lamp	24 VDC pilot lamp (2 red, 2 green, 2 yellow)	6	Pieces	2	12
Terminal Block	Connectors for termination	2	Pieces	1	2
Contactors	24 VDC contactor	2	Pieces	6	12
TOTAL					214

## 5. Conclusion

An interactive, less expensive and more portable PLC training platform for the industrial control of processes has been successfully developed. Students gained an average knowledge improvement of wiring and

programming the PLC on their own by 45.8% as shown by the pre-test and post-test results. Cost of developing the training platform was relatively low (\$ 214) and the overall size of the training platform was relatively small as well.

## **6. Limitations and Future Research Directions**

Future works can consider obtaining more samples of input and output devices to be interfaced with the trainer. Supervisory Control and Data Acquisition (SCADA), Variable Frequency Drives (VFD) and Human Machine Interface (HMI) applications can be considered in future research as well.

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## **References**

- [1] Kim, Y. S., Lee' J. O. and Park C.W. "A hybrid learning system proposal for PLC Wiring Training Using AR", e-Learning in Industrial Electronics (ICELIE), 2011 5<sup>th</sup> IEEE International Conference, pp. 90 – 94, 2011.
- [2] Lee, J. O. and Kim, Y. S "An AR-based Wiring Practice for PLC Training", Journal of International Council on Electrical Engineering, Vol. 1, Issue 4, pp. 425 – 429, 2011.
- [3] Kim, Y. S. and Kim, H. 'Design of a New Virtual Interaction Based PLC Training Using Virtual Sensors and Actuators: System and its Application', International Journal of Distributed Sensor Networks, Vol. 2013, pp. 1 – 8, 2013.
- [4] Barrett, M. "The Design of a Portable Programmable Logic Controller (PLC) Training System for Use Outside of the Automation Laboratory", International Symposium for Engineering Education, Dublin City University, Ireland, pp. 1 – 5, 2008.
- [5] Guo, L. and Pecan, R. "Design Projects in a Programmable Logic Controller (PLC) Course in Electrical Engineering Technology", American Society for Engineering Education, pp. 1 – 10, 2008.
- [6] Petruzella, F. D. Programmable Logic Controllers, McGraw-Hill New York, USA, 4<sup>th</sup> edition, 414 pp, 2011.
- [7] Chitra, S. and Raghavan, V. "Conveyor Control Using Programmable Logic Controller", International Journal of Advancements in Research and Technology, Vol. 3, Issue 8, pp. 1 – 7, 2014.

[8] Bolton, W. Programmable Logic Controllers, Jordan Hill, Oxford, 5<sup>th</sup> Edition, 398 pp, 2009.

[9] Anon, "Review of Available Portable PLC Training", Available at <http://www.program-plc.blogspot.com/2011/04/review-of-available-plc-training>, Accessed on 26<sup>th</sup> August, 2015.