INTERNATIONAL JOURNAL OF
ENGINEERING MANAGEMENT SCIENCE

journal homepage: www.ijems.online/index.php/ijems/index

Design and Implementation of a Cost-Effective PLC Learning Module for Industrial Automation

Dr. Sham M V

Selection Grade lecturer, V.I.S.S.J Government Polytechnic College, Bhadravathi, India.

Received: 05-01-2017 ***Revised: 25-01-2017*** ***Accepted: 28-01-2017***

Keyword

PLC,
Siemens LOGO!,
Low-cost Trainers,
Industrial Automation.

Abstract

Programmable Logic Controllers (PLCs) are the backbone of modern industrial automation; however, the high procurement and maintenance costs of industrial-grade training kits often limit hands-on access for students in resource-constrained engineering and polytechnic institutions. This paper presents the design, implementation, and pedagogical evaluation of a cost-effective PLC learning module based on the Siemens LOGO! 12/24RCE logic module. The developed system integrates essential industrial components—including digital inputs, relay outputs, and Ethernet-based communication—into a portable, user-friendly interface suitable for introductory and intermediate automation courses. To validate the module's effectiveness, a series of structured laboratory exercises was developed, ranging from basic logic gates to complex sequential control using Ladder Diagram (LD) and Function Block Diagram (FBD) programming. Preliminary results from student pilot groups indicate a significant improvement in technical competency and troubleshooting confidence compared to simulation-only environments. Furthermore, a comparative cost analysis demonstrates that the proposed module achieves a 60%–80% cost reduction relative to standard industrial trainers without compromising essential learning outcomes.

1. Introduction:

The rapid evolution of industrial control systems has established the Programmable Logic Controller (PLC) as a fundamental requirement of modern automation, making technical proficiency in logic design and hardware interfacing a core prerequisite for engineering and polytechnic students. However, a significant educational gap exists between theoretical classroom instruction and practical application; while software-based simulations offer an accessible starting point, they often lack the physical difficulties of terminal wiring, sensor calibration, and real-world signal troubleshooting. Furthermore, the high procurement and maintenance costs of industrial-grade modular trainers often limit student access to demo models, delaying the development of essential hands-on skills [5].

To address these constraints, this work details the development of a compact, low-cost PLC learning module utilizing the Siemens LOGO! 12/24RCE (6ED1052-1MD00-0BA8). This LOGO! 8.0 generation was introduced in 2014 [1], [3], this hardware serves as an ideal educational means, offering industrial reliability, an integrated Ethernet interface, and a built-in web server at a fraction of the cost of traditional trainers. By providing a robust interface compatible with LOGO! Soft Comfort V8.0 [2] for both Ladder Diagram (LD) and Function Block Diagram (FBD) programming [4], this module aims to impart hands-on automation education, allowing students to transition from basic motor control to advanced networked monitoring while improving their overall technical competency and troubleshooting confidence.

2. Hardware Design and Architecture

The developed learning module is a self-contained, laboratory trainer designed to bridge the gap between theoretical logic and industrial hardware application as shown in the fgure 1. Cantered on the Siemens LOGO! 12/24RCE (6ED1052-1MD00-0BA8), the system is mounted on a backplane supported by a slotted angle iron frame. The total cost of development is around rupees eight thousand only. This makes the kit easily accessible to all learners.

Figure 1. The photograph of the PLC trainer kit

2.1 Overview of Technical Specifications

The module utilizes the LOGO! 8.0 platform, selected for its proven industrial reliability and cost-effectiveness. Operating on a safe 12/24V DC power supply, the controller features eight digital inputs—four of which are configurable as 0-10V analog inputs—and four 10A relay-type digital outputs [1]. The inclusion of an Ethernet interface, enables high-speed program transfer and networking via LOGO! Soft Comfort V8.0, introduced to standardize modern industrial communication [3].

2.2 Interface Design and Safety Protection

All internal wiring is routed through the rear of the panel to maintain a clean workspace. Key safety features include:

- Safety Interfacing: Standardized 4mm safety sockets (banana jacks), color-coded for signals (red) and common/ground (black).
- Circuit Protection: Reverse-polarity protection and external fuses to safeguard the CPU from student wiring errors.
- Manual Input Simulation: Industrial-grade pushbuttons (NO and NC) and toggle-ready sockets for sensor trigger simulation.

2.3 Integrated I/O Peripherals and Load Simulation

To provide a comprehensive "Hardware-in-the-Loop" (HIL) experience, the trainer incorporates physical loads:

- Visual and Audible Feedback: Four high-intensity pilot lamps and an integrated piezo-buzzer for alarm logic.
- Electromechanical and Thermal Loads: A 24V DC cooling fan and a transparent industrial relay to teach inductive loads.
- Auxiliary Support: An integrated bulb socket for AC/DC lighting circuit simulation.

3. Programming Methodologies

The Siemens LOGO! 8.0 system utilizes graphical programming languages defined by the IEC 61131-3 standard [4].

3.1 Ladder Diagram (LD)

LD is a rule-based language mimicking hard-wired relay control circuit. It directly translates physical wiring into a digital schematic, making it the intuitive starting point for students.

3.2 Function Block Diagram (FBD)

FBD describes a system in terms of signal flow using logic gate blocks (AND, OR, XOR). It is superior for teaching complex automation tasks and introduces concepts of digital electronics [2].

3.3 Comparative Analysis and Software Integration

LOGO! Soft Comfort V8.0 allows for bi-directional conversion between LD and FBD. This ensures the learner understands the underlying computational logic when interfacing with the physical Industrial Relay. As an example the figure2 show the ladder diagram and FBD for implementing Star-Delta starter.

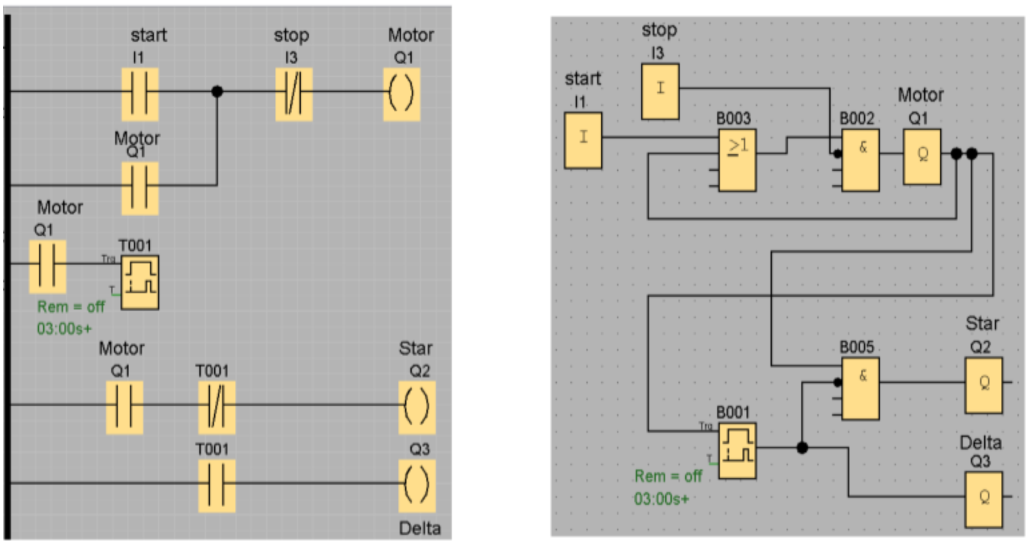

Figure 2. The ladder diagram and FBD for implementing Star-Delta starter

4. Program Verification and Deployment

Verification is handled within the software environment to reduce the risk of electrical damage.

4.1 Software Simulation Environment

The simulation mode (F3) provides virtual representation of I/O, using color-coded "Live Wire" technology to trace logic flow in real-time.

4.2 PC-to-PLC Connection and Networking

Communication utilizes a standard RJ45 Ethernet interface [3]. The PC and LOGO! Unit must be on the same subnet (e.g., 192.168.0.x) to establish a successful ping via the "Accessible Devices" tool [1].

4.3 Transfer and Download Procedure

Logic is written to the controller's internal EEPROM. "Online Test" mode allows students to monitor physical inputs on the kit in real-time within the software interface.

5. Educational Applications and Learning Outcomes for Learners

5.1 Implemented Laboratory Experiments

- Basic Logic Gate Implementation: AND, OR, NOT, and XOR functions using the Lamp.
- Motor Starter Simulation: "Seal-in" circuit for the 24V DC Fan.
- Delayed Industrial Signaling: On-Delay Timers for the Buzzer.
- Sequential Shutdown Systems: Off-Delay Timers for fan cooling.
- Batch Processing & Counting: Up/Down Counters for simulated production.
- Forward/Reverse Motor Interlock: Mutual exclusion logic between two pushbuttons.
- Electromechanical Interface Control: Driving the Industrial Relay (Q4).

5.2 The Learning Outcomes

- In general the learners will be able to:
- Understand basic PLC logic and programming.
- Perform wiring and hardware interfacing.
- Use timers and counters in simple applications.
- Apply safety concepts like interlocking.
- Read and implement ladder diagrams.
- Troubleshoot basic faults.

6. Conclusion

The development of this PLC Trainer Kit provides a robust, cost-effective platform for advancing technical education. By integrating the Siemens LOGO! 12/24RCE with industrial peripherals, the kit successfully links the gap between abstract programming and physical execution. It empowers students to move beyond simulation into real-world troubleshooting, ensuring graduates are equipped with the theoretical knowledge and practical confidence required for the Industry 4.0 requirements.

7. Conflict Of Interest

The authors declared that no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

8. Plagiarism Policy

The authors declare that any kind of violation of plagiarism, copyright, and ethical matters will be handled by all authors. Journalists and editors are not liable for the aforesaid matters.

9. Sources of Funding

The authors received no financial aid to support the study.

References:

[1] Siemens AG, LOGO! System Manual (0BA8 Series), Edition 06/2014, Document Identifier: A5E33039675-AA, Nuremberg, Germany, 2014.
[2] Siemens AG, LOGO! Soft Comfort V8.0 Operating Instructions, Edition 06/2014, Siemens Industry Sector, Nuremberg, Germany, 2014.
[3] Siemens AG, "Delivery Release for LOGO! 8 and LOGO! Soft Comfort V8," Product Note Entry ID: 100704163, Aug. 29, 2014.
[4] International Electrotechnical Commission, IEC 61131-3:2013 Programmable Controllers – Part 3: Programming Languages, 3rd ed., Geneva, Switzerland, 2013.
[5] W. Bolton, Programmable Logic Controllers, 6th ed., Elsevier, Newnes, 2015.