International Scientific Journal of Engineering and Management
ISSN: 2583-6129
Volume: 04 Issue: 04 | Apr – 2025
DOI: 10.55041/ISJEM03010
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Electrical and Robotics Workstation(PLC Educational Kit)

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1.ABSTRACT -

The PLC Educational Kit is a comprehensive training solution designed to introduce students, technicians, and engineers to the fundamentals and advanced applications of Programmable Logic Controllers (PLCs) in industrial automation. PLCs are widely used in industries such as manufacturing, energy, and process control, making them an essential tool for controlling machinery, processes, and systems. This educational kit serves as a hands-on learning platform that bridges the gap between theoretical knowledge and practical application.

The kit includes a fully functional PLC trainer, a variety of input and output devices, sensors, and control panels, providing users with the necessary tools to simulate real-world automation scenarios. The system supports various programming techniques, from basic ladder logic to more advanced functional block diagram (FBD) programming, enabling learners to design, test, and troubleshoot control systems. By using the kit, students can develop their understanding of PLC hardware and software while exploring key concepts such as digital and analog inputs/outputs, timing, counters, sequencing, and data handling.

The educational kit is designed to be highly versatile, offering a wide range of exercises and experiments tailored to different levels of learning. Beginners can start with basic exercises, such as controlling a simple light or motor, while more advanced users can explore complex control systems, including automated conveyors, temperature control, and sequential operations. Additionally, the kit includes an integrated software environment that allows students to write, simulate, and upload PLC programs to the trainer, making it an ideal platform for learning and experimentation.

This paper presents the development and design of an educational kit for Programmable Logic Controllers (PLCs), aimed at enhancing practical learning and understanding of industrial automation systems. The kit provides students with hands-on experience in programming, simulating, and troubleshooting PLC-based systems, which are critical components in modern manufacturing and process industries. The kit includes a range of modular components such as input/output devices, sensors, actuators, and a user-friendly interface for programming and testing. By integrating both hardware and software elements, the kit enables learners to build, simulate, and modify real-world automation projects, facilitating the acquisition of key skills in control systems, ladder logic programming, and system integration. This educational tool bridges the gap between theoretical knowledge and practical application, preparing students for careers in industrial automation and control engineering. The kit is also designed to be adaptable for various educational levels, from introductory courses to more advanced PLC programming and troubleshooting exercises.

Through the interactive nature of the kit, learners can develop essential skills such as troubleshooting, system diagnostics, and problem-solving. As part of the learning process, users will be exposed to common issues faced in real-world industrial environments, preparing them for future careers in automation and control engineering. Furthermore, the educational kit is designed to foster a deeper understanding of the role of PLCs in optimizing industrial processes, ensuring the development of industry-relevant skills.

2.INTRODUCTION

The Programmable Logic Controller (PLC) Educational Kit is an innovative learning platform designed to provide hands-on training in industrial automation and control systems. As industries increasingly rely on automation to improve efficiency, productivity, and safety, the need for skilled professionals with a strong understanding of PLCs has never been greater. This educational kit is aimed at equipping students, engineers, and technicians with the necessary skills to design, program, and troubleshoot PLC-controlled

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systems, preparing them for real-world applications in various industries.

PLCs are essential components in modern industrial control systems, where they are used to automate processes, machinery, and equipment in manufacturing, energy, and other sectors. Unlike traditional relay-based systems, PLCs offer flexibility, reliability, and ease of programming, making them the go-to solution for complex automation tasks. The PLC Educational Kit aims to demystify the complexities of PLCs by offering a practical, interactive learning experience.

The kit consists of a PLC trainer, input/output devices (such as sensors, actuators, and switches), and control panels that mirror the kinds of systems commonly found in industrial settings. These components are integrated into a user-friendly setup that allows learners to simulate real-life automation projects. The kit supports various programming languages, including the widely-used Ladder Logic, as well as more advanced techniques like Functional Block Diagrams (FBD) and Structured Text (ST). This diversity enables learners to experience a broad range of programming paradigms used in the field.

With this hands-on approach, the PLC Educational Kit enables users to start with basic exercises—such as controlling a motor or simple light—and progress to more advanced control systems like automated production lines, temperature control systems, and sequence-driven processes. Students learn to write, test, and debug PLC programs, gaining practical skills in system integration, troubleshooting, and optimizing control processes.

In addition to the core hardware components, the kit includes simulation software that allows users to design and test PLC programs virtually, enhancing their ability to experiment and learn without requiring a physical PLC unit for every task. This makes the learning process more flexible and scalable, supporting both individual study and group-based training sessions.

By offering a blend of theoretical foundations and practical experience, the PLC Educational Kit helps learners understand the principles of industrial automation, the role of PLCs in controlling real-world systems, and the critical skills needed to succeed in the field. Whether used in academic settings, vocational training programs, or personal development, the kit fosters the technical proficiency and problem-solving abilities required to thrive in today’s rapidly evolving automation industry.

Programmable Logic Controllers (PLCs) are integral components in the automation of industrial processes, playing a critical role in controlling machinery, processes, and systems within industries such as manufacturing, oil and gas, automotive, and more. Despite their widespread application, understanding PLCs requires not only theoretical knowledge but also practical, hands-on experience in programming, configuration, and troubleshooting. Traditional classroom teaching often struggles to provide the interactive and immersive learning environment needed to fully grasp the complexities of PLC systems.

To address this gap, the development of an educational kit designed specifically for PLC learning becomes a crucial tool for students and aspiring engineers. This PLC educational kit aims to bridge the theoretical and practical aspects of automation by providing a comprehensive, easy-to-use platform for hands-on training. The kit includes various components such as a PLC unit, I/O modules, sensors, actuators, and software for programming and simulation, enabling students to design, implement, and test real-world automation applications.

The primary objective of this kit is to facilitate the understanding of core PLC concepts, including ladder logic programming, signal processing, process control, and system integration. By offering interactive exercises and simulated environments, students are able to experience the challenges and solutions encountered in industrial settings. Additionally, the kit supports a range of learning levels, from beginner courses introducing the fundamentals of PLCs to advanced projects requiring in-depth system design and troubleshooting.

Ultimately, this PLC educational kit provides students with the necessary tools to develop critical skills in industrial automation, preparing them for careers in engineering and technology sectors that rely on PLC-based control systems.

3. LITERATURE REVIEW

Introduction to PLCs in Education: Programmable Logic Controllers (PLCs) are a fundamental part of modern industrial automation. These devices are widely used in manufacturing, transportation, and utilities for tasks ranging from simple operations to complex process control. Educating students in PLCs is essential for preparing them for careers in engineering and automation technology. However, learning PLC concepts through traditional lectures alone can be insufficient, as hands-on experience is crucial for developing practical problem-solving skills. In response, educational kits that integrate both hardware and software for teaching PLC concepts have gained prominence in academic settings.

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Advancements in PLC Educational Kits: As PLC technology advanced, so too did the complexity and capabilities of educational kits. In the 2000s, educational PLC kits began to include more advanced features such as communication protocols (Modbus, Profibus), SCADA integration, and more sophisticated input/output devices. discussed the development of an advanced PLC kit that supported networking and remote monitoring, allowing students to simulate large-scale industrial systems. The introduction of graphical programming languages, such as the use of Ladder Logic in simulation software, also played a critical role in improving the accessibility of PLCs for students.

Additionally highlighted the growing trend of integrating PLC kits with simulation tools, enabling students to experiment with virtual environments before implementing physical changes. These virtual environments helped reduce the risks and costs associated with hands-on experiments, while still allowing students to gain real-world knowledge.

PLC Kits in Higher Education and Industry Training: In higher education settings, PLC kits have been shown to enhance student learning, especially in practical courses related to automation and control systems demonstrated that the use of a PLC educational kit in undergraduate automation courses resulted in better learning outcomes, with students expressing higher satisfaction due to the hands-on nature of the training. The use of PLC kits also allowed for better integration between theoretical concepts and practical applications, reinforcing the importance of systems thinking in automation design.

Moreover, PLC educational kits are also being used in industry training programs. According to many industrial companies have adopted PLC training kits to enhance the skills of their employees, ensuring they are well-versed in the latest automation technologies. Industry-focused PLC training kits often include real-world scenarios and problems, helping trainees adapt to the specific needs of their employers. This trend has been further emphasized by, who noted the importance of PLC-based training for upskilling workers in industries reliant on automated systems

4. CHALLENGES IN PLC EDUCATION:

Despite the benefits, there are several challenges in designing effective PLC educational kits. One common issue, noted by is the high cost of advanced PLC kits, which can limit access for educational institutions with smaller budgets. Additionally, the rapid pace of technological advancement in PLC systems means that educational kits can become outdated quickly, necessitating continuous updates and investments. Another challenge, discussed is the difficulty in creating kits that are flexible enough to cater to both beginners and advanced learners, as students have varying levels of experience with automation systems.

Another concern is the balance between hands-on experimentation and theoretical learning suggested that many PLC kits, while offering excellent hands-on opportunities, may not always effectively address the underlying theoretical concepts. It is critical for educational kits to strike a balance between practical skills and foundational knowledge in areas such as control theory, system dynamics, and electrical engineering.

5. INNOVATIONS & FUTURE DIRECTIONS:

Recent innovations in PLC educational kits focus on making the kits more versatile, user-friendly, and integrated with modern technologies. Advances such as cloud-based PLC simulation, Internet of Things (IoT) integration, and the incorporation of augmented reality (AR) for remote troubleshooting are gaining momentum. highlighted the use of cloud-based PLC simulation software that allows students to program and test PLC systems remotely, making PLC education more accessible, particularly in the context of remote learning.

The future of PLC educational kits lies in further integration with Industry 4.0 technologiesproposed that PLC kits should evolve to include modules that teach students about cybersecurity in automation systems, AI-based predictive maintenance, and data analytics, as these are becoming increasingly important in modern industrial automation. By adopting a more holistic approach to automation education, these advanced kits would help students better prepare for the evolving demands of the automation industry.

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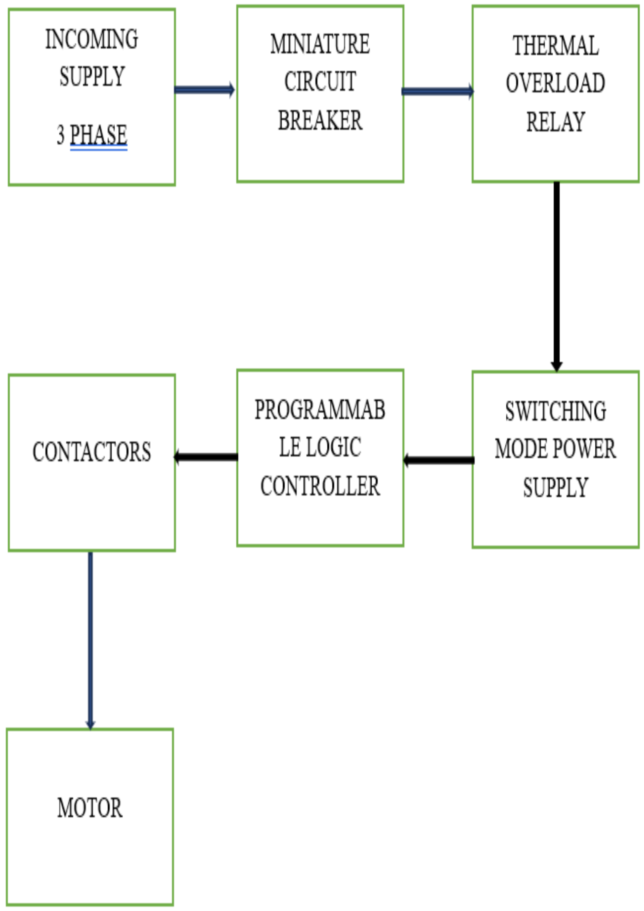
6. BLOCK DIAGRAM



Overview

A PLC Educational Kit consists of several interconnected components that allow users to learn, program, and test PLC-based automation systems. Below is a description of the key blocks in the system.

INCOMING 3 PHASE SUPPLY:-

The Incoming 3-Phase Supply is responsible for providing stable and safe electrical power to the PLC system and its connected components. It ensures that all devices receive the correct voltage and current while protecting them from electrical faults.

MCB (Miniature Circuit Breaker) – Safety Protection

Overcurrent Protection

- Prevents excessive current flow that could damage the PLC, power supply, sensors, and actuators.
- Automatically trips if the current exceeds the rated limit.

Short Circuit Protection

- Detects short circuits and immediately disconnects power to prevent damage to components.
- Ensures user safety by preventing electrical hazards.

Device Protection

- Protects expensive PLC components (CPU, I/O modules, HMI, communication interfaces) from electrical faults.
- Prevents internal overheating and fire risks.

Ensuring Reliable Operation

- Helps maintain a stable power supply to the PLC system by isolating faulty sections of the circuit.
- Reduces downtime and troubleshooting efforts by preventing severe failures.

User Safety

- Provides protection against electric shocks and accidental exposure to high voltage.
- Essential in educational environments to ensure a safe learning experience for students and trainees.

THERMAL OVERLOAD RELAY:-

A Thermal Overload Relay (TOR) is a safety device used to protect motors and electrical circuits from overheating due to excessive current flow. In a PLC Educational Kit, it demonstrates motor protection and fault handling concepts in industrial automation.

Motor Protection

- Prevents motors from overheating by detecting excessive current draw.

- Automatically disconnects the motor circuit if the current exceeds a set threshold.

Fault Detection & Indication

- Provides feedback to the PLC about an overload condition.
- Helps students understand how PLCs monitor and respond to faults.
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Practical Application in PLC Logic

- When an overload condition is detected, the relay trips and sends a signal to the PLC.
- The PLC can be programmed to:
- Trigger an alarm or warning light.
- Log the fault condition in a monitoring system.
- Shut down the motor safely and attempt an automatic restart after a delay.

Enhancing Learning on Industrial Safety

- Demonstrates how real-world industrial systems use overload protection.
- Helps students understand the importance of electrical safety in automation.

CONTACTORS:-

Contactors play a crucial role in a PLC Educational Kit, primarily for switching and controlling high-power electrical loads based on PLC commands. They act as electrically operated switches that handle high currents and voltages, providing isolation and safety.

Load Switching

- Contactors allow the PLC to control high-power loads such as motors, heaters, and lighting systems without directly handling high currents.
- The PLC sends a low-voltage signal to the contactor coil, which then switches the high-power circuit.

Electrical Isolation

- The PLC operates at low voltage (typically 24V DC), whereas industrial machines use higher voltages (110V, 230V, or 415V AC).
- Contactors provide electrical isolation between the low-voltage PLC circuit and the high-voltage load.

Motor Control

- Used in Direct-On-Line (DOL) starters, star-delta starters, and soft starters to control AC motors.
- The PLC controls the contactor, which switches the motor ON or OFF based on programmed logic.

Safety & Protection

- Contactors can be combined with overload relays to prevent damage due to overcurrent or overheating.
- In case of an emergency stop (E-Stop), the contactor can immediately cut power to the load.

Interlocking in Automation

- Used for electrical and mechanical interlocking in complex automation systems.
- Example: In a forward-reverse motor control system, contactors prevent both directions from being activated simultaneously.

High-Durability Switching

- Contactors are designed for frequent switching and can handle millions of operations, making them suitable for industrial automation training.

SWITCHING MODE POWER SUPPLY:-

A Switched Mode Power Supply (SMPS) is an electronic power supply that efficiently converts electrical power using switching regulators. It provides a stable DC voltage required by the PLC and other components in the educational kit.

Voltage Conversion & Regulation

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DOI: 10.55041/ISJEM03010

- Converts AC mains power (230V AC/110V AC) to low-voltage DC (typically 24V DC or 12V DC).
- Ensures a stable and regulated voltage supply for PLC operation.
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Powering PLC & Peripherals

- Provides necessary power to the PLC CPU, input/output (I/O) modules, HMI, and communication interfaces.
- Supplies power to sensors, actuators, relays, and motor controllers.

Protection Against Power Fluctuations

- Protects PLC components from voltage spikes, surges, and power fluctuations.
- Ensures reliable operation even in case of input voltage variations.

Isolation & Safety

- Provides electrical isolation between the high-voltage AC supply and low-voltage PLC circuits.
- Prevents damage due to electrical faults, reducing risks of short circuits and shocks.

Energy Efficiency

- High efficiency (80-90%), reducing energy loss as heat compared to traditional linear power supplies.
- Enables compact design of the PLC Educational Kit by minimizing heat dissipation.

Continuous & Uninterrupted Operation

- Ensures continuous DC power supply to avoid PLC malfunctions or system shutdowns.
- Some SMPS units include battery backup (UPS support) for uninterrupted learning sessions.

PLC:-

A PLC (Programmable Logic Controller) is the core component of the PLC Educational Kit. Its function is to execute automation logic, process inputs, and control outputs in real-time based on programmed instructions. Below are the key functions of a PLC in the educational kit

Input Signal Processing

- The PLC receives signals from input devices such as push buttons, sensors, switches, and encoders.
- These signals can be:
- Digital Inputs: ON/OFF signals (e.g., proximity sensors, limit switches).
- Analog Inputs: Variable signals (e.g., temperature, pressure sensors).
- The PLC converts these signals into a format that it can process.

Program Execution

- The PLC runs a predefined logic program written using Ladder Logic, Structured Text, or Function Block Diagrams.
- The program is executed in a continuous cycle:
- Read Inputs – Checks the status of all connected sensors and switches.
- Process Logic – Executes the programmed instructions (e.g., timers, counters, mathematical operations).
- Update Outputs – Controls actuators like motors, solenoids, and relays.

Output Control

- Based on the logic, the PLC activates or deactivates outputs such as:
- Relay Outputs – Switching on/off lights, buzzers, or solenoids.
- Motor Control – Adjusting speed and direction of AC/DC or stepper motors.
- Pneumatic/Hydraulic Control – Activating valves and cylinders.

Communication & Monitoring

- The PLC communicates with other devices using industrial protocols like:

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- Ethernet/IP, Modbus, Profibus, RS-485, CANbus.
- It connects with Human-Machine Interfaces (HMI), SCADA systems, or PCs for real-time monitoring and control.

Troubleshooting & Debugging

- The educational kit allows students to simulate and troubleshoot real-world industrial automation scenarios.
- PLC programming software provides:
- Live monitoring of inputs and outputs.
- Fault diagnosis and debugging tools.
- Simulation of automation processes beforedeployment.

Practical Learning & Applications

The PLC in the educational kit is used to implement various automation tasks such as:

- Traffic Light Control System (Sequencing and timing).
- Conveyor Belt Automation (Sorting and material handling).
- Water Level Control (PID-based liquid level regulation).
- Robotic Arm Control (Motor coordination and automation).

7. HARDWARE COMPONENTS:-

Sr. No.	Components	Specifications
1.	Contactors	440A, 9A, 230V AC Coil
2.	MCB	16A, 4 Pole
3.	SMPS	24V DC
4.	PLC	Schneider M200 24 I/O 24V DC
5.	Indication Lamps	230V AC
6.	Relay Channel	24V DC, 10 Channel
7.	Timer	230V AC
8.	Copper Wire	1 Sq.mm, 1.5 Sq.mm, 2.5 Sq.mm

8. CONCLUSION

PLC educational kits have evolved significantly over the years, from simple devices for basic control tasks to comprehensive, feature-rich platforms for teaching industrial automation. While they have greatly enhanced the learning experience in automation education, challenges related to cost, complexity, and the balance between theory and practice remain. Nevertheless, ongoing advancements in PLC technologies and teaching methodologies promise to make these educational tools even more effective, enabling future generations of engineers to be better prepared for the increasingly complex world of industrial automation.

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