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PROGRAMMABLE LOGIC CONTROLLER (PLC) TRAINER KIT FOR VARIOUS POWER SYSTEM APPLICATION

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Abstract: This paper presents the design and implementation of a Programmable Logic Controller (PLC) trainer kit using the Siemens LOGO! PLC, model 6ED1 052-1MD08-0BA1. The trainer kit is designed to facilitate hands-on learning for students in automation and control systems. It includes a modular PLC system, a range of input/output devices, and an instructional manual with practical exercises. This kit aims to enhance the practical skills of students and provide a comprehensive understanding of PLC applications in both educational and industrial settings.

Index Terms- PLC, Siemens LOGO, automation, control systems, educational tool, industrial applications, hands-on training, modular system.

INTRODUCTION

A programmable logic controller (PLC) or programmable controller is an industrial computer that has been ruggedized and adapted for the control of manufacturing processes, such as assembly lines, machines, robotic devices, or any activity that requires high reliability, ease of programming, and process fault diagnosis. PLCs can range from small modular devices with tens of inputs and outputs (I/O), in a housing integral with the processor, to large rack-mounted modular devices with thousands of 1/0, and which are often networked to other PLC and SCADA systems. They can be designed for many arrangements of digital and analog 1/0, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or non- volatile memory. The rapid advancement in technology has significantly impacted the field of electrical engineering, particularly in the domain of power systems. Programmable Logic Controllers (PLCs) play a pivotal role in automating and controlling electrical processes, making them essential components in modern industrial and power system applications. Our project, the PLC Trainer Kit for Various Power System Applications, aims to bridge the gap between theoretical knowledge and practical skills in this critical area. This is due to some beneficial advantages offered by PLC such as cost effective, flexible, reliable, and etc. PLC programs are typically written through ladder diagram or other conventional programming method that can be copied from a workstation (i.e.: computer or laptops) or even through PLC hand - held console via cable. A compact PLC has a perpetual number of connecting terminals constructed for input/output (I/O) connection and could be extended if the controller having insufficient I/O (in the case of future expansion). Furthermore, it can be programmable and reprogrammable for various task, thus make the construction it flexible and adaptable to the future changes demand by relevant industries. Learners should experience hands-on skills in PLC as it is a major component in engineering courses especially for learner taking instrumentation and control subject. 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. Unfortunately, unavailability of suitable devices to perform hands-on skills aspect during the practical session in executing the syllabus for several courses such as Automation & Programmable Logic Controller, Industrial Control, Process Measurement, Instrumentation and Final Year Project (FYP). This is due to the existing equipment equipped with toggle switches as the input devices, which it is unsuitable for practical implementation and lights are used as to display the output module (one source of output devices only).

PROBLEM STATEMENT

This gap in practical training resources hinders the development of students problem-solving skills and their preparedness for real world engineering challenges. Existing PLC training kits are typically expensive, lack flexibility, and do not provide comprehensive, realistic simulations of industrial environments.

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Key objectives of our PLC Trainer Kit project include:

i. Educational Enhancement: The kit is designed to equip learners with the practical skills required to program and operate PLCs. It covers the fundamental principles of control systems and offers hands-on training modules that mimic real-world industrial applications.

ii. Skill Development: Users will develop essential programming skills for PLCs, learning how to design, implement, and troubleshoot PLC programs. The kit includes various exercises and examples that cater to different learning levels, from beginners to advanced users.

iii. Versatility and User-Friendliness: Our trainer kit is versatile and user-friendly, capable of demonstrating a wide range of industrial applications. It includes modular components that can be easily configured to simulate different control scenarios, making it suitable for diverse educational and training needs.

iv. Real-World Simulation: The kit is designed to simulate real-world scenarios, providing users with a realistic and immersive learning experience. This approach helps users understand the practical implications of their programming decisions and prepares them for real-life applications.

v. Comprehensive Support: We provide extensive educational support materials, including manuals, tutorials, and example programs. These resources ensure that users can effectively utilize the kit and maximize their learning outcomes.

vi. Scalability, Safety, and Cost-Effectiveness: Our kit is scalable, allowing for expansions and upgrades as needed. It is also designed with safety in mind, incorporating features that protect both the user and the equipment. Additionally, we aim to offer a cost-effective solution that provides high value without compromising on quality.

HARDWARE EQUIPMENTS

i. Siemens Logo PLC:

FIG1: Siemens Logo PLC

The Siemens LOGO! 6ED1052-1MD00-0BA1 is a modular, compact, and user-friendly logic module used for basic control tasks in automation projects. Below are the key specifications and features for this model:

General Specifications
Product Type: Logic Module Series: LOGO! 8
Order Number: 6ED1052-1MD00-0BA1

Hardware Specifications
Power Supply Voltage: 12/24 V DC
Digital Inputs: 8 (4 of which can be used as analog inputs 0-10 V)
Digital Outputs: 4
relay outputs (6A)
Display: 6-line display with 16 characters per lineReal- Time Clock: Integrated, with battery backup

Communication
Interfaces: Ethernet interface (for communication with other LOGO! modules and programming viaLOGO! Soft Comfort software)
Web Server: Integrated (for remote monitoring and control)

Memory
Program Memory: 400 function blocks

Programming

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Programming Software: LOGO! Soft Comfort (available for Windows, Linux, and Mac OS)Program Backup: Micro SD card slot for program storage and transfer.

ii. SMPS [24 V DC / 5A]

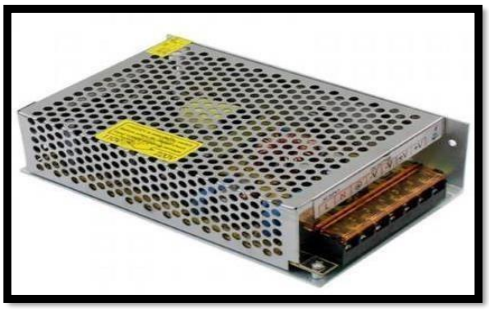

FIG 2: SWITCHED MODE POWER SUPPLY

A switched-mode power supply (or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently.

Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power, see AC adapter) to DC loads, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. A hypothetical ideal switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time (also known as duty cycle). In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistors. The switched- mode power supply's higher electrical efficiency is an important advantage.

We used SMPS of rated 24 V DC & 5A.

SWITCHES

i. POWER SWITCH

FIG 3: POWER SWITCH

A Power Switch provides an electrical connection from a voltage source or ground to a load. It saves power across multiple voltage rails and protects subsystems from damage.

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ii. PUSH BUTTON

FIG 4: PUSH BUTTON

A push-button (also spelled pushbutton) or simply button is a simple mechanism to control some aspect of a machine or a process. Buttons are typically made out of hard material, usually plastic or metal. The surface is usually flat or shaped to accommodate the human finger or hand, so as to be easily depressed or pushed. Buttons are most often biased switches, although many un-biased buttons TOGGLE SWITCH

iii. TOGGLE SWITCH

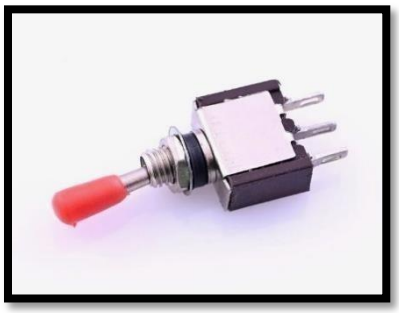

FIG 5: TOGGLE SWITCH

A toggle switch is a type of electrical switch that is actuated by moving a lever back and forth to openor close an electrical circuit.

OUTPUT DEVICES

i. FAN [24 V DC]

FIG 6: FAN

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A fan is a powered used to create a flow of. A fan consists of a rotating arrangement of vanes or, generally made of, or HYPERLINK "https://en.wikipedia.org/wiki/Metal" \o "Metal" metal, which act on the air. The rotating assembly of blades and hub is known as a HYPERLINK "https://en.wikipedia.org/wiki/Impeller" \o "Impeller" impeller, rotor, or runner. Usually, it is contained within some form of housing, or case.

ii. BUZZER [24 V DC]

FIG 7: BUZZER

A buzzer or beeper is an audio signaling3 device, which may be mechanical, electromechanical, or piezoelectric (piezo for short). Typical uses of buzzers and beepers include alarm devices, timers, train and confirmation of user input such as a mouse click or keystroke.

iii. RELAY [24 V DC, 2-CHANNEL]

FIG 8: RELAY

The term Relay generally refers to a device that provides an electrical connection between two or more points in response to the application of a control signal. The most common and widely used type of electrical relay is the electromechanical relay or EMR.

LITERATURE SURVEY

Paper 1: A Practical Technology-Enhanced Approach for Programmable Logic Controller (PLC) Training Course
Sasithorn Chookeaw, Suppachai Howimanporn, Warin Sootkaneung

- The paper emphasizes the importance of continuing education in engineering in the modern era to help

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engineers acquire essential competencies for adapting to a rapidly changing world.

- It discusses the integration of technology and experimental kits in a PLC training course to aid engineers in understanding complex concepts and applying them practically.
- The study highlights the positive impact of using technology for learning activities in the training course, leading to significant improvements in participants' cognitive knowledge and performance on course objectives.
- Participants in the training course expressed positive attitudes and satisfaction, indicating the effectiveness of the experimental kit and technology-enhanced approach in enhancing learning outcomes.
- Overall, the literature survey presented in the paper underscores the significance of practical, technology-enhanced approaches in engineering education to better prepare engineers for the challenges of the modern world.

Paper 2: Development of a Programmable Logic Controller Training Platform for the Industrial Control of Processes
Awingot Richard Akparibo, Albert Appiah, Oliver Fosu-Antwi

- The paper introduces a cost-effective and portable PLC training platform for industrial process control, emphasizing interactivity and practical learning experiences.
- It utilizes the Delta DVP14SS2 PLC, WPLSoft software, switches for inputs, and pilot lamps for outputs in the training system, offering flexibility in wiring and programming various input and output types.
- The study aims to assist beginners and experienced PLC users in constructing their own PLC trainers to enhance their theoretical knowledge and practical skills in PLC programming.
- An application scenario involving traffic light automation is implemented to train Electrical and Electronic Engineering students, allowing them to apply their knowledge in a real-world setting and evaluate the system's usability.
- Pre-test and post-test assessments are conducted to measure the effectiveness of the training platform in improving students' understanding of PLC concepts, highlighting its educational value and impact on learning outcome.

PAPER 3: Programmable Logic Controller (PLC) Protected TransformerBanking Trainer Kit for Electrical Engineering Education
Anthony M. Minoza, Blondie T. Sanchez, and Jayson C. Loreto

- The research paper focuses on bridging the gap between theoretical concepts of transformer banking and practical operation in electrical engineering education.
- It highlights the importance of properly teaching transformer basics in universities to enhance students' understanding of electrical engineering applications.
- The integration of a Programmable Logic Controller (PLC) into the system configuration serves as a protection mechanism, allowing students to learn about different transformer banking types without risking equipment damage or user safety.
- The paper emphasizes the significance of understanding transformer configurations such as delta- wye, wye-delta, delta-delta, and wye-wye, which are essential in electrical engineering education.
- By using low-cost materials, the trainer kit developed in the research offers flexibility in improving efficiency with varying loads, making it a valuable tool for students to expand their knowledge in electrical engineering.

PAPER 4: Design and implementation of a PLC workstation
Matthew Oluwole Arowolo, Adefemi Adeyemi Adekunle, Oluwaseun Opeyemi Martins

- The paper focuses on the design and implementation of a PLC trainer workstation for industrial automatic engineering operation, addressing the challenges of expensive prebuilt hardware kits and programming software acquisition.
- Previous research has proposed various PLC trainers, but they often lack discussions on hardware connections of input/output components, basic PLC automatic operations, and PLC component symbols with descriptions, which are key areas covered in this paper.
- The authors highlight the use of the MITSUBISHI FX 1S-30MR-001 PLC module, MITSUBISHI FXTRN-BEG-EL simulation software, and MITSUBISHI GX Developer version 8 programming software for the PLC trainer workstation

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- The paper presents two automatic control application scenarios to train participants and evaluate the trainer's real-world applicability, showing enhanced knowledge in design step module and LL programming module significantly after training.
- The study involved a survey after training to measure the impact of the approach on PLC programming knowledge, with results indicating improved performance in the modules evaluated, particularly in design step module and LL programming module.

PAPER 5: Programmable Logic Controllers in the Context of Industry 4.0
Martin A. Sehr, Marten Lohstroh, Matthew Weber, Ines Ugalde, Martin Witte, Joerg Neidig, Stephan Hoeme, Mehrdad Niknami, Edward A. Lee

- The paper provides an overview of the state of practice regarding programmable logic controllers (PLCs) in industrial automation, highlighting the persistence of this technology in industry despite being poorly understood by researchers.
- It discusses the standardized software execution patterns in PLC programming as outlined in IEC 61131-3, while also critically analyzing the strengths and weaknesses of current programming styles used in PLC-based automation systems.
- The authors propose deterministic, distributed programming models for PLCs that focus on explicit timing, event-triggered computation, and enhanced security to enable more complex industrial automation applications with improved safety and reliability.
- The research emphasizes the concept of 'frequency locked' tasks in PLCs, ensuring that the execution cycles of periodic tasks remain bounded when running on different PLCs, supported in part by the US National Science Foundation (NSF).
- The paper advocates for reexamining the core PLC programming model to achieve determinism, enable virtual prototyping, leverage multicore architectures, incorporate networking innovations like TSN, and enhance safety guarantees in industrial automation applications.

PAPER 6: Development of an IoT-Based PLC Trainer: Bridging the PracticalDivide in Industrial Automation Education
Adhy Kurnia Triatmaja, Pramudita Budiastuti, Moch Yordan Rismarinandyo

- The paper explores recent studies on the applications of IoT-based PLCs in various contexts, including smart home automation, traffic control, and resource management.
- Notable contributions highlighted in the literature include remote monitoring systems, smart traffic control, water level monitoring, and automated greenhouses, showcasing the diverseapplications of IoT-based PLCs.
- The research acknowledges persistent challenges in understanding and implementing PLCs, emphasizing the need for practical training to bridge the gap between theoretical knowledge and practical application.
- To address these challenges, the study introduces an innovative IoT-based PLC Trainer Kit designed to enhance practical learning by providing hands-on experiences, refining skills, and optimizing applications across different domains.
- Through meticulous design, material selection, and testing, the IoT-based PLC Trainer demonstrates optimal functionality and user-friendliness, making it suitable for deployment in educational institutions and industrial setups.

PAPER 7: Design and Application of a Non-wrapped Programmable LogicController (PLC) Laboratory Kit for Automatic Control Education
Ying Wang, Xiaodong Ren, Zhou Jing, Meilan Liu, Qinke Peng, and Laiyi Fu

- The research paper focuses on the design and implementation of a non-wrapped Programmable Logic Controller (PLC) laboratory kit for automatic control education.
- Traditional PLC platforms are noted for their black box effect and lack of portability, prompting the development of a more flexible and portable laboratory kit.
- The study emphasizes the importance of practical training in PLC systems for college engineering education and highlights the limitations of conventional PLC platforms.
- By incorporating various input elements such as buttons, encoders, sensors, and switches, along with output elements like indicator lights and motor controls, the laboratory kit offers a comprehensive hands-on learning experience

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for students.

- The projects developed on this platform aim to enhance students' practical abilities, promote problem-solving skills, and improve wiring operation proficiency, ultimately meeting the teaching requirements of automatic control education.
- The application of the non-wrapped PLC laboratory kit is intended to cultivate students' design skills, overcome the black box effect associated with traditional PLC training, and enhance their overall learning experience in automatic control education.

CIRCUIT DIAGRAM

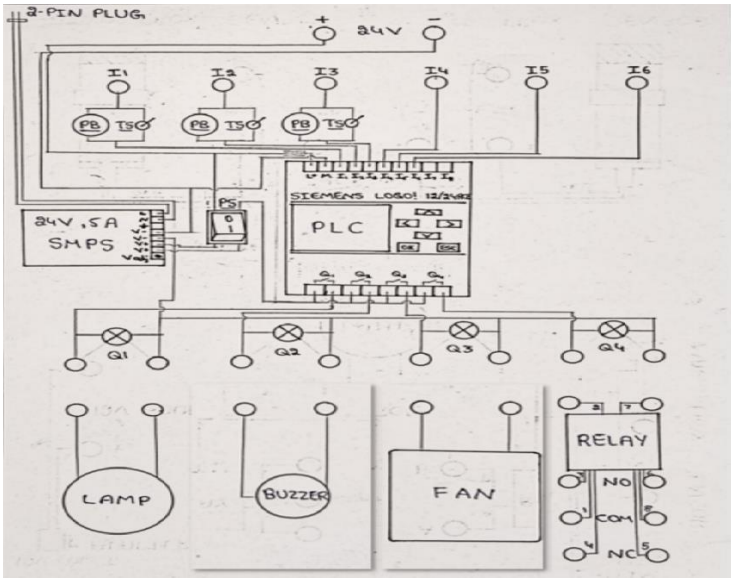

FIG 10: CIRCUIT DIAGRAM

The system begins with a 230V supply to the board, which directs the power to a Switched-Mode Power Supply (SMPS). The SMPS steps down the voltage to 24V, which has been precisely set to 23.7V to ensure optimal performance and compatibility with connected devices. From this power supply, six inputs are connected, providing necessary power for various components, with the capability to extend to eight inputs if needed for additional functionalities or future expansions.

There are four outputs connected to key components: a buzzer, a fan, and a relay, each serving distinct functions within the system. The buzzer is typically used for alert notifications, the fan for cooling to prevent overheating, and the relay for controlling higher power devices or circuits. This configuration ensures that all critical components receive adequate power and can operate efficiently.

A switch is integrated into the system to control the power supply, allowing for manual operation and providing a crucial safety mechanism to turn the system on or off as needed. This not only enhances user control but also adds a layer of safety, preventing unauthorized use or accidental activation of the system. Additionally, the switch allows for easy shutdown during maintenance or in emergency situations, ensuring the safety of both the equipment and the operator.

To protect the system, a diode is used for safeguarding the Programmable Logic Controller (PLC). This diode ensures that the PLC is protected against potential voltage spikes or reverse polarity, which could otherwise cause significant damage. The diode acts as a barrier, allowing current to flow in the correct direction while blocking any harmful surges, thereby maintaining the integrity and longevity of the PLC.

This setup, with its precise voltage regulation, expandable input capability, and protected outputs, ensures efficient power distribution and protection for all connected components. It facilitates a reliable and controlled operation of the entire system, ensuring that all parts work harmoniously and safely.

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RESULT

FIG 11: FRONT-END &BACK-END VIEW OF PLC TRAINER KIT

CONCLUSION

The development and deployment of the PLC Trainer kit for various power system applications has been a transformative addition to technical education, particularly in the field of industrial automation and control. This project has successfully demonstrated the importance and effectiveness of integrating hands-on, practical training with theoretical learning. The PLC Trainer kit, with its modular design and comprehensive instructional materials, offers a robust platform for students to gain invaluable experience in programming, designing, and troubleshooting PLC systems used in real-world power applications.

Enhanced Learning Experience

The PLC Trainer kit has significantly improved the learning experience by:

- Providing a practical, hands-on approach that complements traditional classroom instruction.
- Enabling students to simulate and test PLC programs in a safe, controlled environment before deploying them on actual hardware.
- Bridging the gap between theoretical concepts and practical applications, ensuringstudents are job-ready with skills that match industry demands.

Impact on Education

The project has had a notable impact on technical education by:

- Enhancing student engagement and retention through interactive and immersive learning experiences.
- Allowing for scalability and accessibility, making advanced PLC training available to a broader audience.
- Preparing students for the evolving landscape of industrial automation and powersystems, with a strong foundation in PLC technology.

Future Directions

Looking ahead, future iterations of the PLC Trainer kit could:

- Incorporate emerging technologies such as IoT, machine learning, and advanced robotics to stay current with industry trends.
- Expand its scope to cover a wider range of applications and more complex controlsystems.
- Include enhanced simulation tools and virtual reality components for even more immersive learning experience

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