Design And Development of A SCADA Based PLC Control System Trainer For Lab Experiments

Muhammad Aulia Rahman Sembiring[1], Denny Haryanto Sinaga[2], Arwadi Sinuraya[3], Bakti Dwi Waluyo[4], Reza Arbi Azizi Lubis[5]

{marsembiring@unimed.ac.id[1], denny.sinaga@unimed.ac.id[2], arwadisinuraya@unimed.ac.id[3], bakti_dw@unimed.ac.id[4], rezaarbiazizilubis@gmail.com[5] }

Department of Electrical Engineering Education, Faculty of Engineering, Universitas Negeri Medan, Indonesia[1,2,3,4,5]

Abstract. The development of modern industry drives the need for graduates with competencies in PLC automation systems integrated with SCADA. However, learning in the Department of Electrical Engineering Education at Unimed is still limited by outdated and insufficient equipment, hindering students from fully understanding programmable automation control. This study aims to develop a SCADA-based PLC automation trainer as a practical learning medium for the Electric Motor Installation and Control Systems course. The product was developed using the Research and Development (R&D) method with the ADDIE model through stages of analysis, design, development, implementation, and evaluation. The trainer is equipped with a PLC, HMI, sensors, VFD, and SCADA interface. Validation results showed a feasibility score of 90.2% from material experts and 92.06% from media experts, both in the "very feasible" category. User responses also indicated high practicality and usefulness. This trainer is feasible and relevant for supporting practical learning activities.

Keyword: Trainer; SCADA; PLC; Automation; Development.

1. Introduction

Industry is currently shifting from traditional control systems to modern technology-based automation control systems. One widely used technology is the Programmable Logic Controller (PLC) [1]. In line with this shift, the demand for professionals with automation expertise continues to grow, particularly in the automotive, electronics, and textile industries [2]. To support this need, the Department of Electrical Engineering Education, Medan State University, has used the Smart relay trainer as a learning tool.

However, currently available learning tools, such as the Smart relay trainer, are inadequate to meet the increasingly complex learning needs, particularly related to PLC-based automation technology and Supervisory Control and Data Acquisition (SCADA). At Medan State University, SCADA learning tools are currently unavailable. Many industries expect graduates to be proficient in PLC and SCADA. This creates a significant gap between the competencies expected by industry and the skills of students. In fact, SCADA skills have become one

of the SKKNI standards in the Decree of the Minister of Manpower Number 631 of 2016 which must be mastered by workers in the electrical field [3]. SCADA is also a basic skill that must be understood by electrical engineering students, because its application is the main key in modern automation systems. Without adequate learning media, it is impossible for students to fully understand the concept and implementation of SCADA. Without a trainer, it is difficult for instructors to evaluate students' skills in integrating PLCs with SCADA, such as creating control logic, managing communications, or troubleshooting. This also limits students from experimenting with various types of industrial processes. The absence of practical tools such as trainers can make learning feel monotonous and less interesting. Furthermore, the design or design of SCADA-based PLC trainers available on the market cannot accommodate the learning needs of Electrical Engineering Education Departments, and the price of SCADA-based PLC trainers on the market is quite expensive, as shown in Fig.1

Fig. 1. SCADA-based PLC trainers on the market.
Source : (https://katalog.inaproc.id)

This problem is increasingly pressing, considering that theory-based learning systems alone are insufficient to equip students with relevant competencies. Learning media that approximate real-world industrial situations are needed so students can directly understand the integration between PLC and SCADA.

Previous research on PLC trainer development has demonstrated the effectiveness of PLC trainer media as a learning medium [4]. Furthermore, a conveyor trainer using an outseal PLC [5] was developed. However, existing training kits are still very simple, with switch and light components as input and output component simulators. One relevant solution is the development of a PLC and SCADA-based automation system trainer using unused laboratory tools and materials. The trainer developed is a SCADA-based PLC trainer. The trainer includes sensor components, VFDs, and valves, along with an HMI interface and a SCADA program for process supervision and monitoring. This approach addresses the limitations of learning media. The development of this trainer utilizes Research & Development (R&D) methods, a systematic

development method designed to ensure targeted, effective, and efficient learning media. With this training, students can practice the skills required by industry, from installation and programming to integrating SCADA-based PLCs into automation systems.

Through the development of this PLC and SCADA-based trainer, not only does it meet learning needs but also prepares graduates to face global competition. Students trained with this training will possess superior competencies, be job-ready, and be able to increase industrial efficiency and productivity. Therefore, this technology plays a crucial role in preparing competent, adaptable, and adaptable graduates to the latest technological developments.

2. Research method

Research and Development (R&D) is a research approach to produce a new product or improve an existing one [6]. In its development, researchers use the Research and Development (R&D) method. Research and Development (R&D) is a research method used to produce a specific product and test its effectiveness [7]. Research and Development (R&D) is the conception and implementation of new product ideas or improvements to existing products [8]. This research method uses the ADDIE model. The research flow begins with the analysis, design, development, implementation, and evaluation stages, as shown in Fig.2.
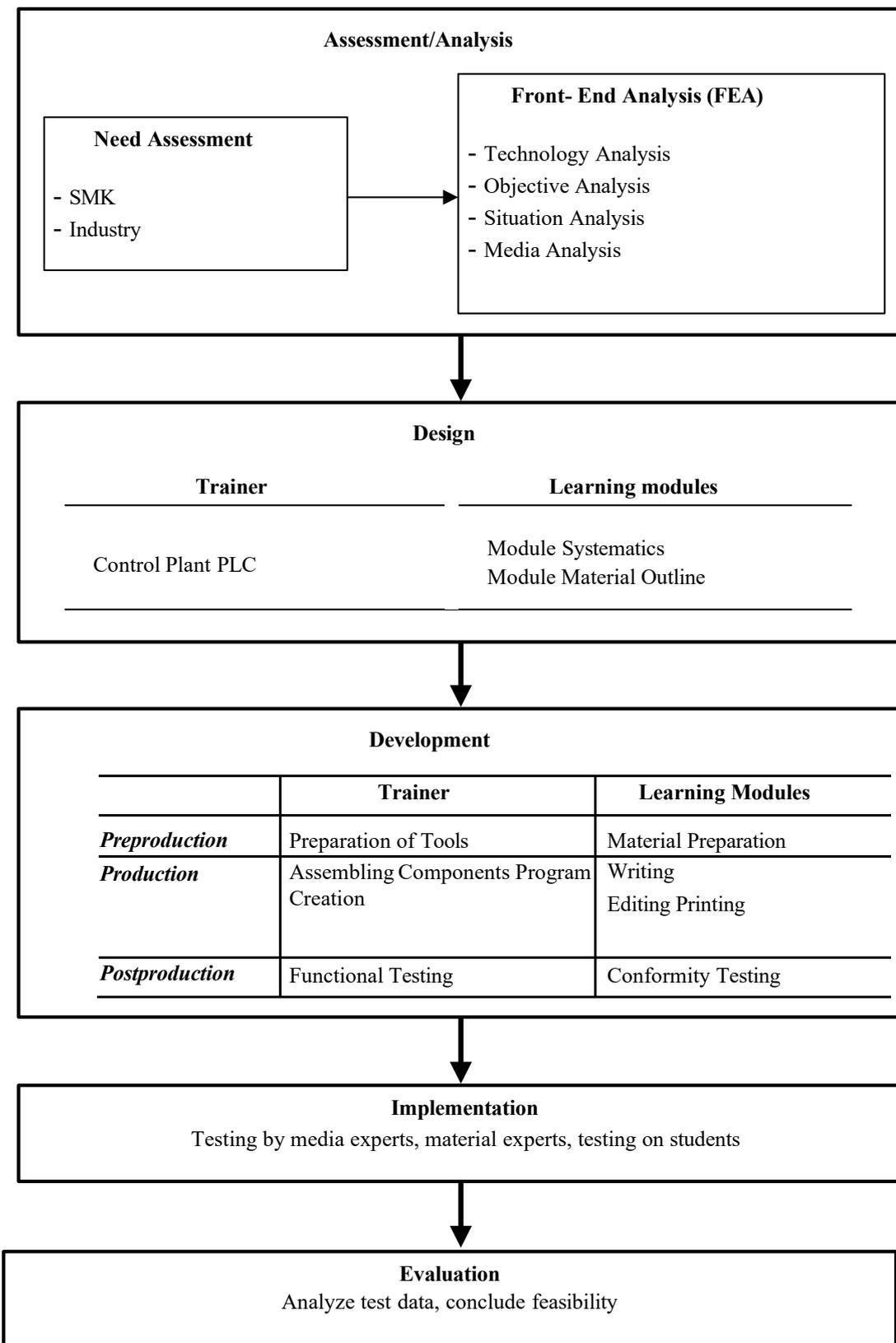
Assessment/Analysis

Need Assessment

- SMK
- Industry

Front- End Analysis (FEA)

- Technology Analysis
- Objective Analysis
- Situation Analysis
- Media Analysis

Design

Trainer	Learning modules
Control Plant PLC	Module Systematics Module Material Outline

Development

	Trainer	Learning Modules
Preproduction	Preparation of Tools	Material Preparation
Production	Assembling Components Program Creation	Writing Editing Printing
Postproduction	Functional Testing	Conformity Testing

Implementation
Testing by media experts, material experts, testing on students

Evaluation
Analyze test data, conclude feasibility

Fig. 2. Research flowchart.

2.1 Research Location and Time

This research will be conducted at the Energy Conversion Laboratory, Department of Electrical Engineering Education, Faculty of Engineering, State University of Medan, from January to October 2025.

D. Population and Sample

The product developed in this research is intended for 30 sixth-semester students at State University of Medan taking the Electric Motor and PLC Installation course. The resulting product is a practical medium in the form of a PLC-based mini SCADA trainer. This trainer is designed to be used as a practical learning tool and to assess the feasibility of the media.

2.2. Research Instruments and Data Collection Techniques

a. Trainer Feasibility Testing

A questionnaire was administered to experts as a testing step to assess the feasibility of the trainer and the developed learning module. Aspects used include material relevance, usability, design, and usability.

b. Functional and Technical Testing

Directly testing the technical and functional performance of each component of the trainer to ensure it works as intended. This serves as the basis for ensuring the trainer is ready for use.

3. Results and Discussion

3.1 Trainer Development

a. Analyze

At this stage, a needs assessment was conducted through interviews with lecturers and industry alumni. The analysis revealed that components frequently used in industry include Omron PLCs, temperature sensors, proximity sensors, and HMI interfaces [9]. The analysis also adjusted the curriculum for the Electric Motor and PLC Installation course to ensure the trainer could be used effectively in learning environments with limited equipment. Focus Group Discussion (FGD) results reinforced the technical specifications, including dimensions, component types, and simulation scenarios.

b. Design

This stage began with designing the automatic control system workflow using AutoCAD and Visio software. The trainer was designed to represent industrial processes with PLCs, VFDs, contactors, pilot lamps, and SCADA components [10]. Block diagrams were created to clarify the relationships between inputs, PLC processes, and outputs. Fig.3 explains how the block diagram of the circuit works
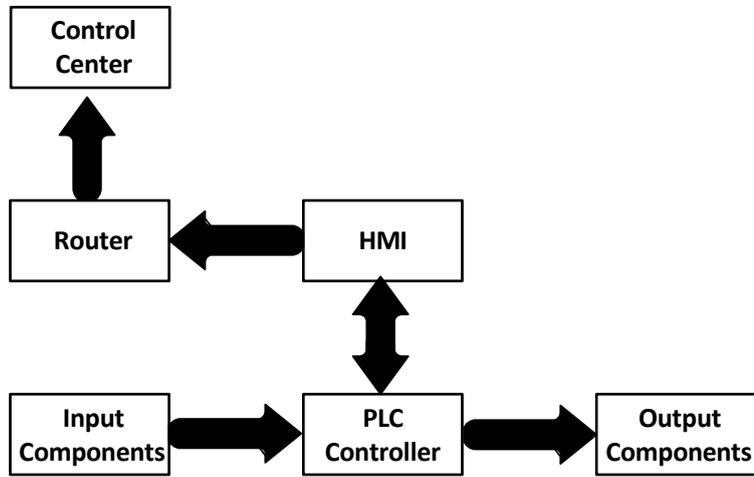
Fig. 3. Trainer block diagram.

Panel layouts and miniature simulators were also designed with labels and LED indicators. CX-Programmer and Easy Builder software were selected for programming and monitoring. The trainer was designed to be modular, ergonomic, and durable, using aluminum profiles and acrylic materials[11]. in Fig.4 is the final design of the trainer
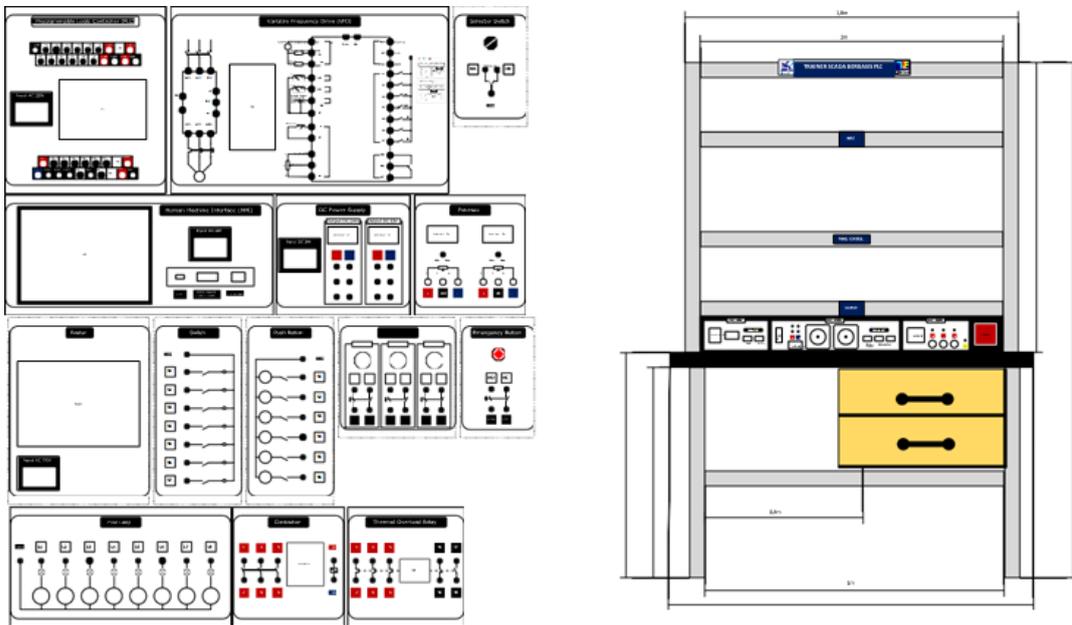

Fig. 4. Trainer layout and frame design.

c. Development

This stage includes preparing tools and materials, assembling physical components, and developing learning worksheets. Assembly was carried out according to the design, starting with the installation of the PLC, HMI, router, and supporting components [12]. Learning modules were also created so that students could understand the practical steps in a structured manner. Technical tests were then conducted to check the connections between components and functional tests using simulation scenarios. The test results showed that the entire circuit functioned as expected. The final result on the trainer is shown in Fig.5.

Fig. 5. Developed control trainer product.

d. Implementation

Initial trials were conducted with expert lecturers to assess feasibility and provide input for design improvements[13]. The trainer was then used by JPTE students in the learning process. Students operated the trainer using the provided worksheets and responded to questionnaires. Additionally, pre- and post-tests were conducted to measure improvements in understanding after using the trainer. Fig.6 is the implementation of the trainer

Fig. 6. Implementation Trainer.

e. Evaluation

The evaluation was conducted quantitatively through assessments by media experts, content experts, and user feedback. Aspects assessed included design, usability, and ease of use. The evaluation results showed an average score of 92.6% from media experts and 90.2% from content experts. The results of the media expert test can be seen in Table 1 and the results of the material expert test can be seen in Table 2.

Table 1. media expert questionnaire results.

Assessment Aspects	Expert 1	Expert 2	Expert 3	Average
Design/Plan	89,2%	92,8%	96,4%	92,8%
Usage/Application	87,5%	93,7%	93,7%	91,6%
Usability	95,0%	87,5%	92,5%	91,6%
Average	91,6%	90,4%	94,0%	92,0%
Media Expert Results		92,06%		"Very feasibility"

Table 2. Content expert questionnaire results

Assessment Aspects	Expert 1	Expert 2	Expert 3	Average
Relevance	85,0%	85,0%	95,0%	88,3%
Usability	90,3%	88,4%	94,2%	90,9%
Average	88,8%	87,5%	94,4%	89.6%
Content Expert Results		90,2%		"Very feasibility"

With a score above 90%, the trainer is declared very suitable for use as a practical and representative learning medium in supporting PLC and SCADA-based control systems at UNIMED.

3.2 feasibility test

The feasibility test involving three media experts and three material experts showed that the trainer fell into the "very feasible" category, with an average validation score exceeding 90%. This indicates that, in terms of design, implementation, and usability, the trainer met the experts' expectations and could be used as a learning tool in the laboratory. As seen in the graph, the media experts gave the highest average score of 92.06, and the material experts gave it 90.2. Fig.7 Final results of the response test by media experts and material experts
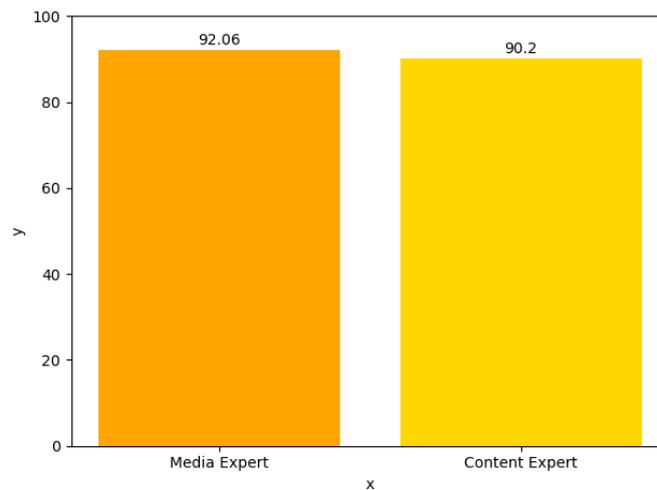

Fig. 7. Graph of final test results of media and Content Expert.

4. Conclusion

This study successfully developed a PLC-based mini SCADA trainer as a learning tool for automated control systems in the laboratory using the ADDIE model through the stages of analysis, design, development, implementation, and evaluation. Based on technical and functional testing, all components including the PLC, HMI, VSD, and contactor performed well and met the specifications[14]. The feasibility assessment from media and material experts showed that the trainer was categorized as "very feasible," with an average validation score exceeding 90%. These findings indicate that the developed trainer meets the design, functionality, and usability requirements, making it suitable to support laboratory learning activities in PLC-based control systems and SCADA at Medan State University.

References

[1] T. A. Ardiansyah and R. Risfendra, "Rancangan Sistem Mounting Device Berbasis PLC Menggunakan HMI," *JTEIN*, vol. 1, no. 2, pp. 49–54, Oct. 2020, doi: 10.24036/jtein.v1i2.16.

[2] I. G. E. Dirgayussa, A. O. Silalahi, I. H. Tambunan, and A. Sagala, "Pelatihan Programmable Logic Controller (PLC) OMRON," *Jurnal Pengabdian Kepada Masyarakat*, vol. 5, no. 3, 2023.

[3] *Standar Kompetensi Kerja Nasional Indonesia Sektor Listrik Sub Sektor Ketenagalistrikan Bidang Instalasi Pemanfaatan Tenaga Listrik*. 2007. [Online]. Available:

https://jdih.kemnaker.go.id/asset/data_puu/SKKNI%202007-170.pdf

[4]   A. Aswardi, R. Mukhaiyar, E. Elfizon, and N. Nellitawati, "Pengembangan Trainer Programable Logic Gontroller Sebagai Media Pembelajaran di SMK Negeri Kota Payakumbuh," *JTEV*, vol. 5, no. 1.1, p. 51, Dec. 2019, doi: 10.24036/jtev.v5i1.104846.

[5]   R. Fauzan and D. Mulyana, "Pengembangan Trainer Conveyor Menggunakan Outseal PLC Pada Mata Pelajaran Instalasi Motor Listrik," *JEVTE*, vol. 2, no. 2, p. 100, Nov. 2022, doi: 10.24114/jevte.v2i2.40540.

[6]   B. Saputro, *Manajemen penelitian pengembangan: (research & development) bagi peyusun tesis dan disertasi*, Cetakan I. Yogyakarta: Aswaja Pressindo, 2017.

[7]   Sugiyono, *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Bandung, Indonesia: CV Alfabeta, 2013.

[8]   E. Winaryati, M. Munsarif, Mardiana, and Suwahono, *Cercular Model of RD&D (Model RD&D Pendidikan dan Sosial)*, Cetakan 1. Semarang, Indonesia: Penerbit KBM Indonesia, 2021.

[9]   K. Triatmaja, P. Budiastuti, and M. Y. Rismarinandyo, "Development of an IoT-Based PLC Trainer : Bridging the Practical Divide in Industrial Automation Education," vol. 5, no. 1, pp. 39–52, 2024, doi: 10.12928/ijemi.v5i1.9732.

[10] F. Anugrah *et al.*, "Perancangan dan Simulasi Trainer Human Machine Interface (HMI) untuk Media Pembelajaran Berbasis CX Designer PLC," vol. 4, no. 2, pp. 136–145, 2020.

[11] U. Pamulang, "Penerapan Trainer Human Machine Interface (HMI) Berbasis CX-Designer Sebagai Media Pembelajaran Programmable Logic Controller (PLC)," vol. 3, no. 4, pp. 27–33, 2018.

[12] T. Logic, C. Dilengkapi, and H. Machine, "Trainerprogrammable Logic Controller Dilengkapi Human Machine Interface (HMI) Guna Penguatan Praktek Otomasi Industri," vol. 5, no. 2, pp. 71–75, 2022, doi: 10.33087/jepca.v5i2.81.

[13] R. A. Silaban and F. Rizal, "The Development of Program Logic Control (PLC) Trainer Media in Vocational High Schools," vol. 4, no. 1, pp. 121–132, 2020.

[14] B. Ramadhan, M. Hidayat, E. Samsul, and S. Ardi, "SCADA SYSTEM USING PLC AND VISUAL STUDIO FOR SCADA TEACHING AID IN POLMAN ASTRA," vol. 3, pp. 316–321, 2018.