JPP

Jurnal Penelitian Pendidikan Indonesia
http://i-rpp.com/index.php/jpp

SCADA Learning Trainer Development for Vocational High School Electrical Engineering Teachers in Semarang

Eko Supraptono, Apriansyah Wibowo*, Tatyantoro Andrasto, Ulfah Mediaty Arief, Sri Sukamta, Fitria Ekarini, Aldo Luhung Baskoro, Fuat Qunefi, Raihan Fa'iq Mubarak, Aisya Fathimah

Universitas Negeri Semarang
*Corresponding author: sultanapri@students.unnes.ac.id

Abstract
One of the most important things that support an effective learning process is the ability of educators to create learning media. The ability to make trainers or teaching aids that support theoretical and practical learning is very important, especially for Vocational High Schools (SMK) teachers in electrical engineering. The purpose of this community service project is to prepare electrical engineering teachers to make Supervisory Control and Data Acquisition (SCADA) trainers suitable for use in the Solar Power Plant (PLTS) curriculum. Fifty teachers from Nurul Baqi Vocational High Schools in Semarang participated in the training for 40 lesson hours delivered with a Project Based Learning (PjBL) approach. The training results showed an increased understanding and application of the SCADA system by the participants, especially in terms of measuring current, voltage, solar radiation, temperature, as well as.

Keywords: *SCADA Trainer Design, Teacher Competency, Productive Teacher, PjBL*

INTRODUCTION

Vocational High Schools (SMK) are expected to provide their students with skills that match the needs of the world of work. Improving facilities and infrastructure in Vocational High Schools is a crucial aspect, given the gap between the material taught in schools and the demands of the industry. In addition, the lack of adaptation from teachers to the rapid development of technology is a factor that increases the gap between the industrial world and schools. This problem is the main cause of the difficulty of Vocational High Schools graduates to be accepted in the world of work. Therefore, it is necessary to adjust the education system and improve facilities so that Vocational High Schools students can be better prepared to face challenges in the industrial world (Aini & Purba, 2022). In February 2023, the Central Bureau of Statistics (BPS) announced the results of the latest survey on the Open Unemployment Rate (TPT) in Indonesia (Badan Pusat Statistik, 2022). The TPT is an indicator to assess the number of workers who have not been absorbed by the labor market. The survey results show that in 2021, the percentage of unemployment rate for graduates of Vocational High Schools reached 9.41%, a significant increase compared to graduates from other education levels, which reached 11.85%. However, in 2023, there was a notable decline in the percentage of TPT for Vocational High Schools graduates, to 9.42%. Nevertheless, Vocational High Schools graduates still occupy the highest position as the largest contributor to the TPT.

The cause of the high unemployment rate can be explained by the lack of competence of Vocational High Schools graduates. This situation is further exacerbated by technological advances that currently adopt the concept of Industry 4.0 (Adha, 2020). One of the latest technological advances in industry 4.0 is the use of Supervisory Control and Data Acquisition (SCADA) in control systems (Raharjo, Ardianto, & Purwitasari, 2022). The use of SCADA is now commonly used in industry as an automatic control system that can be monitored in real-time (Nurjaman & Winanti, 2021). With the advancement of SCADA technology that is able to control and monitor systems in real-time, its application has expanded into the control system of Solar Power Plants (PLTS) to enable real-time control and monitoring (Syahid, Santoso, Riyadi, Juwarta, & Triyono, 2023).

Based on observations with IGVIM partners, it was found that teachers in Vocational Schools, especially electricity majors, have not been able to adapt to the advancement of PLTS technology integrated with Supervisory Control and Data Acquisition (SCADA). In addition, the lack of facilities to improve teacher competence is also a major factor (Sunky & Mukhaiyar, 2023). In the context of the development of the Supervisory Control and Data Acquisition (SCADA) system, teachers have difficulty understanding the system due to limited learning facilities and practical equipment (Satria, Widjanarko, & Anis, 2023). Teachers' learning facilities are limited to online resources such as YouTube and video tutorials, while in the real world, teachers are expected to organize practical learning.

In order to support the development of Supervisory Control and Data Acquisition (SCADA) learning in the future, a "Training of Trainer (TOT) program has been implemented especially for Vocational High Schools teachers majoring in Electricity". With this TOT, it is expected that teachers can gain an in-depth understanding of SCADA application and management, and can transfer the knowledge to students in an effective and up-to-date way (Wahono & Sukir, 2020). The implementation of this program is also expected to help prepare Vocational High Schools students to face the growing technological challenges in the energy and automation industry, as well as improve the overall quality of education in the field of electricity engineering.

Currently, Vocational High Schools (SMK) face challenges in integrating learning facilities and infrastructure with the development of the industrial world which is currently using industry 4.0 (Aini & Purba, 2022). The impact of this mismatch can be seen in the low acceptance rate of Vocational High Schools graduates by the industrial sector. Successful integration between Vocational High Schools and industry is expected to improve the skills of Vocational High Schools students, providing a stronger foundation for their success in the job market. One of the other factors contributing to the low competency of Vocational High Schools students is the lack of adaptation of teachers to the development of industrial technology. Such problems include teaching methods that still rely on manual systems for control concepts related to PLTS system processes, while PLTS systems have switched to Supervisory Control and Data Acquisition (SCADA)-based automated systems.

As a solution to this problem, it is necessary to train teachers to develop Training of Trainer (TOT) designs for Supervisory Control and Data Acquisition (SCADA) systems, especially for Vocational High Schools teachers majoring in Electricity (Nuryanto, 2021). The ability to design this trainer, with the hope of increasing teacher competence related to the system. Increased teacher competence is expected to have a positive impact on improving student skills in their respective schools (Zulfian & Wrahatnolo, 2020).

METHOD

A. Training Program Flow

The implementation of this service activity consists of several elements starting with the formation of a team for division of responsibilities and coordination, followed by communication and coordination with Nurul Barqi Vocational High Schools to reach a program agreement. After that, the MoU was signed and the venue and learning tools were prepared, including materials, tools, and practicum materials. Registration and data collection of participants are carried out after the preparation is complete.

The implementation of the program includes the presentation of SCADA training materials and trainer development by the arranged resource persons. After the program, an evaluation was conducted to identify shortcomings for future improvement. The program ended with the awarding of certificates to participants as a form of appreciation and proof that they had understood the material presented.

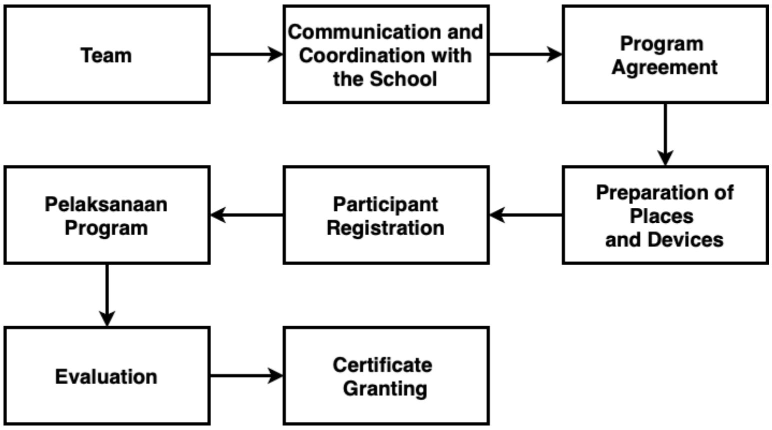

Figure 1. Training Flowchart

B. Training Program Target

The objectives and expected outcomes of the training related to Solar PV technology, where each learning objective is designed to provide participants with comprehensive skills, ranging from basic understanding to more in-depth analytical capabilities. Participants are expected to not only understand the basic concepts, but also be able to apply the knowledge in a practical context related to the management of Solar PV systems.

The learning objectives include the ability to identify Solar PV system characteristics, measure current, voltage, solar radiation, and temperature, calculate power and efficiency, and analyze variables that affect the system characteristics. After the training, participants are expected to achieve competencies in accordance with the objectives, namely being able to identify, measure, calculate, and analyze the results of measurements of Solar PV variables. The training is systematically designed to ensure each participant gains optimal knowledge and skills, including pretests, technical sessions on solar PV components and SCADA integrated with solar PV, to SCADA simulation and programming. The training ends with a post-test to measure the improvement of participants' competencies after the training.

C. Training Program Implementation

SCADA learning trainer development training for Vocational High Schools teachers majoring in electricity engineering was held at Nurul Barqi Vocational High Schools, Gunungpati, Semarang City, on Wednesday, August 7, 2024, from 09.00 to 13.00 WIB. The training was attended by 25 participants consisting of 20 productive teachers majoring in electricity engineering and 5 adaptive and normative teachers. It is hoped that the participants will be able to master the basic and advanced techniques needed to support the learning process at school, and improve the quality of education in the field of electricity engineering.

D. Achievement Indicators

To measure the extent to which participants are able to understand and apply the material taught, achievement indicators are developed as a measure of success in mastering the necessary concepts, technical skills and analytical abilities. These achievement indicators allow trainers to systematically monitor participants' progress and ensure that learning objectives are achieved in accordance with predetermined standards, as detailed in Table I.

Table 1. Indicators of Achievement for Participants

No.	Material		Indicator
1.	Components of solar power plant	1.1	Participants are able to understand the function and role of each main component in a solar power system, such as solar panels, inverters, batteries, and control systems.
		1.2	Participants are able to identify and explain how each component works in the PLTS system circuit.

2.	PLTS input/output	2.1 Participants are able to understand and identify the types of inputs (e.g. solar radiation) and outputs (e.g. electrical energy) of a solar PV system. 2.2 Participants are able to analyze input and output data to evaluate the performance of solar power systems.
3.	Solar Power Plant Installation	3.1 Participants are able to plan and carry out the installation of PLTS systems in accordance with applicable safety and engineering standards. 3.2 Participants are able to inspect and test solar PV installations to ensure that the system is functioning properly.
4.	SCADA System	4.1 Participants are able to understand the basic concepts and functions of the SCADA system in monitoring and controlling PLTS systems. 4.2 Participants are able to identify the main components in the SCADA system and their functions in the operation of solar power plants.
5.	SCADA Programming	5.1 Participants are able to write and implement simple SCADA programs to control and monitor solar power systems. 5.2 Participants are able to perform basic troubleshooting on SCADA programs to solve problems that arise.
6.	SCADA system simulation	6.1 Participants are able to simulate the SCADA system to test the performance and functionality of the SCADA program that has been developed. 6.2 Participants are able to analyze simulation results to improve the effectiveness and efficiency of the SCADA system used.
7.	SCADA Integration with Solar PV	7.1 Participants are able to integrate the SCADA system with the PLTS and ensure communication between the two systems runs smoothly. 7.2 Participants are able to monitor and control the solar power system through the SCADA interface in real-time, and take appropriate actions based on data obtained from the system.

In addition to the achievement indicators, there is a target achievement framework which is a strategic guide to ensure each training objective is achieved as expected. This framework serves as a reference in organizing the steps needed to achieve the competency targets that have been set. Through this framework, trainers can map out the training process in stages, ensuring that each material is delivered appropriately, and participants gain adequate understanding and skills. The Target Achievement Framework also assists in identifying key factors that support training success and provides a clear picture of the expected outcomes of each training session, as illustrated in Figure 2.

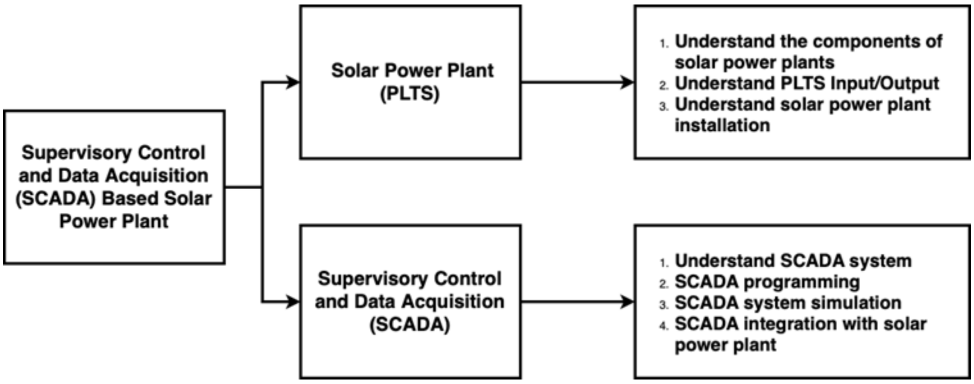

Figure 2. Target Achievement Framework

E. Training Tools

The training tool used in this activity is a solar cell trainer kit, which is a simulation tool designed to introduce participants to the working principles and characteristics of solar power generation systems (Solar PV). The trainer kit consists of the main components of the Solar PV system, such as solar panels, inverters, as well as measuring devices for current, voltage, solar radiation, and temperature. By using this kit, participants can perform various measurements and simulations directly, so that they can practically understand how the Solar PV system works, calculate the efficiency of the power produced, and analyze the factors that affect the performance of the system. The use of this trainer kit is very helpful in strengthening theoretical understanding through interactive and applicable learning experiences. The following is the documentation of the tools used in the training.

Figure 3. Service Training Tool

RESULTS AND DISCUSSION

A. Service Results

SCADA learning trainer development training for Vocational High Schools teachers majoring in electricity engineering was held on August 7, 2024 at Nurul Barqi Vocational High Schools, Semarang City. Organized by the FT UNNES service team, the training was attended by 25 Vocational High Schools teachers with the aim of improving their skills and knowledge in SCADA systems. The event preparation started with coordination and MoU signing between the organizer and Nurul Barqi Vocational High Schools, followed by participant registration and device preparation. During the training, participants learned about solar power plant components, system installation, as well as SCADA integration and programming using a solar cell trainer kit.

The pretest was conducted before the training to evaluate the participants' initial understanding of SCADA and PLTS systems, while the posttest was conducted after the training to assess the effectiveness of learning and the participants' ability to absorb the material. The posttest results are used to evaluate the success of the training and provide feedback for future program improvements.

These two tests play an important role in measuring the extent to which the training succeeded in improving participants' knowledge and skills.

Analysis of pretest and posttest data showed significant improvements in participants' understanding and skills. Participants' understanding of PLTS components increased from 16% to 56%, while understanding of PLTS inputs-outputs rose from 20% to 48%. SCADA programming skills increased from 20% to 44%, and SCADA simulation skills from 28% to 52%. Although the integration of SCADA with PLTS only showed an increase of 8%, overall this training succeeded in achieving its goal of improving the quality of teacher learning in the field of electricity engineering.

B. Discussion

The SCADA learning trainer development training at Nurul Barqi Vocational High Schools successfully improved participants' technical competencies, especially in understanding SCADA architecture and components as well as the use of software such as Wonderware and WinCC. Participants benefited greatly from hands-on practice that helped them understand abstract concepts, which were previously difficult to grasp only through theory. In addition, the training also improved participants' readiness to become SCADA trainers in their respective institutions, although some still felt the need for further experience in real industrial practices.

Post-training discussions showed that participants plan to develop interactive learning methods, such as project-based learning, to teach SCADA. They also suggested developing more structured training modules with easily accessible digital resources, to support the continuity of SCADA learning across institutions. However, challenges include hardware limitations and the need to adapt to technological developments, such as the integration of SCADA with IoT and cloud-based systems.

Although this training was successful in improving the knowledge and skills of the participants, there is still a need for further training that focuses on more complex SCADA applications in the industry. In addition, a communication forum between trainers is needed to share information and experiences, as well as assistance in the implementation of training results so that the impact is broader and more effective.

CONCLUSION

The SCADA learning trainer development training at Nurul Barqi Vocational High Schools organized by the Faculty of Engineering of Semarang State University successfully improved participants' knowledge and skills, especially in understanding PLTS components, system installation, and SCADA. Although the training was effective, there were challenges such as hardware limitations and the need to keep up with technological developments. It is recommended to continue further training that focuses on practical applications and developments in SCADA technology, as well as establishing a communication forum between trainers to strengthen collaboration. It is also necessary to assist the implementation of the training results by involving various parties for wider effectiveness.

REFERENCES

Adha, L. A. (2020). Industrial digitalization and its effects on employment and labor relations in Indonesia. *Journal of Legal Compilation*, 5(2), 267–298. https://doi.org/10.29303/jkh.v5i2.49

Aini, Y. N., & Purba, Y. A. (2022). Analysis of employment absorption and link & match programs for graduates of Vocational High School (SMK) marine & fisheries programs. *Journal of Marine Fisheries Socio-Economic Policy*, 12(1), 23. https://doi.org/10.15578/jksekp.v12i1.10339

Nuryanto, L. E. (2021). Design of a hybrid power plant control system (PLN and PLTS) with a capacity of 800 Wp. *Orbith*, 17(3), 196–205.

Nurjaman, D. F., & Winanti, N. (2021). Brown Field Project SCADA on the operation of hemodialysis mixing tank at PT Sanbe Farma. *Proceedings of Industrial Research Workshop and National Seminar,*Vol. 12, pp. 1–5. https://doi.org/10.35313/irwns.v12i0.2646

Raharjo, A. B., Ardianto, A., & Purwitasari, D. (2022). Random forest regression for solar power plant power production prediction. *Briliant: Journal of Research and Conceptual*, 7(4), 1058. https://doi.org/10.28926/briliant.v7i4.1036

Satria, A., Widjanarko, D., & Anis, S. (2023). Developing Adobe Flash media with Android-based to improve students' learning outcome in anti-lock brake system. *Journal of Vocational Career Education*, 8(100), 1–8.

Sunky, R., & Mukhaiyar, R. (2023). Implementation of Web SCADA on solar power plant system. *Orbith*, 4(2), 792–798.

Syahid, S., Santoso, A., Riyadi, A. H., Juwarta, J., & Triyono, T. (2023). Monitoring and design of solar power plant for energy source of automatic fish feeder. *Orbith: Scientific Magazine of Engineering and Social Development*, 19(1), 106–113.

Wahono, S. J., & Sukir, S. (2020). Development of electrical lighting installation trainer kit with sensor complement at SMK Negeri 1 Sedayu. *Journal of Electrical Education*, 4(2), 158–164. https://doi.org/10.21831/jee.v4i2.35829

Zulfian, N. D., & Wrahatnolo, T. (2020). Development of trainers and jobsheets for electromagnetic control of Arduino-based 3-phase induction motors using Bluetooth sensors for class XII electric motor installation subjects at SMKN 2 Surabaya. *Journal of Electrical Engineering Education*, 9(3), 525–531. https://doi.org/10.26740/jpte.v9n03.p525-531