ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika

ISSN(p): 2338-8323 | ISSN(e): 2459-9638 | Vol. 12 | No. 3 | Halaman 759 - 771
DOI : http://dx.doi.org/10.26760/elkomika.v12i3.759 Juli 2024

Evaluation of The Impact of Photovoltaic Laboratories Development on Higher Education and Industry

MARSUL SIREGAR[1], CRISTONI HASIHOLAN PARDOSI[2], KAREL OCTAVIANUS BACHRI[3], TAJUDDIN NUR[4], LANNY W. PANDJAITAN[5]

[1,3,4,5]Department of Electrical Engineering Atma Jaya Catholic University of Indonesia, Jakarta, Indonesia
[2]Graduate of Electrical Engineering Atma Jaya Catholic University of Indonesia, Jakarta, Indonesia
Email: marsul.siregar@atmajaya.ac.id

Received 17 May 2024 **|** Revised 12 June 2024 **|** Accepted 9 July 2024

ABSTRAK

Transisi energi dari energi konvensional ke energi terbarukan semakin meningkat, sejalan dengan kesadaran akan keberlanjutan penggunaan energi terbarukan secara global. Laboratorium Fotovoltaik Universitas Katolik Indonesia Atma Jaya berkapasitas 5,2 kWp dikembangkan untuk mendukung pendidikan dan pelatihan industri. Tulisan ini menjelaskan dampak positif Laboratorium terhadap sudut pandang mahasiswa dan industri, yaitu tentang kinerja panel surya, evaluasi sistem on-grid dan off-grid, serta pemeliharaan system. Berdasarkan kepuasan mahasiswa disimpulkan sangat puas dan puas berkisar 93,17%, dengan rincian sangat puas 50,14%, dan puas 43,03%. Sedangkan Industri menunjukkan sangat puas dan puas sebesar 93,96%, dengan rincian sangat puas 44,99%, dan puas 48,97%.

***Kata kunci**: Fotovoltaik, Energi Surya, Pendidikan Tinggi, Studi Eksploratori.*

ABSTRACT

The energy transition from conventional energy to renewable energy is increasing, in line with the awareness of the sustainability of renewable energy use globally. The Atma Jaya Catholic University Photovoltaic Laboratory with a capacity of 5.2 kWp was developed to support industrial education and training. This paper describes the positive impact of the Laboratory from the perspective of students and industry, namely on the performance of solar panels, evaluation of on-grid and off-grid systems, and system maintenance. Based on student satisfaction, it is concluded that very satisfied and satisfied are around 93.17%, with details of very satisfied 50.14%, and satisfied 43.03%. While the industry shows very satisfied and satisfied of 93.96%, with details of very satisfied 44.99%, and satisfied 48.97%.

***Keywords**: Photovoltaic, Solar Energy, Higher Education, Exploratory Study.*

1. INTRODUCTION

In the past few decades, the global climate crisis and increased awareness of energy sustainability have driven a worldwide shift towards the use of renewable energy sources **(Setiawan et al., 2022) (Le et al., 2022) (Kumar et al., 2018)**. To overcome dependence on fossil fuels and at the same time reduce the effects of greenhouse gases, nowadays worldwide shift to implementing renewable energy resources such as Photovoltaic Technology. Photovoltaic technology, which converts sunlight into electrical energy, has garnered significant attention as a clean and sustainable solution **(Kaliyamoorthy et al., 2022) (Vasita et al., 2017) (Singh et al., 2019)**.

As an archipelagic nation, Indonesia possesses substantial potential for harnessing solar energy. The limitations of power generation centers in isolated islands make solar energy a promising choice **(Winanti, Halimi, et al., 2018)**. Furthermore, Indonesia's location near the equator provides a daily solar energy potential ranging from 2.82 to 4.62 kWh/kWp **(Winanti, Purwadi, et al., 2018)**. Under normal conditions, Indonesia receives solar irradiation of 3.45 to 5.74 kWh/m2 daily, as shown in Figure 1. In accordance with government regulations, Indonesia has set targets of at least 23% of renewable energy by 2025 and 31% by 2050 **(Suharyati et al., 2019) (Gumintang et al., 2020)**. The country holds significant potential in renewable energy to achieve these goals.

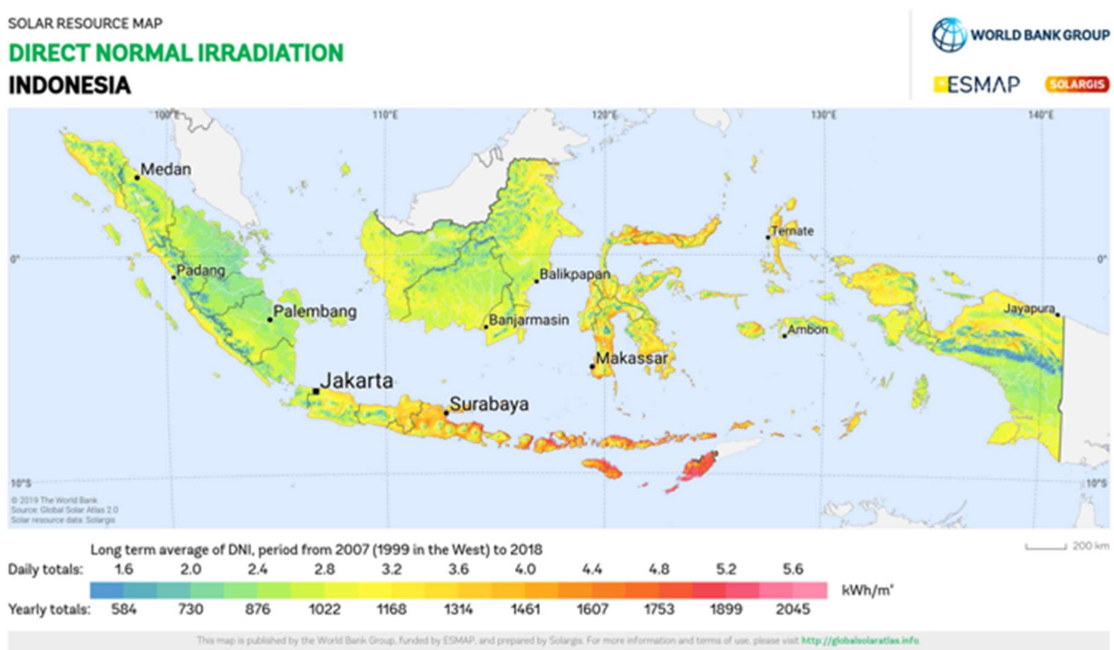

Figure 1. Normal Irradiation Received in Indonesian Regions (*Global Solar Atlas*, n.d.)

The application of photovoltaic (PV) technology as a solar panel in Indonesia has increased rapidly particularly in the higher education and industrial sectors. Advancements in photovoltaic technology have led to more efficient and affordable solar panels **(Tobias et al., 2020)**. Therefore, higher education institutions must prepare the next generation with a strong understanding of this technology. Industries are also increasingly interested in harnessing renewable energy sources to reduce operational costs and environmental impacts.

In response to the above trend, Atma Jaya Catholic University of Indonesia developed and established a 5.2 kWp Photovoltaic Laboratory. This laboratory aims to support higher education in the field of renewable energy, facilitate innovative research, and provide practical training to industry professionals interested in integrating photovoltaic technology into their operations **(Ciocia et al., 2020) (Hartikainen et al., 2019) (Zalewski et al., 2019)**.

In the context of Photovoltaic Laboratory development, it is essential to gather feedback from both students and industry stakeholders **(Martin et al., 2020)**. This is crucial to assess their satisfaction levels with the laboratory's effectiveness. Through this approach, issues or shortcomings in laboratory usage can be identified and rectified, ensuring ongoing improvements in education and training in photovoltaic technology.

This article will outline the steps in the development of the 5.2 kWp Photovoltaic Laboratory, including laboratory architecture, applications used by students for experiments, practical lessons that can be developed, exploratory studies to evaluate impact, and conclusions summarizing the significance of this laboratory in supporting higher education and industrial training in photovoltaic technology.

2. LABORATORY DEVELOPMENT METHOD

2.1 Design and Architecture Laboratory

The Photovoltaic Laboratory Atma Jaya located in Jaya Campus 3, Bumi Serpong Damai, Indonesia. Based on data from the "Global Solar Atlas," the area surrounding the campus receives solar irradiation of approximately 4 kWh/m² per day. The installed Photovoltaic (PV) system has a capacity of 5.25 kWp and occupies an area of 30 square meters. This location was selected due to the absence of obstructions such as tall trees or buildings and was planned as an open area. The Laboratory structure and dimensions as the Front and Side View shown below in figures 2 and 3.

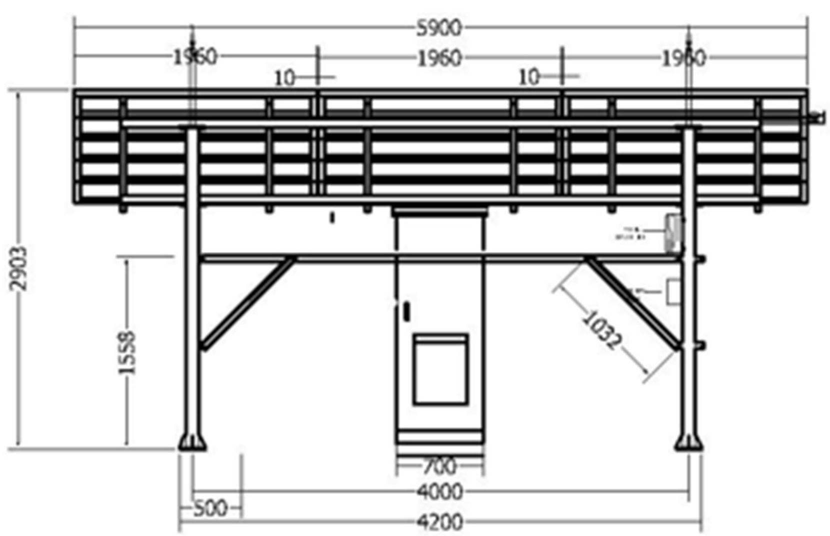

Figure 2. Front View of Laboratory Structure and Dimensions

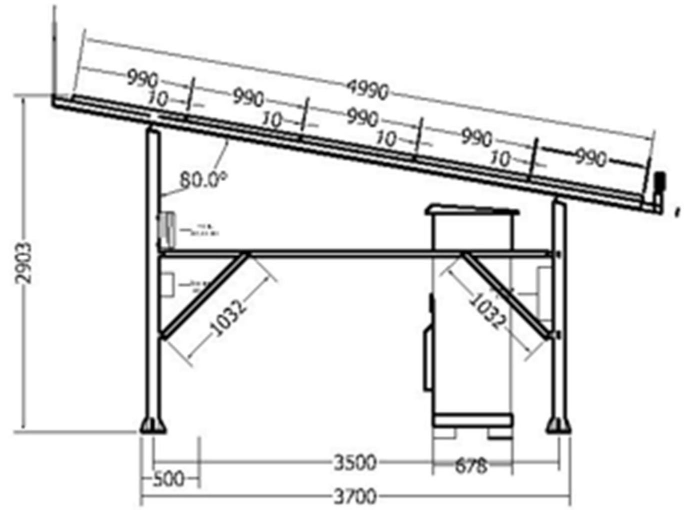

Figure 3. Side View of Laboratory Structure and Dimensions

2.2 System Diagram of Photovoltaic Laboratory

During the operational period, the PV system will run without feeding energy into the main grid, with the main electrical grid used as a reference for voltage and frequency. The Diagram Block of the PV laboratory illustrates using two inverters for experiments involving the DC and AC coupling analysis in the PV system as shown in Figure 4. The final development construction of Photovoltaic laboratory shown in Figure 5.

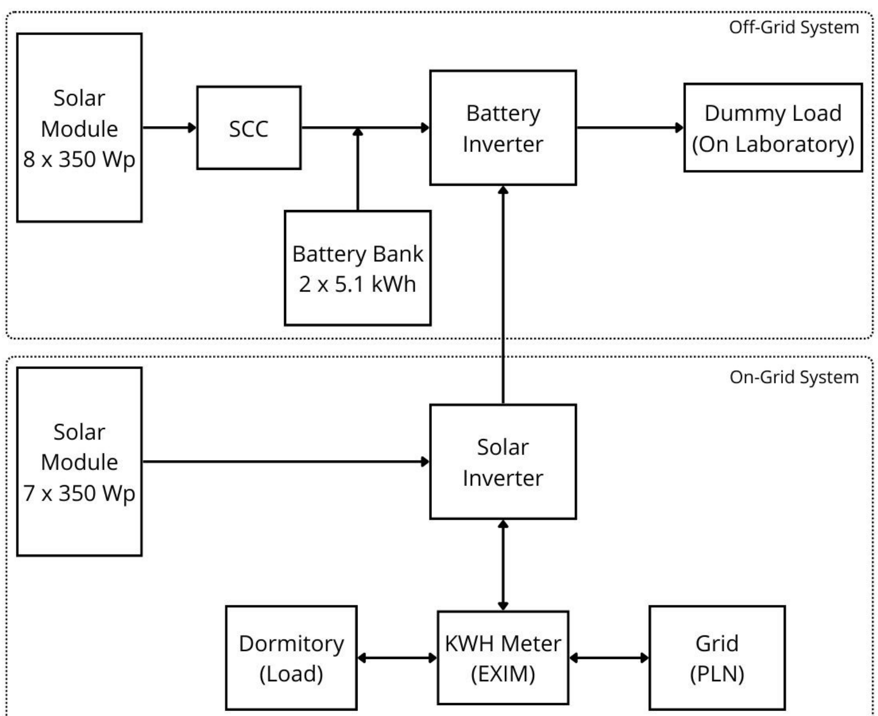

Figure 4. Diagram Block Photovoltaic Laboratory

Figure 5. Photovoltaic Laboratory

Various components supporting the photovoltaic laboratory system include:

a. Photovoltaic Modules
In this project, Monocrystalline silicon solar modules with a power capacity of each module are 350 Wp and an efficiency of 18% are utilized. There are 15 modules arranged in two arrays. The first array consists of seven modules connected in series for the on-grid system. The second array comprises four strings, each consisting of two modules.

b. Battery Inverter
This inverter is used in off-grid mode with a total output power of 3500 VA and operates bidirectionally. The output of the inverter is 220 V, 50 Hz, single phase delivers a pure sinus waveform. With an input of 48 Vdc from the battery to the inverter, It will equivalent to the AC Input voltage ranging from 160 V to 250 V, and a frequency range from 45 Hz to 60 Hz. The inverter has LED/LCDs, battery management systems, and power control to optimize system performance.

c. Solar Charge Controller
This component controls battery charging with a capacity of 4 kWp and uses MPPT (Maximum Power Point Tracking) control algorithms. The nominal input voltage is 48 V, and the controller has protection systems to prevent overloading, reverse polarity, and voltages above and below safe limits.

d. Solar Inverter
This inverter is used in on-grid mode with an output power of 2.5 kW. The inverter generates an output voltage of 230 V in single-phase with a pure sine waveform. The inverter is equipped with a web-based communication interface for remote monitoring to optimize system performance.

e. Battery Bank
LiFePo4 battery banks with an output voltage of 51.2 V and a total storage capacity of 10.000 Wh are used for energy storage. These batteries have a recharge capacity of up to 2000 times with a discharge capacity of up to 90%.

f. Dummy Load
The Photovoltaic Laboratory uses artificial load components to simulate various load conditions on the photovoltaic system. The dummy load components consist of

resistors with resistances of 2 kW and 3 kW. Also, 6 pieces of the bulb with the capacity of each bulb are 100W. Resistors are used to simulate constant power loads or load variations, while bulbs are used to simulate different power consumption in the PV system. This combination allows for testing and validating the PV system's performance in various situations with no need for actual equipment.

g. Control and Monitoring System
   Local and remote monitoring systems exist in off-grid mode. Local monitoring and control use the RCC-03 display, while remote monitoring and control use PLC and SCADA. This system monitors parameters in the off-grid system and controls the dummy load. The on-grid system has a web-based monitoring system that can be accessed via https://ennexos.sunnyportal.com. This monitoring system is integrated with a pyranometer and weather station sensor.

2.3 Operation System

The photovoltaic laboratory can operate in several modes, i.e., an on-grid PV system, an off-grid PV system, or a hybrid simultaneously. In the mode of on-grid PV, the system is connected to the main electrical grid through a solar inverter with seven solar panels linked in series as shown in Figure 6. This system integrates with a pyranometer and weather station as the central data hub for solar irradiation and weather.

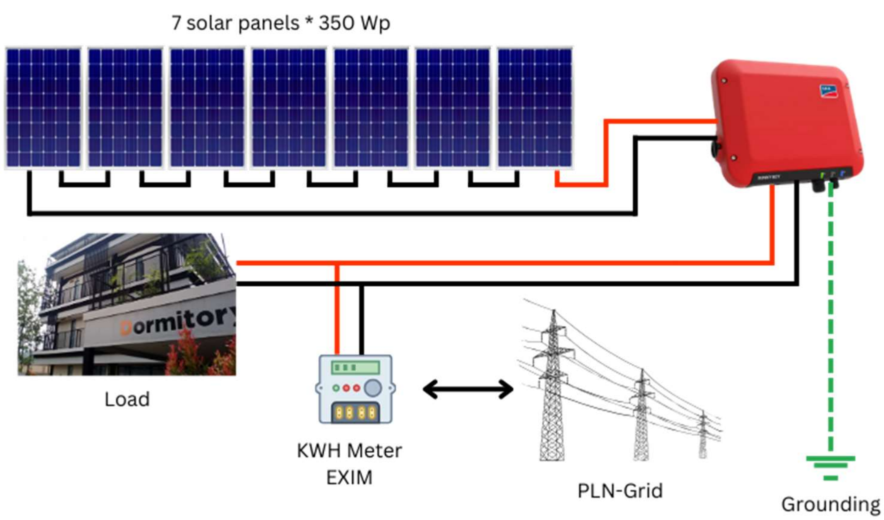

Figure 6. On Grid System of PV Laboratory

Figure 7 shows the Off-Grid System of PV laboratory. When the off-grid PV mode, the system operates independently without being connected to the main electrical grid. The system is supported by eight solar panels, each string consisting of two panels connected in series. It is integrated with a solar charge controller as a battery regulator and a battery inverter for converting DC to AC power for load requirements. This system has an energy storage capacity of 10 kWh.

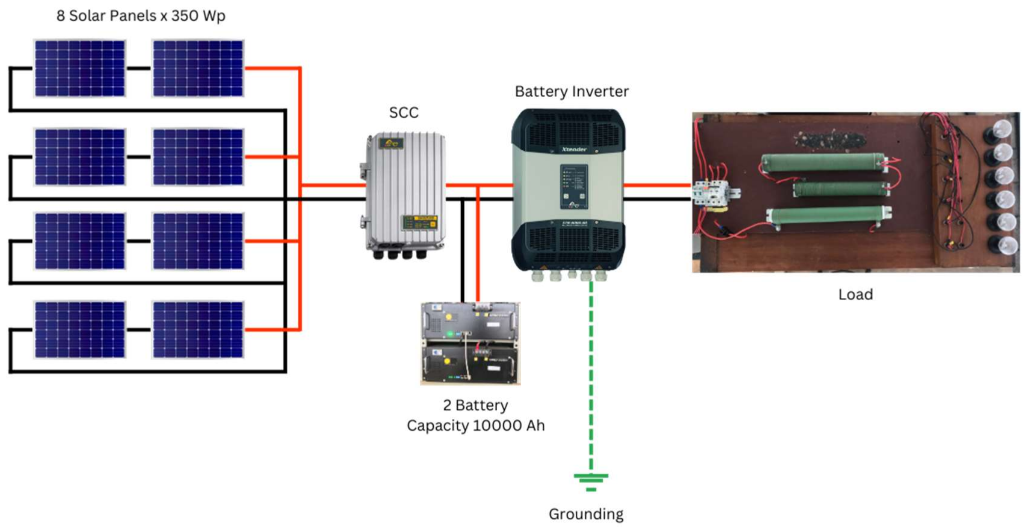

Figure 7. Off Grid System of PV Laboratory

These two modes can be interconnected in a hybrid mode, allowing them to operate together. In hybrid mode, the battery inverter acts as a regulator to control power export-import to and from the battery.

2.3 Practical Learning in The Laboratory

The photovoltaic laboratory can operate in several modes, i.e., an on-grid PV system, an off-grid PV system, or a hybrid simultaneously. In the mode of on-grid PV, the system is connected to the main electrical grid through a solar inverter with seven solar panels linked in series as shown in Figure 6. This system integrates with a pyranometer and weather station as the central data hub for solar irradiation and weather.

The 5.2 kWp Photovoltaic Laboratory at Atma Jaya Catholic University of Indonesia provides comprehensive opportunities for practical learning. This laboratory encompasses an understanding of photovoltaic technology, system monitoring and control, and PV system management. The laboratory can accommodate up to 15 students in one session. Here are the key aspects of practical learning accessible through this laboratory:

a. Solar Panel Performance Measurement Define
   This laboratory enables students to understand how to measure the performance of solar panels directly. They will learn how to measure the actual power output of solar panels, measure the generated voltage and current, and comprehend module efficiency. This practice provides an in-depth understanding of the function of solar panels in actual conditions.
b. On-Grid and Off-Grid System Evaluation
   Students can learn the differences between PV systems connected to the main electrical grid (on-grid) and standalone systems (off-grid). They can understand how to measure and analyze the performance of both system types, including the supporting components of the system. This practice helps understand each system's benefits, limitations, and challenges.
c. PV System Maintenance and Care
   Practical learning involves understanding the maintenance of photovoltaic systems. Students can participate in workshops and maintenance exercises that include cleaning

solar panels, replacing faulty components, and battery monitoring. This helps them acquire the practical skills necessary for maintaining PV systems in the real world.

d. Monitoring PV System Performance
In this laboratory, students will gain hands-on experience in monitoring as well as analyzing the real-time PV system's performance. They will understand how to use SCADA systems to monitor system parameters. This practice helps them quickly identify changes in system performance and take necessary actions.

e. PV System Control and Regulation
Practical learning also includes PV system control. Students will learn how to use PLCs to control the operation of installed load components and switch the system operation mode from off-grid to on-grid. They will understand how to automate the system.

f. Fault Investigation and Repair
Students will understand how to identify faults in PV systems and how to address these issues. They will practice the essential role of troubleshooting in system maintenance and repair. This involves detecting malfunctions in solar panels, inverters, or battery systems and taking appropriate repair steps.

g. Energy Usage Optimization
The laboratory also provides insights into optimizing energy usage. Students will understand how to configure PV systems to fulfill the energy requirement, integrate other sources of energy as well as the grid electricity, and maintain a balance between energy supply and demand.

Finally, students will be introduced to an overview of the economic analysis related to the implementation of photovoltaic technology. They will learn how to calculate the economic feasibility of investing in solar energy, including initial costs, energy savings, and return on investment. With the knowledge they acquire, students will apply all the knowledge they have gained, providing them with real-world experience in designing, calculating, and planning photovoltaic system installations.

3. RESULT AND DISCUSSION

After the laboratory has been commissioned and has been operated, the directed research focuses on an exploratory study to evaluate the impact of the laboratory's use in the context of practical classes. The laboratory was tested by the participants of 124 person which consist of 66 person of the electrical engineering students and 58 representatives from various companies and industries. Students carried out seven practical lessons on photovoltaic technology, system monitoring and control, and system management. After completing each session, they were required to produce practical reports.

The Practical Report serves as a summary of the practical work, including task descriptions, equipment used, procedures followed, observation results, and data analysis obtained during the practical work. Practical reports help students detail and communicate their experiences in executing practical tasks clearly and structurally.

The Experiment Results Report includes experimental data, measurement results, graphs, and data analysis obtained during experiments. Its purpose is to examine students' understanding of the scientific concepts underlying the experiments and their ability to interpret experimental results correctly. The experiment results report provides a deeper insight into students' analytical abilities to analyze data and draw conclusions based on the experiments they conducted. At the end of practical learning, students are asked to provide feedback through an evaluation test that includes several questions measuring the level of satisfaction with practical learning.

Furthermore, the industry has been actively involved in various efforts to maximize the benefits of the photovoltaic laboratory. They have provided support in the form of assessing the laboratory's performance in applying photovoltaic technology in real industrial situations. Additionally, the industry has also participated in providing insights regarding business opportunities and real-world applications of photovoltaic technology. In order to maintain the sustainability and use of future project data, the industry also plays an active role in supporting the collection, analysis, and application of data generated from the laboratory.

The method used to evaluate the photovoltaic laboratory involved several systematic steps to measure effectiveness and user satisfaction. Further details on the evaluation method used follow:

a. Evaluation Form Design
   A Google Form was used as the main tool for collecting evaluation data. The form was designed with structured questions covering various aspects of user experience, such as satisfaction with learning, ease of use of the equipment, accessibility of the laboratory, and practical benefits gained. Students and industry representatives are asked to rate these questions using a scale of 5 to 1, where 5 indicates Extremely Satisfied, 4 indicates Satisfied, 3 indicates Quite Satisfied, Dissatisfied, and 1 indicates Extremely Dissatisfied. This feedback is collected through the Google Form platform as the evaluation test medium.
b. Measured Question Approach
   The questions in the evaluation form were designed to reflect the objectives of the laboratory and the expectations of the users (students and industry representatives). This includes evaluation of theoretical and practical understanding, ability to use technologies such as PLC and SCADA, and the impact of the laboratory on economic understanding and contribution to the renewable energy industry.
c. Data Collection and Statistical Analysis
   The data collected from the evaluation forms were statistically analyzed to thoroughly evaluate user responses. This analysis included calculation of mean scores, distribution of responses, and establishment of trends related to user satisfaction and perceptions of various aspects of the laboratory.
d. Interpretation of Results and Conclusions
   The results of the statistical analysis were used to interpret the extent to which the laboratory met the evaluation objectives and user expectations. This interpretation not only focuses on the level of user satisfaction, but also includes implications for curriculum development, practical benefits for students, and applications of the technology in an industrial context.
e. Recommendations for Development
   Findings from the evaluation are used to formulate strategic recommendations, including laboratory improvements and further development. Input from industry is also considered to enhance the relevance of the laboratory to industry needs, ensuring that the evaluation results lead to tangible improvements in photovoltaic technology education and applications.

This evaluation method is designed to provide a comprehensive understanding of the effectiveness of the photovoltaic laboratory in supporting student learning and the application of technology in practical and industrial contexts. Table 1 provides the information or the distribution of participants as well as the representatives involved in evaluating the satisfaction level with the laboratory. Table 2 shows the Student Satisfaction Level and table 3 provides the Industrial Satisfaction Level.

Table 1. Participants Involved in Satisfaction Evaluation

Participants	Total Participants
Electrical Engineering	42 people
Master of Electrical Engineering	24 people
Companies/Industries	58 people

Table 2. Student Satisfaction Level Evaluation Result

Feedback Questions for Students	Satisfaction Level (%)				
	5	4	3	2	1
Satisfaction with Learning	51,5	48,5	0	0	0
Ease of Use	56,1	43,9	0	0	0
Accessibility	28,8	30,3	27,3	9,1	4,5
Completeness of Components	50	34,8	15,2	0	0
Ease of Using PLC and SCADA	43,9	43,9	12,1	0	0
Ease of Using Web Monitoring System	54,5	45,5	0	0	0
Interaction with Instructors	53	47	0	0	0
Quality of Data for Further Use in Studies	43,9	56,1	0	0	0
Impact on Theoretical and Practical Understanding	57,6	42,4	0	0	0
Understanding Economic Aspects of Photovoltaic Technology	62,1	37,9	0	0	0
Total Average Value	52,1	43,9	3,9	0	0

Table 3. Industry Satisfaction Level Evaluation Results

Feedback Questions for Industry Representatives	Satisfaction Level (%)				
	5	4	3	2	1
Insight into the Industry	48,3	51,7	0	0	0
Relevance to the Current Industry	43,1	31,0	25,9	0	0
Identification of Business Opportunities or Applications	27,6	37,9	34,5	0	0
Evaluation of Students' Abilities in the Industry	37,9	62,1	0	0	0
Future Project Data Sustainability	53,4	46,6	0	0	0
Technical, Economic, and Sustainability Understanding in the Industry	48,3	51,7	0	0	0
Contribution to the Development of the Renewable Industry	41,4	58,6	0	0	0
Improvement or Development Aspects of the Laboratory	53,4	46,6	0	0	0
Potential Collaboration with the Industry	58,6	41,4	0	0	0
Influence on Industry Policies	37,9	62,1	0	0	0
Total Average Value	44,9	48,9	6	0	0

On the basis of Table 2, it can be seen that the majority of the students gave a positive evaluation of their learning experience in the laboratory. They were mostly very satisfied is 51.5%, satisfied is 48.5% with the learning experience. and very satisfied with the laboratory facilities is 56.1%. These results indicate that the hands-on approach used in teaching and practicing photovoltaic technology and monitoring systems was considered effective in improving their understanding of the concepts.

Based on Table 3, it can be obtained that the positive evaluation of the laboratory's contribution to technical, economic, and sustainability understanding in the photovoltaic industry very satisfied is 48.3 %, and satisfied is 51.7% and it can enhance understanding of relevant technical and economic aspects. However, there were challenges in identifying business opportunities or concrete applications of photovoltaic technologies (27.6% felt successful), as well as their relevance to current industry needs (43.1%). Also, we got the information from the industry participants mentioned that the students who have experience in practical work in the laboratory had good abilities in applying photovoltaic technology from an industrial perspective

However, the accessibility aspect of the laboratories only obtained a lower level of satisfaction i.e Very satisfaction only 28.8%, and it is 27.3% of students feel uncomfortable with laboratory accessibility. This is due the room temperature being relatively high during the day, which necessitates some improvements in terms of room cooling. Other recommendations include the potential for further collaboration between the industry and the laboratory regarding research or technology development.

4. CONCLUSION

We succeeded in analyzing the impact of the development laboratory to the Student and Industry as follows: The majority of students approximately 51.5%, are extremely satisfied with the learning experience in the laboratory. Also, it was concluded that the students for ease to use are both extremely satisfied and satisfied, at 93.17%, with details extremely satisfied at 50.14%, and satisfied at 43.03%. The Positive impacts of the laboratory contributed to the development of the renewable energy industry in the region concerned by 58.6%. and the Influence on Industry Policies has a positive impact of 62.1%. Also, based on the evaluation of the student ability from the industrial participants' perspective, they are satisfied as much as 62.1%, where the students who have experience in practical work in the laboratory had good abilities in applying photovoltaic technology.

ACKNOWLEDGMENT

The authors gratefully acknowledge the support from the Erasmus+ Program of the European Union: Capacity Building within the Field of Higher Education eACCESS (EU-Asia Collaboration for Accessible Education in Smart Power Systems), Project number: 610041-EPP-1-2019-1-PL-EPPKA2-CBHE-JP. This paper already presented in the: eACCESS Conference on Smart Power & Emerging Technologies (eACCESS-SPET) on November 2023.

REFERENCES

Ciocia, A., Di Leo, P., Malgaroli, G., Russo, A., Spertino, F., & Tzanova, S. (2020). Innovative Teaching on Photovoltaic Generation. *2020 XI National Conference with International Participation (ELECTRONICA)*, 1–4. https://doi.org/10.1109/ELECTRONICA50406.2020.9305110

Global Solar Atlas. (n.d.). Retrieved July 9, 2024, from https://globalsolaratlas.info/detail?r=IDN&c=-2.661188,118.1042,4

Gumintang, M. A., Sofyan, M. F., & Sulaeman, I. (2020). *Design and Control of PV Hybrid System in Practice_REEP (GIZ)[7407].pdf*. Online Drive ESDM. https://drive.esdm.go.id/wl/?id=E70TMuwXjvnthjJx2lIPbmNPyaJB791M

Hartikainen, S., Rintala, H., Pylväs, L., & Nokelainen, P. (2019). The Concept of Active Learning and the Measurement of Learning Outcomes: A Review of Research in Engineering Higher Education. *Education Sciences*, *9*(4), 276. https://doi.org/10.3390/educsci9040276

Kaliyamoorthy, M., C.R., S., S, U., & Palraj, V. (2022). Impact of Solar Energy on Mitigating Climate changes for a Sustainable Development in India. *2022 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS)*, 1–5. https://doi.org/10.1109/ICPECTS56089.2022.10046744

Kumar, N. M., Subathra, M. S. P., & Moses, J. E. (2018). On-Grid Solar Photovoltaic System: Components, Design Considerations, and Case Study. *2018 4th International Conference on Electrical Energy Systems (ICEES)*, 616–619. https://doi.org/10.1109/ICEES.2018.8442403

Le, P. T., Nguyen, T. S., & An Loi, N. P. (2022). Solar Energy Potential Assessment: Analytic Hierarchy Process Model for Selecting Solar Energy Sites in Vietnam. *2022 6th International Conference on Green Technology and Sustainable Development (GTSD)*, (pp. 155–159). https://doi.org/10.1109/GTSD54989.2022.9989116

Martin, A. D., Cano, J. M., Vazquez, J. R., & Lopez-Garcia, D. A. (2020). A Low-Cost Remote Laboratory for Photovoltaic Systems to Explore the Acceptance of the Students. *2020 IEEE Global Engineering Education Conference (EDUCON)*, (pp. 1333–1337). https://doi.org/10.1109/EDUCON45650.2020.9125211

Setiawan, F. B., Riyadi, S., Pratomo, L. H., & Wibisono, A. (2022). A 5.4 kWp Microgrid Laboratory Development for Higher Education and Industrial Workshop. *2022 14th International Conference on Software, Knowledge, Information Management and Applications (SKIMA)*, (pp. 89–94). https://doi.org/10.1109/SKIMA57145.2022.10029640

Singh, A. K., Pal, K., & Gupta, N. K. (2019). Performance Evaluation of a 4 kW Isolated Solar Powered Lab with IoT Energy Management System. *2019 2nd International Conference on Power Energy, Environment and Intelligent Control (PEEIC)*, (pp. 418–423). https://doi.org/10.1109/PEEIC47157.2019.8976598

Suharyati, Pambudi, S. H., Wibowo, J. L., & Pratiwi, N. I. (2019, September). *Kementerian ESDM RI - Publikasi—Indonesia Energy Outlook*. https://www.esdm.go.id/id/publikasi/indonesia-energy-outlook

Tobias, R. R., Mital, M. E., Lauguico, S., Guillermo, M., Naidas, J. R., Lopena, M., Dizon, M. E., & Dadios, E. (2020). Design and Construction of a Solar Energy Module for Optimizing Solar Energy Efficiency. *2020 IEEE 12th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*, (pp. 1–6). https://doi.org/10.1109/HNICEM51456.2020.9400127

Vasita, J., Shakhiya, Q., & Modi, J. (2017). Feasibility study and performance evaluation of a grid-connected rooftop solar PV system. *2017 International Conference on Information, Communication, Instrumentation and Control (ICICIC)*, (pp. 1–7). https://doi.org/10.1109/ICOMICON.2017.8279067

Winanti, N., Halimi, B., Purwadi, A., & Heryana, N. (2018). Study and Design of Energy-Saving Solar Lamp for Rural Area in Indonesia. *2018 2nd International Conference on Green Energy and Applications (ICGEA)*, (pp. 98–102). https://doi.org/10.1109/ICGEA.2018.8356307

Winanti, N., Purwadi, A., Halimi, B., & Heryana, N. (2018). Study and Design of Energy-Saving Solar Lamp for Small Island in Indonesia: Matakus Island. *2018 Conference on Power Engineering and Renewable Energy (ICPERE)*, (pp. 1–5). https://doi.org/10.1109/ICPERE.2018.8739672

Zalewski, Novak, & Carlson. (2019). An Overview of Teaching Physics for Undergraduates in Engineering Environments. *Education Sciences*, *9*(4), 278. https://doi.org/10.3390/educsci9040278