Conceptual Design of an Integrated Smart Home System with PV Solar Power for Traditional Minahasa Wooden House

Gideon F. Tulangi[*1], Stieven N. Rumokoy[2], I Gede Para Atmaja[3], Daisy D. G. Pangemanan[4], Stanley B. Dodie[5], Maureen Langie[6]
[1,2,3,5,6] Department of Electrical Engineering, Manado State Polytechnic, Indonesia
[4] Department of Civil Engineering, Manado State Polytechnic, Indonesia
E-mail: [*1] **fideltulangi14@gmail.com**, [2]rumokoy@polimdo.ac.id, [3]igedeatmaja69@gmail.com, [4]daisydebora88@gmail.com, [5]stanleydodie@elektro.polimdo.ac.id, [6]maureen.langie@elektro.polimdo.ac.id

Abstract

The traditional Minahasa wooden house is an integral part of Indonesia's cultural heritage. However, in this modern era, the challenge of preserving cultural authenticity while introducing it to the technological era is becoming increasingly urgent. This research aims to design a Smart Home System concept integrated with Photovoltaic (PV) Solar Power Plant for traditional Minahasa wooden houses. The objective of this study is to identify the potential for integrating smart home technology and PV Solar Power Plant in Minahasa wooden houses and to develop a concept that combines traditional elements with modern technology. The research methodology will involve a literature review to understand the concepts of smart homes, PV Solar Power Plant, and the characteristics of traditional Minahasa wooden houses. Additionally, descriptive research through interviews will be conducted in collaboration with industry partners to obtain data and examples of traditional Minahasa wooden houses to be used as benchmarks in the concept design. This research can contribute to integrating modern technology into Indonesia's cultural traditions while enhancing the competitiveness of Minahasa wooden house products in the market. The result of this research is a conceptual design for the implementation of a Smart Home System integrated with a PV rooftop solar power plant system in Minahasa wooden houses. The utilization of solar energy as electrical energy is predicted to achieve an annual energy yield of 16,775 kWh.

Keywords *— IoT, Renewable Energy, Solar Power Plant*

1. INTRODUCTION

One of the leading products of the Minahasa community is its wooden house business. The traditional Minahasa wooden house, known as the Woloan wooden house, is a well-known product in North Sulawesi province. These wooden houses have unique characteristics. They are displayed in specific areas and can be dismantled and reassembled at the buyer's designated location. The market for these wooden houses has reached international destinations. To this day, Minahasa wooden houses remain a popular choice for wooden homes in North Sulawesi and other regions.

The traditional Minahasa wooden house has become an iconic business for residents living in a specific area of North Sulawesi province. These houses are commonly referred to as Woloan wooden houses because they are produced in Woloan village[1]. In the modern era, people generally pay less attention to traditional Minahasa architectural customs. However, the community in Woloan has introduced Minahasa architectural motifs to higher levels, reaching international recognition and admiration for the work of Woloan architects[2]. These traditional Minahasa wooden houses are typically built in the form of stilt houses[3]. In this house trading business, the marketing system involves preparing a complete set of houses. If a customer is interested, the wooden house will be dismantled and reassembled at the buyer's designated location. Besides the attraction of its unique design, the quality of the wood is also a crucial factor in determining the selling price of the wooden house set[4].

A Smart Home system is a remote monitoring and control system for electrical equipment in residential homes, operating automatically [5]. In other words, a Smart Home System can be referred to as an Intelligent Home System[6]. The primary goal of creating this system is generally to make tasks more practical and to secure existing assets [7]. The development of an intelligent home system relies heavily on internet connectivity, which serves as the link between the items to be controlled and the system user[8]. Various household appliances can be controlled automatically, such as gates, doors, water pumps, and lights. The application of smart home technology continues to evolve because this system offers the convenience of monitoring and controlling equipment both automatically and remotely[9].

Indonesia is located in a tropical region, which lies along the equator. This position results in the availability of sunlight on the surface of Indonesia almost throughout the year, except during the rainy season and when thick clouds block the sunlight[10][11]. According to the solar insolation map, Indonesia has the potential for solar energy of 4.5 $kW/m^2/day$[12][13]. Solar radiation reaches the earth's surface directly and indirectly. Directly (direct beam radiation), solar energy reaches the earth's surface. Indirectly, it is reflected by aerosols, atmospheric molecules, and clouds (diffuse radiation). The total irradiation of these two radiation components falling on a horizontal surface is known as global radiation[14].

2. RESEARCH METHOD

The research methodology will involve a literature review to understand the concepts of smart homes, PV Solar Power Systems, and the characteristics of traditional Minahasa wooden houses. Additionally, descriptive research through interviews will be conducted in collaboration with industry partners to obtain data and examples of traditional Minahasa wooden houses, which will be used as benchmarks in the concept design. The research stages are depicted in the flowchart and explained step-by-step as follows:

a) Literature Review: This stage involves searching for and analyzing relevant literature on the concepts of Smart Home Systems, PV Solar Power Systems, and the characteristics of traditional Minahasa wooden houses. The literature review helps in understanding the theoretical framework and existing knowledge related to this research.

b) Descriptive Study: At this stage, a descriptive study is conducted on traditional Minahasa wooden houses, including their characteristics, design, and manufacturing process. This aims to gain a deeper understanding of the current state of Minahasa wooden houses and their potential for further development.

c) Identifying Areas for Technological Enhancement: This stage involves identifying parts of traditional Minahasa wooden houses that can be enhanced with technological elements, such as lighting systems, temperature control, security, and others.

d) Smart Home System Concept Design: At this stage, the concept of a smart system for traditional Minahasa wooden houses is designed. This includes designing the smart home features to be implemented and integrating them with the existing house infrastructure.

e) PV Solar Power System Design: This stage includes designing a Photovoltaic (PV) Solar Power System to be integrated with traditional Minahasa wooden houses. This involves selecting the location for solar panels, system capacity, and other supporting infrastructure.

f) Designing Scenarios for Electricity Utilization: At this stage, various scenarios concept for utilizing the electricity generated by the PV Solar Power System and the Smart Home System are developed. This includes mapping energy usage and the concept of automatic device control.

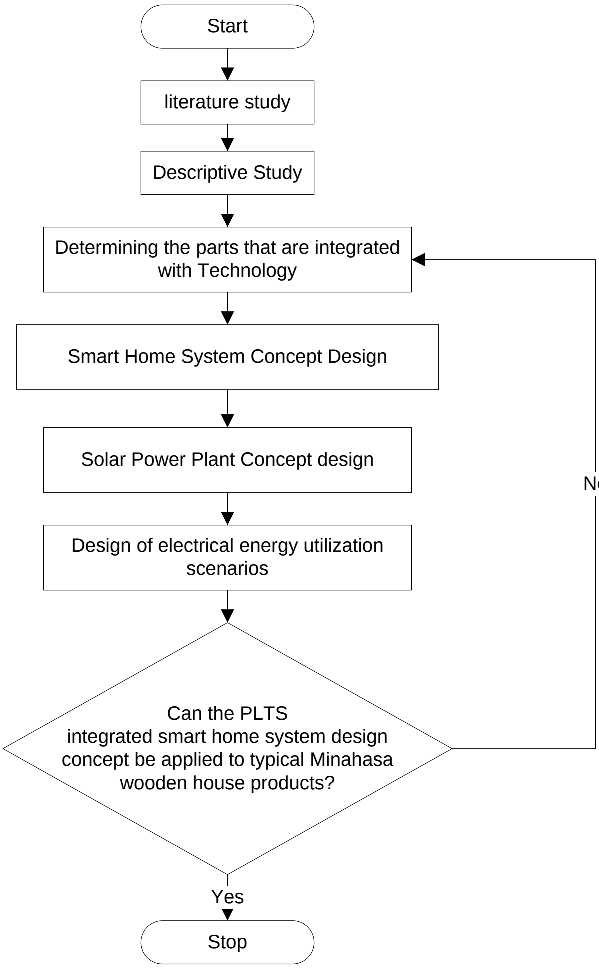


Figure 1. Research Flowchart

3. RESEARCH RESULTS AND DISCUSSION

3.1. Concept Implementation of a Smart Home System in Traditional Minahasa Wooden Houses

Please The Smart Home System applications that can be implemented in traditional Minahasa wooden houses include:

a) Lighting Management: The lighting system that can be implemented with this concept in wooden houses involves using lamps as the main source of light and window curtains to control the entry of natural light. The lighting can be automatically adjusted based on the room's luminance using light sensors, or it can be controlled according to preset times.
b) Water Management: Water management is essential for household needs. Given that wooden houses are typically designed with two floors, a high-elevation water storage tank is usually installed. The smart home concept can regulate the availability of water for household needs.
c) Air Management: The air management system implemented in this concept for wooden houses includes the use of air conditioners. Automatically operated windows that can open and close are also an option. The room temperature can be adjusted based on sensor readings, and remote activation can be an operational feature. In tropical regions, rooms tend to be hot during the day. Wooden house residents can remotely turn on the air conditioner to achieve the desired temperature before arriving home.
d) Security System: Regarding home security, the inclusion of CCTV and door access control can be part of the smart home concept for wooden houses. The activity around the wooden house can be monitored remotely using IoT-based CCTV.

3.2. System Design for Wooden House

In the design of the integrated Smart Home concept with a PV Solar Power System for traditional Minahasa wooden houses, the electrical energy source will come from both the grid and an off-grid PV Solar Power System. The transfer of the electrical energy source is designed using an Automatic Transfer Switch (ATS). This energy source will power the operation of the smart home system. A simplified conceptual design can be seen in Figure 2.

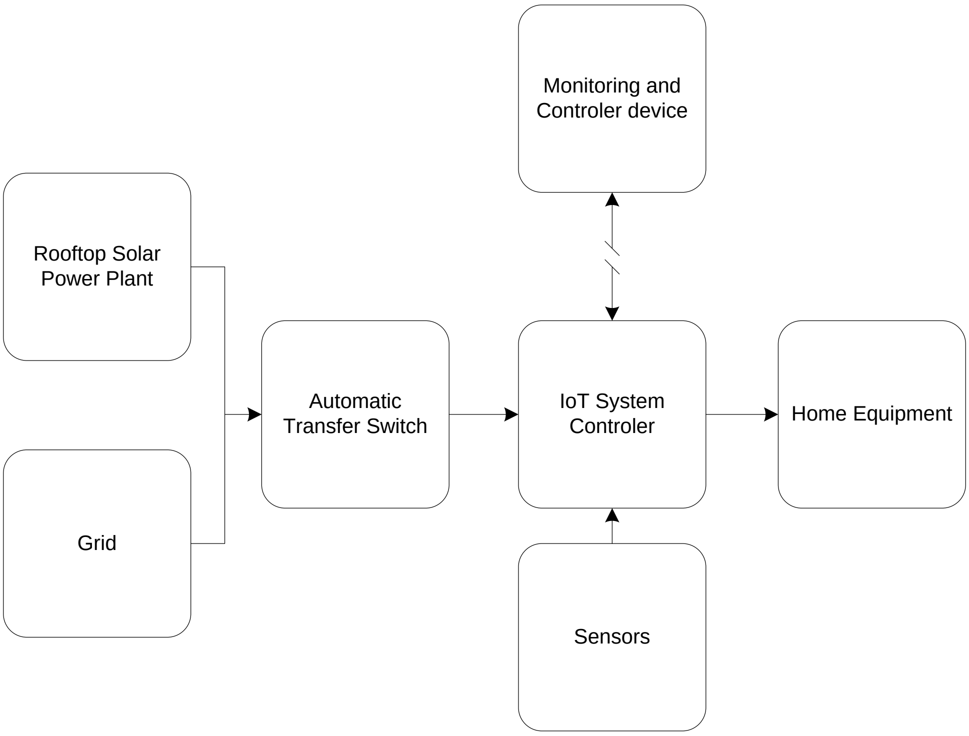


Figure 2. Block Diagram

The traditional Minahasa wooden house comes in various shapes. Characteristically, it is primarily constructed using wood as the main material. In terms of architectural design, the typical Minahasa wooden house is built on stilts with a space underneath. The roof structure is pyramid-shaped. The concept of a wooden house model with solar panels installed on its roof can be seen in Figure 3.

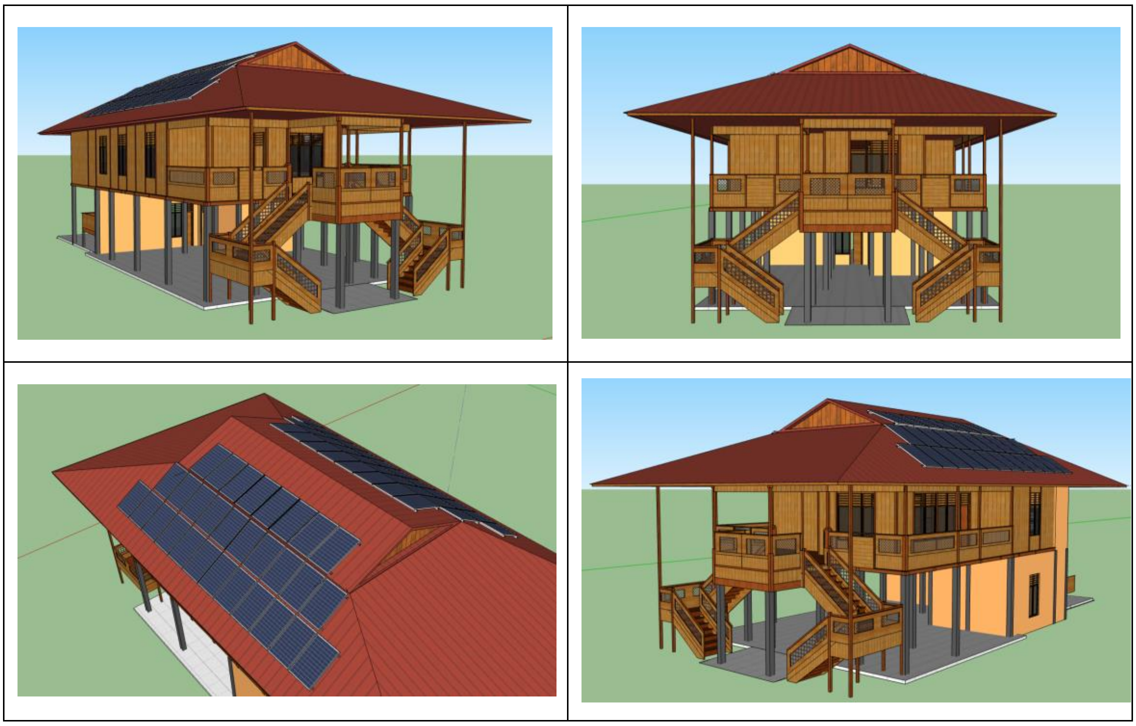


Figure 3. Wooden House Design

To assess the potential electrical power that can be generated through the installation of a rooftop PV Solar Power System, the Sunny Design simulator, accessible at https://www.sunnydesignweb.com/, is used. A sample wooden house is taken from the Woloan area where wooden houses are displayed for sale. The sample calculation point as initial data can be seen in Figure 4.

Figure 4. Location for Simulation

As a consideration for predicting the electricity consumption needs of this wooden house, the estimated annual energy consumption is approximately 3000 kWh. This estimation is only an approximation and not an exact value. In real field conditions, the actual annual energy consumption may be higher or lower. The simulation determined that the Solar Panels used have a capacity of 200Wp each. The installation of solar panels is limited to the left and right sides of the roof. Based on the available roof area, a total of 30 units of solar panels can be installed on each side, resulting in a total of 60 solar panels. The total installed capacity of the solar panels is 12 kWp.

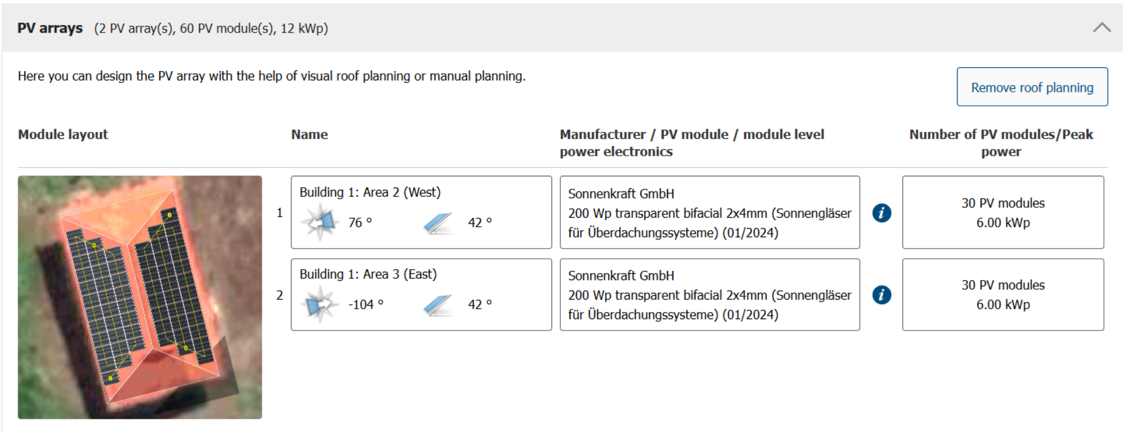
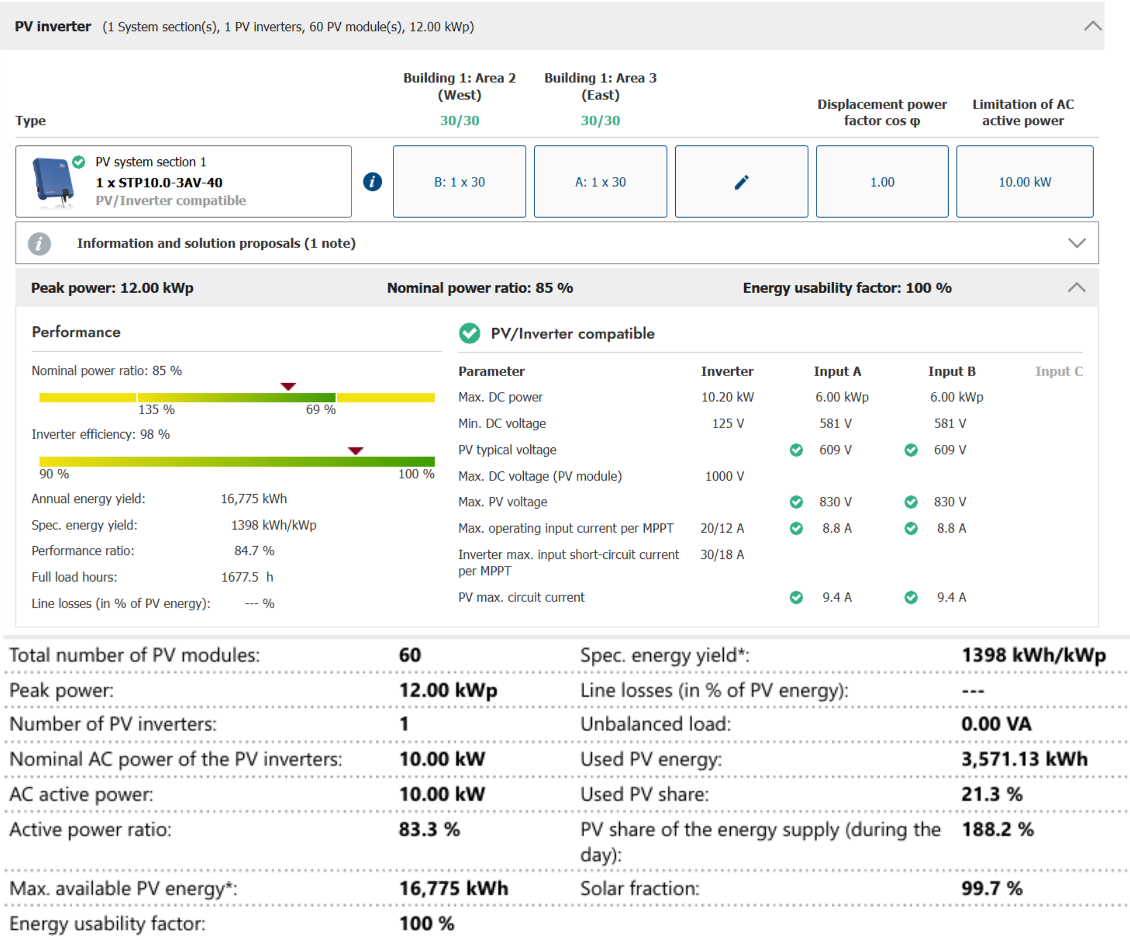


Figure 5. PV Rooftop Instalation

By determining the suitable type of inverter for this system, the predicted Annual Energy Yield is expected to reach 16,775 kWh. This section has demonstrated that the electricity demand can be met through the installation of the PV rooftop Solar Power System. For detailed results, the simulation outcomes can be seen in Figure xx.



Total number of PV modules:	60	Spec. energy yield*:	1398 kWh/kWp
Peak power:	12.00 kWp	Line losses (in % of PV energy):	---
Number of PV inverters:	1	Unbalanced load:	0.00 VA
Nominal AC power of the PV inverters:	10.00 kW	Used PV energy:	3,571.13 kWh
AC active power:	10.00 kW	Used PV share:	21.3 %
Active power ratio:	83.3 %	PV share of the energy supply (during the day):	188.2 %
Max. available PV energy*:	16,775 kWh	Solar fraction:	99.7 %
Energy usability factor:	100 %		

Figure 6. Simulation Result

Based on the simulation results, a typical Minahasa wooden house can install 60 solar panels, each with a capacity of 200Wp, resulting in a total solar capacity of 12 kWp. Using an inverter with an output of 10 kW at the installation point of the sample Minahasa wooden house yields an annual energy yield of 16,775 kWh. Comparing this result with the installed solar panel capacity of 12 kWp, the energy yield obtained is approximately 1,398 kWh/kWp.

4. CONCLUSION

Based on the research conducted, several interesting findings have been obtained. The key conclusions are as follows:

1. The parts of the smart home system that can be implemented in wooden houses include lighting control, air management, water management, and security systems.
2. The utilization of solar energy as electrical energy is predicted to achieve an Annual Energy Yield of 16,775 kWh.

5. SUGGESTED

This research can be further developed towards the design of a prototype for practical application. The prototype can be developed by considering the needs of the users of these traditional Minahasa wooden houses.

6. REFERENCES

[1] Andrey Dymitri Makawekes, "Analisis Keuntungan Usaha Rumah Kayu CV Tumou Pratama Di Kelurahan Woloan 1 Kecamatan Tomohon Barat," *Agri-SosioEkonomi*, vol. 15, no. 1, pp. 17–26, 2013.

[2] M. Marwati, "Studi Rumah Panggung Tahan Gampa Woloan di Minahasa Manado," *TEKNOSAINS Media Inf. Sains dan Teknol.*, vol. 8, no. 1, pp. 95–108, 2014, [Online]. Available: http://journal.uin-alauddin.ac.id/index.php/teknosains/article/view/108

[3] J. N. Matheosz, "Arsitektur Rumah Adat Minahasa Di Kelurahan Woloan Kecamatan Tomohon Barat Kota Tomohon," *HOLISTIK*, vol. 11, no. 22, pp. 1–17, 2018.

[4] F. L. P. J. Lumape and S. S. S. Tumanduk, "Perancangan Gambar Rumah Panggung Pada Tukang Kayu Kelurahan Woloan Dua Kecamatan Tomohon Barat Kota Tomohon," *J. ABDIMAS*, vol. 11, no. 3, pp. 229–238, 2018.

[5] G. N. Alamsyah and S. Winardi, "Sistem Kontrol Dan Monitoring Smart House Berbasis IoT Dengan Smartphone Android," *J. SAINTEKOM*, vol. 12, no. 2, pp. 126–136, 2022, doi: 10.33020/saintekom.v12i2.311.

[6] F. Masykur and F. Prasetiyowati, "Aplikasi Rumah Pintar (Smart Home) Pengendali Peralatan," *J. Teknol. Inf. dan Ilmu Komput.*, vol. 3, no. 1, pp. 51–58, 2018.

[7] H. Andrianto and G. I. Saputra, "Smart Home System Berbasis IoT dan SMS," *TELKA - Telekomun. Elektron. Komputasi dan Kontrol*, vol. 6, no. 1, pp. 40–48, 2020, doi: 10.15575/telka.v6n1.40-48.

[8] F. Z. Rachman, "Smart Home Berbasis Iot," *Snitt*, pp. 369–374, 2017, [Online]. Available: http://jurnal.poltekba.ac.id/index.php/prosiding/article/view/423

[9] J. Wardoyo, N. Hudallah, and A. B. Utomo, "Smart Home Security System Berbasis Mikrokontroler," *Simetris J. Tek. Mesin, Elektro dan Ilmu Komput.*, vol. 10, no. 1, pp. 367–374, 2019, doi: 10.24176/simet.v10i1.2684.

[10] S. N. Rumokoy and C. H. Simanjuntak, "Perancangan Konsep Modul Praktek Instalasi PLTS Skala Rumah Tangga Berbasis Kompetensi Berorientasi Produksi," *Fokus Elektroda*, vol. 04, no. 04, pp. 6–12, 2019.

[11] C. A. O. Kaseger, S. N. Rumokoy, A. A. S. Ramschie, and S. B. Dodie, "Design of Teaching Factory Practice Tools Concept , Perspective : Operation System on Solar Power Plant," *CCIT*, vol. 15, no. 2, pp. 260–271, 2022.

[12] H. Bayu and J. Windarta, "Tinjauan Kebijakan dan Regulasi Pengembangan PLTS di Indonesia," *J. Energi Baru dan Terbarukan*, vol. 2, no. 3, pp. 123–132, 2021, doi: 10.14710/jebt.2021.10043.

[13] A. Gifson and M. P. Pambudi, "Rancang bangun pembangkit listrik tenaga surya (PLTS) on grid di ecopark ancol," *TESLA*, vol. 22, no. 1, pp. 23–33, 2020.

[14] D. L. Pangestuningtyas, "Analisis Pengaruh Sudut Kemiringan Panel Surya Terhadap Radiasi Matahari Yang Diterima Oleh Panel Surya Tipe Larik Tetap," *TRANSIENT*, vol. 2, no. 4, pp. 930–937, 2013.