"DESIGN OF OFF-GRID SOLAR POWER PLANT BASED ON INTERNET OF THINGS"

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ABSTRACT

This research presents the design of an Internet of Things (IoT)-based off-grid solar power generation system. The designed system enables real-time monitoring and control of power output, thereby improving operational efficiency and system performance. This research covers aspects of technical design, component selection, as well as IoT integration, which allows users to remotely manage various parameters such as energy generation, battery level, and load management. By utilizing IoT, the system can remotely monitor and control various parameters, such as energy generation, battery level, and load management, thus ensuring efficiency and real-time performance. This research covers system design, component selection, and integration of IoT technology for monitoring and management, resulting in a more intelligent and automated solar power plant. The implementation of this system aims to improve energy independence, sustainability, and accessibility in remote or rural areas.

***Keywords**: Design Of PLTS Off-Grid PLTS Iot Based.*

INTRODUCTION

Dependence on fossil energy sources as fuel for power plants still dominates most of the existing electrical energy generation system in Indonesia. To reduce dependence on fossil energy as a power plant fuel and switch to using new renewable energy, efforts are made by the government with the issuance of regulations regarding the National Energy Policy. The commitment of the Indonesian government in supporting the National Energy Policy by achieving 23% of the use of new and renewable energy by 2025 is realized with various policies and regulations, one of which is the development of PLTS in Indonesia [1].

Solar energy in Indonesia which is very large throughout the year is a potential source of renewable energy that really needs to be developed, while reducing dependence on fossil energy which is almost exhausted. As an available and environmentally friendly energy, to reduce the greenhouse gas effect, and to support the national program designed by the government regarding renewable energy supply sources [1].

Solar energy can be utilized as one of the renewable energy sources of course by using solar panels as a means of converting sunlight into electrical energy. The use of solar panels in the West Kalimantan region in particular is very effective, because West Kalimantan is one of the areas located by the equator. Areas traversed by the equator have great potential in utilizing solar energy. This is because the region receives intense sunlight throughout the year [2].

To be able to improve the performance of PLTS, namely by utilizing Internet of Things (IoT) technology. PLTS systems connected to IoT can be monitored and controlled in real-time. The use of IoT technology can make it easier to monitor and control power output in real-time, and can be an innovative solution in developing an effective PLTS system [3].

This is where the urgency arises to design an IoT-based off-grid solar power plant, which is not only environmentally friendly, but also easy to operate thanks to its connection with IoT technology. The design of IoT-based off-grid solar power plants in this research is expected to be a solution to the challenges of limited access to electricity in remote areas and as a step forward in the use of new renewable energy that is more efficient and effective [3].

LITERATURE REVIEW

Yanolanda et al (2024) this research discusses the design of a centralized Solar Power Plant (PLTS) with an off-grid system in the Integrated Laboratory Building II at Bengkulu University. This research designs a PLTS that is capable of producing a maximum power of 44,000 W to meet the electrical energy needs of the laboratory building which reaches 17,496 W. The design includes the use of 324 solar panels, 184 12 V 100 Ah batteries, a solar current charging controller, and a 2 kW inverter [4].

Muhammad Naim (2020) this research discusses the design of an Off Grid Solar Power Plant (PLTS) electrical system with a capacity of 1000 Watts in Loeha Village, Towuti District, East Luwu Regency. The research includes an analysis of the equipment needed to support the Off Grid PLTS system, including four Photovoltaic (PV) modules with certain specifications, Solar Charge Controller using MPPT technology, Deep Cycle battery bank, and Bidirectional inverter [5].

Ahmad and Dino (2022) discussed the potential of off-grid solar power generation for household scale in Bagan Deli area using PVsyst software. Using four solar panels of 150Wp each and two batteries with a capacity of 200 Ah, the simulation shows the results of unused energy, losses in the system, and energy supplied to users [6].

Zikra et al (2019) conducted an analysis of the design of a centralized Off-grid Solar Power Plant (PLTS) in Ketubong Tunong Hamlet, East Seunagan District, Nagan Raya. This PLTS is planned with a capacity of 45 kWp to provide electricity at night, but based on analysis, the total electricity demand of the community reaches 287 kWh/day with energy needs more than just lighting [7].

METHOD

Location and Time of Research

This research was conducted at the Energy Conversion Laboratory, Faculty of Engineering, Tanjungpura University Pontianak and the implementation time of this research was 2 months.

Research Variable Data

The data used in this study are data in the form of specifications and each component of the IoT-based off-grid solar power plant. The solar panel used is Maysu Solar 120 WP which amounts to 4 pieces. Inverter/Charge used Epever 1 piece. The battery used is MPower 12 V 100 Ah which amounts to 1 piece. Ethernet Convert Module Epever eBox-WIFI-01 which amounted to 1 piece. For each component used in this study, it can be seen in the pictures below, as well as the specification tables of each component.

Figure 1. Solar Panels Used

Table 1. Specifications of Solar Panels Used

MAYSUN SOLAR 120 WP	
Max. Power	120 WP
Voltage at Pmax	18.2 V
Current at Pmax	6.67 A
Open-Circuit Voltage	21.51 V
Short-Circuit Current	7.19 A
Cell Technology	Mono
Dimension	1020*680*30 mm

Figure 2. Inverter/Charger Used

Table 2. Specifications of Inverter/Charge Used

SOLAR CHARGING	
PV Open Circuit Voltage	60 V
Max. Solar charge Current	30 A
BATTERY INPUT	
System Battery Voltage	12 V
Battery Input Voltage	10.8-16V
INVERTER OUTPUT	
Output Power	1000 VA/800 W
Output Voltage	220/230 Vac
Frequency	50/60 Hz

Figure 3. Battery Used

Table 3. Battery Specifications Used

Dimension	330 x 172 x 215 mm
Weight	30 kg
Nominal Capacity	12 V 100 Ah
Inner resistance	<5,5 M
Float voltage	2,27 – 2,28 vpc
Cicle voltage	2,35 2,4 vdc
Operational temperature	15° C Sampai 45° C
Design life	10 Thn

Figure 4. Ethernet Used

Table 4. Ethernet Specifications Used

Models	eBox-WIFI-01
Iput Voltage	5 VDC
Standby Power Consumption	0.20 W
Operation Power Consumption	0.25 W
Port Baud Rate	300 bps ~ 230400 bps
Communication	RS485 to WIFI

Research Method

The method used in this research is Research and Design. This research method is used to design an off-grid PLTS based on the internet of things. This research will focus on designing an off-grid PLTS based on the internet of things. Where an off-grid PLTS design will be carried out which aims to meet the needs of electricity.

Research Steps

1. **Literature Study**

Literature studies are carried out by searching / collecting information / data and studying supporting theories from various sources of information both obtained offline and online. Data can be found from sources such as journals related to the author's research.

2. **Field Observation**

Field observation is a data collection method used to observe and see carefully the conditions that occur, and is used to prove the truth of the research design that is being carried out. In this study, data collection was carried out directly using a smartphone connected to the research tool components and seeing the conditions of the designed research design.

3. **Solar Panel Schematic**

The installed solar panels are arranged with a series-parallel circuit. Can be seen in Figure 5 below which is a scheme of solar panels consisting of 4 pieces.

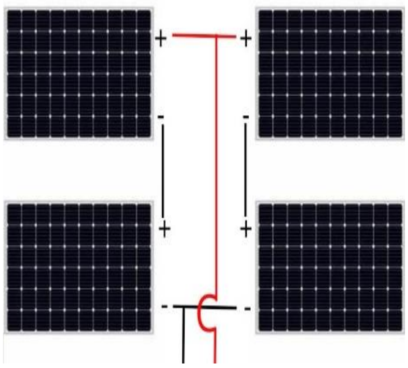

Figure 5. Schematic of Installed Solar Panel

Hardware Design

At the hardware design stage, a device design will be carried out in accordance with the needs of the research. In this hardware design, there are devices designed, namely solar panels, inverters/chargers, ethernet, and batteries.

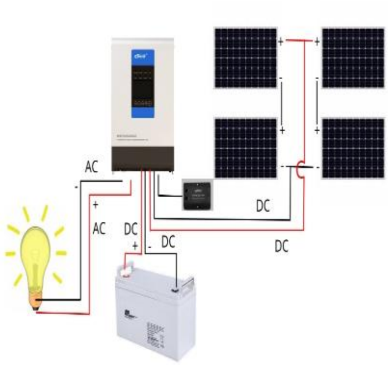

Figure 6. Skema PLTS Off-Grid

Working Principle of Internet of Things in Off-Grid Solar Power Plant

The working principle of Internet of Things (IoT) in Off-Grid Solar Power Plants involves the integration of hardware, software, and network to monitor, control, and optimize the system automatically. Here is the working principle :

1. Data Acquisition

   IoT sensors: Various sensors are installed on solar PV components, such as solar panels, batteries, and inverters, to measure parameters such as sunlight intensity, voltage and current, battery capacity, temperature and humidity. This data is collected in real-time to provide a snapshot of system conditions.

2. Data Communication

   IoT Gateway: Data from sensors is sent to the IoT gateway via communication protocols such as Wi-Fi, Zigbee, LoRa, or GSM.

   Cloud Storage: The gateway sends data to a cloud platform for storage and analysis

3. Data Processing

   In the cloud, data is analyzed using machine learning or big data analytics-based algorithms to detect anomalies (e.g., panel damage or decreased battery capacity). Optimize system settings (e.g., power distribution or battery charging efficiency).

4. Control System

   IoT Actuator: Based on data analysis, the system can control the components of the solar power plant, such as: adjusting the inverter output to meet load requirements, managing battery charge and discharge to avoid overcharge or overdischarge, users can also control the system manually through an app or dashboard.

5. Monitoring and Notification

   IoT Dashboard: Users can monitor the performance of the solar farm in real-time through the app or web.

   Notifications: The system provides notifications if a problem occurs, such as a drop in panel performance or low battery capacity.

6. Security and Maintenance

   IoT enables early detection of potential problems, so maintenance can be done proactively. IoT systems are equipped with data security features to protect sensitive information [8].

Ethernet Convert Module

Ethernet is a tool that can meet the electrical needs of solar power systems that want to monitor and control charging remotely via a smartphone. Ethernet uses wireless or wired communication options with the charge controller. The Ethernet can transmit operational data from the charge controller [9].

Application Display

The application used to monitor and control the power output of the designed PLTS is the application of the components used, the application is Epever Pair. The following is a view of the Epever Pair application.

Figure 7. Epever Pair Application Logo

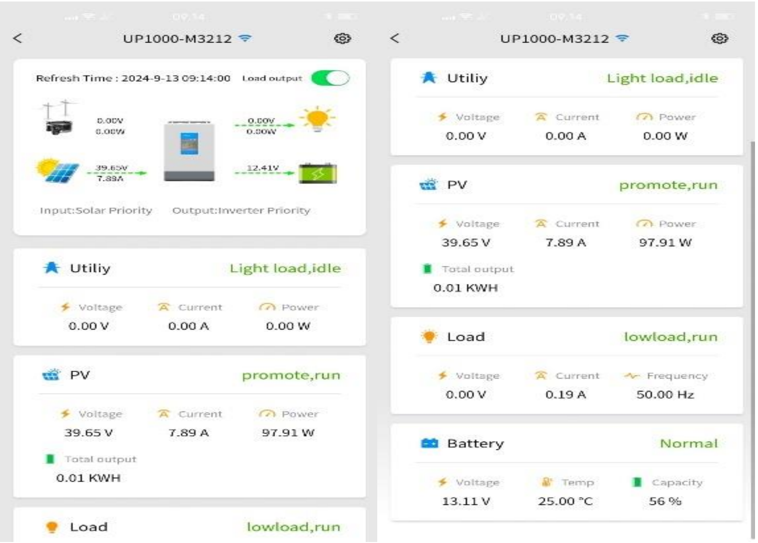

Figure 8. Tampilan Dalam Aplikasi

Determining Capacity and Charging Time as well as Battery Operating Time

To be able to know the capacity of the battery can use the following equation:

$$Battery\ Capacity\ (Wh) = Ah \times V \tag{1}$$

Where: Ah = Current from the battery

V = Battery Voltage

Meanwhile, to be able to calculate how long the battery charging time can use the following equation:

$$Charging\ Time\ (Hour) = \frac{Battery\ capacity}{Solar\ Panel\ Power\ (W) \times System\ Efficiency} \tag{2}$$

To be able to know the battery operating time can use the following equation:

$$Operating\ Time\ (Hour) = \frac{Battery\ capacity\ (Wh)}{Load\ Power\ (W) \times System\ Efficiency} \tag{3}$$

Flow Chart

The steps of the research can be seen in the flow chart below.

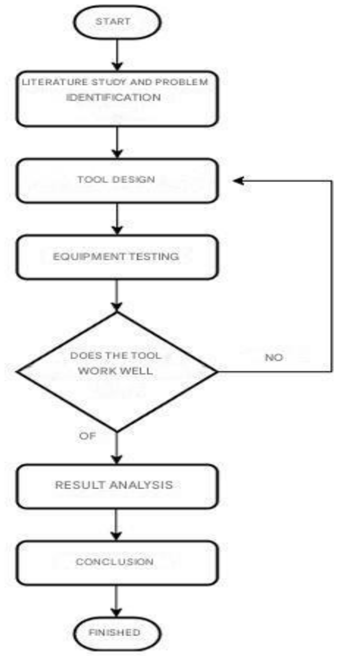

Figure 9. Research Flow Chart

RESULTS AND DISCUSSION

In testing the tools that have been designed, 3 kinds of load tests are carried out, namely testing linear loads, non-linear loads, and mixed loads. For the results of the test can be seen in the table and graph below.

Solar Panel Output Data

The load test referred to in this study is a combination of linear loads and non-linear loads. Load testing was carried out using incandescent lamps, printers, fans, and laptop charges with a total power of 598 Watts. The solar panel output data in the test can be seen in the table and graph below.

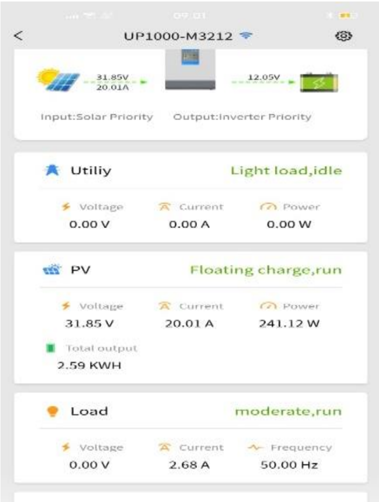

Figure 10. 1st Data Read on Application

Figure 11. 2st Data Read on Application

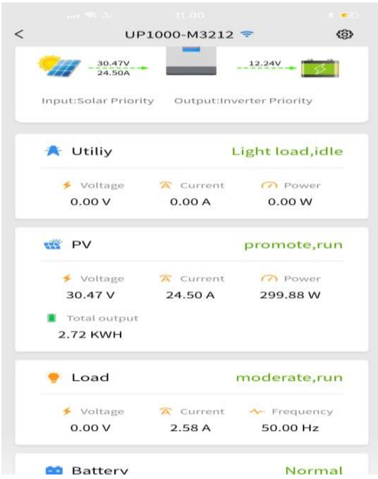

Figure 12. 3st Data Read on Application

Figure 13. 4st Data Read on Application

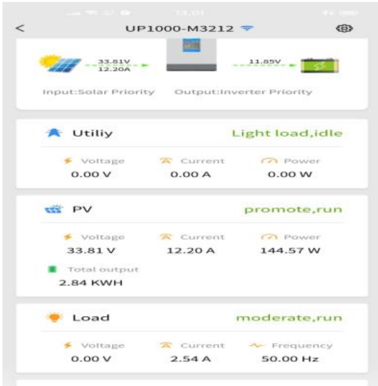

Figure 14. 5st Data Read on Application

Figure 15. 6st Data Read on Application

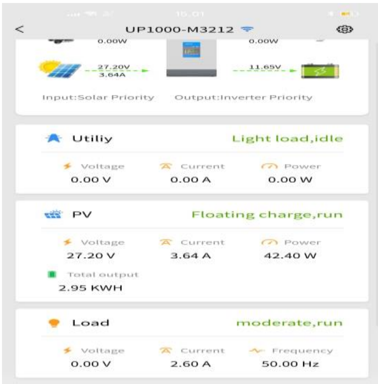

Figure 16. 7st Data Read on Application

Table 5. Solar Panel Output Data

NO	TIME	VOLTAGE (Vdc)	CURRENT (A)	OUTPUT POWER (W)
1	09.00	31,85	20,01	637,31
2	10.00	31,22	23,12	721,80
3	11.00	30,47	24,50	746,51
4	12.00	29,77	24,49	729,06
5	13.00	33,81	12,20	412,48
6	14.00	25,75	20,32	523,24
7	15.00	27,20	3,64	99,01
AVERAGE		**30,01**	**18,32**	**552,77**

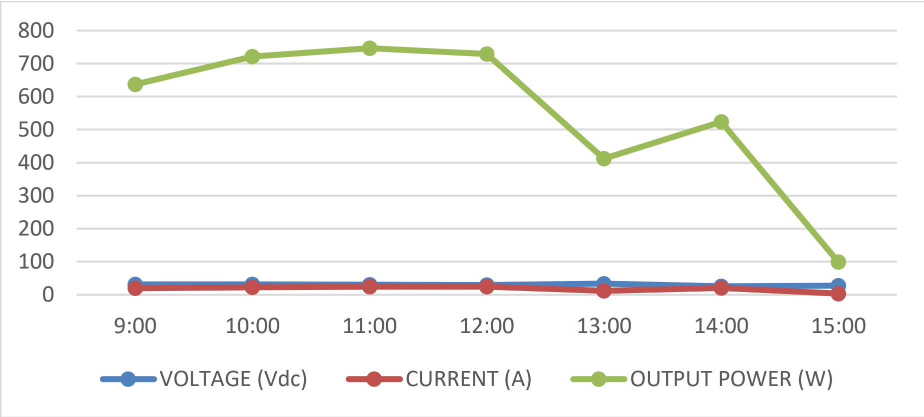

Figure 17. Solar Panel Output Graph

Analysis of Results

From the results of this test, solar panel output data was obtained with a total power of 598 Watts, which used various devices such as incandescent lamps, printers, fans, and laptop chargers. The highest power was recorded at 10am with 721.8 Watts, while the lowest was recorded at 3pm with 99.01 Watts. These results show that the use of load combinations can improve the overall power usage efficiency of the solar panels, as the panels can operate under more stable and balanced conditions. This output data is important for evaluating the performance of the system and knowing whether or not the system is meeting its power requirements. The output power of the solar panel varies due to the changing intensity of solar radiation. From the test results, the designed off-grid solar system can function properly and optimally. The PLTS system connected to IoT can make it easier to monitor and control the power output in real-time. In addition, the system can detect damage to the components of the PLTS equipment.

Calculating Battery Charging Time

To be able to find out the length of time for charging a 12 V 100 Ah battery, the following equation is calculated (1)(2) :

$$Battery\ Capacity\ (Wh) = Ah \times V$$

$$Battery\ Capacity\ (Wh) = 100\ Ah \times 12V = 1200\ Wh$$

The power of the solar panel can change instantly, depending on the intensity of the sun. So assume the power of the solar panel is 120 Wp.

$$Charging\ Time\ (Hour) = \frac{Battery\ capacity}{Solar\ Panel\ Power\ (W) \times\ System\ Efficiency}$$

$$Charging\ Time\ (Hour) = \frac{1200\ Wh}{120\ W \times\ 0{,}8} =\ 12{,}5\ jam$$

So the length of time required to fully charge the battery is 12.5 hours. This time may vary depending on the intensity of the sun and the condition of the system.

Calculating Battery Operating Time

For mixed loads with a total power used of 598 Watts. Then the estimated operating time is :

$$Operating\ Time\ (Hour) = \frac{Battery\ capacity\ (Wh)}{Load\ Power\ (W) \times System\ Efficiency}$$

$$Operating\ Time\ (Hour) = \frac{1200\ Wh}{598 \times 0{,}8} = 2{,}50\ \approx 2\ jam\ 50\ menit$$

So the operational time of the battery is 2 hours 50 minutes when the battery is full. This operating time can change, depending on the total load used.

CONCLUSION

Off-grid solar power plants can be an effective and efficient as well as environmentally friendly solution to meet the needs of electrical energy in areas that have not been reached by conventional electricity. The integration of Internet of Things technology in off-grid solar power plants can enable real-time monitoring and control of power output remotely, thus improving the efficiency of monitoring, maintenance, and power management. The system design results also show that IoT is able to detect engineering problems early, thus helping in minimizing operational disruptions.

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