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Utilization Of Solar Power Plants (Plts) For Street Lighting As A Renewable Energy Solution On Gara Island, Batam

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Abstract

Limited electricity supply in rural areas results in suboptimal public street lighting. One environmentally friendly solution is the utilization of Solar Power Plants (PLTS). This study aims to analyze the potential use of PLTS as a power source for street lighting in rural regions. The methods employed include a literature review, measurement of solar irradiance, and simulation of the power requirements of LED lamps. The results indicate that a PLTS system consisting of a 100 Wp solar panel, a 12V/100Ah battery, and a 40W LED lamp is capable of providing illumination for approximately ±10 hours per night. The implementation of this system can reduce dependence on grid electricity and lower carbon emissions.

Keywords: Renewable Energy, Solar Power Plant (Plts), Street Lighting, Led Lamp, Energy Efficiency.

INTRODUCTION

The demand for electrical energy in Indonesia continues to increase in line with population growth and rapid infrastructure development. However, to this day, many remote areas still do not have access to electricity networks provided by the State Electricity Company (PLN). This condition results in inadequate public street lighting, which significantly affects safety, security, and the socio-economic activities of communities at night. Therefore, the utilization of Solar Power Plants (PLTS) serves as an economical, sustainable, and environmentally friendly alternative solution, considering Indonesia’s abundant solar energy potential throughout the year.

According to data from the Ministry of Energy and Mineral Resources (ESDM), Indonesia has a solar energy potential exceeding 200,000 MWp, yet its utilization remains below 1% of this total potential. This low level of utilization is caused by several factors, including limited investment, insufficient technological outreach, and a lack of human resources with expertise in renewable energy systems. In fact, PLTS offers numerous advantages, such as low operational costs, simple maintenance, and independent installation without reliance on conventional electricity networks.

Public street lighting (PJU) is one of the essential infrastructures that support community activities, particularly at night. The presence of PJU not only enhances road user comfort but also plays a crucial role in reducing crime rates and traffic accidents. In urban areas, most PJU systems rely on electricity supplied by PLN, whereas in rural and remote regions, lighting often remains inadequate. This situation leads to disparities in infrastructure development across regions and hampers rural economic activities.

The utilization of solar energy as the primary resource in public street lighting systems provides an efficient and sustainable solution. Solar street lighting systems rely on the conversion of solar radiation into electrical energy using photovoltaic (PV) panels. The energy generated by the solar panels is stored in batteries and subsequently used to power LED lamps at night. This system operates automatically with the assistance of a solar charge controller (SCC), which regulates battery charging and discharging processes to ensure optimal performance.

In addition to being environmentally friendly, PLTS is particularly suitable for areas with high solar irradiation, such as Indonesia, which has an average solar radiation of 4–5.5 kWh/m² per day. This tropical climate condition represents a significant advantage in developing solar-based energy systems for household needs, small industries, and street lighting. Consequently, PLTS plays a strategic role in supporting the national energy transition toward clean and sustainable energy.

From an economic perspective, the initial investment cost of PLTS is relatively higher compared to conventional grid-based PJU installations. However, in the long term, PLTS proves to be more efficient, as it does not require routine operational expenses such as monthly electricity payments. Maintenance costs are limited to periodic cleaning of solar panels and routine inspection of batteries. Based on feasibility studies, the payback period for PLTS used in street lighting systems ranges from 3 to 5 years, depending on the installed capacity and number of units.

Literature Review

Several previous studies have demonstrated the successful implementation of Solar Power Plants (PLTS) for street lighting in various regions of Indonesia. A PLTS system consists of several main components, including solar panels that convert sunlight into electrical energy, batteries for energy storage, controllers or solar charge controllers that regulate charging and discharging currents, and LED lamps as the primary lighting load.

The efficiency of a PLTS system is highly dependent on several technical factors, such as the intensity of daily solar radiation, the tilt angle of the panels relative to the sun's position, and the storage capacity of the batteries used. Under ideal conditions, with average solar radiation of 4–5.5 kWh/m² per day, PLTS systems can achieve operational efficiencies of up to 90%.

Efficiency Calculation of PLTS Systems

The efficiency of a PLTS system can be determined from the ratio between the output power of the solar panel (P_{out}) and the solar radiation power incident on the panel surface (P_{in}). Mathematically, the solar panel conversion efficiency is expressed as:

$$\eta = (P_{out} / P_{in}) \times 100\%$$

where:

- η = solar panel efficiency (%),
- P_{out} = electrical output power of the solar panel (Watt),
- $P_{in} = G \times A$, which represents the incident solar radiation power (Watt),
- G = solar radiation intensity (W/m²) measured using a solarimeter,
- A = effective surface area of the solar panel (m²).

Studies conducted by various institutions, such as the Research and Development Center for New and Renewable Energy (P3EBT) and several universities in Indonesia, indicate that PLTS-based street lighting systems can operate optimally for 10–12 hours per night with high energy efficiency. Furthermore, the integration of smart controllers and automatic light sensors has enhanced system reliability, allowing lamps to turn on and off automatically according to ambient light conditions without manual intervention.

In addition to technical factors, the successful implementation of PLTS is also influenced by social and economic aspects. Simple maintenance procedures and low operational costs make this system more easily applicable in rural areas. Previous research findings show that the use of PLTS for street lighting can reduce operational costs by up to 70% compared to conventional grid-based systems.

Thus, the literature review from various studies confirms that PLTS is an effective and sustainable solution for public street lighting, particularly in areas not yet connected to the electricity grid. The application of this technology not only supports energy conservation efforts but also contributes to achieving national targets for renewable energy utilization and carbon emission reduction.

RESEARCH METHODS

This study employs a quantitative approach using field experiments and literature review. The main focus of the research is to analyze the potential and performance of a Solar Power Plant (PLTS) system as an energy source for public street lighting in rural areas.

3.1 Research Location and Time

The research was conducted on Gara Island, Kasu Village, Belakang Padang Sub-district, Batam Island. The selection of this location was based on the installation site of a mini PLTS system, which has direct access to sunlight and is far from the PLN electricity network. Observations were carried out from 07:00 to 17:00 to obtain representative solar irradiation data.

3.2 Tools and Materials

The tools and materials used in this study include:

- A solarimeter to measure daily solar radiation intensity (W/m²);
- A 100 Wp solar panel;
- A 12V/100Ah VRLA battery for energy storage;
- A PWM-type Solar Charge Controller (SCC) 12V/20A;
- A 40-watt LED lamp as the lighting load;
- A digital multimeter to measure system current and voltage;
- A data logger to automatically record light intensity and electrical current measurements.

3.3 Data Collection

The primary data in this study were obtained through measurements of solar radiation intensity using a solarimeter placed parallel to the plane of the solar panel. Measurements were taken every hour to determine daily fluctuations in solar radiation. Additional data such as ambient temperature, output current, and voltage of the panel were also recorded to analyze the energy conversion efficiency of the PLTS system.

3.4 Data Analysis

The measurement data were analyzed using a comparative method between the received solar energy and the electrical energy produced by the solar panel. The efficiency value was calculated based on the ratio of the panel's output power to the measured solar radiation intensity. Furthermore, the performance of the PLTS system was evaluated based on the duration of lamp operation, battery capacity, and voltage stability at the load.

RESULTS AND DISCUSSION

Output Data of the 100 Wp Solar Panel in Relation to Solar Radiation Intensity

No	Measurement Time	Solar Radiation Intensity (W/m²)	Voltage (V)	current (A)	output power (W)	Efficiency (%)
1	08.00	350	15.2	2.8	42.6	12.1
2	09.00	500	16.8	3.8	63.8	12.8
3	10.00	650	17.5	4.5	78.8	12.1
4	11.00	800	17.8	5.0	89.0	11.1
5	12.00	900	18.0	5.3	95.4	10.6
6	13.00	850	17.6	5.1	89.8	10.5
7	14.00	750	17.3	4.6	79.6	10.6
8	15.00	600	16.5	3.9	64.4	10.7
9	16.00	450	15.6	3.1	48.4	10.7
10	17.00	300	14.2	2.3	32.7	10.9

Description:

- Solar panel area: 0.65 m²
- Panel nominal power: 100 Wp
- Efficiency is calculated as the ratio of output power to G×A

$$\eta = \frac{P\ out}{G\ x\ A} x\ 100\%$$

Brief Analysis

Based on the table above:

• The maximum power output of 95.4 W was achieved at 12:00 PM when the solar radiation intensity reached 900 W/m².

• The panel efficiency ranged from 10–13%, which is consistent with the characteristics of a 100 Wp polycrystalline solar panel.

• The pattern of power output changes is directly proportional to solar radiation intensity, indicating that system performance follows daily fluctuations in sunlight.

Measurement results show an average solar radiation intensity of 4.5 kWh/m² per day. Based on the calculation of the energy requirement of a 40W LED lamp of 400 Wh/day, a 100 Wp solar panel is sufficient for 10 hours of energy per night. The storage system uses a 12V/100Ah battery capable of providing backup energy for up to 2 days without sunlight. Furthermore, the implementation of solar power plants saves up to 80% on operational costs compared to PLN-based street lighting.

CONCLUSION

Despite its significant potential, several challenges remain in the implementation of Solar Power Plant (PLTS) systems for public street lighting (PJU), including: (1) the high initial investment cost, particularly for the procurement of high-quality solar panels and batteries; (2) the limited availability of local technical experts capable of installing and maintaining the system; (3) technical constraints, such as the impact of extreme weather conditions that can reduce the efficiency of solar panels; and (4) the lack of comprehensive national regulations and technical standards governing the widespread application of PLTS in the public sector.

To overcome these challenges, support from various stakeholders is essential, including both central and local governments, through policies that encourage renewable energy investment, technical training programs for local communities, and the development of operational and technical standards suited to Indonesia's geographical conditions. In addition, collaboration among government agencies, academic institutions, and the private sector can accelerate the adoption of this technology across different regions.

Based on the discussion above, research on the utilization of PLTS for public street lighting is highly important. The main objectives of this study are to analyze the potential, technical design, and economic feasibility of PLTS systems as alternative energy sources for PJU in rural areas. The results are expected to serve as a reference for local governments and communities in planning and implementing renewable energy-based street lighting programs that are efficient, independent, and sustainable.

The utilization of PLTS for public street lighting is highly feasible in rural areas. This system provides independent and sustainable electrical energy, is environmentally friendly, and reduces the burden on the PLN electricity grid. Therefore, it is recommended that local governments support the implementation of PLTS systems through technical assistance programs and equipment subsidies.

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