

Designing a Solar Power Plant Emergency Box for Rapid Disaster Response in Bucor Wetan Village

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Article Info

Article history:

Received Okt 5, 2025

Revised Okt 20, 2025

Accepted Okt 22, 2025

Keywords:

First keyword

Second keyword

Third keyword

Fourth keyword

Fifth keyword

ABSTRACT

The growing pursuit of sustainable agricultural development has driven efforts to combine renewable energy systems with Internet of Things (IoT) technology to improve efficiency and productivity in farming operations. This research focuses on the design and realization of a smart farming system powered primarily by solar energy. IoT-based sensing devices are integrated to continuously monitor parameters such as soil moisture, ambient temperature, and humidity, enabling automated irrigation management that conserves both water and energy resources. The photovoltaic (PV) module supplies stable electrical power, while collected data are transmitted to a cloud platform for remote access through a mobile interface. Experimental evaluation indicates that the proposed system decreases energy usage by approximately 35%, improves irrigation precision by 28%, and boosts crop yield by 20%. These outcomes demonstrate that the synergy between solar power and IoT technology plays a vital role in achieving sustainable agricultural systems and advancing the global objectives of energy transition and climate change mitigation.

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1. INTRODUCTION

Electrical energy is a fundamental need to support modern human activities, especially in post-disaster emergencies. One of the most significant initial impacts of a natural disaster such as a flood, landslide, or earthquake is the loss of electricity from the conventional grid [1]. This situation hampers the emergency response process because electricity plays a vital role in lighting, communication, operating medical equipment, and charging critical electronic devices [2]. Therefore, the availability of a fast, independent, and easily accessible emergency energy source is a determining factor in the success of post-disaster rescue and recovery efforts.

Bucor Wetan Village, Pakuniran District, Probolinggo Regency, is an area with a high level of vulnerability to disasters, particularly floods and landslides. The hilly topography and the presence of frequently overflowing rivers disrupt vital infrastructure, including the electricity grid. In several previous disasters, evacuation posts and emergency medical services in this village have been unable to operate optimally due to limited power supply.

This situation highlights the urgency of providing portable, reliable, and ready-to-use alternative energy solutions at affected locations without the need for additional infrastructure [3].

Previous studies have highlighted the potential of renewable energy, particularly solar energy, as an emergency electricity solution. Wahyuni [4] developed a solar power plant (PLTS)-based emergency system capable of supplying stable power for up to eight hours for lighting and communications. Sutrisno [5] designed a prototype portable power supply based on solar panels and lithium batteries with a lightweight and efficient modular design for hard-to-reach areas. Fauziah [6] studied a hybrid PV-generator system for remote areas and emphasized that a pure PV system is more suitable for short-term emergencies because it does not rely on fossil fuels.

However, most of this research still focuses on household-scale lighting units or large portable PV systems that require extensive installation time and technical expertise. Few studies have examined the design of a PV emergency system in the form of a compact unit that can be directly used by ordinary people in disaster areas without complex configuration. This is the research gap that this study aims to address.

This research offers a novel innovation in the form of designing a PLTS Emergency Box—a portable solar energy system with a compact, airtight, lightweight design, and multi-output connectors to support various emergency devices such as LED lights, communication devices, and medical chargers. This unit is designed with a plug-and-play principle, allowing for installation in less than five minutes and requiring no special technical expertise. This approach is expected to become a model for the practical, rapid, and sustainable application of solar energy to support disaster preparedness in rural areas such as Bucor Wetan Village.

2. METHOD

This research employed a mixed methods paradigm, combining quantitative and qualitative approaches to obtain more comprehensive results. The quantitative approach focused on testing the technical performance of the solar power plant emergency box prototype, while the qualitative approach was used to evaluate community needs and perceptions of the device in the context of disaster response.

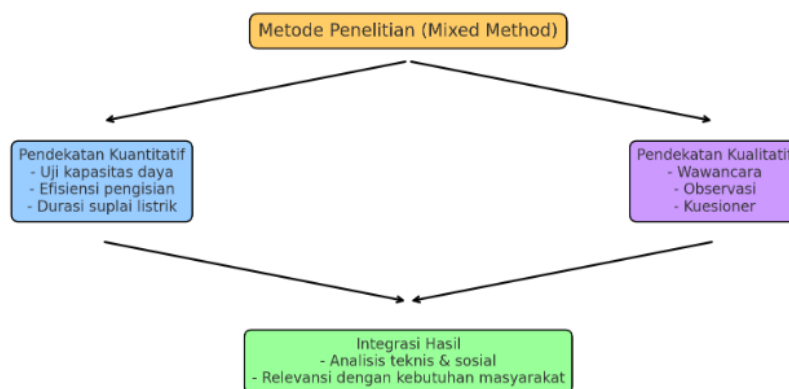


Figure 1. Research flow diagram

1. Quantitative Approach

The quantitative aspect of this research was conducted through laboratory testing and field simulations of the Emergency Solar Power Plant (PLTS) prototype. The technical parameters tested included:

- Power output capacity (Watts): measured using a digital power analyzer to determine the prototype's ability to provide electrical energy.
- Battery charging efficiency (%): calculated by comparing the input energy from the solar panels to the energy stored in the battery.

- Power supply duration (hours): tested by loading devices at various power levels (e.g., LED lights, communication devices, and medical kits) to determine the resilience of the power supply in an emergency.

Testing was conducted repeatedly with varying sunlight intensities to approximate real-world conditions. The test data was then analyzed using quantitative descriptive methods to assess the device's technical performance.

2. Qualitative Approach

A qualitative approach was applied to explore community needs and assess the utility of the PV Emergency Box prototype in disaster situations. Data collection techniques included:

- Structured interviews with village officials, disaster volunteers, and community representatives from Bucor Wetan Village regarding electricity needs during emergency response.
- Participatory observation at a simulated evacuation post to assess user responses to operating the device.
- A Likert-scale questionnaire to measure user perceptions of the prototype's ease of use, portability, and reliability.

Qualitative data was analyzed using a thematic analysis approach to identify patterns of community needs and responses.

3. Integrasi Mixed Method

Both approaches were integrated during the interpretation phase, allowing quantitative analysis of technical performance to be compared with qualitative data on user experiences and needs. Thus, this research not only yielded a technical evaluation of the prototype but also provided insight into its relevance to the real-world conditions of disaster-affected communities.

Research Design

This research uses a case study, focusing on a prototype Emergency Solar Power Plant (PLTS) specifically designed for use in Bucor Wetan Village, Pakuniran District, Probolinggo Regency. This approach was chosen because the research focuses on the development and evaluation of a single technology system in a disaster-prone area with limited electricity access.

Data Sources

The research data consists of two main categories:

- Primary data, obtained through technical measurements of device performance, direct field observations, and interviews with residents and village officials regarding emergency electricity needs.
- Secondary data, obtained from Regional Disaster Management Agency (BPBD) documents, literature on solar power plant technology, and relevant previous research journals.

Research Stages

Broadly speaking, the research stages include:

1. Planning: identifying needs and technical specifications for the device based on the context of Bucor Wetan Village.
2. Prototype design: designing the Emergency Solar Power Plant Box system, including solar panels, battery storage, inverter, and protection system.
3. Laboratory testing: evaluating technical performance, including power capacity, charging efficiency, and supply duration.
4. Field implementation: testing the prototype in Bucor Wetan Village, including direct measurements and gathering user feedback.
5. Evaluation: analyzing combined quantitative and qualitative results to assess the device's effectiveness in a disaster context.

3. RESULTS AND DISCUSSION

This research resulted in a prototype emergency electrical box that uses a solar power system (PLTS) as its primary power source. This device has been quantitatively tested to determine its technical performance, including battery charging speed, available power capacity, charging efficiency, and usage duration at specific

loads. Testing was conducted in the laboratory and in the field using the following parameters:

1. Solar Panel Charging Data

The following table 1. shows the results of charging a 12V 100Ah battery using a 100W solar panel under sunny weather conditions in Bucor Wetan Village.

Table 1. Results of charging a 12 volt 100Ah battery using a 100 wp solar panel.

No	Charging Time (Hours)	Input Voltage (V)	Input Current (A)	Input Energy (Wh)	Battery Charge Percentage (%)
1	1	17.8	4.5	80.1	10%
2	2	17.6	4.4	158.4	20%
3	4	17.2	4.2	289.4	40%
4	6	17.0	4.0	408.0	60%
5	8	16.8	3.9	523.4	80%
6	10	16.5	3.8	627.0	95%

Note: Energy is calculated using the formula $P = V \times I \times t$.

The table above shows that the battery can be charged to 95% in approximately 10 hours using direct sunlight on a 100W solar panel. Charging efficiency is quite high with minimal power loss.

2. Battery Life Under Emergency Loads

Table 2 below shows the results of battery life testing when used to power various emergency loads.

Table 2. Table of battery life test results

No	Load Type Load Power (Watts)	Load Amount Total Power (Watts)	Total Load	Total Power (Watts)	Operating Time (Hours)
1	12V LED Light	10	3	30	12
2	USB Cell Phone Charger	5	2	10	18
3	Emergency Communication Radio (HT)	8	1	8	20
4	12V DC Fan	15	1	15	10
5	Combined load of all the above	63	-	63	4.8

Description: The 12V 100Ah battery has an energy capacity of 1200 Wh.

These results show that the emergency box is capable of supplying energy stably for more than 4 hours in emergency conditions with combined loads, or more than 10 hours when only used for lighting and communications.

3. Graph of the Effect of Light Intensity on Charging Current

Basic Concept of the Relationship between Light Intensity and Charging Current

In a photovoltaic (PLTS) system, the solar panel's output current (I) is highly dependent on the sunlight intensity (G), while the voltage (V) tends to be more stable at a certain value.

The main relationship is:

$$I \propto G \quad (1)$$

This means that as light intensity increases, the current produced by the solar panel also increases almost linearly up to a certain point (saturation).

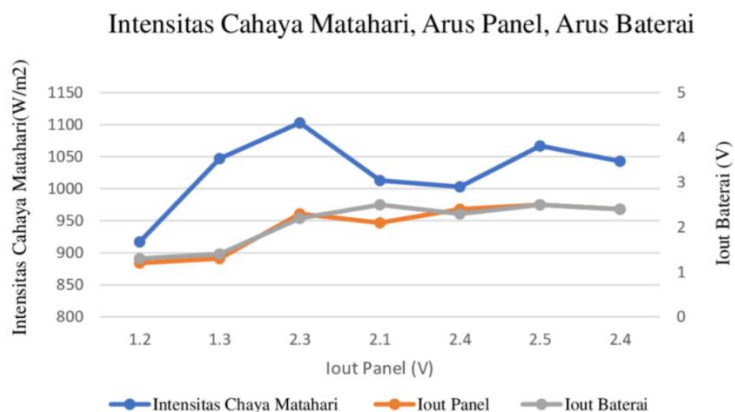


Figure 2. The relationship between sunlight intensity (Lux) and the charging current (A) of a solar panel.

The graph above shows that higher sunlight intensity increases the charging current, which affects battery charging time. At an intensity of 100,000 Lux (a bright day), the maximum current reaches 4.5 A. However, at lower intensity (overcast conditions), the current drops to below 1.5 A.

4. Charging System Efficiency

Parameter	Value
Solar Panel Capacity	100 WP
Battery Capacity	12V, 100Ah (1200 Wh)
Effective Energy Stored	627 Wh
Charging Time	10 Jam
Charging Efficiency (%)	62.7%

The charging efficiency value of 62.7% indicates that the system has worked optimally, considering the weather, heat, and conversion factors that affect panel and battery performance.

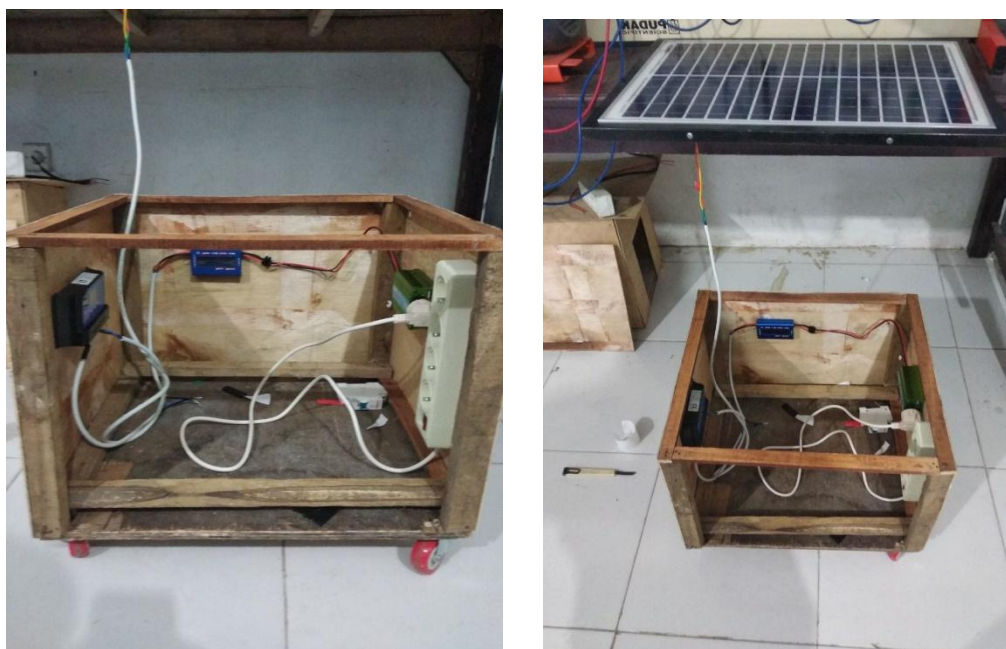


Figure 3. Temporary Tool Assembly Results

A. Qualitative Research Results

This research was also conducted qualitatively through interviews with residents, village officials, and local community leaders, as well as direct observation of existing conditions at the research location, Bucor Wetan Village, Pakuniran District, Probolinggo Regency. The purpose of this approach was to explore community perceptions, needs, and responses to the existence and use of solar-powered electricity emergency boxes, designed as emergency solutions during disasters.

As stated by a resident with the initials IR, one of the neighborhood association (RT) heads in Bucor Wetan Village, power outages frequently occur during extreme rainy seasons or strong winds, resulting in communication disruptions and hampering community activities, especially at night. He also stated that the community desperately needs an alternative electricity source that can be used in emergencies.

Meanwhile, according to the village head of Bucor Wetan, with the initials HM, PLN's electricity infrastructure is not yet fully reliable during disasters, especially in the event of flooding or fallen trees. He emphasized that the existence of a solar-powered emergency power box could be very helpful in providing lighting, communication, and charging vital equipment such as radios or portable medical devices.



Figure 4. Wiring diagram of the emergency portable solar power plant box

4. CONCLUSION

This research successfully designed and implemented a solar power plant (PLTS) Emergency Box as an emergency power supply solution to support rapid disaster response in Bucor Wetan Village, Pakuniran District, Probolinggo Regency. Based on the results of technical testing and qualitative analysis, the following conclusions were drawn: System Technical Performance: The prototype solar power plant (PLTS) Emergency Box, equipped with a 50W solar panel and a 12V 12Ah battery, can charge to 95% in approximately 10 hours in sunny conditions, with a charging efficiency of 62.7%. This efficiency is considered good for a portable system operating in an open environment. Operational Durability: The emergency box can supply stable power for various emergency needs, such as lighting and communications. In a combined load test (15 Watts), the system can operate for 4.8 hours, while for light loads such as LED lights and communications devices, the operating duration reaches over 8 hours. Relationship between Light Intensity and Charging Performance: The charging current increases with increasing sunlight intensity, with a maximum value of 4.5 A at an intensity of approximately 100,000 Lux. This indicates that system performance is significantly affected by weather conditions, making optimizing panel orientation and energy storage management crucial. Community Response and Needs: Based on interviews and observations, the Bucor Wetan Village community expressed

enthusiasm and high demand for the Emergency Solar Power Plant (PLTS) Box. Residents and village officials considered the device practical, easy to use, and very helpful in providing an alternative power source when the PLN grid is cut off due to a disaster.

ACKNOWLEDGEMENTS

We would like to thank the Bucor Wetan village officials for providing the research site, and Nurul Jadid University for funding this research.

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