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Portable Solar Power Generation Technology for Strengthening Field Medical Services During Flood Disaster Situations

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ABSTRACT

Flood disasters frequently disrupt health services due to limited access to electricity in affected areas. This problem hinders the operation of field medical services, particularly for lighting, the operation of basic medical equipment, and emergency communication. This community service activity aims to develop and implement portable Solar Power Generation (SPG) technology as an independent electricity source to support field medical services during flood disaster situations. The implementation method was carried out through a multidisciplinary collaborative approach involving lecturers from different study programs at the Faculty of Engineering, Universitas Islam 45 Bekasi, in cooperation with the Bekasi Branch of the Indonesian General Practitioners Association (PDUI) as a partner. The activity stages consisted of planning, design and assembly of the portable SPG unit, functional testing, implementation, mentoring, and activity evaluation. The results show that the portable SPG unit was successfully developed in a compact, easily portable form capable of providing a stable electricity supply to support field medical services. The partner gave a positive response to the use of the device, considering it practical, safe, and effective for use in disaster emergency conditions. This activity demonstrates that the application of portable SPG-based renewable energy technology can serve as an appropriate solution to support humanitarian services and strengthen the readiness of health services in disaster-prone areas.

1. Introduction

Floods are one of the most frequent types of natural disaster in Indonesia and have a significant impact on various sectors of community life, including health services (Hasibuan et al., 2026). During emergency response conditions, field health facilities often experience limited access to electricity due to damaged infrastructure and disrupted power distribution networks. This condition prevents emergency medical services from operating optimally, particularly in the use of basic medical equipment, lighting, and field communication systems, in line with findings that emergency health services in disaster-prone areas remain limited and require strengthened preparedness (Konstituen – Institut Pemerintahan Dalam Negeri, 2026).

The availability of electricity is a primary requirement for supporting the operation of field medical services. To date, fossil-fuel-powered generators remain the main solution for emergency power supply (Tehnik Unggul Listrindo, 2026). However, the use of generators has several limitations, such as fuel that is difficult to obtain at disaster locations, high noise levels, increasing operational costs due to fuel and routine maintenance needs, and limited device mobility (Hexa Multi Energi, 2025). Therefore, a more practical, independent, and environmentally friendly alternative energy source is needed.

Portable Solar Power Generation (SPG) is one relevant solution for supporting field medical services in disaster situations. This technology offers the advantages of renewable energy use, ease of mobilization, and the ability to provide electricity independently without reliance on the conventional power grid (Kemendikbudristek – Directorate General of Vocational Education, 2024). Portable SPG units can also be designed in a compact form that is easy to carry to disaster-affected locations, as has been demonstrated in the design of an off-grid SPG system as an alternative energy source in the area affected by the Mount Semeru disaster (Nugroho Tri Santosa et al., 2022).

As an implementation of the higher education tridharma, the Faculty of Engineering, Universitas Islam 45 Bekasi, carried out a community service activity in the form of developing and implementing a portable SPG unit to support

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Table 1
Summary of Previous Studies

No	Study and Main Finding	Research Gap
1	Nugroho Tri Santosa et al. (2022) designed a 100 Wp off-grid SPG system as an alternative 220 V charging energy source in the area affected by the Mount Semeru disaster.	Focused on general charging needs; did not address the specific power requirements of field medical equipment.
2	Dhimyati (2022) optimized a solar inverter using PID control with the Ziegler-Nichols method, maintaining an output voltage close to the 220 V setpoint with a small error margin.	Tested under general loading conditions; not yet validated for use with medical devices in a disaster response context.
3	Andriana et al. (2019) and Tauladan et al. (2024) demonstrated that the PZEM-004T sensor module provides accurate voltage and current readings for electrical monitoring systems.	Sensor accuracy was validated in laboratory settings rather than integrated into a complete portable power unit.
4	Hasibuan et al. (2026) reported that integrated medical response and emergency health services after flood disasters still face significant operational constraints.	Did not examine the role of an independent electricity supply in supporting field medical operations.
5	Atonergi (2023) and Hexa Multi Energi (2025) compared SPG and fossil-fuel generators, noting that SPG is more economical and practical for remote or disaster-affected locations.	Comparisons were general and not specifically applied to field medical services during flood emergencies.

field medical services in flood disaster situations. This activity was conducted in cooperation with the Bekasi Branch of the Indonesian General Practitioners Association (PDUI) as the partner and user of the field medical service.

The objective of this activity is to develop portable SPG technology that can be used as an independent energy source for field medical services, to improve the effectiveness of emergency health services in disaster-affected areas, and to strengthen the synergy between higher education institutions and health professional organizations in the application of appropriate technology. The remainder of this paper is organized as follows: Section 2 reviews related works; Section 3 presents key terminology; Section 4 describes the implementation methodology; Section 5 presents the results and discussion; Section 6 discusses the implementation case at the partner site; and Section 7 concludes the paper.

2. Related Works

Several prior studies have examined renewable energy solutions and emergency power systems for disaster contexts, as well as the supporting components used in this activity. Table 1 summarizes the main findings of these studies and identifies the gap that the present community service activity addresses.

3. Terminology

3.1. Portable Solar Power Generation (SPG)

Portable Solar Power Generation refers to a compact, mobile photovoltaic-based power system that converts sunlight into electricity through a solar panel, stores it in a battery via a charge controller, and supplies it to electrical loads through an inverter. Its portability allows the system to be transported and deployed quickly in locations where the conventional power grid is unavailable or disrupted, such as disaster-affected areas (Kemendikbudristek – Directorate General of Vocational Education, 2024; Nugroho Tri Santosa et al., 2022).

3.2. PZEM-004T Sensor Module

The PZEM-004T is a voltage and current sensor module with a high level of measurement accuracy, widely used in electrical monitoring research to read AC/DC voltage, current, power, and energy consumption. The module communicates with a microcontroller via a serial interface (UART/TTL), allowing real-time monitoring of the electrical parameters of a power system (Andriana et al., 2019; Tauladan et al., 2024).

3.3. PID Control for Inverter Voltage Regulation

Proportional-Integral-Derivative (PID) control is a feedback control method used to maintain a system's output close to a desired setpoint by continuously adjusting a control variable based on the error between the measured output and the setpoint. In this study, PID control with the Ziegler-Nichols tuning method is applied to regulate the inverter so that its output voltage remains stable near the 220 VAC setpoint required by standard household electrical equipment, even under varying load conditions (Dhimyati, 2022).

4. Methodology

This community service activity was carried out using a multidisciplinary collaborative approach involving lecturers from different study programs at the Faculty of Engineering, Universitas Islam 45 Bekasi. The activity partner was

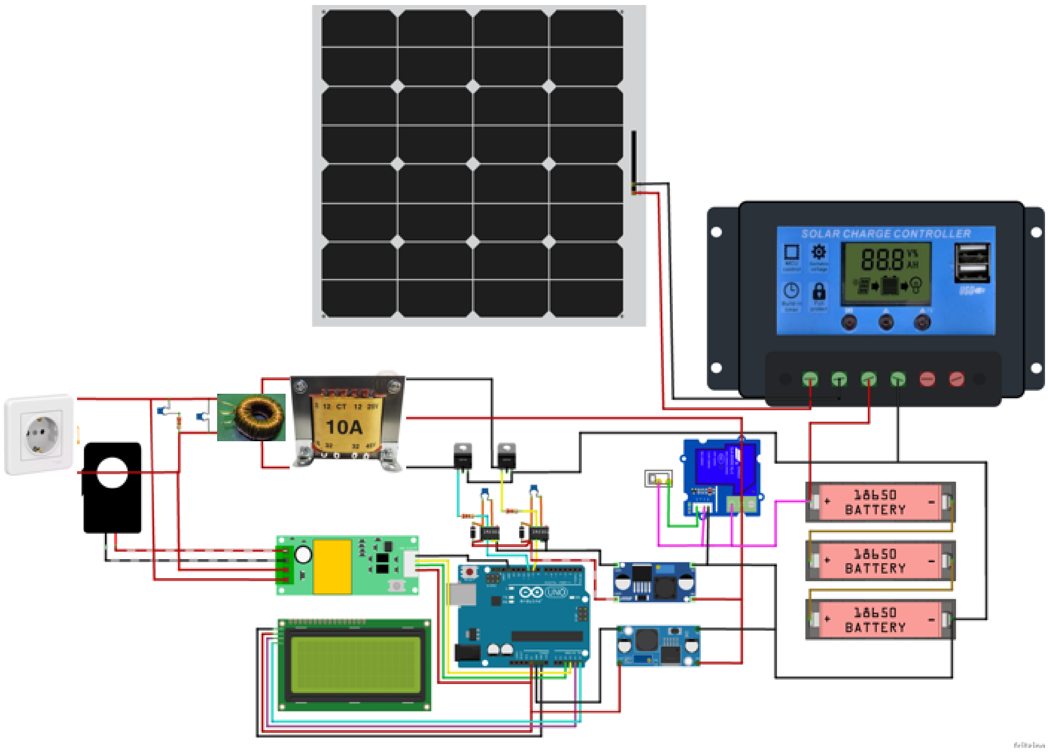

Figure 1: Hardware design schematic of the portable SPG unit.

the Bekasi Branch of the Indonesian General Practitioners Association (PDUI), which acted as the user and evaluator of the portable SPG device. The implementation consisted of five stages: (1) planning and coordination, (2) design and assembly of the portable SPG unit, (3) system testing, (4) implementation and mentoring, and (5) activity evaluation, as illustrated in Figure 1.

The first stage, planning and coordination, was carried out through internal team meetings to formulate the activity concept, determine the initial device specifications, and identify the partner's needs. Intensive communication was held with PDUI Bekasi Branch regarding the electricity requirements of field medical services. In the second stage, the implementation team designed and assembled the portable SPG unit, including the selection of the solar panel, battery, inverter, and solar charge controller, as well as the design of the casing and frame.

The system uses a solar panel, a solar charge controller (SCC), and LiPo batteries as the power generation and storage components, together with an Arduino Uno microcontroller, MOSFETs, a MOSFET driver, a step-up transformer, a relay, and a PZEM-004T sensor as the DC-to-AC inverter, as shown in Figure 1. Assembly was carried out collaboratively by lecturers from the different study programs involved.

The third stage, system testing, was carried out after assembly was completed to ensure power stability, electrical safety, and ease of operation through simulated use under field medical service conditions. Testing was performed to evaluate the performance of the sensor and the PID control system of the inverter. Sensor testing focused on the accuracy of voltage and current readings using the PZEM-004T sensor. The sensor readings were compared with a standard measuring instrument (avometer) to determine the measurement error for AC voltage, AC current, and DC voltage and current as inverter input data, consistent with a calibration method for the PZEM-004T sensor that compares sensor readings with a digital multimeter (Andriana et al., 2019; Tauladan et al., 2024).

Subsequently, PID control testing was carried out using an output voltage setpoint of 220 VAC according to the PLN (state electricity utility) standard. This approach is consistent with research on optimizing a solar inverter using PID control with the Ziegler-Nichols method, which shows that the inverter output voltage can be maintained close to the 220 V setpoint with a small margin of error (Dhimyati, 2022). The testing aimed to determine the system's ability to maintain inverter output voltage stability under various load conditions. Input and output power data of the inverter were recorded using a data logger and then analyzed in graphical form using Microsoft Excel.

PID testing was divided into two stages: short-term testing and periodic testing. Short-term testing was carried out with varying loads and a sampling rate of five data points per second to determine the system's response in reaching the setpoint. Periodic testing was carried out over five days with data collection twice a day and a sampling interval of one data point every five seconds to evaluate system stability under continuous use.

Table 2
Main Components of the Portable SPG Unit

No	Component	Specification	Function
1	Solar panel	100 Wp foldable monocrystalline panel	Converts sunlight into DC electrical energy
2	Solar Charge Controller (SCC)	PWM/MPPT type, 10 A capacity	Regulates charging current into the battery and protects against overcharging
3	LiPo battery bank	3 cells, 18650 type	Stores electrical energy generated by the solar panel
4	Arduino Uno microcontroller	ATmega328P-based board	Controls the PID switching signal for the inverter
5	MOSFET, MOSFET driver, and step-up transformer (10 A)	DC-to-AC switching and voltage step-up stage	Converts DC battery voltage into 220 VAC output
6	PZEM-004T sensor	AC/DC voltage and current sensor module	Monitors voltage, current, and power for the PID feedback control

Table 3
Partner Evaluation of the Portable SPG Unit

No	Evaluation Criteria	Before Implementation	After Implementation
1	Ease of use	Low (reliant on PLN grid / generator)	High (independently operable by medical staff)
2	Device portability	Not applicable (stationary generator)	High (foldable panel and compact casing)
3	Reliability of power supply	Limited during power outages	Stable for lighting and basic medical equipment
4	Safety during operation	Moderate (fuel and noise hazards)	High (no fuel, low noise, low heat)
5	Dependence on fossil-fuel generators	High	Reduced

In the fourth stage, the portable SPG unit that had been verified as fit for use was handed over to the PDUI Bekasi Branch partner for use in field medical services. The implementation team also provided technical mentoring and operational briefing on the use of the device to medical personnel. In the fifth stage, an evaluation was conducted by collecting feedback from the partner regarding ease of use, device reliability, and the benefits of the portable SPG unit in supporting field medical services.

5. Results and Discussion

The main result of this community service activity is the realization of a portable SPG unit specifically designed to support the electricity needs of field medical services in flood disaster situations. The device was developed in a compact and easily portable form, making it suitable for use at disaster locations with limited access. The main components of the device consist of a solar panel, an energy storage battery, an inverter, and a power regulation system, as summarized in Table 2. Integration of all components was carried out with consideration for safety, efficiency, and ease of use. Based on the testing results, the device was able to provide a stable electricity supply for lighting needs and the operation of simple medical equipment.

Figure 2 shows the internal assembly of the inverter unit, integrating the MOSFETs, MOSFET driver, step-up transformer, relay, battery pack, and microcontroller within a repurposed enclosure equipped with active cooling.

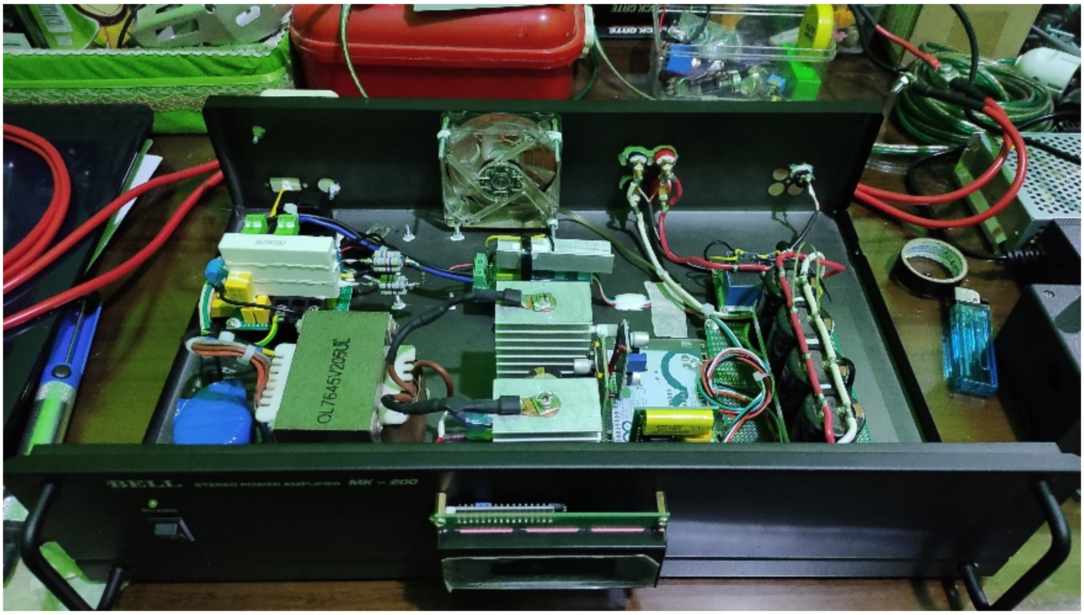

Figure 2: Internal assembly of the inverter unit.

Figure 3: Field operation of the portable SPG unit.

6. Implementation at the Field Medical Service Site

Implementation of the portable SPG unit was carried out in cooperation with the PDUI Bekasi Branch. The device was used to support field medical service activities in flood-affected areas, as shown in Figure 3. The implementation results show that the portable SPG unit was able to help medical personnel carry out emergency health services more effectively.

The use of the device provided several benefits, including: (1) supplying an independent source of electricity without reliance on the conventional power grid; (2) supporting lighting for field medical services; (3) enabling the operation of basic medical equipment; (4) facilitating device mobilization to disaster-affected locations; and (5) reducing dependence on fossil-fuel generators.

6.1. Partner Utilization Evaluation

Based on the evaluation results, the partner gave a positive response to the use of the portable SPG unit. Physicians on duty in the field considered the device easy to use, practical to carry, and reasonably reliable for supporting basic electricity needs in emergency situations. In addition, the use of renewable energy through the portable SPG unit was considered safer and more environmentally friendly than the use of conventional generators, which still depend on a fossil fuel supply that is difficult to obtain at disaster locations (Atonergi, 2023). A constraint that remains is the limited power capacity for operating medical devices with high energy consumption; therefore, increasing the system's capacity is recommended for future activities.

7. Conclusion

This study shows that portable SPG technology has significant potential as an emergency energy solution for field medical services. The multidisciplinary collaborative approach applied in this activity proved effective in producing technology that suits user needs. The activity also highlights the importance of partner involvement from the early planning stage through to evaluation, which enabled the technology development process to proceed in a more applied manner and in accordance with real conditions in the field. From a community service perspective, this activity demonstrates that higher education institutions can make a real contribution to disaster management through the application of appropriate technology based on renewable energy.

The community service activity involving the development and implementation of a portable SPG unit was successfully carried out through collaboration between the Faculty of Engineering, Universitas Islam 45 Bekasi, and the PDUI Bekasi Branch. The portable SPG unit that was developed was able to provide an independent source of electricity to support field medical services in flood disaster situations. The implementation results show that the device is easy to use, safe, and effective in meeting the basic electricity needs of emergency medical services. The application of renewable energy technology through the portable SPG unit provided real benefits for medical personnel in the field while strengthening the role of higher education institutions in applying appropriate technology for the community. This activity is expected to serve as a model for the development of similar technology in other disaster-prone areas and to support the strengthening of humanitarian services based on renewable energy. Future work should focus on increasing system capacity to accommodate higher-power medical equipment and on conducting longer-term field validation across multiple disaster scenarios.

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