SHM PUBLISHER
SURYA HIJAU MANFAAT

Journal of
Electronics Technology Exploration

Homepage: https://shmpublisher.com/index.php/joetex
p-ISSN 3025-3470 | e-ISSN 3026-1066

Off-Grid Emergency Tent Solutions with a Compact Solar Photovoltaic System

Muhammad Zaim Marwan Mazlan[1], Khairul Anuar Mohamad[2], Afishah Alias[3], Muhammad Syahmi Nordin[4], Yusmar Palapa Wijaya[5]
[1,2]Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Malaysia
[3]Faculty of Aplied Science and Technology, Universiti Tun Hussein Onn Malaysia, Malaysia
[4]MT Data Driven Sendirian Berhad, Malaysia
[5]Department of Electronic, Politeknik Caltex Riau, Indonesia

Article Info

Article history:

Received January 17, 2024
Revised February 26, 2024
Accepted March 5, 2024

Keywords:

Compact solar PV
Emergency tent
Off-grid
Sizing
Solar performance

ABSTRACT

In recent years, solar photovoltaic (PV) systems have seen increased utilization for powering a diverse range of applications, from residentials and buildings to off-grid installations, highlighting their growing importance in the global transition towards sustainable development using renewable energy sources. This paper proposes the development of a compact solar PV system for emergency tent systems to aid preparations and rapid response efforts during disasters and unforeseen events. The system aims to support local authorities and communities in mitigating disaster risks due to power outages. The design and implementation of an emergency tent prototype measuring 3×3 m^2, with a power consumption of 0.36 kW/day using a 30 W solar PV panel and battery storage capacity of 40 Ah. The system is sufficient for powering the basic functions of dc bulbs and fans as the primary load.

Corresponding Author:

Khairul Anuar Mohamad,
Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia,
Parit Raja 86400 Batu Pahat, Johor, Malaysia.
Email: khairulam@uthm.edu.my
https://doi.org/10.52465/joetex.v2i1.289

1. INTRODUCTION

In recent years, the global community has frequently experienced disasters such as floods, landslides and haze, along with some rare instances of earthquakes and tsunamis. According to the Index for Risk Management (INFORM) [1], for example, Malaysia's natural hazard and exposure risk is rated at 3.4 out of 10. Floods are the most common disaster, causing significant losses each year, including loss of life, illness outbreaks, crop damage, property damage, and other losses. From 2012 to 2019, Malaysia had the highest population exposure to floods among ASEAN Member States [2]. Over the past two decades (1998-2018), Malaysia has experienced 51 notable natural disaster incidents. These disasters impacted over 3 million people, resulted in the loss of 281 lives, and caused close to US $2 billion in losses. People affected by these crises often struggle in accessing power supplied to meet their families' basic needs. Consequently, securing safe shelter becomes a top priority. Thus, the concept is to introduce a stand-alone and compact solar photovoltaic (PV) system for emergency tent applications to maximize solar energy production both inside and outside the tents for immediate emergency purposes. Standalone systems are necessary when there is no public grid connection or power outages in the area. In other circumstances, separate systems are required, and the solar energy received by the solar panels is essential for standalone systems to operate. This innovative approach not only ensures a reliable power source during critical situations but also underscores the adaptability of solar technology in providing sustainable and self-sufficient energy solutions for emergency response scenarios.

A few researchers have focused on the development and application of solar-powered tents [3], [4], particularly for emergency situations. For example, students at IPB University created the solar panel smart emergency tent (TEDAPIS) as a solution to provide electricity for victims of natural disasters [5]. This innovation integrates smart devices and is designed to provide quick assistance in emergencies. There have been limited studies concerned with the deployment of such tents in real-world scenarios. Another example is the deployment by UNICEF of 457 high-performance, climate-resilient emergency tents to support school reopening in flood-affected districts in Uganda [6]. These innovative tents have been used in an emergency, which include ventilation systems, elevated shade nets, electrical and solar kits for lighting and energy, and three-layered windows to help block out disease-carrying mosquitoes. Despite these advancements, more research is needed to address the challenges and limitations of solar energy technology, such as the dependency on sunlight for energy generation, which can lead to potential interruptions during nighttime and overcast days. However, the integration of effective energy storage solutions, such as batteries, can help mitigate these concerns and ensure a more reliable power supply.

This paper intends to develop a stand-alone compact solar PV system for emergency tent solutions to cover the basic electrical needs by supplying the necessary amount of energy required for a designated area of a tent. The design of solar PV system is designed based on selection of panel PV, inverter, battery and loads. Comprehensive analysis is conducted to show how the performance of the solar PV system wih a particular focus on power consumption provides a robust and self-sufficient energy solution during critical scenarios.

2. METHOD

2.1 Components of a Solar PV System

Figure 1 shows a schematic diagram of a solar PV system designed for an emergency tent by providing a comprehensive overview of its various components and their interconnected relationships. This schematic encompasses the fundamental elements such as solar panels, charge controller, batteries, inverter, load panel, and appliances, explaining the whole connectivity that enables the efficient harnessing and distribution of solar energy within the emergency tent environment [7].

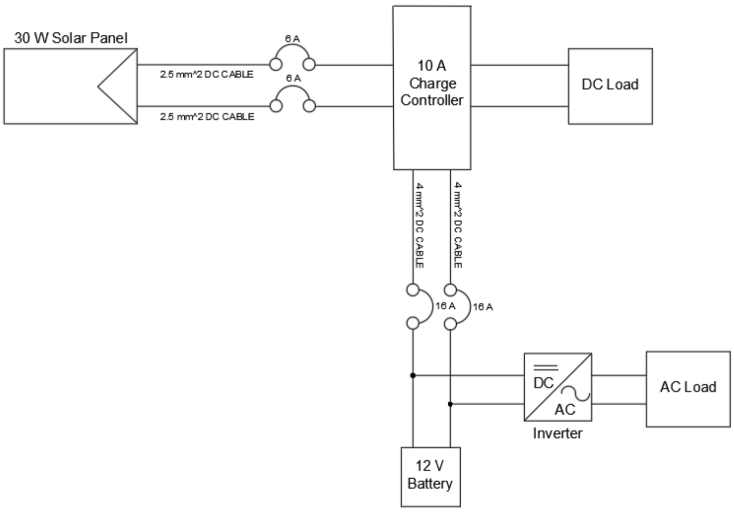

Figure 1. Schematic diagram of a proposed solar PV system for emergency tent

The solar PV system is positioned at latitude = 1°5 52'20.1"N and longitude = 103°07'15.8"E. A fix tilt angle is set to 45° to maximize the amount of sunlight received by the solar panels.

2.2 Design of Solar PV System

This section presents the procedures for designing a solar PV system to meet the specific energy requirements of the tent. Table 1 details the power requirements for the basic loads within the tent. From Table 1, the total power requirements by determining the electrical load profile is 0.36 kW/day.

.

Table 1. Power requirements for the basic loads within the tent

Load	Power Consumed [W]	Quantity	Total Power [W]	Operating time/day [hours]	Total Power watt/day [hours]
LED Bulb	10	1	10	12	120
Fan	10	1	10	24	240
				Total	360

Furthermore, the designing of a solar PV system consists of the procedure namely as panel selection, charge controller, battery sizing, inverter, cable sizing and circuit breaker [8], [9]. Table 2 summarizes the design of the proposed PV system.

Table 2. Specifications of solar PV system's design

		Specification
a.	Solar Panel	
	Monocrystalline Solar Panel	30 W
	Sun Peak Hours	6 hours
	Solar Panel Voltage at maximum power	18 V
	Solar Panel Power Output	120 W
b.	Battery Sizing	
	Battery Efficiency	0.8
	DOD	1
	Nominal Battery Voltage	12
	Battery Capacity	40 Ah (37.50 Ah)
c.	Inverter Sizing	
	Power Consumption	20%
	Inverter Ratings	450 W
d.	Charge Controller Sizing	
	Charge Controller System Voltage	12 V
	Charge Controller Ratings	10 A
e.	Cable Sizing	
	Cable Length	1 m
	Maximum Current	1.66 A
	Cable Material	Copper
	Acceptable Voltage Drop	28%
	Cable Size	2.5 mm^2
f.	Circuit Breaker Sizing	
	Maximum Current	1.79 A
	Circuit Breaker Ratings	6 A

This system is a stand-alone PV system (off-grid), which is designed to operate independently without reliance on the electric utility grid for self-supplying power source to meet certain demands.

2.3 Mechanical Structure of Solar PV-powered Emergency Tent

Figure 2 illustrates the structure of an emergency tent equipped with a solar PV system. The area of the tent is 3×3 m^2, which providing a compact and functional space for immediate emergency situations. The positioning of the tent is important to ensure optimal exposure to sunlight, thereby enhancing the performance of the integrated solar PV system and ensuring a reliable power source in emergency situations.

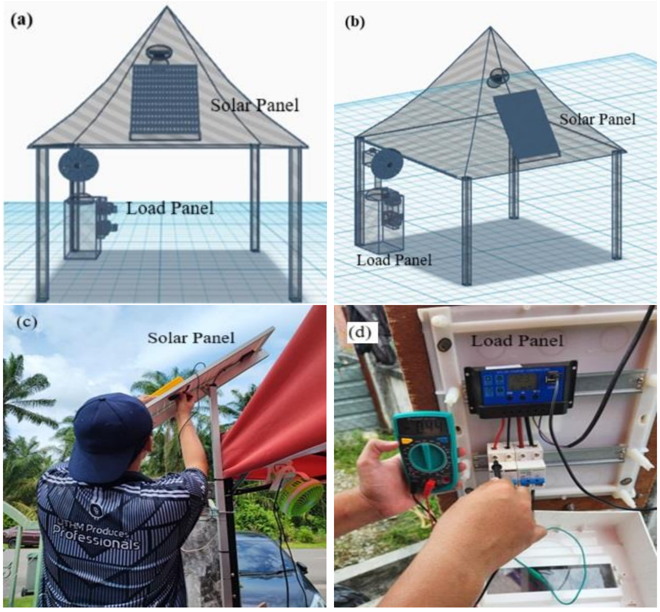

Figure 2. Overview of emergency tent with a solar PV system: (a) Front view, (b) side view, (c) integration solar panel and (d) load panel

3. RESULTS AND DISCUSSIONS

It is important to note that solar performance is influenced by various factors, including solar irradiance, weather conditions, shading, and system efficiency [10]. This data provides valuable insights into the system's performance with the load is in on condition and it's also can be used to assess the effectiveness of the solar installation and identify potential areas for improvement. Figure 3 shows the solar PV system performance during weekdays (June 5 until 9, 2023) with load conditions. The performance of the solar panel varied across the recorded days, displaying an overall increasing trend in power output. On Monday, the power output ranged from 4.54 W to 12.44 W. Tuesday exhibited consistency, with power output ranging from 4.09 W to 9.25 W. Wednesday and Thursday showed slight improvements, with power output ranging from 9.4 W to 10.54 W and 11.7 W to 13.01 W, respectively. Friday recorded the highest performance, reaching 10.59 W to 14.14 W. Throughout the recorded days, both current and voltage values followed similar trends, indicating that higher values corresponded to higher power outputs. This suggests a consistent relationship between the electrical parameters and solar performance. It is evident that Thursday and Friday demonstrated superior solar performance compared to Monday and Tuesday, with Friday exhibiting the highest power output during the recording period.

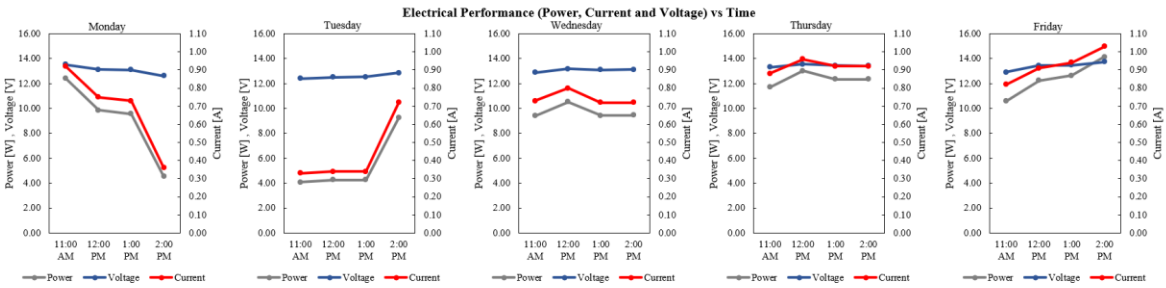

Figure 3. Performance monitoring of the solar PV system during weekdays

Moreover, Table 3 presents data spanning from 08:00 to 14:00 am on June 15, 2023, capturing various time points on sunny days with a tilt angle set at +45°. During the morning hours, irradiance progressively increases, peaking at 10:00 AM with a value of 885 W/m², indicating high solar energy intensity. The ambient temperature remains consistently around 31-33°C, while the solar temperature rises slightly from 37°C to 40°C. At noon, irradiance reaches its highest value in the dataset at 1070 W/m², denoting peak solar intensity. The ambient temperature remains steady, and the solar temperature slightly decreases. In the afternoon, irradiance gradually declines, measuring 865 W/m² by 2:00 PM. The ambient temperature rises, while the solar temperature increases to 45°C.

Table 3. Performance of solar PV system with a fix tilt angle of +45°.

Time	Irradiance [W/m²]	Ambient Temperature [°C]	Solar Temperature [°C]	Power Output [W]	Current [A]	Voltage [V]
08.00	574	31	37	13.69	1.04	13.16
09:00	720	31	37	14.16	1.1	12.87
10:00	885	33	40	20.51	1.54	13.32
11:00	924	32	37	20.87	1.61	12.96
12:00	1070	33	39	24.16	1.84	13.13
13:00	879	37	40	19.89	1.5	13.26
14:00	865	39	45	19.51	1.48	13.18

It can clearly be seen that the amount of power produced is sufficient to cover the needs of essential applications within the emergency tent, ensuring a reliable and sustainable source of electricity during critical situations. Furthermore, this method proves highly effective and stands as a reliable support for local authorities in providing a robust and self-sufficient energy solution during critical scenarios.

4. CONCLUSION

The solar PV system for an emergency tent presents a sustainable solution for emergency situations by utilizing solar energy to power a tent, serving as a shelter for those affected by natural disasters or emergencies. The tent can be rapidly and easily set up, providing a secure and comfortable environment for those in need. The prototype represents a practical response to emergency scenarios, delivering reliable and sustainable energy. It demonstrated excellent power generation capacity, efficient energy storage, and outstanding performance in locally designated situations and field tests. The prototype has laid a robust foundation for developing stand-alone solar systems for emergency tent applications. The prototype stand-alone solar system emerges as valuable tools that can enhance emergency response capabilities, ensuring reliable and sustainable energy sources in critical situations.

REFERENCES

[1] E. Commission, J. R. Centre, M. Marin-Ferrer, K. Poljanšek, and L. Vernaccini, *Index for risk management - INFORM – Concept and methodology, version 2017*. Publications Office, 2017. doi: doi/10.2760/094023.

[2] M. Y. Safiah Yusmah *et al.*, "Understanding urban flood vulnerability and resilience: a case study of Kuantan, Pahang, Malaysia," *Nat. Hazards*, vol. 101, no. 2, pp. 551–571, Mar. 2020, doi: 10.1007/s11069-020-03885-1.

[3] R. Sridharan, M. Sriram, and E. Rajkumar, "SMART SOLAR POWERED TENT," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1123, no. 1, p. 012032, Apr. 2021, doi: 10.1088/1757-899X/1123/1/012032.

[4] A. Sacks, "A Solar Powered Tent for Comfortable Outdoor Living, Emergency and Flexible Activities," *Int. J. Renew. Energy Sources*, vol. 8, pp. 90–114, 2023.

[5] A. D. Lesmana, ohul R. M. Hartman, A. Wahyuningtyas, and I. Irzaman, "TEDAPIS (TENDA DARURAT PINTAR BERTENAGA PANEL SURYA) SEBAGAI SOLUSI PENYEDIAAN ENERGI LISTRIK BAGI KORBAN BENCANA ALAM," in *PROSIDING SEMINAR NASIONAL FISIKA (E-JOURNAL) SNF2019 UNJ*, Pendidikan Fisika dan Fisika FMIPA UNJ, 2019. doi: 10.21009/03.SNF2019.02.PA.15.

[6] UNICEF, "UNICEF deploys over 450 climate-resilient emergency tents to support school reopening in Uganda," 2022. https://www.unicef.org/press-releases/unicef-deploys-over-450-climate-resilient-emergency-tents-support-school-reopening

[7] G. Nagababu, V. S. K. V. Harish, K. Doshi, Y. Bhat, and M. Bansal, "Harnessing Solar Energy for Sustainable Development of Livelihoods," in *Handbook of Climate Change Mitigation and Adaptation*, Cham: Springer International Publishing, 2022, pp. 1249–1284. doi: 10.1007/978-3-030-72579-2_113.

[8] F. L. Luo, "Design of solar-panel energy system," in *2011 6th IEEE Conference on Industrial Electronics and Applications*, IEEE, Jun. 2011, pp. 2304–2309. doi: 10.1109/ICIEA.2011.5975976.

[9] A. A. S. B. P. H. Shahbirin, M. S. bin Rosli, S. P. Ang, S. M. Sulthan, and M. N. Dani, "Design, Implementation, and Analysis of Solar Photovoltaic System Efficiency with Cooling System and Mechanical Tracking," 2023, pp. 21–29. doi: 10.1007/978-981-99-0915-5_2.

[10] A. K. Tripathi, S. Ray, and M. Aruna, "Analysis on Photovoltaic Panel Temperature under the Influence of Solar Radiation and Ambient Temperature," in *2021 International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT)*, IEEE, Feb. 2021, pp. 1–5. doi: 10.1109/ICAECT49130.2021.9392619.