Journal of Renewable Energy, Electrical, and Computer Engineering
Volume 5, Number 1, March 2025. 93-98
eISSN 2776-0049
Research Original Article
DOI: https://doi.org/10.29103/jreece.v5i1.19138

Design of Solar Panel Based Powerbank with Control System BMS (Battery Management System)

Dewi Sholeha✉1 , Yoga Himawan Sasmito2
1,2Electrical Engineering Study Program, Universitas Darma Agung, Medan Jl. Dr. TD Pardede No 21 Medan, 20152, North Sumatra
✉Corresponding Author: alkhansadewi@gmail.com | **Phone: +6285361555506**

Received: October 28, 2024 **Revision: January 15, 2025** **Accepted: March 10, 2025**

Abstract
Electrical energy is the main energy for humans. Electrical energy has a very important role in the development of modern technology in all sectors of households and industry. Electrical energy must be sustainable for human survival. Therefore, the problem of saving electrical power needs to be raised in research. This study aims to design a solar panel-based power bank to meet household electricity needs such as fans. This is done to reduce the use of electricity costs sourced from PLN. The study's results showed that by using 1 sheet of GH Solar 50 Wp solar panel, 4 units of LI-P0 12 Volt 22 AH batteries using a series circuit and an inverter. Each installed component meets the specifications so that this PLTS system can turn on 1 fan unit with a load power of 42.0 Watts. Furthermore, for charging HP of 8 watts and Laptop of 40.3 watts for 2 hours 45 minutes for 1 day.
Keywords: Battery Management System, Solar Panel, PLTS, Powerbank

Introduction
Along with the development of technology, it has had an impact on human life in various fields, one of which is in the field of engineering, namely the use of electrical energy (Okay et al., 2022). There are many impacts given by the development of electricity at this time, where in the past people used petromax lamps for lighting, while now society as a whole has used lighting through electrical energy sourced from PLN (Sholeha et al., 2022). Electrical power is the most important power for humans. With the development of technology, electrical power has become a power that is greatly needed by society (Bhushan et al., 2022; Yuan et al., 2020). Almost all gadgets that help humans require the use of electricity. Electrical power can be converted into various other forms of energy such as electrical energy can be converted into optical energy (light), electrical energy can be converted into heat energy, and electrical energy can be converted into dynamic energy such as in electric fans (Zambak et al., 2022). The development of renewable energy resources originating from nature is increasingly being used by the government. Eight renewable energies have been utilized by the government, namely fuel, biomass, geothermal, water, wind, sun, ocean waves, and tides (Napitupulu et al., 2023). As the years go by, the use of electrical energy will increase due to the large number of industrial project developments, daily human needs, and others. To avoid this from happening, it is necessary to develop an energy utilization program, namely by utilizing energy sources from the sun (Kim et al., 2022). Many technologies are used to increase the absorption of sunlight energy, namely by redesigning to obtain optimal power from solar panels with DC output voltage settings (Hwang et al., 2022). Because the sunlight process always changes from morning to evening, it causes instability of the DC output voltage from the solar panel (Hwang et al., 2022). In this study, a 50 Wp solar panel model was designed using an inverter with DC voltage control using the help of a BMS (Battery Management System) (Wang et al., 2023). The problem of saving electrical power needs to be raised in this study because electrical energy must be sustainable for the survival of humans on Earth (Tarhan et al., 2021). The use of renewable energy from sunlight does not discriminate against groups, because considering the energy crisis in the world approaching the threshold of the world energy crisis in 2050, each country is trying to develop solar panels to balance the use of electrical energy by using a battery charging control system (Lee et al., 2023). The battery charging control system is one of the tools for controlling the entry and exit of electricity received and the energy released by the battery (Sorour et al., 2021). BMS functions to optimize battery performance and extend battery life (Marcos et al., 2021). Therefore, the author took a study entitled "Design of Solar Panel-Based Powerbank with BMS (Battery Management System) Control System" (Al Farizi & Widyartono, 2023).

Literature Review
BMS (Battery Management System)

Battery Management System "BMS" or *Battery Management System* is an electronic system that manages the battery (Liu et al., 2019). The BMS system is essential for monitoring parameters such as charge status, thermal status monitoring, ampere/hour calculation, and terminal voltage and current flow. The BMS also helps control and balance the battery circuit. The BMS is used to keep the cells in the battery safe (Shen & Gao, 2019). The BMS plays an important role in improving battery performance, optimizing safe and reliable operation (Ghalkhani & Habibi, 2023). Key features of the Battery Management System "BMS" That is, the balance charger is used to balance *the voltage* during charging, discharging or using (Habib et al., 2023).

overcharge protection function works when charging the battery (Ghalkhani & Habibi, 2023). When the total voltage reaches the maximum limit, the charging current stops. The overdischarge protection function when the battery is discharged under load. When the total voltage reaches the specified minimum value or the battery cell reaches its minimum value, the current flow to the load stops. Thermal control comes into effect when the battery temperature reaches a certain limit. Air cooling is activated to protect the battery from overheating (Gabbar et al., 2021). There are many missing BMS design features, two important ones are battery pack protection management and capacity management (Tran & Fowler, 2020).

The working principle of the battery is divided into two processes, namely the battery discharge process and the battery charging process. There is a battery discharge process. This is called cell discharge (Huckaba et al., 2020). Naturally, this process will take longer if the battery is empty (Bhushan et al., 2022). The time to discharge (reserve charging time) varies depending on the load used. The more energy provided by the load, the faster the battery discharge time (Jafari & Byun, 2022). For batteries, voltage and current are usually expressed in units of time. If the battery used is a 12V 22Ah battery, the formula for determining battery power is:

$$P = V \times I$$

Research Methods

The research location is in Kasindir Village, located in Jorlang Hataran District, with a research period of one month. The specifications of the materials used consist of:

Table 1. Material Details

No	Material	Details		
1	Solar Panels *(Polycrystalline silicon solar cells)*	a) *Maximum power (Pmax)*	50W	
		b) *Maximum voltage (Vmp)*	20.88V	
		c) *Current maximum (Imp)*	2.40 A	
		d) *Open Circuit Voltage (Voc)*	24.01 V	
		e) *Short Circuit Current (Isc)*	2.51 A	
		f) *Dimensions*	610*580*30mm	
2	*Watt Meter*	Parameter	Range	Resolution
		Current	0 ~ 100 AP	0.01 Ampere
		Power	0 ~ 6554 Watt	0.1 Watt
		Voltage	0 ~ 60 Volt	0.01 Volt
3	Solar *Charge Controller*	10 Ampere		
4	Battery Aki	12 Volt 22 Ampere hours		
5	*Inverter*	*Input Voltage*	Dc12/24V	
		Output Voltage	Usb Dc5.5 V 1 A	
		Output Voltage	Ac 220V 230V 240V 100V 110V 120V	
		Frequency	50Hz/60Hz ±4Hz	
6	BMS (*Battery Management System)*	12 volts/120 amps		
7	Cable	10m		
8	Connecting terminal	12 pins/1 piece		
9	Triplex	1 sheet		
10	Solation	1 piece		
11	Iron elbow	1 stick		
12	Screw	½inc 1 piece		
13	Switch	2 pieces		
14	Bolt	M3x40mm / 4 pieces		

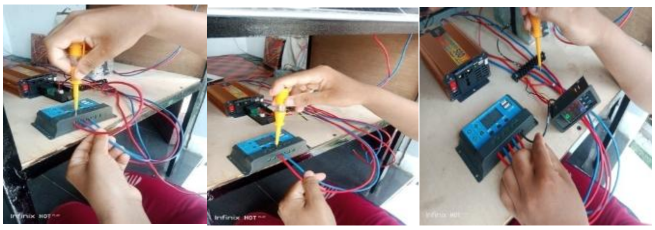
The specifications of the tools used are as follows:

Table 2. Tool Details

No	Tool	Details
1	Gerindra	1 piece
2	Wood saw	1 piece
3	Hand drill	1 piece
4	Cutting pliers	1 piece
5	Peeling pliers	1 piece
6	Screwdriver±	2 pieces
7	Solder+tin	

Research procedures are used as a basis for carrying out research with efficient and sequential steps. The research procedures are:

- Conduct a literature study on the tools used in the research.
- Providing the tools and materials used, namely solar panels, *solar charge controllers, watt meters*, batteries, BMS (*Battery Management System*) and *inverters.*
- Next is the formation of the tool. The formation is carried out by placing the battery*, solar charge controller, watt meter*, BMS (*Battery Management System*) and *inverter* into an iron frame with a plywood base. The tools are arranged so that the cables are connected properly and neatly.
- Then the frame is given wheels, to make it easier to pull or move the tool.



(a) (b) (c)

Figure 1. Information (a) Mounting Solar Panels to Solar Charge Controller, (b) Installing the Battery to the Solar Charge Controller, (c) The Process of Installing a Watt Meter to a Solar Charge Controller and Inverter

Figure 2. Solar Panel-Based Powerbank with BMS Control System

Results and Discussion

a) Load Measurement with Solar Panels for 7 Hours

Table 3. Measurement Results of Solar Panels and Batteries

O'clock	Solar Panels							Battery Aki
	Volt	*Current*	*Watt*	*Watt Peak*	*Ampere Hours*	*Ampere Peak*	*Watt Hours*	Voltage (V)
09.00	13.2	0.12	1.7	1.5	0.012	0.16	0.12	13.2
10.00	13.2	0.17	2.2	2.2	0.208	0.14	2.7	13.2
11.00	13.2	0.18	2.5	2.5	0.446	0.22	5.9	13.2
12.00	13.3	0.24	3.2	3.3	0.618	0.25	8.2	13.3
13.00	13.4	0.34	4.7	4.7	0.927	0.36	12.4	13.3
14.00	13.3	0.56	7.6	10.2	1,920	0.50	17.3	13.3
15.00	13.3	0.22	2.9	2.8	1,810	0.19	24.2	13.2

What is observed in this test is the amount of *Current, Volt, Watt, Wattpeak, Ampere Hours, Ampere Peak, Watt Hours* produced by solar cells within twelve hours. The calculation was carried out at 09.00 to 15.00. What is the maximum Wh indicated by the electricity meter from 11 am to 12 noon. During the test, each parameter produced every hour by the solar panel was observed for 7 hours a day.

b) Battery Capacity Measurement Results and Total Power Generated by Yasaka Fans

Table 4. Yasaka Fan Power Measurement

O'clock		12Volt 22Ah Battery		Yasaka Fan		
Start	Finished	Voltage (V)		Voltage (V)	Current (I)	Power (W)
		Beginning	End			
16.00	18.00	13.0	12.5	225	3.2	42.0

The next load test is the Yasaka fan. The test is conducted to determine how much power is provided by the load and how long the battery capacity can power the load. The results of measurements and observations regarding the use of the Yasaka fan are presented in Table 4 above.

c) Measuring Overall HP and Laptop Performance

Table 5. Performance Measurement of Mobile Phones and Laptops

HP & Laptop Brands	Battery Capacity (mAh)	Current	Voltage	Charging time from empty to full	Power generated during charging
Oppo A31	4230	0.7	225	2 Hours 20 Minutes	12.3
Hp Core i3 Laptop	2620	3.7	225	2 Hours 30 Minutes	40.3

The measurements carried out in this test are intended to determine the time required for each load to charge the battery provided by the battery according to the details of each load. The loads used in this test consist of one laptop and one *mobile phone* , each of which has different details. Information on the loads and the results of this test measurements can be seen in Table 5.

d) Data Capture When Solar Panels Are Installed

Table 6. Measurements When Solar Panels Are Installed with Loads During the Day

Load Type	Average power generated by solar panels	Power/Specifications of each load	Current from each load	The power released by each load
Yasaka Fan	31.53 Watt	50 watt	3.2	42.0
Oppo A31 Mobile Phone		4230 mAh	0.7	12.3
HP Core i3 Laptops		2620 mAh	3.7	40.3

Data collection occurs when the solar panel is directly installed, connected to *the solar charge controller* , connected to the battery, then connected to the inverter, and finally connected to the load.

e) Observation of the results of the solar panel for 7 hours

The study was conducted on June 9, 2024 in Kasindir Village, Jorlan Hataran District, Simalungun Regency. The test was carried out for twelve hours, and measurements were carried out every hour from 09.00 to 15.00. The results of daily observations are presented in Table 3.

The results then continue to show the highest value before the weather conditions become hotter than before. When the heat increases, the electricity meter will display the current Wp value at a higher value. If the weather conditions do not improve, the electricity meter will always show the exact value. From Table 4.1 we can see that the voltage, like other parameters, varies over time. This is because the parameters measured by the power meter depend on the weather conditions. The hotter the sunlight, the better the results. Since the highest voltage of 13.4 V olt occurred at 13.00, we know that at the same time the highest current was 0.56 A mpere and the power was 7.6 W att.

Table 3 shows observations with increasing voltage readings displayed by the solar charge controller . The battery has a power capacity of 260 Wh. The weather conditions during the observation were very hot. This means that the results of charging the solar module are good.

f) Observation when several loads are connected at the same time

If several loads are connected at the same time, the measurement results of the power generated from each load connected at the same time will be different. If the calculation is carried out without exceeding the highest power consumption that the inverter can produce, then the load will still be powered by the battery.

The inverter used produces 500 watts of power with 50% efficiency. Therefore, the actual inverter power is 264 watts. When multiple loads exceed the inverter's capacity operating at the same time, the inverter will burn out/be protected.

So, to check the loads can operate simultaneously, you should first check the specifications. If the amount of power obtained by some of the loads is still below the maximum limit of the inverter, then the load will continue to operate. The installation of the load uses a parallel connection, so that the voltage of several loads is added and multiplied by a voltage of 225V.

For example, charging an Oppo A31 cellphone with a rated current of 0.7A and a laptop with a rated current of 3.7A, then the power generated by the two loads will increase to 52.6 watts. Therefore, loading continues as usual. The experiment was carried out by calculating several other loads simultaneously. The loads that operate simultaneously are the Yasaka fan, cellphone charger, and laptop charger.

Similar to the test above, the measurement only requires measuring each current and voltage on each load. After the load runs at the same time, the fan will turn on. Then your cellphone and laptop will be charged simultaneously. If measured with a wattmeter, the current and voltage of each load are:

Table 7. Simultaneous Load Measurement

Burden	Voltage (V)	Current (A)	Power (W)
Yasaka Fan	225	3.2	42.0
Oppo A31 Mobile Phone	225	0.7	12.3
Core i3 Laptops	225	3.7	40.3

As with the above test, the measured flow values are summed up. The total flow for the test load is 7.6A. The power result at that time was 94.6W. This means that the battery capacity is capable of powering the load for approximately 2 hours 45 minutes with a power of 94.6W. The next test is a load test that approaches the highest capacity *of the inverter.* The highest power *of the inverter* used is 264 Watts and the maximum current of this *inverter* is 5-10 Ampere, so the test is used by trying the fan at speed 3 and charging the Oppo A31 cellphone. If measured with *a wattmeter* , the current and voltage of each load are:

Table 8. Fan Load Measurement and Oppo A31 Mobile Phone

Burden	Voltage (V)	Current (A)	Power (W)
Fan	225	3.0	40
Charging HP Oppo A31	225	0.7	8

As with the above test, the measured flow values are summed up. The total load flow that has been tested is 3.7A. This produces a power of 48W. Therefore, the battery capacity is also capable of supplying a total power of 48W to the load for approximately 5 hours and 30 minutes. In the two experiments above, the first experiment tested all the tested devices simultaneously. And in the test, all consumers can be powered by the inverter , and the battery capacity is capable of providing power for approximately 2 hours and 45 minutes.

In the first experiment, the fan was operated at levels 1 to 3 with a total load current of 42.0 watts . The second test was carried out by testing the fan load at speed 3 and charging the Oppo A31 cellphone. The total current measured was 3.7 A and the rated power was 48 W. In this experiment, the PLTS system was able to turn on one fan unit with a load power of 42.0 watts because each component installed met the specifications. Then charge the Oppo A31 cellphone with 8 *watts of power* and the laptop with 40.3 *watts of power* for 2 hours 45 minutes a day.

g) Efficiency Analysis

The efficiency analysis of the research can be seen from two main aspects, namely the charging efficiency of the solar cells and the efficiency of power usage during load testing. With the following details:

- Charging Efficiency of Solar Cells

Battery charging test on June 8-9, 2024, with very good weather conditions. This condition supports maximum and faster charging. Thus, it can be concluded that the efficiency of battery charging from solar cells depends significantly on weather conditions. Under optimal conditions, charging can be done quickly which means that solar cells work with high efficiency on sunny days.

- Power Usage Efficiency

During testing, the PLTS system was able to state the fan at speed levels 1 to 3 with a power of 42.0 watts. In another experiment, the system also supported charging the Oppo A31 cellphone with a power of 8 watts and using a laptop with a power of 40.3 watts for 2 hours 45 minutes. The total current used in the second test was 3.7A with a power of 48W. From these results, it can be concluded that the PLTS system has quite good efficiency in providing continuous power for various loads over a fairly long period (2 hours 45 minutes). The use of inverters and batteries that are in accordance with system specifications also supports operational efficiency. Overall, the system being tested was able to work optimally. Both in charging and using load power during testing, with sufficient operational time and according to the needs of the tested load.

Conclusion

The conclusion of this study is that the results of the experiments and measurements that have been carried out are in accordance with the characteristics of the test. Measurements with solar cells in charging the battery carried out on June 8-9 were very optimal due to the very hot weather conditions so that battery charging became faster and the load usage capacity lasted longer. When the test was carried out, the entire load could be powered by the inverter and the battery capacity was able to provide power for approximately 2 hours 45 minutes. In the first experiment, the fan was operated at levels 1 to 3 with a total load current of 42.0 watts. The second test was carried out by testing the fan load at speed 3 and *charging* the Oppo A31 cellphone. The total current used was 3.7A and the power was 48W. In this test, each installed component met the specifications so that this PLTS system was able to turn on 1 fan unit with a load power of 42.0 Watts. Furthermore, for *charging* a cellphone of 8 *watts* and a laptop of 40.3 *watts* for 2 hours 45 minutes for 1 day. The effect of BMS on battery voltage on each connector such as parallel and series is almost the same. The effect of BMS is seen in the magnitude of the charging current where when using BMS the current is greater so that the electrical energy that can be stored in the battery is also greater. BMS also affects the continuity of battery performance to be more durable. The efficiency of the panel used is 14.13%.

Acknowledgments

The author would like to thank his parents, relatives, friends and people closest to him who have provided support, motivation and encouragement to the author so that the author can complete this written work.

References

Al Farizi, AM, & Widyartono, M. (2023). IoT-Based Portable Solar Generator Electrical Energy Monitoring for Electricity Needs in Disaster Areas. *JOURNAL OF ELECTRICAL ENGINEERING* , *12* (2). https://doi.org/10.26740/jte.v12n2.p92-97

Bhushan, N., Mekhilef, S., Tey, K.S., Shaaban, M., Seyedmahmoudian, M., & Stojcevski, A. (2022). Overview of Model- and Non-Model-Based Online Battery Management Systems for Electric Vehicle Applications: A Comprehensive Review of Experimental and Simulation Studies. In *Sustainability (Switzerland)* (Vol. 14, Issue 23). https://doi.org/10.3390/su142315912

Gabbar, HA, Othman, AM, & Abdussami, MR (2021). Review of Battery Management Systems (BMS) Development and Industrial Standards. In *Technologies* (Vol. 9, Issue 2). https://doi.org/10.3390/technologies9020028

Ghalkhani, M., & Habibi, S. (2023). Review of the Li-Ion Battery, Thermal Management, and AI-Based Battery Management System for EV Application. In *Energies* (Vol. 16, Issue 1). https://doi.org/10.3390/en16010185

Habib, AKMA, Hasan, MK, Issa, GF, Singh, D., Islam, S., & Ghazal, TM (2023). Lithium-Ion Battery Management Systems for Electric Vehicles: Constraints, Challenges, and Recommendations. In *Batteries* (Vol. 9, Issue 3). https://doi.org/10.3390/batteries9030152

Huckaba, AJ, Sun, DT, Sutanto, AA, Mensi, M., Zhang, Y., Queen, WL, & Nazeeruddin, MK (2020). Lead Sequestration from Perovskite Solar Cells Using a Metal–Organic Framework Polymer Composite. *Energy Technology* , *8* (7). https://doi.org/10.1002/ente.202000239

Hwang, G., Sitapure, N., Moon, J., Lee, H., Hwang, S., & Sang-Il Kwon, J. (2022). Model predictive control of Lithium-ion batteries: Development of optimal charging profile for reduced intracycle capacity fade using an enhanced single particle model (SPM) with first-principled chemical/mechanical degradation mechanisms. *Chemical Engineering Journal* , *435* . https://doi.org/10.1016/j.cej.2022.134768

Jafari, S., & Byun, Y. C. (2022). Prediction of the Battery State Using the Digital Twin Framework Based on the Battery Management System. *IEEE Access* , *10* . https://doi.org/10.1109/ACCESS.2022.3225093

Kim, T., Ochoa, J., Faika, T., Mantooth, H. A., Di, J., Li, Q., & Lee, Y. (2022). An Overview of Cyber-Physical Security of Battery Management Systems and Adoption of Blockchain Technology. In *IEEE Journal of Emerging and Selected Topics in Power Electronics* (Vol. 10, Issue 1). https://doi.org/10.1109/JESTPE.2020.2968490

Lee, YL, Lin, CH, Farooqui, S.A., Liu, H.D., & Ahmad, J. (2023). Validation of a balancing model based on master-slave battery management system architecture. *Electric Power Systems Research* , *214* . https://doi.org/10.1016/j.epsr.2022.108835

Liu, K., Li, K., Peng, Q., & Zhang, C. (2019). A brief review on key technologies in the battery management system of electric vehicles. In *Frontiers of Mechanical Engineering* (Vol. 14, Issue 1). https://doi.org/10.1007/s11465-018-0516-8

Marcos, D., Garmendia, M., Crego, J., & Cortajarena, J. A. (2021). Functional safety bms design methodology for automotive lithium-based batteries. *Energies* , *14* (21). https://doi.org/10.3390/en14216942

Napitupulu, J., Sholeha, D., & Munthe, I. (2023). SOLAR PANEL MODULE OUTPUT ENERGY ANALYSIS USING FLAT MIRROR. *International Journal of Advanced Research* , *11* (01), 1726–1731. https://doi.org/10.21474/IJAR01/16198

Okay, K., Eray, S., & Eray, A. (2022). Development of prototype battery management system for PV system. *Renewable Energy* , *181* . https://doi.org/10.1016/j.renene.2021.09.118

Shen, M., & Gao, Q. (2019). A review on battery management system from the modeling efforts to its multiapplication and integration. In *International Journal of Energy Research* (Vol. 43, Issue 10). https://doi.org/10.1002/er.4433

Sholeha, D., Fitra Zambak, M., Tri Nugraha, Y., & Electrical Engineering Masters Study, P. (2022). Implementation of ANFIS in Forecasting the Development of New and Renewable Energy in Indonesia in 2030. *Muhammadiyah University of North Sumatra Jl. Denai No.* , *5* (2).

Sorour, A., Fazeli, M., Monfared, M., Fahmy, A.A., Searle, J.R., & Lewis, R.P. (2021). Forecast-Based Energy Management for Domestic PV-Battery Systems: A UK Case Study. *IEEE Access* , *9* . https://doi.org/10.1109/ACCESS.2021.3072961

Tarhan, B., Yetik, O., & Karakoc, T.H. (2021). Hybrid battery management system design for electric aircraft. *Energy* , *234* . https://doi.org/10.1016/j.energy.2021.121227

Tran, M. K., & Fowler, M. (2020). A review of lithium-ion battery fault diagnostic algorithms: Current progress and future challenges. In *Algorithms* (Vol. 13, Issue 3). https://doi.org/10.3390/a13030062

Wang, H., Pourmousavi, S.A., Soong, W.L., Zhang, X., & Ertugrul, N. (2023). Battery and energy management system for vanadium redox flow batteries: A critical review and recommendations. In *Journal of Energy Storage* (Vol. 58). https://doi.org/10.1016/j.est.2022.106384

Yuan, WP, Jeong, SM, Sean, WY, & Chiang, YH (2020). Development of enhancing battery management for recycling automotive lithium-ion batteries. *Energies* , *13* (13). https://doi.org/10.3390/en13133306

Zambak, MF, Surianto, S., & Faisal, A. (2022). Study of Power Effectiveness in Wind Power Plants with Solar Power Plants. *Journal of Electrical Technology* , *13* (3). https://doi.org/10.22441 /jte.2022.v13i3.005