# Designing a Battery Pack for Portable Solar Generators

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**ABSTRACT**

*Located on the Asian continent, specifically Southeast Asia, Indonesia is surrounded by four tectonic plates, the Asian plate, the Australian plate, the Indian Ocean plate, and the Pacific Ocean plate. These conditions make Indonesia a country prone to natural disasters. The impact of this disaster can result in power and communication networks being cut off, clean water and fuel being inaccessible. Portable solar generators can provide first aid related to electricity, but the batteries are very limited so the generator can only be used for a short time. The aim of making the Battery Pack is so that it can be used as an additional battery for portable solar generator so that the generator can be used for a longer time, especially in emergency situations. When given an AC load of 35 Watts, a portable solar generator connected to a battery pack can operate for 7 hours 10 minutes. When given an AC load of 55 Watts, it can operate for 4 hours 20 minutes. That is 30% and 44% longer than a generator not connected to a battery pack.*

## INTRODUCTION

The Sulawesi earthquake and tsunami in 2018 was an earthquake with a magnitude of 7.4 MW followed by a tsunami that hit the west coast of Sulawesi Island, Indonesia, northern part on September 28, 2018, at 18.02 WITA. The epicenter of the earthquake was 26 km north of Donggala and 80 km northwest of the city of Palu with a depth of 10 km. The earthquake shocks were felt in Donggala Regency, Palu City, Parigi Moutong Regency, Sigi Regency, Poso Regency, Tolitoli Regency, Mamuju Regency and even Samarinda City, Balikpapan City and Makassar City. The earthquake triggered a tsunami up to 5 meters high in Palu City.

As a result of this earthquake shock, the Roa-Roa Hotel on Jalan Pattimura Palu, as well as the Anuntapura Hospital on Jalan Kangkung, which has 4 floors, also collapsed. The largest mall in Palu, Tatura Mall, also collapsed. The tsunami in Palu caused a ship, the KM Sabuk Nusantara to be blown tens of meters away from Wani Harbor. The port itself was damaged as well as its docks and buildings. Also visible were the ruins of the ATC tower at Palu's Mutiara Sis Al Jufri Airport as well as damage to the port.

Clean water, electricity and fuel oil networks have become difficult to access. Communication between Donggala and Palu was cut off due to the failure of hundreds of BTS. The Ministry of Communication and Information stated that out of approximately 3007 BTS there were 431 BTS that were not functioning or 14.31%. This is because they do not have access to electricity. Several telecommunications networks from Palu to Santigi, Mamuju and Poso were cut off due to the 7.4 magnitude earthquake.

A portable solar generator is a tool that can provide first aid in supplying electrical power for evacuation after a natural disaster occurs and can be used as lighting in the homes of residents affected by natural disasters. However, portable solar generators have a weakness, the generator capacity is limited so it can only be used for electrical loads with a certain capacity in a certain time. Apart from that, the duration of use of portable solar generators at night or when there is no sun is also limited because solar generators use batteries with limited capacity. On this basis, researchers are trying to design a battery pack that can be installed on a portable solar generator so that it can be used to help in natural disaster conditions where the electricity network is cut off after a natural disaster and the generator usage time becomes longer. With this Battery Pack, the SAR Team or volunteers can set up an emergency post where communication equipment, lighting or electrical equipment can be used.

Apart from emergencies, this battery pack can also be used for homes affected by power outages and can also to support exploration activities in forests, mountains, or the middle of the sea where there is no electricity network so that you can still charge communication devices or other equipment.

In 2014, Awangko Arshaduddin bin Awang Zainudin from PETRONAS University of Technology conducted research on portable solar power plants entitled Development of Portable Solar Electricity Generating System. However, this research is only in the form of a calculation concept design and has not been implemented.

In 2015, Debasreeta Mohanty, Saswati Dash, and Shobha Agarwal from the School of Electrical Engineering KIIT University, Bhubaneswar Odisha conducted research on electrical energy storage systems from photovoltaic systems connected to the electricity grid with a capacity of KW to MW entitled Design of Battery Energy Storage System for Generation of Solar Power. However, this research does not discuss electrical energy storage systems from small-scale photovoltaic systems or portable solar power generators.

In 2019, N.H. Ramly et al from University Malaysia Pahang also conducted research on portable solar power plants for emergencies entitled Emergency Portable Solar Power Supply. In this research, a Lead Acid Deep Cycle battery with a capacity of 14 Ah was used, where the battery is not light in weight and not small. The total weight reaches 10 kg.

In this research a Lithium-Ion battery is used, where the battery is smaller and lighter so it can be carried more easily. One of the advantages of using Lithium-Ion batteries is that when charged the charging time is fast, making them suitable for use in situations that require high mobility.

## RESEARCH METHOD

This research uses an experimental research method based on calculation data and data in the field (figure 1). Borg & Gall stated that experimental research is the most scientifically reliable (most valid) research because it is carried out with strict control of confounding variables outside those being experimented with. Another definition states that experimental research is research carried out on variables for which data does not yet exist so that a manipulation process needs to be carried out by providing certain treatments to research subjects whose impact is then observed/measured (future data). Experimental research is also research that is carried out deliberately by researchers by providing certain treatment/treatment to research subjects to generate an event/circumstance that will be studied as a result. The schematic diagram of the battery pack for a portable solar generator is as follows (figure 2).

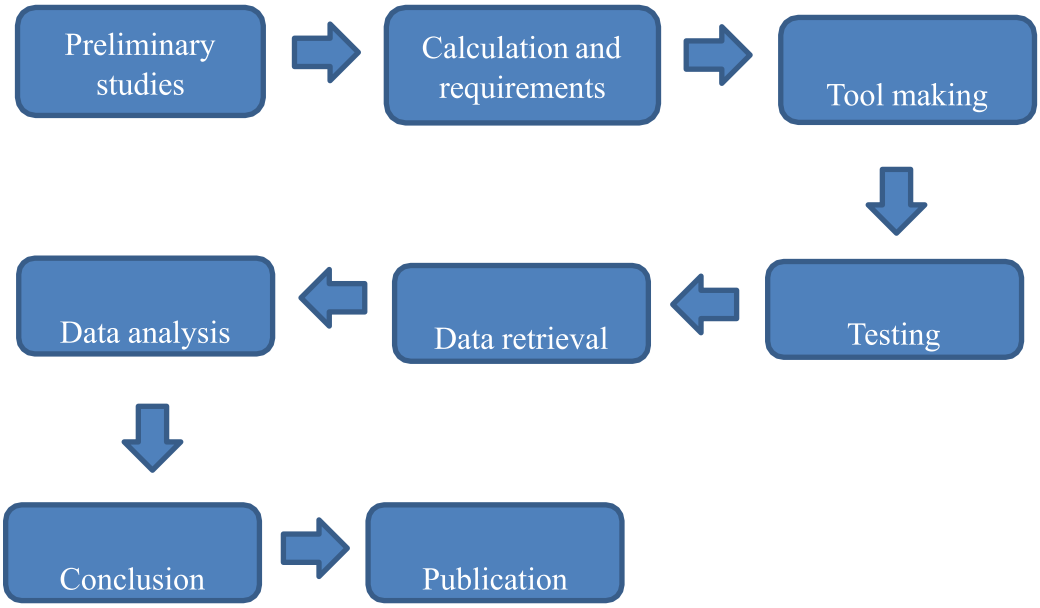


Figure 1. Research Flow Diagram

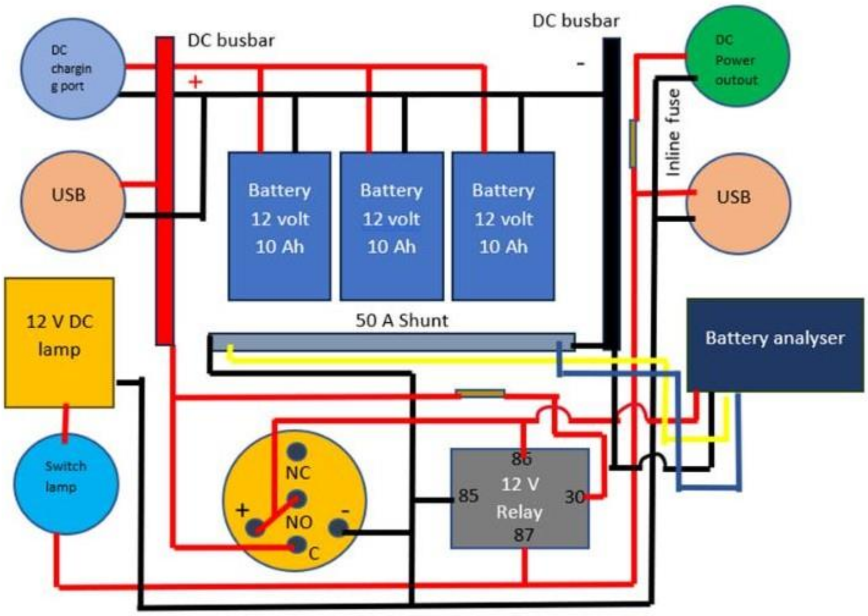


Figure 2. Schematic diagram of battery pack

The 18650-battery rating will affect the number of batteries required. The battery rating used in this research is 3.7 volts, 2000 mAh. It should be noted that by connecting the batteries in series the voltage will increase and if they are connected in parallel the ampere-hour (Ah) of the battery will increase. Because this battery will be connected to a portable solar generator which contains an inverter that requires a voltage range of 10 - 15 Vdc, the 18650-battery connected in series is 3 batteries (3S).

The battery capacity used in the battery pack is 30 Ah which consists of 3 battery packs connected in parallel where 1 battery pack has a capacity of 10 Ah with 3 batteries in series and 5 batteries in parallel. The total number of 18650 batteries required is 45 batteries. Figures 3 and 4 below are examples of batteries connected in series and parallel.

## RESULTS AND DISCUSSION

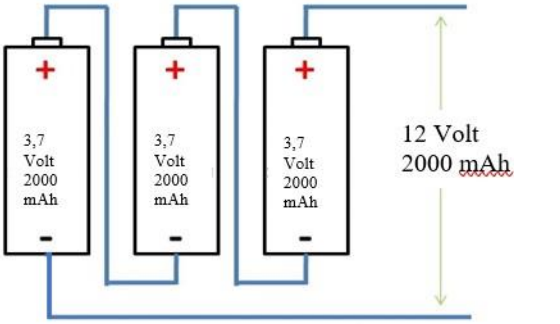


Figure 3. Battery connected in series.

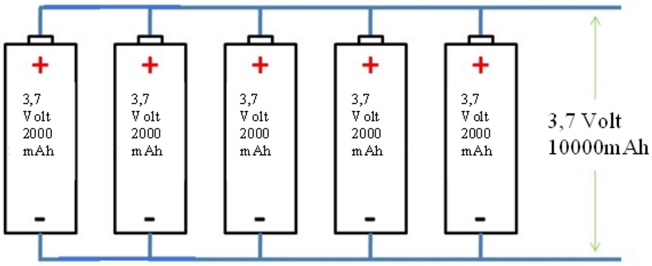


Figure 4. Battery connected in parallel.

This battery pack test is divided into three stages, loading stage, charging stage, and loading stage when connected to a portable solar generator. For load testing, a DC lamp is used with a total power of 20-Watts and a 55-watt load AC lamp via an inverter connected to the battery pack. For battery pack charging test a 12 Volt DC adapter with a current of 2 Ampere is used. The following table is the test results (table 1 and 2).

**Table 1.** Testing results with 20-Watt DC lamp as load.

| No | DC Voltage (V) | DC Current (A) | Power (W) | Minute |
|---|---|---|---|---|
| **1** | 11.9 | 1.66 | 19.8 | **0** |
| **2** | 11.8 | 1.67 | 19.7 | **20** |
| **3** | 11.7 | 1.67 | 19.5 | **40** |
| **4** | 11.7 | 1.66 | 19.4 | **60** |
| **5** | 11.6 | 1.66 | 19.3 | **80** |
| **6** | 11.6 | 1.66 | 19.3 | **100** |
| **7** | 11.5 | 1.65 | 19.0 | **120** |
| **8** | 11.5 | 1.65 | 19.0 | **140** |
| **9** | 11.4 | 1.65 | 18.8 | **160** |
| **10** | 11.4 | 1.63 | 18.6 | **180** |
| **11** | 11.3 | 1.63 | 18.4 | **200** |
| **12** | 11.3 | 1.64 | 18.5 | **220** |
| **13** | 11.2 | 1.64 | 18.4 | **240** |
| **14** | 11.2 | 1.64 | 18.4 | **260** |
| **15** | 11.1 | 1.64 | 18.2 | **280** |

| | | | | |
|---|---|---|---|---|
| **16** | 11 | 1.63 | 17.9 | **300** |
| **17** | 10.8 | 1.62 | 17.5 | **320** |
| **18** | 10.6 | 1.62 | 17.2 | **340** |
| **19** | 10.5 | 1.62 | 17.0 | **360** |
| **20** | 10.2 | 1.6 | 16.3 | **380** |
| **21** | 9.97 | 1.58 | 15.8 | **400** |
| **22** | 9.42 | 1.56 | 14.7 | **420** |
| **23** | **9.16** | **1.53** | **14.0** | **440** |

**Table 2.** Testing results with 50-Watt AC lamp as load.

| **No** | **DC Voltage (V)** | **DC Current (A)** | **Power (W)** | **Minute** |
|---|---|---|---|---|
| **1** | 11.6 | 4.63 | 53.7 | **0** |
| **2** | 11.5 | 4.6 | 52.9 | **20** |
| **3** | 11.4 | 4.6 | 52.4 | **40** |
| **4** | 11.3 | 4.58 | 51.8 | **60** |
| **5** | 11.2 | 4.55 | 51.0 | **80** |
| **6** | 11.2 | 4.5 | 50.4 | **100** |
| **7** | 11 | 4.49 | 49.4 | **120** |
| **8** | 10.9 | 4.4 | 48.0 | **140** |
| **9** | 10.9 | 4.3 | 46.9 | **160** |
| **10** | **10.8** | **4.26** | **46.0** | **180** |

From table 1 above it can be seen that the battery pack can operate for 7 hours 20 minutes with the lowest voltage being 9.16 Volts before the lamp used as a load finally goes out. When loaded with lights with a total load of 55-Watts, the battery pack can operate for 3 hours with the lowest voltage being 10.8 Watts. This is because when testing the 55-watt load, an AC lamp load is used which is connected to the tool via an inverter. The voltage of 10.8 Volts is the cut off voltage of the inverter so that the inverter will turn itself off if the battery voltage reaches 10.8 Volts.

The battery pack charging test was carried out using a 12-volt 2 ampere DC adapter. The following is a graph of the voltage and current charging profile of the battery pack (figure 5).

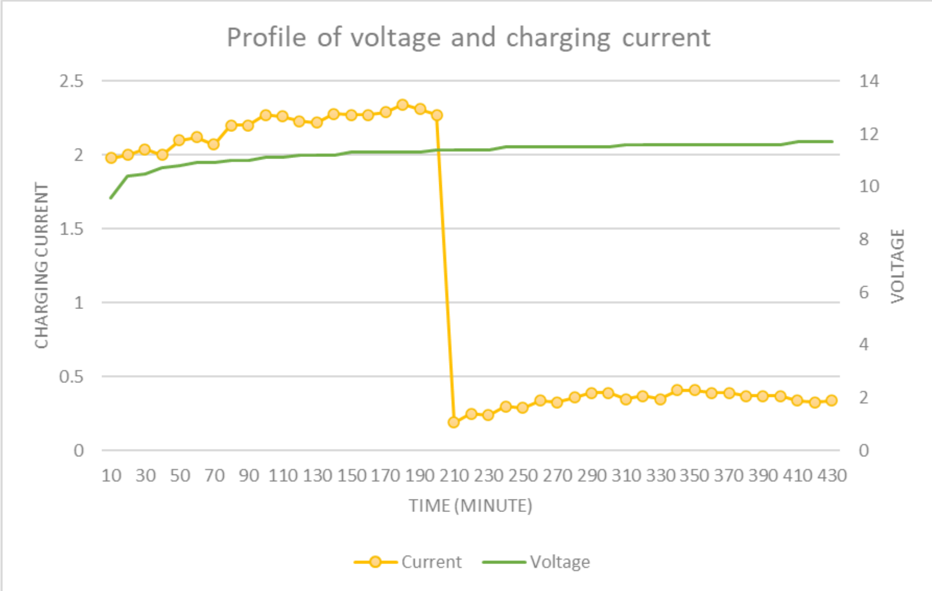


Figure 5. Battery pack charging profile.

From the graph above, it is known that the total time to charge the battery pack using a 12-volt 2 ampere DC adapter is ±12 hours. This time was obtained from direct observation during the charging process. When charging, there is a significant decrease in charging current from 2.27 A to 0.19 A. This occurs because the recharging stage of the adapter used enters the absorption phase when the battery voltage has reached 90% or 11.7-volts of nominal voltage 12.1 volts. To achieve a full charge, the battery charger/adapter maintains a constant voltage on the battery while reducing the current. The battery voltage remains constant during this stage, and the charging current gradually decreases until it reaches a low level known as trickle charge. When the battery is fully charged, the charger enters float mode, keeping the battery at a constant voltage to prevent overcharging.

## CONCLUSION

From the results and discussion presented above, it can be concluded that the battery pack for portable solar generators can function well. This is known from the tests that have been carried out. The first test is that the battery pack can operate for 7 hours 20 minutes when loaded with lights with a total power of 20 watts and the battery pack can operate for 3 hours when loaded with lights with a total power of 55 watts. The greater the load power connected to the battery pack; the faster the tool's operating time will be because the battery will run out more quickly. In the second test, the charging process using a 12-volt dc 2 ampere adapter took approximately 12 hours. This is because the adapter used has several charging stages, the bulk charging stage, the absorption charging stage and the floating charging stage. When the battery is in condition 0 – 90% then the charging is in the bulk charging stage, when the battery condition reaches 90% then the charging is in the absorption stage which is marked by a reduction in charging current from 2.27 Ampere to 0.19 Ampere. The charging stages contained in the adapter aim to maintain the age and performance of the 18650 batteries used.

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