Comparison of Discharge Performance of 12V/100Ah Sun test Gel and AGM Sealed Lead acid Batteries in Stand-alone Photovoltaic Systems in Nigeria

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Abstract

The purpose of this research is to look at how two important lead-acid batteries, the 12V/100Ah Sun Test Gel and the 12V/100Ah AGM sealed lead-acid batteries, perform during discharge in photovoltaic (PV)-based systems in Nigeria. In harsh climatic conditions, such as in Nigeria, where temperatures can reach extremely high levels during the dry season when there is plenty of sunlight, battery performance improves. In this work, the discharge properties of two comparable batteries are compared through discharge testing on two distinct batteries. The results of the discharge tests, as well as a comparison of the two batteries, are presented in this paper.

Keywords: Discharge capacity, discharge current, lead-acid battery, photovoltaic system, comparative Analysis.

1. Introduction

Solar, wind, and hydro energy are the most dependable, feasible, and realistic sources of renewable energy in Nigeria today because of their year round availability Iwuji & Okoro, 2020). Solar energy is abundant energy source for areas where connecting to the national grid may be prohibitively expensive due to the site's distance from the nearest national grid connection point . There are some remote areas of the world where connecting to a power system is prohibitively expensive. Small and medium-sized diesel generators were used to power these remote locations. Diesel generators are inexpensive to purchase but costly to operate and maintain. The diesel generator is harmful to the environment because it emits 3 kg of CO2 gas for every litre of diesel fuel used (Andreas *et al*., 2004). Renewable energy sources are the best options for reducing pollution, ozone depletion, and global warming. Because of their clean, pollution-free, and limitless nature, solar photovoltaic energy and other renewable energy sources such as wind, hydro, geothermal, and so on are the most commonly used renewable energy sources. Although there is nuclear fusion energy which is also an alternative renewable energy. In nuclear fusion, two light atomic nuclei join together to produce a single heavier one while releasing enormous quantities of energy (Matteo, 2022). The fusion of deuteron, the nucleus of heavy hydrogen, and triton, the nucleus of even heavier hydrogen, is the fusion reaction that is of interest for nuclear power. Deuteron-triton fusion, the fuel of choice, produces alpha particles (Chary, 2018). Longer than the planet has been around and longer than the sun will shine, fusion can provide dependable, clean energy. Fusion is a safe and dependable energy source that has the potential to significantly improve the lot of everyone in the world (Sherif, 2019). Far more energy is produced via nuclear fusion, and only trace

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amounts of radioactive waste are left behind. Additionally, the process emits no greenhouse gases and, as a result, has no impact on climate change (Esme, 2022). But in this paper, the researcher has interest in PV power generation. In a PV power generation system, the generated power and the required load power are not equivalent. As a result, a storage device is required to mitigate the impact of solar power fluctuations caused by changes in external factors such as temperature and solar radiation intensity. If standalone PV power generation is used, the battery backup capacity must be substantial in order to maintain uninterrupted power throughout the winter. A single night of energy storage is the bare minimum for a PV-powered system. The maximum size is determined by the number of days required (Andreas *et al*., 2004). Figure 1 depicts a block diagram of a PV system with a storage battery.

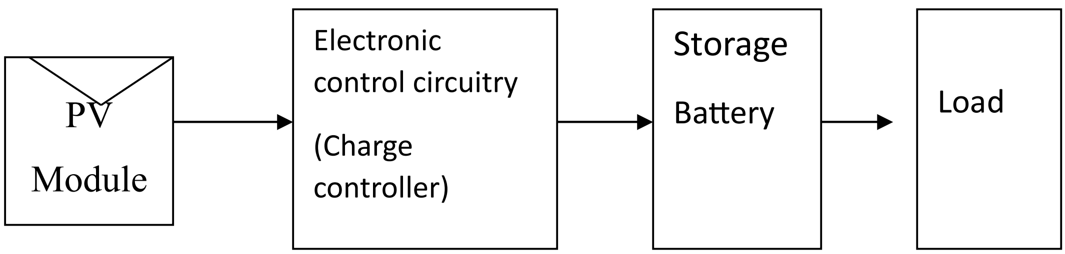

Fig. 1. Block diagram of PV system with storage battery

Recent environmental concerns, such as steadily rising CO2 levels, as well as strategic economic concerns about the anticipated scarcity of fossil fuels, have heightened interest in renewable energy technology. Because renewable energy sources, such as solar and wind, are intermittent, and their generation sources are out of sync with the loads, energy storage devices, such as batteries, must be used to improve the overall performance of renewable energy-based systems (Iwuji & Okoro, 2020, Zahi *et al*., 2014). Energy storage often enhances the efficiency of renewable energy sources by minimizing the variability in the solar produced power and supplying power in the absence of sunshine. In reality, batteries are regarded as the foundation of solar-powered PV off-network frameworks. Among the major battery-powered battery sciences, the lead-corrosive battery is the most mature, and it is typically used in applications where cost is more important than space and weight. It is commonly used as backup batteries for uninterruptible power supplies (UPS), alarm systems, car lighting and starting, and renewable energy framework applications (Zahi *et al*., 2014).

PV system batteries are subjected to frequent charging and discharging procedures. Lead acid batteries with high discharge rates are frequently used in PV applications. Gel-type lead acid batteries are used in remote applications where maintenance-free operation is required. Nickel-cadmium or nickel metal hydride batteries are used in portable applications (Manimekalai *et al*., 2013). There are two kinds of batteries: non-rechargeable primary batteries and rechargeable secondary batteries (Ugbaja *et al.*, 2019). Non-rechargeable batteries cannot be utilized in standalone solar PV systems since they cannot be recharged (Andreas *et al*., 2004, Huggins, 2010). By delivering DC current to their terminals, rechargeable batteries are energy storage devices that may be recharged after being depleted (Norri et al., 2019). When compared to single-use batteries, which produce electricity through a chemical reaction in which a reactive anode is burned, rechargeable batteries are typically a more practical and environmentally friendly option. The anode of a rechargeable battery is also consumed, though at a slower pace, permitting frequent charges and discharges [Iwuji & Okoro, 2020, Ikeh *et al*., 2018). There are three types of lead acid batteries: flooded cell batteries, sealed or gel batteries, and absorbed gas metal (AGM) batteries.

The flooded cell battery is the most common type of battery used in renewable energy systems today. Flooded batteries come in flat and tubular plate designs. The electrodes in flooded batteries are completely immersed in electrolyte. During the charging of flooded batteries to full charge, hydrogen and oxygen gases produced by the chemical reaction at the negative and positive plates escape through the battery's vents. This necessitates regular water additions to the battery. A sealed or gel-type battery's main feature is an immobilized type of electrolyte. Valve-regulated lead acid (VRLA) batteries are another name for sealed maintenance-free lead acid batteries. There are two types of sealed batteries: gelled electrolytes and absorbed glass mats. When compared to flooded electrolyte batteries, immobilized electrolyte batteries will have fewer electrolyte release issues. During the charging process, chemical interactions at the negative and positive plates produce hydrogen and oxygen gases from water. Because this gas recombines to form water, water inputs are not required. Glass mats are sandwiched between plates in AGM batteries. The electrolyte is absorbed by these glass panels. The oxygen molecules from the positive plate pass through the electrolyte in the glass mats and combine with hydrogen at the negative plate to form water. Regulated charging is required for both gel and AGM batteries. Normal lead calcium electrodes are used in these batteries to reduce gassing and water loss. Voltage and current must be controlled to be less than the C/20 rate characteristics (Arjyadhara *et al*., 2012, Chetan, 2011].

2. Methodology

2.1 Materials

The materials used for the study were; charge controller, solar panel, Dc watt meter, storage batteries and LED bulb.

2.2. Experimental procedure

This experimental procedure involved design and installation. When designing a photovoltaic system, the number of component ratings that will be included in a solar PV system to supply dependable power to standalone security lighting must be determined. In order to build the full photovoltaic system, which will as needed supply current to the associated load, the design comprises establishing the values of the component parts. An approximation design was used in this study because the parameters studied were minor and the photovoltaic system was simple. The materials used in this investigation were scaled accordingly.

Load and the energy estimation in watt-hour were calculated.

LED lamp used was 20W, consequently,

$$\text{Energy} = \text{number of hours (Wh)} \times \text{total watts}$$

$$\text{Energy} = 12 \text{ hours } \times 20\text{watts} = 240.0\text{Wh}$$

- The current charge controller would be handled was calculated.

Charge controllers had a nominal system voltage of 12 volts..

$$\text{Charge current} = \frac{\text{maximum Direct current load}}{\text{Voltage of the System}} \ldots\ldots\ldots\ldots\ldots 1$$

$$\text{Charge current} = \frac{20.0}{12.0} = 1.67A$$

- The size of the battery was calculated.

In sizing battery, the following parameters of batteries have to considered, they include;

- The ampere-hour voltage of the system
- .The battery's depth of drain.
- The battery's length of independent days.

To calculate the Ah capacity to be supplied, the energy is divided by voltage as,

$$\text{Energy, E} = \text{watt} \times \text{hour} = \text{current} \times \text{voltage} \times \text{hour}$$

$$\text{Ah} = \frac{\text{Wh}}{\text{V}} = \frac{\text{I} \times \text{V} \times \text{h}}{\text{V}} \ldots\ldots\ldots\ldots\ldots 2$$

$$\text{Ah} = \frac{240}{12} = 20.0\text{Ah}$$

Deep-discharge batteries are typically utilized in photovoltaic systems with a depth of discharge of between 50 and 60 percent. [15]

If the battery's DOD was stated as 50.0%, the useable charge was computed using

$$\text{Exact battery capacity (Ah)} = \frac{\text{Ah}}{\text{DOD\%}} \ldots\ldots\ldots\ldots\ldots .3$$

$$\text{Exact battery capacity (Ah)} = \frac{20.0}{0.50} = 40.0\text{Ah}$$

Days of autonomy was taken into consideration

$$\text{length of independent days} \times \text{Exact battery capacity after DOD (Ah)} = \text{optimum battery capacity needed (Ah).}$$

$\text{ie}2.0 \times 40.0 = 80.0\text{Ah}$

The lowest Ah available on the market was 100.0Ah battery, which was employed in the research.

Consequently, the formula for determining battery capacity is shown below;

$$Total\ battery\ Ah\ capacity = \frac{\text{length of independent days} \times \text{Energy input}}{\text{System Voltage} \times \text{DOD}} \ldots\ldots . .4$$

$$\text{Total Ah capacity of battery} = \frac{2.0 \times 240.0}{12.0 \times 0.50} = 80.0\text{Ah}$$

From the above calculation, only one battery was used because of small load.

- The PV module size was calculated.

The calculation of the daily energy required to be provided by photovoltaic modules and solar photovoltaic modules is part of the process of sizing photovoltaic panels.

$$\frac{overall\ energy}{battery\ capacity} = \text{Watt} - \text{hour} \ldots\ldots\ldots\ldots\ldots.5$$

$$\frac{240.0}{0.80} = 300.0\text{Wh}$$

Lead acid batteries' capacity is 80.0% (Chetan, 2016)

The computation of photovoltaic module power using comparable daily sunlight hours is known as photovoltaic module sizing.

Wattage of solar photovoltaic modules (W) =

$$= \frac{\text{Solar photovoltaic module daily energy supply (Wh)}}{\text{corresponding daily sunlight hours (h)}} \ldots\ldots\ldots\ldots\ldots 6$$

$$= \frac{300.0}{6.0} = 50.0\text{Wh}$$

Installation is the procedure of systematically combining individual components to build a faultless, operational solar PV system that meets predefined requirements. Depending on the demands, photovoltaic systems use a different number of components. In this investigation, two standalone PV security lights were deployed. Stand-alone photovoltaic systems are also known as self-sufficient or autonomous solar photovoltaic systems. They are independent of the grid and all other sources of electricity. They are also known as off-grid PV systems for this reason. In this examination, mechanical and electrical installations were both present. The mechanical component includes attaching the materials needed to mount our solar panel. For mounting the 14-foot-tall galvanized aluminum steel, a 2.5-foot-deep concrete base was built. The solar PV module was installed on a permanent structure facing south. The battery cages were designed to keep our batteries safe. On the other hand, the electrical installation comprises attaching cables to the electrical parts of the system. The charge controller in use featured six terminals for connecting the battery, panel, and load and was rated for 12/24V. The charge controller was initially attached so that it could recommend the best voltage arrangement. The charge controller was then wired with the two wires from the panel and a number of 20-watt LED lights.

4. Results and discussion

The collected data were analyzed using Microsoft Excel. For twenty-six weeks, data were collected from 19.00 hrs to 7.00 hrs of each day of the research. The 19.00hrs to 7.00hrs timing was changed to 0.0–12.0 hours. Specifically, 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, and 12.0 hours to perform a statistical analysis on the data. The output voltages of the AGM sealed and gel cell lead acid batteries were measured at each hour of the day, and the average of the output voltages was calculated over the course of twenty-six weeks. The gradients of the voltage values each week were determined from the graphs of the two lead acid batteries for comparative examination of the batteries.

Table 1: The Gradients of the Voltage Values per Week during the Observation for the AGM sealed and the Sun test gel cell lead acid batteries

Weeks	Gradients of the Voltage Values for each Week	
	AGM sealed battery	Sun test Gel cell Battery
1	-0.0347	-0.0956
2	-0.0385	-0.2137
3	-0.0424	-0.1030
4	-0.0376	-0.1009
5	-0.0396	-0.1047
6	-0.0382	-0.1002
7	-0.0395	-0.0831
8	-0.0363	-0.1091
9	-0.0361	-0.8725
10	-0.0384	-0.6660
11	-0.0362	-0.4266
12	-0.0355	-0.7266
13	-0.0381	-0.4504
14	-0.0381	-0.4504
15	-0.0368	-0.3288
16	-0.0373	-0.5865
17	-0.0388	-1.0002
18	-0.0403	-0.7864
19	-0.0377	-0.6528
20	-0.0367	-0.8919
21	-0.0350	-1.0866
22	-0.0339	-1.1984
23	-0.0465	-0.7765
24	-0.0630	-0.8823
25	-0.0677	-0.8211
26	-0.0618	-0.5458

Table1 shows the gradients of the Voltage Values per Week for 12V/100Ah AGM sealed lead acid battery and the Sun test gel cell lead acid battery. For the AGM sealed lead acid battery, the gradients of the voltage discharge values from week one to week 26 are -0.0347, -0.0385, -0.0424, -0.0376, -0.0396, -0.0382, -0.0395, -0.0363, -0.0361, -0.0384, -0.0362, -0.0355, -0.0381, -0.0381, -0.0368, -0.0373, -0.0388, -0.0403, -0.0377, -0.0367, -0.0350, -0.0339, -0.0465, -0.0630, -0.0677 and -0.0618 as against the following gradients of the voltage discharge values of Sun test gel cell from week1 to week 26; -0.0956, -0.2137, -0.1030, -0.1009, -0.1047, -0.1002,-0.0831, -0.1091, -0.8725, -0.6660, -0.4266, -0.7266, -0.4504, -0.4504, -0.3288, -0.5865, -1.0002, -0.7864, -0.6528, -0.8919, -1.0866, -1.1984, -0.7765, -0.8823, -0.8211 and -0.5458. The negative signs on the figures above show that both batteries discharged but it now depends on the extent on which they discharged. The figures above indicate that the 12V/100Ah AGM sealed lead acid battery being used in Nigeria has little or no substantial increase in its rate of discharge over the first twenty-six weeks of its operation. whereas the 12V/100Ah Sun Test gel lead acid battery had unpredictable and notably had a high discharge rate during the first twenty-six weeks of its use. From Figure 2a, the discharge curve for the 12V/100Ah AGM sealed lead acid battery had low undulation, with average peak-to-peak amplitude of 0.01 Volts/hr. Thus, the line of best fits of the voltage discharge rate for the 12V/100Ah AGM sealed lead acid battery was -0.000627 Volts/hr per week, suggesting a considerably low discharge rate. The 12V/100Ah Sun test gel lead acid battery (Figure 2b) presents a plainly irregular discharge curve with rather strong undulation, with an average peak to peak amplitude of 0.50 Volts/hr. Thus, the voltage flow rate for the 12V/100Ah AGM lead acid battery has a trend that is best described by a straight line. -0.03606 Volts/hr per week, suggesting a comparably extremely high discharge rate when compared with that of a 12V/100Ah AGM sealed lead acid battery (Figure 3). Also comparing comparably the stability of the two batteries, the 12V/100Ah Sun test gel lead acid battery exhibits relatively decent stability from discharge for the first eight weeks of its use. Afterward, it becomes wildly unstable and begins to drain at a very high rate. On the other hand, the 12V/100Ah AGM sealed lead acid battery demonstrated relatively good stability from discharge during the observation period of twenty-six weeks (Figure 3).

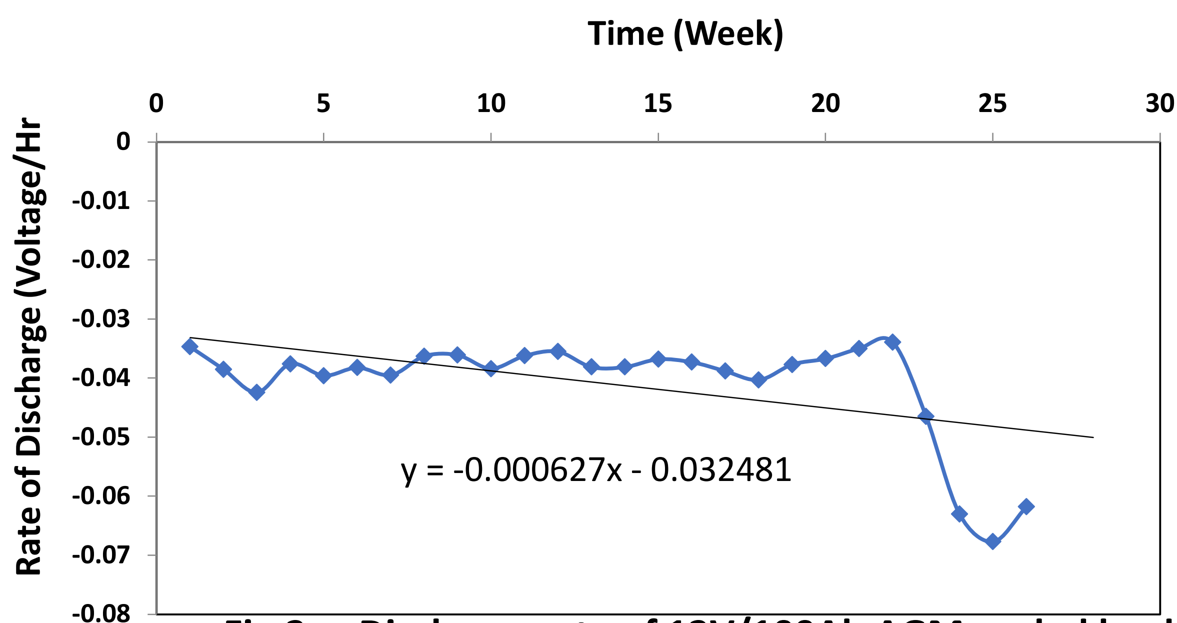

Fig.2a : Discharge rate of 12V/100Ah AGM sealed lead acid Batteries

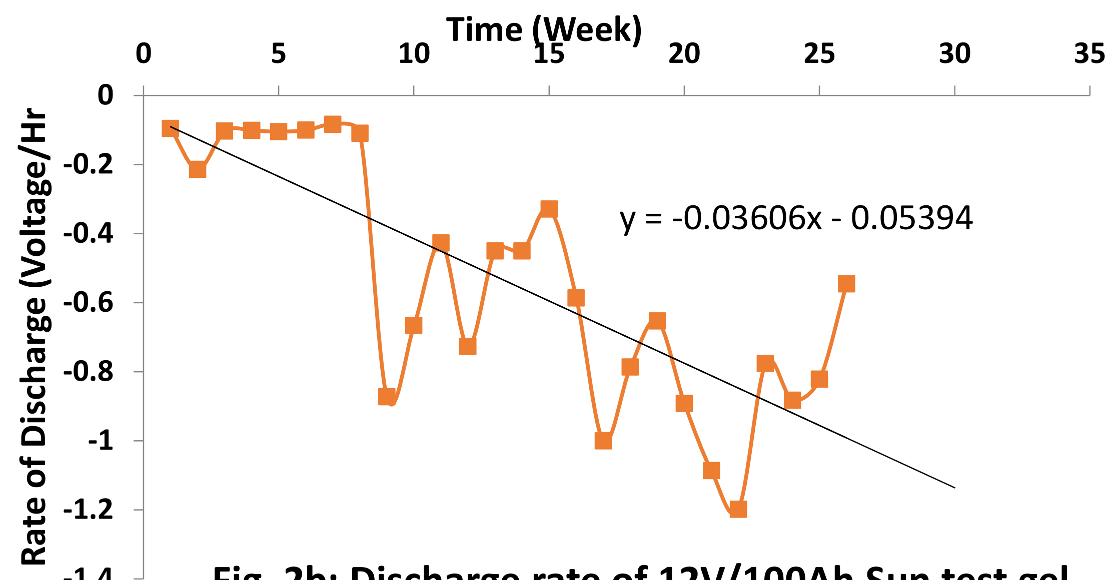

Fig. 2b: Discharge rate of 12V/100Ah Sun test gel Batteries

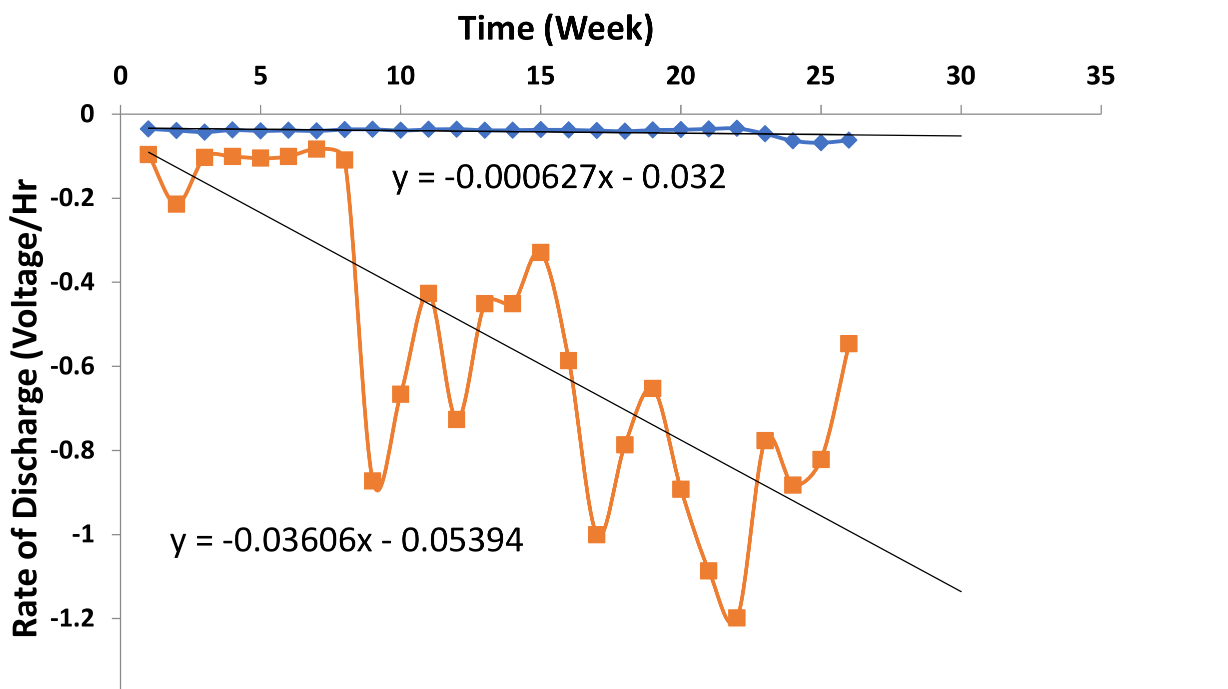

Fig. 3: Discharge rate Comparison between AGM and Sun Test Lead Acid Batteries

5. Conclusion

A comparison investigation was undertaken to analyze the discharge properties of frequently used batteries in solar PV systems. Two batteries were considered. During the initial twenty-six weeks of usage of the 12V/100Ah AGM sealed lead acid, the battery has a negligible propensity to drain, with a flow rate of around -0.000627 Volts/hr per week and During the initial twenty-six weeks of usage of the 12V/100Ah Sun Test gel lead acid battery, the battery experienced a massively higher flow rate of -0.03606 volts per week. During the initial 26 weeks of usage, the 12V/100Ah AGM sealed lead acid battery was noted to be quite consistent and not prone to drain., whereas the In the first 26 weeks of use, the 12V/100Ah Sun Test gel-lead acid battery was very unpredictable and prone to drain. The 12V/100Ah Sun Test gel-lead acid battery's inconsistent behavior was most likely caused by its low charging capacity and responsiveness to a particular amount of solar energy. Consequently, it is better to use a 12 V/100 Ah AGM-sealed lead acid battery.

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