Estimation of Battery Requirements in 600 WP Solar Power Generation Systems

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Abstract. Solar Power Plant as an effort to meet human needs for electrical energy is the right choice for renewable energy. Important components that exist in Solar Power Plant include solar panels, MPPT, batteries and inverters. The function of the battery is to store reserves of electrical energy generated by Solar Power Plant during the day (charging cycle) and at night (discharging cycle). The amount of battery used is a separate design to be able to optimise the installed solar power plant. With the ideal number of batteries, the Solar Power Plant will be more leverage in terms of charging and emptying. The battery used in the 600 Wp Solar Power Plant system at STT Migas Balikpapan is a 12 V 100 Ah deep cycle VRLA type with a total of two installed in series. This is still considered less than optimal because the battery only has a capacity of 100 Ah. In this study, the ideal number of batteries used for Solar Power Plant was calculated, where the ideal number of batteries for 600 Wp Solar Power Plant at STT Migas Balikpapan was six batteries with each type of VRLA deep cycle of 12 V 100 Ah.

Keywords: solar power generation, storage, electric current, electric voltage, charging cycle

1. Introduction
At present the need for renewable energy at a time when fossil energy is already running low[1]. This makes the use of solar energy as an effort to meet human needs for energy to be the right choice because of the nature of solar energy that will not run out and its use and application is easy compared to other renewable energy sources. Indonesia's geographical location near the equator allows it to get enough sunshine throughout the year[2]. However, to utilise solar energy, knowledge, and application of solar power technology are needed so that the understanding of the process of converting solar energy into electrical energy can be achieved where the electricity produced can be used to turn on electrical equipment to facilitate human life[3]. Solar panels are made of semiconductor material that can produce direct current electricity when exposed to light[4]. However, solar panels cannot work alone to produce electricity. It needs some supporting equipment such as Maximum Power Point Tracking (MPPT), batteries and inverters. The function of the battery in a solar power generation system is to store reserves of electrical energy produced by solar panels during the day which can then be used at night[5]. Battery type Valve Regulated Lead Acid (VRLA) deep cycle is very well used in solar power generation systems because the nature of the deep cycle battery has resistance to repetitive
charging and emptying cycles while the use of VRLA type is a maintenance-free factor because it does not require liquid refilling the electrolyte[6]. Calculating the estimated number of batteries of solar power generation systems needs to be done so that the batteries fully absorb the electrical energy that can be produced by solar panels or in other words no electricity is not utilized. Estimated number of batteries can be obtained through a graph of battery voltage concerning time[7]. Bahman [8] has research about determine optimalization about sizing of batteries use in microgrids and Mohammad Reza Aghamohammadi[9] has research about determine optimal sizing of batteries based on frequency control in microgrid. The curve shape on the battery voltage graph illustrates the estimated time needed for a solar power system to charge a battery fully[10]. In this research, we will look for a 12 V 100 Ah deep cycle VRLA battery voltage during the charging process, then an ideal number of batteries needed by the 600 Wp solar power system is calculated according to the data obtained[11].

2. Methodology

Estimated number of batteries needed by a 600 Wp solar power plant is obtained by analysing the value of the VRLA deep cycle 12 V 100 Ah battery voltage during the battery charging cycle. The energy source comes from 6 100 Wp solar cell panels that are designed in a series of 2 units and three parallel units[12]. This research uses 2 VRLA deep cycle 12 V 100 Ah batteries which are arranged in series. Voltage and electric current data obtained from the battery is uploaded to the website by the microcontroller. The analysis conducted in this study is to observe the curve of the electric voltage VRLA deep cycle 12 V 100 Ah. Observations are made during the charge cycle of the battery and also the time needed to charge the two batteries[9] fully. Here is a block diagram in this study that is seen in Figure 1 and the system workflow diagram in Figure 2.

**Figure 1. Block Diagram**

**Figure 2. The System Workflow**
Figure 1 is a block diagram where the block diagram explains the position of the battery. The solar cell is connected to MPPT, which is also connected to the battery. The battery is also connected to the microcontroller where the microcontroller is connected to the data collection module. The battery is also connected to the inverter where the inverter is connected to the load where the load used is the lamp.

The following is an explanation of Figure 2.

- a. Connect the solar panel with MPPT so that the electrical energy generated by the solar panel can turn on the MPPT;
- b. Connect the MPPT with the battery and then the battery charging cycle starts;
- c. Connect the battery with a microcontroller where the microcontroller takes data on the battery and uploads the data to the website continuously;
- d. Perform data retrieval from the website where data retrieval is only done during the process of charging the battery until the battery is full. Data were taken in the form of voltage and electric current on the battery;
- e. If there is not enough data, the battery is discharged, starting by connecting the battery to the inverter, then connecting the inverter to the load so that the light is on. The battery was discharging process analysing out until the battery is unable to turn on the load, indicated by the lights off. Then the battery charging process starts again; and
- f. Data analysis is made from data that has been obtained and made in graphical form.

3. Result and Discussion

The solar power generation system as a result of the design of the device is installed in the Balikpapan STT Migas campus environment where the solar panels are located on the roof of the Ruby Building so that solar radiation can enter without being blocked by shadows. The electrical energy generated by the solar panels is directed towards the Balikpapan STT Migas Instrumentation Laboratory using a cable of approximately ± 10 meters. The following in Figure 3 are solar cell panels installed, and Figure 4 is the MPPT, batteries, microcontrollers, and inverters that are in the laboratory.

3.1. Data Retrieval

Battery voltage data were taken on 25 and 26 May 2019 starting from 06.00-14.00 WITA with consideration that solar radiation was available at that hour where this conclusion was obtained from the data. Battery voltage data collection for solar power plants starts when the battery charge is empty and ends when the battery charge is full[13]. The data is a real-time battery voltage value every ± 24 seconds, which is uploaded by the microcontroller to the website www.infomateri.com/tabel.php. Next in Figure 5 is a graph of battery voltage concerning time.
3.2. Analysis Results

Based on Figure 5, the following analysis is obtained.

a. The minimum voltage value for solar electricity generation batteries is 24.76 V.
   The minimum battery voltage value, which is 24.76 V, is the point where the battery in a solar
   power generation system is no longer able to light the load, so at this voltage, the battery must be
   charged.

b. The maximum voltage value for solar power generation batteries is 28.66 V.
   The maximum battery voltage value, which is 28.66 V, is the point at which the battery is full. At
   this point, the MPPT will cut off the current flowing into the battery to avoid overcharge, which
   can reduce battery life.

c. Work efficiency of solar power generation batteries.
   From the deep cycle VRLA battery datasheet, it is known that the battery has a depth of discharge
   of 20%. This type of battery should be able to discharge until the remaining battery voltage is 10.5
   V. Because both batteries are installed in series, the minimum battery voltage is 10.5 × 2 = 21 V.
   However, the graph shows that the battery is no longer able to light the load when the value of the
   battery voltage is 24.76 V. The value is much higher than the minimum battery voltage of 21 V. If
   calculated using Equation 1, the battery's work efficiency is as follows.

\[
\frac{28.66 \, V - 24.76 \, V}{28.66 \, V - 21 \, V} \times 100\% = 50.9\%
\] (1)

This is certainly very detrimental because the battery is only able to light the lamp in a shorter
   time than it should. This factor can occur due to several things, including the declining state of
   health (SOH)[14], or the selection of inverters that are not good.

3.3. Battery Charging Time

From Figure 5, it is also found that the battery charging cycle occurs when the curve line moves up.
When the battery is full, the curve tends to form a flat line. From the battery voltage graph, it is found
that on May 25, 2019, the battery charging time was 11500 seconds while for May 26, 2019 was
14400 seconds so that the average for data collection every day was 3.6 hours. For detailed
   calculations, can be seen in Equation 2.

\[
\frac{11500 + 14400}{2} = 12950 \, \text{seconds} \approx 3 \, \text{hours} \, 36 \, \text{minutes}
\] (2)
3.4. Ideal Amount of Battery

The geographical location of Balikpapan City is near the equator, so it is estimated that the time of day is approximately 12 hours. The city of Balikpapan makes it possible to receive sufficient solar radiation throughout the day throughout the year. From the comparison of the average length of battery charging with the time of the availability of solar radiation, it can be concluded that the number of solar panels in the solar power generation system is too much and is not proportional to the number of installed batteries. Prices incurred for solar panels should be reduced further. Solar panels that have been installed should not be removed again. However, the solution so that solar power plants in STT Migas Balikpapan can produce electricity with the maximum is to increase the number of batteries. Based on the length of daytime in Balikpapan and the length of time the battery is charged at the solar power plant, the ideal number of batteries used can be calculated using Equation 3.

\[ \frac{12 \text{ jam}}{3.6 \text{ jam}} \times 2 = 6.67 \text{ batteries} \approx 6 \text{ batteries} \quad (3) \]

The number of installed batteries is only one-third of the ideal number of batteries used. The batteries used should have the same type of batteries that already exist in solar power plants, namely the 12 V 100 Ah deep cycle VRLA battery type.

3.5. Inverter Type Selection

As explained in the previous discussion, choosing the type of inverter affects the working efficiency of the battery. The inverter which is currently installed in the solar power plant at STT Migas Balikpapan is a modified sine wave 24 V 1000 W type inverter. This type of inverter requires a minimum input voltage of 24 V which in this case causes the inverter to not work if the input voltage from the battery is approaching 24 V or on the battery voltage chart that is at a voltage value of 24.76 V. In the previous discussion it was found from the datasheet that two deep cycle VRLA batteries arranged in series allow the battery to work up to a minimum battery voltage of 21 V. Therefore, the voltage loss occurs is 3.76 V. The selection of the recommended type of inverter for solar power plants in STT Migas Balikpapan is a type of pure sine wave 12 V 500 W inverter, because this type of inverter has a voltage harmonic distortion that is smaller than the modified sine wave type inverter, able to produce stable power and can control larger currents, even pure sine wave inverters have higher prices.

4. Conclusion

From the results of data analysis of the off-grid PLTS system at Balikpapan Oil and Gas STT, two main conclusions are obtained, namely the minimum battery voltage value of 24.76 V while the maximum battery voltage value is 28.66 V, and the ideal number of batteries used by PLTS is 6 VRLA batteries 12 V 100 Ah deep cycle. For further research, the working efficiency of batteries is still not optimal, which is equal to 50.9%. This factor can occur due to several things, including errors in reading data by the microcontroller, the state of battery health (SOH) which decreases, or the selection of the inverter is not good. The ideal number of batteries used when number 2 out of the estimated six batteries needed is still underutilised to the size of 600 Wp solar cells. For the selection of modified sine wave inverters, it turned out to be less precise, causing the electric energy in the battery to not be fully used, it is recommended to use a pure sine wave type inverter because it has a smaller harmonic voltage distortion, is capable of producing stable power and can control more current big.

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