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Battery Inspection Of 380 kWp Off-Grid Solar Power Plant (PLTS) on Mules Island, East Nusa Tenggara

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Abstract

Off-Grid Solar Power Plant is a power generation system that uses solar energy. Battery maintenance is important in maintaining the stability of this system. This research focuses on battery maintenance by checking in a keHua monitoring tool for 389 battery units and monitoring the battery graph for 30 days. The results showed that there were 15 batteries that experienced a voltage drop below 1.83 Volts. The voltage drop occurred between 21:00 and 00:00, so the batteries were considered damaged. The battery capacity requirement on Mules Island, East Nusa Teggara increased from 778 kWh in 2019 to 936.9 kWh in 2021. To maintain the reliability of the Off-Grid Solar PV system on Mules Island, it is necessary to replace 15 damaged battery units and add a new battery capacity of at least 157.9 kWh so that the system can run well and customers can enjoy electricity for 24 hours as at the beginning of the implementation.

Keywords*: Off-Grid PLTS, Battery Maintenance, System Performation, KeHua Monitoring*

1. INTRODUCTION

Solar power plants (PLTS) are the development of solar energy technology that is affordable, inexhaustible, and clean will provide great long-term benefits, at this time many have utilized solar panels as independent power plants without having to rely entirely on PLN **(Mangapul & Alifyanti, 2016).** Meanwhile, the amount of fossil fuels for electrical energy is very limited. That's why new and renewable energy is needed (*renewable energy*) **(Alipura, 2009).** One of them is to reduce the use of fossil fuels and use renewable energy sources such as solar energy. The trend of energy use in the world has changed, starting to switch from fossil energy to renewable energy, especially solar power which is very abundant **(Kaltschmitt et al., 2007).**

One solution that can be utilized as an alternative power plant is a solar power plant (PLTS) with a modular system that is portable **(Ruskardi, 2015).** The use of solar panels can save the use of fossil fuels whose amount is decreasing every year **(Agary & Tanudjaya, 2015)**

Solar panels are devices that convert direct current from solar energy. The advantages of this modern technology are ease of maintenance, cleaning, savings, installation, and ease of operation **(Fhery & Idris, 2019).** When the solar power plant charges the battery of the solar panel, which receives solar energy and converts it into electrical energy, the output of the panel when it is working is voltage and current. When charging occurs, the controller connected between the solar panel and the battery continues or regulates the output current from the panel. After the current enters the controller, the current will enter the battery, the impact of the current entering the battery is the gradual increase in the voltage in the battery **(Setiawan & Puriyanto, 2020).**

Solar Power Plant on Mules Island, East Nusa Tenggara (NTT) with a capacity of 778 kWh, the batteries used in the Mules Island Solar Power Plant have a total of 389 battery units to cover 3 villages for 24 hours, especially at night starting from 18:00 to 06:00 WIT. The type of battery used in Mules Island Solar Power Plant is Lead Carbon Battery, battery specification 2V CN1000 (1000Ah). This battery maintenance is used, one of which is to check the performance of the battery, whether it is still running normally or not, because if there is a voltage drop, the system becomes unstable and electricity supply to the community cannot be carried out for 24 hours. Improper charging and discharging can quickly shorten battery life **(Sugeng & Saputra, 2019), (Qurthobi et al., 2018).**

Because in Mules Island was found that the voltage drop on the battery was due to the increasing needs of customers/consumers, therefore it was necessary to know the adequacy of battery energy and analyze the battery performance of Off-Grid PLTS on Mules Island.

2. METHODOLOGY

2.1 Flowchart

In this section, the research steps will be explained through the research flow chart in Figure 1.

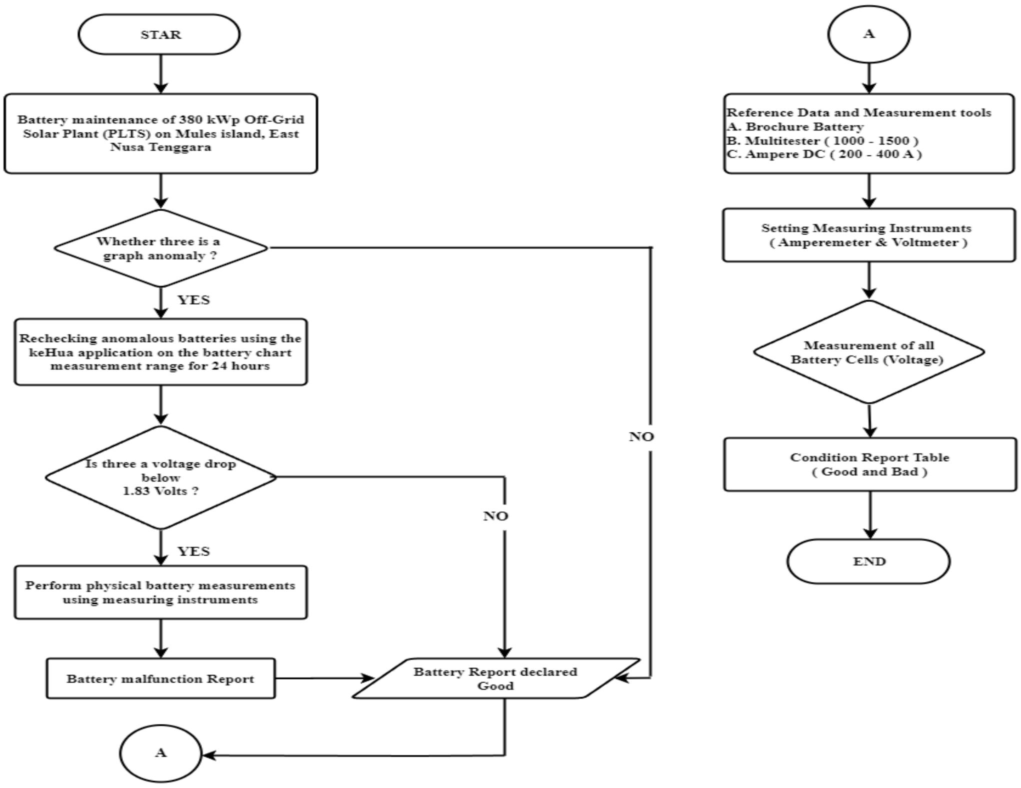


Figure 1. Flowchart of Battery Inspection

A. Checking 389 batteries one by one, by looking at the battery chart on the kehua application using a 30-day chart measurement range. can be seen in figure 2 of the battery room location.

Figure 2. Storage Space Battery

B. Check the battery graph anomaly, where if an anomaly occurs then the process continues to the next step, if no anomaly occurs then the process is complete (battery is reported as good).

C. Figure 3 shows a recheck of the battery graph anomaly, using the KeHua application over a narrower range of battery graph measurements of 24 hours, to determine whether or not a voltage drop below 1.83 Volts occurred.

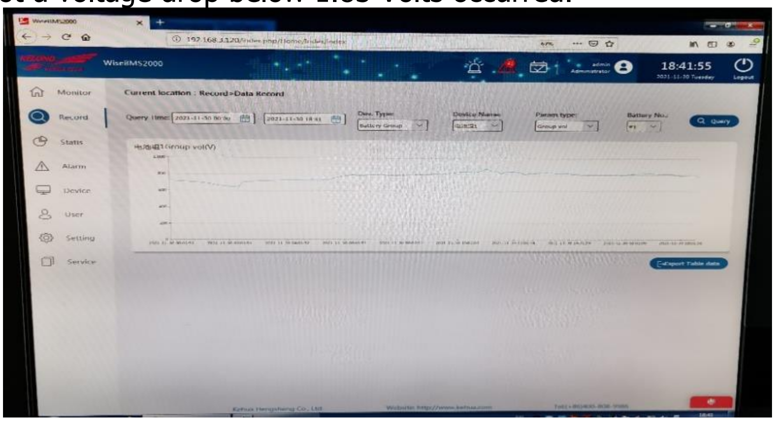


Figure 3. Digital Battery Check in KeHua Monitoring

D. If there is a voltage drop below 1.83 Volts then the process continues to stage 5, while if there is no voltage drop below 1.83 Volts then the battery is reported as Good.

E. Take physical measurements of the battery using a measuring device as shown in Figure 4 below:

Figure 4. Checking the Battery Directly

The activity was carried out at night 4 times, namely at 21.00 WIT, 22.00 WIT, 23.00 WIT and 24.00 WIT, Battery measurements are taken when the system is running and directly take measurements using a measuring instrument (Digital Multimeter).

2.2 Data Processing

At this stage, the author processes the data obtained from the results of data collection to process data on Solar Power Plant Batteries (PLTS). The data obtained will then be used in the following calculations:

2.2.1 Calculation of Usable Battery Energy

This is the maximum capacity of the battery used. this means that only 80% of the available energy can be used and 20% remains in reserve (**Nano, 2019**). Then we can calculate the usable energy using the formula with equation 2.1

$$\text{Usable Energy} = \text{Battery Capacity} \times 80\%\ \text{DoD} \qquad (2.1)$$

Where :
DoD : Percentage of depth of discharge

2.2.2 Calculating Energy Available to Customers

The following is a calculation based on the technical specifications of the inverter parameters where the inverter efficiency is 92% and the Cos phi inverter is 95% (inverter datasheet attachment). The calculation formula used is equation 2.2

$$\text{Total Energy Available to customers} = \text{UsableEnergy} \times 92\% \times 95\% \qquad (2.2)$$

2.2.3 Battery Energy Sufficiency Analysis

To analyze the adequacy of battery energy, field data is taken regarding the amount of energy use by customers in 2019, 2020, and 2021. After calculating the battery capacity and the amount of energy available to customers, then to find out the value of battery energy adequacy, a value comparison must be made to get the conclusion of the analysis.

2.2.4 Battery Analysis based on Battery Voltage Measurement

In this battery analysis, sampling data for 30 days for all battery data as many as 389 units. And taking data for 24 hours specifically on batteries that indicate problems.

2.2.5 Battery Analysis based on Battery Voltage Measurement

In this analysis, namely taking data based on the results of direct measurement of problematic batteries using a digital multimeter measuring instrument. The measurement process is carried out at night for 4 measurements, namely at 21.00 WIT, 22.00 WIT, 23.00 WIT, 24.00 WIT.

3. RESULT AND ANALYSIS

The main devices in the PLTS system on Mules Island consist of solar panels, controllers, inverters and batteries. This PLTS runs using two systems to cover 3 villages on Mules Island, East Nusa Tenggara (NTT) with a capacity of 778 kWh, where during the day the load from residents' homes is supplied directly by the PV Module while in parallel the battery is charging from the PV Module, and at night, the load from residents' homes is supplied by batteries that have been charged in the afternoon.

3.1 Battery Configuration Data of Mules Island Solar Power Plant

Figure 5 shows that the battery configuration is divided into 8 battery lines arranged in series where on battery line no.1 there are 51 batteries, battery line no.2 there are 50 batteries and battery lines no. 3-8 there are 48 batteries.

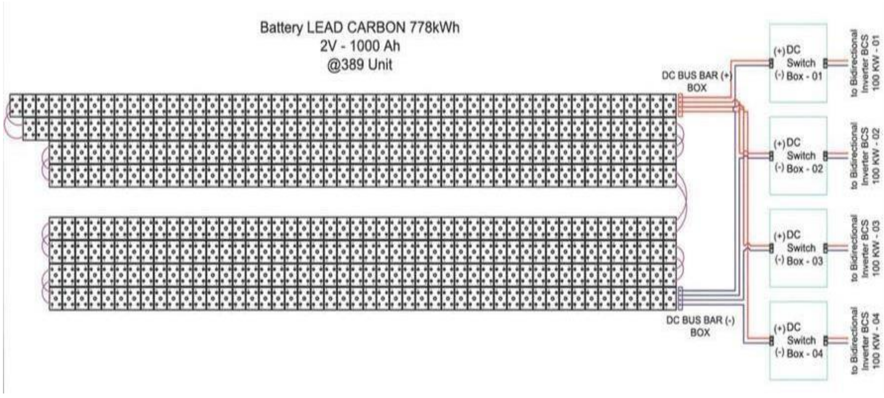


Figure 5. Battery Configuration of Solar Power Plant on Mules Island

To measure the performance of the Mules PLTS battery, we need to calculate the value of the Battery Energy Availability on the island of Mules, whether it is able to cover the expected value or not, which is 544 kWh.
Before we can calculate the Battery Energy Availability value, we must first know the usable Battery Energy value which can be calculated by equation 3.1.

Usable Energy = battery capacity × DoD 80% (3.1)

The battery DoD value is obtained from the battery technical specification datasheet so that the usable energy value can be obtained by:
Usable energy = 778 kWh × 80% = 622.4 kWh

3.2 Calculation Energy Available to Customers

The total energy available to customers can be calculated by equation 3.2
Usable energy × Inverter efficiency × Cos Phi (3.2)
The calculation results are as follows: 622.4 kWh × 92% × 95% = 544 kWh

3.3 Battery Energy Sufficiency Analysis

To analyze the adequacy of the current battery (after the system has been running for 3 years), the researchers took field data related to the amount of energy use by customers. This customer energy usage data (loading data) was taken on November 25, 2021 for 24 hours, where this data was obtained when the author made a maintenance visit in 2021, while the 2019 and 2020 data were obtained from the field supervisor's data recap.
Table 1 shows that by using the calculation formula of usable energy and customer energy availability, the calculation to get the value of the battery capacity requirement should be as follows:

Table 1. Battery Capacity based on calculation

2019		2020	2021
Consumer Need Energy	: 245,1 kWh	: 509,5 kWh	: 654,4 kWh
Efficiency	: 92 %	: 92 %	: 92 %
Cos Phi	: 95 %	: 95 %	: 95 %
Distribution Panel Energy	: 280,4 kWh	: 582,9 kWh	: 748,7 kWh
DoD	: 80 %	: 80 %	: 80 %
Batery Spesification Capacity	: 350,5 kWh	: 728,6 kWh	: 935,9 kWh

The conclusion of this analysis is that the battery capacity is no longer sufficient to meet customer needs, where the battery energy adequacy (in 2019) is 778 kWh, while the battery capacity requirement in 2021 (based on customer energy calculations) is 935.9 kWh.

3.4 Battery Analysis Based on KeHua Monitoring

Figure 6 shows that in analyzing the feasibility of this battery the author uses data on the KeHua Battery Monitoring Application. This battery monitoring is done by checking one by one the graphs on all 389 batteries analyzed, the results of checking obtained 2 (two) battery graph models as shown below:

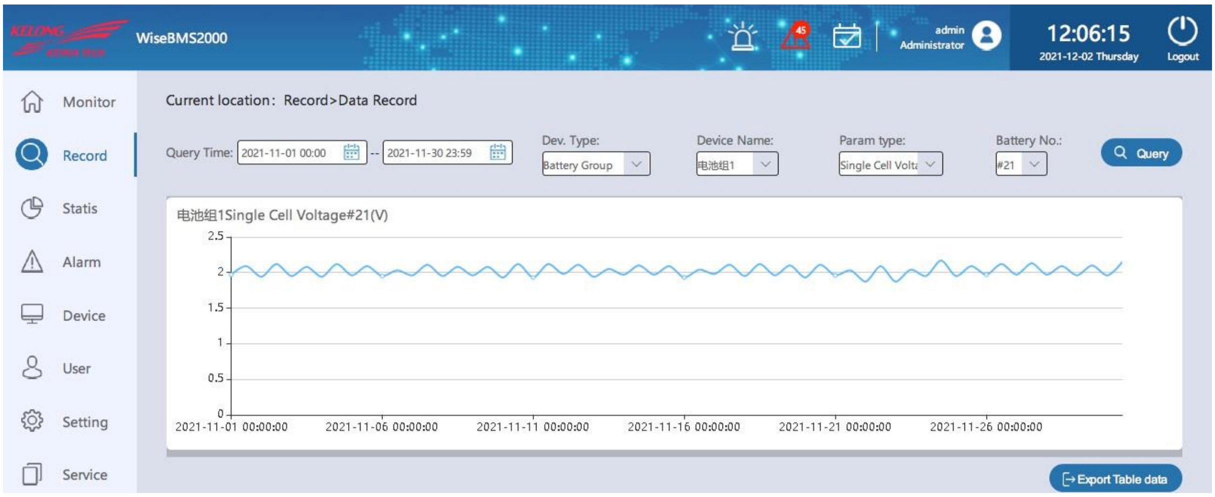


Figure 6. Battery chart without anomaly

The graphical image of model 1 above is categorized as a battery with good or good performance, where the graph shows that the riple energy of the battery is still within the 2 Volt range (according to the battery specifications) and does not experience a voltage drop, this indicates that the battery can cover the load for 24 hours and charge again during the day.

Figure 7 battery energy riple experiencing a voltage drop below 1.83 volts and occurs repeatedly during 30 days of observation, so the results of the analysis based on the graph in the KeHua application indicate an anomaly in the battery.

Figure 7. Anomalous Battery Chart

3.5 Battery Analysis Based on Battery Voltage Measurement

Figure 8 shows that this advanced measurement is carried out by directly measuring the damaged battery using a measuring instrument carried out at certain hours, to see whether the battery voltage is still within specifications or not.

Figure 8. Battery Voltage Measurement

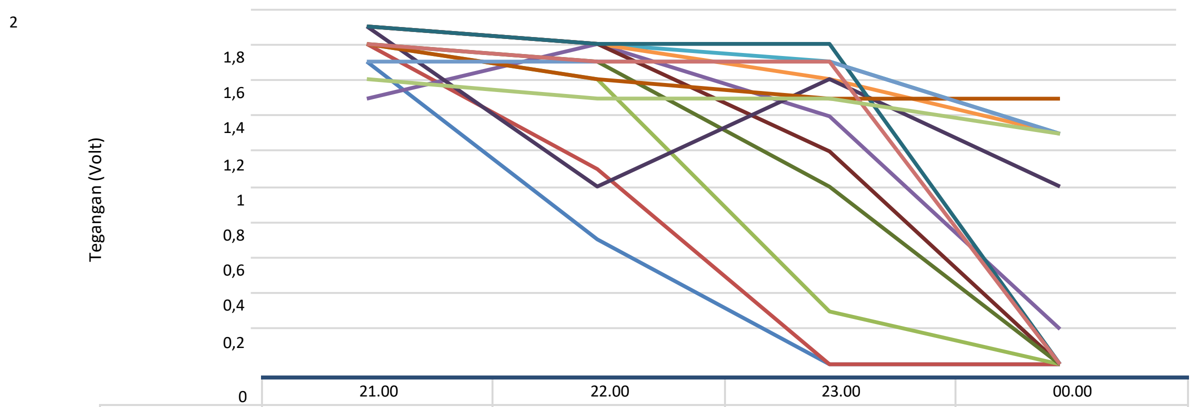
This measurement is carried out at the hour where the battery experiences a voltage drop according to the previous analysis, namely at 20.00 WIT to 08.00 WIT. Data from 15 battery voltage measurements can be seen as in Table 2 below:

Table 2. Battery voltage measurement results

No Battery	Battery			
	21.00	22.00	23.00	00.00
28	1.7	0.7	0	0
52	1.8	1.1	0	0
90	1.8	1.6	0.3	0
135	1.5	1.8	1.4	0.2
158	1.9	1.8	1.7	1.3
197	1.9	1.8	1.6	1.3
208	0	0	0	0

No Battery	Battery			
	21.00	22.00	23.00	00.00
219	1.9	1.8	1.2	0
226	1.8	1.7	1	0
250	1.9	1	1.6	1
285	1.9	1.8	1.8	0
183	1.8	1.6	1.5	1.5
212	1.7	1.7	1.7	0
216	1.8	1.7	1.7	0
265	1.6	1.5	1.5	1.3

Figure 9 shows the data graph below, which shows the relationship between the measurement time (horizontal) and the measured voltage (vertical) for all 15 reported faulty batteries.



	21.00	22.00	23.00	00.00
Baterai No 28	1,7	0,7	0	0
Baterai No 52	1,8	1,1	0	0
Baterai No 90	1,8	1,6	0,3	0
Baterai NO 135	1,5	1,8	1,4	0,2
Baterai No 158	1,9	1,8	1,7	1,3
Baterai No 197	1,9	1,8	1,6	1,3
Baterai No 208	0	0	0	0
Baterai No 219	1,9	1,8	1,2	0
Baterai No 226	1,8	1,7	1	0
Baterai No 250	1,9	1	1,6	1
Baterai No 285	1,9	1,8	1,8	0
Baterai No 183	1,8	1,6	1,5	1,5
Baterai No 212	1,7	1,7	1,7	1,3
Baterai No 216	1,8	1,7	1,7	0
Baterai No 265	1,6	1,5	1,5	1,3

Figure 9. Voltage Measurement Chart of 15 Batteries

Based on the graph data above, it can be seen that the measurement results of the 15 batteries have a voltage value that is decreasing (within a period of 4 measurements) even to a value of 0 volts, which should still be in the 2 volt range, if the battery voltage continues to decrease and reaches a value of 1.83 volts, the battery will cut off the power to the main load.

By analyzing the graph of the battery voltage measurement results above, it can be concluded that the 15 batteries are in a damaged state and need to be replaced immediately for the system to operate as expected.

Figure 10. Investigation team and Optimization of Solar power generation system

Figure 10 shows investigation team that performs maintenance on the Solar Power Plant system on Mules Island

4. CONCLUSIONS

Maintenance of the PLTS battery system on Mules Island can be done in two ways, namely checking the battery condition using the KeHua application and measuring the battery directly using a measuring instrument. Based on the results of checking and analyzing the PLTS battery device on Mules Island, both using the KeHua application graph analysis and direct measurement on the device, it turns out that there are 15 battery units experiencing decreased performance or damage. In addition, the author has also analyzed the adequacy of battery energy, namely by comparing the current customer energy demand data with the installed battery capacity data. Where the analysis results state that the installed battery capacity is 778 kWh while the required battery capacity requirement is 935.9 kWh. So that to maintain and maintain the reliability of the off-grid PLTS system on Mules Island, East Nusa Teggara, it is necessary to replace 15 units of damaged battery devices and add a minimum new battery capacity of 157.9 kWh so that the system can run well and customers can enjoy electricity for 24 hours as at the beginning of the implementation.

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