The Spirit of Society Journal
International Journal of Society Development and Engagement
LPPM - Universitas Narotama
ISSN : 2594 - 4777 (Online)
2597 - 4742 (Print)
https://jurnal.narotama.ac.id/index.php/scj/index

Performance Evaluation of Floating Solar Power Plant in Sidobandung Bojonegoro

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Abstract: Sidobandung Village is a village that will develop the potential as a tourism village. One of the potentials that has been successfully built is a reservoir. With the construction of the reservoir in this village, tourism activities began to be seen. The number of visitors who came increases the village's income. Yet, Currently it only open on daytime conditions. Therefore, in its development, there is a desire to open services at night. The problem is how to reduce electricity costs. One of the facilities to support this is to build a floating generator (PLTS) which was built in collaboration with one of the expert vocational colleges in the field of floating buildings located in Surabaya. This floating PLTS is a renewable energy source, in accordance with the village's wish to become an educational tourism village. This floating PLTS is expected to be able to supply 30 lamps which each having a power of 50 watts for street lighting around the reservoir. The total lamp load is about 100 watts. The PLTS system that was built consists of 10 solar cell panels, each solar cell panel has a capacity of 330 WP. With a total of 4 batteries with specifications of 12 Volt 200 Ah. This system is being evaluated. The evaluation results show that the battery capacity is only able to supply 15 lamps for 12 hours. So to supply all the required load, 12 batteries are needed.

Keywords: PLTS, floating, battery, new renewable energy

INTRODUCTION

To meet the increasing demand for energy, the government continues to develop various alternative energies, including renewable energy. Renewable energy potential, such as biomass, geothermal, solar energy, water energy and wind energy has not been widely utilized, even though the potential for renewable energy in Indonesia is very large [Spencer et al, 2018].

Population growth continues to increase resulting in energy needs also continue to increase. This is in contrast to the dwindling availability of fossil energy which has been the main fuel. Fossil energy itself is non-renewable energy because it takes a very long time to form [Yousuf et al, 2020].

To use solar energy for small-scale power generation, a voltage regulator is needed so that the resulting voltage is constant. In addition, a battery is also needed as a medium energy storage. From the battery the resulting voltage is then used to supply the load [Srivastava et al, 2022].

The lighting on this Floating PLTS is a lamp that is installed in the reservoir (named Sidobandung Bojonegoro) with a total of 30 light pole points surrounding the reservoir with a lamp power used of 50 Watt. The purpose is to illuminate the reservoir and optimize the operation of the reservoir at night. This lamp is generally installed for lighting, so it requires a bright light. It is very effective and efficient in supplying electricity to the lamp. Moreover by using solar energy stored in the battery it can be used automatically at night without having to use electricity from PLN.

Basic Theory

Solar power plants or abbreviated as PLTS are power plants with solar energy sources. This power plant is based on new and renewable energy in its operation. PLTS is an alternative generation system that is appropriate for applications in areas that are difficult to access by large power generator systems such as the PLN network [Ramadhani, 2018]. PLTS is also a solution to overcome the fuel crisis and the lack of electricity in remote areas, small islands. The aim of this floating PLTS is to optimize the use of reservoirs to generate electricity from solar panel modules which are supported by panel frames and floating buildings which will later be used to light the entire reservoir area to cover the shortage of electricity supply. So that the whole system can operate more economically and efficiently.

In the operation of this floating PLTS, there are several things that need to be considered, including [Medina et al, 2018]:

a. Load characteristics or fluctuations in energy usage (load profile) in which during 24 hours the load distribution is uneven for each time. This load profile greatly affects the supply of energy. To overcome these problems, a combination of energy sources between renewable energy sources and diesel generators or PLN is the answer.

b. Characteristics of power generation, especially taking into account the natural energy potential to be developed.

c. Characteristics of the natural conditions themselves, such as the change of day and night, seasons and others.

In General, floating PLTS works in the following order [Yuliarto, 2017]:

a. In low load conditions, 100% of the load is supplied from the battery and the PV module during the full battery condition will be used for another load.
b. For loads above 75% of the inverter load (depending on each parameter) or when the battery is empty to the level indicated as a charger (converts AC voltage to DC voltage) to charge the battery.
c. In peak load conditions, if the electricity supply is not reached, a battery will be added to increase the voltage to the load to achieve the required peak load.

The floating Solar Power Plant (PLTS) system implemented in the Sidobandung Kec.Bojonegoro Regency reservoir is shown in Figure 1.

METHODOLOGY

To get good evaluation results, the method used is as follows:

1. Retrieval of measurement data
   Data is obtained by measuring the output or output of the solar cell panel with a certain time span. This is to see the change in voltage generated from the solar cell panels.

2. Data analysis.
   The data is then analyzed to find out whether the system built is in accordance with the load requirements desired by the reservoir tourism manager.

3. Write reports.
   The results of the analysis are used as a basis for providing input to managers to increase the capacity or capability of the PLTS system.

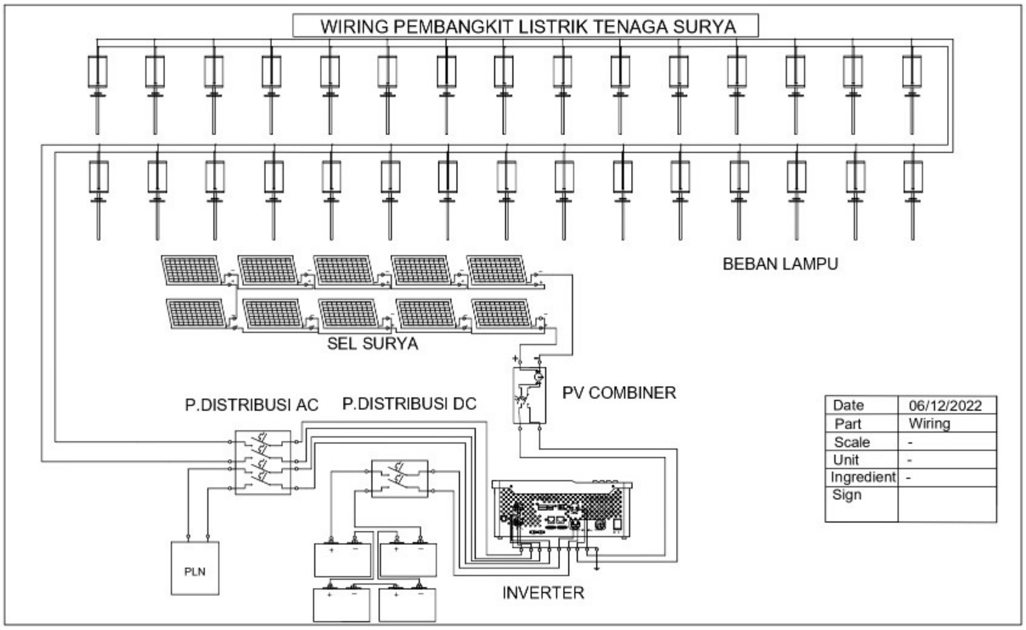

Figure 1. Floating PLTS System and Wiring

RESULTS AND DISCUSSION

Measurements were taken when the sun was in position at 07.00 WIB until 18.00 WIB when the intensity of the sun began to decrease in the afternoon. The measurement results are shown in table 1.

Table 1. Calculation of Measurement Results

Measurement Time (WIB)	Array Voltage (DC) (V)	Current Arrays (DC) (A)
07.00	403.9	40.9
08.00	404	40.8
09.00	405.1	40.7
10.00	403.4	40.9
11.00	406	40.6
12.00	405	40.7
13.00	406.2	40.6
14.00	388.7	42.4
15.00	383.4	43.0
16.00	370.7	44.5
17.00 WIB	356.2	46.3
18.00 WIB	349.3	47.2

From the data above, the voltage from 10 solar panels is obtained in series where for the average output value of 1 solar panel alone can supply a voltage of 40 Volts or 400 Volts if all 10 panels are serialized so that the voltage of one panel will be multiplied by the total of the panels in series and of the total If the voltage is used for a 50 Watt power load for the lamp, the current flowing in the installation has an average of 0.125 A.

With real-time measurement data, it can be calculated as follows:

1. Electrical loads on the Sidobandung Reservoir, Bojonegoro

The load supplied by the solar cell power supply is the DC load on the lamp of 50 Watt AC and 100 Watt DC for tenants which are turned on for 11 hours, where for this DC load there are 30 lampposts surrounding the reservoir as a whole so the daily AC load is 16500 WH or 16.5 KWH for a 50 Watt lamp and 33000 WH or 33 KWH for a DC daily load for a 100 Watt tenant.

To determine the total AC load if the lamp has a power of 50 Watt, use equation (1)

$$\text{Total load (Ah/day)} = \frac{Total\ AC\ load\ (\frac{Wh}{day})}{System\ Voltage} \quad (1)$$

$$= \frac{16500}{48}$$

$$= 343.75 \text{ Ah/day}$$

AC Load Output Energy = 343.75 Ah/day

Meanwhile, to determine the total AC load and inverter voltage input for lighting lamps in a Floating PLTS-based reservoir is to use equation (2) and (3)

$$\text{Ein-inverter} = \frac{AC\ load\ output\ beban\ AC}{Inverter\ efficiency} \quad (2)$$

$$= \frac{16500}{0{,}94}$$

$$= 17.553 \text{ Wh/Day}$$

$$\text{Ah/day AC load} = \frac{Inverter\ input\ energy}{Inverter\ input\ voltage} \quad (3)$$

$$= \frac{16500}{48}$$

$$= 343.75 \text{ Ah/day}$$

So the total load Ah/day of electrical load is 343.75 Ah/Day and the available power in the inverter is 17,553 Wh/Day

2. Calculation of Batteries in the Sidobandung Reservoir, Bojonegoro

Then to calculate the capacity of the battery to be used can be found by equation (4)

$$\text{Nbat series} = \frac{Tegangan\ Sistem}{Vsat} \quad (4)$$

Is known:

VSystem = 120 Volts

vbat = 12 Volts

$$\text{Nbat series} = \frac{120}{12}$$

$$= 10$$

So the number of batteries used in the floating PLTS in the Sidobandung reservoir, Bojonegoro is 10 series batteries.

3. Calculation of Total Storage Capacity, Energy and Battery Load Current

Calculation of the capacity of the battery to be used can be found by equation (5), as follows:

$$\text{Totalstorage capacity} = \frac{\text{Usable Storage Capacity (Ah)}}{(MDOD)} \quad \text{.........................(5)}$$

$$= \frac{200}{0{,}80}$$

$$= 250 \text{ Ah}$$

So the storage capacity of the battery is 250 Ah

Then to determine the battery energy is by equation (6) as follows:

Great = Vbat x AhBat x Nbat x DOD % ....(6)

= 12 V x 200 x 16 x 80 %

= 30720 Wh or 30.7 kWh

So the battery energy is 30720 Wh or 30.7 kWh

And for the load current can be calculated as follows:

Total load current = DC load current + AC load current

= 1500/11 + 100/11

= 145.45

So the total load current on the Floating PLTS in the Sidobandung reservoir, Bojonegoro is 145.45A.

4. Battery spare time calculation

To determine the battery spare time is by equation (7) as follows:

$$\textit{discharge time} = \frac{\text{Kapasitas Nominal Baterai x DOD \%}}{\text{Total arus beban}} \quad \text{.........................(7)}$$

$$= \frac{200\text{x } 16 \text{ x } 80\ \%}{145}$$

$$= 18 \text{ Hours}$$

5. Inverter Capacity Calculation

In accordance with the existing inverter specification data, the DC load that enters the inverter can be determined by equation (8), as follows:

$$\text{DC Load} = \frac{\text{AC Load}}{\text{Inverter Efficiency}} \quad \text{.........................(8)}$$

$$= \frac{16500}{0.94}$$

$$= 17.533 \text{ Wh/day}$$

So the DC load needed by the inverter is 17,533 Wh/day.

6. PV Power Effectiveness Calculation

In accordance with the specification data of PV modules that are serialized to generate electricity with the most effective hours of operation at hours can be determined by equation (9), as follows:

Power / PV unit	= Power x Units ……………………………………… …………………(9)
	= 330 Volts x 10 Units
	= 3300 Wp
PV power	= Power x Units x Hours of effective operation …………………………(10)
	= 330 Volts x 10 Units x 4 hours
	= 13200 Wp or 13.2 kWp

So the power per unit of PV and the overall power of the supplied PV is 330 Wp and 13200 Wph.

RESULTS AND DISCUSSION

In this discussion, where planning the maximum current of the modules in one string that the planner wants to achieve is 10 A. By using 10 solar panel modules in series with a capacity of 3300 Wp and a nominal voltage of 330 V, if using the equation I = P/V, then I = 330 / 42 = 7.85 A, then the output of each string on the system is installed with a 10 Ampere MCB and the output of the 10 strings is installed with a 100 Ampere MCB. However, after measurements and equations were carried out to calculate the array output, the maximum current of the array was 29.3 Amperes. The result is a calculation of IMPP x Nstring, where the IMPP of the module is 2.93 and the number of strings is 10 strings, so 2.93 x 10 = 29.3 Amperes. So the actual current is in accordance with the installed module circuit where there are 10 modules with a power capacity of 330 Wp and a maximum voltage of 42 V per module and a maximum current of 2.93 Amperes. However, the measurement results also prove that the largest current is 31.7 Amperes.

In this system, the battery spare time should be able to supply at least from 16.00 WIB to 07.00 WIB where there is no more sunlight, so the spare time should not be more than 15 hours. However, after calculating with the equations used, the battery can supply up to 11 hours of spare time. In general, in this, it is planned that the spare time for the batteray to supply lighting is 1 day equal to 11 hours.

CONCLUSION

Solar module with a power capacity of 330 Wp with Vmax = 42 Volts and Imax = 7.85 Amperes. Where there are 10 solar panel modules that are serialized to form an array, each module is installed in series and in very bright conditions it can produce the largest voltage from the array with a value of 406.2 Volts at 13.00 WIB, while the largest current is with a current value of 47. 2 Amperes at 18.00 WIB.

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