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Design of Solar Power Plant: Analyze Its Potential in Parangtritis Area Using PVsyst Simulator

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ABSTRACT
The high demand of electrical energy nowadays occurs globally, including in Indonesia. One solution to overcome the problem of electricity consumption is to design solar power plants in Indonesia. The location of Parangtritis beach itself has a high potential radiation value when compared to other beaches in the Southern coast area of Yogyakarta. The total electricity demand in that location in one day is 2.9 MWh which theoretically can be supplied by 681 kWp solar power plant. The design uses a PVsyst simulator with a configuration of 2,064 solar panels with a capacity of 330 Wp each, batteries with a total capacity of 90,625 Ah, and a total area of 4256 m2. The total solar power plant investment is 23 billion IDR, including maintenance and operational costs of 234 million IDR per year.

Keywords— Renewable energy, Solar Power Plant, PVsyst

1. INTRODUCTION

The development of technology has an impact with the increasing use of electricity needs every year. If we look at the current conditions in Indonesia, based on data obtained from the Ministry of Energy and Mineral Resources in 2019. With respect to the power plant development, Indonesia's electricity consumption increased to reach 964 KWh per capita and it is projected to be 3 MWh per capita and 6.7 MWh per capita in 2030 and 2050 respectively [1].

Under these conditions, Indonesia needs additional energy supply to meet the electricity consumption demands. On the other hand, the majority of existing power plants in Indonesia still use fossil resources which will eventually run out. The problem is to utilize the energy source from the sun as energy for electricity generation.

Parangtritis Beach in Yogyakarta Southern part, aside from having the potential of solar energy, the area is also one of the main tourist destinations which certainly requires many public facilities. Therefore, if a power plant is built, it can be used to supply public facilities, food stalls, shops, and houses around the coast. In addition, with the construction of solar power plants on Parangtritis Beach, it can become an attraction for tourists visiting there. The construction of this power plant can also be an alternative energy resources in the surrounding area.

Photovoltaic cell or Solar cell is one of the technology that has become popular in the last few decades. Its technology that converts directly the solar energy coming from the sun into electricity and simply can be used by household electrical appliances. It makes the power plant very convenience to use. The only challenges that resist the expansion of this technology is the cost of the supporting components (BoS or Balance of System), especially the battery, inverter, and installation/labour. However, the manufacturing cost of PV historically is going downward and the trend is expected to continue in the future[2].

Similar PV projects in the rural area in Indonesia have been conducted. For example, the analysis of communal PV module in Kaliwungu village, Banjarnegara by Ariani et al [3]. The village has total electricity consumption about 9 MWh. Ariani reported that the PV module capacity to supply the electric energy to the village is 2.85 KWp, supported by battery 464,678 Ah, charge controller 60 A, and inverter 3500 W.

Another example of PV modules implementation in the rural area is from the cell installation at *Batik* home industry in Wijirejo, Yogyakarta [4] [5]. This home-scale business utilizes 400 Wp, from the total of 800 Wp capacity, to supply their electricity for lighting system and water pump. The total electricity needed to run the *Batik* production is 891 Wh per day.

By using PVsyst, this paper analyzes the potential of solar energy in the Parangtritis beach Yogyakarta. This includes the proposed specifications of the solar system components and the estimated cost needed to build the system.

2. METHODOLOGY

The formula used in this methodology section are taken from *Instalasi Pembangkit Listrik Tenaga Surya, Dos & Don'ts* published by Directorate General of New and Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources Indonesia in collaboration with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and Energising Development (EnDev) Indonesia [6].

2.1. Solar Power Plant

Solar power plant is a power generation system that converts solar energy into electrical energy. Electricity generation can be done in two ways, i.e. directly using photovoltaic and indirectly by concentrating solar energy sourced from the sun. Photovoltaic directly converts light energy that comes from the sun into a form of electrical energy that utilizes the photoelectric effect of the sun. To calculate the solar system capacity, the following equation can be used:

$$P = \frac{\text{E}}{\text{t x } kef \text{ x eff.modul}} \quad (1)$$

where,

P : PV module capacity (kWp)

E : Total electricity needs (kWh)

Eff. Module : module efficiency

T : Effective time (h)

kef : solar system coefficient value

2.2. Solar Panel

Solar panel are panel that consist of a series of several solar cells connected in series or arranged in parallel and positioned so that they can be square or rectangular in shape. This panel is then laminated and coated using special glass which is then given reinforcement to the frame or frame positioned on all four sides. The following formula can be used to calculate the number of solar panels used on a system:

$$\text{Numbers of Panel} = \frac{\text{PV module total capacity}}{\text{Solar Panel Capacity}} \quad (2)$$

2.3. Solar Charge Controller

The solar charge controller itself functions as a controller or regulator of the power and voltage that goes into the batteries sourced from solar panels. This device ensures the batteries used are not overcharged during the day, and the power does not move back towards the solar panel at night, causing the battery to become drained. To calculate the need for a Solar Charge Controller, then Formula (3) is used.

$$\text{SCC} = \frac{\text{PV module total capacity}}{\text{SCC Output (kW)}} \quad (3)$$

2.4. Inverter

Inverter is an electronic device that can be used and serves to change direct current electricity (DC) so that it becomes alternating current electricity (AC). The inverter device itself converts direct current (DC) electricity sourced from devices such as batteries, or solar panels that produce alternating current electricity (AC). Generally, on solar system systems, inverter devices are used to change the DC electrical voltage stored in the battery components to be subsequently converted into AC mains voltage. Then the mains voltage which has been converted into AC voltage is connected to the load so that it can be used directly by the customer.

2.5. Battery

Battery is an electro-chemical component that has the function to store electrical energy which is then stored in chemical form. Battery are classified into two types, i.e. primary batteries and secondary batteries. Batteries used in solar system system is secondary batteries. Secondary batteries are more often used and have large capacity values, namely VRLA (Valve Regulated Lead Acid) batteries. In addition to VRLA batteries, there are also other types of batteries namely SLA (Sealed Lead Acid) and Li-Ion (Lithium-Ion) types. To calculate the need for a battery used, the following calculation formula is used:

$$\text{Battery} = \frac{\text{Autonomy x needs (MWh)}}{\text{Eff}} \quad (4)$$

where,

Autonomy : 1, *battery backup for 1 day

η : Battery Efficiency x Cable Efficiency

Battery η :0.85

Cable η : 0.98

After obtaining the results in MWh units, it is converted to Ah units using the following formula (5) as follows:

$$\text{Battery} = \frac{\text{Battery (MWh)}}{\text{Voltage}} \quad (5)$$

The result obtained then calculated using 80% Depth of Discharge (DOD).

$$\text{Battery Capacity} = \frac{\text{Battery (Ah)}}{\text{DOD}} \quad (6)$$

3. RESULTS

3.1. Local Radiation Value

Radiation values were obtained using PVsyst software sourced from NASA SSE database by entering the coordinates of the location points of Parangtritis beach. The following is radiation values at Parangtritis beach in kWh/m^2-day.

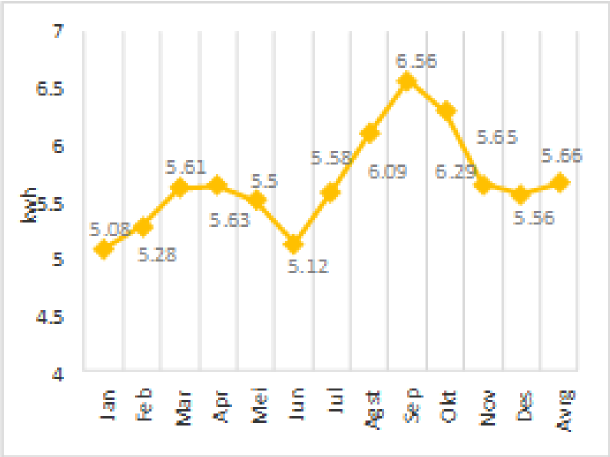

Figure 1. Radiation values at Parangtritis

3.2. Location Temperature

Location temperature is used to find the string sizing configuration for each panel array. The location temperature of Parangtritis Beach was obtained from PVsyst software. The following is the temperature data from the location of Parangtritis beach.

Table 1. Location temperature characteristic

No	Properties	Value
1	Minimum Extreme Temperature	22° C
2	Average Temperature	25° C
3	Maximum Extreme Temperature	30° C

3.3. Total Load Needs

The total power requirements at the site are obtained by conducting surveys directly at the location and using sources from the Parangtritis village local government.

Table 2. Total load needs per day

No	Type	Load (Wh)	Number of Unit	Total (Wh)
1	Households	2,680	631	1,691,080
2	Shops	2,292	71	162,732
Total load (before losses)				1,53,812
Energy Reserve Tolerance (30%)				556,143
20% losses				481,991
Total load (final)				2,891,946

3.5. Solar System Capacity

Photovoltaic solar system capacity is determined based on Formula (1) and the total electricity consumption in table 2 (rounded to 2.9 MWh).

$$P = \frac{2{,}9 \text{ MWh}}{6 \text{ jam x } 0{,}8 \text{ x } 0{,}885} = 0{,}681 = 681 \text{ kWp}$$

3.6. Battery Capacity

The capacity of the battery used takes into account system autonomy, i.e. battery backup when there is no sun shining on the location. The following are Formula (4) and (5) for finding battery capacity.

$$\text{Battery} = \frac{1 \text{ x } 2{,}9 \text{ MWh}}{(0{,}85 \text{ x } 0{,}98)}$$

$$\text{Battery} = 3.48 \text{ MWh}$$

$$\text{Battery (Ah)} = \frac{3.48 \text{ MWh}}{48 \text{ V}} = 72{,}500 \text{ Ah}$$

where,
48V = nominal voltage of bank battery circuit

The total system requirements are determined by carrying out calculations taking into account the depth of discharge value using the calculation formula below:

$$\text{Battery capacity} = \frac{\text{Battery (Ah)}}{\text{DOD}}$$

$$\text{Battery capacity} = \frac{72{,}500}{0.8} = 90{,}625 \text{ Ah}$$

Then, solar system with a total capacity of 681 kWp requires a total battery of 90,625 Ah.

3.7. Number of Solar Panel

The number of solar panels is calculated using Formula (2).

$$\text{Number of Panel} = \frac{681\text{kWp}}{330\text{Wp}}$$

$$\text{Number of Panel} = \frac{681{,}000\text{Wp}}{330\text{Wp}}$$

$$\text{Number of Panel} = 2{,}064 \text{ Panel}$$

3.8. Number of Solar Charge Controller

The number of SCC is calculated by Formula (3).

$$\text{SCC} = \frac{681 \text{ kWp}}{6 \text{ kW}}$$

$$\text{SCC} = 114 \text{ sets}$$

3.9. Inverter Capacity

With a total solar system capacity of 681 kWp, the implementation is above the system requirements. The type of inverter used is a central inverter with a capacity of 720 kW so that, it can accommodate inputs up to 808 kWp.

3.10. Design of Solar Panel Array

The determination of panel array configuration also considers the use of SCC, because if the current and voltage output is too high, it can cause damage from SCC. Whereas the panel array configuration uses a 7 panel configuration which is paralleled in one string, and there are 6 strings arranged in series in an array. See figure 1 for the detail layout of panel array.

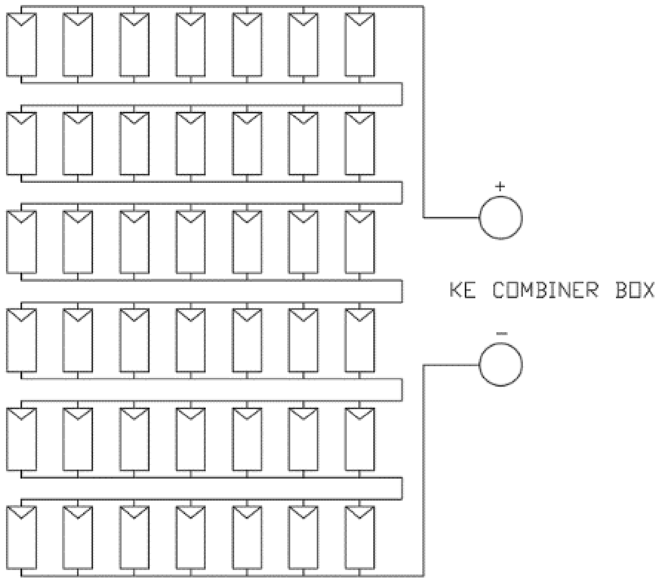

Figure 2. Design of solar panel array

3.11. Area of Solar Power Plant

The area of the solar power plant can be calculated using the PVsyst application by entering the total capacity of the solar panel required. Based on the experiment, the Solar Plant area is 4256 m^2.

3.12. Costs

The cost calculation is calculated by using the overall costs required by the solar cell system. So that the Nett-Present-Value (NPV) value will be obtained from the location and operational costs per year for solar system Photovoltaics.

3.12.1. Development Cost

The main components are inverters, solar charge controllers, solar panels and batteries. While the additional components are cabling, racks, and labour services.

Table 3. Main component cost

Component Type	Total Cost (IDR)
Main components	16,136,616,148
Additional Components	6,772,849,320
Total cost	22,909,465,468

3.12.2. Operational Cost

Operational costs in one year obtained from approximately 1% of the total investment costs of system design [7].

Table 4. Secondary component cost

No.	Description	Cost (IDR)
1	Salary 4 Technician	172,800,000
2	Maintenance	40,000,000
Total Cost		212,800,00
Unexpected Cost (10%)		21,280,000
Grand Total		234,080,000

3.12.3. Inflow

Flow of cash receipts or called inflow on the plan is calculated based on the total load needs of the number of customers in one month. The price is assumed to be Rp 914.8 per kWh, according to the regulation from Ministry of Energy and Mineral Resources no. 50 year 2017 [8]. Electricity consumption (kWh)/ year is the product of total customer, daily electricity consumption (2.68 kWh for households and 2.29 kWh for shops), and 356 days (one year).

Table 5. Inflow cash

Total Customer	Elec. Consump. (kWh)/ year	Annual Income (IDR)/ year
631	617,244.2	564,654,994.2
71	59,397.18	54,336,540.3
Total income		618,991,534.5

4. CONCLUSION

Based on calculations, the total capacity of Solar power plant is 681 kWp. As for the area used by solar module is 4256 m^2. When compared with the rule of thumb for regions in Indonesia with 7-8 m^2 per kWp (GIZ, 2018), the Parangtritis Beach area has a better area per kWp with a value of 6.25 m2 per kWp. The total solar panels used are

2,064 solar panels that have a capacity of 330 Wp each. The total solar charge controller used is 114 units, each of which has a current output of 100 A and 1 central inverter with a capacity of 720kW.

The initial investment cost needed to purchase the entire solar system component or BoS is based on a calculation of 22.9 Billion IDR, while the operational costs for each year is 234 Million IDR. The calculation of the value of electricity sales which refers to the ESDM Regulation number 50 in 2017 is 619 Million IDR per year.

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