

The Design of Solar Power Tree in Tourist Village Area in Situgede Village, Karangpawitan Subdistrict, Garut Regency

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ABSTRACT

Energy is a basic need for every human being in the world, including in Situgede Village which is located in Karangpawitan Subdistrict, Garut Regency. According to the design concept of the Situgede village as a tourist village, there would be built a solar power plant for which construction a concept of Solar Power Tree was designed. The methods employed in the design process started from calculating the total load estimation, calculating battery capacity, determining the peak wattage value of the PV module, determining the inverter, determining the SCC, to designing the physical power of the Solar Power Tree. The result was a design of Solar Power Tree having capacity of 2 kWh with a total estimated load of 1896 Wh.

Keywords: Power Plant, Solar cell, Solar Tree, Design, Alternative Energy

1. INTRODUCTION

Energy is the basic need of every human being in the world, even in Indonesia. In Indonesia, the energy needs that are mostly consumed are derived from fossil fuels. Until 2018 the utilization of energy sourced from fossil fuels reached 86%, while the utilization of new and renewable energy reached 14%. Based on the research by Suharyati (**Surhayati, 2019**), power plants in Indonesia are still dependent on fossil fuels.

One of the potential utilizations of new and renewable energy in Indonesia is solar energy. Indonesia is located on the equator where solar radiation intensity is higher than the areas outside the equator line. Because of the fact, the potential for solar energy utilization in Indonesia is quite high. The potential of solar energy in Indonesia reaches an average of 4.8 kilowatt hours per square meter per day (**National Energy Council, 2016**). In fact, Indonesia has reached an average solar energy potential of 5 kWh/m²/day (**Rumbayan, 2012**).

Situgede village is a village located in Karangpawitan Subdistrict, Garut Regency. Located 16 km from the city of Garut, Situgede village is recently designed as a tourist village by the Ministry of Villages, Development of Disadvantaged Regions, and Transmigration of the

Republic of Indonesia. As part of the concept design of Situgede village as a tourist village, a power plant with pikohydro and solar power will be built. For the construction of the solar power plant, a concept of Solar Tree Power is needed. Therefore, the purpose of this research is to design Solar Tree Power and determine its specifications for the tourist village area in Situgede Village, Karangpawitan Subdistrict, Garut Regency.

2. METHODOLOGY

2.1 The Design of Solar Power Tree System

In this study, the system design process began from regional observation, load estimation calculation, to the design of the Solar Power Tree. Figure 1 here illustrates the block diagram of the Solar Power Tree design process.

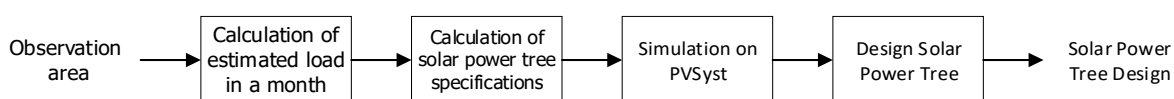


Figure 1. Solar Power Tree Design Diagram Block

Based on Figure 1, the first thing done in the design of solar power tree was observing the location, which was done in Situgede Village, Karangpawitan District, Garut Regency (-7.2°N / 108.0°E, 753 m). The data that had to be obtained was on the potential of solar irradiation energy (Wh / m²) and on load estimation. After getting observation data from the location, the estimated load in a month could be calculated using the following formula **(Nissar & Ahmad, 2017)**:

$$\text{Estimated total load a month} = 30 \text{ days} \times \text{Estimated daily load} \quad (3)$$

After estimating total load of a month, the next thing to do is the calculation of solar power tree specifications, of which result can be simulated on PVSyst so that a design for solar power tree could be created. The calculations of Solar Power Tree specifications include:

2.1.1 Determining System Voltage

In determining the voltage of the system, calculation is not required. Rather, it is estimated based on the requirement of the system on the needed electrical equipment **(Nissar & Ahmad, 2017)**.

2.1.2 Determining the Size of the PV Array

In determining the size of PV array, the formula is as follows:

$$PV_{array\ size} = \frac{1}{\eta_{baterai} \times \eta_{SSC} \times \eta_{wiring}} \quad (2)$$

(Nissar & Ahmad, 2017).

The result of the calculation can be used to determine the value of Energy (E) in the array by employing the following formula:

$$E_{array} = E_a \times PV_{array\ size} \quad (3)$$

(Nissar & Ahmad, 2017).

2.1.3 Determining the Total PV Array Current

Total pv array (I_{DC}) flows can be determined by:

$$I_{DC} = \frac{W_{peak}}{V_{DC}} \quad (4)$$

Where W_{peak} can be obtained from the formula :

$$W_{peak} = \frac{P_{array}}{\text{Length of time irradiation}} \quad (5)$$

(Nissar & Ahmad, 2017).

2.1.4 Determining W_{peak} on PV Array

In determining W_{peak} on the required panels, the value of W_{peak} resulted from the above calculation is divided by the numbers of the planned panels **(Nissar & Ahmad, 2017).**

2.1.5 Determining Battery Size

In determining the size of the battery, the formula is used:

$$\text{Total DC load requirement} = \frac{P_{array}}{\text{System Voltage}} \quad (6)$$

(Nissar & Ahmad, 2017).

Since the system can run without sunlight (autonomous), then we can calculate the capacity of the battery with the formula:

$$\text{Autonomous battery capacity} = \text{Autonomous day} \times \text{The total load needs of DC} \quad (7)$$

(Nissar & Ahmad, 2017).

Battery capacity can then be calculated by dividing the result from autonomous battery calculation by multiplying Efficiency by DoD as the following formula:

$$\text{Battery capacity} = \frac{\text{Autonomous battery capacity}}{\text{Efficiency of Battery} \times \text{DoD}} \quad (8)$$

(Nissar & Ahmad, 2017).

2.1.6 Determining Inverter Capacity

The size of the inverter should be suitable for the average load and peak load that last for more than 30 minutes. The estimated or measured load profile should be established to identify continuous load and peak load. The capacity (rating) of the inverter should not be higher than the capacity of the photovoltaic module **(Nissar & Ahmad, 2017).**

2.1.7 Determining the Solar Charge Controller Capacity

In determining the capacity of the Solar Charge Controller, the value of W_{peak} is calculated using the above W_{peak} formula, then look for SCC marketed with W_{peak} capacity **(Nissar & Ahmad, 2017).**

2.2 Testing Methods

To test the Solar Power Tree, its design is simulated using PVSyst. PVSyst is a software created to analyze a solar power generation system, either in off-grid or on-grid design. It is recommended to use PVSyst with the latest version. The version of PVSyst software used in this program was PVSyst version 6.81. After simulated, the result can be analyzed to create Solar Power Tree **(Mermoud & Witmerr, 2017).**

3. RESULTS AND DISCUSSION

The data obtained from solar power tree testing using PVSyst are shown in Table 1.

Table 1. Simulation results using PVSyst

Months	Globhor kWh/m ²	GlobEff kWh/m ²	E_Avail kWh	Eunused kWh	E_miss kWh	E_user kWh	E_Load kWh	SolFrac kWh
January	123.8	113.4	92.2	30.97	0.000	58.78	58.78	1.000
February	121.1	113.3	91.9	34.42	0.628	52.46	53.09	0.988
March	134.1	128.8	103.4	42.39	0.000	58.78	58.78	1.000
April	136.1	136.6	109.5	48.34	0.000	56.88	56.88	1.000
May	143.5	148.6	119.3	56.28	0.040	58.74	58.78	0.999
June	135.7	142.8	116.6	56.19	0.000	56.88	56.88	1.000
July	130.7	135.7	110.3	48.90	0.000	58.78	58.78	1.000
August	143.9	145.5	118.1	54.59	0.000	58.78	58.78	1.000
September	142.7	139.8	112.6	52.45	0.235	56.65	56.88	0.996
October	144.0	136.8	109.6	49.52	2.336	56.44	58.78	0.960
November	166.3	153.0	124.8	64.33	0.000	56.88	56.88	1.000
December	134.8	122.8	100.7	40.40	2.040	56.74	58.78	0.965
Annual	1656.7	1617.0	1309.0	578.79	5.280	686.76	692.04	0.992

In Table 1 there are 8 columns. The first is GlobHor column consisting of data on the potential of solar energy in 12 months. This data can be obtained from NASA, Meteonorm, and direct measurements on the spot. GlobEff column contains the data on the potential of solar energy affected by shading, environment and climate. E_Avail column contains data of energy available in a region. The EUnused column contains data in the form of energy available in the PV array, when the battery is full. The E_miss column contains the data on energy lost when the grid does not exist and the battery is empty. The E_User column contains data on the energy supplied by the plant to the load. The E_Load column contains data about the energy the load requires. And lastly, the SolFrac column contains comparative data between the energy supplied to the load and the energy required by the load (Mermoud & Witmerr, 2017).

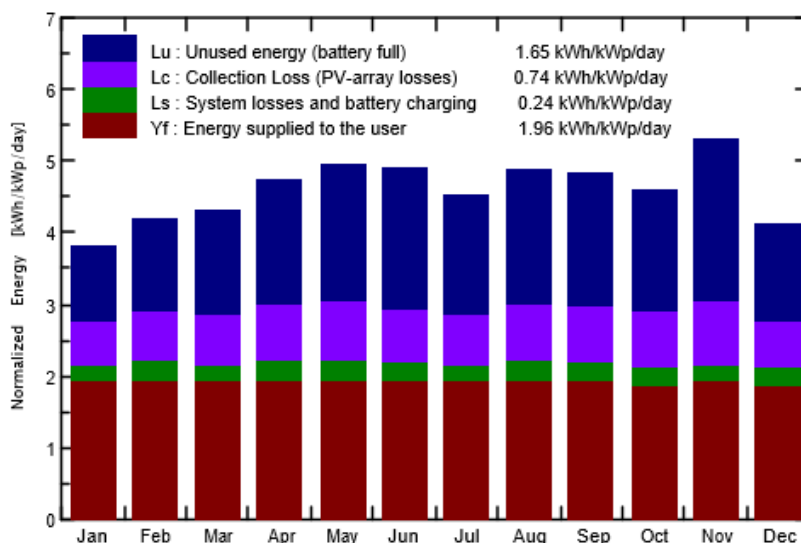


Figure 2. Normalized productions graph

The graph in Figure 2 shows normal production on the Solar Power Tree for a year. The graph also mentions Lu (unused energy) which shows energy that is not used when the battery is in

full condition which averages 1.65 kWh / kWp / day. Then there is Lc (collection loss) which shows the magnitude of the loss in the average PV array of 0.74 kWh / kWp / day. The graph also includes Ls (system losses and battery charging) which shows losses on the system and power usage for charging batteries which average 0.24 kWh / kWp / day. Lastly, there is Yf (Energy supplied to user) which shows the amount of energy supplied to the average load of 1.96 kWh / kWp / day.

Based on the graph in Figure 2 and Table 1, what need to be considered is the E_Miss column and the EUnused column. The E_Miss column as discussed earlier, contains less energy data due to the energy supplied no more than the energy required by the load, so that the data in the column must be zero. To make the value in the E_Miss column zero, usually in the design the wp value for the PV Array is enlarged or, if it cannot be done, in the load estimation it needs to be reduced until the value in the E_Miss column reaches zero. In addition, when the Wp value on the PV Array is enlarged more than it should be, the solar power tree will produce large values in EUnused column, meaning that the system wastes too much energy.

Table 2. Solar Power Tree Specifications

System Voltage	48 V _{DC}			
Energy size PV Array	2411,712 Wh			
Total of Current PV array	8,374 A			
Number of Array	6 Array			
W_{peak} in PV Array	160 W _p			
Battery Size	139,11 Ah			
Inverter Capacity	Rated capacity	1500VA		
	Rated power load	1000W		
	Input	DC input	DC 10,5-15V (12V)/ DC 21-30V (24V)	
		AC input	190-275V AC	
	Output	Frequency	50Hz/ 60Hz±5% (Auto)	
		Voltage	110V/ 120V/ 220V/ 230V/ 240V AC	
		Frequency	50Hz/ 60Hz±5% (Auto)	
		Wave form	Pure sine wave	
Transfer efficiency		≥85% (full load)		
Solar Charge Controller Capacity	Charging Current		10 Amp	
	Battery Voltage:		12V	
	Maximum supported panel:		200Wp	

From Table 2 showing the solar power tree specification design, it can be seen that this Solar Power Tree still can be used in time of low loads. With a system voltage of 48 V, the resulting current of 8.374 A and W_{peak} on an array of 160 W_p, a solar power tree such as Figure 3 can be designed.

Solar Power Tree Design in Tourist Village Area in Situgede Village, Karangpawitan Subdistrict, Garut Regency

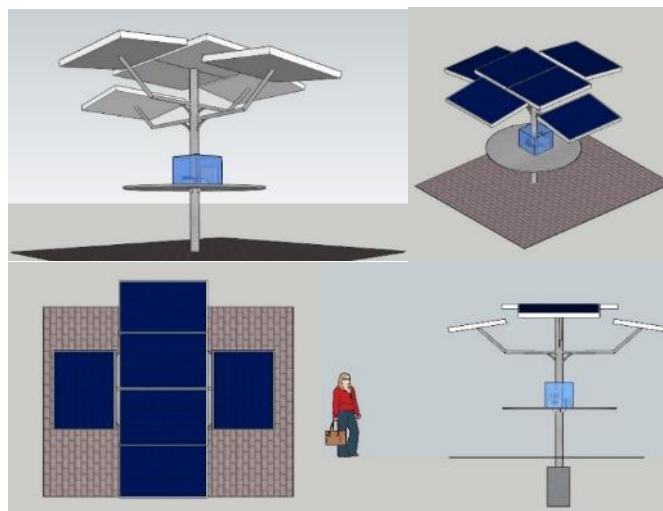


Figure 3. Solar Power Tree construction design

Solar Power Tree for Situgede tourist village areas is designed as high as 3 meters to get more optimal sunlight, to overcome the problem of shading by trees as well as to make it attractive enough to become an icon of the tourist village. The Solar Power Tree also has 6 PV Array panels of 1 m² each with a Wp value of 160 Wp and is equipped with a 3 m² umbrella to shield from hot weather and rain. What's more, it can protect the power house that will be placed under the table. Then there is a table mat of 2 m² that can be functioned as storage and can also be used as a communal place welcoming visitors equipped with a place for charging mobile phones. Battery, Inverter and SCC will be stored under the table.

The implementation of Solar Power Tree was carried out in PHP2D 2020 activities, located in Situgede Village, Karangpawitan Subdistrict, Garut Regency. Solar Power Tree design was done in the second week of September then components that had to be purchased for building Solar Power Tree were listed. While the design was in progress, social activities were also carried out in the second week of September, including socialization of the program to the village apparatus as well as to the target communities.



Figure 4. Road widening process and making Solar Power Tree foundation

Solar Power Tree design implementation was carried out starting from the first and second weeks from October. Solar Power Tree building activities started from the assembly of inverters, and Solar Charge Control. In addition, some teams began preparing for land clearing for solar power tree planting. Evaluation and monitoring activities were carried out every two weeks from September to November. The process of building and planting Solar Power Tree can be seen in Figure 4 and Figure 5.



Figure 5. Solar Power Tree construction installation process

Figure 6 shows the solar power tree that has been completed and planted. The Solar Power Tree which has a capacity of 1200 wp can be used as an education media for the local community and for the tourists who come to the village. The second function of the Solar Power Tree is as lighting for farmers who guard their farmland at night and the third function is as a place for farmers to have gathering after they finished their work at their farms.



Figure 6. Solar Power Tree installed

4. CONCLUSIONS

From the results of the solar power tree design for the tourist village area in Situgede Village, Karangpawitan Subdistrict, Garut Regency, it can be concluded that the program is successful in completing the design with an estimated load of 1896 Wh per day, or of 56.88 kWh in a month. The solar power tree has 6 PV array with wp value in PV array as much as 160 Wp. The solar power tree is also equipped with an inverter ATO-OGI-1500 having the required inverter capacity of 1 kW. As it requires SCC capacity of 10 A, Solar Charge Controller - SCC1210NM is used with battery capacity of 139,111 Ah.

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