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Study of The Potential for Installing a Solar Power Plant on The Roof of The Temanggung Regional Library Building

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Abstract
Due to its equatorial location, solar energy is one of Indonesia's renewable energy sources, which has great potential. Solar Power Plant (PLTS) is a power generation system that uses renewable energy as its primary input, which photovoltaic cells aid to convert into electrical energy. The rooftop PLTS is a development of solar panels that are currently commonly used by the general population. Calculating the potential for electrical energy from a rooftop photovoltaic system (PLTS) was the aim of the study, which was conducted at the Regional Library Building in Temanggung Regency, Central Java. With PVsyt software (version 7.2.6), the potential of rooftop solar power plants may be calculated. The grid-connected rooftop photovoltaic system has the capacity to produce 4859 kWh of electrical energy annually, according to the analysis that was done. The PLTS system has an overall efficiency of 82.05%.

Keywords*: photovoltaic, PLTS, PVsyt software, rooftop, Temanggung Library Building*

1. Introduction

Solar energy is one of Indonesia's renewable energy sources with great potential because Indonesia is geographically located on the equator and its average energy production is around 4.80 kWh/m^2/day [1]. Therefore, Indonesia has the opportunity to propose a solar power plant (PLTS). PLTS is a technology power plant that uses renewable energy as its main product, which is then converted into electrical energy using solar cells.

Based on solar radiation data collected from 18 locations in Indonesia, the solar radiation in Indonesia can be calculated sequentially referred to as follows: in the western and eastern regions of Indonesia, the distribution of radiation in the western region of Indonesia is around 4.5 kWh/m^2/day, and the monthly variation is around 10 percent; and in Eastern Indonesia, it is around 5.1 kWh/m^2/day, with monthly variations of around 9% [2].

Based on the application and configuration, PLTS is divided into two classes, namely off-grid or independent PV systems and grid-connected (on-grid) or PLTS PV systems. Centralized PLTS (off-grid) is an alternative electricity generation system used in remote or rural areas that are not covered by PLN. This power plant uses solar energy as the main energy source to produce electrical energy on demand.

Using solar panels is one way of utilizing renewable energy sources, which can meet the electricity needs of the Indonesian people, although not in full. Achieving the solar renewable energy target set by the government requires the commitment of various parties. The library building that builds PLTS can be an example for the community to become volunteers in advancing PLTS in Indonesia. District Regional Library Temanggung is involved in the development of new renewable energy, one of the efforts is the use of building roofs for PLTS roof is connected to a network or grid.

A variety of methods and software tools are available for calculating rooftop solar PV potential. A piece of software that is utilized is PVsyst 7.2.6 [3]. PVSyst is a software package used for the complete process of learning, measuring (sizing) and analyzing data from PLTS systems. PVSyst was developed by the University of Geneva, which is divided into grid-connected systems, stand-alone systems, pumping systems and direct current networks for public transportation (DC-grid) [4]. The project design feature in the PVsyst software is used to analyze the energy production potential and performance of the PLTS system. There are several studies on calculating solar energy potential using PVSys software, the results of which are quite good [5, 6, 7]. In this feature, the simulation will be run by creating a PLTS system design according to what you want to plan [8].

The aim of the research was to calculate the potential electrical energy from rooftop PLTS, which was carried out at the location of the Regional Library Building, Temanggung Regency, Central Java.

2. METHODOLOGY

2.1 Observation

The first stage in this research is conducting observations at the Temanggung Regency Regional Library Building to determine the condition of the building, the geographical location of the building, collecting data to support research, and determining the position of installing solar modules by considering the availability of the building's roof area by considering sunlight capture so that there is no disturbance.

From observations, the Temanggung Regency Library Building is located on General Sudirman Street, No. 184, Kowangan, District Temanggung, Temanggung Regency, Central Java, Indonesia, and is located at coordinates 7°11'39.01"S and 110°11'52.70"E. The library building can be seen in Figure 1.

Figure 1. The Temanggung Regency Regional Library Building

Based on considerations and calculation results, the roof area of the main Building that can be installed with solar modules is 233 m^2. It can be seen in Figure 2.

Figure 2. The roof area of Temanggung Regency Regional Library Main Building (Source: Google Earth)

2.2 Geographic Parameters

Geographic parameters can be viewed by entering location coordinates or by selecting a location on the map. The accuracy of geographic coordinates will influence meteorological data, which is one of the parameters for further simulations. As shown in Figure 3, the Temanggung Regency Regional Library Building is located at coordinates 7˚11'39.01”S and 110˚11'52.70”E.

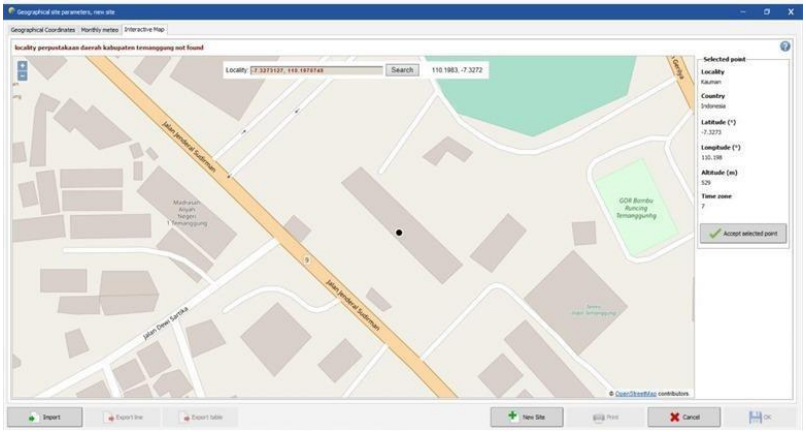

Figure 3. Geographical Parameters of the Temanggung Regency Regional Library Building (Source: PVSyst 7.2.6)

2.3 Orientation Parameters

The orientation of the PV module, in this case, the tilt angle and azimuth of the PV module, is one of the factors that influences the PV system's ability to capture solar energy sources [9]. The azimuth angle is the angle at which the solar panel faces north or south. Based on the orientation simulation carried out, the resulting plane field parameters are 10° and azimuth is 0°.

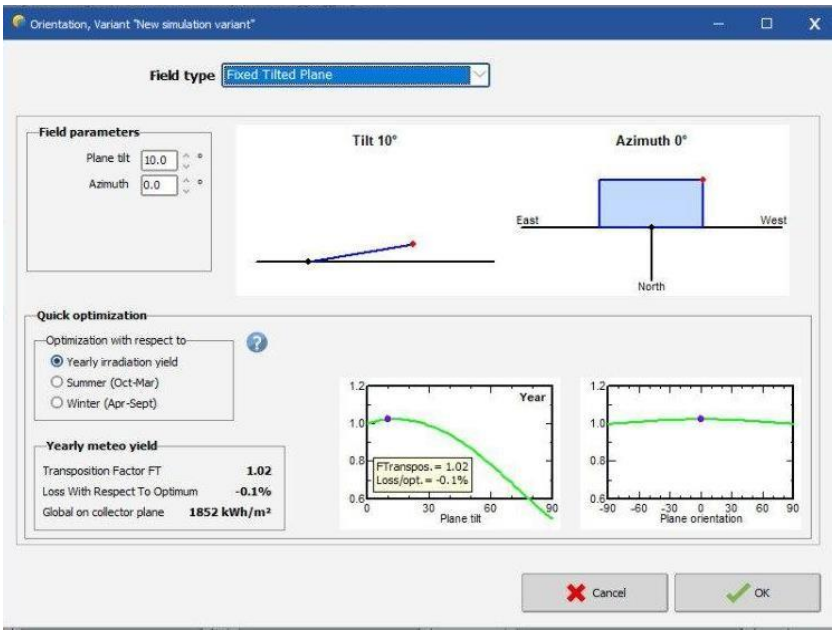

Figure 4. Orientation Parameters
(Source: PVSyst 7.2.6)

2.4 System Parameters

The selection of photovoltaic solar panels and inventors is a step that must be taken within the parameters of this system. This research uses a Si-Mono module with specifications of 250 Wp, 26 V, and 60 cells, as shown in the figure 5.

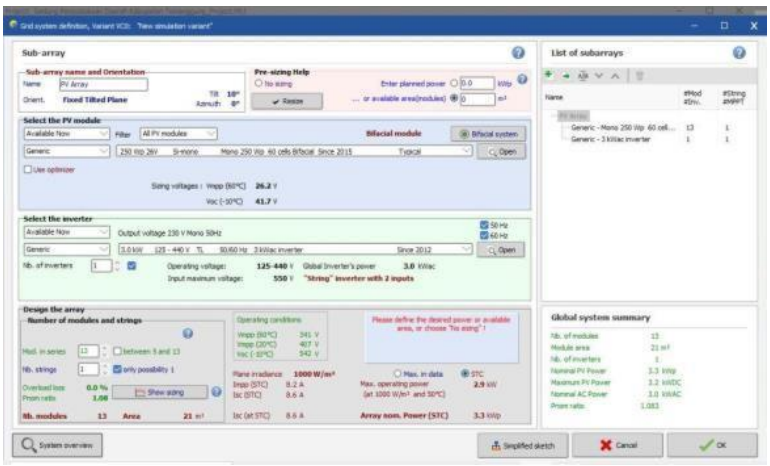

Figure 5. System Parameters
(Source: PVSyst 7.2.6)

3. RESULTS AND DISCUSSION

3.1. Overview of simulation results

Obtained from PLTS in the District Regional Library Building. Temanggung. The number of inverters is 1 unit, or 13 photovoltaic solar modules with a total peak power of 3520 Wp. The roof area required for installing the solar modules is 21.1 m².

Project summary

Geographical Site	Situation		Project settings	
Kauman	Latitude	-7.33 °S	Albedo	0.20
Indonesia	Longitude	110.20 °E		
	Altitude	529 m		
	Time zone	UTC+7		

Meteo data
Kauman
Meteonorm 8.0 (2010-2014), Sat=100% - Synthetic

System summary

Grid-Connected System	No 3D scene defined, no shadings	
PV Field Orientation	**Near Shadings**	**User's needs**
Fixed plane	No Shadings	Unlimited load (grid)
Tilt/Azimuth 10 / 0 °		

System information

PV Array		Inverters	
Nb. of modules	13 units	Nb. of units	1 Unit
Pnom total	3250 Wp	Pnom total	3000 W
		Pnom ratio	1.083

Results summary

Produced Energy	4859 kWh/year	Specific production	1495 kWh/kWp/year	Perf. Ratio PR	81.03 %

PV Array Characteristics

PV module		Inverter	
Manufacturer	Generic	Manufacturer	Generic
Model	Mono 250 Wp 60 cells Bifacial	Model	3 kWac inverter
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	250 Wp	Unit Nom. Power	3.00 kWac
Number of PV modules	13 units	Number of inverters	1 unit
Nominal (STC)	3250 Wp	Total power	3.0 kWac
Modules	1 String x 13 In series	Operating voltage	125-440 V
At operating cond. (50°C)		Pnom ratio (DC:AC)	1.08
Pmpp	2923 Wp		
U mpp	357 V		
I mpp	8.2 A		
Total PV power		**Total inverter power**	
Nominal (STC)	3 kWp	Total power	3 kWac
Total	13 modules	Nb. of inverters	1 Unit
Module area	21.1 m²	Pnom ratio	1.08
Cell area	18.5 m²		

Figure 6. Summary of PLTS System Simulation in the Temanggung Regency Regional Library Building (Source: PVSyst 7.2.6)

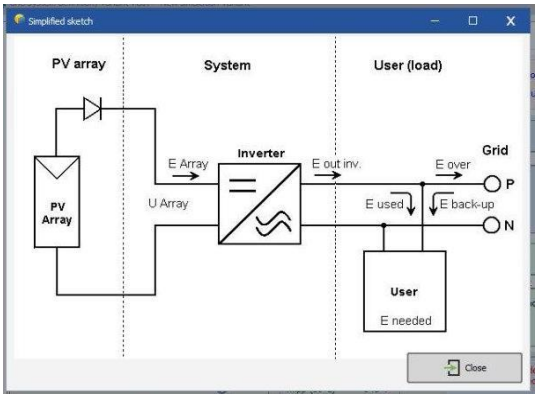

Figure 7. Simple Scheme of the PLTS System in the Temanggung Regency Regional Library Building (Source: PVSyst 7.2.6)

The PLTS system in the Temanggung Regency Regional Library Building that is being simulated is a type of grid-connected PLTS, namely a power plant that operates in parallel with a distribution network that has been supplied by another power plant (PLN network) and operates without using batteries.

3.2. Electrical Energy Potential

The potential for electrical energy that can be produced by a grid-connected rooftop PLTS system in the District Regional Library Building. Temanggung. The highest global horizontal irradiation was in October at 182.7 kWh/m^2, and the lowest was in January at 123 kWh/m^2. The highest horizontal diffuse irradiation was in October at 87.04 kWh/m^2, and the lowest occurred in July at 58.76 kWh/m^2. The highest ambient temperature was in October at 25.85 degrees Celsius, and the lowest was in February at 24.59 degrees Celsius.

Table 1. Simulation Results of Electrical Energy Potential for a 3520 Wp grid-connected rooftop PLTS System in the Temanggung Regency Regional Library Building
(Source: PVSyst 7.2.6)

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	123.0	70.57	24.66	117.2	112.7	319.8	307.5	0.808
February	133.7	77.00	24.59	130.5	126.1	357.0	344.3	0.812
March	129.0	81.79	24.95	128.8	124.5	353.0	340.2	0.813
April	144.5	76.97	25.09	149.5	145.1	408.6	394.6	0.812
May	146.6	75.88	25.68	156.0	151.4	427.2	412.9	0.814
June	147.2	60.21	24.96	161.1	156.7	441.3	426.6	0.815
July	163.3	58.76	24.74	178.0	173.2	485.4	469.3	0.811
August	172.8	71.96	24.82	183.0	178.3	498.3	481.7	0.810
September	173.1	77.53	25.07	176.4	171.7	478.1	462.2	0.806
October	182.7	87.04	25.85	179.5	174.4	484.1	467.6	0.801
November	153.6	85.05	25.20	147.1	142.2	401.7	387.6	0.810
December	145.8	83.56	24.91	138.1	133.1	378.3	364.8	0.813
Year	1815.2	906.33	25.05	1845.3	1789.4	5032.9	4859.3	0.810

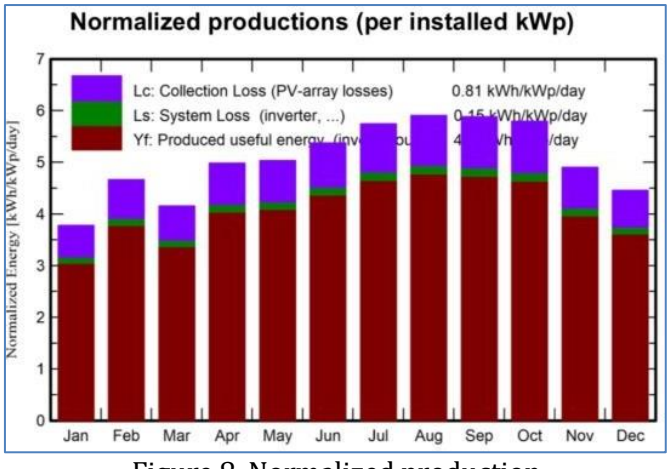

Figure 8. Normalized production
(Source: PVSyst 7.2.6)

Effective energy at the output of the array was highest in August at 498.3 kWh and lowest in January at 319.8 kWh. Energy injected into the grid was in August, namely 481.7

kWh, and the lowest was in January at 307.5 kWh. The highest performance ratio was in June at 0.815, and the lowest was in October at 0.801.

Normalized energy production is described in International Electrotechnical Commission (IEC) standards and is a standard parameter for evaluating the performance of photovoltaic systems [10]. Based on information from this graph, the highest normalized energy production value is in August, and the lowest is in January.

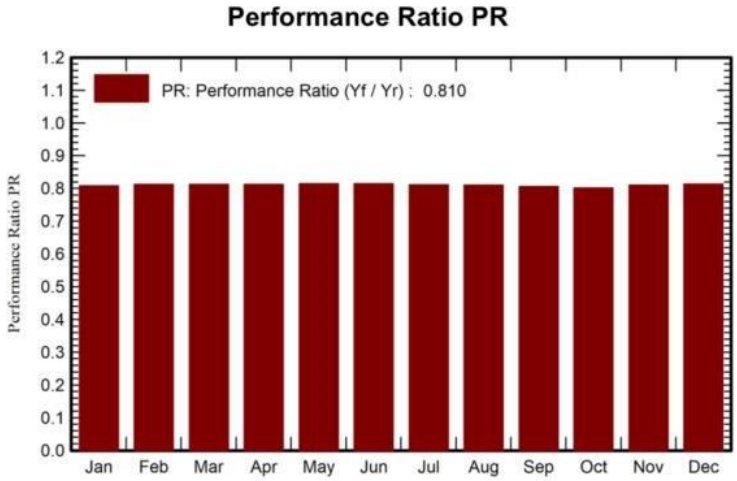

Figure 9. Performance Ratio
(Source: PVSyst 7.2.6)

Table 2. Summary of Simulation Results of the Grid-Connected Rooftop PLTS System
(Source: PVSyst 7.2.6)

Produced Energy	4859 kWh/year
Spesific Production	1495 kWh/kWp/year
Performance Ratio	81.03 %
Normalized Production	4.03 kWh/kWp/day
Array Losses	0,81 kWh/kWp/day
System Losses	0,15 kWh/kWp/day

The nominal energy of the photovoltaic array is 5813 kWh. Then there are various types of losses according to the values set in the Loss Diagram. The energy produced by the system is 1,043,434 kWh, indicating that the entire system has an efficiency of 82.05%.

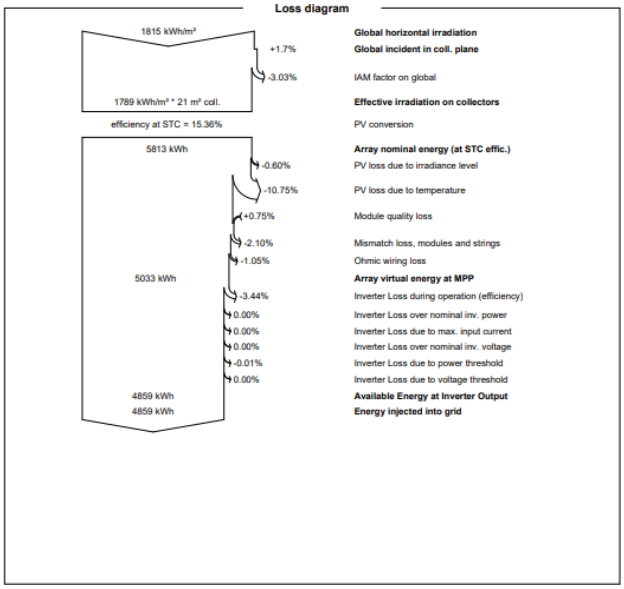

Figure 10. Loss System Diagram
(Source: PVSyst 7.2.6)

4. CONCLUSION

Based on the analysis carried out, it can be concluded that the potential electrical energy produced by the grid-connected rooftop PLTS system in the Temanggung Regency Regional Library Building is 4859 kWh/year, or 4,859 MWh, with a specific production of 1459 kWh/kW/year, or 1,459 MWh, using a mono 250 Wp 60 cells solar module. The overall efficiency of the PLTS system is 82.05%. If this system is implemented, it will be able to reduce greenhouse gas emissions from energy supply and produce significant efficiency for the library.

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