Energy Production Estimation and Data Monitoring System In 300 kWp Rooftop Solar Power Plant XYZ, Inc.

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***Abstract*—One of the greatest potential for renewable energy comes from solar energy. In Indonesia, the potential for solar energy can reach 3.294 GWP. This amount is very large when compared to other renewable energy production potentials. However, the problem with the solar power plant system is that the production of energy produced is influenced by time, weather, location, and the efficiency of the system can affect energy. This study discusses from the design process, estimation of energy production, and monitoring data on PV mini-grid. The calculation is done by estimation using PVsyst software. The monitoring system is made based on the specifications used. The design of this system is made to record data by measuring performance ratio and also calculating the efficiency of the system.**

Keywords—estimate, performace, efficiency

I. INTRODUCTION

One of the countries which has the greatest potential for renewable energy is Indonesia. This is because Indonesia is located on the equator and its geographical condition has a high potential to be used as a renewable energy power plant such as solar power plants. Of the several renewable energy plants, the potential for solar power generation is one of the largest. Where has the potential for energy production from solar energy of 3,294 GW [1]. This makes many parties compete to build solar power plants in Indonesia and the commitment of countries in the world to reduce emissions based on the Paris Agreement [2].

Solar Power Plant is a type of power plant that utilizes photon energy from the sun into electrical energy. The weakness of solar energy is the influence of weather and location factors which greatly affect the efficiency of solar power plant [3]. This requires a well-planned design. One of the important things is the estimation of energy production in solar power plants. With this estimate, it is hoped that it will assist contractors in designing efficient power generation systems.

One of the energy production values from solar power plant is determined by the solar irradiation factor. The units for measuring solar irradiation is expressed by (W/m^2). With knowing the irradiation power in units per square meter, it is possible to estimate the total energy production [4]. However, the irradiation received by solar panels is also influenced by environmental factors such as weather, ambient temperature, panel temperature, and wind. So that the factors that affect efficiency in terms of the environment also need to be considered.

In addition to environmental factors, solar power plant installation also greatly affect the efficiency of energy production [5]. This is because the wrong installation technique can cause a lot of power losses that shouldn't happen. One form of loss from installation factors such as inverter losses, connection losses, or losses caused by human error. The amount of losses in the solar power plant system is made in the form of a percentage of system efficiency which is commonly referred to as the Performance Ratio (PR). This value is usually a reference whether the solar power plant system to be built is effective or not when compared to the potential for solar energy in the area.

II. METHODS

A. Shadow Analysis

Energy production from solar power plants depends on solar irradiation. The process of converting photon energy from the sun into electrical energy will be more optimal when the surface of the PV module is fully illuminated by sunlight and is not covered by shadows. The effect where an object is obscured by light because it is blocked by another object is called a shadow.

Fig. 1 3D Design

The shadow on the solar power plant system is kept to a minimum so that the energy generated from the solar energy becomes more optimal[14]. To find out and estimate shadows in the design, PVsyst and Sketchup software are used to be able to simulate shadow effects in 3D. Initially 3D designs were created using Sketchup, it was done to simplify the 3D design process.

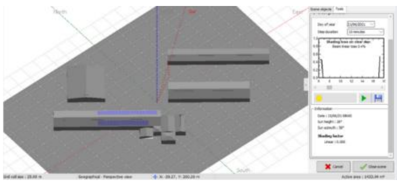

Fig. 2 Shadow Pattern Analysis

B. Optimum PV Module Orientation

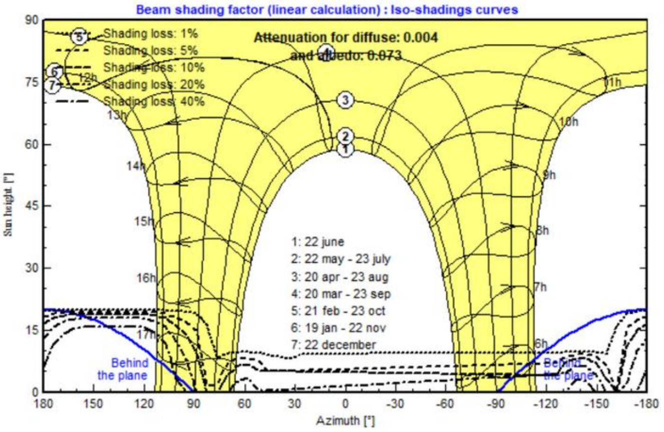

Fig 3. Sun Angle Graph

The shape of the earth's surface which is oval and has a slope of 23.5º makes each area has a different path and angle of the sun. Based on the simulation using PVsyst software, the sun's path in the Klaten area has an altitude range of 0º-90º. And the most optimum height will be obtained when the azimuth angle is at 0º. These factors will also affect the difference in the time of the sun's path. The longest solar path time occurs in December with a time of 11 hours 25 minutes.

TABLE 1. EFFICIENCY COMPARISON OF EACH ANGLE

Tilt / Azimuth	0	10	20	30	40	50	60	70	80	90
-180	-2	-4.7	-9.6	-17.2	-25.4	-35.6	-46	-53	-60.5	-66.1
-160	-2	-4.8	-9.4	-16.4	-24.5	-33.3	-44.3	-51.5	-58.4	-64.4
-140	-2	-4.1	-8.4	-14.1	-20.9	-29.2	-36.8	-45.2	-51.7	-58.2
-120	-2	-3.7	-6.9	-11.7	-17.8	-24.1	-31.1	-38.4	-44.9	-51.5
-100	-2	-2.8	-5.2	-9.1	-14.3	-19.6	-26	-32.9	-40	-46.5
-80	-2	-2.1	-3.7	-6.9	-11.4	-16.8	-22.9	-29.7	-36.9	-44.2
-60	-2	-1.2	-2.3	-5.5	-9.7	-15.6	-21.7	-29.7	-37	-44.7
-40	-2	-0.6	-1.4	-4.2	-9	-15.2	-22.8	-31	-39.4	-47.9
-20	-2	-0.2	-0.7	-3.6	-8.1	-15.1	-22.9	-32.9	-42.4	-51.6
0	-2	-0.1	-0.5	-3.4	-8.5	-15.4	-24.2	-33.5	-43.6	-52.5
20	-2	-0.2	-0.8	-3.7	-8.1	-15.1	-23.6	-32.7	-42.3	-51.6
40	-2	-0.6	-1.5	-4.1	-8.9	-15	-22.5	-30.9	-39.4	-47.9
60	-2	-1.3	-2.4	-5.3	-9.7	-15.4	-22.1	-29.5	-37.1	-44.8
80	-2	-2	-3.7	-6.9	-11.3	-16.9	-23.2	-30	-37.1	-44.2
100	-2	-2.8	-5.3	-9.1	-14.1	-19.8	-26.2	-32.2	-39.8	-46.5
120	-2	-3.6	-7	-11.8	-17.6	-24.2	-31.2	-38.2	-45.1	-51.6
140	-2	-4.2	-8.5	-14.3	-21.3	-29.1	-37.3	-45.1	-52.2	-58.3
160	-2	-4.7	-9.5	-16.1	-24.3	-33.5	-42.9	-51.6	-58.6	-64.4
180	-2	-4.8	-9.8	-16.8	-25.5	-35.4	-45.5	-53.6	-60.4	-66.1

To get the highest efficiency value in energy production in solar power plant, it can be done by placing the PV module with the most optimal angle[15]. Although the sun's angle is always changing, there is a way that can be done is to place the PV module orientation angle which has the greatest average solar irradiance. Based data on table 1 which is a comparison of energy production at each angle of Azimuth and Tilt, it states that in the Klaten area the most optimum PV direction angle is at Azimuth 0º and Tilt of 10º.

C. Electrical System

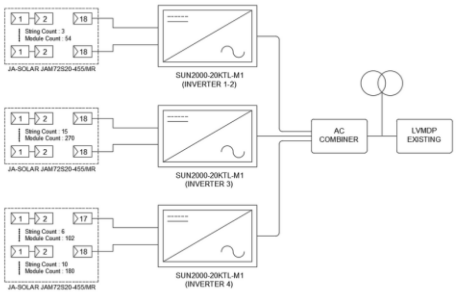

Fig 4 PV Module and Inverter Interconnection

Specifications of electrical components used by considering several factors such as quality, demand, and budget. The number of PV modules installed in XYZ, inc. are as many as 660 pcs or equivalent to a maximum power of 300.3 kWp. Although on the DC side the power is 300.3 kWp, the power value on the AC side does not need to be the same as DC because there is an efficiency value. The ratio of DC power to AC power is named DC/AC Ratio. The best DC/AC Ratio value is below 1.3.

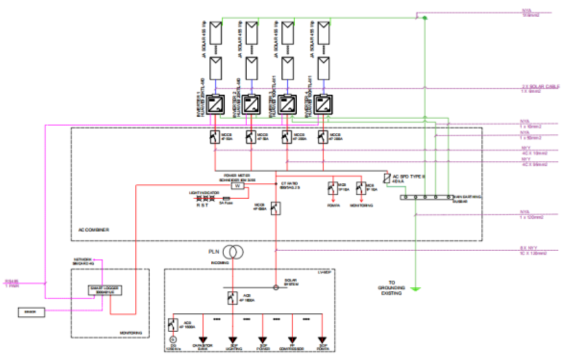

Fig 5. Electrical Single Line Diagram

The total number of 660 PV modules is divided into 34 strings. Each string has 17 series and 18 series as shown in Figure 4.6. The serial number of each string is matched to the nominal voltage of the most efficient inverter. Based on the datasheet the most efficient voltage is 618V for 100kW inverter and 600V for 20kW inverter. While the number of strings can be adjusted to the power that will be generated in the system as needed.

III. RESULTS AND DISCUSION

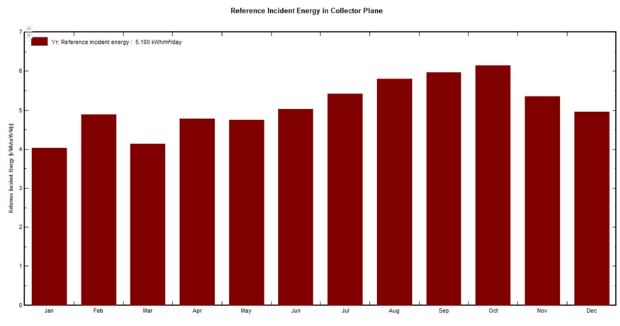

Fig 6. Average Solar Irradiation in Klaten Area

TABLE 2. SYSTEM SPECIFICATION

Rooftop wide	6232.21 m^2
Total PV Module	660 pcs
DC Nameplate	300.3 kWp
AC Nameplate	240 kWac
PV Module Brand	JA SOLAR 72S20-455
Inverter Brand	SUN2000-100KTL SUN2000-20KTL

Based on the simulation results using PVsyst software, it can be seen in Fig 9 the estimated energy production in the Klaten area is 5.1 kWh/m^2/day. This value is equivalent to energy cost savings of Rp. 5,610.00/m^2/day. Seeing the rooftop area of XYZ, Inc. covering an area of 6,232.21 m^2. This makes the potential for energy savings higher if the available land is maximized for solar power plant installations.

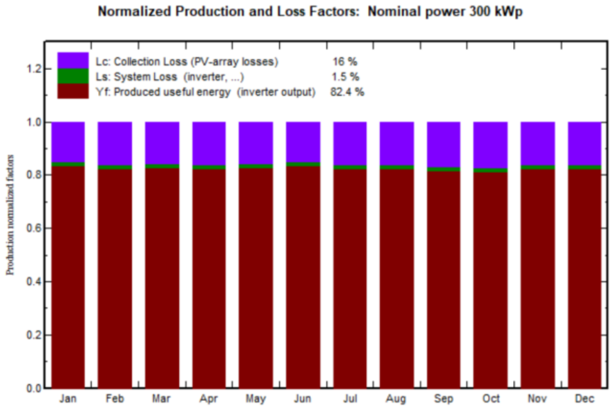

Fig 7. Performance Ratio Estimation per Month

By considering the four factors that affect the Performance Ratio and also data retrieval through PVsyst simulation. The estimation result of the Performance Ratio from the rooftop PV mini-grid design is 82.4%. This value has met the minimum standard for the Performance Ratio value. Simulation results using software still need to be checked because the data used in the software is still not updated so it does not provide a good level of simulation accuracy.

TABLE 3. MAIN SIMULATION RESULT

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	126.1	86.38	27.16	124.6	120.0	31845	31288	0.836
February	138.1	72.59	27.12	136.9	132.7	34502	33875	0.824
March	129.6	79.67	27.47	128.3	124.0	32495	31913	0.829
April	144.6	71.63	27.58	143.2	138.6	36062	35419	0.823
May	148.4	67.90	28.29	147.3	142.1	37260	36604	0.828
June	151.2	63.28	27.53	150.4	145.1	38382	37707	0.835
July	168.7	53.10	27.48	167.8	162.1	42329	41570	0.825
August	180.8	67.12	27.44	179.6	174.5	45323	44506	0.825
September	180.3	72.64	27.65	178.9	173.9	44639	43831	0.816
October	191.9	85.56	28.45	190.3	185.3	47405	46540	0.814
November	162.0	83.39	27.77	160.3	155.4	40370	39644	0.823
December	155.3	81.66	27.43	153.7	148.6	38780	38083	0.825
Year	1876.9	884.94	27.62	1861.3	1802.3	469392	460980	0.825

Based on data from table 3, it can be seen that the total production per year from rooftop solar power plants is 460,980 kWh. Its production potential can be equivalent to nominal money, with the price of electricity for the >200kVA group being Rp. 1114.74/kWh. So the potential cost savings of XYZ, Inc. is Rp. 513,509,440.00. However, this value is not a net cost saving value. Because there is a fairly large investment cost in the construction of rooftop solar power plant and some routine maintenance costs every year.

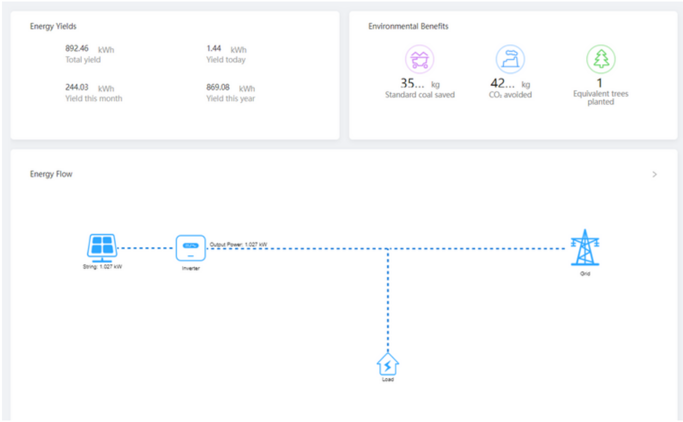

Fig 8. User Interface Monitoring

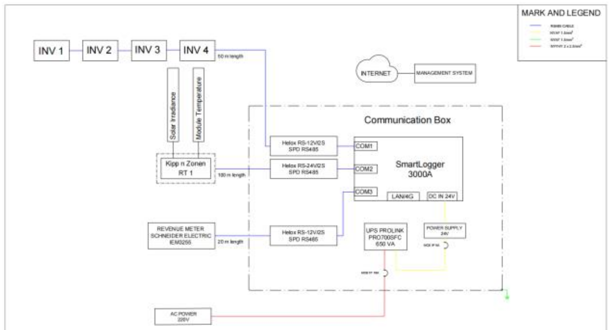

Fig 9. Monitoring System

To find out information on solar power plant performance, the monitoring system collects some parameter information from sensors and inverters. In this case the sensor used is the Kipp n Zonen RT 1 type which is a temperature sensor and irradiation sensor, a Schenider Power Meter which measures power on the AC side, and also an inverter which can measure the amount of power received from the PV module which is converted into AC power.

In Figure 12 there are several sensors and components used in the monitoring system. To integrate all these components, it is necessary to make interconnections between sensors. Therefore, the communication system uses RS-485 with ModBus communication used to transmit data from sensors to the SmartLogger 3000A. All data will be stored in data logger and calculate Performance Ratio value

IV. CONLUSION

The design process before construction is one of the important stages which must be considered. In the design of solar power plant, the estimates of energy production can be done using a PVsyst simulation as was done in this study. The simulation results through PVsyst can be used as a basic reference but cannot be fully justified because the calculations from this simulation have several shortcomings such as weather data that has not been updated and also the human error factor that makes the system not ideal. Therefore, we need a monitoring system that is able to calculate the amount of Performance Ratio (PR) on the solar power plant system to see how much efficiency it is.

ACKNOWLEDGMENTS

We thank to Selaras Daya Utama, Inc. which has been willing to provide an internship. We thank to Mr. Ronny Haloho as Project Manager who has given us lot of advice while completing this research. And also we thank to *Dept. Electrical Engineering,* UNS which has been given us opportunity to start an internship program.

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