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Design of a Household-scale Solar Power Plant Using PVSYST Software

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Abstract. One of the efforts to help provide electrical energy from renewable energy sources on the island of Java is to develop solar power plants. Solar energy on the island of Java is very potential because the intensity of sunlight is adequate, as an area close to the equator. Solar energy is also one type of environmentally friendly energy, so it is perfect to use for the long term. In this study, a household-scale solar power plant was designed. As a tool, PVSYST software is used in this design. The designed electrical power capacity is equivalent to the home category PLN customers, namely 900 VA. The results of this design are expected to be a reference for electrical energy customers so that they can be considered to start switching to using renewable energy sources.

Keywords. Solar power plant, Household-scale customer, Pvsyst software.

INTRODUCTION

The sun is one of the essential elements in life to help humans in many ways, a source of vitamin D, drying clothes, and more. In addition, the sun can be used as an alternative power plant [1]. The need for electrical energy in Indonesia is increasing as the population grows every year [2]. This growth causes the distribution of electricity to be uneven, so that rural blood does not get enough electricity [3]. Solar or solar power plants are alternative renewable energy that utilizes a form of change from sunlight with a certain height and intensity to become electric power [4]. Indonesia is very suitable to be an option to develop solar power plants. This fact is because Indonesia is an archipelago with a tropical climate constantly exposed to the sun every year [5].

Every year Indonesia's electricity demand continues to increase in line with the increasing economy and population density [6]. Especially in Java, Madura, and Bali (Jamali), in 2018, it is estimated that it will reach 271 TWh or growing by around 5.9% per year. From 2017 Jamali's electricity needs of 255 TWh (RUPTL 2019). The total installed capacity of electricity in Java and Bali in 2018 was around 40,510 MW consisting of the State Electricity Company (PLN) of around 26,937 MW, IPP of around 10,495, and PPU of around 2,546 MW. Every year the State Electricity Company strives to continue to increase the capacity of the amount of electricity it has [7].

In 2018 the power capacity of electrical energy in Java, Madura, Bali was around 40,510 MW, increasing 5% from 2017 to anticipate the surge in electricity demand. The State Electricity Company every year continues to increase the power capacity of its electrical energy [7]. One of them is by developing a Solar Power Plant. Especially the Java and Bali regions get enough sunlight to be used as environmentally friendly alternative energy. There are so many advantages that can be used using a solar power plant; namely, it is easy to use and fast in operation, and does not require a long time to start and stop. The operational costs are relatively cheap, compared to other power plants, the load is easy to change, and the number of disturbances is relatively tiny.

The Solar Power Plant that will be used in this study uses a power of 900, 1300, 2200-watt peak using an On-Grid system directly connected to the PLN network to save electricity usage. With the above background, the author wants to design an On-Grid Solar Power Plant for household needs.

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FUNDAMENTAL

Solar Power Plant

A solar power plant's primary component is a solar panel made up of solar cells. Solar cells can be used in everyday life, particularly in locations where grid electricity is unavailable or in trouble, such as isolated areas. Solar cells in the form of modules or solar panels are used in various applications in daily life, including water pumps and handheld calculators. They can also be used to charge electronics such as mobile phones and tablets [8].

The conversion of solar energy to electricity is referred to as the solar cell conversion principle. It involves multiple phases, the first of which is light absorption in the semiconductor. The following stage involves producing and separating positive and negative charges from other solar cell sections to generate a voltage in the solar cell. Then, in an electric power flow, the separate charges are transferred to the electrical terminal [9].

The photoelectric effect refers to the electrons emitted from a metal surface due to light being shot. The photoelectric effect occurs when a semiconductor material, such as silicon is exposed to sunlight and emits an electric charge. The impact is due to the photovoltaic process, which converts light energy to electrical energy [10].

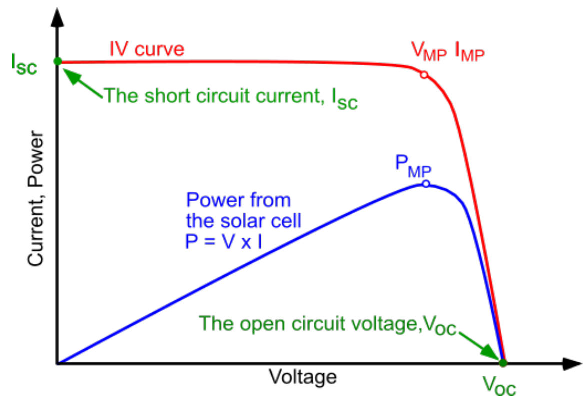

FIGURE 1. Typical of a solar cell characteristics

Figure 1 shows the characteristics of solar cells, where it can be seen that the cell temperature will affect the power generated. If, for example, the cell temperature is constant and if the radiation obtained from sunlight is increasing, then the effect obtained is that the power obtained is more significant. If the radiation from the sun is assumed to be constant and the temperature obtained is getting smaller, less power is produced. This is because the temperature is very influential on the performance of the solar panels. In addition, the temperature can also cause a decrease in the efficiency of solar panels [11].

The operation of solar cells is essential to get the maximum value, which depends on several factors that affect the performance of solar cells. Solar panels can operate optimally if the temperature remains normal at 25ºC. If there is an increase in temperature that is higher than the average temperature in the solar panel cells, it will weaken the open-circuit voltage (Voc) generated. Every 1ºC increase in solar temperature from 25ºC will decrease the power generated by about 0.5%.

The intensity of sunlight produced will affect the solar cell itself. The sunlight in the morning is not as hot as during the day. This affects the sunlight that is different for each location. Each location will vary and greatly depends on the state of the spectrum from the sun to the earth. Sunlight is very influential on the power generated by solar cell panels. The speed of the wind around the solar cell panel is also very influential because the faster the wind blows, the more it will help the cooling of the panel surface so that the temperature can be maintained in a conducive temperature range. The earth's atmosphere in each region is different every day. Sometimes cloudy, cloudy, raining, hot, air dust particles, smoke, air-water vapor, fog, and pollution also significantly affect the maximum result of electric current [12].

The positioning of the panels also determines the solar energy that can be optimally absorbed by the solar cells. Therefore, the placement of solar panels is critical so that the performance of solar panels can be maximized. The optimum orientation of the panels towards the sun is fundamental because it affects the maximum energy yield. In addition, the orientation angle of the panel is also very, giving maximum energy results.

Implementation of Solar Power Plant

Solar Power Plant (SPP) is a power generation system that utilizes sunlight to be converted into electrical energy through a photovoltaic module, which is a renewable energy that is more efficient, environmentally friendly, and reliable. SPP is one of the alternative generators that can meet the community's electrical energy supply, especially in Indonesia. SPP is currently used by people who live in remote areas that cannot reach the PLN network. Moreover, it has been realized that the country of Indonesia is located in the equator, which has excellent and rich solar energy rays so that the community can utilize this condition to generate electrical energy.

Solar power plants have several main components in their preparation, including solar panels, solar charge controllers, batteries, and power inverters.

Solar panels are an essential component in an SPP because they function as a generator of electrical energy. The solar charge controller is a device that functions to control the voltage that enters the battery. Batteries are devices that function to store the electric charge generated by solar panels. The power inverter is one of the essential tools in solar power generation. According to the design circuit, the inverter functions to convert DC electric current to AC at the required voltage and frequency. Figure 2 shows the schematic diagram of a solar power plant.

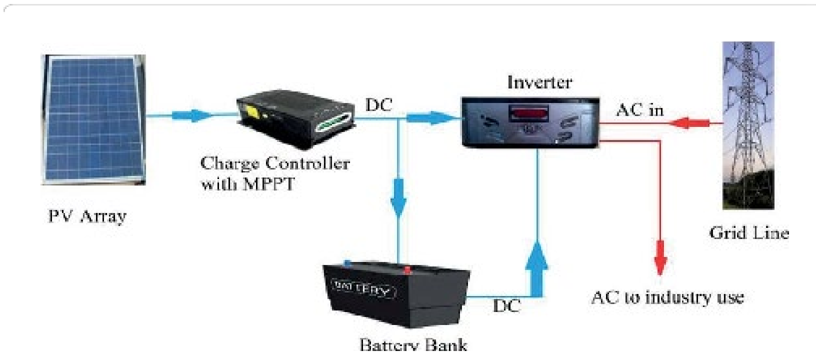

FIGURE 2. Schematic diagram of a solar power plant

METHODS

This research begins with system design. In designing the system, PVSyst software version 7.1 is used as the main application to be used as material for analyzing the performance of the Solar Power Plant. The system is designed to obtain information about the power generated by the cell beam with sufficient sunlight intensity, using the PVsyst application. PVsyst is used to measure the solar power plant itself. This study used data in the form of the duration of sunlight and the average temperature each month. These data were obtained from the BMKG of Central Java province, Indonesia. In addition, data collection was also obtained from the estimated daily load in people's homes. The solar panel used is one unit with a capacity of 900 Watt Peak with a DC to AC converter 1500 V. The research was carried out in Kutoarjo District, Purworejo City, Central Java Province, Indonesia, shown in Figure 3.

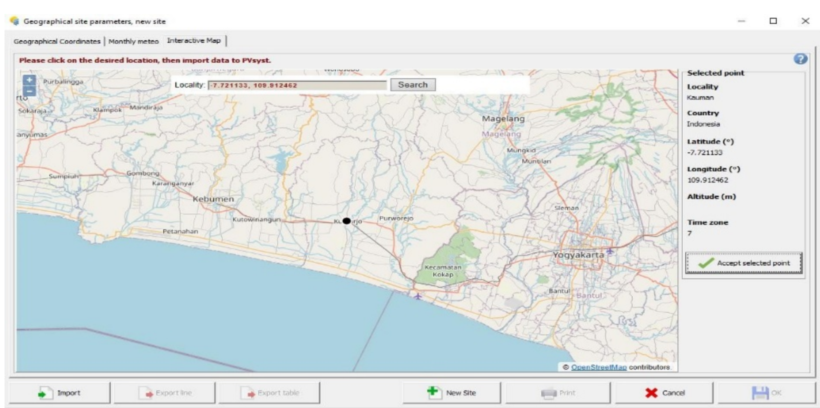

FIGURE 3. Location of this study

RESULTS AND DISCUSSION

Design of Solar Power Plant Components

Several main parameters need to be determined in designing a solar power plant (SPP) at PVSyst, including the power to be designed (Planned Power), selecting the brand of solar cell or PV modules, and the brand of the inverter to be used. Other parameters affect the number of modules in the series and the number of strings. This parameter will be filled automatically by the PVSyst system. The solar power plant (SSP) design in this study has a capacity of 900 watts. This capacity is similar to the power of electric customers those consumers widely use in Indonesia. The components used in the SSP design consist of three main components, namely solar panels, power inverters, and batteries, as shown in the specifications in Table 1.

TABLE 1. Specification of SPP components

No.	Device Name	Brand Name	Capacity	Total
1	Solar Panel	Canadian Solar Inc CS6C	100 watt peak	9
2	Power Inverter	Canadian Solar CS1-700TL1P-GI	1500 watt	1
3	Battery	Panasonic Litium-ion DCB-102Z	900 Ah	1

Design of Solar Power Plant in PVSyst Software

The design of a solar power plant (SPP) with the specifications in Table 1 is simulated in the PVSyst software. The simulation results will show the amount of energy obtained from SPP in each month in one year. The simulation results in the PVSyst software are shown in Figure 4 and Figure 5. In Figure 4, the amount of electrical energy produced each month for an SPP with a capacity of 900-watt peak (Wp).

It can be seen in Figure 4 that the electrical energy produced by the SPP in the design by ignoring the shading factor has an electrical energy production that varies every month. The most significant production of electrical energy occurred in November at 5.46 kWh/kWp/day, and the lowest was in December at 4.22 kWh/kWp/day.

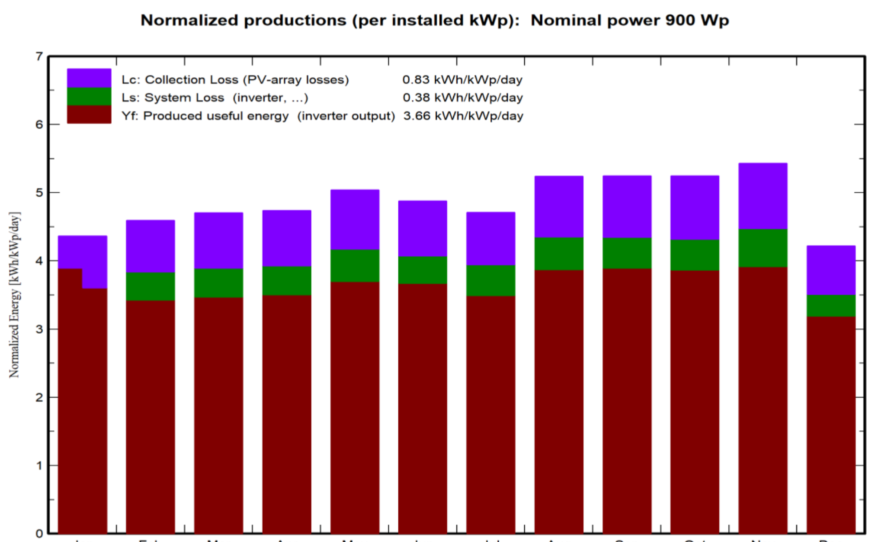

FIGURE 4. Electrical energy produced by the SPP

Figure 5 shows the performance ratio of a solar power plant (SPP) with a capacity of a 900-watt peak as designed in this study. The performance ratio of the SPP system in this design is simulated by ignoring the shadow factor. Based on the simulation results using PVSyst software as shown in Figure 5, it is shown that the highest performance ratio occurs in January, which is 89,5%, while the lowest SPP performance ratio occurs in November, which is 72.5%.

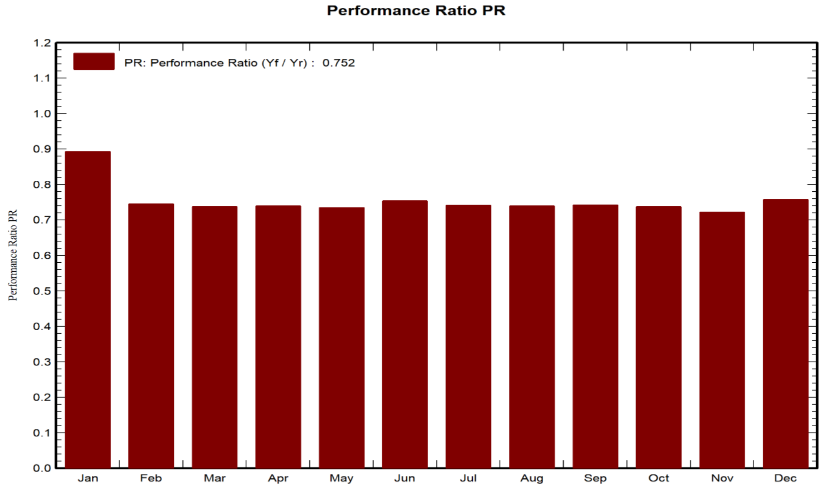

FIGURE 5. Performance ratio of a solar power plant

Minimizing network losses or losses in the electrical power distribution system has often become an essential issue in the last decade. Of all the electric power system components, the one that causes the most considerable losses is the distribution system. In the PVsyst software, a loss diagram can provide a detailed illustration of the resulting losses, as shown in Figure 6. Based on the losses diagram in Figure 6, it can be seen that the total energy produced by the solar cells is 1327 kWh. The figure also shows that the total energy consumption is 1276 kWh, divided into 1203 kWh for household power consumption and 286 kWh for injection into the PLN grid. The overall net energy produced is 1276 kWh, indicating that the solar power system designed in this study has an efficiency of 96.2%.

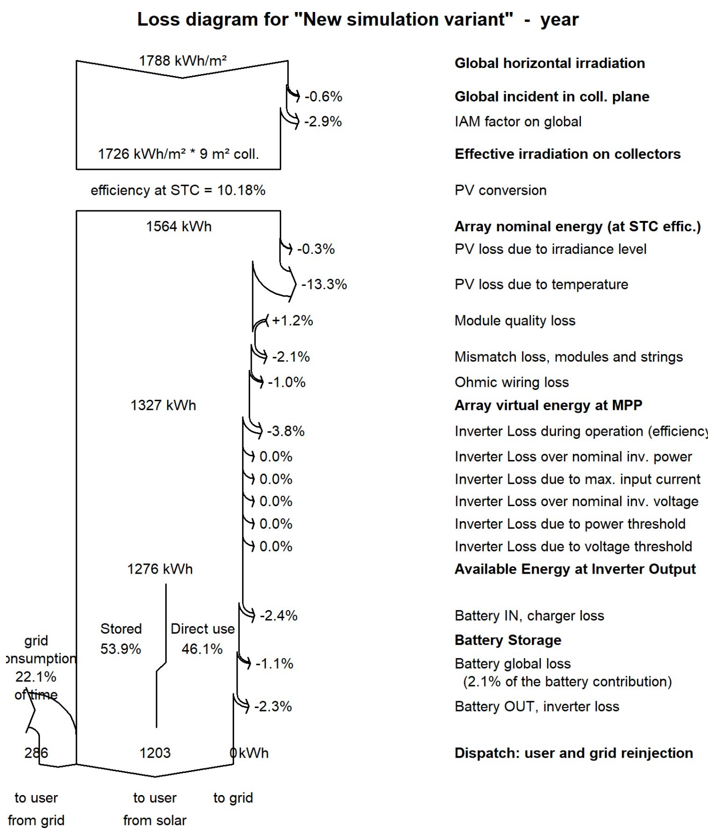

FIGURE 6. Losses diagram of a solar power plant

CONCLUSION

The solar power plant design results in this study were tested using PVSyst software to measure the system's performance. Performance measures used are the ratio of performance, energy production, and system losses. Based on the simulation results using PVSyst software in this work, it is shown that the highest performance ratio occurs in January, which is 89,5%, while the lowest SPP performance ratio occurs in November, which is 72.5%. The most significant production of electrical energy occurred in November at 5.46 kWh/kWp/day, and the lowest was in December at 4.22 kWh/kWp/day Based on the losses diagram in PVSyst software, the total energy produced by the solar cells is 1327 kWh. The figure also shows that the total energy consumption is 1276 kWh, divided into 1203 kWh for household power consumption and 286 kWh for injection into the PLN grid. The overall net energy produced is 1276 kWh, indicating that the solar power system designed in this study has an efficiency of 96.2%

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REFERENCES

1. D. Yu, A.G. Ebadi, and K. Jermsittiparsert. Risk-Constrained Stochastic Optimization of a Concentrating Solar Power Plant, *IEEE Transactions on Sustainable Energy*, 11(3), (2020). pp. 1464 - 1472.
2. A.N.N Chamim, A.P. Irawan, and R. Syahputra. Implementation of Automatic Transfer Switch on the Solar Home System at the Goat Farm Houses, *Journal of Electrical Technology UMY*, Vol 4, No 2 (2020), pp. 79-86.
3. S. Debnath, P.R.V. Marthi, Q. Xia, J. Pan, and M. Saeedifard. Renewable Integration in Hybrid AC/DC Systems Using a Multi-Port Autonomous Reconfigurable Solar Power Plant (MARS), *IEEE Transactions on Power Systems*, 36(1), (2021). pp. 603 - 612.
4. M. Younas, R. Kamal, M.S. Khalid, and A. Qamar. Economic Planning for Remote Community Microgrid Containing Solar PV, Biomass Gasifier and Microhydro, *in proceedings of 2018 Clemson University Power Systems Conference (PSC)*, (2018). pp. 1 – 7.
5. R. Syahputra and I. Soesanti. Planning of Hybrid Micro-Hydro and Solar Photovoltaic Systems for Rural Areas of Central Java, Indonesia, *Journal of Electrical and Computer Engineering*, 2020.
6. M.A.H Sirad. Analysis of the Potential of Renewable Energy in South Sulawesi as Power Electrical Needs, *Journal of Electrical Technology UMY*, Vol 1, No 4 (2017), pp. 196-201.
7. S. Suripto, R.A. Al Hasibi, R.O. Wiyagi, Sanupal, Y. Jusman, and D. Aribowo. Analysis of the Utilization of Putri Cempo Landfill Waste for Power Plants and Their Effects on the Surakarta Electric Power Distribution Network, *Journal of Electrical Technology UMY*, Vol 3, No 4 (2019), pp. 125-134.
8. Y. Ardiyanto, I.T Sujoko, W.A. Wibowo, V.D.H. Nugraha, and F.E. Saputra. Prototype Design of Unmanned Surface Ship to Detect Illegal Fishing Using Solar Power Generation Technology, *Journal of Electrical Technology UMY*, Vol 3, No 1 (2019), pp. 14-18.
9. M.R. Islam, A.M.M. Ur-Rahman, K.M. Muttaqi, and D. Sutanto. State-of-the-Art of the Medium-Voltage Power Converter Technologies for Grid Integration of Solar Photovoltaic Power Plants, *IEEE Transactions on Energy Conversion*, 34(1), (2019), pp. 372 - 384.
10. H.A. Sher, K.E. Addoweesh, and K. Al-Haddad. An Efficient and Cost-Effective Hybrid MPPT Method for a Photovoltaic Flyback Microinverter, *IEEE Transactions on Sustainable Energy*, 9(3), (2018). pp. 1137 – 1144.
11. E. Du, N. Zhang, B.M. Hodge, Q. Wang, and Z. Lu. Operation of a High Renewable Penetrated Power System With CSP Plants: A Look-Ahead Stochastic Unit Commitment Model, *IEEE Transactions on Power Systems*, 34(1), (2019). pp. 140 - 151.
12. I. Akhtar, S. Kirmani, M. Jameel, and F. Alam. Feasibility Analysis of Solar Technology Implementation in Restructured Power Sector with Reduced Carbon Footprints, *IEEE Access*, 9, (2021). pp. 30306 - 30320.