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Planning Analysis Of Hybrid Power Plants In Cijeruk District Using Homer

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A B S T R A C T

The population in Cijeruk District, Bogor Regency has grown by 6.27% over the last 5 (five) years. In line with the increasing population growth, the need for electrical energy from year to year is also increasing. The growth in electricity consumption needs to be accompanied by efforts to provide sufficient electricity. One of these efforts is to use renewable energy as a source of electrical energy through hybrid generation system technology. Solar energy potential of 550 – 650 W/m2 and wind energy potential of 4 – 6 m/s in Cijeruk District can be utilized for Hybrid Power Plants. Hybrid Power Plant planned by using HOMER and retrieves load data from the local electricity company. The data obtained will be tested with a model made from HOMER. The optimal Hybrid Power Plant system configuration for Cijeruk District consists of solar and wind power plant. The solar and wind power plant system give a maximum output of 2,733,348 kWh/year and can supply 37.3% of the total load. Solar irradiation shading affects the output power generated by the solar power plant system by 80.5%, while the wind speed affects the output power generated by the wind power plant system by 98.9%. The energy density generated in Cijeruk District in the solar power plant system is 159.81 kWh/m2 per year, while in the wind power plant system is 4.52 kWh/m2.

KEYWORD:
Hybrid power plant, solar irradiation shading, wind speed, energy density, HOMER.

INTRODUCTION

Cijeruk District, seen from the Energy Potential Map on the Ministry of Energy and Mineral Resources website, has the potential for solar, wind and biomass energy. Insolation in Cijeruk District ranges from 550 – 650 W/m2, wind speeds range from 4 – 6 m/s.

PV panel output varies due to various factors, one of which is the clarity index [1]. The clearness index shows the amount of solar irradiation that is reduced due to clouds and aerosols in the atmosphere [2]. In addition, clouds also cause partial shading on PV panels [3]. Partial shading is a condition where the PV module does not receive the same irradiation as other modules in the same panel [4].

The Wind Power Plant works by turbine rotation caused by the wind which is passed on to the generator, and this generator will produce electricity [5]. The electric power generated by the generator is influenced by many factors, one of them is the wind speed [6].

The use of renewable resources as an energy source has various kinds of limitations, one of them is sustainability [7]. The relationship between power generation and the area of land used is an important element of sustainability [8]. The relationship between the two can be seen from the energy density value. Energy density is the value of energy generation every hour per unit area of land where the power plant is installed [9].

The planned hybrid power plant utilizes the potential of solar and wind energy. Analysis of the optimal hybrid system configuration is necessary so that the system can make a significant contribution to the electricity demand. Also, analysis of the effect of solar irradiation shading on PV panel output and analysis of the effect of wind speed on wind turbine output is necessary in order to determine the optimization of each generator. Along with that, analysis of the power density generated by the hybrid power plant system is also necessary because it is used to determine the sustainability of the system itself. This research uses the HOMER and retrieve load data from the local electricity company.

The data obtained tested with a model made by HOMER and compared with the superposition method.
This research is important to supports government programs in achieving the target of the portion of new renewable energy in the primary energy mix. According to the Institute for Essential Services Reform (IESR, 2022), the portion of new renewable energy in the new primary energy mix in 2021 can only reach 11.2% of the target of 23% in 2025. In addition, this research also supports the 2060 Carbon Neutral program according to Indonesia's target in the document Indonesia Long-Term Strategy for Low Carbon and Climate Resilience 2050.

METHOD

Research Flowchart

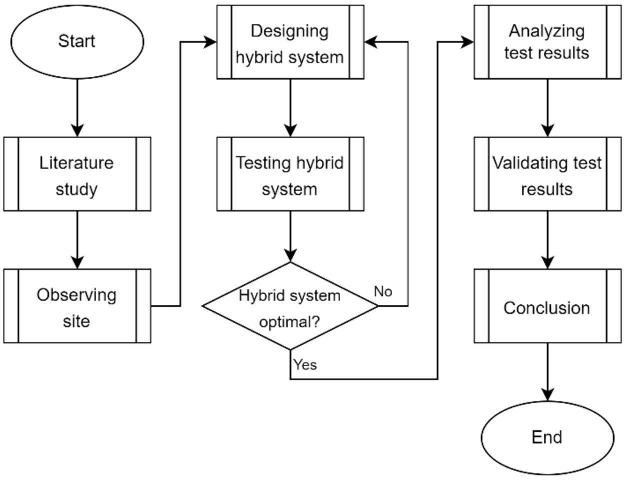

Fig. 1 Research Flowchart

The research starts with literature study, where it is known that Cijeruk District according to the Ministry of Energy and Mineral Resources on the Energy Potential Map page, has a solar radiation insolation of 550 – 650 W/m2 and a wind speed of 4 – 6 m/s. This condition is in match with research needs which require a place with sufficient potential sources of renewable energy for a hybrid power system. The energy consumption and historical loads data of the district were collected from the local electricity company.
Designing hybrid system begins with determining the hybrid design based on the components to be used. The system design then modeled at HOMER. Manual calculations are used to find out the capacity of the components to match the area where the research is located. The hybrid system used is a parallel hybrid system which is off-grid.
The obtained load profile, solar irradiation, wind speed, and temperature data were inputted into HOMER. The next phase is selecting and inputting the components used as well as the supporting parameters which consists of economic constraints and system constraints such as discount rate, inflation rate, etc. The results obtained from HOMER are then calculated and compared according to the area of land where the study is located. From the results of this analysis, it is seen how the relationship between the output power of the PV and the shading of solar radiation through the value of the clearness index and the relationship between the output power of the wind turbine and the wind speed. In addition, an analysis is also carried out on how the energy density in Cijeruk District is based on the output of each power plants.
The test scenario for the analysis uses the superposition method, where it is assumed that the energy source has limitations so that only 50% of its maximum potential is available. There are 5 (five) test scenarios assuming the percentage of new renewable energy as follows.

Table 1. Renewable Energy Percentage on HOMER

Power plant	Renewable energy percentage on HOMER				
	Testing scenario				
	(a)	(b)	(c)	(d)	(e)
Solar	100%	0%	100%	50%	100%
Wind	0%	100%	100%	100%	50%

The conclusion obtained from the results of this study is expected to be used as a reference for the local government to develop renewable energy potential with a profitable investment value.

Time and Place of Research

This study was conducted in September - October 2022. The study was conducted in a land in Cijeruk District, Bogor Regency. The land has an area of 3,5211 ha.

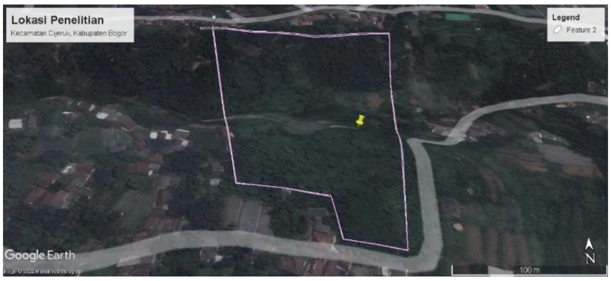

Fig. 2 Research Location

Data Collection Method

Based on the literature study by documentation method on the energy map of the Ministry of Energy and Mineral Resources, obtained that solar radiation in Cijeruk district is 550 - 650 W/m^2 and a wind rate of 4-6 m/s. The method is also used to collect supporting data such as discount rates and inflation rates. Field observation method used to collect energy consumption and load profile data from the local electricity company..

Hybrid System Topology

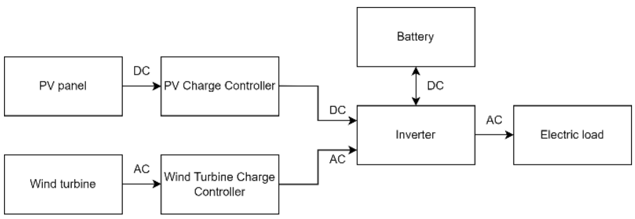

Fig. 3 Hybrid System Topology

The topology of the hybrid power generator system uses an off-grid system where all electrical energy sources come from renewable new energy. Solar and wind power system uses a charge controller to prevent batteries from overcharging. The topology adjusted to HOMER as shown in Figure 3. 5. The main components in the system are wind turbine, PV panel, inverter, and battery, supporting components are also needed, namely Busbar AC/DC.

RESULTS AND DISCUSSION

Electricity Energy Consumption

Data on electricity consumption per month in Cijeruk district can be seen in Table 4. 1. Electrical energy consumption per day is 19,082 kWh/day with a peak load of 2,133.69 kWh.

Table 2 Electric Energy Consumption in Cijeruk District in 2021

Month	Electric energy consumption (kWh)
January	**587.551,82**
February	**519.189,51**
March	**606.442,19**
April	**575.796,02**
May	**579.356,33**
June	**579.179,32**
July	**585.746,44**
August	**611.238,36**
September	**578.507,71**
October	**585.104,4**
November	**564.332,8**
December	**592.486,02**

Solar and Wind Energy Potential

Based on the NASA Prediction of Worldwide Energy Resource (POWER) database, Cijeruk District has an average solar energy potential of 4,76 kWh/m^2/day with an average clearness index of 0,481/year, while the average wind speed per year in Cijeruk District is 3,15 m/s. Wind energy potential.

Designing Hybrid System

Designing hybrid power plant system consists of designing solar and wind power plant. The solar power plant uses monocrystalline Trina Tallmax M Plus panel with a capacity of 345 Wp totaling 5.304 units and are equipped with MPPT. The total output of the PV panels is 1.829,88 kW. The wind power plant uses HAWT with a capacity of 5,1 kW totaling 24 turbines. The arrangement of PV panels and wind turbines can be seen in the following figure.

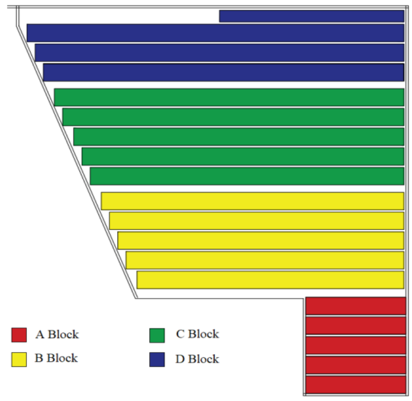

Fig. 4 PV Panels Layout

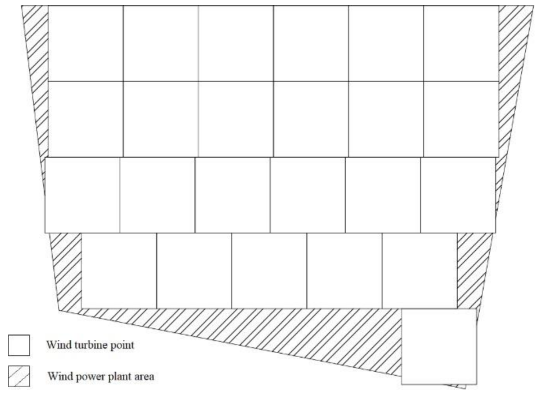

Fig. 5 Wind Turbines Layout

The electric energy storage system uses 20 Li-Ion batteries with a capacity of 1,670 Ah. The system uses a Dynapower SPS – 100 inverter with a capacity of 100 kW. The total capacity of the inverters used is adjusted to the total output power of the PLTS and PLTB systems, which is 1,500 kW, so that 15 inverters are used.

Test Results of Hybrid Power Plant Design

The hybrid power plant system design was tested using 5 test scenarios with the percentage of renewable energy sources according to ... The result is the hybrid power plant system design worked optimally in scenario (a), scenario (c), and scenario (e) where the maximum output power was 2.733. 348 kWh/year which can supply 37.3% of the total load.

The hybrid power plant system is then tested with predictions of electricity consumption for the next three years. Prediction of electricity consumption using the least square method regression analysis resulted in a conclusion that electricity consumption will continue to increase every year. Based on the test results, the hybrid power plant system with load prediction works optimally with the same scenario for the next 3 years even though the met load is less due to an increase in the demand for electricity consumption.

Analyzing the Relationship between Solar Irradiation Shading and Solar Power Plant Output

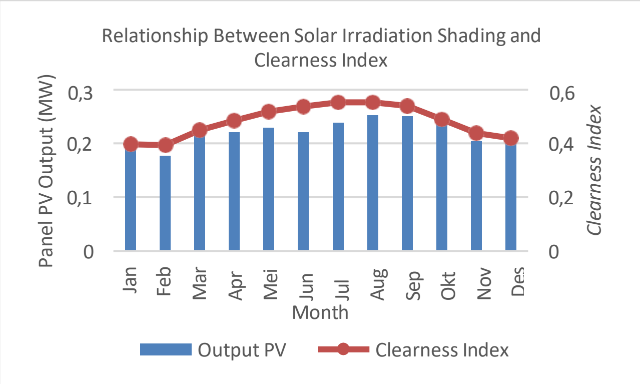

Fig. 6 Relationship Between Solar Irradiation Shading and Solar Power Plant Output

Based on the figure, the greater the value of the clearness index ratio, the greater the power of the solar power plant. This means that the smaller the shading of solar irradiation received by the PV panel, the greater the output power that can be generated.

The strength of the relationship between the output of solar power plant to the clearness index can be known by the correlation coefficient which can be calculated through regression analysis. The quantification used to measure the dependency between those two variables is the Pearson correlation.

Based on Pearson correlation, the correlation coefficient of 0.897291 indicating that the two variables have a very strong positive relationship. Meanwhile, the coefficient of determination (r_{xy}^2) = 0.805131 = 80.5% indicates that the variance that occurs in the power output of solar power plant is 80.5% determined by the clearness index value and 19.5% is determined by other factors. In other words, solar irradiation shading affects the power generated by the PV panels by 80.5%.

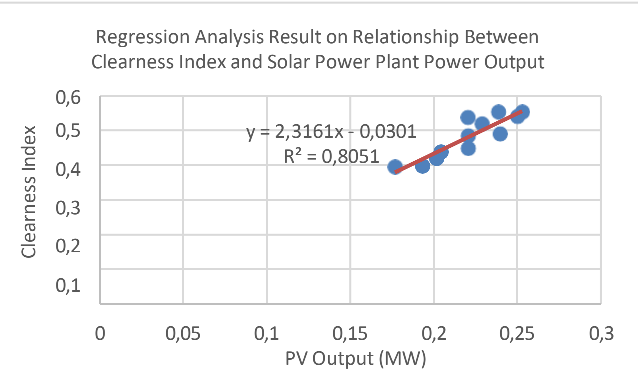

Fig. 7 Regression Analysis Result on Relationship Between Clearness Index and Solar Power Plant Output

Analyzing the Relationship Between Wind Speed and Wind Power Plant Output

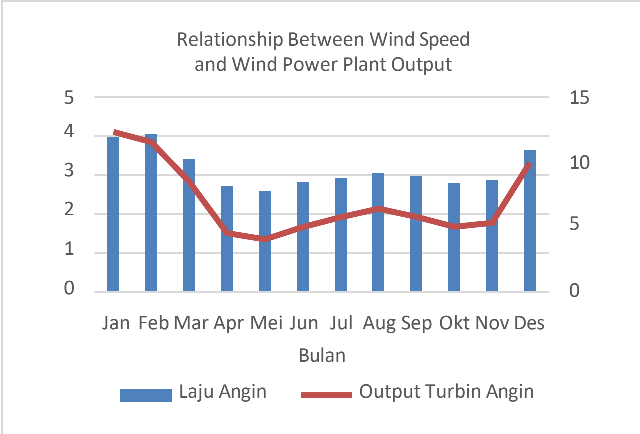

Fig. 8 Relationship Between Wind Speed and Wind Power Plant Output

Based on the figure, the greater the wind speed at the research location, the greater the power generated by the wind turbine. The strength of the relationship between wind speed and wind turbine output power can be analyzed further with regression analysis.

Based on Pearson, the correlation coefficient value is 0.994726 indicating that the two variables have a very strong positive relationship. Meanwhile, the coefficient of determination ($r_{xy}2$) = 0.989479 = 98.9% indicates that the variance that occurs in the wind power plant output is 98.9% determined by wind speed and 1.1% is determined by other factors. In other words, the wind speed affects the power generated by the PV panels by 98.9%.

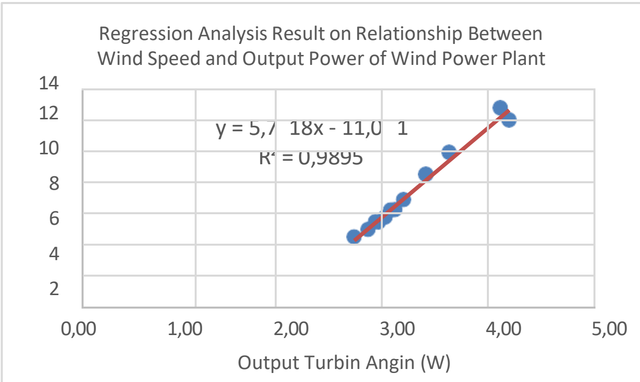

Fig. 9 Regression Analysis Result on Relationship Between Wind Speed and Output Power of Wind Power Plant

Analyzing Energy Density of the Solar and Wind Power Plants

The amount of energy density in Cijeruk District is based on the planned hybrid system consisting of the energy density produced by solar and wind power plant. The energy density in Cijeruk District for the solar power plant system is 47.59 Wh/m^2 with a total of 5,304 PV panels and a capacity of 1,829.88 kW. The density of the PV panels has decreased by 72.71% where the density of the solar power plant system is smaller than the density set by the factory. This is because the output power generated by the PV panel depends on the solar irradiation available at the study site.

The energy density for the wind power plant system is 213.08 Wh/m^2 with a total of 24 wind turbines and a capacity of 1.75 kW. The density of the wind power plant system in Cijeruk District is also different from the energy density set by the wind turbine factory. The density of wind turbines has decreased by 70.75% where the density of the wind power plant system is less than the density set by the factory. This is because the output power generated by the wind turbine depends on the level of wind available at the study site.

CONCLUSION

1. The optimal configuration of the hybrid power plant system for Cijeruk District is by using the solar and wind power plant systems. The solar power plant system uses monocrystalline PV panels with a capacity of 345 Wp with a total of 5,304 panels equipped with MPPT. The PLTB system uses 24 HAWT type wind turbines with a capacity of 5.1 kW. The storage system used is in the form of 20 Li-Ion batteries with a capacity of 1 kW, while the inverter system uses 15 inverters with a capacity of 100 kW. The hybrid power plant system works optimally in scenario (a), scenario (c), and scenario (e) where the maximum output power is 2,733,348 kWh/year which can supply 37.3% of the total load.
2. Solar irradiation shading and the output power of the solar power plant system has a strong positive relationship, where solar irradiation shading affects the output power produced by the solar power plant system by 80.5%.
3. Wind speed and the output power of the wind power plant system have a strong positive relationship, where the wind speed affects the output power produced by the wind power plant system by 98.9%.
4. The energy density in Cijeruk District for the solar power plant system is 47.59 Wh/m2, decreased 72.71% from the density set by the factory. The wind power plant system has a density of 213.08 Wh/m2, decreased 70.75% from the density set by the factory.

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