Simulation of the Use of Solar and Wind Energy as a Hybrid Power Plant in Malahing Village Using Software Homer

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Abstract. The need for electricity is increasingly becoming a problem because of limited energy sources so that there are several villages that have not received electricity supply from PLN, one of which is Mallahing Village. The geographical location of the village supports the use of Solar and Bayu Hybrid Power Plants, so simulations need to be carried out to determine the optimal configuration and electrical system. Mallahing village has a potential wind speed of 3.58 m/s and a potential solar irradiation of 4.63 kw/m2. The simulation results get the optimal configuration for the load requirement of 231 kwh/day is to use a PV capacity of 16.1 Kw, a Wind Turbine with a capacity of 5.1 kW of 15 units, an Inverter of 16.3 Kw and a Storage of 220 kWh. The electrical system on the solar panels produces a total production of 22,276 kwh/yr. Meanwhile, the wind turbine electrical system produces a total production of 70.446 kwh/yr. The optimal configuration has a Net Present Cost of Rp. 3,862,619,107.74. Of the total system production, solar panels supply electricity by 24% and wind turbines supply electricity by 76%. Based on the results of the study, it was found that the optimal configuration and operation of the system for 25 years and based on the potential for wind speed and solar irradiation at the research site, wind turbines produce more electrical energy to supply load needs compared to solar panels because solar panels only operate from morning to evening.

Keywords: Simulation · Homer · Mallahing · Hybrid and Energy

1 Introduction

The increase in population parallels the increasing need for land as a residence. According to data from Badan Pusat Statistik (2021), there was an increase in population density of 142 m^2 with a population of 272.682,5. So, people make the sea a solution to overcome the density of settlements. In addition, there are problems in the distribution of electrical energy in the absence of infrastructure. Thus, the use of power plants with renewable energy sources can be used as a solution for the distribution of electricity in the area.

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The potential for renewable energy in Indonesia is very large, including 32.6 GW of bioenergy, 94.3 GW of water energy, 207.8 GW of solar energy, 28.5 GW of geothermal energy, 17.9 GW of marine energy and 60.6 GW of wind energy. GW. However, this energy cannot be utilized optimally because of the high investment costs for the construction of renewable energy plants [1].

East Borneo is one of the provinces in Indonesian, which crosses the equator. One of the villages in East Borneo is Malahing Village. The Malahing Village is a floating village that is above the sea, residents in the floating village only install stakes according to sloping sea, lanes whose average sea depth is still 5–10 m in coastal areas [2]. Malahing Village has not yet received an electricity supply from PLN because its location does not allow access to transmission lines. Based on the area traversed by the equator it has solar energy that can be utilized because of the amount of sunlight it receives throughout the year. In addition, the location of Mallahing Village is above the sea so, sea wind energy and solar can be utilized.

The potential for hybrid power plants can be identified by conducting simulations to obtain the optimal scheme of power generation based on the ability of solar energy and wind energy in Mallahing Village. So, we need software to simulate the potential based on solar irradiation and wind speed at the research site. Homer Energy software is software that can be used to simulate the design of power plants such as a combination of Solar Power Plants and Wind Power Plants.

Based on the problems described, it is necessary to simulate a Hybrid Power Plant by utilizing solar and wind energy at the Malahing Village location to determine the optimal configuration. The purpose of this simulation is to provide an overview of the operation of the Hybrid Power plant system and its operation within a certain period so that it becomes a reference for the manufacture of a Hybrid Power plant in Mallahing Village as a power supply.

2 Methods

2.1 Malahing Village

Malahing Village is a residential area with distinctive characteristics in the coastal area of Bontang City. The geographical condition of this area is in a coastal area over water, with tidal conditions. Malahing Village is one of the floating villages above the sea of Bontang City, residents in the floating village only install stakes according to sloping sea lanes whose average sea depth is still low 5–10 m (coastal area), the village is located at 0.114.20 North Latitude and 117.530 North Latitude. This village has a population of 221 people and 55 families. This village has not received electricity supply from PLN due to the distance and location above the sea, which makes it difficult to get a transmission and distribution network. Currently, the people of Mallahing Village use generators and solar modules to meet their electricity needs, although not for 24 h. Solar modules often experience damage so sometimes they have to switch to generators to anticipate them (Fig. 1).

Fig. 1. The location of Mallahing Village which is above the sea

2.2 Energy

Energy is an object that can be changed or utilized. Solar energy is energy produced from the sun and called solar irradiation expressed in units of power divided by area. While wind energy is energy created from the difference in air pressure that moves from high to low pressure and is expressed in units of distance in time.

2.3 Solar Cell

The material for receiving sunlight is solar cells, which are made of semiconductor materials and arranged into a single module. A photovoltaic module is a tool used to absorb and convert sunlight into electrical energy. A solar cell has the function of converting solar irradiation into electrical energy with direct current. The power capacity can be generated by solar panels can be determined using the following Equation [3].

$$\mathrm{P_{pv}} = \mathrm{Y_{pv}.f_{pv}.}\left(\frac{\overline{\mathrm{G}}\mathrm{T}}{\overline{\mathrm{G}}\mathrm{TSTC}}\right)$$

Information: $P_{pv} = PV\ Output$ (kW)
$Y_{pv} = PV\ Capacity$ (kW)
$f_{pv} = PV\ Derating\ Factor$ (%)
$\overline{\mathrm{G}}_{\mathrm{T}} = Solar\ Irradiance$ (Kw/m^2)
$\overline{\mathrm{G}}_{TSTC} = Solar\ Irradiance\ Standart\ Test\ Condition$ (1 Kw/m^2)

2.4 Wind Turbine

The wind turbine is a device used to generate electrical energy by utilizing wind speed. The kinetic energy of the wind is harnessed by the turbine and converted into electrical energy. Wind turbines are the main component in the electric power generation system. Wind turbines have two main types, namely wind turbines with a horizontal axis and a vertical axis. The following is a formula to determine the power generated by a wind turbine [4].

$$P = \frac{1}{2}\rho \times A \times v^3 \times C_p$$

Where: P = Turbine Output (watt).
C_p = Constanta Betz (59.3%).
ρ = AirDensityy (1.225 kg/m^3).
A = turbine sweep area (m^2).
V = Wind Speed (m/s).
With the sweep area of the turbine formula is:

$$A = \frac{\pi}{4}D^2$$

Where: D = Diameter blade (m).

2.5 Inverter

The inverter is a component that functions to convert DC into AC or direct current into alternating current. AC is used for electrical needs such as loads at home. In the Hybrid system, the inverter not only functions to change the output current but there is also an inverter that has additional functions such as being able to be connected directly to storage or batteries because it is equipped with battery charge control. The following is how to determine the capacity of the inverter.

$$\text{Inverter Capacity (Watt)} = \text{Wmaks} + (25\% \times \text{Wmaks})$$

Where: Inverter Capacity	= Required inverter capacity (watt).
Wmaks	= Maximum load power capacity (watt)
25%	= Backup power.

2.6 Battery

The use of batteries in the hybrid system as a storage of energy produced by solar modules and wind turbines is channeled to the load. The battery can store electrical energy from the Solar Power Plant and Wind Power Plant components. Several types of chemicals used in battery technology are Liquid Lead-Acid, Nickel-Iron (NiFe), Nickel-Cadmium (NiCad), Alkaline, Gel-cell, and Lithium-Ion.

2.7 Hybrid Syestem

Solar power plant and wind power plant systems use solar energy and wind speed to generate electrical energy. This combination of solar modules and wind turbines is referred to as a hybrid, a system consisting of two or more energy sources ombined to produce electrical energy. This system uses energy stored in the form of batteries as a backup when there is no wind or sunlight.

2.8 Software Homer

HOMER (Hybrid Optimization of Multiple Energy Resource) is a software application developed by the national renewable energy laboratory in the United States. This application using to design and evaluate technical and financial options for off-grid and on-grid power systems for generation applications. Making it possible to consider a large number of technology options take into account the availability of energy resources and other variables. This software has several calculation parameters to get the cost of producction during the simulation. The parameters in question are:

a Capital Cost

Capital cost is the initial cost of a component or the total cost of installing the component at the beginning of the project. Capital cost can also be interpreted as the price of these components.

a Replacement

Replacement is the cost of replacing a component at the end of its life, as determined by the lifetime parameter in the component model.

a Operation and Maintenance

Operation and Maintenance costs are costs associated with the operation and maintenance of these components. This cost is set for each component, the costs included are the operational and maintenance costs of the components for one year. The determination of O&M costs was obtained from previous research using the same components and other sources such as the internet.

Homer will calculate different configurations of possible designs based on the given inputs and simulate the power system. According to the input design possible to compare component onfigurations with the latest Hybrid models (wind and solar). The way homer works produce simulation, optimization, and sensitivity analysis. These parts have their respective uses and work sequentially. So, the results obtained are optimal. Net Present Cost (NPC) is the total cost used to manufacture components from installation to project operation.

$$\text{NPC} = \text{Capital} + \text{Replacement} + \text{O\&M} - \text{Salvage}$$

Information: Replacement Cost = Component replacement costs (Rp).
Capital Cost = Component cost (Rp).
Salvage = Remaining cost of components (Rp).
O&M Cost = Operational and maintenance costs (Rp).

2.9 Research Procedures

There are several stages in this research as simulation planning of Homer software in the following block diagram (Fig. 2).

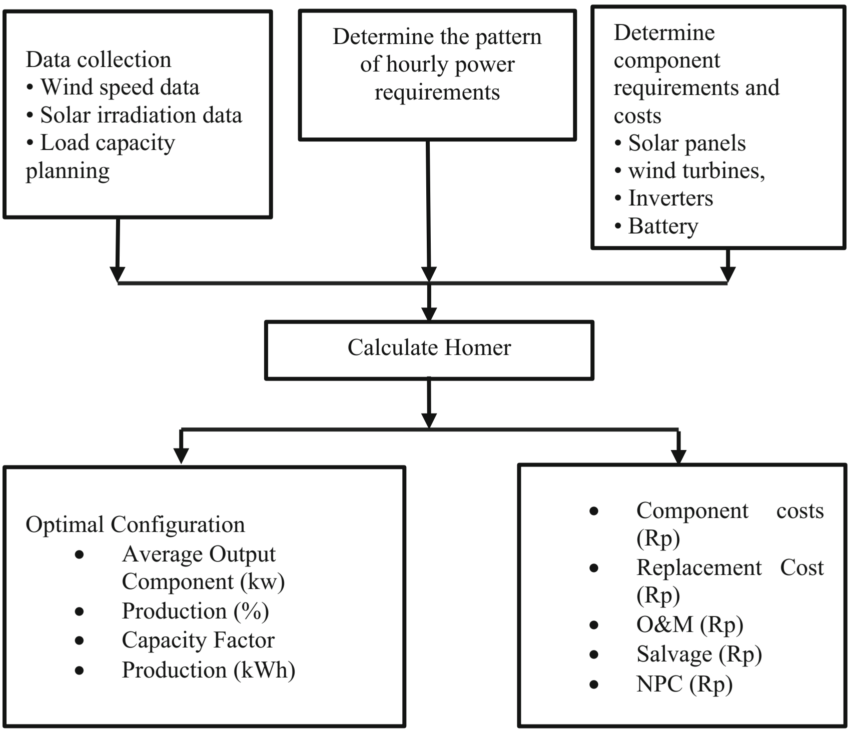

Fig. 2. Block diagram running simulation in research stage

3 Result and Discussion

3.1 Resources Energy

Wind Speed Data
Wind resources were determined using the NASA Prediction of Worldwide Energy Resources database. The database provides the average wind speed for each month. The following is a Table 1 of the average wind speed for each month for one year.

Solar Irradiation Data
Solar irradiation data is obtained from the United States Space Agency NASA Prediction of Worldwide Energy Resources, then the average solar irradiation per month in one year will be obtained. The following is Table 2 Average solar irradiation every month for one year.

Load Profile
The hybrid power plant simulation in Malahing village is planned for 55 houses assuming 900 VA customers. The load data needed in the simulation is the average data consumption of elecricity in one day. According to the National Team for the Acceleration of Poverty Reduction (TNP2K), based on data from PLN, for R_1/900 VA customers the average electricity consumption in one month is 126 kWh. The average consumption is 44.2 kWh per day, and the simulation planning of 55 houses uses an average eletricity consumption of 231 kWh/day.

Table 1. Wind speed data in Malahing Village 2021

Month	**Wind Speed (m/s)**
January	3,92
February	3,50
March	3,55
April	3,65
Mei	2,89
Juny	3,02
July	4,09
August	3,63
September	3,19
Oktober	4,08
November	3,58
December	3,91
Average	**3,58**

Table 2. Solar Irradiation Data in Mallahing Village 2021

Month	Irradiance (kWh/m^2/d)
January	4,21
February	4,93
March	4,93
April	4,98
May	4,62
Juny	4,69
July	4,46
August	4,66
September	4,67
Oktober	4,96
November	4,42
December	4,10
Average	**4,63**

3.2 Load Profile Hourly

Usage within 24 h follows the variation pattern provided by Homer software in the Community category. The load is percentage to make it easier to input the load as needed. The peak load is at 18.00 – 21.00 which is 16.3 Kw. The following is a load profile Table 3 for 24 h on Homer software with the Community load category.

3.3 Determining Component Capacity and Cost

At this stage, it is carried out with the aim of getting the type and capacity of the component in accordance with the system planning and at the same time providing limits on the search for homer simulation calculations.

Inverter

Inverter Capacity (Watt) = Wmaks + (25% x Wmaks)

= 16,300 + (25% x 16.3)

= 20.370 W

Required inverter capacity above 20.370 W

Pv

Table 3. Hourly load power

Hours	**(kW)**
00	2.71
01	2.71
02	2.71
03	2.71
04	2.71
05	4.07
06	6.79
07	9.51
08	10.86
09	10.86
10	10.86
11	10.86
12	10.86
13	10.86
14	10.86
15	10.86
16	12.22
17	13.58
18	16.30
19	16.30
20	16.30
21	16.30
22	12.22
23	6.79
Total	**231**

The specification and lighting conditions, monorystalline solar panels can produce more power than polycrystalline solar panels. So, the solar panel planning will use a monocrystalline type with a capacity of 330 Wp.

Tabel 4. Component and cost homer

Input	Unit	Cost	O & M	Life Time
Load	231 Kwh/d	-	-	-
PV	Canadian CS60 330 wp	Rp. 2.427.000	Rp. 300.000	25 years
Wind Turbine	AWS H 5,1 KW	Rp. 115.440.000	Rp. 1.200.000	20 Years
Inverter	Apollo MTP-413 25 kW	Rp. 225.000.000	-	10 years
Storage	Li-lion 1 kw	Rp. 1.079.000	-	15 years

Wind Turbine
Determination of the wind turbine used to adjust to the research site. The average wind speed in Malahing Village is 3.58 m/s, the type of turbine selected is a wind turbine that can operate at a low speed below the average wind speed at the research site. The wind turbine used is a 5.1 KW horizontal wind turbine.

Battery
The battery is a Lithium Ion because it has a better lifespan and recharge. Then the type of battery used is Li-lion 1 kW.

Schematic Hybrid power plant of wind and solar
The generator scheme consists of wind turbine components, solar panels, batteries, inverters, and electrical loads. The components have respective functions, quantities, and capacities based on the procedure for determining what has been carried out. The following is a schematic drawing of the generator on homer software (Fig. 3).
Generator working principle

1. If the total power of the Solar Panel and Wind Turbine exceeds the load requirement, while the battery energy is not fully charged (SOC $<$ 100%). Then the excess power is stored in the battery.

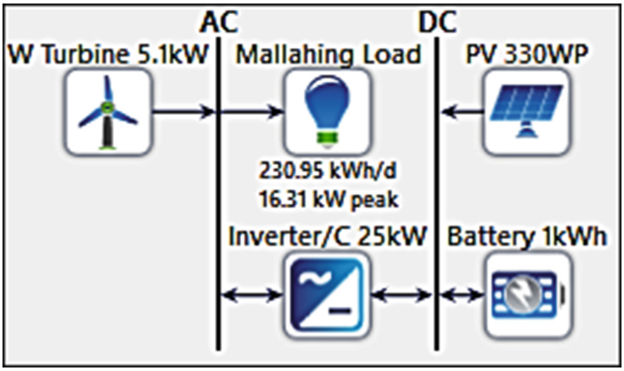

Fig. 3. Schematic PLTH Wind and Solar

Architecture				Cost	CS6U-330P	AWS5.1kW
CS6U-330P (kW)	AWS5.1kW	1kWh LI	Leon25 (kW)	NPC (Rp)	Production (kWh/yr)	Production (kWh/yr)
16.1	15	220	16.3	$3.86B	22,276	70,446
	30	200	16.3	$5.96B		140,892

Fig. 4. Optimal configuration result from homer calculation

2. All electrical power generated by the Solar Panel and Wind Turbine is supplied to the load, while the lack of energy will be assisted by the battery.
3. In the condition that the Solar Panel and Wind Turbine power does not produce electrical energy to serve the load, the energy will be supplied from the battery.
4. When the energy produced by the Solar Panel and Wind Turbine exceeds the load requirement and the battery is in full condition (SOC = 100%), the excess energy (Excess Electicity) will be channeled to the dump load.

3.4 Result

The simulation that has been run produces an optimal configuration based on the smallest NPC value. The following are some of the optimal configurations resulting from the homer calculation (Fig. 4).

The results of the homer calculation to get the optimal configuration for solar and wind hybrid power plants are using a PV capacity of 16.1 kW, a wind turbine capacity of 5.1 kW of 15 units, and inverter of 16.3 kW, and storage of 220 kWh. This configuration produces a net present cost of Rp 3,862,619,107.74 or $247617.45. The NPC value generates by the simulation is not the total cost of the entire system but is only limited to knowing the optimal configuration. It cannot be considered the cost of the whole system because the NPC value because not take into account the supporting components and infrastructure of the system.

Homer's calculation results get a simulation of the system's operation for 25 years. The operation of a hybrid power plant of wind and solar systems can be the aspect of electricity and economic cash flow. The following is a Table 4 of electrical results from the homer simulation.

Table 5 is the result of electricity from solar panels. Rated capacity is th total capacity of solar panels needed to supply the load is 16.1 Kw. The mean average output power of

Table 5. Electrical sistem PV

Quantity	Value	Units
Rated Capacity	16,1	kW
Mean Output	2.54	kW
Mean Output	61	kWh/day
Capacity Factor	15.8	%
Total Production	22,276	kWh/yr

the solar panels is 2.54 kW if, the average per day is 61 kWh/day. The capacity factor is 15.8%, obtained from the divison between the average output and the component capaity. The total production of power produced by solar panels per year is 22.776 kWh/yr.

Table 6 shows the electrical output of the wind turbine. Rated capacity is the total capacity of the wind needed to supply the load, which is 76.5 kW. The mean average output power of the wind turbine is 8.04 kW and the average per day is kWh/day. The capacity factor as a percent, the capacity factor is 10.5%, is obtained from the result of the division between the average output and the component apacity. Total production is the total power produced by wind turbines per year, which is 70.446 kWh/yr.

The resulting cost calculation is for 25 years of the project's life, so the cost of replacement, maintenance and salvage costs are system costs that last for 25 years, and the cost that arises from year to year will be displayed. The costs incurred in the life of the project (total NPC) are obtained from the total amount as the results of the NPC calculation resulting from the sum of all costs as investment costs, replacement, salvage costs and maintenance for a predetermined life (Table 7).

From the Homer simulation calculation results, the NPC results are based on the sum of the values of Capital, Replacement, O&M, and Salvage. From some of these components, it can be seen that the component that uses the most replacement costs, maintenance, and the remaining costs of the components. The results are displayed based on the selected configuration, and the overall cost flow of the components will be known from year to year during the calculated project life. It can be seen that the total cost of the components that have been inputted, the system capital is Rp. 2,234,469,974.,76, Replacement of Rp. 2,262,560,000.00 Operational & Maintenance Rp. 816,810,799.64 And reduced by salvage of Rp. 1,451,221,666.67. So the total NPC is Rp. 3,862,619,107.74.

Table 6. Electrical sistem Wind Turbine

Quantity	Value	Units
Rated Capacity	76,5	kW
Mean Output	8,04	kW
Capacity Factor	10,5	%
Total Production	70,446	kWh/yr

Table 7. NPC economic aspect calculation result

Component	Capital (Rp)	Replacement (Rp)	O & M (Rp)	Salvage (-Rp)	Total (Rp)
PV	118.699.974,00	0	366.810.799,00	0	485.510.774,41
Wind Turbine	1.731.600.000,00	1.731.600.000,00	450.000.000,00	-1.298.700.000,00	2.614.500.000,00
Inverter	146.790.000,00	293.580.000,00	0	-73.395.000,00	366.975.000,00
Stroage	237.380.000,00	237.380.000,00	0	-79.126.666,67	395.633.333,33
System	2.234.469.974.,76	2.262.560.000,00	816.810.799,64	-1.451.221.666.67	3.862.619.107,74

4 Conclusion

1. Based on the results of the simulations that have been carried out, it can be concluded that the most optimal configuration of the Solar and Wind Hybrid Power Plant in Mallahing Village with a load requirement of 231 kwh/day is to use a PV capacity of 16.1 Kw, Wind Turbine capacity 5.1kW of 15 units, Inverter of 16.3 Kw and Storage of 220 kWh.
2. The electrical system on the solar panel produces a mean output of 2.54 kw and a total production of 22,276 kwh/yr. While the wind turbine electrical system produces a mean output of 8.04 kw and a total production of 70.446 kwh/yr.
3. The optimal configuration has an NPC value of Rp. 3,862,619,107.74. Obtained from the sum of the total capital system of Rp. 2,234,469,974.,76, Replacement Rp. 2,262,560,000.00, Operational & Maintenance Rp. 816,810,799.64 And reduced by salvage of Rp. 1,451,221,666.67.
4. Total system production, solar panels supply electricity by 24% and wind turbines supply electricity by 76%. Based on the results of the study, it was found that the optimal configuration and operation of the system for 25 years and based on the potential for wind speed and solar irradiation at the research site, wind turbines produce more electrical energy to supply load needs compared to solar panels because solar panels only operate from morning to evening.

Acknowledgements. The results of this research provide an overview of the generator system by utilizing solar and wind energy sources in Malahing village. The drawback of this researh is that the resulting economic analysis does not an economic result of the entire system. So, it can not be used as an economic reference for power plant planning, and futher research can provide an economic picture of the entire system.

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