Feasibility Study of Hybrid Renewable Energy Power Generation Installation

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Keywords: HOMER, people, PLN, NPC, COE, Annualized cost, Renewable penetration, total electricity production.

Abstract: Application of electrical energy from year to year is getting bigger along with population growth, industry, and others. The National Grid Electricity (PLN) as the main provider of electrical energy networks must have a backup of electricity to meet the growing electricity needs for people. This study aims to provide a backup provider of people electricity needs sourced from renewable energy. In this plan HOMER software is used to design renewable energy power generation systems from solar and wind energy. The function of HOMER software to optimize the size of the type of generator, especially the constituent components of hybrid generator so that more economical power generator are obtained as providers of electricity reserves. The results of electrical energy generated from the design of a hybrid power system amounted to 221.866 kWh. Renewable penetration of components in generating electrical energy by 84% of the total electrical energy produced. The cost of energy (COE) issued per 1 kWh is Rp. 980,45/kWh and the net present cost (NPC) in the construction of a hybrid power is Rp. 2.789.010.000. Whereas the annualized cost of maintenance of components of hybrid power issued in a year is Rp. 215.742.140

1 INTRODUCTION

Application of electricity from year to year is increasing. This is due to the increasing population from year to year so that application of electrical energy consumed by the people is getting bigger. To meet the increasing application of electricity, new references are needed in providing electrical energy, especially energy sources from nature, because for now as a large amount of electricity generated from fossil fuels (Tangirala Venkat, 2017). Where, in application of fossil fuels will have a negative impact on the environment and the amount of fossil fuels is very limited and will run out if often used. For this reason, people are required to find energy sources that are unlimited and are environmentally friendly.

Renewable energy is an energy that comes from nature and is unlimited. In addition, in its application renewable energy is very friendly to the environment. There are several types of renewable energy that can be converted into electrical energy, namely water, wind, solar, ocean waves, biomass and others (Suherman et al., 2017).

In this study, the author will design a renewable energy hybrid power system where solar will be used as a provider of electrical energy of people. However, in the process of designing this generator there are several factors that must be considered, including wind speed and air heat. This factor is the most important factor in determining the location of this generator. For this reason, it is necessary to study in advance to determine the natural conditions in which this power generator will be located. This study aims to find out whether this power generator is effective if it is placed in a location that is the object of research.

The hybrid system design in this study uses HOMER software (Hybrid Optimization of Multiple Energy Resources). This software is able to design, simulate and determine the best system configuration. In addition, this software is able to perform mathematical calculations regarding the costs that will be incurred from a hybrid power system (Kunaifi, 2015).

This study aims to determine the effect of parameters (wind speed, sunlight intensity, and load data of electricity consumption of people) on the results of the optimization of the design of hybrid power generation systems.

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2 LITERATURE REVIEW

2.1 HOMER

HOMER is a software used to design and analyze hybrid energy systems and was developed by the national laboratory renewable energy, United States. HOMER models electric power systems and costs during operation, which is the total installation and system operating costs. In addition, in HOMER there are many system design options that can be used based on technical benefits and economic value (Yasuha et al., 2017).

In operation, HOMER performs 3 main tasks, namely:

1. Simulation.
2. Optimization.
3. Sensitivity analysis.

a Net Present Cost (NPC)
Net present cost is the total cost that will be used during the installation period or the operation of the components throughout the project. To find out the value of NPC by using the equation 1.

$$NPC = CapitalCost + ReplacementCost + O\&MCost + FuelsCost – Salvage \quad (1)$$

Where:
Capital costs : Cost of capital component (Rp).
Replacement : Cost of replacement components costs:(Rp). O&M costs : Costs of operating and maintenance (Rp)
Fuel costs : Fuel costs (Rp).
Salvage : Costs of remaining components (Rp).

b Total Energy Production
To find out the amount of electrical energy generated from renewable energy systems (hybrid power) throughout the operating system can be known by using equation 2

$$ETotalproduction = Ewindturbine + EGrid \quad (2)$$

Where,
ETotal Production : Total electricity production (kWh)
EWind turbine : Total wind energy production (kWh)
EGrid : Total energy production from the PLN network (kWh)

c Annualized Cost
Annualized cost is used to determine the total annual cost of the design of a hybrid power system. To find out the annual cost of the HP system can be known by using the formula in equation 3.

$$Annualizedcost = CapitalCosts + Replacementcosts + O\&Mcosts + Fuel\ costs – salvage \quad (3)$$

Where,
Annualized cost (AC) : System annual fee (Rp)
Capital costs : Cost of component capital (Rp)

d Cost Of Energy
The cost of energy is used to determine the costs incurred per kWh of the system. To find out the costs incurred can be calculated using the formula in equation 4

$$COE = \frac{TotalAC}{E_{tot.production}} \quad (4)$$

Where, COE : Costs incurred per kWh (Rp) Total AC : System annual fee (Rp) $E_{tot.production}$: Total energy production (kWh)

e Renewable Penetration
Renewable penetration is used to find out how much electrical energy is generated from the total electrical energy produced by hybrid power (HP) systems. The renewable value of penetration can be calculated using equation 5

$$RP = \frac{E_{tot.component}}{E_{tot.prod.system}} \quad (5)$$

Where, RP : Renewable penetration (%) $E_{tot.component}$: Total electricity generated from solar panels and wind turbines(kWh) $E_{tot.prod.system}$: Total production of electrical energy generated by the system(kWh)

2.2 Hybrid System Generator

The hybrid system generator is a combination of two or more power generator with different energy sources both from natural sources and those from conventional energy. The purpose of the hybrid power generation system is to complement each of the two types of combined generator, both in terms of weaknesses and increasing the amount of electricity production (Arota et al., 2013).

2.2.1 Wind Turbine

Basically, a wind turbine system that captures the kinetic energy of the wind and converts it into mechanical energy (motion) through a turbine knife and then the mechanical energy is converted intoelectrical energy through an electric generator (Aziz et al., 2018). To find out the power produced by wind turbines that will be used in this study, it can be known by using equations 6

$$P = \frac{1}{2} * p * A * V^3 \quad (6)$$

Where: P : Power (W)
p : Wind mass (1,225 kg/m3)
A : Cross sectional area of the turbine (m2) (1/4 * Φ * D)
V : Wind blow speed (m/s)
D : Diameter of wind turbine (m)

2.3 Photovoltaic

When the PV module is exposed to solar, the PV module will produce direct current (DC) electricity. By using an inverter, direct current electricity will be converted into alternating current (AC). There are 2 main types of PV systems, namely on grid and off grid (Tan and Seng, 2011).

Based on the manufacturing technology, there are 2 types of solar panels that are often used, namely:

1 Monokristal solar cell
2 Polikristal solar cell

Factors that affect the level of performance of solar panels, namely:

1 Temperature
2 Solar intensity
3 Orientation of solar module circuits
4 Angle of solar orientation

2.4 Payback Period

Payback period is a method used to determine the time needed to recover costs incurred in the project builder (ESDM, 2017). To find out the value of a payback period can be calculated using Equation 7.

$$PaybackPeriod = \frac{Investmentcosts}{yearlyincome} \quad (7)$$

Before knowing the value of the payback period, first know the value of yearly income from the sale of electricity. Income from electricity sales can be calculated using Equation 8. The selling price of renewable electricity for the Java region as a whole is Rp.911 per kWh (Negara, 2016).

$$Income = totalenergyproductionxsellingprice \quad (8)$$

Where:
Payback period : Return on capital (year)
Investment costs : Capital issued (Rp.)
Yearly income : Income earned per year(Rp.)
Total energy production: Electricity produced by generator per year (Rp.)
Selling price : Costs incurred per kWh (Rp.)

3 EXPERIMENTAL METHOD

The flow chart in this study can be seen in Figure 1.

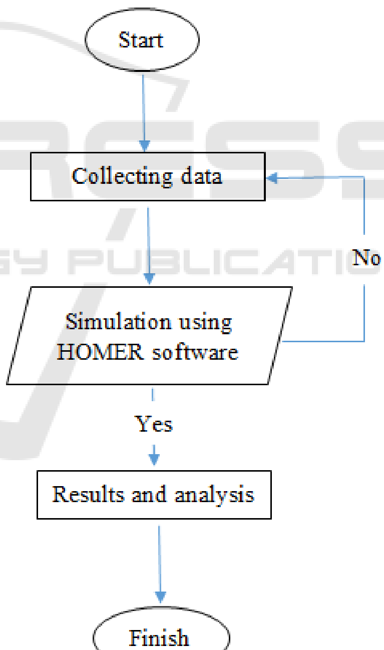

Figure 1: Research flow diagram

In the first step in completing this research, it is collecting data. Data collected in the form of wind speed, solar intensity, and electricity energy consumption data (in a year). For wind speed and solar intensity data obtained from the NASA site. While the data on people electricity consumption is obtained from the PLN distribution in Bantul. In addition, additional data is needed in literature studies such as journals, papers (national and international), and books (Daryanto, 2007). This data is used as a reference in the completion of this research. In the second step, the data that has been obtained is then processed using Microsoft Excel. Data that is processed using Microsoft Excel is the data electricity consumption of people. This data processing aims to determine the overall amount of electricity consumption of people in a year. In the third step, simulating the HOMER software. This simulation aims to design a schematic of a hybrid power (HP) system and find out the amount of electrical energy generated from a HP system. After the HP system is designed, then enter the data that has been obtained on the HP system designed in the HOMER software.In the last step, the data entered on the HP system is then analyzed by HOMER software (Betha et al., 2017). The results of the analysis of the HOMER software in the form of the amount of electricity generated, the net present cost (NPC), and others. In addition, the results of the HOMER software analysis are to produce an optimal system (Tong, 2010).

3.1 System Design

In designing schematic hybrid power (HP) generation systems there are several components used, namely wind turbines, solar cells, batteries, and converters. The design of the HP system can be seen in Figure 2.

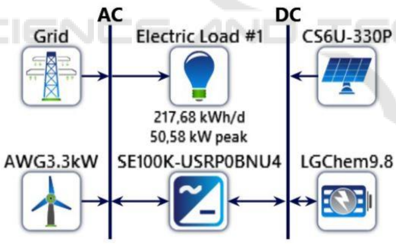

Figure 2: Schematic design of HP systems

3.2 Components of HP Systems

3.2.1 Wind Turbine

Wind turbines used to design schematic HP systems are 3 pieces aleko WG3000 3000W wind power generator and can be used for 20 years.

3.2.2 Solar Cell

The solar cell used in the schematic design of the HP system are 273 pieces of CanadianSolar MaxPower CS6U-330P types and can be used for 25 years.

3.2.3 Baterai

Batteries used in schematic HP systems are 10 pieces of LGChem RESU10 9,8kWh battery types and can be used for 10 years.

3.2.4 Inverter

Inverters used in schematic design of HP systems is 1 pieces of SolarEdge 100kW 277/480V 3-phase inverter and can be used for 15 years.

3.3 Parameters Used

3.3.1 Wind Speed

Wind speed data in this study were obtained from the NASA site. Where, the data used is monthly average wind speed data in a year. Wind speed data can be seen in Figure 3.

Month	Wind speed (m/s)
January	6,655
February	6,730
March	5,740
April	5,210
May	6,930
June	6,385
July	5,630
August	5,820
September	5,915
October	5,670
November	4,455
December	7,730

Figure 3: Monthly Wind Speed Data.

3.3.2 Solar Radiation

Solar radiation data in this study were obtained from the NASA site. Where, the data used is monthly average wind speed data in a year. Solar radiation data can be seen in Figure 4.

Month	Solar radiation (kWh/m^2/day)
January	6,070
February	3,860
March	5,340
April	6,690
May	5,120
June	4,860
July	5,490
August	5,630
September	6,560
October	6,780
November	7,040
December	2,550

Figure 4: Monthly Solar Radiation.

3.3.3 Load Data

Load data in this study were obtained from PLN Bantul distribution. The load data used is monthly average electricity consumption (kWh) of the people in a year. The amount of load data used are 100 data samples. After the load data is obtained then input using HOMER software. The window for inputting load data in the HOMER software can be seen in Figure 5.

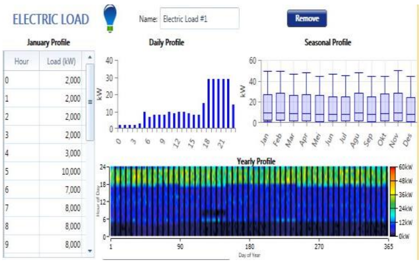

Figure 5: Load setting window

4 RESULTS AND ANALYSIS

4.1 Effect of Parameters on Hybrid System Design

There are 3 parameters used in designing the hybrid power generator system, including wind speed, solar radiation, and electricity consumption of the people. These three parameters greatly affect system output. If one of the parameters does not meet the standards for hybrid power generator constituent components, the performance of the system does not work optimally.

4.2 Results of Schematic Optimization of Hybrid Power Generator

The optimization results aim to determine the variable level of the main components in hybrid power generator when operating. Where, the optimization results were obtained when the simulation process in the HOMER software was finished running. Figure 6 shows the results of variable optimization of each component contained in the hybrid power generator schematic design.

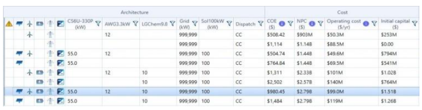

Figure 6: Results of hybrid power generator schematic design optimization

4.3 Total Energy Production

Component	Production (kWh)	Efficiency (%)
Canadian Solar MaxPower CS6U-330P	91.058	41
aleko WG3000 3000W *wind power* generator	97.024	43,7
Grid	33.784	15,2
Total	221.866	100

Figure 7: Total Energy Production.

Based on Figure 7, the total production of electrical energy from wind turbines is greater than solar cell. It can be happen because the output power of the wind turbine is greater than the solar cell which is 43.7% in producing electrical energy even though the number of wind turbines used is less than that of the solar cell while the solar cell produces electricity is 41%.

4.4 Net Present Cost (NPC)

The total cost used for components in the installation project or the operation of hybrid power generator is Rp. 2,789,010,087. The distribution of component cost can be seen in Figure 8.

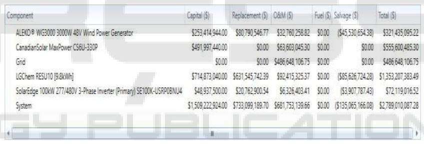

Figure 8: Distribution cost of Net Present Cost

4.5 Annualized Cost (AC)

Total annual costs incurred from the hybrid power generator system is Rp.215,742,140.17. The annualized cost value will be used to determine the Cost of energy value. The distribution of annual costs of components from system design can be seen in Figure 9.

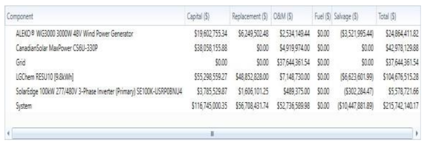

Figure 9: Distribution of annual component costs

4.6 Cost Of Energy (COE)

Cost of energy was calculated to determine the cost incurred per 1 kWh of the system design. The cost ofenergy generated from a hybrid system simulation uses a HOMER is Rp.980/kWh.

$$COE = \frac{TotalAC}{Totalenergyproductionsystem} = \frac{Rp.215.742.140}{221.866kwh} = 972perkwh \quad (9)$$

4.7 Renewable Penetration

Renewable penetration is used to determine the performance of wind turbine and solar cell in generating electricity (Lambert et al., 2006). To determine the performance of wind turbine and solar cell can be known by using equation 5. The amount of electrical energy generated from renewable energy components can be seen in Figure 10.

Component	Production (kWh)
Canadian solar maxpower CS6U-330P	91.058
AWG HC 3,3 kW wind turbine	97.024
Total	188.082

Figure 10: Electrical Energy Produced From Renewable Energy Components.

$$RP = \frac{E_{tot.RES}}{E_{tot.sys}} x100\% = \frac{188.082}{221.866} x100\% = 84,8\% \quad (10)$$

Based on the calculation of renewable penetration, the performance level of the hybrid power generator components is 84.8% in generating electricity from the total electricity produced.

4.8 Sector of Electricity Use from the Hybrid Power Generator System

Electrical energy produced from the hybrid power generator system, besides being used for the electricity needs of the Wonoroto Hamlet people is also used for the needs of tourists who come in tourist attractions located in Gadingsari Village, Bantul, such as providing charging station facilities at tourist attractions in Gadingsari Village.

4.9 Payback Period

To find out the time needed to restore development cost capital can be calculated using Equation 7 and Equation 8.

$$Income = Totalenergyproductionxsellingprice = 221.866x911 = 202.119.926,00peryear. \quad (11)$$

$$Paybackperiod = \frac{investmentcost}{yearlyincome} = \frac{2.789.010.086}{202.119.926} = 13year8month \quad (12)$$

The payback period to recover the cost of capital spent to build a hybrid power generator in Wonoroto Hamlet for 13 years 8 months.

5 CONCLUSIONS

1 Total electricity generated from a hybrid power generator system as a electricity provider of people reserves is 221,866 kWh per year.

2 Electricity generated from the design of the hybrid power generator system is sufficient for the electrical energy use of the people in Wonoroto Hamlet.

3 The hybrid power generator (bayu-solar cell) is feasible to be built as a electricity provider of people energy reserves in Wonoroto Hamlet because the amount of electricity produced is greater than the people electricity usage of 110,235 kWh per year and the payback period for the construction of power is less than time project planning.

4 Hybrid power generator (wind-solar cell) can supply renewable energy at 84.8% of the total electricity produced

REFERENCES

Arota, A. S., Kolibu, H. S., and Lumi, B. M. (2013). Perancangan sistem pembangkit listrik hibrida (energi angin dan matahari) menggunakan hybrid optimization model for electric renewables (homer). *Jurnal MIPA*, 2(2):145–150.

Aziz, A. S., Tajuddin, M., and Adzman, M. (2018). feasibility analysis of pv/wind/battery hybrid power generation: a case study. *Int. J. Renew. Energy Res*, 8(2):661–671.

Betha, D., Satish, M., and Sahu, S. K. (2017). Design and control of grid connected pv/wind hybrid system using 3 level vsc. In *2017 IEEE 7th International Advance Computing Conference (IACC)*, pages 466–471. IEEE.

Daryanto, Y. (2007). Kajian potensi angin untuk pembangkit listrik tenaga bayu. *Balai PPTAGG-UPT_LAGG*.

ESDM (2017). Peraturan menteri energi dan sumber daya mineral no. 177 k/70/mem/2019.

Kunaifi, K. (2015). Program homer untuk studi kelayakan pembangkit listrik hibrida di propinsi riau. In *Seminar Nasional Informatika (SEMNASIF)*, volume 1.

Lambert, T. et al. (2006). Micropower system modeling with homer", in integration of alternative sources of energy by felix a. farret and m. godoy simoes.

Negara, P. L. (2016). Peraturan menteri energi dan sumber daya mineral no.28 tahun 2016.

Suherman, A., Priane, W. T., Salmah, A., and Rosdiansyah, R. (2017). Studi kelayakan pembangkit listrik tenaga hibrida di pulau panjang. *Gravity: Scientific Journal of Research and Learning Physics*, 3(1).

Tan, D. and Seng, A. K. (2011). Handbook for solar photovoltaic (pv) systems. *Published by Energy Market Authority, Building and Construction Authority*, pages 4–7.

Tangirala Venkat, K. (2017). Solar wind, hybrid renewable energy systems. *Publisher: IEEE, India Info*, 12(2).

Tong, W. (2010). *Wind power generation and wind turbine design*. WIT press.

Yasuha, J. X. L., Saifi, M., et al. (2017). *Analisis Kelayakan Investasi Atas Rencana Penambahan Aktiva Tetap (Studi Kasus Pada PT Pelabuhan Indonesia III (Persero) Cabang Tanjung Perak Terminal Nilam)*. PhD thesis, Brawijaya University.