SOLAR AND WIND ENERGY MODELLING FOR CENTRAL BANGKA REGENCY, BANGKA BELITUNG PROVINCE

Wahyu Edifikar[1*], Bertha Maya Sopha[2], Ahmad Agus Setiawan[3]

[1]Computer Engineering, Faculty of Engineering, Universitas Nahdlatul Ulama Yogyakarta
[2]Mechanical and Industrial Engineering Department, Faculty of Engineering, Universitas Gadjah Mada
[3]Engineering Physics Department, Faculty of Engineering, Universitas Gadjah Mada
*Correspondence: edifikar.w@unu-jogja.ac.id

Abstract

Central Bangka is a developing regency in Bangka Belitung Island Province. Geographically Bangka Belitung Islands is not far from the equator. The development of human resources and infrastructure for the energy sector is an integral part of regional development efforts. To fulfill the district's energy, we need to look at the potential of renewable energy such as wind power and solar power within the district. This research also provides the potential renewable energy capacity configuration through a simulation.

This research used the simulation approach method to map the energy demand over the district and renewable energy available in the region. Energy demand data received from the National Electrical Company (PLN) of Bangka Belitung Province, and potential renewable energy data were obtained from the Ministry of Energy and Mineral Resources of The Republic of Indonesia and the NASA website. Software HOMER is used to analyze electrical energy potential from renewable energy sources.

The simulation shows wind energy could provide 0.15 – 0.19 kW and solar power at 3.99 – 4.96 kW/m^2/day. The optimum configuration of energy supply consists of 61.4% solar energy and 38.6% wind energy. The hybrid configuration above using the solar photovoltaic (PV) output of 286,981 kWh/year and wind generator output of 180,758 kWh/year and an estimated value of $1,663,598.53 for capital cost, $134,548.34 of operational cost, and cost of energy generated at $0.43/kWh.

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1. Introduction

Fossil fuel (such as oil, coal, and natural gas) with limited supply is Indonesia's primary energy source. Renewable energy sources must be used as a solution to fulfill the energy demand. In 2013, there are many new and renewable energy policy changes, technology development, and deployment in the world, including Indonesia (Zervos et al., 2016). Setiawan et al. (2008) designed a mini-grid hybrid power system to supply electrical energy in meeting a demand for clean water in the remote Maldives. Khan and Iqbal (2005) examined the complete measurement of a battery-diesel-battery PV-wind-fuel cell-diesel system for remote home areas in Newfoundland, Canada.

In Indonesia, colossal wind and solar energy boost new and renewable energy research at Central Bangka Regency in Bangka Belitung Province (Kusdiana, 2016). Wind blow at a speed rate of 6.3 knots (3,24 m/s) and maximum speed at 10.7 knots (5.5 m/s) In the Bangka Tengah district. Meanwhile, solar intensity ranged between 28.1% to 86.1% (RPJMD Central Bangka Regency, 2010-2015).

PT. PLN (Persero) Bangka Belitung area is the leading electrical energy supplier in Bangka Tengah district, using a Diesel engine to produce the electricity. The electrical energy supply for Bangka Tengah district has 7.5 MW (7.511 kW) with energy production at 37,985,654 kWh and power wattage demand at 24,072,350 kVA and increasing (PLN Bangka Belitung area, 2015).

This study aims to describe and design the potential mix of wind and solar renewable energy sources as a power generation source. Wind and solar energy utilization are expected to support PLN to provide electricity supply in Central Bangka Regency.

2. Methodology

This research has some steps, preliminary studies, problem identification, data collection, data preparation, analysis, and conclusion withdrawal. Preliminary studies identify the problem with some book studies concerning potential, technology, and references and then determine the research goal.

In the identification step, an observation for wind and solar energy is done to fulfill the research's goal. This modeling aims to give some perspective of combined renewable energy power plant configuration, so the optimization method was used. HOMER software helped to provide some view of the current condition from data gathered. Simulation results are based on an economic and technical issue. The modeling approach in this study uses the optimization approach (Neshat et al., 2014).

The data in this study is used as input data in a hybrid system power plant simulation. It consists of diesel power plant electrical condition of Bangka Belitung area, load, wind energy potential, and solar energy potential. Aside from primary data, there will be secondary data such as population, maximum load demand, existing electrical infrastructure, and existing renewable energy infrastructure in Central Bangka Regency. Data for research gathered from many sources, some from Energy and Mineral Resources Ministry (ESDM), National Aeronautics and Space Administration (NASA), Meteorological and Geophysics agency and some other agencies in regards to renewable energy for Central Bangka Regency, as well as international institution such as National Aeronautics and Space Administration (NASA).

Hybrid Optimization Model for Electrical Renewable (HOMER) was used in this research. HOMER is a software that helps to optimize and analyze the hybrid power plant. Data were categorized and simulated with the help of HOMER software. With HOMER's ability at hybrid power plant modeling, a conclusion for the most optimum

configuration can be seen based on energy resources data and electrical energy usage data gathered. Solar and wind potential data as a critical input in simulation. In the HOMER
itself, the value of electricity generation using PV can be calculated by Formula 1, whereas the generation of electricity by a wind turbine is calculated by Formula 2 (Lambert, 2005).

$$P_{PV} = f_{PV} \times Y_{PV} \times \frac{GT}{GT_{STC}} \qquad (1)$$

where: P_{PV} = PV power production (W); Y_{PV} = power output testing with standard conditions (kW); F_{PV} = PV derating factor (%); GT = moment radiation surface of PV array (kW/m^2); $GT_{,STC}$ = instantaneous radiation according to standard test conditions (1 kW/m^2).

$$P_{turbin} = 0{,}5 \times \rho \times A \times v^3 \times \eta \qquad (2)$$

where: $P_{turbine}$ = power production (W); ρ = air density (Kg/m^3); A = the area of the turbine (m^2); V = wind speed (m/s); η = efficiency (%)

HOMER's main job was to simulate, optimize, and sensitivity analysis. The model was simulated at every hour for a year to see the efficiency factor, viability, and cost-effectiveness. The optimization method used analyzed the most cost-effective system combination, which fulfills the technical requirements. Sensitivity analysis analyzes the effect of different inputs such as load demand, fuel cost, sun radiation, and average wind speed (Zoubeidi et al., 2012).

The simulation was analyzed and determined to be the best combination of renewable energy potential and electrical energy demand in Central Bangka Regency. The operational implication to the current electrical condition in Bangka Tengah Regency was told at the end.

3. Result and Discussion

This hourly load usage was from PLN Bangka Belitung area which supply 7 area (Koba, Simpang Katis, Lubuk Besar, Sungai Selan, Namang, Pangkalan Baru and some of Pangkal Pinang). Residential usage was the highest. Figure 1 below shown the profile.

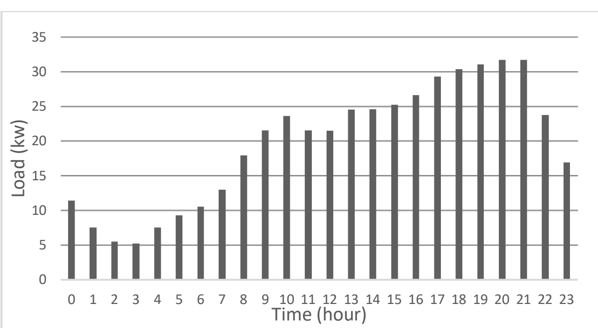

Figure 1. Daily Electrical Energy Consumption Profile

The location for this research was obtained based on wind speed and surface temperature data from Energy and Natural Resources Ministry in collaboration with Denmark Researcher (DANIDA). Figure 2 is the wind speed map, and Figure 4 is the surface temperature map.

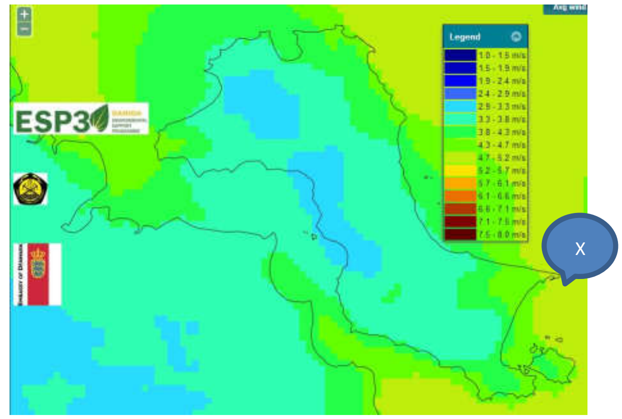

Figure 2. Wind Speed Map

The potential for wind energy is based on wind speed and wind availability. Daily wind speed is shown in Figure 3.

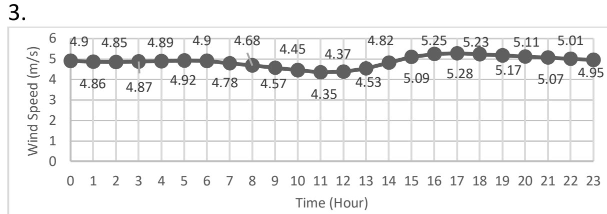

Figure 3. Daily Wind Speed

The potential data of solar radiation taken from the NASA website is already connected to HOMER. The potential of solar energy is considered from the amount of solar radiation shown in Figure 5.

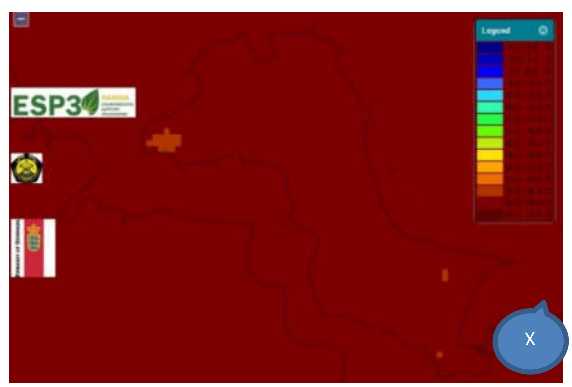

Figure 4. Surface Temperature Map

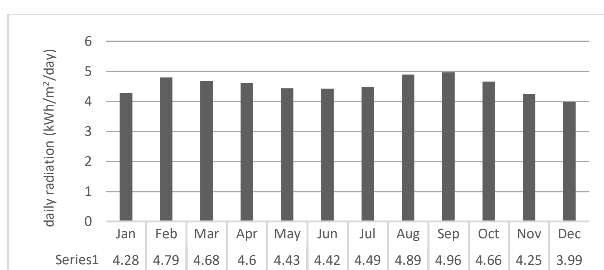

Figure 5. Daily Radiation Solar Level

Inputs on HOMER are electric load data, wind speed data, solar radiation data, earth surface temperature, and diesel fuel prices. Some supporting parameters as simulated controllers in HOMER are component cost (initial cost, replacement cost, O & M), emission penalty, component age on system, loading schedule, efficiency, and system components' capacity. HOMER simulation output is hybrid system configuration, NPC, COE, operating cost, Capital Cost, Renewable fraction, and an electrical generated part of the simulation device. The HOMER modeling flow is shown in Figure 6.

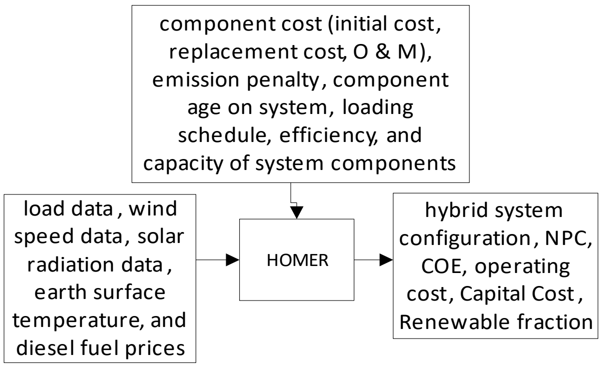

Figure 6. HOMER Modeling Flow

HOMER simulation schematic is shown in Figure 7. The components used in this research simulation are electrical load, diesel generator, PV, wind turbine, converter, lithium battery.

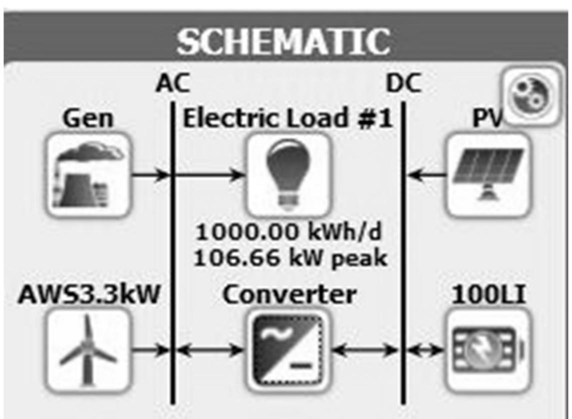

Figure 7. HOMER Simulation Schematic

There are four sensitive variables as input for HOMER simulation. Those are diesel fuel cost, wind speed, solar radiation, and daily load demand.

Table 1. Sensitive Variable

Diesel Fuel Price	$/L	0.7	1.4	2.0
Solar Radiation	kWh/m^2/day	2.50	4.54	5.50
Wind Speed	m/s	2.50	4.90	7.00
Load	kWh/day	1,000	1,250	1,500

HOMER simulation results used net present cost for the primary reference. But still, open to the best choice to put into consideration based on the simulation. The most efficient power plant configuration is based on the economic and renewable energy factors shown in Table 2.

Table 2. Simulation Result Configuration

PV (kW)	AWS (kW)	Gen kW	100 LI	COE ($)	NPC ($) (k)	Op cost ($)	Capital ($) (k)
216.53	46		8	0.43	1,849	14,563	1,663
181.98	40	120	7	0.45	2,106	48,756	1,483
328.64			16	0.51	2,194	3,446	2,150
272.52		120	8	0.50	2,330	67,690	1,465
	67	120	2	0.50	2,353	120,250	816
		120	1	0.64	2,970	220,513	151
143.28	48	120		0.66	3,065	166,053	942
	76	120		0.66	3,084	183,083	744
166.83		120		0.67	3,124	198,714	584
		120		0.69	3,197	245,420	60
	244		12	0.85	3,640	44,040	3.077

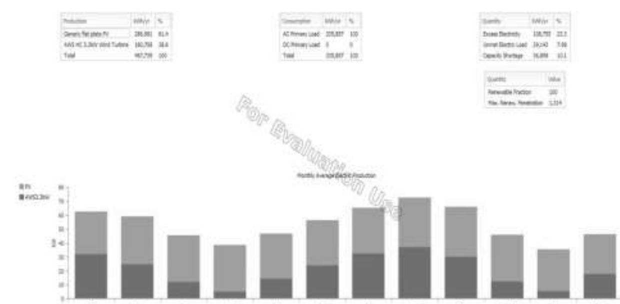

Figure 8. Electrical Production Result

The simulation result in Figure 8 showed 100% energy supplied by renewable energy with 61.4% solar energy and 38.6% wind energy. Electricity energy produced at 467,739 kWh/yr with PV at 286,981 kWh/yr, and wind turbine produced 180,758 kWh/yr. Total electricity energy consumption at 335,857 kWh/yr and yield an excess of 180,758 kWh/yr (23.3% from total energy produced). Economic comparison between diesel generator and renewable energy are shown in Table 3 below.

Table 3. Comparison of 1 Diesel Generator with PV + Wind Turbine

	Generator	PV+wind turbine
COE (S/kWh)	0.68	0.43
NPC ($)	3,197,302	1,849,774
Operating Cost ($)	245,420.8	14,563.86

	Generator	PV+wind turbine
Fuel Cost ($)	180,654	0
Capital Cost ($)	60,000	1,663,599
Renewable fraction (%)	0	100

The capital cost of using renewable energy is very high compared to 1 diesel engine (at $1,603,599). But when other factors such as production cost, renewable fraction, and operating cost are put into account, then renewable energy could be the best choice. The Bangka area's electricity tariff is at $0.1366/kWh (Rp 1,819/kWh). Suppose compared to renewable energy tariff which at $0.43/kWh then electricity tariff provided now already very cheap.

New technology must be applied to reduce the price, increasing energy output per plant, and cooperate with an investor is needed or subsidized by the government. In the simulation with the hybrid system, no emissions are found, or in other words is 0, another case with generators using generators. Table 4 shows the emissions generated by generators using generators of the same load for hybrid plants.

Table 4. Diesel Generator Emission

Emission	Quantity (kg/year)
Carbon Dioxide	337.774
Carbon Monoxide	2.129
Unburned Hydrocarbons	92,9
Particulate Matter	12,9
Sulfur Dioxide	827
Nitrogen Oxides	2.000

4. Conclusion

Central Bangka Regency has 3.99 to 4.96 kWh/m^2/day of solar energy and wind energy at 0.15 to 1.09 kW. Modeling results with load increased variations from 25% to 50% stated that the hybrid power plant can supply the whole demand with a composition of 61.4% solar energy and 38.6% wind energy. Recommendation from HOMER simulation and modeling for solar and wind energy showed a configuration of PV with output at 286,981 kWh/yr and wind turbine with a result of 180,758 kWh/yr. Capital cost to make the plant was estimated at $1,663,598.53 and operational cost at $134,548.34, so production cost (COE) is at $0.43/kWh.

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