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Economic Operation of Hybrid Power Plant The Wind In Bantul D.I. Yogyakarta

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Abstract
Hybrid Power Plants (PLTH) are power plants consisting of PLTS with wind turbines. The Bayu Baru PLTH must be regularly evaluated because the PLTH components are susceptible to damage. This evaluation aims to ensure that electrical energy continuity is maintained. PLTH performance can be measured through the performance of each generation component. The performance of PLTH solar panels and wind turbines can be measured from the output power of these components. With HOMER software simulation, you can calculate the economic level of a hybrid generating system based on the lowest NPC value. Simulation results with HOMER software show that the most economical generating components in PLTH are wind turbines with a capacity of 5kW and 2.5kW based on LCOE values of $0.190 and $0.171/kWh.

Abstrak
Pembangkit Listrik Tenaga Hybrid (PLTH) Bayu Baru adalah pembangkit listrik yang terdiri dari PLTS dengan panel surya dan PLTB dengan turbin angin. PLTH Bayu Baru secara rutin harus dievaluasi karena komponen-komponen PLTH Bayu Baru yang rentan terhadap kerusakan dikarenakan hampir semua komponen pembangkitan berada di lapangan. Evaluasi ini bertujuan agar kontinyuitas penyaluran energi listrik tetap terjaga. Kinerja PLTH Bayu Baru dapat diukur melalui kinerja tiap komponen pembangkitannya. Kinerja panel surya dan turbin angin PLTH Bayu Baru dapat diukur melalui daya keluaran dari komponen tersebut. Simulasi software HOMER dapat menghitung tingkat ekonomis dari PLTH Bayu Baru dan dapat mengoptimasi desain sistem pembangkit hybrid berdasarkan nilai NPC terendah. Hasil simulasi dengan software HOMER, keseluruhan sistem PLTH Bayu Baru dengan project life time 25 tahun membutuhkan NPC sebesar $ 583.569, dan COE sebesar $ 1,198/kWh. Komponen pembangkit yang paling ekonomis pada PLTH Bayu Baru adalah turbin angin berkapasitas 5kW dan 2,5kW didasarkan pada nilai LCOE $ 0,190 dan $ 0,171/kWh .

Kata kunci : Evaluasi, Optimasi, Hybrid

INTRODUCTION

The geographical location of Baru Beach on the southern coast of Java Island which directly faces the Indian Ocean has the potential for renewable energy from solar energy sources that shine all day long and wind energy with an average wind speed intensity of 4 m/s[1]. This condition is quite feasible to be used as a hybrid energy source [4]. This has been implemented through the construction of the Bayu Baru PLTH which is the result of collaboration between the government, the private sector, universities and the surrounding community.

This research aims to analyze the performance of wind turbines and solar panels at the Bayu Baru PLTH, determine the optimal potential for renewable energy (wind energy and solar light) at the Bayu Baru PLTH, conduct a performance analysis of the Bayu Baru PLTH system using HOMER software to off-grid conditions, configuring to optimize the performance and economics of the Bayu Baru PLTH system through HOMER simulation for off-grid conditions [4].

METHOD

Bayu Baru PLTH Simulation Using HOMER Software

Bayu Baru PLTH Daily Load

The Bayu Baru PLTH model will be simulated using main load data. The average electricity load at the Bayu Baru PLTH is 3.57 kW with the average consumption of electrical energy used being 85.6 kWh per day. The peak load that may occur is 13.3 kW in one year.

Solar Energy Potential

The potential of solar energy as an energy source is expressed in brightness index data (Clearnex Incex) and solar radiation (Solar Radiation), namely the global average of solar radiation on a horizontal surface, expressed in kWh/m2, for each day of the year.
Data on solar energy potential for the Bayu Baru PLTH location obtained an average brightness index of 0.483 and an average Daily Radiation of 4.802 kWh/m2/d.

Wind Energy Potential

Based on wind energy potential data obtained from the anemometer data logger at the Bayu Baru PLTH location, the average wind speed at Baru Pandansimo Beach measured from a height of 15 meters from the ground is 3.42 m/s.

New Off-grid Bayu PLTH Model

The Bayu Baru PLTH model that will be simulated is the entire Bayu Baru PLTH system. The overall system model at the Bayu Baru PLTH, consists of 29 kW solar panels and 61 kW wind turbines consisting of 27 1 kW wind turbine units, 2 2 kW wind turbine units, 2 2.5 kW wind turbine units, 1 5 wind turbine unit kW and 2 10 kW wind turbine units as well as battery and inverter components

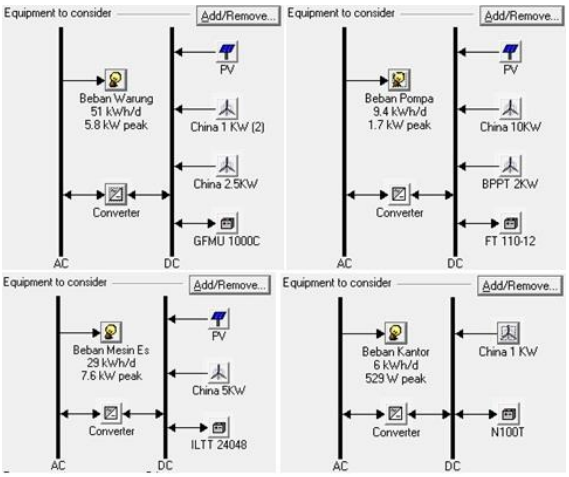

Figure 1 Hybrid system model

Wind Turbines

The wind turbine used is type 3 Blades Upwind with 6 capacity variations, namely 1kW 240V, 1kW 48V, 2kW 240V, 2.5kW 240V, 5kW 240V, and 10 kW 240V. The following are the costs incurred for a wind turbine installed 15 meters above the ground and with a life time of 10 years.

Table 1 Wind Turbine Component Costs

Wind turbine	Units	Cost (US$)		
		Capital	Change	O&M
1kW/48V	6	27.045	16.048	250
1kW/240V	21	101.261	63.125	632
2kW/240V	2	9.639	5.292	120
2,5kW/240V	2	10.025	6.252	100
5kW/240V	1	7.696	5.662	80
10kW/240V	2	32.139	25.680	340

Solar Panels

The solar panels used consist of 3 groups, namely the 15 kW 120V group, 10kW 48V, and 4 kW 240V. The following are the costs for solar panels.

Table 2 Cost of Solar Panel Components

Group Solar Panels	Cost (US$)		
	Capital	Change	O&M
15kW/120V	83.438	76.515	25
10kW/48V	54.149	46.850	15
4kW/240V	20.514	19.366	10

Inverters

The inverters used at the Bayu Baru PLTH consist of 3 units of handmade inverter 2 kW 48V, 3 units of Luminous Cruze inverter 3.5 kW 48V, 2 units of Luminous Jumbo inverter 7.5 kW 120V and 1 unit of Chinese inverter 5 kW 240V. So the total inverter capacity is 36.5 kW with capital costs of $ 8259, replacement costs of $ 4880 and operation and maintenance costs of $ 261.

Battery

The batteries used by PLTH Bayu Baru consist of 4 different types of batteries with a total capacity of 4260Ah, 360KW. The following are the costs for the battery.

Table 3 Cost of battery components

Battery	Units	Cost (US$)		
		Capital	Change	O&M
SkyBatt	60	13.056	10.931	150
Luminous	40	18.196	16.562	200
PowerFit	40	8.921	7.287	120
Sacred Sun	72	22.397	20.272	120

Restrictions on PLTH Operation

The economic constraints used when the PLTH system was simulated were the investment loan interest rate as of September 2016 of 11.01% [6], inflation of 5.8% [7], project term of 25 years. The system control limits in the dispatch strategy used are cycle charging with a setpoint states of charge of 80% and a maximum annual capacity shortage of 0.4%. The temperature limits on the other tab in HOMER are taken from air temperature data from the NASA website.

RESULTS AND DISCUSSION

PLTH configuration

This configuration consists of solar panel components with a capacity of 15 kW, 2 units of 2.5 kW capacity wind turbines, 6 units of 1 kW capacity wind turbines, and an inverter with a capacity of 16.5 kW.

The simulated configuration from HOMER can be calculated for the energy generated by all PLTS and PLTB components at the Bayu Baru PLTH. Apart from that, the overall costs of the system can be calculated.

Table 4 Maximum PLTH production in 1 year

Generator Type	Capacity (kW)	Average Output (kW)	Total Production (kWh/th)	LCOE ($/kWh)
Solar Panels	15	2,2	18.987	0,203
Solar Panels	10	1,43	12.516	0,317
Solar Panels	4	0,62	5.428	0,270
Wind Turbine 1 kW	21	2,5	21.547	0,538
Wind Turbine 1 kW (2)	6	0,81	7.139	0,438
Wind Turbine 2 kW	4	0,24	2.072	0,541
Wind Turbine 2,5 kW	5	0,72	6.306	0,191
Wind Turbine 5 kW	5	0,66	5.792	0,170
Wind Turbine 10 kW	20	2,4	20.608	0,202
Total	**90**		**100.395**	

The total capacity of PLTH is 90 kW, with solar panel capacity being 29 kW (32.2%) and wind turbine capacity being 61 kW (67.8%). The maximum electrical energy production that PLTH can produce in one year is 100,395 kWh, with solar panel output being 36,931 kWh/year (36.79%) and the total output of wind turbines being 63,464 kWh/year (63.21%).
This data can be seen that in PLTH, the electrical energy output from solar panels is more effective than the output from wind turbines. This is because the solar panel capacity is only 32.2% of the total PLTH capacity and can produce an energy output of 37.5% of the total PLTH output.
The PLTH load itself in the HOMER simulation in a year is 34,565 kWh or only about a third of the power that can be generated by PLTH 100,395 kWh. So there is excess power of around 65,830 kWh each year. In terms of the electrical energy generated, of course PLTH is far from effective.
In terms of the generation price for each component, the cheapest generation price is for a wind turbine with a capacity of 5 kW totaling 1 unit at a price of $ 0.170/kWh

Cost Summary

Of the entire existing PLTH system, the capital cost of the entire PLTH system is $ 398,277. The total replacement cost of existing components is $162,003. The overall system operation and maintenance cost is $36,403, and the residual cost of the system after a 25 year project time is $26,158. So the total NPC obtained is $ 583,569.

Table 5. Summary of overall costs of the PLTH system

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	130.289	0	704	0	0	130.993
China 1 kW	101.261	62.544	8.907	0	-9321	163.392
China 1 kW (2)	27.045	15.900	3.523	0	-2.370	44.099
China 2 kW	9.639	5.243	1.691	0	-781	15.792
China 2,5 kW	10.025	6.195	1.691	0	-923	16.988
China 5 kW	7.696	5.610	1.409	0	-836	13.879
China 10 kW	32.139	25.444	4.792	0	-3.792	58.583
Luminous	18.196	7.967	2.819	0	-1.630	27.351
Power Fit	8.921	3.505	1.691	0	-717	13.400
SkyBatt	13.056	5.258	2.114	0	-1.076	19.352
Sacred Sun	44.794	19.502	3.383	0	-3.991	63.688
Inverter	8.259	4.835	3.679	0	-721	16.052
System	**398.277**	**162.003**	**36.403**	**0**	**-26.158**	**583.569**

The COE (energy price) calculation uses the following stages. First you have to calculate the CRF (capital recovery factor) using the formula

$$CRF(i,N) = \frac{i(1+i)^N}{(1+i)^N - 1} \quad \text{.....(1)}$$

$$CRF(0{,}05;25) = \frac{0{,}05(1+0{,}05)^{25}}{(1+0{,}05)^{25}-1} = 0{,}07095$$

Second, you have to calculate the Cann,tot value with the equation

$$C_{NPC} = \frac{\text{Cann,tot}}{\text{CRF (i,Rproj)}} \quad \text{.....(2)}$$

$$Cann,tot = 583569 \times 0{,}07095 = \$\ 41404{,}22 \text{ / year}$$

The third step is to calculate COE (energy price) with the following equation

$$COE = \frac{C_{ann,tot}}{E_{prim\ AC}} \quad \text{.....(3)}$$

$$COE = \frac{41404{,}22}{34565} = \$\ 1{,}198/kWh$$

From the results of manual calculations using the same equation as HOMER, the price of electrical energy generated by PLTH is $ 1,198/kWh. This price is very expensive when compared to the price of electrical energy from the network which is only $0.138. The price of PLTH electricity can reach 10 times the price of grid electricity.

Comparative Analysis of 4 Groups and Combined Bayu Baru PLTH Systems

- Configuration of 4 New Bayu PLTH Group Systems

The current condition at PLTH Bayu is that the generation system is divided into 4 groups

Table 6 Simulation results for 4 PLTH load groups

load	Load/years (kWh)	NPC ($)	COE ($/kWh)	Energy (kWh/th)	Residual Energy (kWh/th)	Percent
Roadside stall	18.472	185.411	0,709	26.046	3.573	13,70%
Office	2.205	186.049	5,988	21.595	19.132	88,60%
Pump	3.446	111.735	2,301	25.345	21.380	84,40%
Ice Machine	10.402	106.449	0,726	17.488	5.515	31,50%

From the table above, it can be seen that the distribution of generating components for each group is uneven.

- Reconfiguration of Combined PLTH Systems

Combined reconfiguration of PLTH is a system where the sources of generation and load are made into 1.

Table 7 Results of the combined reconfiguration of the PLTH system

Load	Load/years (kWh)	NPC ($)	COE ($/kWh)	Energy (kWh/th)	Residual Energy (kWh/th)	Percent
Total	34.565	583.569	1,198	100.395	54.769	54,55%

From the table above, it can be seen that when all existing systems are combined into 1, it appears that there is 54.55% residual energy.

CONCLUSION

The potential for PLTH using solar panels and wind turbines with a capacity of 90 kW with the existing solar energy potential and wind speed, through the Homer PLTH software can produce a maximum electrical energy of 100,395 kWh/year. The entire PLTH system with a project duration of 25 years produces an NPC of $ 583,569, and a COE of $ 1,198/kWh. The most economical generating components seen from the initial capital costs and the energy generated are the 5 kW wind turbine and the 2.5 kW wind turbine. Combining the 4 Group PLTH system into one system will be more effective, because the continuity of the distribution of electrical energy to the load will be better maintained and more reliable. Suggestions for development from this research could be in the form of planning a new hybrid power plant for the needs of the surrounding community.

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