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Planning of Hybrid Power Supply System based on Renewable Energy using HOMER

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Abstract

This paper presents results of planning of hybrid power supply system based on renewable energy (RE) to supply loads (electricity customer) at remote village which PLN's (state electric company) electric distribution is not installed yet. Configuration of system had been planned contains alternative of component of generator set-diesel, small wind turbine (SWT) battery charging, battery, converter/inverter, and photovoltaic (PV). Planning was done using HOMER software. After all of needed data were inputted, the best system configuration will be given by HOMER that is the configuration that has smaller total *net present cost* (NPC).

A case study has been planned is a hybrid power supply system for serving loads in remote villages at Kuta, Lombok Tengah District, Nusa Tenggra Barat (NTB) Province. Average is 8kWh/day with peak load is 1.6 kW and load factor is 0.205. HOMER gives optimum system configuration that is hybrid of two 1kW units of SWT, a 1kW unit of generator set-diesel, one 250 Ah, 6V unit of battery, and two 2kW units of converter/inverter, without PV. This configuration has US$ 30,404 of total NPC and US$ 13,500,- of initial cost. Average cost per kWh of useful electrical energy produced by the system (*cost of energy* (COE)) is US$ 0.815/kWh.

Keywords: hybrid power supply system, renewable energy, generator set, PV, small wind turbine battery, and inverter.

INTRODUCTION

Background

Indonesia is an archipelagic country consists of about 17,000 islands scattered around the equator, which is between 6º North Latitude – 11º South Latitude, and 95º West Longitude – 141º East Longitude. The largest islands are Sumatra, Kalimantan, Sulawesi, Java, Bali, Lombok, Sumbawa, Halmahera, Maluku, East Nusa Tenggara (NTT) and Irian Jaya Islands.

Power generations, transmission and distribution business is done by PLN (Perusahaan Listrik Negera). Until 2005, the total power plant in Indonesia was 25,218 MW, consisting of 21,768 MW (86.3%) owned by PLN and 3,450 MW (13,7%) owned by Private Electricity (IPP-Independent Power Producer). The growth of electricity demand during the last 10 years has reached an average of 6 - 9% per year. The national electrification ratio until 2005 was 54.8% [5].

One of the unsolved problems in island countries such as Indonesia is the difficulty of sharing electrical energy between islands, caused by the deep and long dividing straits. For example the Java Bali Electrical System with Lombok Electrical System which is separated by the deep and long Lombok Strait.

As a tropical country, Indonesia has the potential of solar energy with an average daily solar radiation of 4.8 kWh/m2/s. This energy can be used as a heater and power plant [2,3].

The potential of wind energy in Indonesia is generally small because wind speeds are generally low at around 3 - 8 m/sec. But in certain areas especially in eastern Indonesia, the wind speed is more than 5m/s [2,4,8].

The geographical location of Nusa Tenggara Barat Province is 115º46' East Longitude – 119º5' East Longitude, and 8º10' North Latitude – 9º5' South Latitude.

In order to raise the electrification ratio or reduce the energy crisis, the government has to issue energy-saving policies and encourage diversification and extensification of energy sources, among them renewable energy sources including: solar energy, wind energy, hydroelectric, biomass, biodiesel and geothermal energy [1].

Most of the people of NTB Province live in remote villages who have not been able to enjoy electricity. Field observations indicate that it is very difficult to find the electricity at the remote area.

Because the province of NTB has the potential of renewable energy (RE), such as solar radiation and wind speed, sufficient to generate electrical energy it is necessary to plan an (RE)-based hybrid power supply to serve loads in remote rural areas. It is also intended to support the Kyoto Protocol which highlights important issues about the deterioration of the greenhouse effect, global warming, and climate change caused mainly by exhaust fossil fuel pollution (Anonymous 1, Anonymous 7).

Indonesia is one of the signatories of the Millennium Development Goals (MDGs) declaration in September 2000. Therefore, Indonesia must be committed and consistent to implement the eight MDGs objectives: (1) tackling poverty and hunger, (2) achieving basic education for all, (3) promoting gender equality and empowering women, (4) reducing child mortality, (5) improving maternal health, (6) combating HIV/AIDS, malaria and other diseases, (7) ensuring environmental sustainability , (8) building a global partnership for the environment. Therefore, the addition of puskesmas units in backward rural areas supplied by an RE-based power supply system will support several MDGs goals, at least 4, 5, 6 and 7 [10].

The problem to solve is how to plan an RE-based power supply system to serve loads in remote areas by considering natural resources such as average solar radiation and average wind speed in NTB Province.

RESEARCH PURPOSES

This study aims to plan a hybrid power system based on renewable energy to serve loads in remote rural areas in NTB Province.

The planned hybrid power system configurations contain photovoltaics, small wind turbines (SWT), generator sets (gen-sets), bank batteries, and converters (inverters).

LITERATURE REVIEW

Several researchers and relevant departments have reviewed the potential of natural resources in NTB province as a first step for planning a renewable energy. The results of their studies gave different results although not significant.

Deptamben NTB (2005) [2] has measured the average wind velocity in several places, as shown in Table 1. The Department also informed that the average daily solar radiation in the NTB Province is 4.85 kWh / m^2/day.

Hauffmants (2005) informs that the average wind speed in Lombok Island is between 2 - 8 m/s. While solar radiation is 2100 kWh/(a m^2).

Table 1. Average wind speed in remote places in NTB province 2005 [2]

Places	Average speed (m/det)
Desa Selayar - Lotim	3.4
Doropeti – Dompu	3.6
Bajopulo – Bima	3.9
Sambelia – Lotim	4.1
Sonatu – Dompu	3.5
Tembere – Lotim	4.0
Giligede – Lobar	4.1
Pai, Sape – Bima	3.3
Sajang – Lotim	4.0
Kute – Loteng	5.3

RESEARCH METHODS

The methods used in this research are:

1. Determine the profile of loading of electrical equipment in a simple type of load,
2. Survey of literature or reports from relevant agencies, such as Deptamben NTB Province, Bappeda NTB Province, BPS NTB Province, PLN Region NTB, and BMG NTB Province. The survey was conducted to obtain the average radiation data of sunlight, the average speed of the wind, and the backward rural data in NTB Province.
3. Survey of new purchase price and maintenance cost per year from generator, battery, converter, PV module, and SWT through internet. This data is needed to determine the net present cost of each planned system configuration.
4. Input all data in the HOMER (Hybrid Optimization Model for Electric Renewable) software provided at National Renewable Energy Laboratory-NREL (www.homerenergy.com)
5. The running program result will result in a total net present cost (NPC) of the smallest containing the type and capacity of the system components.

THEORY OF SUPPORT

Annualized cost of a project component is the operating cost of the component plus annual capital and replacement costs during the project period.

The Initial Capital Cost of a project is the total funds needed to purchase the system components when the project starts.

The project cost replacement is the selling price of the project component at the end of the project life.

The Net Present Cost (NPC) of a project is the present value of the cost of installing and operating the system until the age of the project is completed. Total NPC is calculated by the following formula.

$$C_{NPC} = \frac{C_{ann,tot}}{CRF\,(i, R_{proj})} \qquad \text{..........(1)}$$

$$CRF\,(i, N) = \frac{i(1+i)^N}{(1+i)^N - 1} \qquad \text{..........(2)}$$

$$i = \frac{i' - f}{1 - f} \qquad \text{..........(3)}$$

with

CRF = *capital recovery factor*

$C_{ann,tot}$ = *total annualized cost* (\$/yr)

i = *interest rate* (%)

i’ = *nominal interest rate*

f = *annual inflation rate*

R_{proj} = *project life time* (yr)

N = *loan life* (yr)

Project life time is time period of project system including cost of operational system.

Cost of Energy (COE) is cost average per kWh using of electric energy produced by system.

$$COE = \frac{C_{ann,tot} - C_{boiler}E_{thermal}}{E_{prim,AC} + E_{prim,DC} + E_{def} + E_{grid,sales}} \quad .....(4)$$

with

C_{boiler} = *boiler marginal cost* ($/kWh)

$E_{thermal}$ = *total thermal load served* (kWh/yr)

$E_{prim,AC}$ = *AC primary load served* (kWh/yr)

$E_{prim,DC}$ = *DC primary load served* (kWh/yr)

E_{def} = *deferrable load served* (kWh/yr)

$E_{grid,sales}$ = *total grid sales* (kWh/yr)

HOMER uses project life time to calculate the annualized replacement cost and annualized capital cost of each component, as well as the total NPC of the system [6,7].

MATERIALS AND RESEARCH WAYS

All data mentioned above, including fuel price for generator, is input into HOMER version 2.2 Beta application software. Once HOMER is installed in a personal computer, this software can get online the average solar radiation data on all places in the world, as long as it is known geographically and the time division globally.

RESULTS AND DISCUSSION

The remote area as a place where the loads (the area where the planned power supply) will be built is in the remote countryside around Kuta, Central Lombok regency not yet reached by PLN's distribution network.

Some of the following data are required to be inputted into HOMER software.

1. Profile of Electricity Load

Loads need electricity for lighting, refrigerators, medical equipment, communications equipment, water pumps, sterilizers, and fans. Figure 1 shows the hourly loading profile per day of electrical equipment in a simplest type of clinic (load). The average daily load is 8 kWh / day.

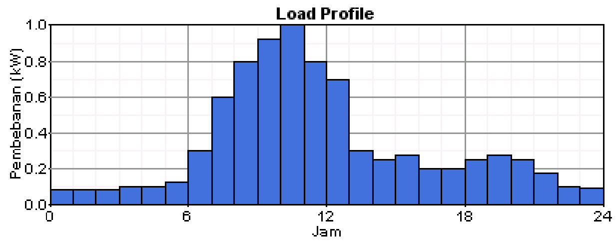


Figure 1. Profile of daily load of a clinic at remote area

2. Average Radiation of sunlight in NTB Province

This software can access online radiation data of the global average sunlight at a place by input geographic position and time division. By inputting the geographical location of NTB Province as mentioned above and dividing the time zone as in Bali (provided in the database), the data will be obtained as shown in Figure 2. The mean annual sun radiation is 5.17 kWh / m^2/day.

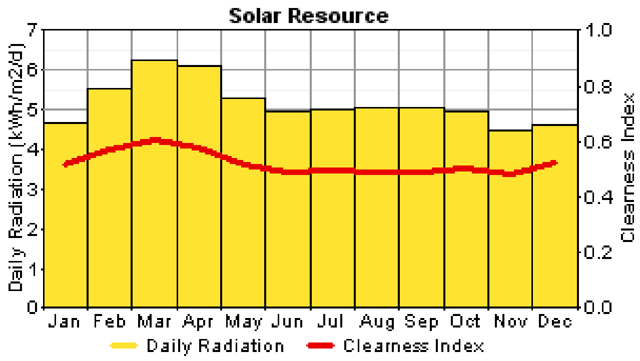


Figure 2. Average monthly solar radiation in NTB Province

3. Average wind speed in rural Kuta Lombok Tengah

The average monthly wind velocity profile in remote rural Kuta Lombok Tengah is shown in Figure 3. The average annual wind speed is 5.3 m/s.

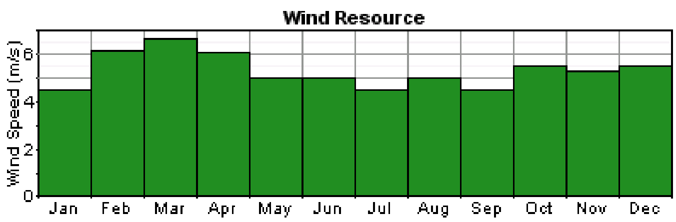


Figure 3. Average monthly wind speed in rural Kute Lombok Tengah

4. System configuration

The planned system has a configuration as shown in Figure 3. The commercially available system components have the following data.

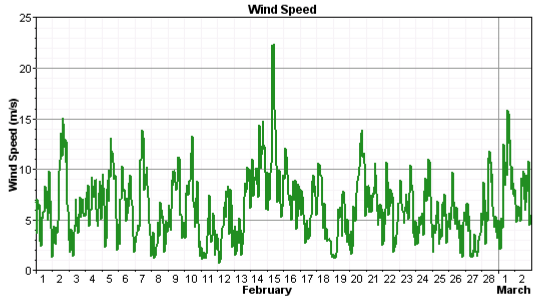


Figure 4. Average wind speed per hour at Kuta Beach Central Lombok in February 2005 (Anonymous 6)

Load Expenses (Beban Puskesmas (clinic)):

AC, one phase, 50 Hz, 220Vrms load, average load 8 kWh / day, peak load 1.6 kW, load factor 0.205.

Generator set (Gen1):

Capacity 1 kW, single phase, 50 Hz, 220Vrms, capital cost (capital) US $ 800, replacement cost US $ 600, operating and maintenance (O & M) US $ 0.025. Gen1: ac output, age 15000 hours, and minimum load ratio 30%, diesel fuel (US $ 0.5 / liter).

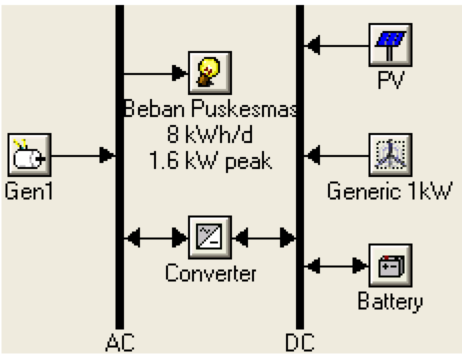


Figure 5. Configure the hybrid power supply system

Converter:

Capacity 2kW, capital $ 2500, $ 2500 replacement, O & M $ 20 / year, age 15 years, efficiency 90%.

Photovoltaic Module (PV):

Capacity 1 kW, capital $ 6900, $ 6900 replacement, O & M $ 0, age 20 years.

Small Wind Turbine -SWT (Generic):

Capacity 1 kW, capital $ 10000, $ 5000 substitute, O & M $ 150 / year, age 15 years, tower height 25 meters.

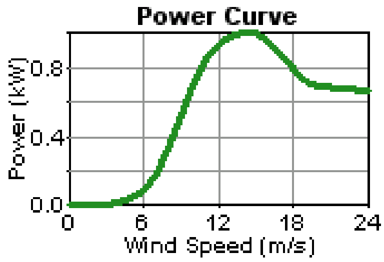


Figure 6. Wind turbine power curve

Battery:

Capacity 250Ah, 6V

The following are given some other instruments HOMER needs in decision making. Annual real interest rate of 6%, project age estimated 25 years, assuming there is no addition of electrical load.

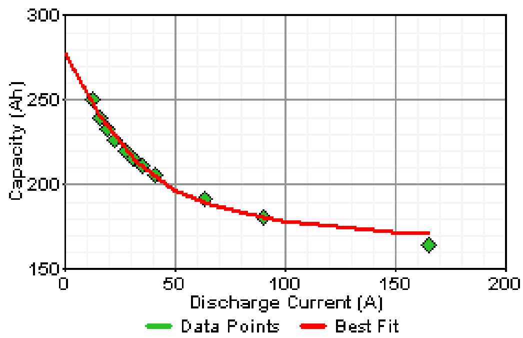


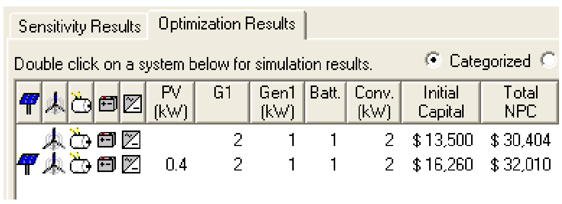
Figure 7. Battery charging characteristics

5. Planning Results

After inputting all the data above into software HOMER then the result of running program shown in Figure 8.

Figure 8 shows that the system configuration in Figure 5 turns out to be the preferred component, i.e. the component having the smallest NPC is US $ 30,404, consisting of two units of wind turbine (@ 1kW) with one generator unit, one battery unit, and two converter units (@ 2kW).

Details of all parameters of the hybrid system components and the air pollution generated by the generators are shown in the Appendix.


Sensitivity Results | Optimization Results

Double click on a system below for simulation results. Categorized

PV (kW)	G1	Gen1 (kW)	Batt.	Conv. (kW)	Initial Capital	Total NPC
	2	1	1	2	$ 13,500	$ 30,404
0.4	2	1	1	2	$ 16,260	$ 32,010

Figure 8. Results of system planning that gives the smallest total NPC

CONCLUSION

Referring to the average wind speed and solar radiation in remote rural areas of Central Lombok Kuta and other data mentioned above; the most optimum renewable energy system-based power supply configuration can serve the burden of loads (8 kWh/day, peak load 1.6 kW, and load factor 0.205) is a hybrid between two 1kW SWT units, a 1kW generator unit, a 250 Ah, 6V battery unit and two 2kW converters / inverter units, without PV. This configuration has a total NPC of US $ 30,404 and an initial charge of US $ 13,500. The cost of producing electrical energy per kWh (COE) is US $ 0.815 / kWh.

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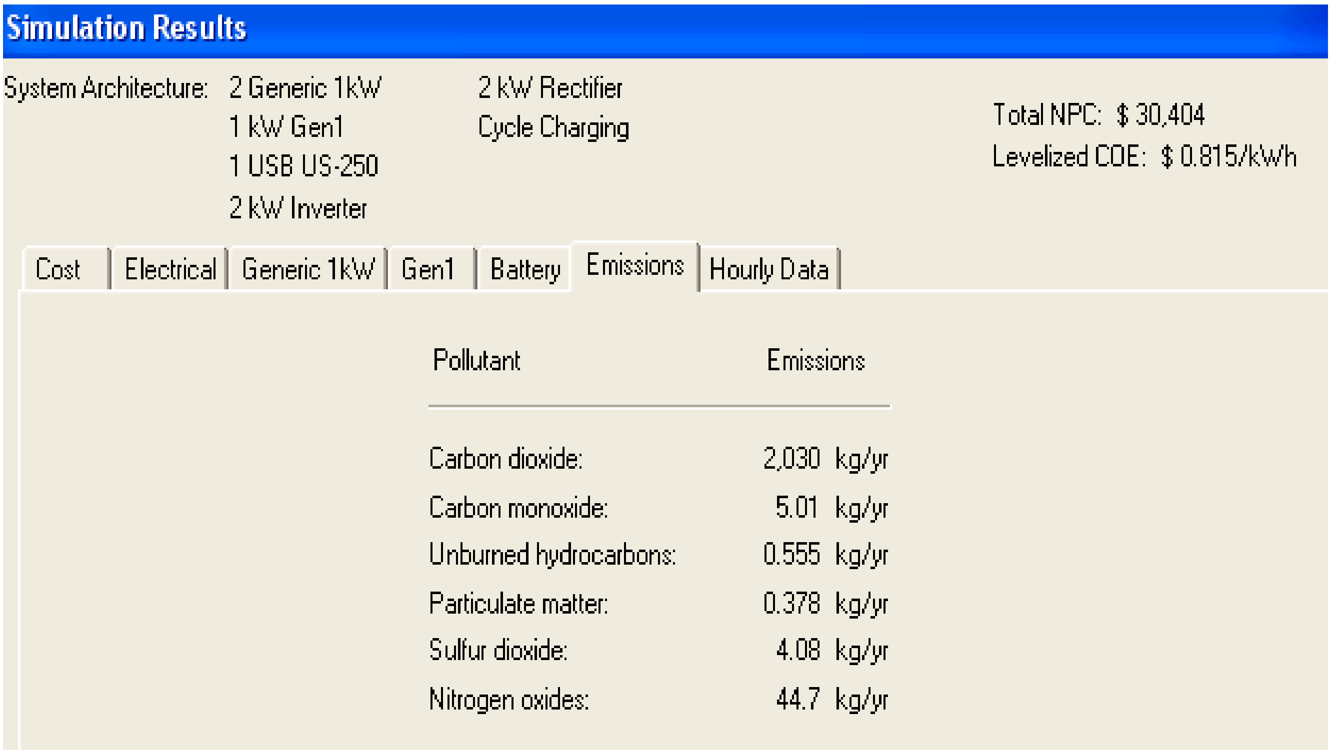
APPENDIX



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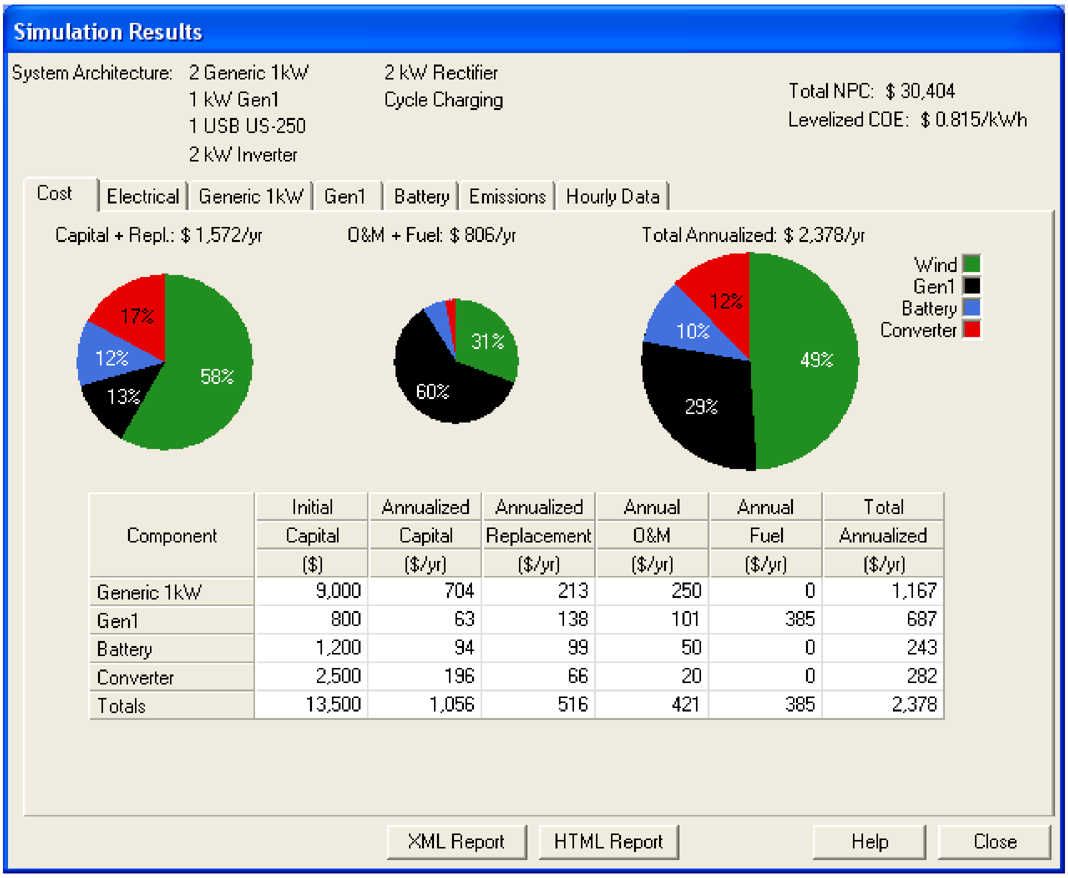

Component	Initial Capital ($)	Annualized Capital ($/yr)	Annualized Replacement ($/yr)	Annual O&M ($/yr)	Annual Fuel ($/yr)	Total Annualized ($/yr)
Generic 1kW	9,000	704	213	250	0	1,167
Gen1	800	63	138	101	385	687
Battery	1,200	94	99	50	0	243
Converter	2,500	196	66	20	0	282
Totals	13,500	1,056	516	421	385	2,378