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Renewable Energy Plan for Mutiara Residence using Hybrid Optimization Model for Electric Renewable

Hadi Sutanto Saragi
Faculty of Industrial Engineering, Del Institute of Technology, Sitoluama, Indonesia

Abstract: Day after day the energy conservation sources declined to maintain the conventional sources of energy needed to do the incorporation of renewable energy sources. It can overcome constraints on sources of energy conservation that has begun to decline. Mutiara residence since, 1990 using the energy generated by the diesel generators. Mutiara residence has already started to discuss about the utilization of wind turbine generator and also use solar PV as a source of renewable energy that will be used. Research has been performed using a non linear algorithms MADS it is done to conduct the examination of the most cost effective or optimal configuration between a set of systems that are used with electricity needs were supplied 2.205 kWh/day. In addition, research is also conducted to estimate that if either the hybrid system power plant will benefit for the investor in a period of 10 years.

Key words: Solar PV, wind turbin generator, diesel generator, optimization, power plant, configuration

INTRODUCTION

Mutiara residence is located in North Sumatera, Indonesia at 3°36'54.04" North latitude and 98°42'55.60" East longitude. Mutiara residence has long been supplied by diesel generator, unfortunately sometimes diesel generators unable to research properly because of a maintenance process, even worse, the diesel generator is found to be higly consumptive for oil and operational cost. Mutiara residence has enough solar and wind resources to utilize. Hybrid Optimization Model for Electric Renewable (HOMER) is a software has been used to find the best cost (US$) efficient based on hybrid renewable system configuration for the residence (EHOMER, 2011).

HOMER is a software that can be used to obtain the cost-efficient configuration based on renewable hybrid system for Residence. The load profile, solar radiation data, wind speed data, prices of the system components have to be provided to the software (EHOMER, 2011). HOMER execute hundreds or thousands of hourly simulations to ensure the best possible balance between supply and design in order to design the most optimum system (EHOMER, 2011) in order to observe the impact of changes of the parameters such as solar isolation variation, PV investment cost variation, wind speed and diesel fuel price variation on the optimum result, a sensitivity analysis can be applied (EHOMER, 2011). HOMER simulates the operation of a system by making energy balance calculations for each of the 8.760 h in a year (EHOMER, 2011). For each hour, HOMER compares the electric and thermal demand in the hour to the energy that the system can supply in that hour and calculate the flows of energy to and from each component of the system. For systems that include batteries or fuel-powered generators, HOMER also decides for each hour how to operate the generators and whether to charge or discharge the batteries. After simulating all of the possible system configurations, HOMER displays a list of configurations sorted by net present cost (sometimes called lifecycle cost) that can be used to compare system design options (EHOMER, 2011).

Experimental algorithm: The algorithms start from producing a sequence of autocorrelated number, one for each time step of the year by using the first-order autoregressive model:

$$Z_t = b \times Z_{t-1} + f(t)$$

Where:

Z_t = The value in time step i
Z_{t-1} = The value in time step i-1
b = The autoregressive parameters
f(t) = A noise function that returns a random number from normal distribution with mean of zero and standard deviation of 1[7]

HOMER establish the autoregressive parameter equal to the one-time-step autocorrelation coefficient:

$$b = r_1$$

To calculate the one-time step autocorrelation coefficient from an-hour autocorrelation factor, HOMER take example by logarithmic decay in the autocorrelation function in which case the following equations gives the autocorrelation parameter for a lag of k time steps:

$$r_k = r_1^k$$

Solving that for r_1 gives:

$$r_1 = \exp\left[\frac{\ln(r_k)}{k}\right]$$

NOMAD will solve the optimization problem of the form:

$$\frac{\min}{z \notin \Omega} f(z_t)$$

where, $\Omega = (1, 2, 3, \ldots, t)$. The break event point calculated by net present cost divided by net cash flow.

MATERIALS AND METHODS

Experimental modeling and method: Among the renewable energy sources, solar PV and wind energy have been utilized with diesel engine in this study. The hybrid generation system consists of an electrical load, renewable energy sources and other system components such as PV, wind turbines, battery and converter. Figure 1 shows the hybrid energy renewable system.

Mutiara residence consist of houses and small load for electricity. Mutiara residence have 22 MWh/day load average. Figure 2 will shown daily load profile for Mutiara residence.

The hybrid power system will need a lot of batteries to save the power from PV panels on the daylight because peak load occur around 23.00 a clock. HOMER synthesizes solar radiation values for each of the 8760 h of the year. The Graham algorithm produces realistic hourly data and it is easy to use because it requires only the latitude and the monthly average values. The synthetic data displays realistic day to day and hour to hour pattern. The synthetic data are created with certain statistical properties that reflect global average value. So, data generated for a particular location will not perfectly replicate the characteristics of the real solar radiation. But tests show that synthetic solar data produce virtually the same simulation results as real data (Sureshkumar *et al*., 2012; PTPLN., 2014). In this study, monthly average global radiation data has been taken from NASA (National Aeronautics and Space Administration). Figure 3 shows the graphics solar radiation data throughout the year.

HOMER synthetic wind data generator is little different to use than the solar data as it requires four parameters. The Weibull value K is a measurement of distribution of wind speed over the year. The value of K is taken as 2.

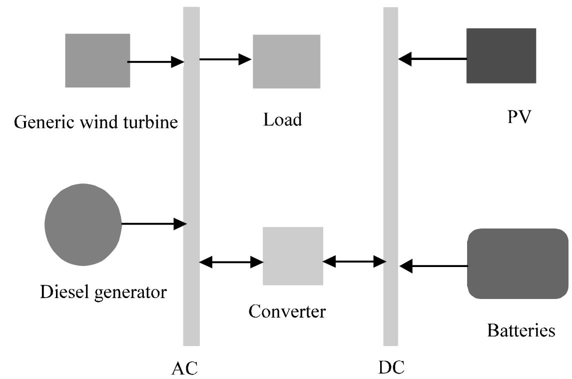

Fig. 1: Complete hybrid energy renewable system (EHOMER, 2011)

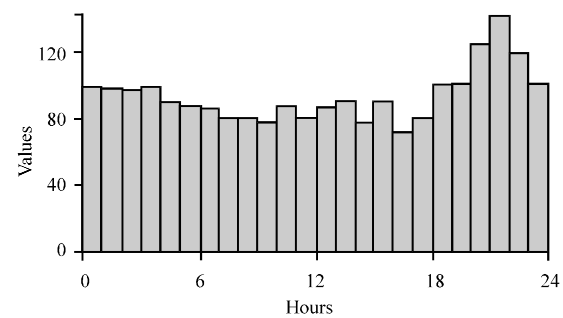

Fig. 2: Mutiara residence daily load profile (EHOMER, 2011)

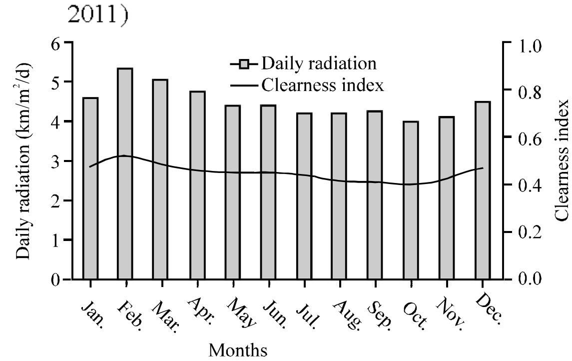

Fig. 3: Solar radiation data throughout the year; Global horizontal radiation (EHOMER, 2011)

The autocorrelation factor measures the randomness of the wind. Higher values indicate that the wind speed in 1 h tends to depend on how strongly the wind speed in the previous hour. Lower values mean that the wind speed tends to fluctuate in a more random fashion from hour to hour. The autocorrelation factor value is taken as 0.85. The diurnal pattern strength is a measure of how strongly the wind speed depends on the time of day.

Table 1: Wind speed data

Months	Wind speed (m/sec)
January	9.470
February	8.030
March	9.650
April	10.060
May	14.470
June	13.850
July	12.030
August	8.350
September	7.900
October	5.640
November	7.910
December	8.530
Annual average	9.657

Table 2: Solar PV array specification

Parameters	Units	Values
Capital cost	US$/kW	5000
Replacement cost	US$/kW	6000
Operation and maintenance cost	US$/years	60
Life time	Years	30
Derating factor	Percent	80
Tracking system	No tracking system	No tracking

Table 3: Specification of diesel generators

Parameters	Units	Values
Capital cost	US$/kW	1800
Replacement	US$/kW	1000
Operation and maintenance cost	US$/h	0.3
Operational life time	Hours	262.800
Minimum load ratio	Percent	30
Fuel curve intercept	1/h/kW rated	0.08
Fuel curve slope	1/h/kW output	0.25
Fuel price	US$	0.8

In most locations, the afternoon trends to be windier than morning. Higher values indicate that there is a strong dependence on the time of the day. In this study, the diurnal pattern is 0.25. The hour of peak wind speed: it is simply the time of day tends to be windiest on an average throughout the year.

Table 1 shows the monthly wind speed average value of Mutiara residence. About 50 m anemometer height is considered in this simulation. The relation between anemometer height and wind speed is shown in Fig. 4.

The hybrid generation system incorporates PV panels, wind turbines, diesel generators, batteries and converters. Capital cost, replacement cost, O and M cost etc., have to be provided to the Software for the simulation and modeling purpose. PV panels is the most expensive capital cost in hybrid generation system. Because the capital cost is expensive, 110 kW PV panels are considered for hybrid generation system (Pauschert, 2009). The parameters considered for solar PV are state in Table 2.

The cost of a diesel generator depends on its size. The diesel generators utilized are of 500 kW (Pauschert, 2009). Technical and economical parameters furnished in Table 3 (Delene *et al*., 2000). Because of the operation cost for diesel generator is high then the supply power

Table 4: Specification of wind turbine

Parameters	Units	Values
Capital cost	US$/quantity	2000
Replacement	US$/quantity	1500
Operation and maintenance	US$/year	100
Operation life time	Years	30

Table 5: Spesification of batteries

Parameters	Units	Values
Nominal voltage	Volt	2
Nominal capacity	Ah (kWh)	3000Ah
Maximum charge current	A	610
Round trip efficiency	%	86%
Minimum stage of charge	%	30%
Capital cost	US$/Quantity	2171
Replacement cost	US$/Quantity	200
Operation and maintenance	US$/kWh/year	200

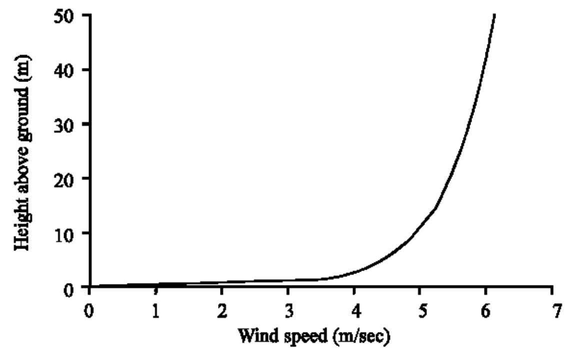

Fig. 4: Relation between wind speed and anemometer height

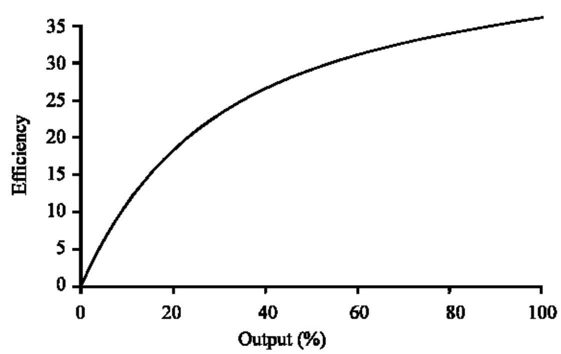

Fig. 5: Efficiency curve of 500 kW diesel generators (EHOMER, 2011)

from diesel generator should be minimize. From the simulation data the efficiency of diesel generator is shown in Fig. 5. Generic 20 kW wind turbine can be considered for the hybrid system. Specification cost of wind turbine furnished in Table 4 (Pauschert, 2009).

From data simulation, the power index base on wind speed shown in Fig. 6. Most of the house appliances are compatible for AC current now a days. As the electricity generated from PV is DC, converter is needed to change it to AC. Table 5 shows the technical and economical parameters of the converters (Pauschert, 2009).

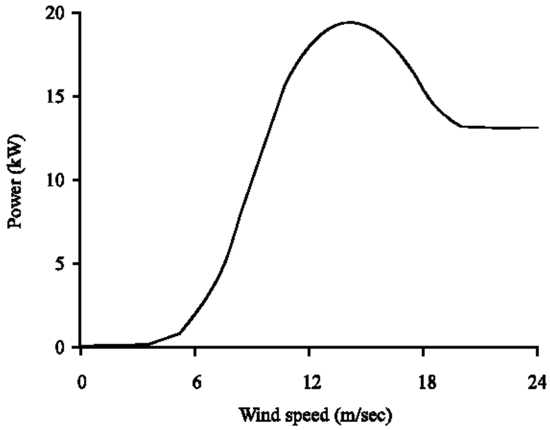

Fig. 6: Power curve of generic 20 kW wind turbine; Power curve

RESULTS AND DISCUSSION

The purpose is to reach the hybrid energy generation model with the minimum cost per kWh or least net present cost and minimum excess electricity (EHOMER, 2011). When hundreds of simulation to the end, HOMER point out the best hybrid configurations with respect to net present cost and cost/kWh. The configuration in this simulation that gives the lowest Cost Of Energy (COE) US$0.513/kWh and the lowest total Net Present Cost (NPC) US$5.280.743 with a renewable fraction 61% and excess electricity 16.8% is configured with a 140 kW PV, 200 kW diesel generator, 15×20 kW wind turbine, 200 kW converters and 150 batteries. Operating cost for system is US$ 300.789/years (Fig. 7).

From January until march and June until December the renewable energy are dominated power generation. On April until may the diesel generator are dominated because the source of renewable energy is insufficient to produce energy. The lack of sun rays and wind on march and april cause the PV panels and wind turbine can't produce sufficient energy. Figure 8 shown the annual energy production.

The diesel generator give impact for the operating cost particularly diesel fuel. PV give impact for the capital cost and for replacement cost batteries are dominated because of saving energy from the PV panels need a lot of batteries. The cash flow summary shown in Fig. 9. The BEP for hybrid energy generation is 20 years. The lifetime of hybrid energy generation is about 30 years and will give profit for the investor for 10 years remain.

PV (kW)	G20	Label (kW)	H3000	Conv. (kW)	Initial Capital	Operating Cost ($/yr)
140	15	200	150	200	$ 1,435,650	300,789
110	15	200	150	200	$ 1,285,650	312,839
120	15	200	150	200	$ 1,335,650	309,187
130	15	200	150	200	$ 1,385,650	305,326
150	15	200	150	200	$ 1,485,650	298,236
100	15	200	150	200	$ 1,235,650	317,885
140	15	200	150	300	$ 1,445,650	302,122
110	15	200	150	300	$ 1,295,650	313,857
130	15	200	150	300	$ 1,395,650	306,148
120	15	200	150	300	$ 1,345,650	310,601
150	15	200	150	300	$ 1,495,650	299,255
120	15	200	100	200	$ 1,227,100	320,915
100	15	200	150	300	$ 1,245,650	319,819
100	15	200	100	200	$ 1,127,100	329,905
140	15	200	100	200	$ 1,327,100	314,960
110	15	200	100	200	$ 1,177,100	326,709
130	15	200	100	200	$ 1,277,100	319,175
120	15	200	100	300	$ 1,237,100	322,414
100	15	200	100	300	$ 1,137,100	331,490
140	15	200	100	300	$ 1,337,100	316,263
110	15	200	100	300	$ 1,187,100	328,207
150	15	200	100	200	$ 1,377,100	313,605
130	15	200	100	300	$ 1,287,100	320,932
140	15	200	200	200	$ 1,544,200	302,287
150	15	200	100	300	$ 1,387,100	315,216
110	15	200	200	200	$ 1,394,200	315,344

Fig. 7: Optimization result (EHOMER, 2011)

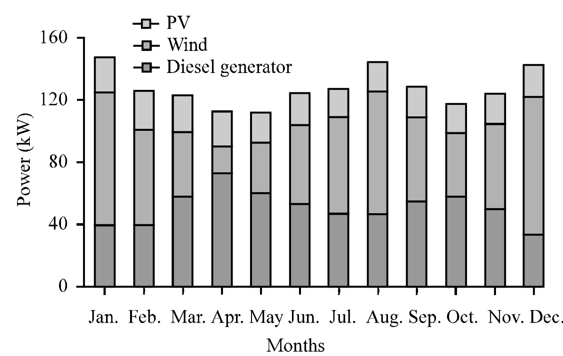

Fig. 8: Annual energy production from hybrid generation system; Monthly average electric production (EHOMER, 2011)

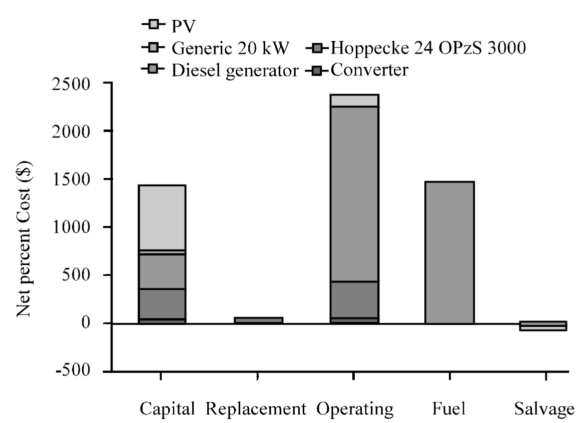

Fig. 9: Cash flow summary hybrid energy generation system (EHOMER, 2011)

CONCLUSION

This study has discussed on optimization result and effective cost for hybrid energy system in mutiara residence. The result analysis show the combination of PV panels, wind turbine, batteries and diesel generator will be the optimal choice and give some profit for the investor who want to invest the hybrid energy system. The net present cost for hybrid energy system is US$5.280.743 and the cost of energy is US$0.513/kWh. The hybrid power system offers several benefits such as utilization rate of wind generation is high load can be satisfied in the optimal way.

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