Optimization of Renewable Energy Hybrid System for Grid Connected Application

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Abstract

Hybrid energy systems are pollution free, takes low cost and less gestation period, user and social friendly. Such systems are important sources of energy for shops, schools, and clinics in village communities especially in remote areas. Hybrid systems can provide electricity at a comparatively economic price in many remote areas. This paper presents a method to jointly determine the sizing and operation control of hybrid energy systems. The model, PV wind hydro and biomass hybrid system connects to grid. The system configuration of the hybrid is derived based on a theoretical domestic load at a typical location and local solar radiation, wind and water flow rate data and biomass availability. The hybrid energy system is proposed for 10 of teacher's houses of Industrial Training Institute, Mersing. It is predicted 10 kW load consumption per house. The hybrid energy system consists of wind, solar, biomass, hydro, and grid power. Approximately energy consumption is 860 kWh/day with a 105 kW peak demand load. The proposed hybrid renewable consists of solar photovoltaic (PV) panels, wind turbine, hydro turbine and biomass. Battery and inverter are included as part of back-up and storage system. It provides the economic sensitivity of hybridization and the economic and environmental benefits of using a blend of technologies. It also presents the trade off that is involved in optimizing a hybrid energy system to harness and utilize the available renewable energy resources efficiently.

Key word: Optimization, Hybrid System, Renewable Energy, HOMER, Cost of Energy

1. INTRODUCTION

Malaysia is a tropical country where solar energy is available throughout the year with solar radiation in the range of 1419 to 1622kWh/m2/year. Under such a climatic condition, photovoltaic systems become another favorable renewable energy source. The application of renewable energy system has become an important alternative as power provider in rural electrification program when the price of oil is reaching its highest level. However the evaluation of the correct type of renewable energy system needs to be done so that the system can be optimized. The energy demand is predicted to increase from 11,050MW in 2001 to 20,087MW in 2010 In Malaysia (Ninth Malaysia Plan, 2006).

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Several studies have been done demonstrating the ability to optimize hybrid configurations of renewable energy systems in order to maximize performance while minimizing cost. The optimization of hybrid energy systems in the context of minimizing excess energy and cost of energy is addressed by Razak, Sopian and Ali,2007. The high upfront cost hybrid systems warrants the need to optimize unit sizing for reliable and cost effective energy system. they used the Hybrid Optimization Model for Electric Renewable (HOMER) software to find optimum sizing and minimizing cost for hybrid power system with specific load demand.

This paper discusses the optimization solution for hybrid renewable energy system configuration and demonstrates how the optimized design solution may not be the optimal implementable solution. This paper attempts to develop a general model to find an optimal hybrid system among different renewable energy combinations for a site community, minimizing the total life cycle cost while guaranteeing reliable system operation. Solar PV, wind, hydro, biomass and battery backup are considered in the model. A case study is conducted in a typical town of Mersing, Malaysia. The objective is to find the suitable component sizes and optimal operation strategy for an integrated energy system. The results will lead to the design and planning of an optimal hybrid energy system ensuring reliable and economical power supply to the site community.

2. SITE SELECTIONS AND SYSTEM CONFIGURATION

Figure 1. Map of Mersing

The hybrid energy system is proposed for 10 of teacher's houses of Industrial Training Institute, Mersing. It is predicted 10 kW load consumption per house. The hybrid energy system consists of wind, solar, biomass, hydro, and grid power. Approximately energy consumption is 860 kWh/day with a 105 kW peak demand load.

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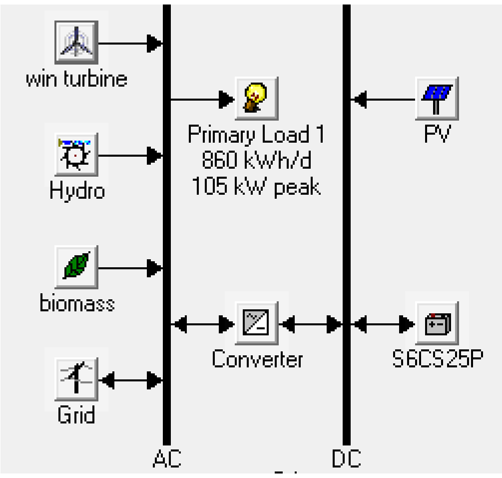

Figure 2. Solar-wind-hydro-biomass generator and Grid Hybrid Configuration

2.1 Solar PV Panels

The total capacity ranges of solar PV panels is between 10 to 20 kW. The intial cost of 1kW panels is \$15000, the replacement for panels is \$13000 and estimate the operating and maintenance (O&M) is \$100 . The lifetime of the panels is 20 years. Monthly clearness index and daily radiation is as shown in Table 1. The sites of Mersing is situated between latitudes 2^0 and 26^0 North, and longitudes 103^0 and 50^0 East.

Table 1. Monthly Solar Radiation

Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.495	4.854
February	0.533	5.446
March	0.530	5.552
April	0.533	5.496
May	0.508	5.011
June	0.525	5.017
July	0.511	4.944
August	0.502	5.048
September	0.508	5.250
October	0.508	5.194
November	0.467	4.602
December	0.476	4.579
Average:	0.508	5.080

2.2 Wind Turbine

Wind turbine that used in this system is FL 30. The wind turbine has a capacity of 30 kW AC. Its initial cost is \$30000 and its replacement at \$25000 with lifetime 15 years. Annual operation and maintenance cost is \$240. Its hubbub anemometer is located at 25 meter height. The turbine is estimated to last the project. The monthly wind speed is as shown in Table 2.

Table 2. Monthly Wind Speed

Month	Wind Speed (m/s)
January	6.700
February	5.400
March	3.800
April	1.700
May	2.100
June	3.100
July	4.300
August	4.500
September	3.300
October	1.700
November	2.700
December	5.900
Annual average:	3.765

2.3 Hydro Turbine

The hydro generator is a pico hydro type that has a capacity of 6.62 kW with capital cost is \$8000 and its replacement costs \$7000. The lifetime of the generator is estimated at 25 years. The design of available head and flow rate of turbine is 30 m and 30 L/s. while the turbine efficiency is 75 %..

2.4 Biomass

Load from biomass is designed between 100 to 120 kW with capital cost is \$8500 and replacement costs \$7500. The lifetime of the generator is estimated at 15000 operating hours. The biomass cost is \$20/t (source from: frontline bioenergy website). The monthly available biomass is shown in Table 3.

Table 3. Monthly Available Biomass

Month	Available Biomass (tonnes/day)
January	8.000
February	8.000
March	8.000
April	8.000
May	8.000
June	8.000
July	8.000
August	8.000
September	8.000
October	8.000
November	8.000
December	8.000

2.5 Battery

The type of battery that used for the configuration system is Surrette 6CS25P with the rating 6 v, 1,156 Ah 694 kWh. Initially cost of 1 kW is $900. The replacement batteries will cost $900. Sizes to consider is 80, 100 and 140 strings.

2.6 Converter

A power electronic converter is used to maintain the flow of energy between ac and dc. The size of converter that used in this system is 20 to 25 kW. The capital cost of 1 kW inverter is $1000 and its replacement costs $1000. The lifetime of the inverter is 15 years.

2.7 Grid Connected

Grid connected system is designed for $0.4/kWh of sellback price and $0.2/kWh of grid price. Variables of grid sell capacity are 20 kW, 15kW and 10kW.

2.8 System Optimization for Grid Hybrid Connected

Five power systems representing the optimal configuration were considered and the results are summarized in figure 2 for PV wind hydro biomass hybrid system connects to grid.

3. RESULTS AND DISCUSSIONS

The Homer simulation performs the optimization process in order to determine the best solution of grid hybrid system based on several combination of equipment. Hence, multiple possible combinations of equipments could be obtained for the grid hybrid energy system due to different number of solar panel, wind turbine, hydro turbine, biomass and number of batteries and size of power converter.

In the optimization process will simulate every combination system configuration in the search space. The feasible one will be displayed at optimization result sorted based on the Total Net present Cost (TNPC). The combination of system components is arranged from most effective cost to the least effective cost. The optimization results of grid hybrid energy system are obtained for every selection of sensitivity variables. Table 4, shows a list of optimization results for grid hybrid system for 25 years.

Table 4 shows that if different amount of grid sale capacity, it will different of total TNPC and COE. At grid sale capacity 10 kW, show the highest cost of the TNPC ($4,018,489) and COE ($0.819/kWh). While grid sale capacity added at 15kW and 20 kW, TNPC and COE have decrease. For this study, trend show that when increasing of grid sale capacity, TNPC and COE will decrease.

For energy production, Table 5, shows that grid sale capacity 20 kW was recorded the highest among the other at 563,385kWh/yr and the energy purchased from grid which is same all of configuration, 40 kWh/yr. The total energy production produced by grid sale capacity 20 kW is 563,385 kWh/yr.

Table 5. Hybrid Connected Energy Production

kWh/yr	Grid Sale Capacity (kW)		
	10	15	20
PV array	14,838	14,838	14,838
Wind turbine	197,807	197,807	197,807
Hydro turbine	49,309	49,309	49,309
biomass	229,971	265,950	301,302
Grid purchase	40	40	40
TOTAL	491,963	527,942	563,385

Table 4. Summarized Total Net Present Cost of Optimum Hybrid System Configuration

Grid salecapacity (kW)	PV (kW)	Wind	Hydro (kW)	Lebel (kW)	battery	Converter (kW)	Grid (kW)	Initial capital ($)	Operating cost ($ / yr)	Total NPC ($)	Cost of Energy ($ / kWh)	Ren. Frac	Biomass (t)	Lebel (hrs)
10	10	5	6.62	100	160	20	5	1,327, 000	172,29	4,018, 489	0.819	1	373	3,933
15	10	5	6.62	100	200	25	5	1,363, 000	165,22	3,943, 997	0.804	1	345	3,648
20	10	5	6.62	100	100	25	5	1,327, 000	167,03	3,936, 365	0.803	1	377	3,933

The electricity purchase price for this study was taken at $ 0.2 / kWh and sellback rate is at $ 0.4 / kWh. The excess energy will return back to grid at rate $0.4 kWh as shown in Table 6.

Table 6. Excess of energy

Energy	Grid sale capacity (kW)		
	10	15	20
energy purhcase (kW)	40	40	35
energy sold (kW)	75,900	112,560	149,717

IV. CONCLUSIONS

This paper has discuss on the optimization sizing of grid hybrid energy system. Although the application and implementation of renewable energy systems for commercial application with isolated grids are primarily dependent on the availability of the renewable resources on the specific site of interest and site demand configuration. There are a number of economic considerations and design tradeoffs to be taken in order to optimize cost and performance. A thorough analysis of the site conditions and identification of site limitation is required to optimize the design and implementation of a hybrid energy system. The simulation results for three differential grid sale capacity indicate that the most economically feasible system for 20 kW would be composed of solar PV panels, wind turbine, biogas, and hydro, battery, and inverter. There is a high potential of hybrid energy system in Mersing than can used for supporting renewable energy,that will reduce 94,534 kg/year of gas emission (CO2).

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