Prospect of PV-wind-diesel hybrid system as an alternative power supply for Miangas Island in Indonesia

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Abstract

The purpose of this paper is to conduct a feasibility study of hybrid power system based on renewable energy resources for Miangas island, which is located on the border between Indonesia and the Philippines. It is the outermost island that situated in the North part of Sulawesi mainland which became the front porch of Indonesian territory. The prospect of PV-wind-diesel-battery hybrid system as an alternative power supply for Miangas island has been analyzed using HOMER (Hybrid Optimization Model for Electric Renewable). The predicted monthly average daily radiation in Miangas island is 5.52 kWh/m^2. The wind speed varies seasonally from 3.1 m/s to 5.3 m/s. The hybrid system analysis has showed that the electricity is generated in a year is 240,068 kWh in which electricity energy sharing consist of PV, wind, diesel are 77%, 0.5% and 22.5% respectively. In addition, the simulation results for the proposed hybrid system in Miangas island community find the value of cost of energy (COE) as 0.3178 USD/kWh, Net Present Cost (NPC) as 986,356 USD and operating cost as 52,887 USD.

Keywords: Renewable energy, hybrid system, island communities, remote island, Indonesia

1. Introduction

For the sake of island communities in the border area of Indonesia, it is necessary to pay special attention so that the energy needs of remote areas and island communities are met on a sustainable basis. Dependence on the supply of fossil fuels from the island to the island that have high transportation costs and produce greenhouse gases need to be minimized. For this reason the utilization of renewable energy as an alternative energy source for energy generation needs to be studied. Additionally, the need to provide the islands for energy security become important issue for energy policy of the nation.

Miangas island was chosen as the location to be studied because of its specificity located on the border between Indonesia and the Philippines is the outermost island which became the front porch of Indonesian territory. Miangas island is situated in regency of Talaud Island, North Provience of Indonesia. It is located at latitudes 05^0 33' 20.8'' North and longitudes 127^0 09' 6.8'' East. It takes 3 hours by boat from Malonguane (the nearest city as the capital of Talaud region). The total land area is approximately 3.2 km2. According to the data from Statistics Centre of Indonesia, the communities of Miangas island consists of 881 people in 2015.

Miangas island is facing the high cost of diesel fuel due to remoteness from Sulawesi mainland. This article presents a feasibility study of wind-PV-Diesel-Battery hybrid system for a remote island in Indonesia, the case study of Miangas island in order to decrease the dependency to the high cost of stand alone diesel system. A previous study [1] found that the potential of renewable energy resources for Indonesia's island should be considered to be interest as an alternative power supply for island communities need. A result of the mapping of solar energy potential in Indonesia, the Northern part of

Sulawesi island can be one of the most suitable region for generating electricity from solar energy.

The organization of this article is as follows. Section 2 presents a brief literature reviews of previous work of anlyzing the hybrid system using HOMER in many locations. Sections 3 describes the methods that use in this study consists of load profile data, resources data and component input for system analysis. Section 4 provides the simulation results of the HOMER for the case study of Miangas island. Section 5 gives the conclusions.

2. Literature Review

This section presents literature review about the analysis works for power system infrastructure model for island communities by utilizing HOMER (Hybrid Optimization of Multiple Energy Resources) software from National Renewable Energy Laboratory (NREL).

HOMER software has been used to perform the techno economic feasibility of possible models in developing the power system infrastructures. HOMER is an optimization software package, which can handle different technologies (including PV, wind, hydro, fuel cells) and evaluate design options for both off-grid and grid-connected power systems for remote, stand alone and distributed generations applications [2].

There are many studies has been conducted to study of HOMER utilization for analysing the model of power system generation. Dursun et al [3] studied a micro-grid wind-PV hybrid system for a remote community with 50 houses in order to find the optimal configuration and present a techno-economic analysis for the considered power generating system by the HOMER software. Bekele and Palm [4] presented a feasibility study for a stand-alone solar-wind based hybrid energy system for a model community of 200 families using HOMER software. Lipu et al [5] conducted a feasibility study of solar-wind- hybrid in rural and remote areas of Bangladesh. Al-Badi [6] evaluated the techno-economic feasibility of a hybrid wind-PV-deiesel power system to satisfy the load of Al Hallaniyat Island.

Many studies have been reported analysing renewable energy based on power generation using HOMER. Himri et al. [7] study of hybrid power system for a remote village in Algeria, while Nandi and Gosh [8] present a study of a Bangladesh village and Nfah et al [9] report case study of Ethiophia. Although several studies are conducted for hybrid renewable energy system, no research is reported for the case of Miangas island in Indonesia.

The location of the community is important to know as electricity demand patterns differ with geograhical site and cultural habits [10]. HOMER uses the optimizer propietary algoritm to search for the lowest net present cost system for the specific load and condition [11]. Homer's software capability for modeling has been demonstrated, through two experiments on small-scale systems by comparing HOMER modeling results with direct measurement results [12].

Hybrid renewable energy system that combined the types of renewable energies sources can be a more reliable approach for meeting the electric energy demand of remote areas. By combining a diesel generator with photovoltaic and/or wind system can decrease diesel fuel consumption and minimize the operating cost of the system [13]. The balanced system can provide stable outputs from sources and minimzes the dependeance of the output upon seasonal changes, futhermore it optimizes utilizationof the different renewable sources of energy available [14].

Renewable sources for generating electricity in the hybrid system are photovoltaic (PV), wind turbines, generators, battry and converter. Photovoltaic (PV) panels convert solar radiation into direc current (DC) power, while wind turbines convert wind energy to AC/DC power. Generators are dispactable energy sources which can compensate for renwable sources in system. The other components in hybrid systems are batteries which are used in order to increase the reliability of the system. Whenever the renewable sources can suply the demands, the excess energy can be stored in the batteries. Subsequently whenever renewable sources are not available, the batteries feed electricity into the system. Another components used in hybrid systems is a converter, which is change the DC power to AC power [15].

3. Methods

The method to conduct the techno economic study of hybrid power generation for communities in the remote island of Indonesia is using HOMER software. This software developed by the National Renewable Energy Laboratory (http://www.homerenergy.com) a division of the US Department of Energy used to design a hybrid power plant system using renewable energy.

The data collected for the input, in the form of population data and the daily load average condition of electricity in Miangas island are given in Table 1.

Table 1. The data collected in Miangas Island

Item	Value
Number of People	881
Number of Households	324
Daily Load Average (kWh)	657

Feasibility of solar energy system mainly depends on solar radiation available at the specific location. Data of solar energy sources in term of solar radiation in Miangas island have been taken from NASA (National Aeronautics and Space Administration) website by input the latitude and longitude of the location. The average annual solar radiation equals to 5.53 kWh/m2/day. HOMER also gives the clearness index data and wind speed for Miangas island. Clearness index is the amount of global solar radiation on the surface of the earth divided by the extra-terrestrial radiation at the top of the atmosphere [16]. Solar energy potential in Indonesia has been studied and mapped by Rumbayan et al [17] . The maps can provide useful information for national as well as regional and local renewable energy planning in the islands of Indonesia. They are the first maps to be published in the literature and will benefit decision makers and engineers to develop solar energy systems.

The data of solar radiation, cleaness index and wind speed in Miangas island are presented in Table 2.

Table 2. Average Monthly Solar Radiation in Miangas Island

Month	Solar Radiation (KWh/m^2/day)	Clearness Index	Wind Speed (m/s)
January	5.01	0.53	4.83
February	5.43	0.54	5.05
March	6.05	0.58	4.76
April	6.40	0.62	3.58
May	5.73	0.56	3.08
June	5.00	0.50	4.18
July	5.32	0.51	4.69
August	5.50	0.54	5.30
September	5.84	0.57	4.32
October	5.71	0.57	4.34
November	5.38	0.56	3.95
December	5.01	0.54	4.42

The monthly load profil of electricity demand for Miangas island community for one year that used in HOMER simulation is presented in Fig. 1.

Fig. 1. The monthly load profile for island communities in Miangas Island.

The simulation of the system was done by HOMER (Hybrid Optimization Model for Electric Renewable) software that developed by National Renewable Energy Laboratory, USA. HOMER software is using for designing of Distributed Generator (DG) systems either off grid or on grid. Its algorithms permit to assess the technical and economic feasibilities of a big system that has lots of technical options and variations. Optimization and the sensitivity analysis are two of its great features. The input of HOMER for modelling the system configuration is consist of load profile, component specifications including size and numbers, resources data, economics, system control, emissions, constraints etc. HOMER provides a method for finding the least-cost system model based on load profile, system components and energy sources data.

The proposed hybrid system of power supply of electrical energy to serve Miangas island consists of PV, wind turbine, diesel generator, battery and converter are shown in Fig. 2.
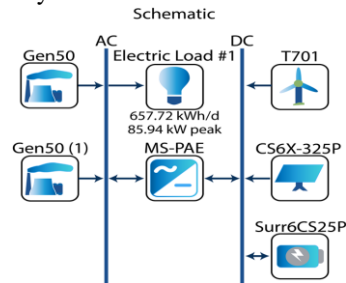

Fig. 2. The proposed of hybrid power generation model for Miangas Island.

There are two buses in the system; AC and DC bus. The output energy of solar PV is stored in a battery which is on the DC bus side. To convert AC from DC, a converter MS-PAE is used. The design for solar power systems uses Canadian solar Max Power C56x-325P 200 KW of PV, Pika T701 1.5 KW of wind turbine, Diesel Generator 2x50 kW and battery Surrette 6CS25P. The detail description of the components of the hybrid system as the input for analysis are presented in Table 3.

Table 3.The components of the hybrid system analysis

Characteristics	PV Module	Wind Turbine	Diesel Generator	Battery	Converter
Model	Solarmax Power	Pika T701	Generic Fixed	Sur6CS25P	Magnum
Power	200 kW	1.5 kW	50 kW	820 AH; 16 V	200 kW
Life time	25 years	20 years	15 years	20 years	10 years
Capital Cost	25,000 USD	5995 USD	25,000 USD	1000 USD	2255 USD
Replacement	20,000 USD	5995 USD	25,000 USD	500 USD	2255 USD
Maintenance	0	100 USD	1500 USD	0	0

4. Results

The study performs the optimization through HOMER software. It performs the energy model for each system configurations feasible and estimates the cost of installing and operating the system over the life time of the project. HOMER simulates all of the possible system configurations that meet the electricity demand for Miangas island by considering the renewable energy resources such as solar and wind energy potential. The capacity and cost of the proposed hybrid system based on PV-Wind –Diesel-Battery model components are presented in Table 4.

Table 4. The capacity and cost of the proposed hybrid system components

Item	Value
Capacity of PV	200 kW
Capacity of Diesel	2 x 50 kW
Battery	80 string
Capacity of Converter	25 kW
Energy cost per kEh (COE)	0.3178 USD
Net Present Cost (NPC)	986.356 USD
Operating Cost	52.887 USD

HOMER determines the value of the appropriate component capacity so as to produce a good and reliable power system in serving the load in terms of capacity of power plant component, yearly electric energy production, initial capital cost, total Net Present Cost (NPC), energy cost per kWh (COE). The simulation results show that the hybrid (wind-PV-diesel battery) system has net present cost (NPC) 986356 USD with Cost of energy (COE) 0.3178 USD/ kWh.

The annual electricity production from the hybrid sistem design proposed is 431,114 kWh in which 77% electricity comes from PV, 22.5% electricity comes from diesel and 0.5% electricity comes from wind turbine. This proposed hybrid power system can produce as 166,329.018 kWh per year of excess electricity for Miangas island. The monthly average electricity production is shown in Figure 3.
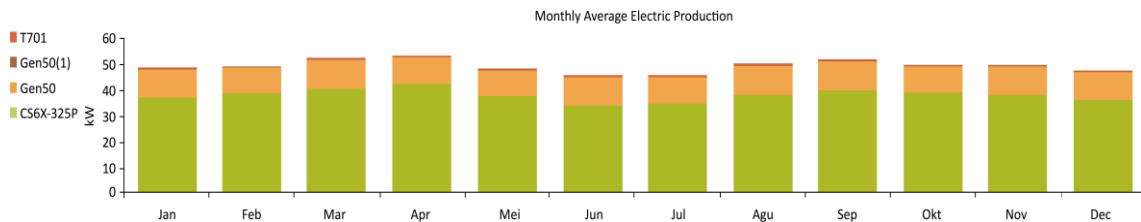

Fig. 3. The monthly average production based on the proposed hybrid power system in Miangas Island.

The Fig. 3 shows the significant part of sharing electricity production from renewable energy that can be perform for Miangas island. The result shows that the prospect of renewable energy from solar energy and wind energy in Miangas island could be an alternative supply to generate electricity for remote community island.

In order to show the consequences of changing diesel price in the island, a sensitivity analysis has been conducted. Table 5 presents the sensitivity analysis for diesel prices ranging e.g 1 US$/L, 2 US$/L and 3 US$/L case.

Table 5. Sensitivity analysis result for diesel price

Diesel Fuel [US$/L]	Cost of Energy [US$]	Net Present Cost [US$]	Operating Cost [US$]	Initial Cost [US$]
1	0.317	986,356	52,887	296,660
2	0.463	1,440,000	87,018	311,660
3	0.608	1,890,000	119,609	340,121

The sensitivity analysis performs that the increasing of diesel prices could effect to the increasing of cost of energy (COE), net present cost (NPC), operating cost as well as initial cost significantly.

5. Conclusion

Based on the simulation result using HOMER software, the model of power plant system based on hybrid energy that consist of PV-Wind-Diesel and Battery for island community's electric energy demand in Miangas island can be obtained. Additionally the Cost of Energy (COE), Net Present Cost (NPC) and operating cost for proposed hybrid PV-Diesel power generation can be assessed.

This study can be an initial analysis for further analysis in implementing the infrastructure of power system based on renewable energy resources for island communities. The proposed PV-wind-diesel Hybrid power electricity generation become an alternative way for the remote island to meet electricity demand for the sake of security, welfare and beauty as an added value in Indonesia's border region.

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