Development of Power System Infrastructure Model for the Island Communities: A Case Study of Kokorotan Island in Indonesia

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Abstract—The purpose of this study is to develop a model of power system infrastructure based on renewable energy available locally in a remote island. This research is a case study for Kokorotan Island that located in eastern Indonesia region of Talaud Island regency of North Sulawesi province in Indonesia. The research methods used are data collection and data analysis using software HOMER. The monthly average daily radiation is 5.62 kWh/m^2, while the wind speed ranging from 3 to 5.3 m/s in Kokorotan island. The proposed hybrid power system model consists of a PV component of Canadian Solar Max Power C56x-325P of 150 KW PV, 70 string of Surette 6CS25P, 1 wind turbine of 1.5 kW Pika T701, Diesel Generator 50 kW and converter Magnum MS4448PAE 25 kW. The annual electricity production from the PV Diesel system for Kokorotan island is 312.595 kWh in which 80% electricity comes from renewable energy (PV and Wind energy) as well as 20% electricity comes from diesel. The cost of generating electrical energy in the term of cost of energy (COE), Net Present Cost (NPC) and operating cost are 0.314 US$/kWh, 725.086 US$ and 37.973 US$ respectively. The cost of generating electrical energy with renewable energy is relatively high then it is necessary to have policies and strategies for the development of power infrastructure for the sake of the energy security of island communities in Indonesia.

Keywords—Renewable Energy; infrastructure model ; island communities; remote island; Indonesia

I. INTRODUCTION

The eastern region of Indonesia, especially the island which is the outermost island that becomes the front border requires special attention in the case of energy problems. 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 infrastructure needs to be discussed and studied.

Renewable and locally available renewable energy infrastructures for island communities need to be assessed and developed. Talaud Islands 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.

Kokorotan island, which is one of the remote island on the border of Indonesia with the Philippines, situated in regency of Talaud Island It is located at latitudes 04^0 37'North and longitudes 127^0 09'East. It takes 3 hours by boat from Malonguane (the nearest city as the capital of Talaud region). The total land area is approximately 1710 km^2. According to the data, the communities of Kokorotan island consists of 232 households. The island of Kokorotan as the part of Talaud islands is shown in Figure 1.

Figure 1. Map of Talaud Islands and Kokorotan Island [1]

Kokorotan island is facing the poor electricity accsess due to geographical inaccessibility, lack of electrical infrastructure and low population condition. However this island has chosen to be analysis as a model for power system infrastructure based on renewable energy availability for island communities. This paper presents a power system infrastructure model for island communities based on renewable energy that locally available for Kokorotan island as the remote island which is situated in the border of Indonesia and Phillipines. The adoption of a pro-island energy policy in the foremost island as a terrace that needs to be enriched for the sake of security, welfare and beauty as an added value in Indonesia's border region.

II. POWER SYSTEM INFRASTRUCTURE MODEL FOR ISLAND COMMUNITIES

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 infrastructure. Dursun et al [3] studied a micro-rid 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. Bekel and Bjorn [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. Shaahid et al [5] evaluated the technical and economic potential of hybrid-wind-PV-diesel power systems to meet electrical energy demand of a remote village by suing HOMER software.

The location of the community is important to know as electricity demand patterns differ with geograhical site and cultural habits [6].

III. METHODS

The research method used is primary and secondary data collection, data analysis using HOMER software. The data collected in this study, in the form of population data and the power electricity demand of electricity in Kakorotan island [7] are given in Table 1.

Table 1. Communities Data in Kokorotan Island

Number of People	881
Number of Households	232
Power Electricity Demand	260 W/ day/ household

Feasibility of solar-wind hybrid renewable energy system mainly depnds on solar radiation and wind energy potential available at the specific location [8]. Data of renewable energy sources in term of solar irradiation and wind speed in Kokorotan island have been taken from NASA (National Aeronautics and Space Administration) website through HOMER are summarized in Table 2.

Table 2. Average Monthly Solar Radiation an Wind Speed in Kakorotan Island [9]

Month	Solar Radiation(KWh/m^2)	Wind Speed (m/s)
Jan	4.527	2.57
Feb	4.953	2.57
March	5.583	2.57
April	5.714	2.57
May	5.094	2.57
June	4.466	3.08
July	4.601	3.59
August	4.850	4.11
Sept	5.418	3.08
October	5.125	3.08
Nov	4.648	2.05
Dec	4.719	2.57

The monthly power electricity demand in Kokorotan island is decribed in Figure 2.

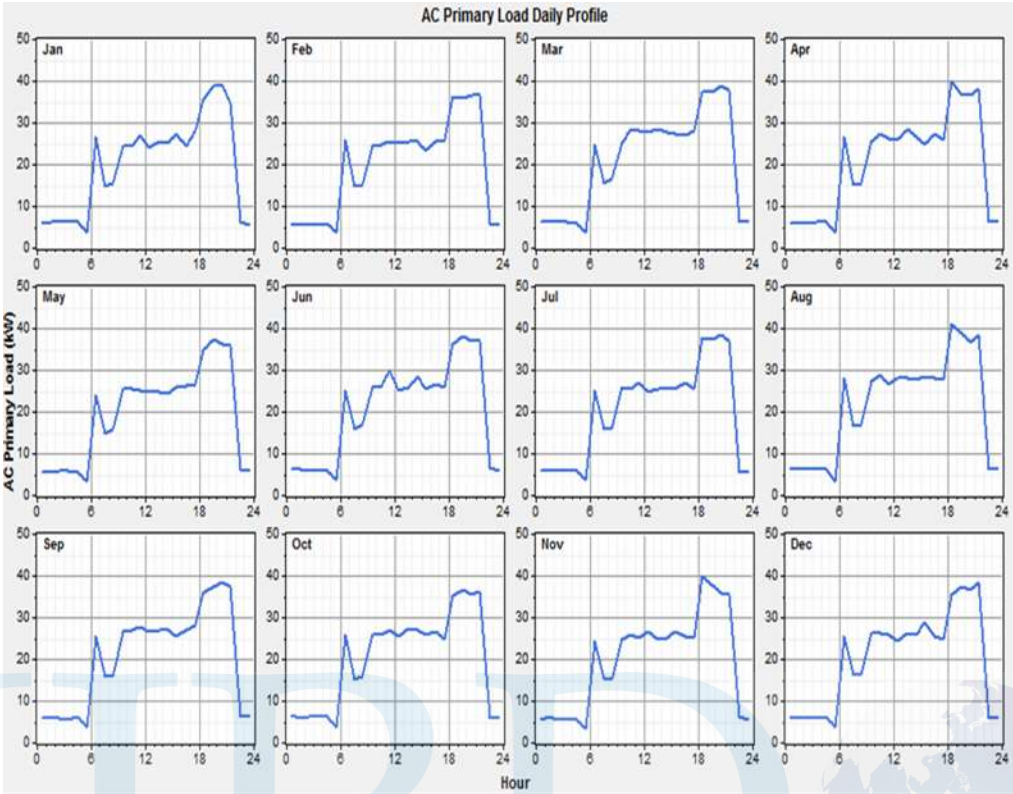

Figure 2. Monthly Load Profile of Power Demand for Kokorotan Island

This data collection required for input to software HOMER is primary data, secondary data and literature study. 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. 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 [10].

IV. SIMULATION RESULTS

For the determination of the type of wind turbine to be proposed, the average wind speed in the Kakorotan islands is crucial in the selection of wind turbines. This is done to optimize the existing wind potential in Kakorotan Island. It is proposed that turbine type Pika T701 (1,5 kW) with consideration of wind speed that exist in Kakorotan island.

The design for solar power systems uses 150 kW solar panels with a polycrystalline silicon type. The batteries used in this system simulation are battery type Surrette 4KS25P deep cycle batteries that have a normal voltage of 4 volts, capacity 1.350 Ah.

Input parameters required on HOMER software are load data, wind speed, solar radiation, and component data used such as capital cost, replacement, O & M and others. The proposed of power system infrastructure model based on renewable energy that consist of renewable energy in terms of wind energy and PV as well as Diesel Generator for Kakorotan island as shown in Figure 3.

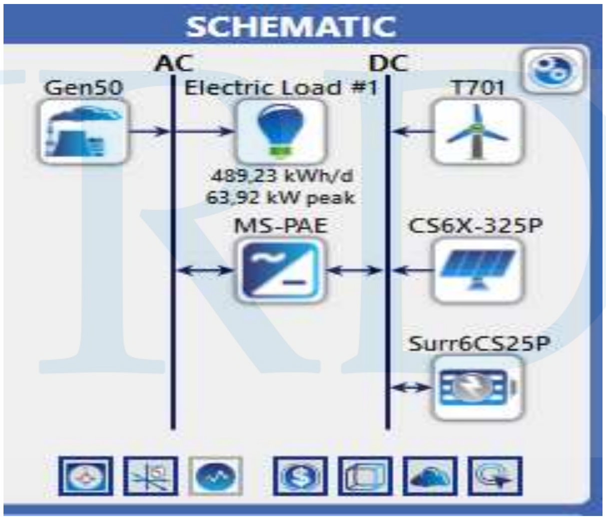

Figure 3. The Proposed of Power System Infrastructure Model based on Renewable Energy for Kakorotan Island

HOMER determines the value of the appropriate component capacity so as to produce a good and reliable power system in serving the load in Kokorotan island based on PV-Wind-Diesel power system. The simulation results in term of capacity of components, energy production, cost of energy (COE), total Net Present Cost (NPC) and operating cost are presented in Table 3.

Table 3. The simulation results in term of capacity of components, energy production, cost of energy (COE), total Net Present Cost (NPC) and operating cost

Capacity of PV	150 kW
Capacity of Wind Power	1.5 kW
Capacity of Diesel	50 kW
Capacity of Battery	70 string
Capacity of Converter	25 kW
Yearly energy production from PV	249.688 kWh
Yearly energy production from Diesel	61.538 kWh
Yearly energy production from Wind Turbine	1369 kWh
Energy cost per kWh (COE)	0.3141 US$
Net Present Cost (NPC)	725.086 US$
Operating Cost	37.973 US$

The results of monthly average electricity production from proposed hybrid power system configuration in Kakorotan island are shown in Figure 4.

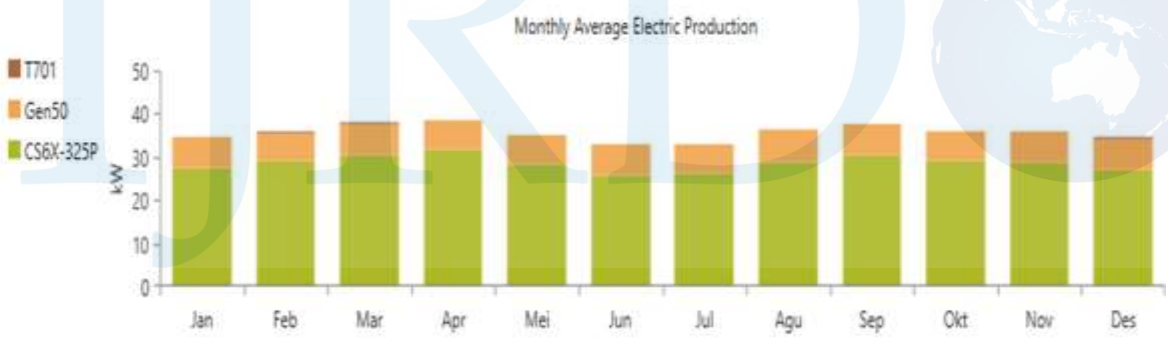

Figure 4. The monthly average electric production from PV-Wind-Diesel system for Kokorotan Island

The annual electricity production from the hybrid system for Kokorotan island as 312.595 kWh in which 79.5% electricity comes from PV, 20% electricity comes from diesel and the remaining comes from wind energy. From the simulation results, the excess electrical energy generated by PV and wind turbine generators can be use for backup electrical energy of energy consumption on Kakorotan Island.

V. CONCLUSIONS

Based on the simulation result using HOMER software, the model of power plant system for island community's electric energy demand in Kakorotan Island can be obtained. The annual electricity production from the PV Diesel system for Kokorotan island is 312.595 kWh in which 80% electricity comes from renewable energy (PV and Wind energy) as well as 20% electricity comes from diesel. The cost of generating electrical energy in the term of cost of energy (COE) as 0.314 US$/kWh, Net Present Cost (NPC) as 725.086 US$ and operating cost as 37.973 US$. For future work, the model of power plant system for island community will be conduct for sensitivity analysis for fuel price change for the remote island.

ACKNOWLEDGMENTS

The author would like to thank Yulianus Salasa for his help for data collection.

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