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Design of Distributed Generation with a Hybrid System in KarimunJawa Island

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ABSTRACT

The current condition, in Karimunjawa Island, is supplied by diesel power with a total power output of 400kW. The number of households in this island is 1545, while the number of electricity customers as many as 850 homes with the local electrification ratio of 55%. With such high load electrification, the generator is only operated from 05.00pm-06.00pm every day to limit the operating costs. Methodology used was the determination of the size of the PV generator capacity based on the percentage of daily generation. The selection of conversion technology with hybrid concept synergizes photovoltaic to be combined with diesel. Loading simulations are performed with HOMER application that provides a variety of features on a variety of configurations and scenarios designed.The first scenario is in the form of giving additional capacity by using the power of 100kW of PV system and at peak load by adding the duration of the day with 5 hours, it is obtained the production of PV of 800kWh/day with the selling price of $ 3,900;/kWh. The second scenario is in the form of giving additional capacity by using the power of 100kW of PV system at noon for 10 hours and during peak load, it gains total value production of PV with1400kWh/day and distributed to system with a selling price of Rp 3,867/kWh.

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1. INTRODUCTION

Electrification Ratio (RE) in Central Java Province in 2014 reached 89.76%. Electricity supply by PT PLN of UPJ Kudus and the Office of Energy and Mineral Resources of Jepara regency contributed electrification ratio of 90.59%. [7]. Karimunjawa Island is part of the Karimunjawa sub-district of Jepara regency where its geographical location is in the form of island. The electricity system in this island is not connected to the grid of Java island, so that, the electrical system is run independently.

The survey results figure out that the electric customers in Karimunjawa island are 850 houses with the number of households of 1545, Therefore, the ratio of local electrification only reaches 55%. The main problem of electricity in Karimunjawa Island is the restrictiveness of electrical energy supply by generator with the capacity of 400 kW which have to supply the load from 5:00 p.m-6:00 a.m or about 13 hours. In addition to capacity, the continuity of supply becomes limits to the community in carrying out the business and economic activity. [1][3][6]

The high costs and uncertain availability of diesel fuel for generators is a problem that must be solved either by the government or local community. In addition to long-term plans to build a plant with a large capacity, efforts to use renewable energy can be an alternative. Archipelago which has a great potential of wind and solar energy is expected to explore new ways of utilizing one or both to meet the need.

Through a capability-based approach of the existing electric power system, the needs of the local electrical energy are planned by expanding capacity and the duration of electricity supply gradually. The planned design features high flexibility which is intended to be able to predict the amount of electricity production to the costs incurred in a comprehensive manner. The application of this design is simulated using HOMER Energy software with the most optimal combination output based on the solar energy potential in Karimunjawa Island.

2. POTENTIAL ENERGY AND SOLAR ENERGY CONVERSION TECHNOLOGY

2.1 Solar Radiation

The average global solar radiation on a horizontal surface in every hour per year will be used as a standard for designing a PV system at a specified location. The hourly solar radiation data obtained from NASA states that annual average of daily solar radiation on a horizontal surface at the site of Karimunjawa Island situated in 5°42'- 6°00'S, 110°07'- 110°37'E is 5.23 (kWh/m^2/d). [8]. the fluctuations in solar radiation can be seen in Figure 1.

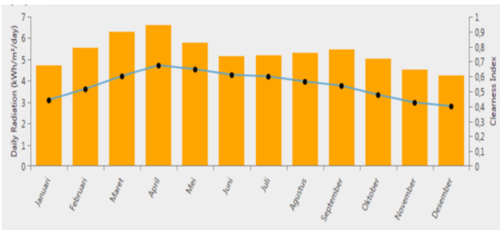

Figure 1. Potential solar radiation intensity for a year

2.2. Photo Voltaic Technology Development

Nowadays, *Photo Voltaic* is a power generation technology that has been accepted internationally as a reliable power supplier. It continues to experience rapid development both as a technology and application. During the past 30-40 years, PV module prices have followed a downward trend exponentially with the average costs for a PV module is currently below $1.00/Wp and in some areas these costs are substantially lower. In recent years, this trend has been the same at some point, yet, the projected price for PV modules is expected to be cheaper and cheaper which is in line with the lower production costs modules and the increase efficiency of PV module along with its installation. [1] [8] [9]

The improvement in the future market price for solar energy conversion devices becomes important considerations in an early developer of effective rooftop PV program in Karimunjawa Island.

3. GENERATION SYSTEM AND EXISTING PATTERN LOAD

The provision of electric energy supply in Karimunjawa Island in the field is using diesel-generator and multiple use of a thermal and solar power station in small off-grid capacity.

Diesel existing in Karimunjawa Island with a power output of 500kVA or 400kW is utilized to supply as many as 850 customers for 13 hours starting at 5:00 p.m-6:00 a.m. load pattern is assumed to be flat and not fluctuated since the power is absorbed completely during the time as illustrated in Figure 2 below.

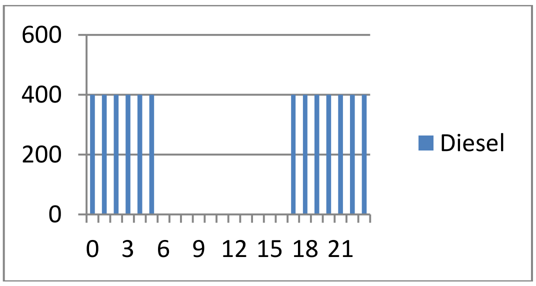

Figure 2. Profile of Diesel Power Output in Karimunjawa Island

4. MODELING SYSTEM SCENARIO

Ideas put forward here is to design generators combined with the number of solar power station with desired capacity and operational time. The hybrid combinations of plant design in Karimunjawa island is illustrated in figure 3 below.

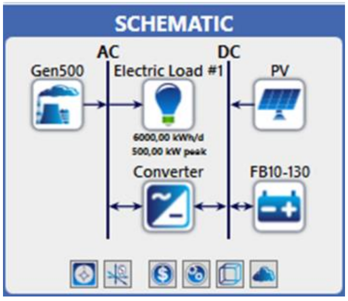

Figure 3 Hybrid Generators Combination in Karimunjawa Island

The selection and size of the component *(sizing)* of hybrid power systems has been conducted with the help of HOMER software. The software supports the design of electric power systems for hybrid system applications. [2][5]

Karimunjawa Island is with Main Generator Supply of 500kVA/400kW. This loading is in flat design and not fluctuating electrical load, if it is designed to have fluctuation, the HOMER system operation will require generators with a size of greater than 400 kW, while, in fact, what available is 400kW.

These generators supply the load from 5.00 p.m. to 6:00 a.m. or for 13 hours. Started at 6:00 a.m. to 5:00 p.m., there is no electricity in Karimunjawa Island. The Scheme of loading and electric energy generation by using diesel in Karimunjawa Island can be seen in figure 4.

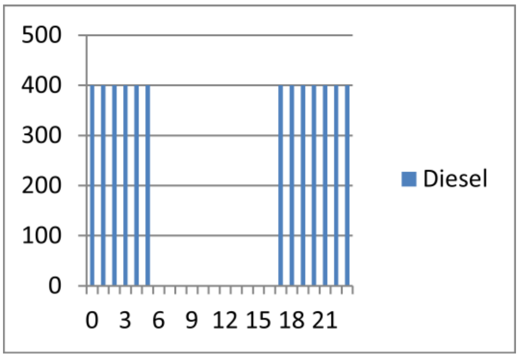

Figure 4. Load Pattern and Generator System in Karimunjawa

Under these conditions, the scenario modeling system is planned with 2 ways. First, From 10:00 am to 02:00 pm, the electrical load is 100 kW which is supplied by using PV. Second, Diesel supplies 400 kW during 5:00 pm to 06:00 am. The peak load is 25% of the regular load which is equal to 500 kW, 400 kW of diesel and 100 kW of PV.

By ignoring the efficiency of equipment, the scenario modeling which is done without using HOMER software with the manual approach result the load from morning until mid-day by using PV with a capacity of 100 kW, 100 kWh battery and 100 kW inverter.

To supply the peak load occurring during 3 hours, 100 kW is for each hour or amounting to 300 kWh. It is by the assumption that a maximum energy of sunlight occurs from 9:00 am to 02:00 pm or 5 hours. PV capacity of 60 kW for 5 hours produces an output of 300 kWh with battery capacity of 300 kWh and inverter of 100 kW.

The total electrical load in Karimujawa is 6000 kWh / day, consisting of 5,200 kWh from diesel and 800 kWh from PV. The Contribution of PV *(Renewable Energy)* for the system is 13%. The scheme of load pattern and generation of the first scenario can be seen in Figure 5.

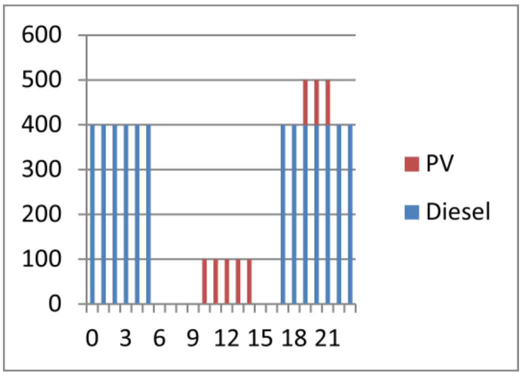

Figure 5. The first load pattern and generator scenario modeling

The second scenario with additional PV capacity of the system to 21%, it is done by turning on electricity 24 hours with details of 100 KW of PV to supply from 06:00 am to 05:00 pm and at peak load of 100 kW of PV, 400 kW of diesel which occurr at 07.00pm-09.00 pm. As the first scenario, the diesel supplies from 5:00 p.m. to 6:00 a.m with 400 KW.

Modeling and loading plant of the second scenario can be seen in Figure 6.

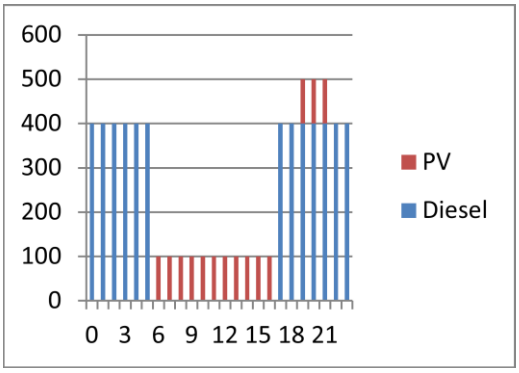

Figure 6. The second scenario of modeling and loading plant

5. THE RESULT OF SIMULATION

The simulation and optimization by utilizing HOMER software results various different configurations based on the minimum limitation of renewal energy contribution.

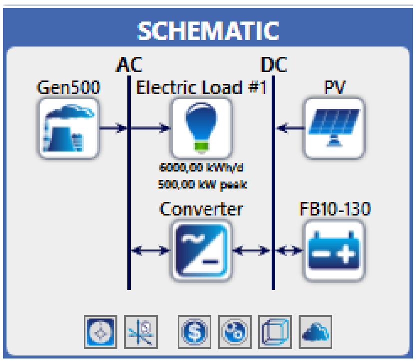

Figure 7. The Architecture of PLTH, Karimunjawa Island

Tabel 1. The Composition of first scenario at PLTH Karimunjawa Island

Components		Total	Unit
PV	Generic flat plate PV	250	kW
Generator	500kW Genset	400	kW
Battery	CELLCUBE® FB 10-130	82	Strings
Converter	System Converter	150	kW
Dispatch Strategy	Cycle Charging		

Tabel 2. List of the Component Cost Input

Components	Capital (Rp)	Replacement (Rp)	O&M (Rp)
Generator	0	0	500,000/hour
PV Plat	17,080,000	0	500,000/year
Battrey Cell Cube	640,000,000	640,000,000	10,000,000/Year
Convertor (Inverter + Control)	1,600,000	0	500,000/Year

The period setting of this PLTH project will have been conducted for 10 years. The costs or total cost of this hybrid generator will be divided into 10 years' length as it is supposed to be, the total of annual cost which covers making components, replacing component, costs for maintenance and fuel will be counted and divided to the amount of the produced electrical energy whose result will affect the cost sell of electrical energy for each kWh. The NPC total cost for first scenario is Rp 85,413,436,416.

The total production of first scenario electricity is 2,282,892 kWh/year which consists of PV 17% (384,892 kWh/year) and diesel 83% (1,898,000 kWh/year). The monthly electric production from January to December results that the diesel is always constant like flat-designed modelling which produces electricity for 216,7kW/month, while the PV produces electricity with fluctuation based on the level of solar lighting. The electrical energy which is produced is as follows: 34.0 kW; 38.2 kW; 44.0 kW; 44.2 kW, 44.9 kW; 44.4 kW; 48.2 kW; 53.4 kW; 55.3 kW; 49.1 kW; 38.8 kW; 32.5 kW. For more detail, please see the figure 8 below.

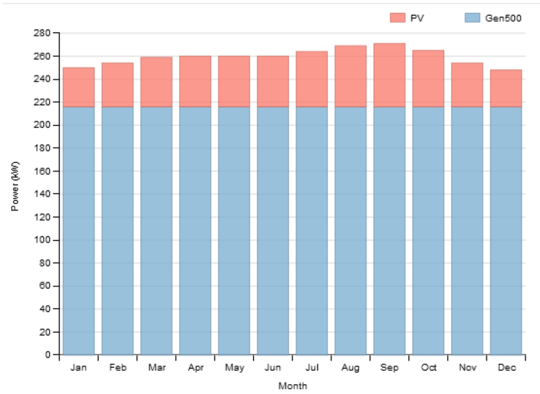

Figure 8. Monthly Electrical Production for the First Scenario

While at the second modelling scenario, the amount of the component can be seen on the table 3 below.

Tabel 3. The second scenario component composition of PLTH in Karimunjawa Island

Components		Total	Unit
PV	Generic flat plate PV	450	kW
Generator	500kW Genset	400	kW
Battery	CELLCUBE® FB 10-130	90	Strings
Converter	System Converter	150	kW
Dispatch Strategy	Cycle Charging		

The total unit of PV in the second scenario is higher than the first one which reaches 450 kW, the total of battery is also added becoming 90 pcs, while the generator and the inverter remain the same as the previous one. So that the capital cost and the total of system is rising. The total of system cost is Rp 93,173,436,416; while the annual system cost is 9,317,343,616.

The total of electricity production in the second scenario is 2,590,807 kWh/year, which consists of PV 26.74% (692,807 kWh/year) and generator 73,265 (1,898,000 kWh/year). The monthly electricity production of diesel generator in average is 216.7 kWh in a year. While the PV production is varied depending on the radiation level of solar lighting which happens in Karimunjawa Island. The fluctuation of energy produced is 61.3 kW; 68.7 kW; 79.1 kW; 79.6 kW; 80.7 kW; 80.0 kW; 86.7; 96.1 kW; 99.5 kW; 88.4 kW; 69.8 kW; 58.5 kW; for more detail, please see the figure 9 below.

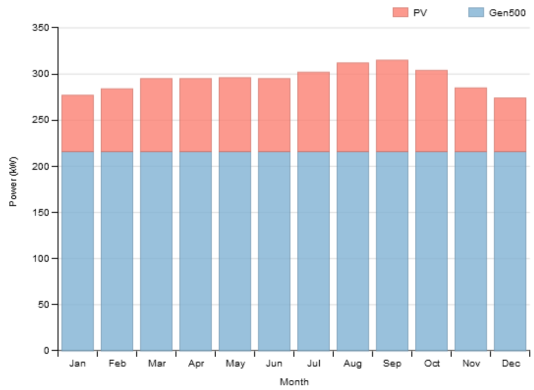

Figure 9. The Monthly Electricity Production of the Second Scenario

The comparison of the previous operational cost when using the diesel as like in the figure 5 where the sell price for each kWh is Rp 2,500,- to cover the lack of the operational cost, an abonnement of Rp 30.000,-/month for each RT, and 50.000,- /month for each business is added.

On the planning of the first scenario with the total load of 6000kWh/day as at the figure 6 is supplied by PV 13% (800 kWh/day). The total cost of making the component of PLTH is Rp 56,970,002,432; there is no cost for component replacement, this is because the length of the project is 10 years, the tools are still at the *lifetime* or warrant, except the generator. This generator is existed before, so that, it does not include the cost of component making. The generator replacement is not included in the cost system because it belongs to local government. The cost for all component maintenance and operation is Rp 12,572,498,944; while the cost for diesel fuel for 10 years is Rp 42,110,935,040,- with the price Rp 8,600/liter; the total amount of making system is Rp 85,413,436,416; divided for ten years, therefore the annual cost is Rp 8,541,343,872;. The cost of the first modelling is Rp 3,900/kWh; this is acquired from the annual operational cost of the system Rp 8,541,343,872; divided to the total of electricity consumption which is 2,190,000 kWh/year.

250 kW PV with the average output of 1054.50 kWh/day, 1kW in average produces 4,216 kWh/day. The operation time of PV is based on the data which have been inserted acquired from NASA, which is for 4,376 hours/year or 12 hours/day in average. The cost for *livelized* cost or PV sell price if it is independent from the system is Rp 1,429 kWh/year, this price is acquired from the total cost of PV without considering the battery and inverter which cost Rp 549,999,992,- divided to annual PV production which is 384,892 KWh/year.

The 400 KW generators are on for 4745 hours/year, the electricity production is 1,899,000 kWh/year. The diesel cost if it is independent to the PLTH system is Rp. 2343/kWh. The fuel consumption is 489,662 liter/year, with the price of Rp8, 600/liter, so that, the cost for fuel consumption is Rp 4,211,093,504;

In the second scenario modelling by extending the time for electricity usage to be 24 hours as in the figure 7, the load in the morning to the late afternoon is 100 KW, while on the evening is like in the first scenario, the amount of component which is used is the 400 KW of generator, 450 KW of PV, 150 KW of Inverter, and 90 pcs of Battery. The total load is 6600 kWh/day; PV supplies 21% (1.400 kWh/day). The cost of tool making is Rp 65,490,001,920; As like in the first modelling, there is no component replacement. The cost for maintenance and operation is Rp 14,372,499,456; the fuel cost is Rp 42,110,535,040; the total cost during the project is Rp 93,173,436,416;.

The total annual cost of the system is Rp 9,317,343,616; with the electricity price consumption is 2,409,000 kWh/year, so that the sell price is Rp 3,867/kWh.

The cost of the levelized PV of the second scenario is Rp 1,429/KWh. This cost is acquired from the annual total cost of PV without the cost for battery and inverter which is Rp 989,999,968; divided with the electricity production which is 692,807 KWh/year. While the production cost for generator is the same as the first scenario.

Based on the default system of HOMER for the generator of 500 KVA / 400 KW, it produces emission as on the table 4 below.

Table 4. Pollutant and Emission of Diesel Generator

Pollutant	Emissions	Units
Carbon dioxide	1289441	Kg/yr
Carbon monoxide	3183	Kg/yr
Unburned hydrocarbons	353	Kg/yr
Particulate matter	240	Kg/yr
Sulfur dioxide	2589	Kg/yr
Nitrogen oxide	28400	Kg/yr

6. CONCLUSION

The first scenario has load of 5200 kWh/day with an addition of 800 kWh/day. PV of Total electricity load in Karimujawa Island is 6000 kWh/day. The annual operational cost of the system is Rp 8,541,343,872; divided to the total of electricity consumption which is Rp. 2,190,000 kWh/year, so that the sell price of the first modelling is Rp 3,900/kWh.

In the second scenario by extending the electricity load to be 24 hours, the total amount of the load is 6600 kWh/day. The total cost during the project is Rp 93,173,436,416; the total annual cost of the system is Rp 9,317,343,616; with the electricity consumption is 2,409,000 kWh/year, so that the sell price is Rp 3867/kWh. The operational cost of utilizing diesel with the load of 5.200 kWh/day so far is sold for a kWh is Rp 2500,-, the price difference offered in the second scenario above is the cost which consumers must pay.

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