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Hybrid of Photovoltaic and Diesel Power Plant in Celagen Island

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Abstract. Celagen Island is one of the outer islands in Bangka Belitung Islands Province. The population of Celagen island is 1234 people and dominated by fishermen. Currently, electricity is supplied from 1 unit of photovoltaic with capacity 80-kWp and coupled with three units of diesel power plant with capacity 100 kW. To meet the electricity needs of 1069 kWh /day, supply from diesel power plant already sufficient. But for the economics of the cost of providing primary fuel, a hybrid from photovoltaic and diesel power plants needs to be done. Hybrid power plants are one of the options to meet the electrical energy needs of geographically difficult areas to connect to the on-grid electricity network. The hybrid system with 72% of electricity from the diesel power plant and 28% of electricity from photovoltaic is very economical. The economic analysis shows that with this modeling, the cost of providing primary fuel is lower by 1228 rupiah/kWh if only using diesel power plant.

1. Introduction

Celagen Island is one of a small island group in the South Bangka Regency, Bangka Belitung Islands Province. Administratively it is included in the Pongok Islands sub-district with an area of 92128 km^2 and a population of 1234 people [1] which is dominated by fishermen's livelihood, as shown in Figure 1. To meet the electricity needs on Celagen Island, in 2013, State Electricity Company (Perusahaan Listrik Negara, PLN) built a photovoltaic with a capacity of 80 kWp. Along with population growth and peak load, the power capacity of photovoltaic can no longer meet all existing load requirements. Therefore in 2017, PLN built a new diesel power plant with a capacity of 3 units of 100 kW [2].

Fig 1. Location of Celagen Island [3]

It is necessary to model a hybrid power plant between solar power plants and a diesel-powered electric generator. In addition to diversifying the source of electricity generation, it also aims to obtain an economical plant based on the basic cost of providing electricity, but still meets the electricity needs of the entire community on the island of Celagen.

Hybrid power plants are one of the options to meet the electrical energy needs of geographically difficult areas to connect to the on-grid electricity network. Besides, the use of hybrid electricity, such as photovoltaic, also utilizes the local potential in the area, reducing losses because the distance between the generator, transmission and load, and the use of renewable energy, can reduce carbon dioxide emissions [4] [5].

Several modeling of hybrid power plants have installed in Indonesia; hybrid models of a hydroelectric, diesel and photovoltaic in Nusa Penida [6], diesel and wind in East Timor [7], and photovoltaic-diesel in Peucang Island [8] also photovoltaic-wind in Kakorotan Island [9].

Also, several modeling of hybrid power plants has implemented in the Bangka Belitung Islands. The modeling of hybrid power plants based on photovoltaic and diesel power plants for the Semujur island community, amounting to 90 families [10]. Modeling of other micro-hydro-based and photovoltaic based hybrid power plants for 180 families in Sadap, Regency of Central Bangka [11].

With an average intensity of solar irradiation of 4.95 kWh/m^2 , photovoltaic is one of the choices of types of power plants to meet electrical energy needs in Bangka Belitung Island [12]. However, meeting these electrical energy needs is also related to the cost of providing basic fuel. This study will described when the fulfillment of electricity is only from the diesel or hybrid photovoltaic and diesel.

2. Methodology

1. Data collection including load data, generator technical specifications and electrical distribution system on Celagen Island
2. Model of hybrid operating system accordance with the specification of a diesel power plant and photovoltaic
3. Analyze of the magnitude of the operating costs of each plant and the most optimal loading scheme between plants
4. Calculate the cost of providing fuel for power plant

3. Results and discussion

3.1 Modeling Results of the diesel power plant

The electricity system on Celagen Island consists of a generating system and direct distribution to residential areas. The modeling of diesel power generation systems is modeling to function as a reference and to find out the cost in the system during the operation of a diesel . The load parameters on Celagen Island in Table 1

Table 1 Diesel power plant in Celagen Island [2]

Total of electrical energy in February 2019	29920 kWh
Average of electrical energy/day	1069 kWh
Operating hour	24 hours
Specific Fuel Consumption (SFC)	100% = 0.227 L/kWh 75% = 0.229 L/kWh 50% = 0.231 L/kWh
Capacity	three units x 100 kW

Total electrical energy needs on Celagen Island per day is 1069 kWh with a peak load of 116.8 kW, and it happens between 06.00 – 07.00 PM. The load profile in Figure 2, besides displaying daily electrical energy requirements and peak loads, also shows the annual electrical energy requirements of the community on the island of Celagen

Fig 2 Load profile on Celagen Island [13]

The diesel engine operated amounts to 2 x 100 kW with 8760 hours and the electricity produced is 497.215 MWh/year to get the optimal value. In the operation of a 100 kW diesel engine, diesel fuel is needed in the amount of 161924 liters. If the price of diesel oil used is 7153.3 rupiah/liter (after 10% tax), then the 100 kW diesel generator fuel costs are 1.158 million rupiahs/year with the cost of producing electricity produced by a 100 kW diesel engine at 3269 rupiah/kWh.

3.2 Modeling results of a hybrid diesel power plant and photovoltaic

In the modeling of hybrid systems, photovoltaic uses a monocrystalline type with a capacity of 80 kWp by considering favorable capital prices so that the investment costs incurred are smaller.

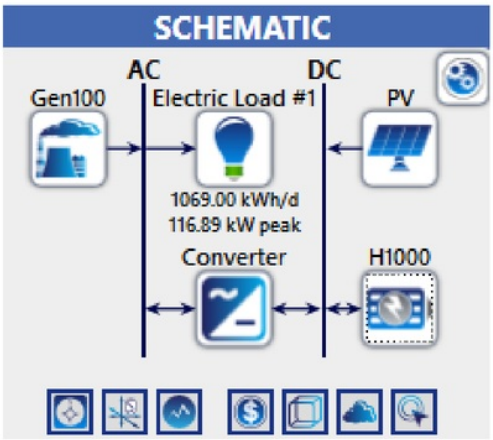

Figure 3 Schematic of a hybrid power plant [13]

To determine the number of photovoltaic required, type of the photovoltaic panel in the modeling of a hybrid power plant system has the following detailed specifications:

Table 2 Specification *PV panel* [13]

Name	*Generic Flat PV panel*
Abbreviation	*PV*
Panel Type	*Flat Plate*
Rated Power (P_{max})	80 kW
Cell Efficiency	20 %
Derating Factor	80 %
Voltage at Pmax (V_{mp})	37,5 Volt
Temperature Coefficient	- 0,5
Standard test condition	25^0C
Size	-

The planning of photovoltaic array modeling in the hybrid system is to supply 100% electricity usage, with the average daily electricity consumption on the island of Celagen is 1069 kWh. For the location of Celagen Island, average solar radiation 5.13 kWh/m^2/day, and maximum temperature according to the Agency for Meteorology, Climatology, and Geophysics Pangkalpinang is 28.2 ^{0}C [14].

Based on calculation for the photovoltaic area, using 4 unit panels of photovoltaic with output power 80 kWp. The efficiency of photovoltaic is 20%. Then, we determine the number of batteries, which affect the form of electrical energy capacity, voltage, and current capacity in the battery. Photovoltaic with a capacity of 80 kWp and taking into account the battery requirements for three days without irradiation, the number of batteries is 189 units and 1 unit of an inverter with a capacity of 100 kW

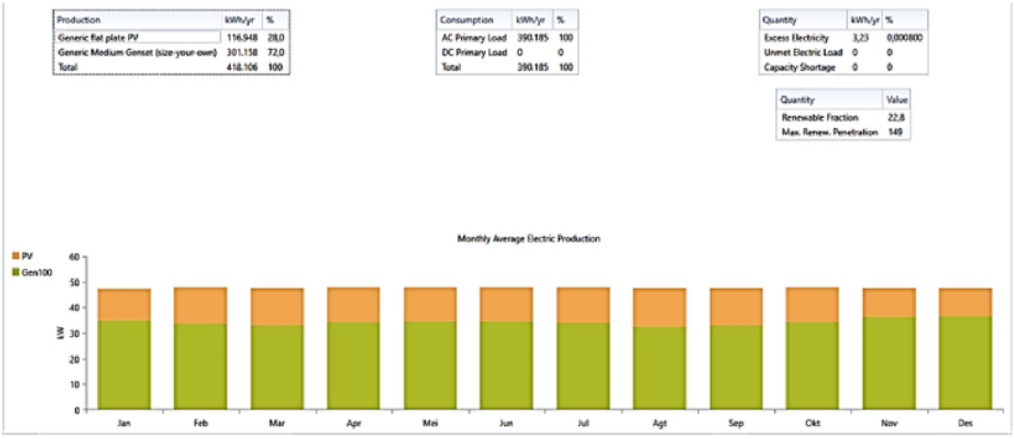

Figure 4 Modelling result of hybrid power plant [13]

Figure 4 shows the simulation results from the modeling of hybrid systems. It is showing the contribution of electrical energy produced by diesel generators is 301.158 MWh/year or about 72%, and the electricity produced by photovoltaic is 116.948 MWh/year or around 28%. Totally from two plants when 100% is 418.106 MWh/year. The value of electricity production is indeed lower than the operation of only diesel generators at 497.215 MWh/year. But the cost of producing electricity produced by a 100 kW diesel generator 3269 rupiah/kWh is more expensive compared to the production costs of electricity produced by hybrid power plant 2041 rupiah / kWh.

From two of modeling, it can be seen different of power plant only diesel generators and hybrid diesel generators-photovoltaic from totally produced of electricity (MWh/year) and cost of electricity production (rupiah/kWh).

4. Conclusion

Modeling of generator system shows that the electricity produced is 497.215 MWh/year with the cost of producing electricity 3269 rupiahs/kWh. For hybrid system, the contribution of electrical energy from a 301.272 MWh/year diesel generator or about 72% and electrical energy from a photovoltaic 116948 kWh/year or about 28%. And, finally, from the modeling result, electricity production costs generated by the hybrid system 2041 rupiah/kWh or lower 1228 rupiah/kWh when compared to the diesel power plant.

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