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# THE OPTIMUM SIMULATION ANALYSIS OF SUSTAINABLE MICROGRID ELECTRICITY SYSTEM BASED ON HYBRID POWER PLANT ON TUNDA ISLAND, BANTEN PROVINCE

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**Abstract.** Tunda Island is one of the islands in a group of 17 islands in the north of Java, Banten Province. Electrical energy in Tunda Island is supplied by 2 Private Diesel Genset, each of which has an installed capacity of 100 kVA and 75 kVA, with an operating time of 4-5 hours per day starting from 18.00 to 22.00. The microgrid electrical system has several advantages, in terms of efficiency, microgrid can reduce the use of fossil fuels in power plants, besides that it can reduce losses caused by the distribution system because the location of the microgrid generator is relatively close to the load. In terms of reliability, the microgrid electrical system can optimally manage energy sources for 7 days and 24 hours. In addition, the microgrid electrical system has the ability to work without being connected to the grid. With the use of a microgrid electricity system, the electricity costs that must be paid are less and most importantly can reduce carbon emissions, because the plants used in the microgrid electricity system generally use renewable energy. In this study, scenarios were made to determine the most optimum LCoE value using an optimization approach with the help of homer pro software. The operating pattern for the Tunda Island electricity system is obtained, namely, the load is carried during the day by Solar PV Power Plant and at night using a generator that has been controlled using the force on & force off mode. From the simulation obtained the lowest LCoE in the Solar PV Power Plant Hybrid configuration with capacity of 240 KWp, 302.4 KWh battery & 200 KW inverter. The ability to pay for electricity for the residents of Tunda Island is still possible if subsidized tariffs are imposed, the range of ability to pay for the residents of Tunda Island is IDR/KWh 726.45-1452.91 and their ability will decrease if they are subject to non-subsidized PLN tariffs. With PLN as the PSO, the differrence in tariffs with the local Generation Production Cost will receive a subsidy from the government. Furthermore, the sustainability of this microgrid system will have the benefit of a continuous supply of electricity. So, it can be felt by the people of Tunda Island which is managed by State-Owned Enterprise (PT. PLN Persero).

**Keywords:** Tunda Island; microgrid; LCoE; solar PV.

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## INTRODUCTION

Tunda Island is one of the islands in a group of 17 islands in the north of Java Island, Banten Province (Mujiyanto, Garcia, Haryadi, Rahayu, & Budikusuma, 2020); (Nurruhwati, Ardiansyah, Yuliadi, & Partasasmita, 2020). Administratively, it belongs to the Tirtayasa District, Serang Regency. Geographically, it is located at coordinates 5°48'18" to 5°49'20" South Latitude and 106°15'14" to 106°17'27"E. On this island, there is one kelurahan or village namely Wargasara Village which consists of two villages, namely: West Village and East Village. The area of Tunda Island is ±260 ha which is occupied by 450 families with a population of 1502 people whose work on marine products, namely fishermen (80%), farm laborers (10%), and other workers (10%). The economic welfare of the community can not be said to be good (Kehlbacher, Bennett, & Balcombe, 2012), around 200 heads of families are included in the pre-prosperous and prosperous economic group 1. At the beginning of 2015, the Serang district government has determined Tunda Island as a tourism destination. Previously, during normal times, electricity on Tunda Island was supplied by 2 non-PLN Diesel Power Plants, each with an installed capacity of 100 kVA and 75 kVA, with an operating time of 4-5 hours per day starting from 18.00 to 22.00. The outputs of this thesis study are in the form of the PLTH Operation and Maintenance system method and the electricity network system to customers, the performance or capability of the PLTH (Han & Lim, 2010); (Kostopoulos, Papalexandris, Papachroni, & Ioannou, 2011), namely the integration between Diesel Genset based on fuel, with Solar PV based on renewable energy, in the form of the total power of Hybrid Power Plant, the amount of fuel that can be saved (Khelif, Talha, Belhamel, & Arab, 2012), the excess electrical energy that can be stored in the BES, the cost of generating electricity and its emission output. The data processing in this study is entirely assisted by the HOMER software (Kolter & Johnson, 2011); (Morris et al., 2013); (Anastasopoulou et al., 2016). Furthermore, to ensure the sustainability of this microgrid system so that the benefits are felt by users on the island of Tunda, it is necessary to carry out an Institutional Sustainability approach through PT. PLN (Persero) already has an operating and maintenance management organization that is already running well.

## METHODS

This paper uses a simulation in the form of HOMER Pro software which is used to make modeling and simulation of a combined system for a generator system that is integrated with the Solar PV system on Tunda Island, Banten Province. This simulation uses data from NASA predictions from databases around the world. In this simulation, we use variations in the area of Solar PV to find out the most optimal LCoE value with the generator operating scenario below.

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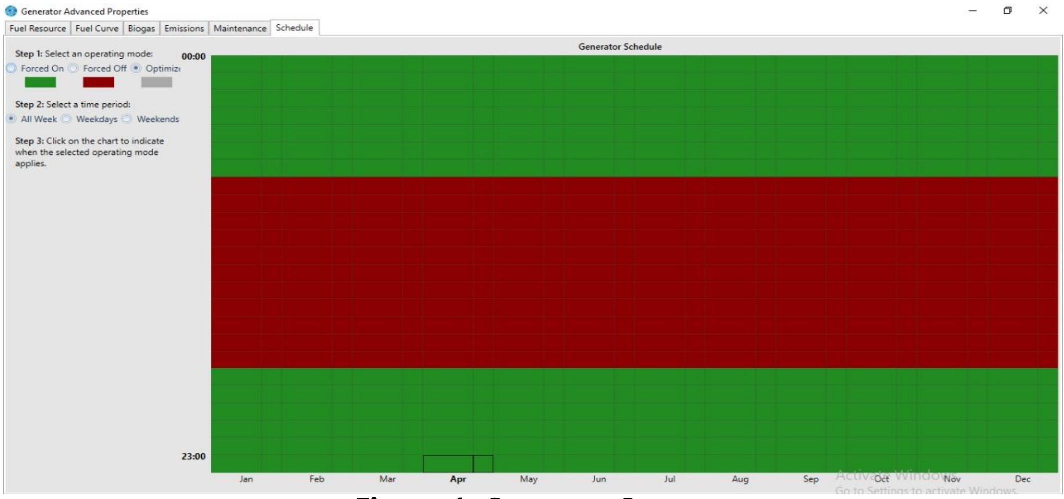


**Figure 1.** Generator Pattern

In Figure 1 The green color shows the live operation pattern starting from 6 pm to 6 am. The red color represents the off-operation pattern for the generator. It is hoped that the following operating pattern will make the system that will enter the network adaptable. During the day with sufficient solar intensity and the generator operating pattern is off, the Solar PV penetration enters to carry the load. In this study, scenarios were made to determine the most optimum LCoE value using an optimization approach with the help of homer pro software. In the scenarios made, there are 3 scenarios, where the capacity of the Solar PV that is designed is varied. The results obtained show several parameters that can be analyzed, namely (Fedulov, Fedorenko, Kantor, & Lomakin, 2018): NPC (Net Present Cost) is the total cost used consisting of initial costs (Capital Cost), Operation & Maintenance (O&M), and replacement costs (Replacement) (Martin, Lazakis, Barbouchi, & Johanning, 2016); (Xia, Shi, Si, Du, & Xi, 2021). The electrical load used is a residential load type because the load value is around 100 kWh. The modeled electrical load uses the Long Island load curve reference.

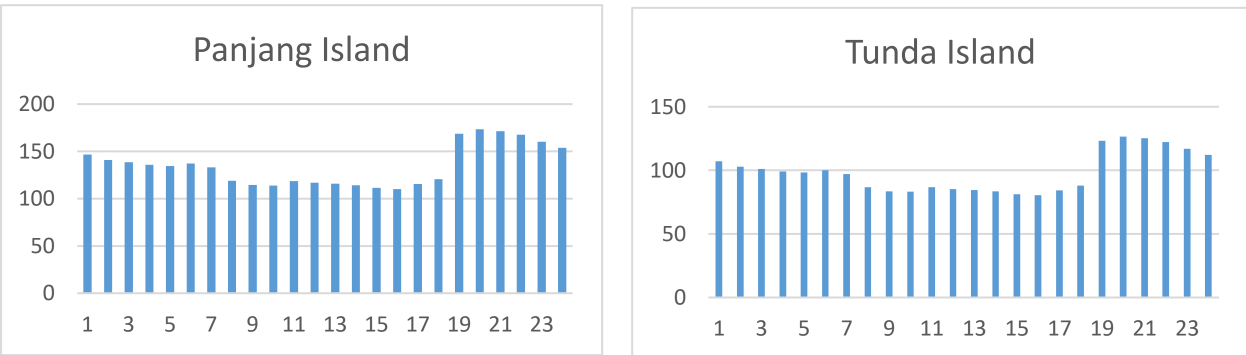


**Figure 2 .** Long Island & Tunda Island Load Curves

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Levelized Cost of Energy Homer (LCoE) defines as the average cost per kWh of useful electrical energy produced by the system.

$$LCOE = \frac{\dfrac{\frac{i'-f}{1+f}\left(1+\frac{i'-f}{1+f}\right)^{N}}{\left(1+\frac{i'-f}{1+f}\right)^{N}-1} x\, C_{NPC,tot}}{E_{served,ACprim}}$$

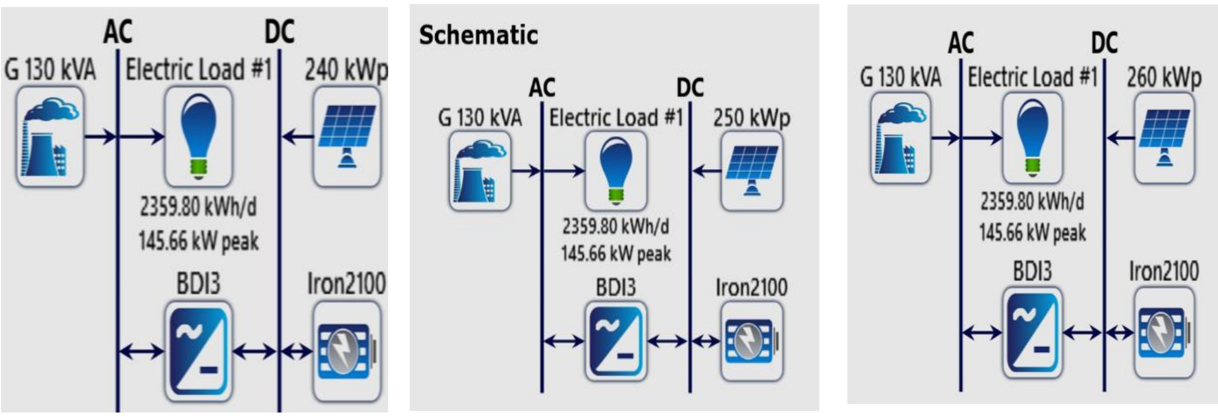
Where, i' = Discount rate (%)

f = Inflation rate (%)

N = Lifetime project (Years)

$^{E}$Serverd = Total electrical load served (kWh/yr)

The Net Present Cost (NPC) of a component is the present value of all the costs of installing and operating the component over the project lifetime, minus the present value of all the revenues that it earns over the project lifetime. HOMER calculates the net present cost of each component in the system, and the system as a whole such as capital cost, operation & maintenance (O&M), and replacement cost. Figure 3 following is a schematic of each system. There are 3 scenarios of the Solar PV system designed by varying the Solar PV area, namely the 240 kWp, 250 kWp & 260 KWp SOLAR PV system. The block diagram below is an off-grid model and is all set for 25 years, with a random variability of 0% day today and a time step of 5%.




(a) (b) (C)

**Figure 3.** Configuration System (a) Sistem Solar PV 250 kWp (b) Sistem Solar PV 250 kWp (c) Sistem Solar PV 250 kWp

Below, is an attached estimate of the initial costs used. Indonesia's discount rate is 4% and an inflation rate of 3% in October 2020, which has been applied for 25 years.

**Table 1.** Cost of Configuration Solar PV systems

| Component | Unit | Cost |
|---|---|---|
| ***a. PV Module*** | | |
| PV module | ($/kWp) | 500 |

| | | |
|---|---|---|
| Mounting, labour cost & logistic | ($/kWp) | 272 |
| Balance of System & Construction Cost | ($/kWp) | 328 |
| ***Total Solar PV installation costs*** | ***($/kWp)*** | ***1100*** |
| ***b. Converter*** | | |
| Converter | ($/kWp) | 350 |
| Other hardware costs (including racking and wiring) | ($/kWp) | 150 |
| ***The total cost of the converter + installation ($/kW)*** | ***($/kWp)*** | ***500*** |

**(Source: Canadian Solar, SMA Inverter, ABB Baterai, 2021)**

## RESULTS AND DISCUSSION

After the simulation, the most optimal value is found in the 240 kWp solar pv system configuration with an LCoE value of cUSd 18.20 /kWh. The following is a Time Series Plot Analysis of the 240 kWp Solar PV System. The graph below illustrates the penetration of sources in the form of generators and Solar PV from the grid into the Tunda Island electricity system modeled in one day on 9 September. The most visible system is supplied by the generator on the red line and has been started from 5 pm to 6 am.

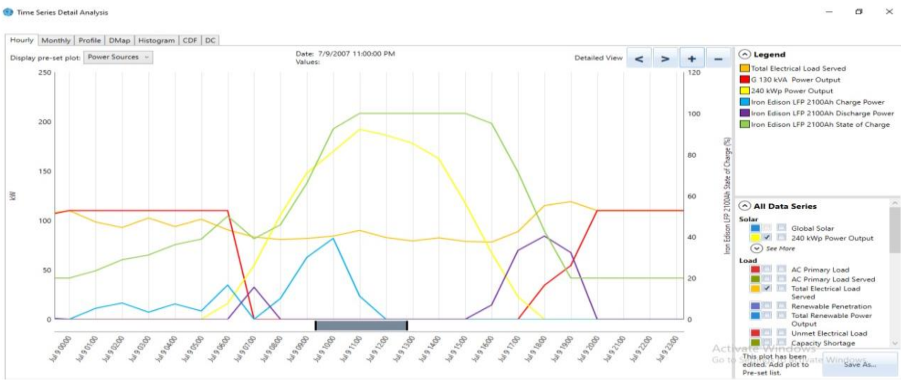



**Figure 4.** Diesel Fuel Calculation

Based on KEPEMEN ESDM NO. 169 of 2021 concerning the amount of generation production cost at PLN in 2020 for the area, referring to Panjang Island, the generation production cost is cUSd 19.25 /kWh. So, it is still under the local generation production cost. However, based on the calculation of the ability to pay off the local community, it is still below the LCoE obtained as shown in table 1 below.

**Table 2.** Tunda Island Ability to Pay

| **Keterangan** | **900 VA** |
|---|---|
| Income (IDR) | 2-4 million |
| Expenditure (IDR) | 1,9-3,8 million |

| | |
|---|---|
| Usage (kWh) | 137,65 |
| **Proportion of Electricity Expenditure to Total Expenditure (%)** | **5%** |
| **Payability, Average Approach (Rp/kWh)** | **1089,68** |
| **Payability Range (IDR/kWh)** | **726,45-1.452,91** |

## CONCLUSIONS

The operating pattern for the Tunda Island electricity system is obtained, namely, the load is carried during the day by Solar PV and at night using a generator that has been controlled using the force on & force off mode. According to the results of the simulation and manual calculations, the LCoE results for each scenario are obtained, namely scenario 1 with 240 kWp and cUSD 18.20, scenario 2 with 250 kWp generated cUSD 18.32, and the last scenario with 260 kWp obtained the LCoE value of cUSD 18.45. In the first scenario, the maximum SOLAR PV contribution produced at 11 am is 192.20 kW, scenario 2 is 200.21 kW and the last scenario is 208.22 kW. From the simulation obtained the lowest LCoE in the Solar PV Hybrid configuration with a Solar PV capacity of 240 kWp, 302.4 kWh battery, 200 kW inverter. With the installation of a prepaid kWh meter, arrears in electricity bills will no longer occur, with the activation of the limiter feature, the potential for inverter damage due to overload can be avoided. The ability to pay electricity for the residents of Tunda Island is still possible if subsidized tariffs are imposed [8], the range of ability to pay for the residents of Tunda Island is IDR 726.45-1452.91 and their ability will decrease if they are subject to non-subsidized PLN tariffs. With PLN as the PSO, the difference in tariffs with the local generation production cost will receive a subsidy from the government.

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