Study on the development of the Kodingareng Island Electricity System Hybrid PLTD with PLTS using the HOMER Software

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***Abstract*—**Kodingareng Island has a number of a population of 4526 people, where the electricity system is supplied by a generator with a capacity of 460 kVA which operates for 12 hours every day. Kodingareng Island has a source of New Renewable Energy (EBT) that can be developed, namely solar energy with an average potential of 5,870 kWh/m²/ day. In this study, the calculation of the parameters made 3 system scenarios. Scenario 1 system used only comes from generators operating on Kodingareng island, scenario 2 systems used are PLTS with energy storage while scenario 3 systems used are generators operating on Kodingareng island with solar panels + energy storage. The result of this research is that the generator system in scenario 3 is able to generate power of 1,830,487 kWh/year and has a percentage yield of 51, 2% of renewable electrical energy sources of the total energy produced. From the economic value of the generator system in scenario 3, the lowest NPC is Rp. 37,251,880,000 compared to scenario 2 with scenario 1 and the CoE value for scenario 3 is Rp.2,597/kWh.
***Keywords*—**Renewable Energy, PLTH and Economic Analysis

I. INTRODUCTION

Today, the use of solar cells as a power generatoris increasingly being used. Not only in large industries but has been widely used by the wider community. The advantage of this system is that one system can cover the shortcomings of the other system, besides that it makes it easier to carry out system maintenance because the supply of electrical energy can be maintained without having to cut off the power flow. One of the uses of a hybrid system is the use of a Solar Power Plant (PLTS) with a Diesel Power Plant (PLTD).Theuse of this hybrid system allows PLTS to cover the shortcomings of PLTD and vice versa. By utilizing this technology, the community's dependence on electricity from PLN can be reduced or even eliminated so that thecommunity can become an energy-independent society

Kodingareng Island is an inhabited island in Ujung Tanah District, Makassar City and has a distance of about 15 km from the main island of Makassar City. To serve the need for electric lighting,the people of Kodingareng island rely on electricity supply from PLTD and PLTS owned by PT. PLN (Persero). The generators function alternately (switches) and not directly connected to the PLN network (Off Grid). However, this energy source has not been able to meet all the loads on the island of Kodingareng.

So this study proposes the application of a PLTD hybrid power plant with a PLTS that combines the two energy sources consisting of solar panels and a diesel generator to ensure that the electricitysupply needs on Kodingareng Island can be met evenly and are able to produce an optimal hybrid power generation system plan on the island. Kodingareng uses simulation in software HOMER (Hybrid Optimization Model for Electric Renewable).

II. THEORETICAL BASIC

1. Solar Power Generation

Solar Power Generation System (PLTS) is a solution to meet the energy needs in today's era. PLTS converts direct sunlight into electrical energy. Based on the type of energy that comes from the sun, namely heat and light, solar power systems aredivided into two types (solar thermal and PLTS). Generally solar thermal utilizing solar heat as a water heater, while PLTS converts direct sunlight energy into electricity by photovoltaic (PV) modules.

PV generates direct current or electricity direct current (DC). Household electrical appliances that almost entirely use alternating current oralternatingcurrent (AC) causes the need for an inverter to convert the DC current generated by PV into AC current.

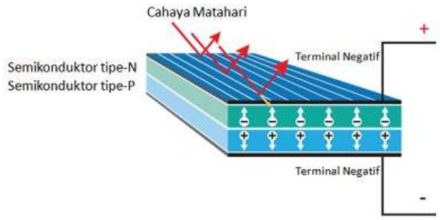

Figure 1 Photovoltaic Schema Cell

Thesolar power plant itself operates without causing noise pollution, reducing environmental pollution, a long service life of up to 30 years, and relatively low maintenance costs. Although the initial capital required is very large, the energy produced after 4 years of operation will replace the energy used to make it. Suppose the service life is 20 years, then after operating for 4 years, the energy expended for 15 years does not require expenditure.

2. Diesel Generation

Diesel Power Plant (PLTD) isa power plant that uses a diesel engine as the prime mover (prime mover). Prime moversis equipment that has the function of producing the mechanical energy needed to rotate the generatorrotor.

Diesel generators convert chemical energy from fuel into mechanical energy to drive the rotor of an induction generator to produce electrical power. Fuel injection and engine rotational speed can be determined by fuel consumption compared to power load. Low capital costs and high fuel efficiency when operating at maximum capacity arethe advantages of diesel generators. However, the drawbacks of diesel generators are very high fuel costs and produce gas emissions that have a negative impact on the environment

3. Hybrid system plant

Hybrid system generator is acombination of generators with a combination of different energy sources. Hybrid system generation can overcome the limitations of fuel in energy sources. Generally, a hybrid system generator consists of a diesel generator, AC power delivery system, DC power delivery system, loads, renewable energy sources, energy storage systems, converters, combined diesel generator systems, load shedding, load management or monitoring systems. In hybrid system generation, the output from the renewable energy source initially needs tobe conditioned to reduce load shock.

The purpose of designing a power plant with a hybrid system is to obtain fuel efficiency (saving fuel) from conventional generators (generally dieselgenerators) and also to improve reliability (reliability) generators with renewable energy sources. Development and use of generators with renewableenergy sources very rapidly, it is known that PV and Wind Turbine (WT) has been widely applied as a generator. The nature ofrenewable energy such as PV and WT which can only produce energy for a certain time is used as the basis for the application of hybrid system generators.

4. Feasibility Analyst

In conducting an economic analysis of the feasibility of the PLTH system, there are several indicators that are often used, namely analysis for: Net Present Value (NPV), Profitability Index (PI), Cost of Energy (COE) and Internal Rateof Return (IRR):

a. Net Present Value

Net Present Value or NPV is used to analyze the profit of an investment or project, the formula used is sensitive to changes in the value of currency or goods. The formula for determining NPV is as follows (Usman, 2014).

$$\text{NPV} = -\text{S} + \sum_{t=1}^{n} \frac{NCF_t}{(1+i)^t}$$

b. Profitability Index

Profitability Index (PI) is the ratio of all net cash present value with the initial investment.This technique is also known as the cost benefit ratio model.*benefit cost ratio*). The PI technique is calculated using the following equation:

$$PI = \sum_{t=1}^{n} \frac{\sum_{t=1}^{n} NCFt\,(1+i)^{-t}}{\text{II}}$$

c. Cost of Energy

Cost of Energy (CoE) of a PV mini-grid system is the quotient between the sum of O&M and the Initial Investment cost which has been multiplied by the capital recovery factor and the total energy produced per year. The following is the equation in determining the value of CoE.

$$\text{COE} = \frac{\text{Sx CRF} + \text{O}\&M}{A\,kWh}$$

$$\text{CRF} = \frac{i(1+i)^n}{(1+i)^n - 1}$$

d. Internal Rate of Return

Internal Rate of Return (IRR) is the value of the interest rate which is the balance point between all expenses and income. In other words, the interest rate at which the acquiredNPV is equal to 0 is called the IRR.

The IRR calculation method uses investment by calculating the interest rate that equates the present value of the receipts received with the present value of the investment expenditures. The formula for calculating theIRR is as follows:

$$\text{IRR} = i_1 + \frac{NPV_1}{NPV_1 - NPV_2}(i_2 - i_1)$$

5. Homer

HOMER or Hybrid Optimization Model for EnergyRenewable is a model Micropower to make it easier to evaluate the design of the network single (grid-off) as well as networks connected to the system (grid-connected). In designing the generating system, it is necessary to pay attention to the system configuration, including: what components cannot be included in the system configuration, how many and what size of each component must be used, the numberof technology options in calculating costs and the availability of energy resources.

HOMER also works to do simulation in analyzing the potential of solar energy,the cost of developing renewable energy and doing optimization. The HOMER simulation process is useful for knowing the performance and characteristics of the power generation system. The optimization process is useful for configuration in a feasible and economical power plant. The advantages of this software are that it is easy to use,can perform simulations, optimize a model and thenautomatically find the optimum system configuration that can supply the load with the lowest current cost (NPC), and can use sensitivity parameters for better and more accurate results. (Tom Lambert, et. all., 2006).

III. RESEARCH METHODS

1. Place and Time

This research will be carried out on Kodingareng Island, Ujung Tanah District, Makassar City starting from June to November 2021

2. Research Procedure

a. Study of Literature

This literature study serves to examine andlearn all things related to theory to support system analysis

b. Data retrieval

The data used in this study consists of primary data and secondary data.

1. Primary Data

Primary data is data that obtained from the results of measurements, calculations, and direct observations in the field. In this thesis, the primary data isthe installed load data which consists of the following data:
a. Photovoltaic Panel data
b. Battery data
c. Data Battery Chontroller Regulator (BCR)
d. Load data

2. Secondary data

Secondary data is data sourced from reference books, journals, and theses that are relevant to the thesis discussion. The secondary data used in this thesis are as follows:
a. Homer's program
b. Equipment Specification

IV. RESULT AND DISCUSSION

1. Projected load requirement

Estimation of electrical load growth is basically to determine the maximum load of an electric power distribution system in planning for additional power. Therefore, an estimate is not always 100 % accurate. Regression analysis is useful for obtaining a functional relationship between two or more variables. In addition, regression analysis is useful for obtaining a functional relationship between two or more variables. In addition, regression analysis is useful for getting the influence between predictor variables on the criterion variables or predicting the effect of the predictor variables on the criterion variables (Nur D. Hidayati, 2018)

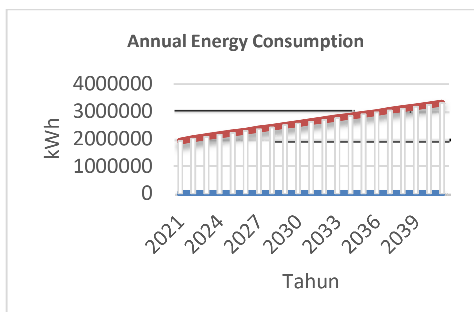

Figure 2 20 years energy projection

In Figure 2 shows that the consumption ofIn the next 20 years, energy consumption on the island of Kodingareng will increase from year to year.

2. Generating System Configuration

Simulation and optimization using HOMER is carried out by simulating several scenarios, namely the design of scenario 1, scenario 2 and scenario 3 simulations.

a. Scenario 1

The available generator configuration for scenario 1 is PLTD with a capacity of 1 x 200 kW and 1 x 160 kW, respectively. The principle of using this configuration is that because the addition of PLTS requires additional land and transportation costs are more expensive, scenario 1 option becomes one of the optimization of generators on Kodingareng Island. The following is the capacity of PLTD that is available on the island of Kodingareng:

Table 1 Scenario 1

Generator Type	
PLTD	
Capacity	1 x 200 kW
	1 x 160 kW

The operating system of this PLTD configuration is quite simple. Starting from the fuel in the form of oil which is used to drive a diesel engineso that it can turn a generator and produce electrical energy. This electrical energy can be directly distributed to the load in need becausethe output is already in the form of AC current.

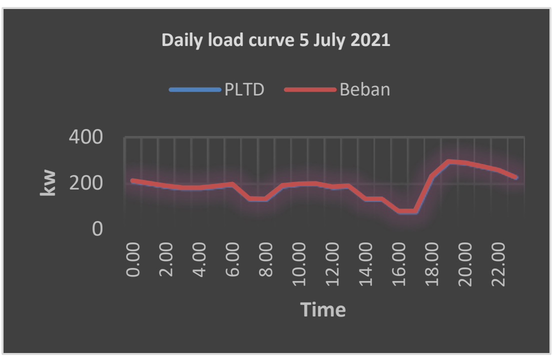

Figure 3 Load curve Exixting PLTD

b. Scenario 2

The operating system of the 100% PLTS configuration with battery storage is used for areas that do not yet have their own power plants. In addition, this configuration can also be used for the long term as a substitute for PLTD for areas that are still using PLTD. The following are the characteristics of the designedPV mini-grid:

Table 2 Scenario 2

Generatot Type	
PLTS	
Capacity	2.109 kWp
Number of Panels	11.100 unit
Battery	2.584 x 2.345 Ah
Inverter	350 kW

The operating system of this 100% PLTSstarts from the energy generated by the solar panels in the form of DC current. PLTS will operate during the day starting from 07:00 to 18:00. Then at night the energy that has been stored in the battery will supply the load needs at night starting at 18:00 to 07:00. In addition, the storage on the battery can also be used during the day if the PLTS cannot operate because the sun does not arise. On the next daythe PLTS will resume operation during the day, where the excess load generated by the PLTS will be used to charge the battery which on the previous day the stored energywas already used at night.

Based on the results of the simulation in HOMER, the curve in Figure 4 is obtained, which shows that the PLTS configuration with batteries is able to meet the load demand.

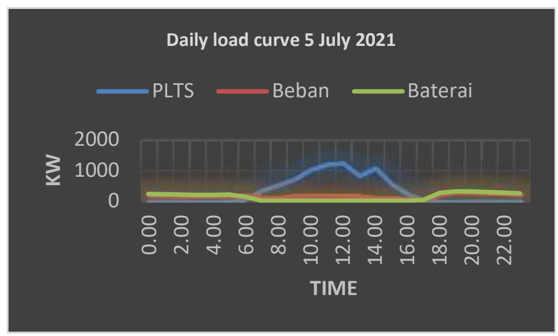

Figure 4 PLTS + Battey daily load curve

c. Scenario 3

The operating system of this PLTD and PLTS configuration is used to meet energy needs on Kodingareng Island by optimizing the potentialof solar energy on Kodingareng Island:

Table 3 Scenario 3

Generator Type			
PLTD		PLTS	
Capacity	200 kW	**Capacity**	590 kWp
		Number of Panels	3.106 unit
	160 kW	**Battery**	360 x 2345 Ah
		Inverter	300 kW

The principle of using this configuration is that at night the diesel power plant will be in parallel with the battery to meet peak load requirements. Then during the day when the sun shines and hits the installed solar panels, it will generate electrical energy in the form of DC current. This is what will be used to meet the needs of the day load so that the load demand for 24 hours can be met.

Because the output of PLTS is still in the form of DC current, it must be converted first usingan inverter so that it becomes AC current. Due to the possibility that the energy generated by PLTS exceeds the load demand due to erratic solar radiation as shown in Figure 5, the excess of PLTS output during the day will be stored by the battery. When the afternoon when the level of solar radiation is low enough, the battery will start operating to meet the load demand until the battery capacity that has been stored nears runs out. Followed by the use of PLTD which lasts from the time of the battery until the sun is stable enough to meetthe load demand.

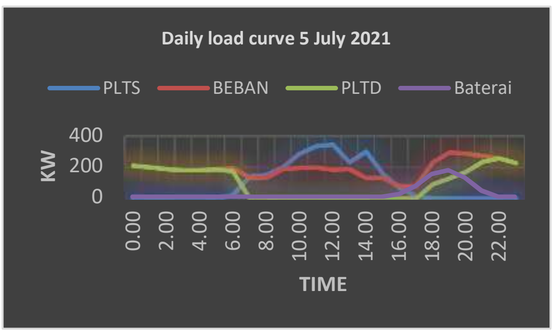

Figure 5 PV mini-grid hybrid daily load curve with PLTD

3. Generating system simulation results

Simulation and optimization using HOMER is doneby simulating several scenario systems such as simulation scenario 1, scenario 2, and scenario 3. This aims to see the system that is more optimal from an economic perspective in this case is the NPC. The optimal simulation results for scenario 1 are systems with PLTD capacities of 220 kW and 160 kW. Scenario 2 consists of 2,109 kW solar panels, 2,584 batteries and a350 kW inverter. Scenario 3 consists of 220 kW and 160 kW diesel generators, 590 kWp solar panels, 360 batteries and 300 kW inverters. The parameters of the simulation results can be seen in Table 4 below:

Table 4 System simulation results

Parameter	Skenario 1	Skenario 2	Skenario 3
NPC (Rp)	45.252.580.000	55.480.050.000	37.251.880.000
Investment (Rp)	782.300.000	42.623.577.192	8.951.142.105
Operating Cost (Rp)	4.959.341.000	1.433.759.000	3.156.796.000
CoE (Rp/kWh)	3.034	3.722	2.597
Production electrical energy (kWh/yr)	1.663.305	3.644.549	1.830.487
Consumption fuel (L/yr)	493.582	0	256.283
Contribution renewable energy (%)	0	100	51,2%
Excess Energy (kWh/yr)	0	1.779.030	88.270

The parameter used to determine the optimal generating system is the NPC according to the workings of HOMER. Based on Figure 4.5, the NPC comparison of the three generator system scenarios obtained that the optimal generator system is scenario3 because it has a low NPC compared to scenario 1 and scenario 2. with scenario 3 can reduce the consumption ofdiesel fuel.

4. Feasibility Analysis of Generating System

The feasibility of this system is determined based onthe calculation results of NPV, PI, DPP and IRR. Calculationof NPV, PI, DPP and IRR is determined by the PVGross Cost, DF and PV Gross Benefit. PVGross Cost generated by multiplying DF by the cash outflow while PV Gross Benefit obtained by multiplying the cash inflows by DF. Cash inflows are obtained by multiplying consumption of electrical energy by CoE and cash outflows are obtained from operating costs, which consist of replacement, operation and maintenance costs and fuel costs.

The cash inflow from this generating system is obtained from the electrical energy used, which is 1,663,087 kWh/year per year multiplied by the CoE of Rp 2,597/kWh, - so that the cash inflow is Rp 4,319,036,939/year. The cash outflows each year are operating and maintenance costs, investment costs,fuel costs and replacement costs of the generating system.

a. NPV

$$NPV = \text{Rp}34.393.908.296 - \text{Rp}33.090.374.057 = \text{Rp}1.303.534.240$$

The results of the present value calculation, which has a positive value of Rp. 1,303,534,240 (> 0). shows that the power plant system to be developed is feasible.

b. PI

$$PI = \frac{34.393.908.296}{33.090.374.057}$$
$$= 1{,}039$$

The result of the PI calculation is 1.039 (>1). shows that the investment in the power plant system to be developed is feasible

c. Payback Peride

$$\text{Payback Periode} = \frac{Rp8.951.142.105}{Rp1.777.974.835}$$

= 5 year 1 Month

The repayment of the capital costs incurred for the power plant on the island of Kodingareng is 5 years and 1 month.

d. Internal Rate of Return

To get the final result of the IRR, we need to find a discount set that generates a positive NPV. After that, you will find the discount rate that generates a negative present value.

$$IRR = 14 + \frac{84.635.578}{84.635.578 - (-232.672.502)} (15 - 14)$$
$$= 15{,}65\ \%$$

V. CLOSING

Conclusion

a. The base load served by the PLTS generator is 78kW and the peak load is 199 kW, while the baseload served by the PLTD is 180 kW and the peakload is 294 kW.
b. Based on the planning analysis of the electricalload requirements on Kodingareng Island forthe next 20 years, the load needs for Kodingareng Island are 11,332 kWh, the base load is 181 kW and the peak load is 723 kW.
c. Based on the simulation results with HOMER software, with 3 scenarios of the generating system, the most optimal configuration in terms of economic parameters is scenario 3 which consists of PLTS with a capacity of 590 kWp, batteries with a capacity of 2345 Ah with a total of 360 units, inverter with a capacity of 300 kW and PLTD with a capacity of 360 kW and the contribution of renewable energy is 51.2%.
d. Based on the economic feasibility analysis, this power plant system is feasible to run based on the eligibility criteria obtained, namely Net Present Value amounting to Rp1,303,534,240 (>0), Profitability Index 1.039 (>1), Payback period is 5 years 1 month and Internal Rate of Return which is 14.27% greater than Discount Factor used

Suggestion

Alternative land for the placement of additional PLTS on the island of Kodingareng considering the currently available land is not sufficient

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