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ANALYSIS OF POWER GENERATION AND DISTRIBUTION OF HYBRID ENERGY FOR ELECTRICITY LOADS IN BATAKAN VILLAGE

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ABSTRACT

The need for electrical energy continues to increase over time. However, in Indonesia power plants are still dominated by fossil fuel power plants, and there are still many areas without access to electricity. The use of renewable energy is needed to replace fossil fuels considering that fossil fuels can run out one day. The coastal area of Batakan Village in Tanah Laut Regency, South Kalimantan Province, was chosen as the focus location for conducting hybrid power plant simulations because this village is located in a coastal area where wind and solar energy sources are abundant. Batakan Village is approximately 40 km from Pelaihari City. Medium-voltage network transmission system (JTM) is supplied from Pelaihari City, and it is almost certain that this village experiences large power losses over long distance. This power loss will be detrimental if an effort is not made to reduce it. The purpose of this research is first to determine the optimal hybrid power plant configuration design to reduce power loss in the electricity system in Batakan Village. Second, it will analyze the power loss of the hybrid power plant system in Batakan Village, and finally, this research is going to analyze the investment feasibility of the hybrid power plant system in Batakan Village. In this study, the design of renewable energy plants, such as solar power plants (PLTS) with a total capacity of 406.1 kW and wind power plants (PLTB) with a total capacity of 125 kW, and the electricity network (grid system) are used together in a hybrid power generation system. The ETAP software was used to analyze the power losses of the hybrid power generation system, while the HOMER software was used to determine the net present value (NPV) and cost of energy (COE) of the hybrid power generation system. The results show that the configuration of the solar, wind, and grid systems is the most optimal. It is obtained from the results of ETAP simulations that have been carried out during average load and peak load conditions that by including the Solar Power Plant and Wind Power Plant power losses in the electricity system in Batakan Village can be reduced from the previous one using the system configuration only connected to the PLN power grid (grid system only). The total power losses incurred was 269.1 kW of active power and 1613.5 kvar of reactive power at average load reduced to 266.9 kW of active power and 1568.9 kvar of reactive power. At peak load the total power losses were 423.4 kW of active power and 2573.0 kvar of reactive power and they deceased to 41.,5 kW of active power and 2510.5 kvar of reactive power. In terms of investment, the COE value decreased by IDR 111, and the NPC decreased by IDR 6,600,000,000 at the average load. At the peak load COE decreased by IDR 88, while NPC by IDR 7,000,000,000. The return of investment (ROI) value is 13.2%, which indicates that the investment is still in the profitable stage.

Keywords*: Hybrid Power Plant, Solar Power Plant, Wind Power Plant.*

I. INTRODUCTION

ELECTRICITY consumption will almost certainly continue to increase over time due to economic and population growth. To fulfill the electricity demand, it is necessary to develop electric power plants that use both fossil resources and renewable energy. Given the limited availability of fossil resources, it is necessary to develop renewable power plants [1]. Wind power plants (PLTB) are power plants that use renewable energy sources owing to the nature of wind, which is environmentally friendly and will never run out in nature [2]. Solar power plants (PLTS) are power plants that convert sunlight into electrical energy through solar panels consisting of several solar cells (photovoltaic) arranged in series or parallel to produce electrical energy [3]. Power plants from the grid in Indonesia mostly still use steam power plants that use coal which is a nonrenewable energy source and will run out one day [4]. The three energy resources above will be combined in a hybrid system to achieve optimal renewable energy generation. To analyze the power losses of the hybrid power generation system, a software called ETAP is used, while a software called HOMER is used to simulate the economic side [5].

Batakan Village is located in the Tanah Laut Regency, South Kalimantan Province. Pelaihari City is the center of the government and economy of Tanah Laut Regency. The electricity system of Tanah Laut Regency is mostly supplied from the 150 kV substation located in Pelaihari City. Batakan Village is approximately 40 km from Pelaihari City. The medium-voltage network (JTM) transmission system from Pelaihari City will certainly experience large power losses, considering that the two regions are at great distance (6). This power loss will be detrimental if no effort is made to reduce the loss [7]. In response to the conditions above, the electricity system in Batakan Village or more specifically on the coast of Batakan beach requires an additional supply of electricity from nearby existing resources to reduce power losses generated from the transmission line of the medium-voltage network (JTM) GI Pelaihari to Batakan Village. Wind and sun are available in nature, which cannot be exhausted and can be converted into electrical energy [8]. The development of this hybrid power plant is considered appropriate because Batakan Village is in a coastal area with the potential for strong winds and sufficient sunlight.

II. Research Method

The articles must consist of at least eight pages. Do not change the font size or line spacing to insert more text on a limited number of pages. Use italics for emphasis; do not use underscores.

To insert an image in Word, place the cursor at the insertion location and use Insert | Picture | From file or copy the image into the Windows clipboard and select Edit | Paste Special | Picture (with the "float over text" option unselected). The editorial team of the Jurnal ELTIKOM will make the final editing for your article.

A. Related Research

Research conducted by Nebey [9] entitled *Design of Optimal Hybrid Power System to Provide Reliable Supply to Rural Areas of Ethiopia Using Matlab and Homer* showed that hybrid configuration of renewable energy generation could supply a load of 300 households. Wind energy generation produces 52% of the total electricity produced, hydro energy generation produces 35%, and solar energy generation produces 13%. The equation of the previous [9] and this research is used to obtain the amount of production of each renewable energy plant using HOMER software. The difference between previous [9] and this research is that the previous research only used HOMER software, while current research uses another software, namely ETAP, which is useful for obtaining system power flow analysis (load flow analysis).

Research conducted by Lei et al. [10] entitled *Sustainable Operation-Oriented Investment Risk Evaluation and Optimization for Renewable Energy Project: a case study of wind power in China* showed that the use of a clean development mechanism (CDM) in a wind energy generation system can reduce investment risk and optimize renewable energy operations in China. The similarity between previous [10] and this research is that net present value (NPV) is an important reference in determining the profitability of an investment. The difference between previous [10] and this research is that the value of cost of energy (COE) is also taken into account in determining the feasibility of the investment.

Research conducted by Soba et al. [11] entitled *Optimization of Hybrid Power Plant Capacity electricity load on Bunaken Island Using HOMER Software* found that when supplying electricity load in Bunaken Island, solar power plants (PLTS) produced electricity of 1,374,514 kWh per year (61%) and diesel power plants of 879,024 kWh per year (39%) with a cost of energy (COE) value of 0.334 $/kWh. The similarity of previous [11] and this research is in the use of HOMER software to obtain the value of net present cost(NPC) and cost of energy (COE). The difference between previous [11] and this research is that previous research [11] only used solar and diesel energy generation, whereas this research used wind, solar, and electricity generation from PLN network (grid system).

B. Research Location

The location of this research was on the coast of Batakan Village, Tanah Laut Regency, South

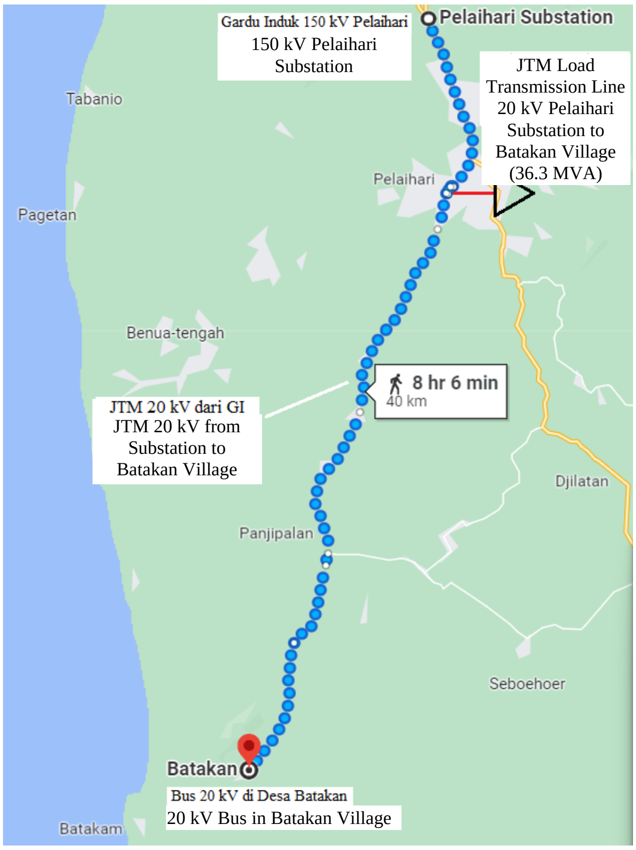


Figure 1. Distance from Pelaihari Substation to Batakan Village

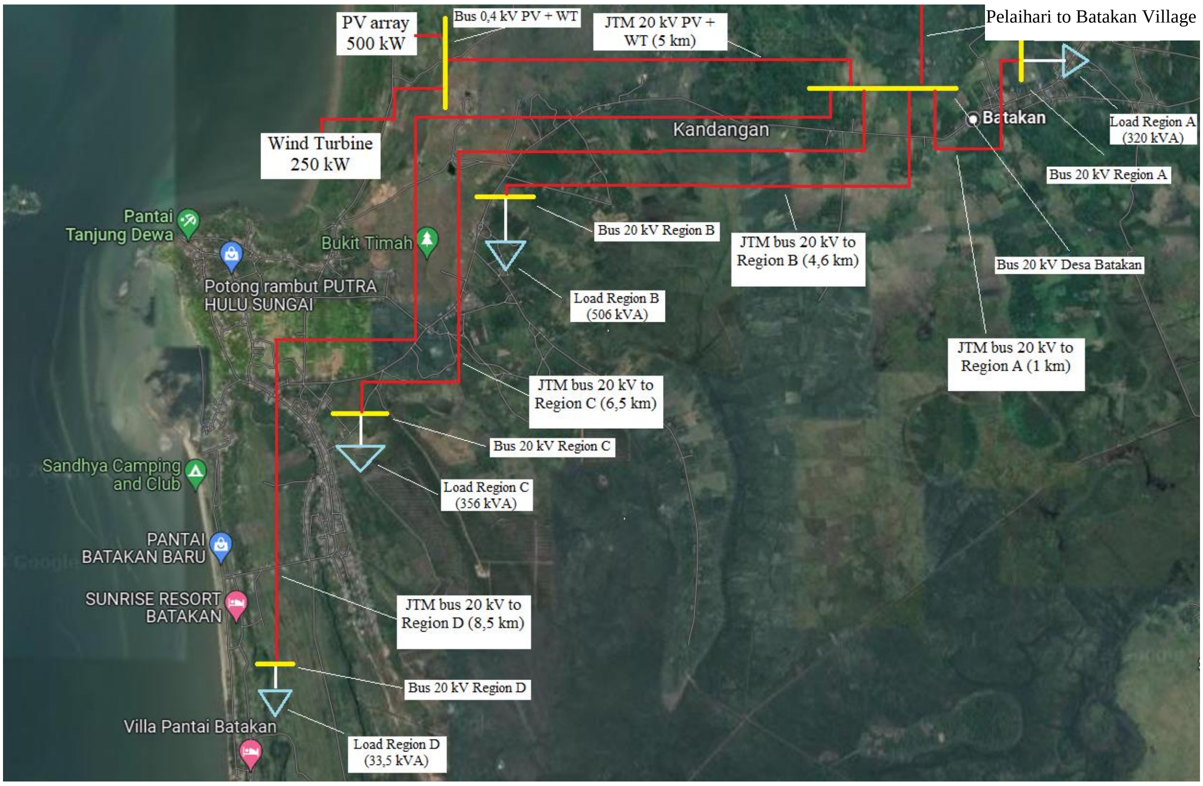


Figure 2. Map of Batakan Village

Kalimantan Province with coordinates -4.097767 and 114.629843 with a daily load of 15,928 kWh and 1,216 kVA at peak load and 12,742.4 kWh and 927.8 kVA at average load. The Pelaihari substation is the nearest substation that can deliver a 20 kV voltage through a medium-voltage network (JTM) to the electricity load in Batakan Village. This substation is approximately 40 km from Batakan Village. The distance from Pelaihari Substation to Batakan Village is shown in the Figure 1.

Along the 20 kV transmission line from GI Pelaihari to Batakan Village, there is an electric load originating from the Pelaihari Load. According to data from Central Bureau of Statistics in Tanah Laut Regency in 2020, the installed electricity capacity in Pelaihari District was 36,266,397 kW or 36.2 MW. The location of the research is Batakan Village, Tanah Laut Regency, South Kalimantan Province, and the research location map is shown in Figure 2.

As displayed in Figure 2, there are four areas in Batakan Village that have a relatively dense population; therefore, the demand for electricity increase in these areas. The position of the PV array, wind turbine, and 20 kV power network bus is in Region A. According to a survey the data from the Central Statistics Agency (BPS) of Tanah Laut Regency in 2020, the total number of electricity users of PLN was 2,124.

C. Research Tools and Materials

The tools used in this research are ETAP software to analyze the power losses in hybrid power generation systems [12] and HOMER software to analyze the investment and economy of hybrid power generation systems [13].

D. Method

This research used descriptive and quantitative research methods. The quantitative data in this study are historical data on the number of PLN electricity users in Batakan Village obtained from the Central Statistics Agency (BPS) of Tanah Laut Regency in 2020 [14]. To reduce power losses that occur in the power grid system, a renewable energy plant is connected. This is to protect components in undervoltage conditions by the inclusion of an electricity supply from the renewable energy plant. To determine whether the power losses in the hybrid energy generation system can be reduced by the inclusion of renewable energy plant, the ETAP software is used, which uses the Newton-Raphson method to determine the power flow that occurs in a system.

TABLE 1
COMPONENTS OF A HYBRID POWER GENERATION SYSTEM

Alphabetical	Component	Index	Parameters	Unit	Formula	Capacity
A	Electrical Load at Peak Load Conditions	A0	Electric load to be supplied	kVA	-	1216
		A1	Electric load to be supplied	kW	A0 * 0,85	1033.6
		A2	Lowest Daily Solar Insolation	kWh/m^2	-	3.81
B	Solar Panel Capacity	B1	Maximum Power	kWp	A1/A2	271.3
		B2	Capacity Addition	%	-	150
		B3	Total Solar Panel Capacity	kWp	B1*B2	406.1
C	Solar Panel and Wind Turbine Farm	C1	Panel Efficiency	%	-	17.33
		C2	Effective Land Area	m^2	B3/C1	2348
		C3	Land Area of Photovoltaic Array and Wind Turbine Farm	m^2	C2 * 150%	3522
D	Solar Panels	D1	Solar Panel Efficiency	%	-	17.33
		D2	Capacity of Each Solar Panels	Wp	-	285
		D3	Number of Solar Panels	Unit	(B3*1000)/D2	1427
		D4	Total Solar Panel Power	kW	(D3*D2)/1000	406.1
E	Wind Turbine	E1	Capacity of Each Wind Turbine	kW	-	25
		E2	Number of Wind Turbines	Unit	((A1/2)-D4)/E1	5
		E3	Total Wind Turbine Capacity	kW	E1 * E2	125
G	Travo PV + WT	G1	Transformer Capacity	MVA	(A1/1000) * 2	2
J	Inverter	J1	Capacity per Unit	kW	-	100
		J2	Number of Inverters	Unit	D4/J1	4
		J3	Nominal Voltage	Vdc	-	480
K	Solar Panel Cable	K1	Total Length of Solar Panel Cable	m	D3 * 2	2854
L	Low Voltage Network (JTR)	L1	Total Length of Low Voltage Network for PV	m	-	50
		L2	Total Length of Low Voltage Network for WT	m	-	50
		L3	Total JTR Steel Iron Poles	Unit	-	4
M	Medium Voltage Network (JTM)	M1	Medium Voltage Network (PV + WT)	m	-	5000
		M2	Total JTM Steel Iron Poles	Unit	M1/50	100
N	Circuit Breaker	N1	Low Voltage Circuit Breaker	Unit	-	2
		N2	High Voltage Circuit Breaker	Unit	-	2

E. Data Source

The data on daily electricity users of the Batakan Village was obtained from the Tanah Laut Regency Central Statistics Agency. Topological data and the condition of the Batakan Village area were obtained from Google Maps. Data on the renewable energy potential of Batakan Village were obtained from the website of NASA Surface Meteorology and Solar Energy, and data on the price of each component in the hybrid power plant system were obtained from online shopping sites.

F. Data Collection Methods

The data collection method was based on the study of literature in which data are collected from several sources, such as books, journals, previous research, websites on the internet, and others related to this research.

G. Research Stages

The first stage of this research was to determine the daily electricity load of the Batakan Village community. From the data obtained from the Central Statistics Agency (BPS) of Tanah Laut Regency in 2020, there are around 2124 households, 1 mosque, 12 prayer rooms, 4 health centers, 15 restaurants, 1 school, and 216 public street lighting with an estimated daily peak energy of 15,928 kWh and 1,216 kVA, while the daily average energy is estimated at 12,742.4 kWh and 972.8 kVA [15]. After obtaining amount of electricity load to be supplied, the capacity of each component in the hybrid power plant can be determined, as listed in Table 1.

Table 1 shows several units: 1) the alphabet, which shows each component used briefly, 2) the component unit, which shows the name of each component used in the hybrid power generation system, 3) the index component, which is a derivative of the alphabet, 4) the parameter, which is the techinal specification of each component in the hyrid power generation system, 5) the unit, which is the type of technical specification of each component, 6) the formula, which is the equation used to obtain the specifications of each component parameter of the hybrid power generation system, and 7) the capacity, which is the value of the specifications of each component parameter of the hybrid power generation system.

The design is then carried out in ETAP software, which has four configurations. These are the configuration of the system using electricity only from the grid system (grid system only) during the average load and peak load, and the configuration of the renewable energy generation system connected to the power grid (on-grid system) during the average load and peak load. The single line diagram of the

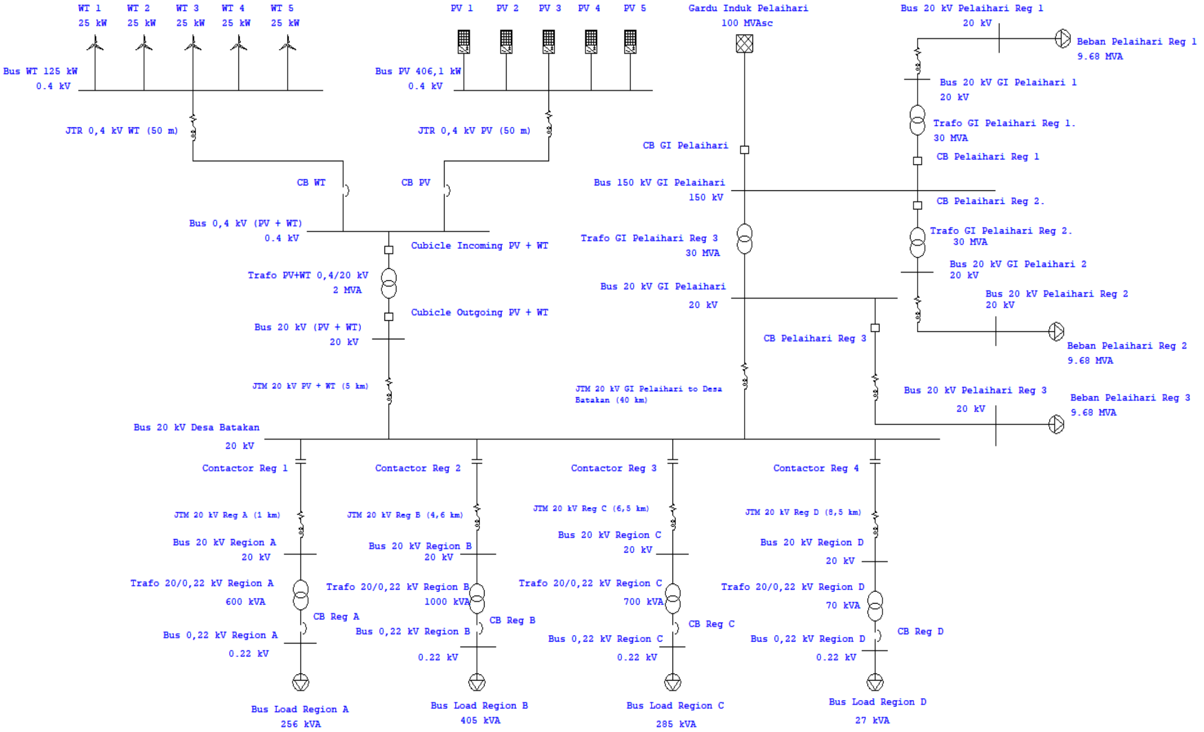


Figure 3. System Configuration Using Only Electricity from the Power Grid at Average Load

configuration of the hybrid power plant using only electricity from the power grid system (grid system only) during the average load is shown in Figure 3, while the single line diagram of the configuration of the renewable energy generation system connected to the power grid (on-grid system) during the average load is shown in Figure 4. The single line diagram of the configuration of the hybrid power plant using only electricity from the power grid system (grid system only) during peak load is shown in Figure 5, and the single line diagram of the configuration of the renewable energy generation system connected to the power grid (on-grid system) during peak load is shown in Figure 6.

As shown in Figure 3, the configuration of the hybrid power plant using only electricity from the power grid system (grid system only) at the average load supplies a load of 12,742.4 kWh of active power and 927.8 kVA only from the grid power system of 150 kV Pelaihari substation. This is because the CB GI Pelaihari is closed (closed CB), while the solar power plant (PV array 406,1 kW) and wind power plant (wind turbine 125 kW) do not supply electricity because CB WT and CB PV are open (Open

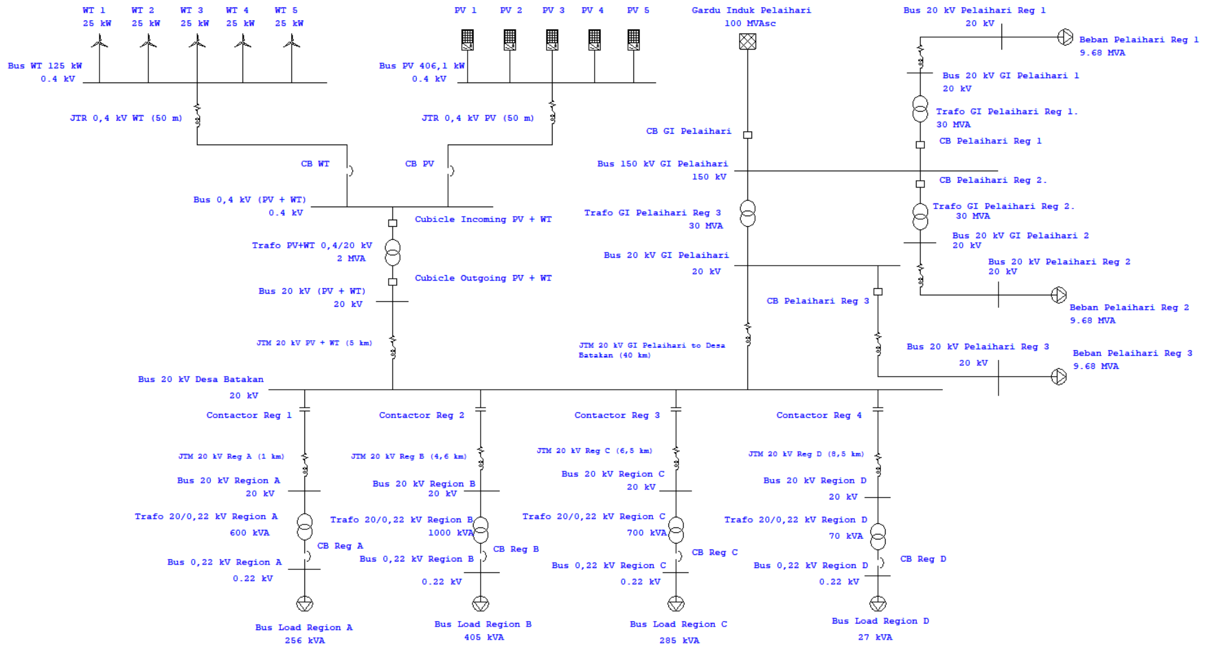


Figure 4. Configuration of Renewable Energy Generation Connected to the Power Grid at Average Load

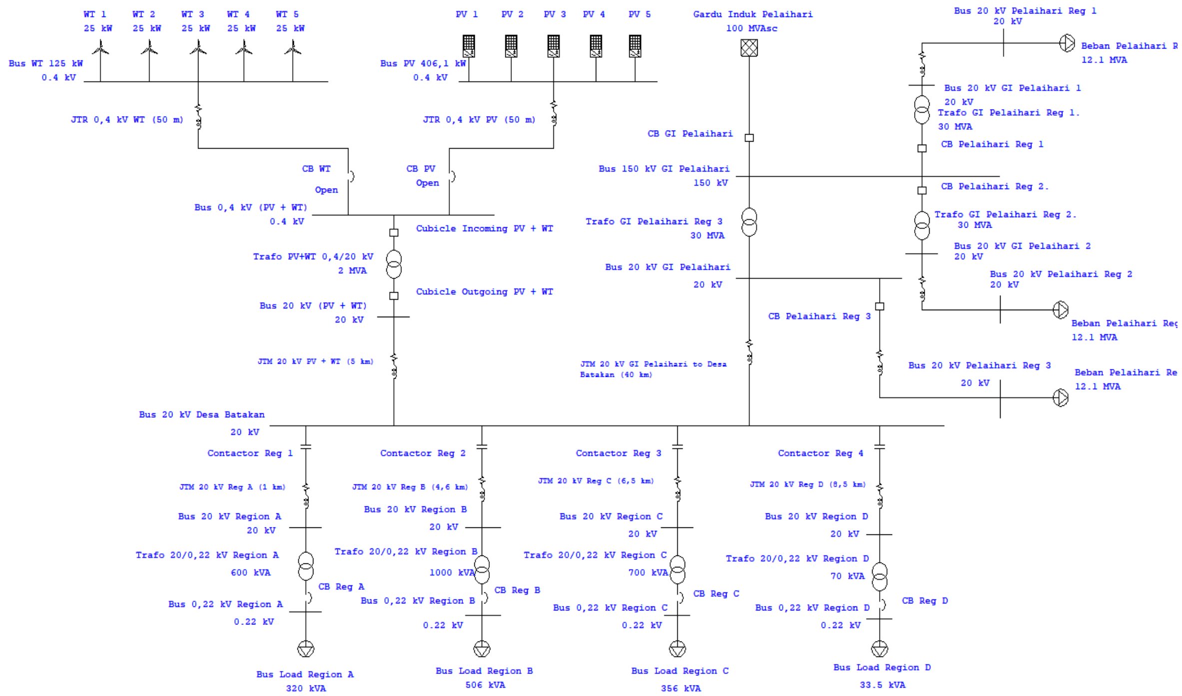


Figure 5. System Configuration Using Only Electricity from the Power Network at Peak Load

CB). The Pelaihari Substation produces electricity, which is then connected to the 150 kV bus of GI Pelaihari. The electricity then flows to the 20 kV bus of Batakan Village through a 20 kV transmission line as far as 40 km. Electricity from the 20 kV bus of Batakan Village is then flowed to each 20 kV bus in each existing load region. Afterwards, the voltage is reduced with a step-down transformer to 220 volts for residential uses.

TABLE 2
INITIAL INVESTMENT COST OF EACH COMPONENT OF HYBRID POWER GENERATION SYSTEM

Component Name	Quantity (Unit)	Initial Investment Cost (Rupiah)
125 kW Wind Turbine	5	910,188,000.00
285 W Solar Panel	1427	3,249,279,000.00
100 kW Inverter	4	107,569,304.12
Step Up Transformer (2 MVA)	1	215,944,087.76
Slocable PV (2854 meters)	1	54,226,000.00
300mm^2 XLPE Cable (100 meters)	1	21,775,554.00
185mm^2 AAAC Cable (5000 meters)	1	276,000.00
Iron Steel Pole (500 dAN)	100	500,000,000.00
Incoming and Outgoing Cubicles	1	48,000,000.00
Total Investment Cost		5.382.981.945.88

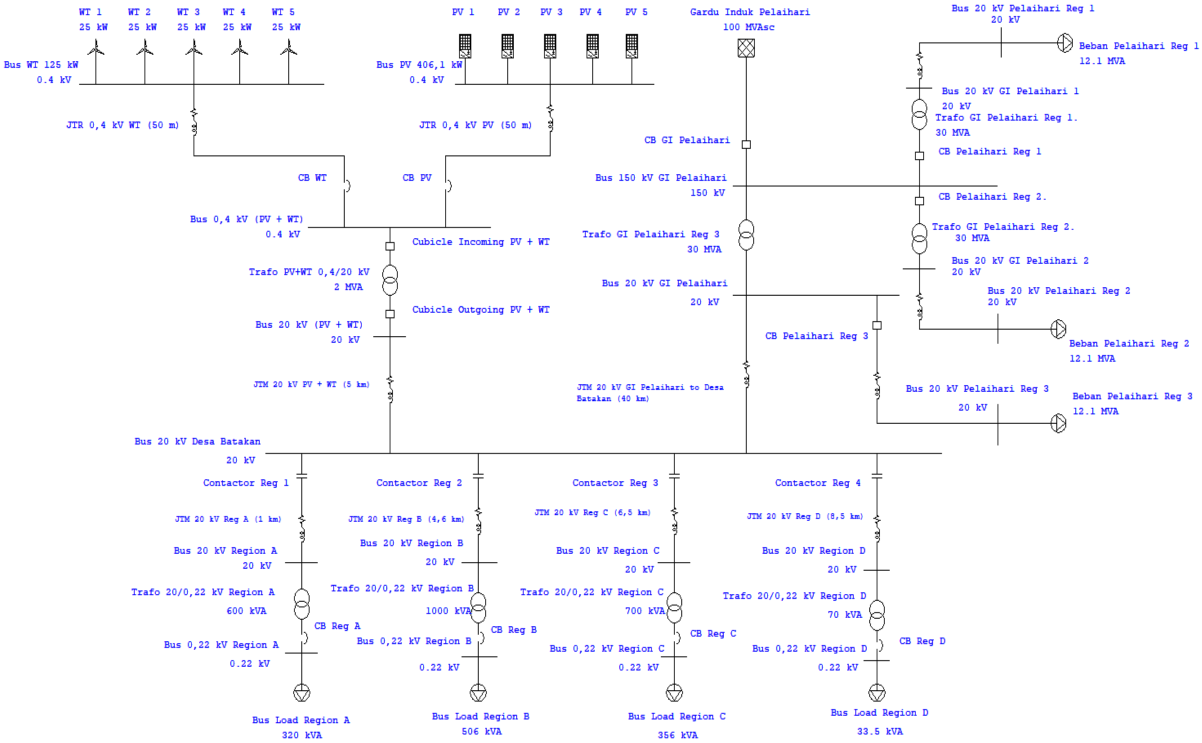


Figure 6. Configuration of Renewable Energy Generation Connected to the Power Grid at Peak Load

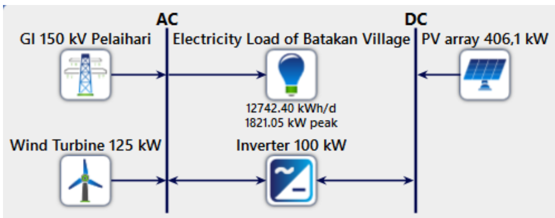


Figure 7. System Configuration in HOMER Software at Average Load

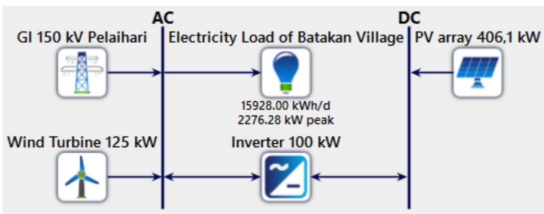


Figure 8. System Configuration in HOMER Software at Peak Load

Figure 4 shows that the on-grid system configuration at the time of the average load, which supplies a load of 12,742.4 kWh of active power and 927.8 kVA that supplies the electrical load, is generated from solar power plants, wind power plants, and power plants from the 150 kV Pelaihari substation (grid power system). They work together to supply electricity because CB PV, CB WT, and CB GI Pelaihari are closed (closed CB). Solar power plants, wind power plants, and power plants from the power grid (grid power system) produce electricity which is then distributed distributed to the 20 kV bus of Batakan Village through a 40 km transmission line and a 5 km of transmission line for renewable energy generation. Electricity from the 20 kV bus of Batakan Village is then flowed to each 20 kV bus in each load region, which is then reduced with a step-down transformer to 220 volts for residential uses.

As shown in Figure 5, the configuration of the hybrid power plant using only electricity from the power grid system (grid system only) at the peak load supplies a load of 15,928 kWh active power and 1,216 kVA reactive power only from the grid power system of 150 kV Pelaihari substation. This is because the CB GI Pelaihari closed (closed CB), while the solar power plant (PV array 406.1 kW) and wind power plant (wind turbine 125 kW) do not supply electricity because CB WT and CB PV are open (open CB). The Pelaihari Substation produces electricity, which is then connected to the 150 kV bus of GI Pelaihari. The electricity flows to the 20 kV bus of Batakan Village through a 20 kV and 40 km transmission line. Electricity from the 20 kV bus of Batakan Village is then flowed to each 20 kV bus in each existing load region, and then the voltage is reduced with a step-down transformer to 220 volts for residential uses.

As displayed in Figure 6, the on-grid system configuration at the time of the peak load, which supplies a load of 15,928 kWh active power and 1,216 kVA that supplies the electrical load, is generated from solar power plants, wind power plants, and power plants from the 150 kV Pelaihari substation (grid power system). They work together to supply electricity because CB PV, CB WT, and CB GI Pelaihari are closed (closed CB). Solar power plants, wind power plants, and power plants from the power grid (grid power system) produce electricity which is then distributed to the 20 kV bus of Batakan Village through a 40 km transmission line and a 5 km transmission line for renewable energy generation. Electricity from the 20 kV bus of Batakan Village is then flowed to each 20 kV bus in each load region, which is then reduced in voltage with a step-down transformer to 220 volts for residential uses. In terms of the use of HOMER software, the design of the hybrid power plant system in HOMER software aims to determine the investment and economic analysis of the system. In this study, two conditions were considered, namely during the average load and during the peak load. Before designing the system configuration, the estimated initial investment cost of each component in the hybrid power plant is determined, as shown in the Table 2.

It is estimated that the total initial investment cost of the hybrid power generation system is IDR 5,382,981,945.88. Then, the hybrid power generation system in HOMER software is designed during both the average load conditions and peak load conditions. The design is then divided into two conditions: conditions during average load and conditions during peak load. The configuration simulated in the HOMER software consists of several components, such as Photovoltaic CS6k-285M-FG with a total capacity of 406.1 kW, Wind Turbine EO25IIA with a total capacity of 125 kW, 4 inverters with a capacity of 100 kW with a total inverter capacity 400 kW, 150 kV Pelaihari Substation, and Batakan Village electric load with an average daily load of 12,742.40 kWh/day and a peak daily load of 15,928 kWh/day.

After all system configurations have been designed using ETAP and HOMER software, simulations are run to obtain the results of the research. These are the analysis of system power losses in the ETAP software and an investment and economic analysis of the system in the HOMER software. The configuration of the hybrid power generation system at the average load and peak load in the HOMER software can be seen in the following Figures 7 and 8.

III. Result and Discussion

A. *Simulation of Hybrid Power Plant System at Average Load in ETAP*

Simulations of hybrid power generation system at an average load can be performed properly in ETAP software. There are two configurations, which are the configuration of the system connected only to the grid (grid system only) in Figure 9, and the configuration of the renewable energy generation system connected to the grid (on-grid system) in Figure 10.

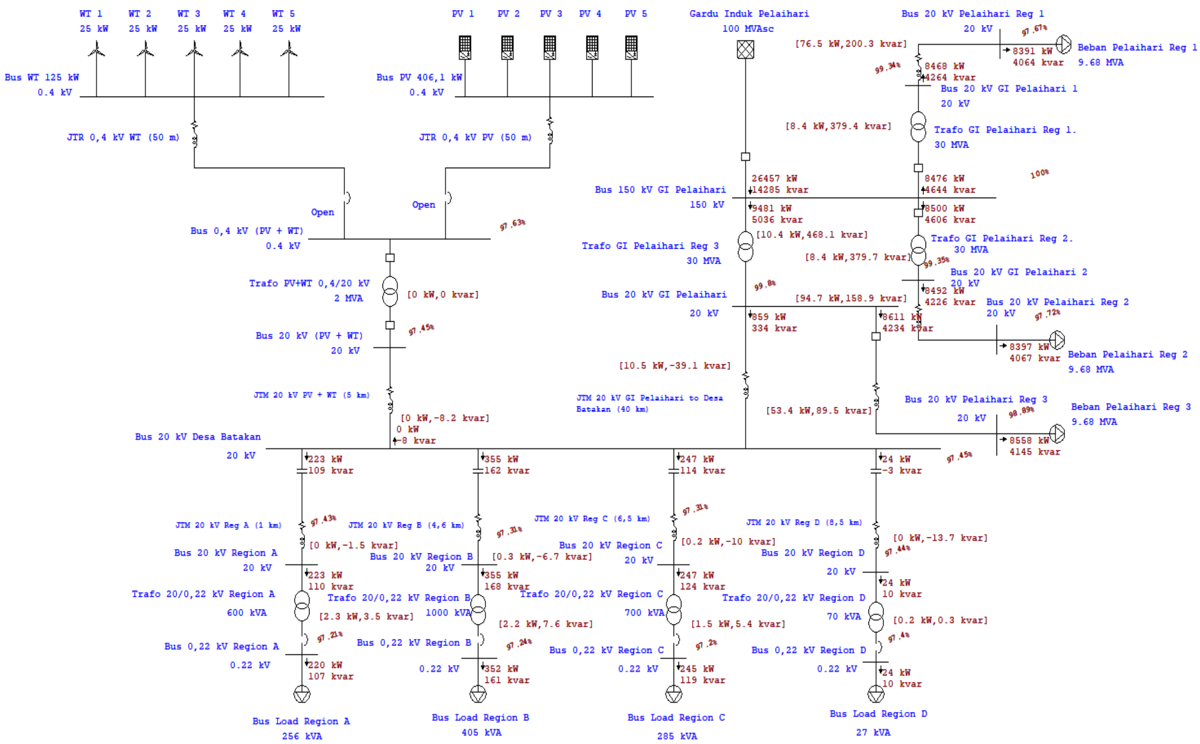


Figure 9. ETAP Simulation Results of the System Configuration only Connected to the Grid (Grid System only) at Average Load

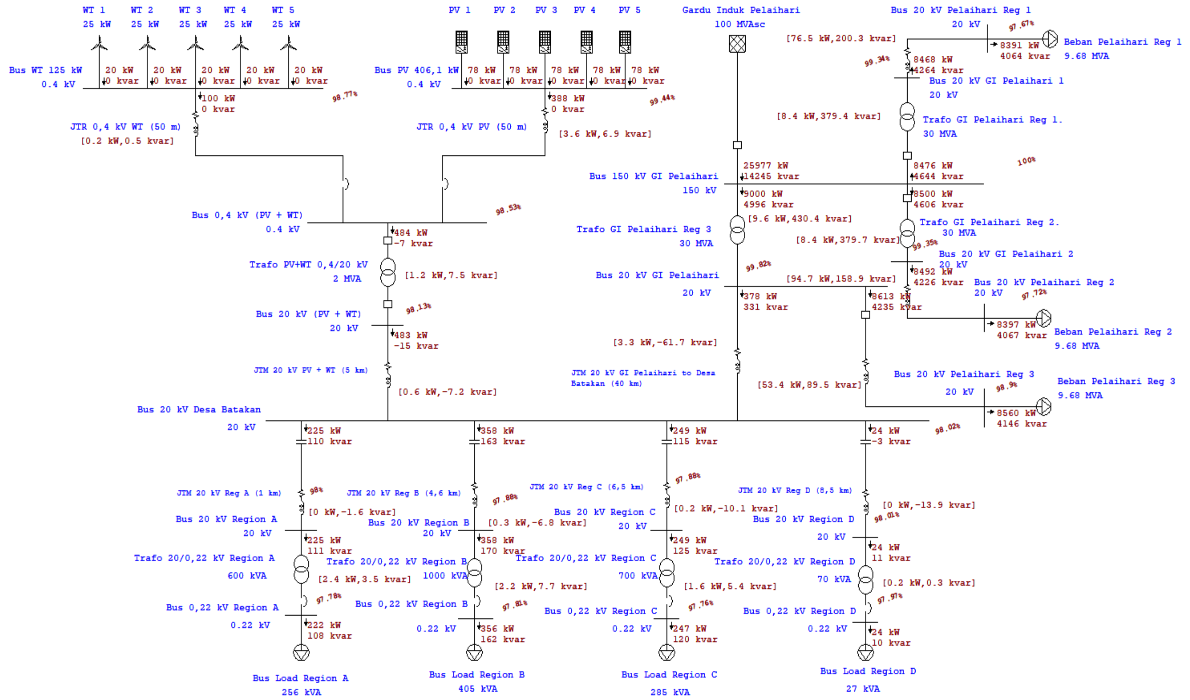


Figure 10. ETAP Simulation Results of Renewable Energy Generation Connected System Configuration (on-grid system) at Average Load

As shown in Figures 9 and 10, all buses in the hybrid power generation system have a normal status and can work according to their respective ratings under average load conditions, both in the configuration of the hybrid power generation system only connected to the grid (grid system only) and in the configuration of the hybrid power generation system connected to the renewable energy power plant (on-grid system). As can be seen from the color of the bus, no bus displays red and purple, which means that no bus has critical status or in marginal status. Critical status indicates that the bus operating rating value has a difference by more than 5% of the specified rating value on the bus, while the marginal status is a condition where the bus is still within the tolerance limit or the bus operating rating value still has a difference of less that 5% of the specified rating value on the bus.

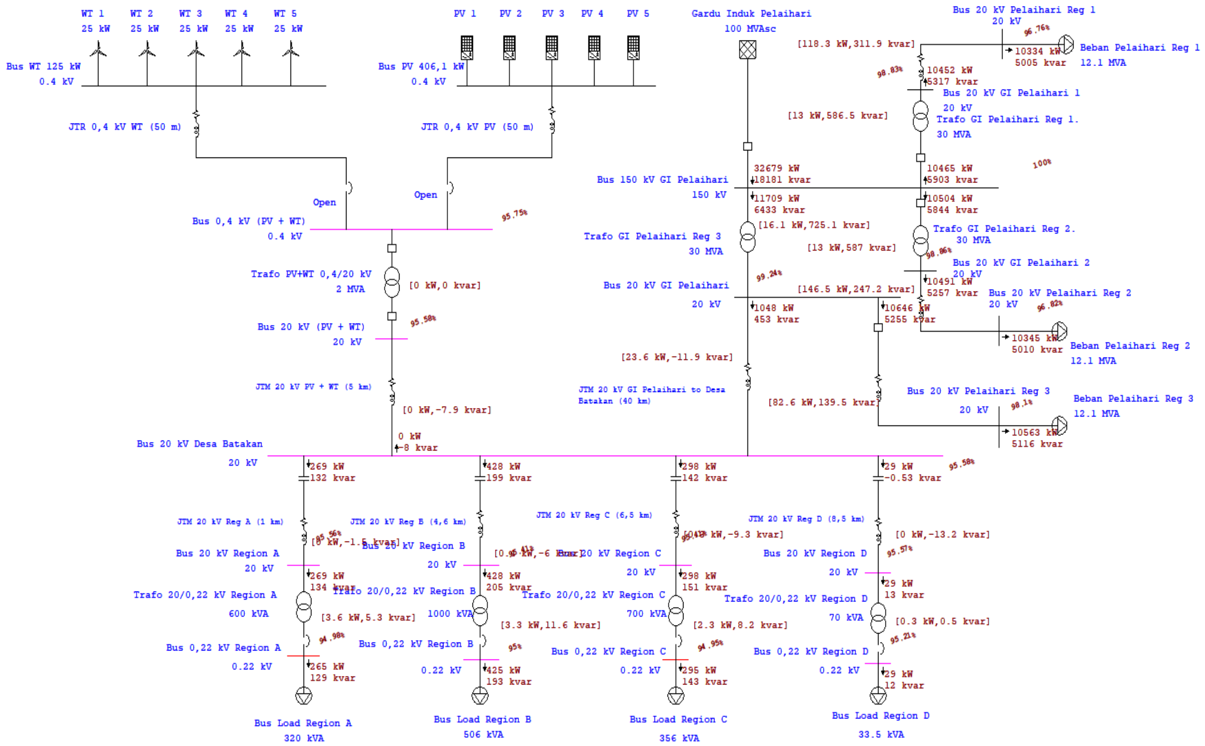


Figure 11. *ETAP Simulation Results of the System Configuration only Connected to the Grid (Grid System only) at Peak Load*

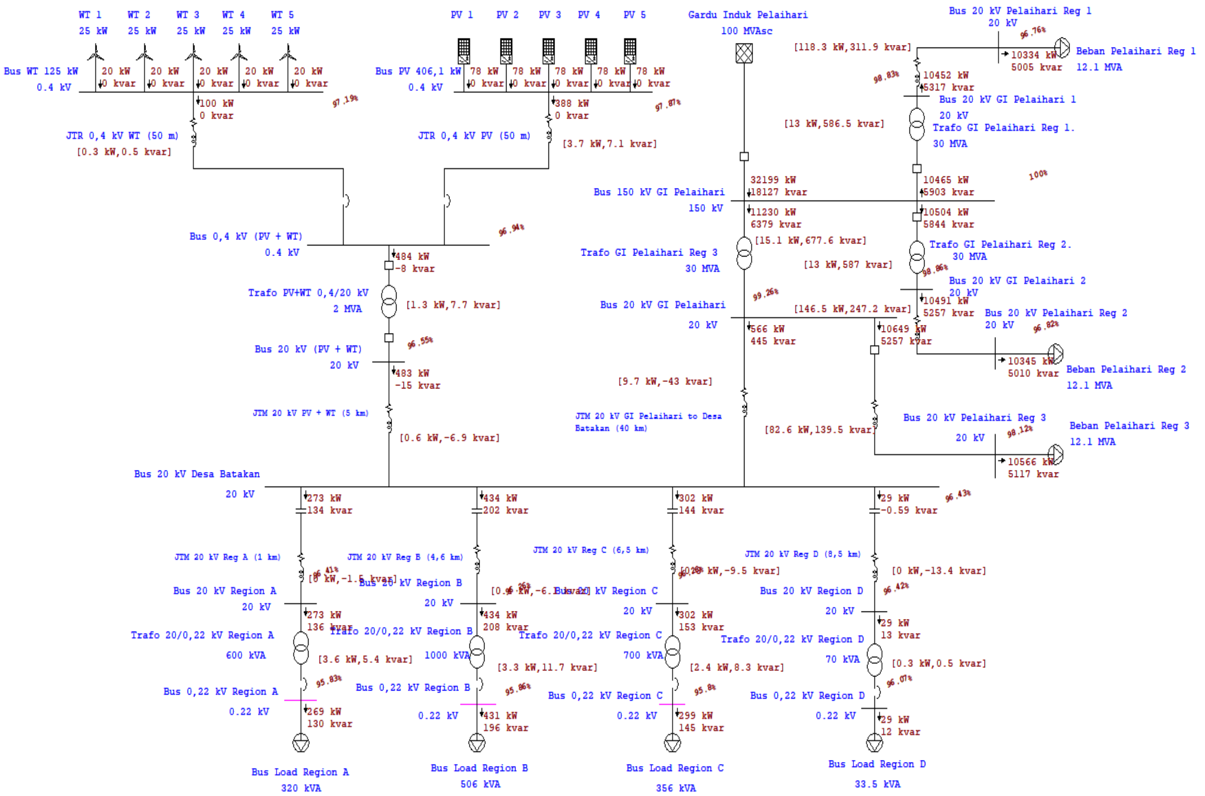


Figure 12. ETAP Simulation Results of Renewable Energy Generation Connected System Configuration (on-grid system) at Peak Load

B. ETAP Simulation of Hybrid Power Plant System at Peak Load

The configuration of hybrid power plant system at the peak load can be simulated properly in ETAP software. There are two configurations: the configuration of the system only connected to the grid (grid system only) and the configuration of the renewable energy generation system connected to the grid (on-grid system). As displayed in Figure 11, the results of the simulation in ETAP software with a hybrid power generation system only connected to the grid (grid system only) at peak load conditions show that there are 2 buses that show red color indicating that the buses are in critical status. They are Bus 0.22 kV Region A and Bus 0.22 kV Region B. Meanwhile, there are 9 buses that show purple color indicatingthat they are inmarginal status. These buses are the 0.22 kV Bus Region B, 0.22 kV Bus Region D, 0.4 kV Bus (PV + WT), 20 kV Bus (PV + WT), 20 kV Bus Batakan Village, 20 kV Bus Region A, 20 kV Bus Region B, 20 kV Bus Region C, and 20 kV Bus Region D.

In Figure 12, it can be seen that the results of the simulation in the ETAP software with the configuration of a hybrid power plant system connected to a renewable energy power plant (on-grid system) under peak load conditions show a reduction in the number of components in critical status from two to zero. Furthermore, buses that have marginal status have been reduced from nine components to only three components. There are three buses that show purple color, indicating that they are in marginal status. These are 0.22 kV Bus Region A, 0.22 kV Bus Region B, and 0.22 kV Bus Region C.

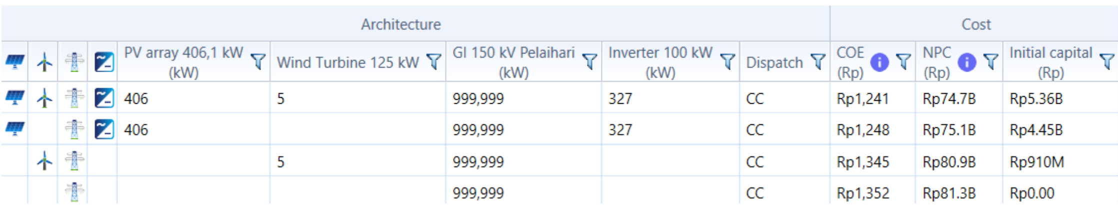
C. Comparison of Power Losses at Average Load and Peak Load

A comparison in power losses that occur during average load conditions and peak load conditions in system configuration only connected to the grid (grid system only) and system configurations connected to renewable energy generation (on-grid system) is shown in Table 3.

Table 3 shows that the total power losses decrease when renewable energy generation is connected to the system. Under average load conditions the total power losses that occur in the system configurations only connected to the grid is 269.1 kW and 1613.5 kvar, whereas in the system configuration connected

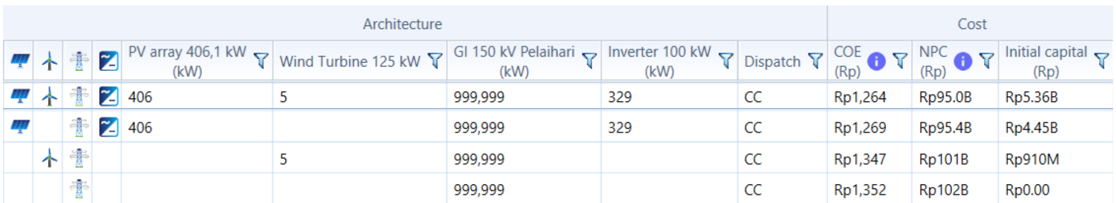
TABLE 3
COMPARISON OF POWER LOSSES

Component	System Configuration Connected to Network Only				System Configuration Connected to the Grid and Renewable Energy Generation			
	Average Load		Peak Load		Average Load		Peak Load	
	kW	kvar	kW	kvar	kW	kvar	kW	kvar
JTM 20 kV GI Pelaihari	10,5	-39,1	23,6	-11,9	3,3	-61,7	9,7	-43,0
JTM 20 kV Pelaihari Reg 1	76,5	200,3	118,3	311,9	76,5	200,3	118,3	311,9
JTM 20 kV Pelaihari Reg 2	94,7	158,9	146,5	247,2	94,7	158,9	146,5	247,2
JTM 20 kV Pelaihari Reg 3	53,4	89,5	82,6	139,5	53,4	89,5	82,6	139,5
JTM 20 kV Reg A	0	-1,5	0	-1,5	0	-1,6	0	-1,5
JTM 20 kV Reg B	0,3	-6,7	0,4	-6,0	0,3	-6,8	0,4	-6,1
JTM 20 kV Reg C	0,2	-10,0	0,3	-9,3	0,2	-10,1	0,3	-9,5
JTM 20 kV Reg D	0	-13,7	0	-13,2	0	-13,9	0	-13,4
PV + WT 0,4/20 kV Transformer	-	-	-	-	1,2	7,5	1,3	7,7
JTM 20 kV PV+WT	-	-	-	-	0,6	-7,2	0,6	-6,9
GI Pelaihari Reg 1 Transformer	8,4	379,4	13,0	586,5	8,4	379,4	13,0	586,5
GI Pelaihari Reg 2 Transformer	8,4	379,4	13,0	587,0	8,4	379,4	13,0	587,0
GI Pelaihari Reg 3 Transformer	10,4	468,1	16,1	725,1	9,6	430,4	15,1	677,6
20/0,22 kV Reg A Transformer	2,3	3,5	3,6	5,3	2,4	3,5	3,6	5,4
20/0,22 kV Reg B Transformer	2,2	7,6	3,3	11,6	2,2	7,7	3,3	11,7
20/0,22 kV Reg C Transformer	1,5	5,4	2,3	8,2	1,6	5,4	2,4	8,3
20/0,22 kV Reg D Transformer	0,2	0,3	0,3	0,5	0,2	0,3	0,3	0,5
Total Power Losses	269,1	1613,5	423,4	2573,0	266,9	1568,9	414,5	2510,5



Architecture					Cost		
PV array 406,1 kW (kW)	Wind Turbine 125 kW	GI 150 kV Pelaihari (kW)	Inverter 100 kW (kW)	Dispatch	COE (Rp)	NPC (Rp)	Initial capital (Rp)
406	5	999,999	327	CC	Rp1,241	Rp74.7B	Rp5.36B
406		999,999	327	CC	Rp1,248	Rp75.1B	Rp4.45B
	5	999,999		CC	Rp1,345	Rp80.9B	Rp910M
		999,999		CC	Rp1,352	Rp81.3B	Rp0.00

Figure 13. HOMER Simulation Optimization Results during Average Load



Architecture					Cost		
PV array 406,1 kW (kW)	Wind Turbine 125 kW	GI 150 kV Pelaihari (kW)	Inverter 100 kW (kW)	Dispatch	COE (Rp)	NPC (Rp)	Initial capital (Rp)
406	5	999,999	329	CC	Rp1,264	Rp95.0B	Rp5.36B
406		999,999	329	CC	Rp1,269	Rp95.4B	Rp4.45B
	5	999,999		CC	Rp1,347	Rp101B	Rp910M
		999,999		CC	Rp1,352	Rp102B	Rp0.00

Figure 14. HOMER Simulation Optimization Results during Peak Load

to the renewable energy plant is 266.9 kW and 1568.9 kvar. In this condition the power losses have decreased by 2.2 kW and 44.6 kvar. By contrast, under peak load conditions the total power losses that occur in the system configuration only connected to the grid are 423.4 kW and 2573.0 kvar, and in the system configuration connected to the renewable energy generation is 414.5 kW and 2510.5 kvar. Thus, the power losses have decreased by 8.9 kW and 62.5 kvar.

D. Results of the Simulation of Hybrid Power Plant System in HOMER Software at Average Load and Peak Load Conditions

The simulations of hybrid power generation systems during the average load and peak load can be simulated properly using HOMER software. The results are shown in Figures 13 and 14. In Figure 13, it can be seen that the hybrid power generation system with the PV + WT + Grid Power configuration at average load obtains a net present cost (NPC) value of IDR 74,700,000,000 with a cost of energy (COE) of IDR 1,241/kWh, and a total initial investment cost or initial capital of IDR 5,360,000,000. This configuration has the lowest NPC and COE values of all configurations.

Figure 14 shows that the hybrid power generation system with the PV + WT + Grid Power configuration at peak load obtains a net present cost (NPC) value of IDR 95,000,000,000 with a cost of energy (COE) of IDR 1,264/kWh, and a total initial investment cost or initial capital of IDR 5,360,000,000. This configuration has the lowest NPC and COE values of all configurations.

E. Comparative Economic Analysis of System Configuration Only Connected to the Power Grid with Renewable Energy Generation Connected to the Power Grid

The results of the HOMER software simulation show that the configuration of the grid system connected to the renewable energy generation (on-grid system) is more profitable than the system configuration that uses only electricity from the grid (grid system only). As illustrated in Figure 15, the use of system configurations connected to renewable energy plants is more profitable than system configurations that only use electricity from the grid system only. This is evidenced by the magnitude of the net present cost (NPC) value of the system configuration connected to the renewable energy plant, which is IDR 95,000,000,000, lower than the NPC value obtained from the system configuration using only electricity from the network, which is IDR 102,000,000,000. This could mean a saving of IDR 6,574,850,000.

TABLE 4
COMPARISON OF INVESTMENT ANALYSIS RESULTS IN HOMER SOFTWARE

Configuration	*Cost of Energy* (COE)		*Net Present Cost* (NPC)	
	Average Load (Rp)	Peak Load (Rp)	Average Load (Rp)	Peak Load (Rp)
PV+WT+*Grid System*	1,241	1,264	74,700,000,000	95,000,000,000
PV+*Grid System*	1,248	1,269	75,100,000,000	95,400,000,000
WT+*Grid System*	1,345	1,347	80,900,000,000	101,000,000,000
Grid System	1,352	1,352	81,300,000,000	102,000,000,000

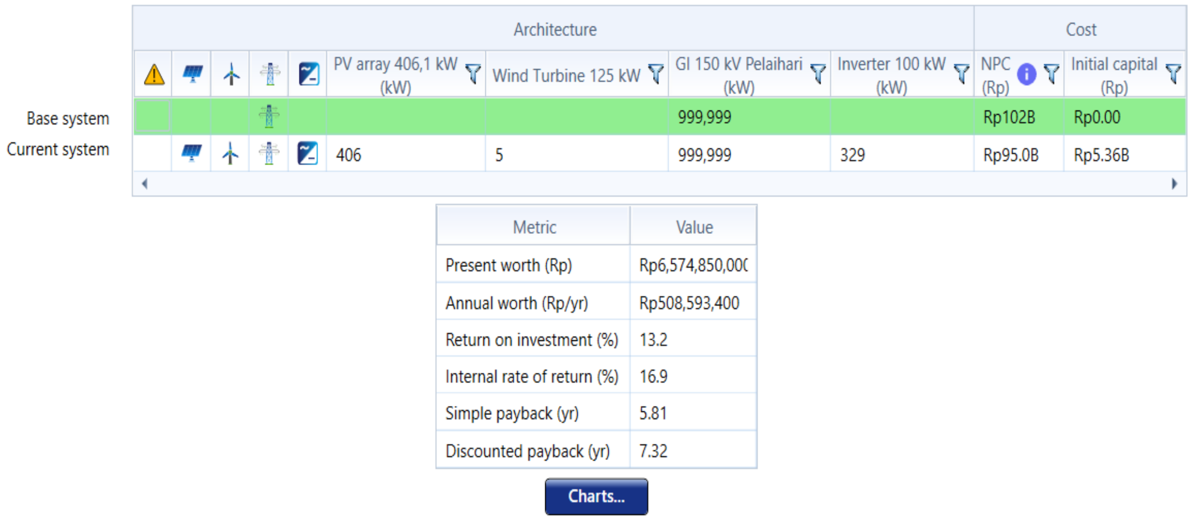


Figure 15. HOMER Simulation Optimization Results during Peak Load

F. Results of Comparison of Investment Analysis at Average Load and Peak Load

The results of the comparison of the investment analysis obtained from the simulations in the HOMER software during the average load and peak load can be seen in Table 4. As shown in Table 4, during the life cycle of renewable energy plants, which is 25 years, in all conditions, both at average load and peak load, the photovoltaic + wind turbine + grid system configuration seems to always have lower COE and NPC values than the other configurations. At the average load, the COE value of the PV+WT+Grid system configuration is IDR 1,241, which is lower than the configuration that uses only the grid system (IDR 1,352). The NPC value at the average load of the PV+WT+Grid system configuration is IDR 74,700,000,000, which is also lower than the configuration that only uses the grid system (IDR 81,300,000,000). On the other hand, at peak load, the COE value of the PV+WT+Grid system is IDR 1,264, which is lower than the configuration that uses only the grid system which is Rp 1,352. The NPC value at the peak load of the PV+WT+Grid system is IDR 95,000,000,000, which is also lower than the configuration that only uses the grid system (IDR 102,000,000,000). It is likely that investment is still at a profitable stage because the value of return of investment (ROI) from average load and peak load conditions still show a positive value: both are 13.2%.

IV. CONCLUSION

Based on the results of the simulations that have been carried out using both ETAP software and HOMER software, the most optimal hybrid power configuration is the solar power plant (PLTS) + wind power plant (PLTB) + grid system configuration, as evidenced by the reduced power losses when the renewable energy generation system is included in the system. Furthermore, in terms of the investment, the reduced cost of energy (COE) value and the net present cost (NPC) value when renewable energy plants help supply the electricity to Batakan Village community during both average and peak loads. The ETAP simulations have been carried out during average load and peak load conditions and include the solar power plant and wind power plant. The results show that power losses in the electricity system in Batakan Village can be reduced. The previous system only used the system configuration which was only connected to the PLN power grid (grid system only). The total power losses decreased from 269.1 kW of active power and 1613.5 kvar of reactive power at average load to 266.9 kW of active power and 1568.9 kvar of reactive power. Meanwhile, at peak load the total power losses decreased from 423.4 kW of active power and 2573.0 kvar of reactive power to 414.5 kW of active power and 2510.5 kvar of reactive power. Finally, based on the HOMER simulations that have been carried out at average load and peak load, by including the solar power plant and the wind power plant, the net present cost (NPC) value and the resulting cost of energy (COE) value are smaller. At the average load, the system configuration only connected to the power grid (grid system only) results in an NPC value of IDR 81,300,000,000 and COE value of IDR 1,352/kWh. The values decrease to IDR 74,700,000,000 for the NPC value and IDR 1,241/kWh for the COE value of the renewable energy generation system connected to the power grid (on-grid system). At the peak load, the system configuration is only connected to the power grid (grid system only). This causes an NPC value of IDR 102,000,000,000 and a COE value of IDR 1,352/kWh to decrease to IDR 95,000,000,000 for the NPC value and IDR 1,264/kWh for the COE value of the renewable energy generation system connected to the power grid (on-grid system). The findings suggest that cost saved by including the renewable energy generation into the system for 25 years is IDR 6,574,850,000 with a return of investment (ROI) value of 13.2%. This may indicate that this investment is still profitable.

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