Simulation of 20 kV Biomass Power Plant Interconnection System

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Abstract. The need for new plants is needed to balance the demand for high electricity. To anticipate this, it is necessary to accelerate the achievement of the level of utilization of new and renewable energy (EBT) in the energy mix for electricity supply by encouraging the use of energy from water, biomass, solar, wind to electricity. The Biomass Power Plant (PLTBm) is one of the environmentally friendly alternative power plants that produce electricity and heat by burning biomass in boilers in this case from wood waste from furniture and old rubber trees. The Interconnection System will be implemented in this PLTBm, where interconnection with the existing 20 kV system will be carried out. Research carried out includes power flow, voltage drop, losses, and short circuit. By conducting this study, it can be seen the profile of the overall system operation before and after this interconnection. The simulation results show that the PLTBm connected to the nearest feeder point from the generator is the best choice in terms of making the system voltage better between 19.1 kV and 20.17 kV. Power losses range from 439 kW and 5005.4 Kvar as well as short circuit currents, namely 13.73 KA.

Keywords: **interconnection; biomass; configuration; simulation.**

1 Introduction

Electrical energy has become one of the needs in the modern era today. Demand for electricity has increased along with technological developments, growth in population, business and industry. The need for new plants is needed to offset the high demand. The power plant must be adapted to the conditions of each area [1]. Currently, the most widely used power plant in Indonesia is PLTA, PLTU, and PLTD. To overcome the increasing electricity demand, the government opens the opportunity for all parties to participate in the electricity sector development. Accelerating the achievement of the level of utilization of new and renewable energy (EBT) in the energy mix for electricity supply by encouraging the use of water, biomass, solar, wind energy into electricity. The electrical energy generated by both PLN and Independent Power Producer (IPP) is sought to be integrated into a transmission and distribution network before the energy reaches consumers. Therefore the authors in this study made a simulation of a Biomass Power Plant (PLTBm) with a capacity of 1 x 9.9 MW which was interconnected with a 20 kV network. PLTBm is a generator that generates electricity and heat by burning biomass in the boiler. The biomass comes from wood waste from the furniture industry, and old rubber trees [2].

This interconnection system study certainly needs to know the best connection point option in PLTBm, make a connection design and determine the type of PLTBm delivery to a 20 kV system, and find out changes in voltage profile, short circuit current and power losses after connecting to a 20 kV network [2] Besides that, load growth projections are also carried out for several next years, so the load points can be estimated in the number of each grid according to its geographical structure. The accumulation of load growth for each grid is the growth of regional load (macro) [1]. Interconnection is said to be feasible if the amount of short circuit current does not exceed the resistance value of the short circuit current of the equipment which can range from 25 kA, small losses and voltage drop of + 5% -10% based on the Decree of PLN Directors tNo.0357.K.DIR / 2014. In the future, research can be a reference for the developer in interconnecting the Biomass Power Plant to a 20 kV system

2 Interconnections System

The interconnection system is an electric power system consisting of several electricity centers (generators) and several substations (GIs) that are interconnected with one another through a transmission line and serving the load at the connected substation. The purpose of the interconnection system is to maintain the continuity of electricity supply if one of the generating centers is disturbed but can still be supplied from other interconnected plants. [3]. Interconnection systems must pay attention to reliability quality which includes aspects of frequency, voltage, current and power. This study discusses an interconnection study of new plants that

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will be connected to existing networks, later this study includes studies of power flow, voltage drop, short circuit, losses. Interconnection studies are a study to determine the impact caused by the presence of new plants that enter the transmission or distribution network system. Interconnection studies not only discuss the stability of a system but also discuss the configuration model of network interconnection systems, the electricity data of the surrounding area, and the analysis of impacts on the system and the solution. With the interconnection study, it is known which connection point is the best and which network configuration model to use.

2.1 Working principle of PLTBm

The biomass power plant here still uses water. The water used in this cycle is called demin water, which is water that has a conductivity level of 0.2 us (micro siemen). As a comparison, the mineral water we drink daily has a conductivity level of around 100-200 us. To get this demin water, each system is usually equipped with a Desalination Plant and Demineralization Plant which functions to produce this demin water [4].

But here it is not discussed about the Desalination Plant or Demineralization Plant. If we look at the process of cooking water that is simply how it cycles at this biomass power plant. Cooked water until it evaporates and this steam is used to rotate turbines and generators which will produce electricity [4]. There are also advantages of biomass plants as follows:

- Biomass is a renewable energy
- Biomass is an environmentally friendly energy
- Biomass plants have good mobility so they can be placed anywhere. This biomass generator is also the same as other conventional plants, such as PLTU, PLTMH is related to its protection system. There is no special protection system found in Biomass Generators because in principle this biomass plant is the same as a PLTU, it's just that the fuel is different.

2.2 Study of power flow with computer simulation

Electrical changes use carefully crafted programs to carry out load flow studies. A typical program is able to handle systems with more than 2000 rails, 3000 lines, and 500 transformers. Of course, this program can be expanded to even larger systems as long as the computer facilities used are quite large.

The data provided on the computer must contain a diagram of a system line, series impedance values and shunt administration of the transmission line, transformer rating and impedance, shunt capacitor rating and transformer tapping settings. Then clues about whether the rail is swinging, a rail that is regulated where the amount of voltage is made constant by generating Q reactive power, or a rail with a predetermined value P and Q. Where these values will not be made constant, the quantities are given in the list are interpreted as first estimates. Usually, the limits of the generation of P and Q must also be specified, and so too with the limits of the kilovolt ampere line. Jiki has no other provisions, programs usually specify 100 MVA as a basis. Charging the total lines in the megavars determined for each line takes into account the shunt capacitance and is equal to three times the nominal line voltage in kilovolts multiplied by Ichg, and divided by 103. The computer program creates an π-nominal representation of the line by bisecting equal capacitance calculated from the megavars value charging is given, between the two ends of the line. For a long line, the computer can be programmed by counting π equivalent for capacitance that is spread evenly along the line [3].

3 Reconfiguration and Simulation

Before carrying out this process, first, determine the type of conductor and the conductor diameter that will be used in the connection study process. Then determine the network configuration that will be used. After the process of collecting data, the next step is the process of computer simulation to identify the conditions of the existing distribution system and the impact caused after the connection is made on each option [5]. The connection simulation step is as follows:

1. Single line diagram depiction using ETAP 12.6
2. Enter the input rating of equipment available on single line diagrams such as transformer ratings, generators, conductor types, and buses.
3. Network loading according to projected load data in the year of operation of the plant
4. Connecting PLTBm to each option
   The simulation process is carried out as follows:
   a. Power flow analysis
   b. Short circuit analysis
   c. Analysis Falls Voltage
   d. Losses

The simulation process is carried out on each option and in two conditions, namely before and after connection. This aims to see changes in the profile of power flow and short circuit that occur when the power plant enters the existing 20 kV system [6]. Each line in a distribution network has an impedance value that can affect the existence of power losses and voltage drop [7]. This must be overcome so that the energy sent is the same as the energy received. Network reconfiguration is an effective and efficient way to reduce losses on the distribution network [3].

In a distribution system, there is often an unbalanced load on each phase (a distribution system is a three-phase system) or an overload occurs due to the use of electronic equipment from consumers of electrical energy. This situation, if left uninterrupted, will cause a decrease in the reliability of the electric power system and the quality of the electricity that is distributed and cause damage to the equipment in question. For that, we need an action that reduces unbalanced loading on the phase and overloads (overloading) on the electricity distribution network [7].

4 Result and Analysis

4.1 System conditions before connection

4.1.1 Network of topology

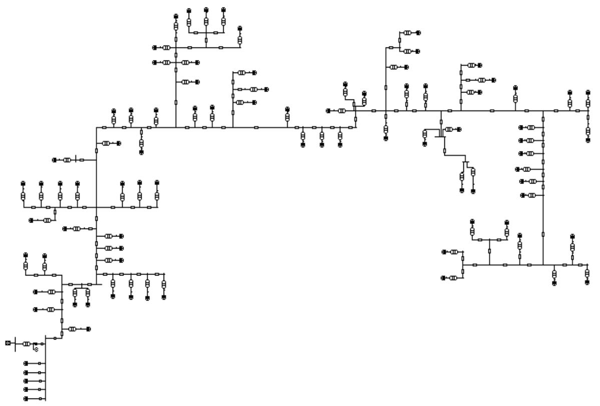

Fig.1. System Topology of Network 20 kV Transformer GI KIM

4.1.2 Bus Data

Table 1. Bus Data

Bus Information		Voltage %	Load MVA	Condition
ID	Type			
BUS MV GI KIM	Load	98.1	50.146	Normal
DS 01	Load	94.85	0.205	Critis
Bus Palu Merbo	Load	94.68	0.211	Critis

4.1.3 Transformer Data

Table 2. System Data Transformer 20 kV GI KIM and busbar KI.11

ID	Capacity (MVA)	Prim kV	Sec kV	% Z1	X1/R 1
ML-3	0.100	20	0.40	4.0	1.50
ML-34	0.160	20	0.40	4.0	1.50
ML-36	0.200	20	0.40	4.0	1.50
ML-329	0.630	20`	0.40	4.0	1.50
T-air limbah	0.356	20	0.40	4.0	1.50
T-Ps	0.710	20	0.40	5.0	3.50
Transfor mer GI KIM	60	150	20	`13	45

Some transformers experience critical conditions due to an increase in load, following the transformer experiencing a critical condition due to an increase in load [8].

Table 3. Critical Of Transformer Data

ID	Capasity (MVA)	Loaded (MVA)	Percentage %
ML-36	0.2	0.206	103.1
ML-38	0.16	0.174	108.1
ML-91	0.16	0.173	108.3
ML-230	0.2	0.284	142
ML-331	0.1	0.12	113.8
ML-586	0.1	0.113	112.6
ML-782	0.1	0.113	112.6
MT-310	0.1	0.112	112.1
MT-312	0.1	0.106	105.8

4.1.4 Line Data

Table 4. Line Data

ID	Size mm^2	Length m	R	X	Y
Line1	262	3000	0.14	0.228	0.0000039
Line16	158	350	0.23	0.245	0.0000032
Line24	77.3	230	0.46	0.272	0.0000021
Line46	262	150	0.14	0.228	0.0000039
Line53	158	250	0.23	0.245	0.0000032
Line75	77.3	230	0.46	0.272	0.0000021

4.2 Selection of conduct types

In conducting a connection simulation it is necessary to select the type of conductor that has a current-carrying capacity (KHA) that can accommodate the current from the PLTBm generator. In general, the 20 kV network in Indonesia uses AAAC conductor types. PLTBm with a capacity of 9.9 MW, the strong current from the generator can be calculated as follows

$$P = \sqrt{3}\, x\, V\, x\, I\, x\, Cos\ \theta \quad (1)$$

$$I = \frac{900\ kW}{\sqrt{3}\ x\ 20\ kV\ x\ \ 0,85} = 336,22\ A$$

because there is a derating factor which results in a decrease in the value of the conductivity of the conductor in the conductor, the conductor chosen must have a value of CRC that is much greater than 336.22 A. Usually to find out what the rating of the conductor is divided by 0.6.

$I_{generator}$ = 336.22 A

KHA of conductor = 336.22 / 0.6 = 560.36 A

with a value of CRC 560.36 A, the conductor chosen is AAAC with a cross-sectional area of 240 mm^2. To find out the maximum power that is capable of flowing this conductor, you must pay attention to the derating factor that occurs which can reach 15%.

Value of KHA 240 mm^2 = 585 A

Derating factor = (100%-15%) x 585 = 497,25 A

$$S = V\ x\ I\ x\ \sqrt{3} \quad (2)$$

$$S = 20\text{ kV} \times 497.25 \times \sqrt{3} = 17.22\text{ MVA}$$

where $\cos\varphi = 0.85$. The power that is capable of flowing conductors is as follows.

$$\text{Power that can be accommodated} = S \times \cos\varphi = 17.22\text{ MVA} \times 0.85 = 14.6\text{ MW} \quad (3)$$

For the selection of network configuration according to N-1 conditions, namely when there is a disruption in a network, there is a network backup that is able to transfer all power from the generator. Then the SUTM that will be created in this connection has a configuration of two circuits. The increase in the length of the distribution network line will also result in greater power losses. Active power losses are influenced by the length of the line between the distribution substation and the consumer. In addition, active power losses can also be caused by the amount of electricity flowing in the distribution line branch. The amount of electric current flowing in this branch occurs because of the accumulation of load on the branch [6].

4.3 Load forecast

Load requirements from an area must be estimated in advance to ensure that the power of the plant to be built can be optimally absorbed [2]. PLTBm is planned to be operational in 2019 and will be connected to a 20 kV system. For this reason, it is necessary to forecast peak loads to determine the load requirements in 2019. PLTBm which will be connected to the GI KIM 1 power transformer or one of the feeder points of KI.11 so that load forecasting at each connection point is needed. Load growth refers to the average growth of the area to be interconnected. In this case, the reference for growth is 7.75%. Then the load on each feeder of the KIM substation on transformer 1 will be increased by 7.75% per year until 2019. The following is the projection of the burden of one of the transformers I, namely KI. With the above method, all loads on transformer 1 can be estimated.

4.4. Connection point plan

Splicing is done at the closest feeder point from the plant location, namely the KI.11 DS-01 point feeder. K.11 is one of the feeders of the GI KIM 1 transformer. The topology of the connection plan can be selected in Fig. 2.

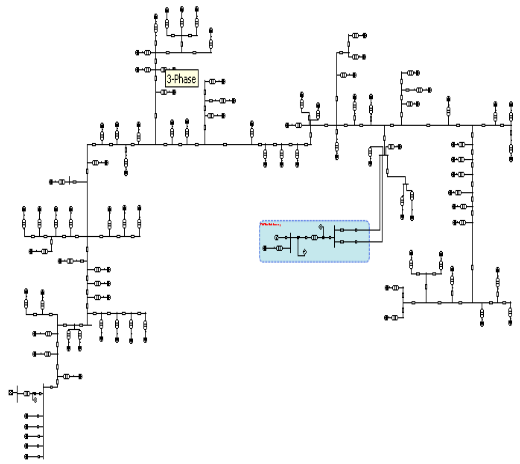

Fig.2. Network of topology

The connection point plan can be seen in Table 5 as seen below

Table 5. Connection point plan

No	Feeder KI.11-Titik DS-01	
1	Connecting point	Feeder KI.11
2	Conductor type	SUTM 20 kV, AAAC
3	Conductor diameter	3 x 240 mm^2
4	Exisisting voltage	19,5 kV
5	Distance of gen	400 meter
6	Recommend	Build a new 20 kV SUTM Network along the 400 m from the PLTBm location to feeder point I. 11

4.5. Simulation of Power Flow Result

The following are the results of the power flow analysis simulation with the condition of Peak Load Time (WBP) simulation, with power factor = 0.85. In the simulation, three buses will be considered, namely the GI bus. KIM Bus DS 01 is the connection point, and the Palu Merbo bus is the most end bus of the KI buster.11.

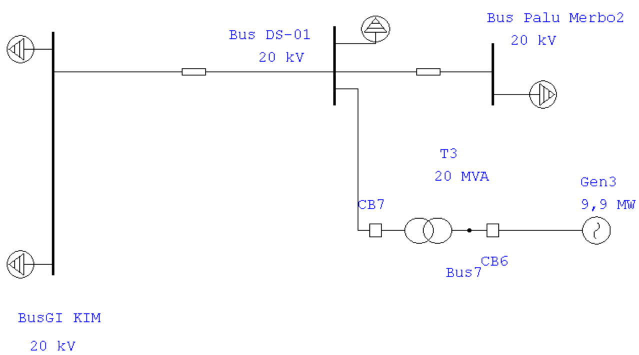

Fig.3. 20 kV network system is simplified

4.5.1 Voltage condition of busbar

Evaluation of the busbar voltage profile before and after the simulation is carried out to ensure there are no more busbars that experience critical conditions (the drop voltage exceeds the permitted limit). The complete results of the simulation can be seen in Table 6 and Table 7.

Table 6. Busbar voltage conditions before the connection

Voltage condition of Busbar			
Name of Bus	Before connection		
	kV	%	Condition
GI.KIM	19.619	98.1	Normal
DS-01	18.97	94.85	Critical
Bus Palu Merbo	18.93	94.68	Critical

Table 7. Busbar voltage condition after the connection

Voltage condition of Busbar			
Name of Bus	After connection		
	kV	%	Condition
GI.KIM	19.619	19.75	Normal
DS-01	18.97	20.18	Normal
Bus Palu Merbo	18.93	20.13	Normal

From the table above it can be seen that the voltage is better because the voltage in each busbar is in a safe condition, which is between 19.7kV - 20.18kV.

4.5.2 Losses of power condition

Power losses are one of the important parameters that need to be considered after network interconnection is made so that the system does not have a problem.

Table 8. Power losses condition before the connection

Power Losses		
From to line	Condition before connection	
	kW	kVAR
PLTBm - GI KIM	-	-
PLTBm – DS 01	-	-
Total Losses	415	6414
% Losses compared to the power absorbed	0.98 %	

Table 9. Power losses condition after connection

Power losses		
From to line	Conection to DS-01	
	kW	kW
PLTBm - GI KIM	-	-
PLTBm – DS 01	6	6
Total Losses	439	439
% Losses compared to the power absorbed	0.95 %	

Simulation results for the magnitude of network losses of power conditions before and after interconnection can be seen in Table 8 and Table 9. Table 8 and Table 9 show that the power losses after the network interconnection is relatively small, which is 0.95%, are still limited to what is permitted.

4.5.3 Power absorbed

This simulation is needed to see how far power is absorbed after network interconnection is done. The simulation results show that the absorption of power is still not maximal, but still within the permissible limits.

Table 10. Power conditions absorbed before the connection

Power absorbed		
From to	Condition before connection	
	kW	kVAR
PLTBm - GI KIM	-	-
PLTBm – DS 01	-	-
Power Absorbed	42,650	32,859

Table 11. Power conditions absorbed after connection

Power Absorbed		
From to	After connection	
	kW	kW
PLTBm - GI KIM	-	-
PLTBm – DS 01	9010	9010
Power Absorbed	44,867	44,867

4.6. Short circuit simulation results

The following are the results of a short circuit analysis carried out on 3 conditions, namely three-phase, one-phase, ground-to-phase, two-phase disturbances to the ground. This short circuit simulation is carried out to ensure the system is in a safe condition when a disturbance occurs.

Table 12. Result analysis before the connection

Short circuit current					
Name of Bus	Condition before connection				
	3 Phase	L-G	L-L	L-L-G	Safe condition <25kA
GI.KIM	12.39	12.96	10.73	13.11	Safe
DS-01	3.84	3.72	3.32	3.79	Safe
Bus Palu Merbo	2.93	2.85	2.54	2.90	Safe

The simulation results of the value of the short circuit current rise when compared to the conditions before interconnection. Produce short circuit current that does not exceed the maximum standard of existing equipment on the system, which is 25 kA

Table 13. Result analysis after the connection

Name of Bus	Short circuit current				
	Condition before connection				
	3 Phase	**L-G**	**L-L**	**L-L-G**	**Safe condition <25kA**
GI.KIM	14	14.11	12.16	14.53	Safe
DS-01	3.94	3.79	3.41	3.89	Safe
Bus Palu Merbo	2.98	2.89	2.58	2.96	Safe

The simulation results show that the closer to the bus that has a fault the greater the current will be while the voltage will decrease. This is caused by the relationship of current and voltage that is inversely proportional so that the greater the current the voltage will be more. Under normal circumstances, the current and voltage are distributed evenly to all parts of the system and are only affected by losses on the resistor.

5 Conclusion

Based on the research and simulation that has been done, it can be concluded that the option of PLTBm connection point is interconnected to KI.11 feeder at DS-01 point. Connection design uses a 240 mm2 AAAC type conductor with two circuit configurations. AAAC conductors were chosen because they generally use this type of conductor on a 20 kV system. The entry of PLTBm into a 20 kV system makes the system voltage better between 19.1 kV to 20.17 kV, power losses (439 kW + 5005.4 kVAR). However, the introduction of the PLTBm to the 20 kV. The short system made a current flow becomes higher, that is, before connecting the highest short circuit current, which is 12.96 kA and after the connection, that is 13.73 kA, but still in the standard of the maximum limit of existing equipment, which is 25 kA.

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