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Analysis the Impact of Distributed Generation Interconnection on the 20 kV Distribution Network: A Study Case of the Waste-to-Energy in Bantar Gebang and the Tambun Area Distribution Network

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***Abstract:* -** The need for electricity in Indonesia is increasing along with the growth of world industry in Indonesia. The use of power plants with fossil energy sources is decreasing with the aim of improving the environmental system. Electricity needs can be fulfilled by Distributed Generation (DG), namely generation that is connected to a distribution network in order to fulfill power needs and improve electricity quality. In Bekasi City, the Directorate General of the Bantar Gebang Waste-to-Energy Plant (WtE) is being built with a drained power of around 786 kW. In this research, an analysis will be carried out on the Bantar Gebang WtE, which is connected to the Tambun area distribution network. The simulation results show that the voltage drop at the transformer load is 0.3% to 3% in general. With PVUR values on sample transformers of 0.171%, 0.578%, and 0.187% and real and reactive power losses on Underground Lines, Overhead Lines, and transformers of 144 kW and 173 kvar leading before interconnection. After interconnection, there was an increase in real power loss to 147 kW and an improvement in PVUR values to 0.156%, 0.563%, and 0.183%, and reactive power to 164 kvar. The use of power at the Tambun feeder Dodge Substation has also decreased due to the interconnection of the Bantar Gebang WtE, which can generate around 786 kW of power to supply power to the distribution network connected to the Bantar Gebang WtE DG.

Keywords: Distributed Generation, WtE (PLTSa) Bantar Gebang, Distribution Network of Tambun, Power Fulfillment.

I. INTRODUCTION

The need for electricity in Indonesia is increasing along with the times. Decentralized power generation (Distributed Generation) is also becoming increasingly popular due to the rapid development of technology. People who become consumers of electricity at the same time can become electricity producers. With the development of Industry 4.0, development is needed in the generation sector from renewable energy that does not depend on central generators (Idoniboyeobu et al., 2020; Rahman et al., 2021).

Distributed Generation is the use of small-scale generators that are dispersed and connected to the electricity distribution system with the aim of helping with electricity needs or utilizing electricity potential in areas that are capable of producing electricity in small quantities, as well as fulfilling the main electricity needs as a power plant. that helps with basic needs and peak electricity consumption (Borges & Falcão, 2003). The use of Distributed Generation can also reduce energy losses because it is connected directly to the distribution system and not through the transmission system. Distributed generation is designed to have low maintenance costs, be environmentally friendly, have high efficiency, and be easy to use as an energy source. Energy sources that can be used in distributed generation include sunlight, wind, natural gas, biofuels, water, waste, and others (Borges & Falcão, 2003; Jaganathan

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& Saha, 2004). Distributed power plants can utilize natural resources found in inland areas by using river currents for PLTMH or combustion from WtE (PLTSa) waste in urban areas.

Bekasi City is one of the largest landfills in Indonesia, with a daily delivery of 3000–7000 tons of waste per day. With this, the DKI government is also responsible for the disposal of waste that is disposed of in Bekasi City, which is located in Bantar Gebang. The DKI government is building WtE, which is intended to reduce waste accumulation in Bantar Gebang, can generate 786 kWh of electricity with a waste consumption of 100 tons per day, and is connected directly to the Bantar Gebang distribution system.

Distributed generation introduces technologies that can help improve power reliability and quality and reduce power losses. The use of distributed generation can provide a power system connection that can increase the voltage profile by 2 to 3 times passively from reactive power that utilizes capacitor banks to reduce power losses (Felix et al., 2017). Optimum installation of distributed generation can have a positive impact; on the other hand, if it is not installed optimally, it will have an impact on increasing power losses and can make the voltage drop lower or higher than the capability limit (Hadavi et al., 2014).

II. LITERATURE REVIEW

2.1 Electrical System Reliability

If the distributed generation unit is operated correctly, it will have a positive impact on system reliability. For example, if distributed generation is used as a backup generator to meet an insufficient power supply in the event of a disruption to the transmission or distribution network, this is important to maintain the supply of electricity to customers. Installing distributed generation can also save on electricity financing by paying the difference between the energy used from the central generator and the amount of distributed generation energy that is put into the grid (Balamurugan et al., 2012; Borges & Falcão, 2003).

2.2 Electric quality

Distributed generation can also isolate itself when the main electricity network experiences a disturbance caused by a sudden change in load or a sudden change in load flow capacity in the transmission system, so that distributed generation can help maintain the voltage level, phase imbalance and the electricity frequency within a reasonable range. according to generator capacity (Balamurugan et al., 2012; Hosseinzadeh et al., 2021).

2.3 Power Losses

Because the installation of distributed generation can have an impact on repairing losses, distributed generation should be placed in areas with high losses. The installation of distributed generation will also have an impact on active and reactive power. In feeders with high loss rates, the use of distributed generation with a capacity of 10%–20% of the load on the feeders will help improve the value of losses (Borges & Falcão, 2003; Ogunjuyigbe et al., 2016)

Based on the explanation above, the research questions (RQ) in this study related to the value of the voltage profile, active power, reactive power, and power losses are arranged as follows:

RQ 1: What is the value of the voltage profile, active power, reactive power, and power losses for each phase in the 20 kV distribution network at the Tambun feeder before interconnection with the Bantar Gebang WtE?

RQ 2: What is the impact of the value of the voltage profile, active power, reactive power, and power losses for each phase in the 20 kV distribution network on the Tambun feeder after interconnection with the Bantar Gebang WtE?

RQ 3: Can the use of WtE in Bantar Gebang (786 kW) improve the characteristics of the 20 kV distribution network at Tambun feeders based on comparisons before and after interconnection?

The purpose of this research is to know and study the impact caused by DG on the distribution network that affects real and reactive power losses, voltage profiles, and phase voltage imbalance

III. METHODS

3.1 Research procedure

In this study, the objects and locations of research at PT PLN UP3 Bekasi City are as follows:

3.1.1 Research Object

This research makes the Bantar Gebang PLTSa, which is a DG managed by the National Innovation Research Agency (BRIN), the DKI Provincial Government, and PT PLN UP3 Bekasi City the objects of research on the distribution network.

3.1.2 Research Locations

This research was conducted at PT PLN UP3 Bekasi City, which is located on Jl. Cut Mutia No. 44 RT006/RW007 Margahayu, East Bekasi District, Bekasi City, West Java (17113). Who owns the Tambun area distribution network data that is connected between the Tambun substation and DGs

In this study, a research flow was made to achieve the research objectives. The diagram can be seen in Fig 1.

1) In the literature study, collect sources related to the research title as basic information to support research. A search for related journals was carried out on the Google Scholar website, IEEE, ScienceDirect, Researchgate, and also online media articles.
2) Field S by taking primary and secondary data through interviews. The data obtained is in the form of numbers related to PLN measurements. Interviews were also conducted to find out data that was not recorded by the related PLN but known by other related PLN units.
3) The data that has been obtained is in the form of a one-line diagram relating to the Tambun substation and also the Bantar Gebang PLTSa distributed generation that has been validated.
4) Data processing was carried out using the ETAP 19.0.1 simulation by designing a one-line diagram according to the data obtained from the related PLN. At the design stage, two scenarios were made: scenario 1 without distributed generation and scenario 2 with distributed generation.
5) Running an unbalanced power flow simulation on stage 19.0.1
6) Obtain the output data from the simulation for scenarios 1 and 2. If the results converge, then proceed to the simulation stage; if the results do not converge, then the simulation is repeated with the appropriate data.
7) After processing the data using the convergent ETAP 19.0.1 simulation, the results obtained are analyzed. The results of voltage, power losses, and others are in accordance with the problem formulation.
8) The overall conclusion of the research process is obtained regarding the research title.

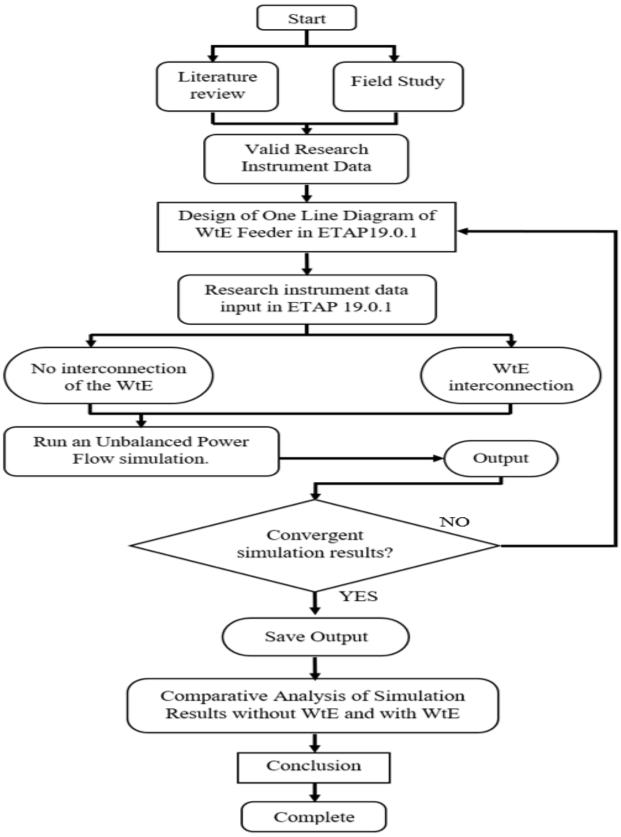

Figure 1. Flowchart of research procedures

3.2 Research Instruments

In this research, the research variables are voltage, power, and power losses, which will be measured and tested using the ETAP 19.0.1 simulation software as one of the research instruments. To obtain data that is in accordance with the research variables. As can be seen in Fig. 2, several research instruments are used, as follows:

1) Determine the research variables that will be used in the research. The research variables are known to be one-line diagrams, voltage, power, and power losses.
2) Dividing two research methods, namely field studies and literature studies, as a theoretical basis
3) In the field study, two research instruments were used with observation, namely looking at data variables directly and conducting interviews to find out data that was not recorded or visible.
4) Try out the research instrument using the ETAP 19.0.1 software to find out whether the data variables can be used and show no errors.
5) If the data variables can be used correctly, the research instruments used can be validated. If not, then return to determining the data variable.

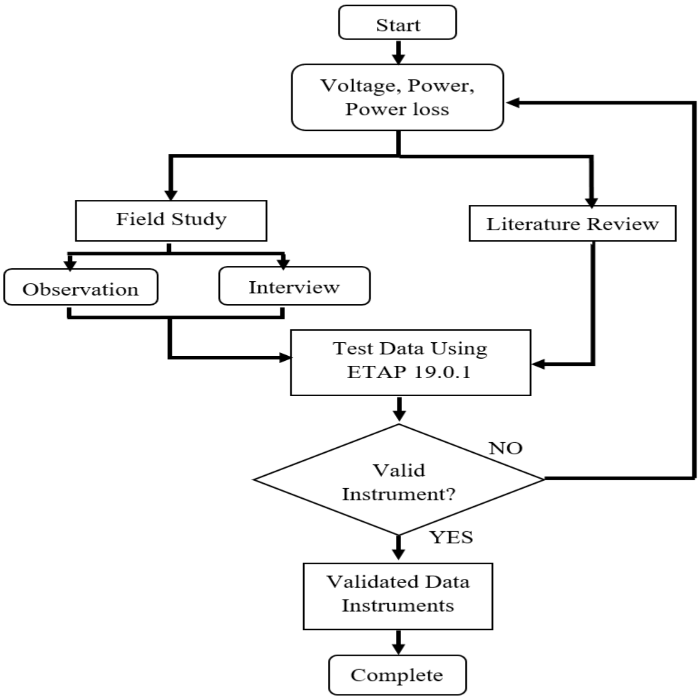

Figure 2. Flowchart of research instruments

IV. RESULT AND DISCUSSION

4.1 Scenario 1: Power Flow Data Before Distributed Generation Interconnection in the Tambun Distribution Network

The data processing that has been done with the ETAP 19.0.1 software produces the following data findings:

Table 1. Description Of ETAP Simulation Results 19.0.1

Bus	Description
Bus 1	Tambun Feeder Dodge Substation's Primary voltage is 150 kV.
Bus 2	Tambun Feeders Dodge Substation has a secondary voltage of 20 kV.
Bus 3	WtE in Bantar Gebang's primary voltage is 6.6 kV.
Bus 4	WtE in Bantar Gebang has a secondary voltage of 20 kV.
Bus 5	The interconnection point between the Tambun Substation and the Bantar Gebang WtE is connected to the Switch.
Bus 58	The central point of interconnection between the Bantar Gebang Substation and WtE (About 4 KM)
Bus 109	The farthest point of the Bantar Gebang substation and WtE interconnection (About 8 KM)

Table 2. Active Power and reactive power in scenario 1

Scenario 1 (no interconnection to WtE in Bantar Gebang)					
Generators					
Bus	**Phase**	**Voltage**	**MW**	**MVAR**	
1	R	150 kV	1.478	0.705	
	S		1.44	0.674	
	T		1.491	0.652	
3	R	6.6 kV	0	0	
	S		0	0	
	T		0	0	
1	R,S,T	150 kV	4.409	2.031	
3	R,S,T	6.6 kV	0	0	
Load Flows					
Bus	**Phase**	**Voltage**	**MW**	**MVAR**	**Ampere**
2	R	20 kV	1.475	0.567	137.4
	S		1.42	0.590	134.0
	T		1.434	0.537	133.0
4	R	20 kV	0	0	0
	S		0	0	0
	T		0	0	0
2	R,S,T	20 kV	4.329	1.694	404.4
3	R,S,T	20 kV	0	0	0

Based on the results of scenario 1 in Table 2, it is known that if the real power usage is 4.409 MW and the reactive power is 2.031 MVAR, the real power decreases to 4.329 MW and the reactive power becomes 1.694 MVAR. The real power loss from the primary to secondary bus transformer is caused by copper losses in the transformer windings. Meanwhile, the reactive power loss is caused by the use of electromagnetic components.

Table 3. Voltage profile data in Scenario 1

Voltage profile in scenario 1							
Transformers	**Bus From - To**		**Phase**	**Bus Voltage (%)**		**Voltage Drop (%)**	**%PVUR**
Tambun Sub-Staion	1	2	R	99.8	99.5	0.3	0.171
			S	100	99.5	0.6	
			T	100.1	99.8	0.3	
WtE in Bantar Gebang	3	4	R	100	100	0	0
			S	100	100	0	
			T	100	100	0	
DCUK	59	58	R	99.2	98.4	0.8	0.578
			S	99.1	97.5	1.6	
			T	99.4	98.3	1.1	
DHRM	108	109	R	99.1	97.9	1.2	0.187
			S	99.0	98.0	1.1	
			T	99.3	98.2	1.1	

In Table 3, it can be seen that the transformers used as samples have a voltage drop with a value that is still far from the limit set by the SPLN for a voltage increase of 5% and a voltage drop of 10%. The voltage drop is not large because the distance between the feeder and the load is not too great. Meanwhile, the voltage imbalance is still far from the limit set by the SPLN, with a value of 2% PVUR.

Table 4. Power loss data in scenario 1

Power losses in scenario 1								
Type Conductors	**Total**	**Phase**	**Power Flow Bus M - N**		**Power Flow Bus N -M**		**Losses**	
			MW	**MVAR**	**MW**	**MVAR**	**kW**	**kvar**
Under-Ground	45	R	3,408	1,359	-3,404	-1,566	3,2	-207
		S	3,256	1,348	-3,253	-1,555	3	-207
		T	3,359	1,233	-3,356	-1,442	3,1	-207
Over-head	32	R	0,891	0,502	-0,891	-0,509	-0,6	-7
		S	0,810	0,453	-0,810	-0,461	0,1	-8
		T	0,897	0,411	-0,897	-0,418	0,8	-7
Transformers	74	R	2,950	1,477	-2,918	-1,267	32	210
		S	2,856	1,471	-2,851	-1,344	4,3	127
		T	2,922	1,396	-2,824	-1,263	98	133
Total							144	-173.6

The real power losses in scenario 1 are generally caused by the resistance and reactance of the conductors. In Underground Lines, the reactive power loss has a leading character, which is caused by the capacitance effect. This happens because the distances between the phases are close to each other. Meanwhile, Overhead Lines has a small capacitance effect because the distance between the phases is greater. The real power loss in the transformer is caused by the transformer windings and will be at its maximum when the load is at its peak. The reactive power loss in the transformer has a lagging character according to the load on the consumer. In a network, the real and reactive power losses are added up to determine the nominal and character of the power loss. After adding up, it is known that the real power loss is 144 kW and the reactive power loss is 173.6 kW.

Substitution of Underground Lines to Overhead Lines with a length of 471 meters can improve the reactive power loss of 14.6 kvar. So if you replace Underground Lines with Overhead Lines for 5.7 KM, the reactive power loss will improve to 13.9 kvar lag.

4.2 Scenario 2: Power Flow Data After Distributed Generation Interconnection in a Distribution Network

After interconnection with the WtE in Bantar Gebang on the distribution network, the following findings are known:

Table 5. Active Power and reactive power in scenario 2

Scenario 1 (no interconnection to WtE in Bantar Gebang)					
Generators					
Bus	**Phase**	**Voltage**	**MW**	**MVAR**	
1	R	150 kV	1.217	0.703	
	S		1.18	0.675	
	T		1.229	0.655	
3	R	6,6 kV	0.263	0.003	
	S		0.26	0.000	
	T		0.264	0.002	
1	R,S,T	150 kV	3.626	2.033	
3	R,S,T	6.6 kV	0.786	0.005	
Load Flows					
Bus	**Phase**	**Voltage**	**MW**	**MVAR**	**Ampere**
2	R	20 kV	1.212	0.572	116.6
	S		1.16	0.593	113.7

	T		1.175	0.544	112.4
4	R	20 kV	0.263	0.010	22.9
	S		0.26	0.008	22.5
	T		0.259	0.013	22.5
2	R,S,T	20 kV	3.547	1.740	342.7
3	R,S,T	20 kV	0.782	0.031	67.9

In Table 5, it is known that the real power usage at the Tambun Substation has decreased from scenario 1 due to the Bantar Gebang PLTSa DG interconnection with a power capacity of 786 kW.

Table 6. Voltage profile data in Scenario 2

Voltage profile in scenario 1							
Trans-formers	**Bus From - To**		**Phase**	**Bus Voltage (%)**		**Voltage Drop (%)**	**%PVUR**
Tambun SubStaion	1	2	R	99.9	99.6	0.3	0.156
			S	100	99.5	0.6	
			T	100.1	99.7	0.4	
WtE in Bantar Gebang	3	4	R	99.8	99.5	0.3	0.157
			S	100	99.4	0.6	
			T	100.1	99.7	0.4	
DCUK	59	58	R	99.2	98.4	0.8	0.563
			S	99.2	97.5	1.6	
			T	99.4	98.3	1.1	
DHRM	108	109	R	99.1	97.9	1.2	0.183
			S	99.0	98.0	1.1	
			T	99.3	98.2	1.1	

In scenario 2, it is known that the voltage value has a voltage improvement of around 0.015% by measuring the voltage unbalance value on the transformer. This is due to the interconnection of DG PLTSa Bantar Gebang so that the voltage between the phases is improved and the voltage imbalance/PVUR value is corrected.

Table 7. Power loss data in scenario 2

Power losses in scenario 2								
Type Conductors	**Total**	**Phase**	**Power Flow Bus M - N**		**Power Flow Bus N -M**		**Losses**	
			MW	**MVAR**	**MW**	**MVAR**	**kW**	**kvar**
Under-Ground	45	R	3,146	1,354	-3,143	-1,562	3,12	-207
		S	2,999	1,346	-2,996	-1,553	2,93	-207
		T	3,096	1,233	-3,093	-1,441	2,98	-208
Over-head	32	R	0,891	0,502	-0,892	-0,509	-0,6	-7
		S	0,810	0,453	-0,810	-0,461	0,09	-8
		T	0,897	0,411	-0,897	-0,417	0,82	-7
Transformers	74	R	2,952	1,481	-2,918	-1,267	34,1	213
		S	2,857	1,474	-2,852	-1,344	4,97	131
		T	2,923	1,399	-2,824	-1,263	98,8	136
Total							147,2	-164

After interconnection with WtE in Bantar Gebang in Scenario 2, it is known that the real power loss increases by 3 kW and the reactive power loss decreases by 9 kvar. The addition of real power losses is due to transformers, and the addition of lagging reactive power losses is caused by the use of generators in generators. The use of WtE (PLTSa) in Bantar Gebang in order to improve reactive power losses close to 0 or 0.6 kvar lagging is with a generating capacity of 4.5 MW with an additional real power loss of 29.7 kW and a total real power loss of 173.8 kW.

4.3 Comparison of Scenarios 1 and 2 on Distribution Networks

After carrying out both scenarios for the distribution network, a comparison of the two data sets is carried out as follows:

1. Before the interconnection, the power supply from the Tambun Substation was 4,329 MW, and after the interconnection, it was reduced to 3,547 MW with the power input from WtE in Bantar Gebang (786 kW) and increasing the reactive lagging power supply caused by the generator at the generator.
5 If you look at the voltage drop on the Tambun Substation transformer, the DCUK transformer, and the DHRM transformer, there is no improvement due to the rounding off of the numbers in the ETAP software. Improvements occur with a value of 0.03% in the phase that has interference. Overall, the improvement in the quality of the voltage can be seen from the decrease in the value of the phase imbalance after the interconnection of WtE in Bantar Gebang.
6 The Underground Line's real power loss has improved after interconnection, one of which is due to the voltage improvement. However, the reactive power loss on the Underground Line is leading and increases by 1 kV on phase T. The cause of the reactive power with a leading character is the effect of capacitance on conductors that are close together between phases and cable insulation. In Overhead Lines, there is no improvement or decrease in real or reactive power losses. But in the transformer, the real power loss and lagging reactive power loss increase in the R, S, and T phases due to the transformer interconnection at the Bantar Gebang DG and the generator.

V. CONCLUSIONS

Based on the results of the research that has been done, it can be concluded that The Bantar Gebang DG simulation results before interconnection show that the power flowing from the substation is 4,329 MW with a real and reactive power loss of 144 kW and 173 kvar leading. The voltage profile value is within safe limits, according to SPLN. The voltage values are far from +5% and -10%, and the voltage unbalance is still less than 2% with the respective sample transformer values of 0.171%, 0.578%, and 0.187%. The simulation results of WtE (PLTSa) in Bantar Gebang after interconnection show that the power flowing from the substation is 3,626 MW, with an increase in real power loss and improvement in reactive power to 147 kW and 164 kvar leading. The voltage profile value is within safe limits, according to SPLN. The value of voltage unbalance has improved to 0.156%, 0.563%, and 0.183%. The installation of the WtE in Bantar Gebang distributed generation is appropriate in terms of power output of 786 kW because it can meet consumer needs and improve the voltage value and reactive power of 9 kvar, but with an increase in real power loss of 4 kW.

RECOMMENDATIONS

Based on the results of the research that has been done, the following recommendations are obtained:

1. There are still many shortcomings in this research that need to be corrected in future research to determine the impact of distributed generation interconnection on distribution networks when the power flow is unbalanced
2. This research can then carry out imbalances using different simulation applications such as MathLab or Dig Silent.
3. Conduct research related to the placement of distributed generation in unbalanced power flow distribution systems
4. Conduct research by adding simulation models and other methods so that the simulation of the impact of distributed generation can be more optimal and the research data is more varied

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