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Analysis of Load Flow and Short Circuit Against the Addition of Distributed Generation (DG) in Distribution Networks

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Abstract

This study tries to determine the level of change in short-circuit fault currents on certain buses in the Andalas University distribution network due to the installation of a new generator. Simulation of load flow and short circuit faults uses a 20 kV Andalas University distribution network system model to which a renewable generator with a capacity of 200 kW will be added. The simulation results of the load flow on a 20 kV distribution system paralleled with DG show that the voltage drop is still in accordance with the provisions of PT. PLN, this is due to the voltage drop in the distribution system is not up to 10% of the nominal 20 kV. While the short circuit simulation results, the largest single-phase and three-phase short-circuit current values occur at the Nursing_P location of 9.362 kA. However, the short circuit capacity has not yet reached a maximum voltage of 20 kV 500 MVA or 14.4 kA. So that the amount of short circuit current contributed by Nursing_P is within normal limits and does not require additional equipment to protect the fault current.

Keywords: distributed generation; load flow; short circuit; renewable energy

Introduction

The development of renewable energy and energy conversion needs to be done immediately due to the decline in fossil energy. The decreasing production of petroleum fuels encourages people to play a role in developing and utilizing renewable energy sources and the world's readiness to reduce greenhouse gas emissions, which encourages the Government to continuously increase the role of new and renewable energy as part of maintaining energy security and independence. Based on Government Regulation No. 79 of 2014 concerning National Energy Policy, where the target for the new and renewable energy mix is at least 23% in 2025 and 31% in 2050 (Wijaya et al., 2017).

The use of electrical energy in large enough quantities for educational institutions such as campus buildings cannot avoid creating continuity of smooth activities, so it is necessary to add electrical energy from renewable energy sources. The addition of renewable energy sources can be one of the alternative solutions for supplying electricity so that the demand for electrical energy can be met and save energy consumption from PT. PLN (Syafii, Zaini, et al., 2019). These renewable energy sources will later connect to other distribution networks, such as energy sources that do not pollute the environment and renewable environmentally friendly energy (Syafii, Gazaly, et al., 2019). Distributed generation is a generator that is becoming popular because it provides several benefits (Mehigan et al., 2018). Renewable generators are sources of electrical energy that have a small capacity compared to existing sources of electrical energy and can be connected directly to the distribution network. Distributed generation in distribution networks significantly improves network quality, such as improved voltage profile, increased reliability, and decreased power losses (losses) after adding distributed generation (Adajah et al., 2021). It has distributed generation sources such as gas turbines, photovoltaic cells, microturbines, wind generators, fuel cells, biomass, and other renewable energy storage systems. In recent years photovoltaic (PV) and wind power generation have developed rapidly as one of the sources of distributed generation used (Musirikare et al., 2018)(Tjahjono et al., 2015).

The current power system has expected to be a reliable and high-quality system, which means it has good quality and continuity does not harm living things and the surrounding environment (Arizaldi et al., 2021). The addition of new generators in the distribution network has a significant effect on improving the quality of the network. The current is considerable and exceeds the nominal limit resulting in a short circuit that can cause damage to the electrical power system equipment (Dewi et al., 2018). The amount of short-circuit current depends on the type and location of the fault itself. The more significant the short-circuit current, the more significant the impact. Therefore, we need a system that can overcome the impact of these disturbances and also maintain the safety and reliability of the electric power system properly, and the system must be supported by an appropriate safety system so that disturbances can be isolated and continuity is maintained called a protection system. This protection system will automatically separate the parts of the system that are affected by interference from the power system. Circuit breakers, transducers, and relays are three parts of the protection system. Protection relays play an essential role in the operation of various power systems. Relay coordination is an essential aspect of the design of a protection system because the coordination scheme must ensure fast, selective, and reliable relay operation to isolate the faulty part of the power system (H. H. Zeineldin, Hebatallah M. Sharaf, Doaa K. Ibrahim, 2015). Relay protection is vital in overcoming the occurrence of short circuit faults. The performance of the protection system needs to be improved, especially on the protection relay. So to improve the performance, it is necessary to analyze the settings and coordination of the relay by describing the characteristic curve of the protection relay (Mehmed-Hamza & Stanchev, 2019). Problems encountered every time in the distribution system, such as if one of the feeders has a problem, can cause other feeders on the same bus to trip because a short circuit can trip up the relay on the incoming feeder. In addition, it can also cause by a lack of coordination in relay settings between the outgoing substation and the express feeder supplying the substation, which also causes all outgoing feeders at the substation to blackout.

Literature Review

Distributed Generation (DG)

Distributed generation can be defined as small size generators operating in isolation or connected to an electrical distribution system(Hao et al., 2019). These generators may be conventional generators such as coal fuel, hydro-powered synchronous machines, as well as sources that include rapidly developing technologies such as photovoltaic, wind turbines, fuel cells and microturbines. DG can bring advantages such as reducing system losses, increasing power quality and reliability (Aksoy & Nuroğlu, 2018). Distributed power generation based on renewable energy sources is becoming popular because it provides several benefits such as economic benefits with high efficiency, lower losses, as well as environmental benefits in reducing greenhouse gas emissions (Datta et al., 2018)(Abdel-Ghany et al., 2015). Due to the depletion of fossil fuels and environmental concerns about global warming, renewable energy sources have emerged as a new paradigm for meeting the energy needs of our society. In recent years, electricity production from hydro, solar, wind, geothermal, tidal, wave and biomass energy sources has received increasing attention. In 2012 electricity production from renewable energy sources worldwide exceeded 1470 gigawatts (GW) which represents about 19% of global energy consumption (Yaramasu et al., 2015).

Single-Phase to Ground Short Circuit Fault

A single-phase short-circuit to ground fault is a short circuit that occurs because the phase conductors and the ground are in contact with each other. This single phase to ground short circuit fault often occurs in electric power distribution systems, the percentage of this fault is about 70% of other short circuit faults. This disturbance is temporary, there is no permanent damage at the point of disturbance (Al qoyyimi et al., 2017) as shown in Figure 1.

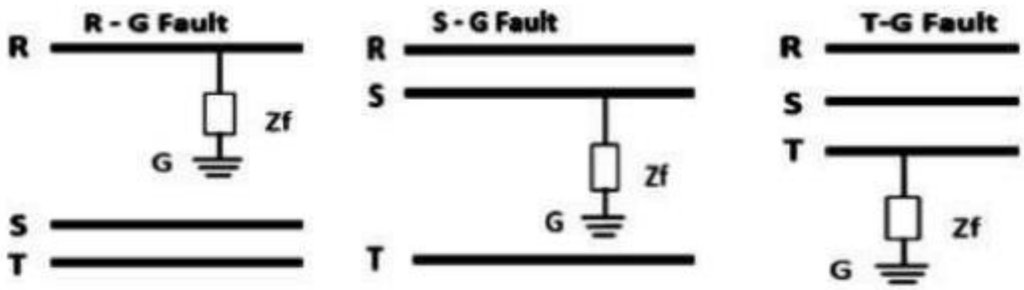

Figure 1. Single-Phase to Ground Short Circuit Fault

To calculate the value of the total impedance (Zn) can use the equation:

$$Z_n = \frac{Z_1 + Z_2 + Z_0}{3} \quad (1)$$

Information: Z_1 = Positive sequence impedance
Z_2 = Negative sequence impedance
Z_0 = Zero order impedance

Two-Phase Short Circuit (Inter-Phase) Fault

Interphase short circuit (line to line) is a short circuit that occurs due to the contact of one phase conductor with another phase conductor, resulting in overcurrent (over current). Interphase short circuits can be caused by contacting the phase conductors due to tree branches blown by the wind. The percentage of short circuit faults between phases is 15% as shown in Figure 2.

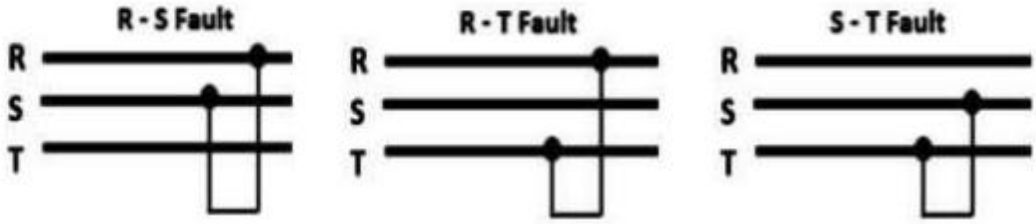

Figure 2. Two-Phase Short Circuit (Inter-Phase) Fault

To calculate the value of the total impedance (Zn) can use the equation:

$$Z_n = \frac{Z_1 \times Z_2}{\sqrt{3}} \tag{2}$$

Information: Z_1 = Positive sequence impedance
Z_2 = Negative sequence impedance
Z_0 = Zero order impedance

Two-Phase to Ground Short Circuit Fault

Two-phase short-circuit to ground fault is a short-circuit fault that occurs when two-phase lines or two-phase conductors are connected to ground. The percentage of two-phase short circuit to ground fault occurs is 10% as shown in Figure 3.

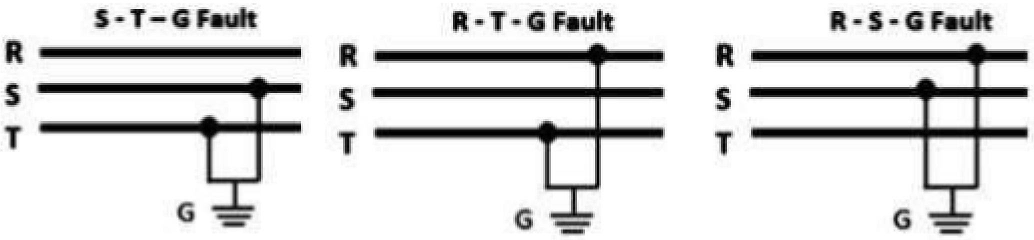

Figure 3. Two-Phase to Ground Short Circuit Fault

To calculate the value of the total impedance (Zn) can use the equation:

$$Z_n = \frac{Z_1 \times Z_0 \sqrt{3}}{Z_1 + Z_0} \tag{3}$$

Information: Z_1 = Positive sequence impedance
Z_2 = Negative sequence impedance
Z_0 = Zero order impedance

Three-Phase Short-Circuit Fault

Three-phase short-circuit fault is a short-circuit fault that occurs due to the contact of the three phase conductors, this disturbance can be caused by a tree falling which then hits the phase wire, thereby breaking the phase wire simultaneously. The percentage of occurrence of this short circuit is 5%. The three-phase short-circuit fault can be seen in Figure 4.

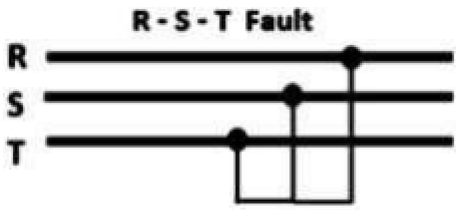

Figure 4. Three-phase short-circuit fault

To calculate the value of the total impedance (Zn) can use the equation:

$$Z_n = Z_1 \tag{4}$$

Information: Z_1 = Positive sequence impedance

Three-Phase To Ground Short Circuit Fault

Three-phase short-circuit fault to ground is a short-circuit fault that occurs due to the contact of the three phase conductors and is connected to ground. The percentage of three-phase short circuit to ground fault is 5%. Three-phase short circuit to ground can be seen in Figure 5.

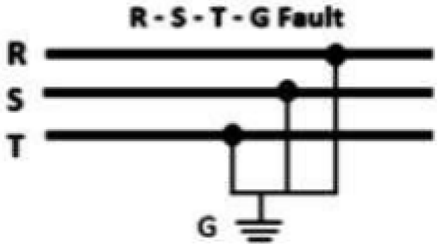

Figure 5. Three-Phase to Ground Short Circuit Fault

To calculate the value of the total impedance (Zn) can use the equation:

$$Z_n = Z_1 + Z_0 \quad (5)$$

Information: Z_1 = Positive sequence impedance
Z_0 = Zero order impedance

Materials & Methods

Distribution Network Specification

In this study, the data used for load flow analysis with Solar Power Plant and Wind Power Plant on the Andalas University voltage power network. Then the primary data used consists of load data and transformer data. The distribution network of Unand has nine units of transformers with different capacities according to the needs of each faculty on the Andalas University campus. The data of the transformer and its capacity are as shown in Table 1. Loading data take when there is a peak electrical load.

Table 1. Data Transformer In Distribution Network

Transformer Name	Capacity (kVA)
Faculty of Engineering	630
Faculty of Mathematics and Natural Sciences	1000
Faculty of Agriculture	1000
PKM	250
Faculty of Animal Husbandry	630
Faculty of Social Sciences	630
Faculty of Nursing	315
Faculty of Medicine	630
Andalas University Hospital	2000

Furthermore, load data on the Andalas University electricity distribution network system is also needed in this research. The load data and its capacity can be seen in Table 2.

Table 2. Load Data on Distribution Network

No	Bus ID	kVA	kW	kVar
1	Engineering	250	212	132
2	Mathematics and Natural Sciences	337	287	178
3	Animal Husbandry	196	167	103
4	Social Sciences	176	150	93
5	Agriculture	294	250	155
6	Nursing	148	125	78
7	PKM	164	140	86
8	Andalas University Hospital	327	323	54
9	Medicine	302	274	126
	Total	2194	1928	1005

In this study, the distribution network system of Andalas University 20 kV consists of 21 buses with a single line diagram model in Figure 6. Meanwhile, when the condition of the Andalas University distribution network system is paralleled with a DG of 200 kW. The DG used in this study these are the Solar Power Plant and the Wind Power Plant.

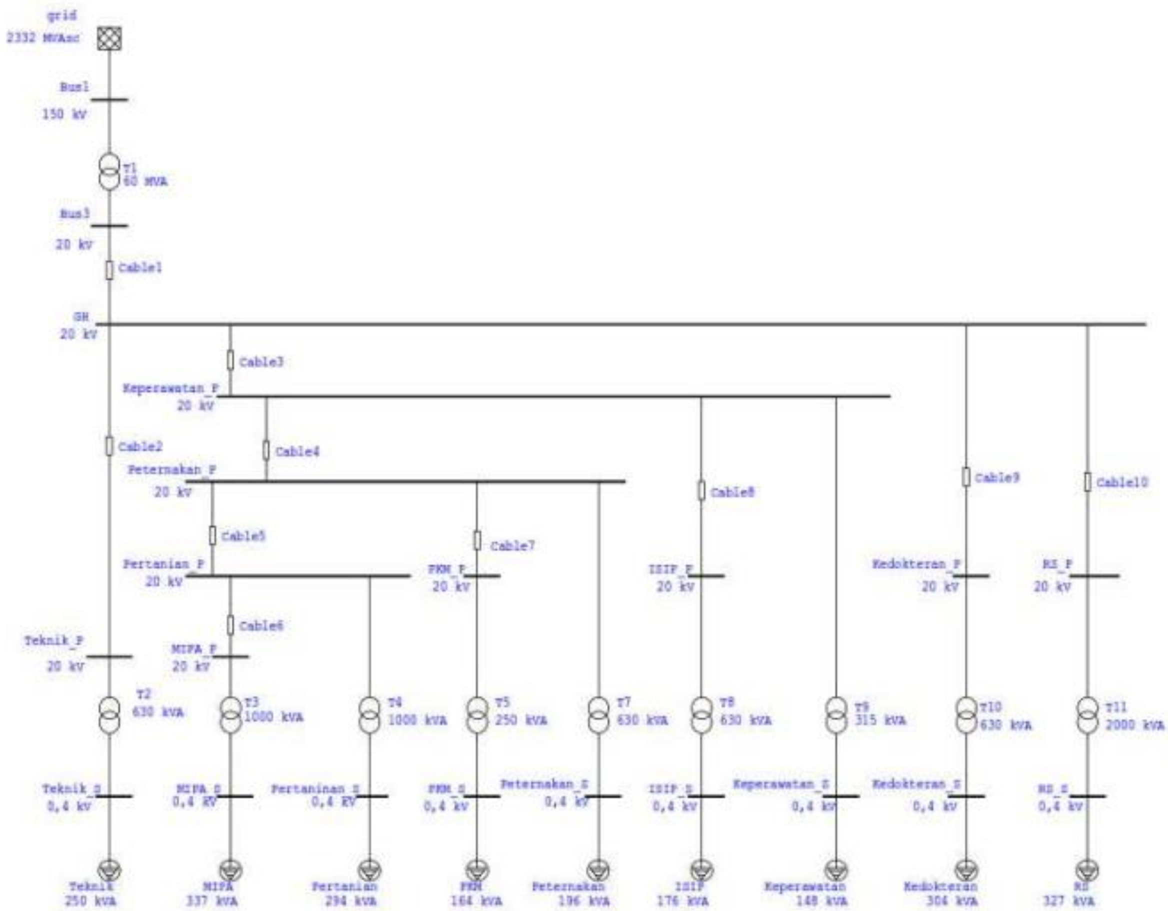

Figure 6. Single Line Diagram of 20 kV Distribution Network System Andalas University

Research Steps

This research begins with a literature study which is used as a guide in conducting research. Furthermore, collecting data containing a 20kV distribution network system connected to the Andalas University network system. Then make a single line diagram circuit modeling. After the single line diagram modeling has been completed, then the next step is to simulate load flow testing and short circuit testing on the system with the addition of DG as shown in Figure 7.

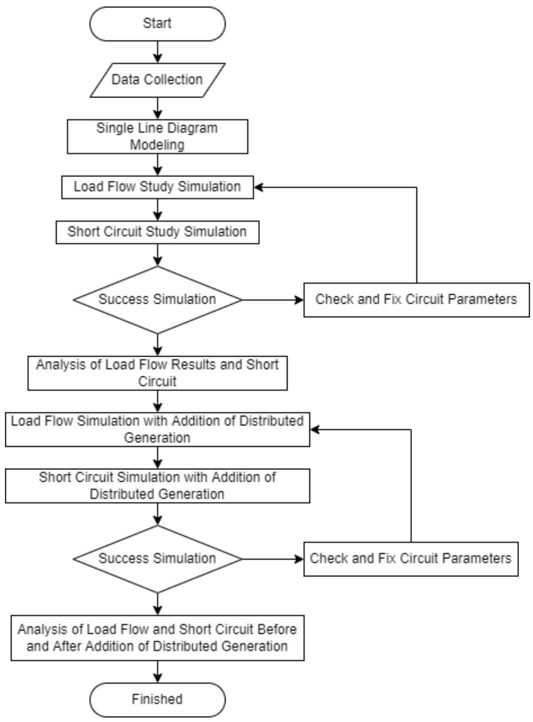

Figure 7. Research Flowchart Load Flow Analysis and Short Circuit with the Addition of Distributed Generation

Results and Discussion

Load Flow Study Before Adding Distributed Generation (DG) 200 kW

In this load flow study simulation, it will be checked whether the voltage conditions along the distribution network of Andalas University are sufficient to parallel the electrical energy with DG at a predetermined interconnection point. The results of this simulation are shown in Table 3.

Table 3. Voltage Conditions at GH and Buses in Andalas University's 20 kV System Before Parallel with DG 200 kW

Measuring Point	Voltage Condition	Information
Bus 20 kV GH	19,973 kV	Qualify
Nursing_P	19,951 kV	Qualify
Animal Husbandry_P	19,935 kV	Qualify
Agriculture_P	19,932 kV	Qualify
At the Connecting Point	19,965 kV	Qualify
Mathematics and Natural Sciences_P	19,929 kV	Qualify
PKM_P	19,933 kV	Qualify
Social Sciences_P	19,95 kV	Qualify
Medicine_P	19,969 kV	Qualify
At the Connecting Point	19,966 kV	Qualify

Based on the simulation results in Figure 8, it can be concluded that the voltage value in the distribution system of 20 kV Andalas University before paralleling with DG 200 kW is in accordance with the provisions of PT. PLN (Persero). So that it can be done in parallel with DG because the voltage drop is not up to 10% of the nominal 20 kV.

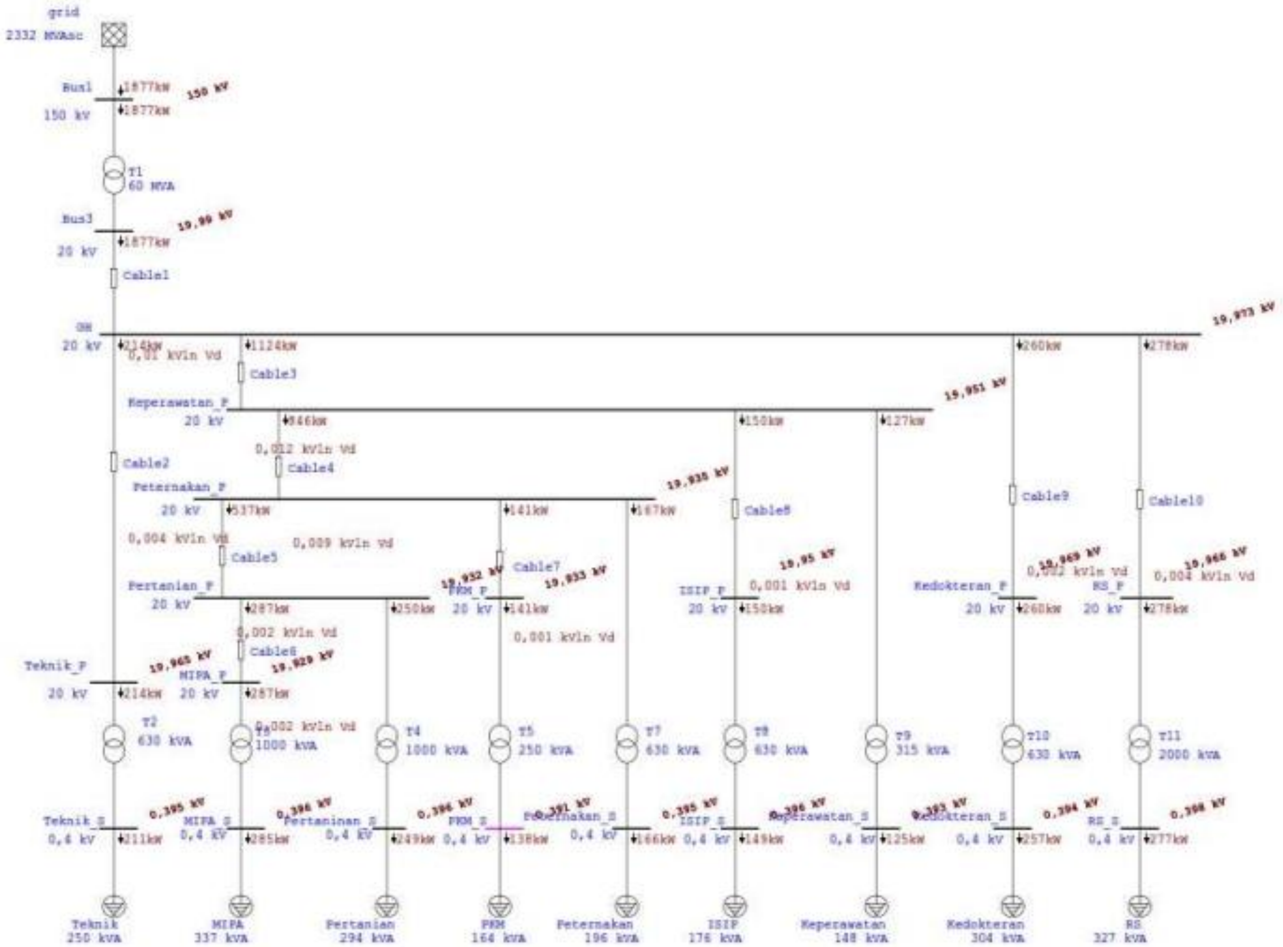

Figure 8. Andalas University 20 kV Distribution System Before Parallel with DG 200 kW

Load Flow Study After Adding Distributed Generation (DG) 200 kW

The simulation of load flow studies on the distribution network of Andalas University after being parallel with the 200 kW (DG) Wind Power Plant and Solar Power Plant aims to examine the operating conditions of the system. The results of the simulation of the operating conditions of the system are shown in Table 4.

Table 4. Voltage Conditions on GH and 20 kV System Buses at Andalas University After Parallel with 200 kW DG

Measuring Point	Voltage Condition	Information
Bus 20 kV GH	19,97 kV	Qualify
Nursing_P	19,95 kV	Qualify
Animal Husbandry_P	19,94 kV	Qualify
Agriculture_P	19,93 kV	Qualify
At the Connecting Point	19,97 kV	Qualify
Mathematics and Natural Sciences_P	19,93 kV	Qualify
PKM_P	19,93 kV	Qualify
Social Sciences_P	19,95 kV	Qualify
Medicine_P	19,97 kV	Qualify
At the Connecting Point	19,97 kV	Qualify

Based on the simulation results in Figure 9, it can be concluded that the voltage value when the condition of the 20 kV distribution system of Andalas University is parallel with the Solar Power Plant and the 200 kW Wind Power Plant is in accordance with the provisions of PT. PLN (Persero). So that the 20 kV distribution system of Andalas University can be operated because the voltage drop is not up to 10% of the nominal 20 kV.

Table 5. Comparison of Voltage Conditions of 20 kV Distribution System Andalas University Before and After Parallel With DG 200 kW (Solar Power Plant, Wind Power Plant)

Load Point	Voltage (kV)		Information
	Grid	DG (Solar Power Plant and Wind Power Plant)	
Bus 20 kV GH	19,973 kV	19.97 kV	Qualify
Nursing_P	19,951 kV	19.95 kV	Qualify
Animal Husbandry_P	19,935 kV	19.94 kV	Qualify
Agriculture_P	19,932 kV	19.93 kV	Qualify
At the Connecting Point	19,965 kV	19.97 kV	Qualify
Mathematics and Natural Sciences_P	19,929 kV	19.93 kV	Qualify
PKM_P	19,933 kV	19.93 kV	Qualify
Social Sciences_P	19,95 kV	19.95 kV	Qualify
Medicine_P	19,969 kV	19.97 kV	Qualify
At the Connecting Point	19,966 kV	19.97 kV	Qualify

In table 5 is a comparison of the voltage on the distribution system of 20 kV Andalas University before and after parallel with DG 200 kW. The results show that after the installation of the 200 kW DG the distribution system can still be operated, because the difference is not too significant and still meets the requirements as shown in Figure 9.

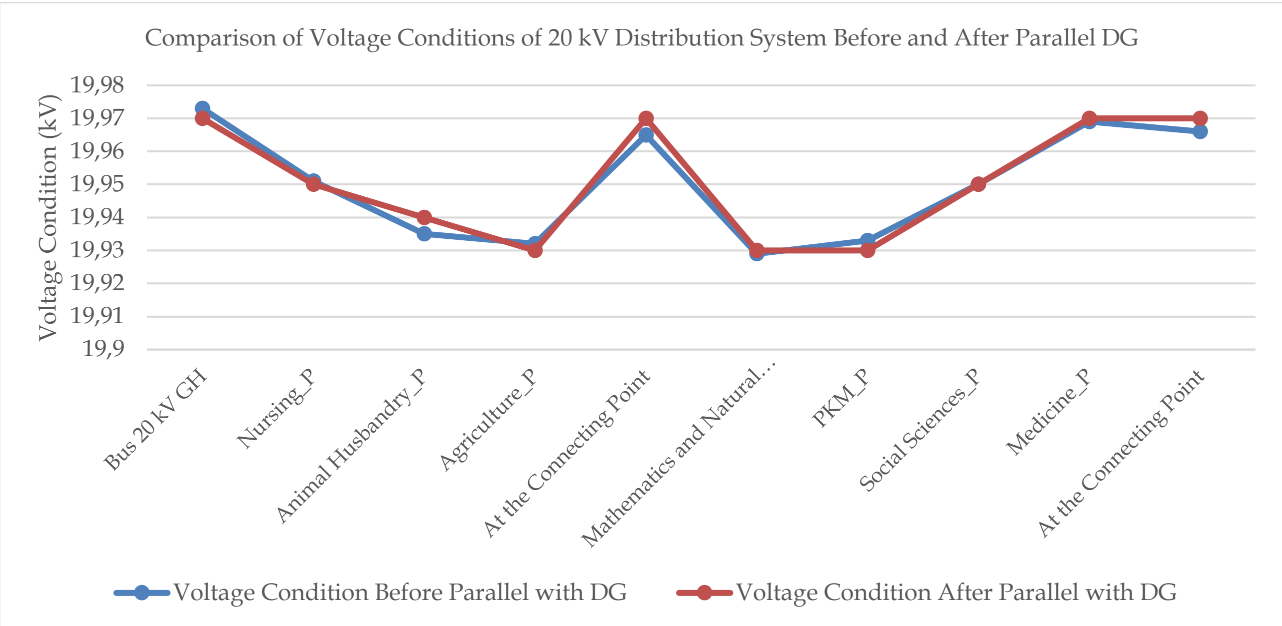

Figure 9. Comparison of Voltage Conditions of 20 kV Distribution System Before and After Parallel with DG

Based on Figure 9, it can be seen that the voltage conditions before and after parallel with the DG 200 kW Solar Power Plant and the Wind Power Plant with a 20 kV system at Andalas University are up and down.

Short Circuit Study Before Addition of Distributed Generation (DG) 200 kW

In the short circuit study simulation, it will be checked whether the short circuit fault current condition along the Andalas University electricity distribution network does not spike high when it will be paralleled from electrical energy to DG at a predetermined interconnection point or not. The simulation results of the short circuit study are shown in Table 6.

Table 6. Three-Phase Short Circuit Fault Current Conditions at Three Fault Locations in Andalas University 20kV System Buses Before Parallel with DG

Disturbance Location	Three Phase Fault (KA)	Information
Nursing_P	8,495	Secure
Mathematics and Natural Sciences_P	7,001	Secure
Animal Husbandry_P	6,05	Secure

Based on the results of the short circuit simulation, it can be concluded that the value of the fault current in the distribution system of 20 kV Andalas University before paralleling with DG is in accordance with the provisions of the Regulation of the Minister of Energy and Mineral Resources concerning the regulation of electricity distribution (Distribution Code) in 2009 determined short circuit capacity equipment voltage 20 kV maximum 500 MVA or 14.4 kA. So there is no need to add a security system or protection system at the fault location as shown in Figure 10.

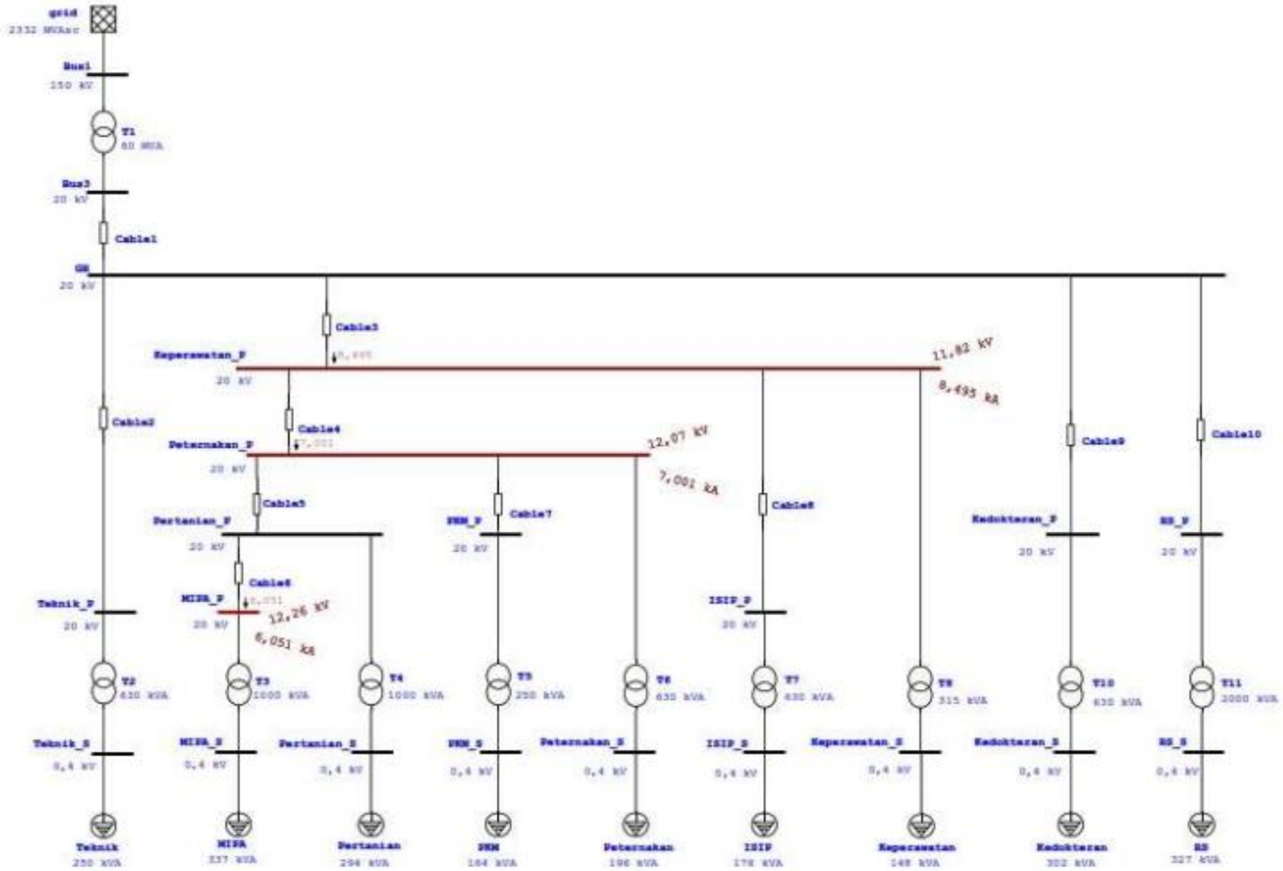

Figure 10. Three-Phase Circuit Fault Current Conditions in Andalas University 20 kV System Before Parallel DG

Short Circuit Study After Addition of Distributed Generation (DG) 200 kW

Short circuit simulation on the distribution system of Andalas University with parallel DG 200 kW aims to check the operating conditions of the system when DG is parallel. Then the goal is also as a plan for a security system in the distribution system. The simulation results are shown in Table 7.

Table 7. Three Phase Short Circuit Fault Current Condition in Andalas University 20 kV System After Parallel with DG

Disturbance Location	Three Phase Fault (KA)		Information
	Before Parallel	After Parallel	
Nursing_P	8,495	9,362	Secure
Mathematics and Natural Sciences_P	7,001	7,049	Secure
Animal Husbandry_P	6,051	7,997	Secure

After simulating the short-circuit fault on the Andalas University 20 kV distribution network with the addition of a renewable generator, the short-circuit current value at each fault point can be seen in table 8.

Table 8. Comparison of Short Circuit Fault Results in 20 kV Distribution Network Andalas University with the addition of DG

Disturbance Location	Three Phase Fault (KA)	Phase to phase (KA) fault	Single Phase to Ground Fault (KA)
Nursing_P	9,362	8,105	8,512
Mathematics and Natural Sciences_P	7,048	6,103	6,058
Animal Husbandry_P	7,997	6,923	7,012

Based on the short circuit simulation results in Table 8, the largest 1 phase and 3 phase short circuit current values occur at the Nursing_P location of 9,362 kA. Based on the Regulation of the Minister of Energy and Mineral Resources concerning the rules for the distribution of electricity (Distribution Code) in 2009 it is determined that the short-circuit capacity of 20 kV voltage equipment is a maximum of 500 MVA or 14.4 kA. So that the magnitude of the short circuit current at the Nursing_P location is within normal limits and no additional equipment is needed to protect the fault current [19].

Conclusions

Based on the simulation results, the short-circuit current capacity obtained has a good influence on the Andalas University network system with the addition of distributed generation. So that with this research the addition of new generators can be an alternative source of electricity supply so that the demand for electrical energy can be fulfilled and can also save energy consumption from PT. PLN (Persero).

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