Load Flow Analysis and Short Circuit Faults with the Additional Distributed Generation Wind Turbine 300 Kw at Andalas University

Fadhel Putra Winarta¹, Yoli Andi Rozzi¹

¹Master Program in Electrical Engineering, Faculty of Engineering, Andalas University, West Sumatra

ABSTRACT

The study of electric power flow analysis (Load Flow) is intended to obtain information about the flow of power or voltage in an electric power system network. This information is needed to evaluate the performance of the power system. Electrical power flow problems include calculating the flow and system voltage at certain terminals or buses. The benefits of this power flow study are to find out the voltage at each node in the system, to find out whether all the equipment meets the specified limits to deliver the desired power, and to obtain the original conditions in the new system planning. This study is divided into two: the analysis of data when the conditions have not been added wind turbine and after the addition of 300 kW wind and the Newton-Raphson method will be used in analyzing the power flow of the electric power system. Based on the results of the tests, it is found that the overall value of losses for power flow before the addition of DG is 0.031 MW and 0.037 MvarAR, for the voltage drop with the lowest percentage, namely on bus 10 with a percentage of 96.63 for the system and the 20 kV system on bus 19 with a percentage of 99.03, the largest% PF load was in lump 1 with 98.64 and the smallest% PF was in lump7 with a value of 84.92. The short circuit data value on the 20 kV bus system at Andalas University before the addition of DG with 3-phase disturbances averaged 13.354 A, 1-phase disturbances averaged 3.521 A, 2-phase disturbances averaged 11.719 A and 2 ground phases of 12.842 A. Whereas for the value of power flow after the addition of DG in the form of the wind turbine of 300 kW the overall value of losses is 0.032 MW and 0.042 MvarAR, for the voltage drop with the percentage for voltage drop with the lowest percentage is bus 10 with a percentage of 96.63 for system 0, 4 kV and a 20 kV system on bus 14 with a percentage of 98.1, the largest% PF load is in lump 1 with 98.64 and the smallest% PF is in lump7 with a value of 84.92. The short circuit data value on the 20 kV bus system at Andalas University after the addition of DG with 3 phase disturbances has an average value of 13.354 A, 1 phase disturbance averages 3.523 A, 2 phase disturbances average 11.737 A and 2 phases ground is 12.059 A. For the source in this system, after the addition of DG, there was a change in the% PF of the PLN grid, namely 79.53 and the wind turbine -83%.

INTRODUCTION

Analysis of the flow of electric power (Load Flow) is an analysis used to plan and determine the amount of power in an electric power system. During its development, the industry requires large electric power and uses electrical equipment as a means of production [1]. The benefit of the analysis of electric power flow is to determine the amount of power in the electric power system so that it can be seen whether it still meets predetermined limits, can find out the number of Losses that occurred, and to obtain initial conditions in the new system planning. This analysis includes determining the amount of voltage (V), active power (P), reactive power (Q), and phase angle (δ) of each bus in the system [2]. Furthermore, the main objective of the power system study is to determine the voltage magnitude, voltage angle/vector, active power flow and reactive power in the line, and power losses that appear in an electric power system.

Distributed Generations or often referred to as (DG) are small-scale power plants that are connected to the power grid and as a source of energy [3]. Distributed Generation (DG) is one of the technologies used for the latest generation of electrical systems so that consumers can connect directly to the power grid [4]. The benefits of DG have been evaluated in saving energy costs, energy value, and in terms of capacity as well as improving the voltage profile, reducing line losses and reducing environmental impact [3].

Wind Turbines have been developed in many countries, especially those that have a large wind power potential [5]. The exploitation of wind energy is expected to reduce dependence on power plants that use energy derived from oil or fossil fuels.
Electrical energy is generated by utilizing wind power through a turbine to drive an electric power generator. As wind energy is the most popular renewable energy source, the increased use of wind power in distribution systems can greatly affect the system's voltage stability during transients and sudden load changes [5].

ETAP is a comprehensive analysis software to design and simulate a power circuit system [2]. Analyzes that can be used by ETAP include load flow, short circuit, transient stability, etc. [6]. To analyze a series, complete and accurate series data is needed so that the calculation results can be justified.

This study aims to determine the electrical system at Andalas University with two conditions, namely when before the addition of the Wind Turbine and after the addition of the Wind Turbine of 300 kW at the feeder section Pauh Limo. The methods to be used are Newton-Raphson and ETAP as the software used to carry out the power flow mechanism regarding the performance of active power, reactive power, voltage profile, and power losses of each bus in the system. Then input will be given to optimizing the conditions in the electrical system after the power flow analysis mechanism is carried out.

METHOD

This research will be carried out in several stages as follows:
1. Electric power system modeling using ETAP software
2. Data input process, namely: generator data, transformers, transmission lines, and loads.
3. Calculating the flow of power using the Newton-Raphson method
4. Evaluate the power flow and bus voltage on each bus in the system.

This study uses simulation software to analyze the flow of electric power. The data analysis process was carried out using the power flow calculation method. The data that has been obtained will then be analyzed, so that accurate data analysis results will be obtained and following existing theories.

Analysis of the flow of electric power with simulation software based on a single line diagram and input data from known research results. In running the software, the first step is to draw a line diagram of the electrical system at Andalas University. After the inline diagram is drawn, each component in the inline diagram such as the source (power grid), buses, loads, and others will be given input data according to the characteristics of these components. If the data entered is not correct, the simulation software will not run the command to analyze the power flow (error). Then after the data entered is complete and correct, then the available power flow method will be selected. The Newton-Raphson method will be chosen to be used in running the program. Based on data analysis, the results can be used as an electrical reference at Andalas University. The results are in the form of a report consisting of input data and a report on the results of the power flow calculations performed by the program.

RESULTS AND DISCUSSION

Transformer Capacity and Load Data

In the distribution system at Andalas University, there are 9 transformers and 9 loads connected to the PLN GI Pauh Limo grid. The capacity value of the transformer in each area can be seen in Table 1.

Table 1. Transformer Capacity

| Transformer Name | Capacity (kV) |
|------------------|--------------|
| Public Health    | 315          |
| Engineering      | 630          |
| Animal Sci       | 630          |
| ISIP             | 630          |
| Agriculture      | 1000         |
| MIPA             | 1000         |
| PKM              | 250          |
| Hospital         | 2000         |
| Medical          | 630          |

Furthermore, the load to be used is Lumped Load, with the load capacity value can be seen in Table 2.

Table 2. Load Capacity

| No Bus | Load Name | kW  | kVar   |
|--------|-----------|-----|--------|
| 10     | Public Health | 199 | 123    |
| 8      | Engineering | 118 | 73.223 |
| 14     | Animal Sci  | 156 | 96.401 |
| 12     | ISIP       | 139 | 86.392 |
| 18     | Agriculture | 233 | 144    |
| 20     | MIPA       | 268 | 166    |
| 16     | PKM        | 133 | 82.705 |
| 4      | Hospital   | 300 | 50     |
| 6      | Medical    | 260 | 974.426|
| Total  |            | 1806 | 974.426|

Load Flow Study Data

The load flow power flow simulation is applied to the electric power system at Andalas University. The simulation results of the single line diagram of the electric power system at Andalas University can be seen in Figure 1.
Figure 1. Single Line Diagram of Andalas University Electric Power System

Table 3. Overall Load Flow Data

| Study ID | Untitled |
|----------|----------|
| Study Case ID | LF       |
| Data Revision | Base     |
| Configuration | Normal   |
| Loading Cat | Design   |
| Generation Cat | Design  |
| Diversity Factor | Normal Loading |
| Buses | 20 |
| Branches | 19 |
| Generators | 0 |
| Power Grids | 1 |
| Loads | 9 |
| Load-MW | 1,821 |
| Load-Mvar | 0,97 |
| Generation-MW | 1,821 |
| Generation-Mvar | 0,97 |
| Loss-MW | 0,031 |
| Loss-Mvar | 0,037 |
| Mismatch-MW | 0 |
| Mismatch-Mvar | 0 |

Table 3 shows the power losses that occur in the electric power system at Andalas University as a whole. This system has active power losses of 0.031 MW and reactive power losses of 0.037 Mvar.

Table 4. Bus Drop Data

| ID Bus | Nominal kV | Voltage | MW Loading |
|--------|------------|---------|------------|
| Bus 1  | 20         | 100     | 1,821      |
| Bus 2  | 20         | 99.32   | 1,809      |
| Bus 3  | 20         | 99.3    | 0.299      |
| Bus 4  | 0.4        | 98.99   | 0.299      |
| Bus 5  | 20         | 99.3    | 0.261      |
| Bus 6  | 0.4        | 97.73   | 0.258      |
| Bus 7  | 20         | 99.31   | 0.118      |
| Bus 8  | 0.4        | 98.5    | 0.117      |
| Bus 9  | 20         | 99.22   | 1.13       |
| Bus 10 | 0.4        | 96.45   | 0.196      |
| Bus 11 | 20         | 99.21   | 0.139      |
| Bus 12 | 0.4        | 98.25   | 0.138      |
| Bus 13 | 20         | 99.09   | 0.789      |
| Bus 14 | 0.4        | 98.02   | 0.155      |
The simulation results of % PF are shown in table 6 with the largest% PF in Lump1 while the lowest% PF in Lump7.

Table 7. Source

| ID   | Rating | Rated MVA |
|------|--------|-----------|
| Grid | 2826,27| 0,97      |
| PLN  |        | 59,58     |
|      |        | 88,26     |

**Short Circuit Data on a 20 kV Bus System**

Table 8. Short Circuit Analysis Data on 20 kV Bus

| Bus ID | 3-Phase Fault | Line-to-Ground Fault | Line-to-Line Fault | Line-to-Line-to-Ground |
|--------|---------------|----------------------|-------------------|------------------------|
| Bus 1  | 81,587        | 7,392                | 70,893            | 72,153                 |
| Bus 2  | 9,042         | 3,808                | 8,037             | 8,271                  |
| Bus 3  | 7,623         | 3,467                | 6,757             | 6,996                  |
| Bus 5  | 7,623         | 3,467                | 6,757             | 6,995                  |
| Bus 7  | 7,067         | 3,317                | 6,253             | 6,492                  |
| Bus 9  | 7,390         | 3,410                | 6,581             | 6,815                  |
| Bus 11 | 6,413         | 3,133                | 5,694             | 5,928                  |
| Bus 13 | 5,664         | 2,903                | 5,048             | 5,273                  |
| Bus 15 | 5,071         | 2,700                | 4,510             | 4,730                  |
| Bus 17 | 4,819         | 2,611                | 4,293             | 4,508                  |
| Bus 19 | 4,590         | 2,525                | 4,087             | 4,299                  |

**Load Flow Study Data with the Addition of Wind Turbine 300 kW**

The load flow power flow simulation is applied to the electric power system at Andalas University. The simulation results of the single line diagram of the electric power system at Andalas University with the addition of a Wind Turbine of 300 kW on the bus with the lowest voltage magnitude from the results of the previous load flow data analysis, namely on bus 10 can be seen in Figure 2.

Table 9 shows the power losses that occur in the electric power system at Andalas University as a whole after adding the 300 kW Wind Turbine. This system has active power losses of 0.032 MW and reactive power losses of 0.042 Mvar.
Table 9. Overall load flow data

| Study ID    | Untitled |
|-------------|----------|
| Study Case ID | LF       |
| Data Revision | Base     |
| Configuration | Normal   |
| Loading Cat | Design  |
| Generation Cat | Design   |
| Diversity Factor | Normal Loading |
| Buses       | 20       |
| Branches    | 19       |
| Generators  | 0        |
| Power Grids | 1        |
| Loads       | 9        |
| Load-MW     | 1.824    |
| Load-Mvar   | 0.976    |
| Generation-MW | 1.824   |
| Generation-Mvar | 0.976   |
| Loss-MW     | 0.032    |
| Loss-Mvar   | 0.042    |
| Mismatch-MW | 0        |
| Mismatch-Mvar | 0       |

In table 10, the purple voltage column indicates the bus is in marginal condition (safe critical condition) while the colorless one is still within safe limits. The lowest bus voltage obtained in the load flow simulation after adding the Wind Turbine using ETAP, for a 0.4 kV system the largest voltage drop occurs on bus 10 with a percentage of 96.63. Whereas for a 20 kV system, the largest voltage drop occurred on bus 14 with a percentage of 98.1.

Table 10. Bus Drop Data

| Bus ID | Nominal kV | Voltage | MW Loading |
|--------|------------|---------|------------|
| Bus1   | 20         | 100     | 1.524      |
| Bus2   | 20         | 99,38   | 1.513      |
| Bus3   | 20         | 99,36   | 0.299      |
| Bus4   | 0.4        | 99,05   | 0.299      |
| Bus5   | 20         | 99,36   | 0.261      |
| Bus6   | 0.4        | 97,79   | 0.258      |
| Bus7   | 20         | 99,37   | 0.118      |
| Bus8   | 0.4        | 98,56   | 0.117      |
| Bus9   | 20         | 99,29   | 0.93       |
| Bus10  | 0.4        | 96,63   | 0.3        |
| Bus11  | 20         | 99,28   | 0.139      |
| Bus12  | 0.4        | 98,33   | 0.138      |
| Bus13  | 20         | 99,17   | 0.789      |
| Bus14  | 0.4        | 98,1    | 0.155      |
| Bus15  | 20         | 99,16   | 0.134      |
| Bus16  | 0.4        | 96,83   | 0.131      |
| Bus17  | 20         | 99,11   | 0.5        |
| Bus18  | 0.4        | 98,08   | 0.231      |
| Bus19  | 20         | 99,1    | 0.267      |
| Bus20  | 0.4        | 97,91   | 0.266      |
Table 11. Balancing Load Flow Data

| ID       | Type    | kW Flow | kvar Flow | Amp Flow |
|----------|---------|---------|-----------|----------|
| Agriculture | Transf. 2W | 232     | 147       | 8        |
| Animal Sci | Transf. 2W | 156     | 97,493    | 5,356    |
| Cable1   | Cable   | 1524    | 1162      | 55.32    |
| Cable2   | Cable   | 299     | 52,722    | 8.83     |
| Cable3   | Cable   | 261     | 123       | 8.379    |
| Cable4   | Cable   | 835     | 906       | 35.8     |
| Cable5   | Cable   | 118     | 73,85     | 4,044    |
| Cable6   | Cable   | 791     | 499       | 27.18    |
| Cable7   | Cable   | 139     | 87,27     | 4,773    |
| Cable8   | Cable   | 134     | 85,076    | 4,611    |
| Cable9   | Cable   | 267     | 170       | 9,217    |
| Cable10  | Cable   | 500     | 316       | 17.22    |
| Engineering | Transf. 2W | 118     | 73,841    | 4,044    |
| Hospital | Transf. 2W | 299     | 52,695    | 8.83     |
| ISIP     | Transf. 2W | 139     | 87,262    | 4,773    |
| Medical  | Transf. 2W | 261     | 123       | 8.379    |
| MIPA     | Transf. 2W | 267     | 170       | 9,217    |
| PKM      | Transf. 2W | 134     | 85,069    | 4,611    |
| Public Health | Transf. 2W | 95,703  | -319      | 9,688    |

Table 12. Data Load Flow Report (Load)

| ID        | kW   | Amp  | % PF  |
|-----------|------|------|-------|
| Lump1     | 299  | 441.5| 98.64 |
| Lump2     | 258  | 419  | 90.8  |
| Lump3     | 196  | 344.8| 85.06 |
| Lump4     | 117  | 202.2| 84.97 |
| Lump5     | 138  | 238.6| 84.93 |
| Lump6     | 155  | 267.8| 85.07 |
| Lump7     | 131  | 230.5| 84.92 |
| Lump8     | 231  | 400  | 85.07 |
| Lump9     | 266  | 460.9| 85.01 |

The simulation results of % PF after being added with a wind turbine of 30 kW are shown in table 11 with the largest % PF in Lump1 while the lowest % PF is in Lump7.

Table 13. Source

| ID     | Rating | Rated kW | MW   | Mvar | Amp  | % PF  |
|--------|--------|----------|------|------|------|-------|
| Grid   | 2826.27| 20       | 1.524| 1.162| 55.32| 79.53 |
| PLN    | MVA    |          |      |      |      |       |
| WTG1   | 0.3 MW | 0.4      | 0.3  | -0.186| 527.2| -85   |

**CONCLUSIONS**

This study discusses two scenarios that were analyzed and simulated. In the first condition, the power flow and short circuit will be analyzed in a 20 kV bus system without DG, while the second condition is after the addition of DG in the form of a Wind Turbine of 300 kW. From the analysis of the data obtained, it can be concluded that the overall Losses value for the power flow before the addition of DG is 0.031 MW and 0.037 Mvar. The voltage drop value with the lowest percentage occurs on bus 10 with a percentage of 96.45 for a 0.4 kV system, while for a 20 kV system occurs on bus 19 with a percentage of 99.03. Then for the largest % PF load in lump 1 with a value of 98.64% and the smallest % PF occurred in lump 7 with a value of 84.92%. Furthermore, it can be obtained the short circuit data value on the 20 kV bus system at Andalas University before the addition of DG with 3 phase disturbances with the acquisition of an average value of 13.354 A, 1 phase disturbance averaging 3.521 A, 2 phase disturbance averaging 11.719 A, and 2 phases to the ground amounted to 12,842 A. As for the value of the power flow after the addition of DG in the form of a Wind Turbine of 300 K. Losses values that occur as a whole are 0.032 MW and 0.042 Mvar, for the voltage drop with the lowest percentage, namely on bus 10 with a value of 96.63% on a 0.4 kV system, and for a 20 kV system that occurs on bus 14 a percentage of 98 is obtained. , 1. For the largest % PF load was found in lump 1 with a value of 98.64 and the smallest % PF occurred in lump 7 with a value of 84.92. Then for the short circuit data value that occurs in the 20 kV bus system at Andalas University after the addition of DG with 3 phase disturbances, the average value is 13.354 A, 1 phase disturbance averages 3.523 A 2 phase disturbances average 11.737 A, and 2 ground phase is 12,059 A. Furthermore, the source value in this system is obtained, after the addition of DG, there is a change in the % PF of the PLN grid, namely 79.53 and the wind turbine -83%.

**ACKNOWLEDGMENT**

**REFERENCES**

[1] A. Zeggai and F. Benhamida, “Power flow and Short circuit of 220 kV Substation using ETAP,” Proc. Alger. Large Electr. Netw. Conf. CAGRE 2019, pp. 158–163, 2019.

[2] N. Raphson, “Analisa Aliran Daya Sistem Tenaga Listrik Pada Bagian Penyulang 05Ee0101a Di Area Utilities Ii Pt. Pertamina (Persero) Refinery Unit Ivcilacap Menggunakan Metode,” vol. 1, no. 1, pp. 1–6.
2019.

[3] A. K. Singh and S. K. Parida, “Novel sensitivity factors for DG placement based on loss reduction and voltage improvement,” *Int. J. Electr. Power Energy Syst.*, vol. 74, pp. 453–456, 2016.

[4] A. M. Borbely and J. F. Kreider, “Distributed generation: The power paradigm for the new millennium,” *Distrib. Gener. Power Paradigm. New Millen..*, no. January 2001, pp. 1–400, 2001.

[5] V. Rai, S. Sehrawat, and K. Pandey, “Transient Stability Analysis of Wind Turbine Based Micro Grid using ETAP Software,” vol. 3, no. 4, pp. 1515–1518, 2014.

[6] S. Klungtong and C. Chompoo-Inwai, “Power flow monitoring and analysis for 24.6 MW at 6.9 kV bus Diesel Power Plant(DPP) using ETAP,” *2016 Int. Conf. Smart Grid Clean Energy Technol. ICSGCE 2016*, pp. 307–312, 2017.

**AUTHOR(S) BIOGRAPHY**

**Fadhel Putra Winarta**
Fadhel Putra Winarta was born in Curup, January 24, 1993. Completed his undergraduate education at the Faculty of Electrical Engineering from 2011 to 2016. He obtained his S.Pd degree from Padang State University, Indonesia, in 2016, and is currently carrying out a master's degree at Andalas University, Indonesia.

**Yoli Andi Rozzi**
Yoli Andi Rozzi was born in Bengkulu, January 15, 1987. Completed his undergraduate education at the Faculty of Electrical Engineering from 2005 to 2010. He obtained his ST degree from Bengkulu State University, Indonesia, in 2010, and is currently carrying out a master's degree at Andalas University, Indonesia.