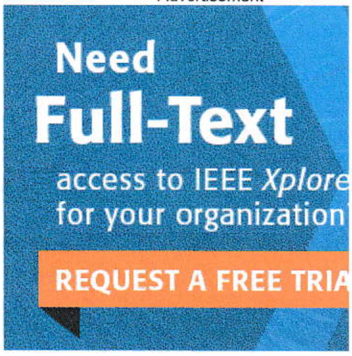

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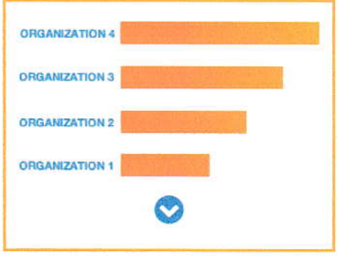

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Abstract

This article presents the load flow study of Unand feeder with addition of photovoltaic (PV) system. Power flow analysis is needed in the feasibility study of the PV system installation. In this study 300 kW solar power capacity was selected in the simulation of power flow analysis to evaluate the best system states. The results of the study using four cases show that the best voltage profile is obtained in conditions where the PV system is placed on the bus which have lowest voltage and on the load bus which farthest from the source. All load bus voltages have increase above 0.9 p.u in this case and and the lowest voltage within SPLN standard. The lowest level of losses of 55.429 kW is obtained in case three where PV is placed only on buses with the lowest voltage value. Power losses are obtained far below 10% as the losses permitted according to the PLN standard. Therefore, The integration of PV system into an Unand distribution network can improve the voltage profile and reduce total system losses. © 2019 IEEE.

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***Abstract*— This article presents the load flow study of Unand feeder with addition of photovoltaic (PV) system. Power flow analysis is needed in the feasibility study of the PV system installation. In this study 300 kW solar power capacity was selected in the simulation of power flow analysis to evaluate the best system states. The results of the study using four cases show that the best voltage profile is obtained in conditions where the PV system is placed on the bus which have lowest voltage and on the load bus which farthest from the source. All load bus voltages have increase above 0.9 p.u in this case and and the lowest voltage within SPLN standard. The lowest level of losses of 55.429 kW is obtained in case three where PV is placed only on buses with the lowest voltage value. Power losses are obtained far below 10% as the losses permitted according to the PLN standard. Therefore, The integration of PV system into an Unand distribution network can improve the voltage profile and reduce total system losses.**

Keywords—Load flow analysis, Feeder Unand, PV system

I. INTRODUCTION

Universitas Andalas (Unand) is an educational institution that has many buildings inside the campus and the entire building gets electrical energy from Pauh Limo Substation through Unand feeder. The need for a large amount of electrical energy is unavoidable in order to get lighting and activate facilities that require electricity in all buildings in the university. This has caused the institution have to pay electricity from public utility with a total amount of 700 million IDR per month.

The own power plants using renewable energy is one solution that has been chosen to meet university electricity needs, so that Unand can become an independent campus. This solution refers to environmentally friendly energy and and has a potential for use. Environmentally friendly energy is a term used to describe everything that is considered a source of energy and energy that is friendly to the environment [1]. In particular, this term refers to renewable energy that does not pollute the environment.

Padang is one of the cities in Indonesia that gets sunlight throughout the year with high radiation, so the potential of solar energy can produce 4.8 kWh/ m^2/day of electrical energy [2]. In addition, other energy that has the potential to be renewable without damaging the environment i.e. water energy that can be managed into hydro power plant. Both of these can be used as reliable renewable energy in tropical area [3].

The explanation above is the reason for the need for research related to the study of power flow from the Unand distribution system. Where the study of power flow is carried out to analyze how the state of the flow of power from the system, both in terms of power losses, voltage profiles in the form of voltage drop in the electrical system when it is added to renewable energy-based power plants.

II. LOAD FLOW ANALYSIS OF UNAND NETWORK

A. Unand Feeder

Unand Feeder is a feeder that delivers electricity from the Lima Pauh substation to the Universitas Andalas Area. The need of electrical energy in Universitas Andalas is around 2 MW, almost all are supplied by PLN. Results of design studies [2] shows that the peak load of Engineering Faculty can be shaved with the PV systems integrated in the network. The results of an economic feasibility study have also been carried out on the reference [4] show that PV system development on a Unand network is profitable. While the electricity study will be presented in this paper.

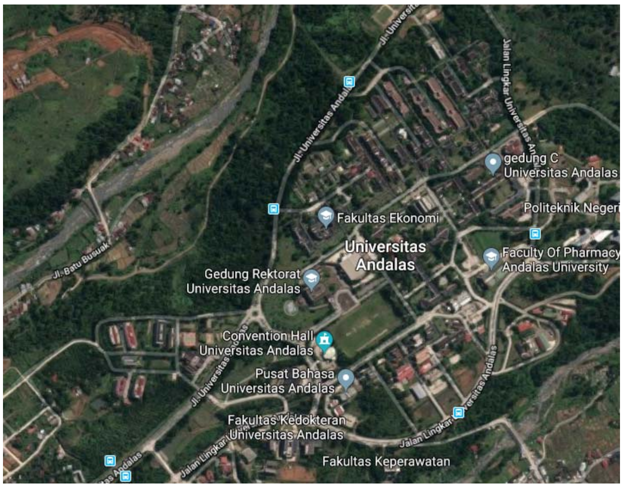

Fig 1. Location of Unand Electrical System.

The location of the building gets the electricity supply from the Unand feeder as shown in the map screenshot Figure 1. To support the benefits of scattered plants in electric power systems, good planning is needed including determining the placement location and the amount of dispersed power used. In this paper we will explain the influence of large, number, and location of solar power plants used on voltage performance and power losses. The power system used is the Unand distribution system 20 buses. The calculation of power flow using is the Newton Raphson method which was built with Microsoft Visual Studio software based on C ++ programming.

B. Distribution Load Flow with PV System Integration

Power flow calculations for transmission systems differ from power flow for distribution systems. distribution system electric power flow needs to consider the condition of load imbalance, the presence of lateral one and two phases. Various methods have been used to obtain distribution system power flow calculation algorithms [5] and still continue so now. Some methods of solving distribution power flow that have been widely used are using the forward and backward methods and symmetrical component methods. Public domain software such as OpenDSS [6] and RDAP use the forward and backward methods in solving distribution power flows. The symmetrical component methods in [7] is used in this study with additional PV model [8].

The PV is model as PQ bus which active power obtain from multiplication of PV voltage and current. It is necessary to connect solar cells in series in order to scale up the voltage produced by a PV generator. A module may have a power output from a few watts to hundreds of watts. And the power rating of an array can vary from hundreds of watts to megawatts. The cells connected in parallel increase the current and cells connected in series provide greater output voltages. If the array is composed of Np parallel connections of photovoltaic cells, saturation currents may be expressed as: Ipv =Ipv,cell * Np, and I0 =I0,cell * Np.

The line data configuration needs to be included as part of the single phase line data. The symmetrical components method uses line configuration data based on phase matrix impedance format as follows:

Raa	Rab	Rac
Rba	Rbb	Rbc
Rca	Rcb	Rcc

Xaa	Xab	Xac
Xba	Xbb	Xbc
Xca	Xcb	Xcc

Yca	Ycb	Ycc
Yca	Ycb	Ycc
Yca	Ycb	Ycc

If the line configuration data is given in sequence impedance matrix, the data need to be converted to phase matrix impedance using the following equation:

$$\boldsymbol{Z}^{012} = \boldsymbol{A}^{-1}\boldsymbol{Z}^{abc}\boldsymbol{A} \quad (1)$$

Or

$$\boldsymbol{Z}^{abc} = \boldsymbol{A}\,\boldsymbol{Z}^{012}\ \ \boldsymbol{A}^{-1} \quad (2)$$

The balanced load data have to be divided by three in three phase load data format. Furthermore, the node voltage magnitude initial value was set at 1.0 pu for all phase and the phase angle shifts to 120° each others in three phase bus data format.

III. METODOLOGY

In this section, the data needed for power flow analysis will be described in the presence of a solar power plant connection at the low voltage network of Universitas Andalas. The main data needed consists of bus data and line data. Data bus that is in the feeder unand pathway is like table 1. Table 1 is loading data at Universitas Andalas. Loading data is taken at the time of Universitas Andalas electrical peak load in 11.00 -15.00.

TABLE 1 UNAND NETWORK LOAD DATA

Bus ID	Bus Name	kW	kVar
8	Engineering	118	73.223
10	Public Health	199	123
14	Animal Science	156	96.401
12	ISIP	139	86.392
18	Agriculture Tech	233	144
20	MIPA	268	166
16	PKM	133	82.705
4	Hospital	300	50
6	Medicine	260	120
Total		1806	974.426

Furthermore, the line data for electrical power delivery uses 70 mm^2 AAAC conductor for a 20 kV network and a low-voltage conductor cable of 400 V. Therefore, the 20 kV line impedance is: 0.4608 + j 0.3572 Ohm/km. So the line configuration data for the Unand system is:

```
0.614  0.154  0.154
0.154  0.614  0.154
0.154  0.154  0.614

0.476  0.119  0.119
0.119  0.476  0.119
0.119  0.119  0.476

0      0      0
0      0      0
0      0      0
```

The Unand electrical system consists of nine 20kV/400V transformers such as shown in Table 2.

TABLE 2 DATA DAN LOCATION OF DISTRIBUTION TRANFORMERS

No	Trafo Name	Location	Capacity (kVA)
1	Public Health	Public Health Faculty	315
2	Engineering	Engineering Faculty	630
3	Animal Sci	Across A Building	630
4	ISIP	ISIP Faculty	630
5	Agricalture	Agriculture Tech Faculty	1000
6	MIPA	Biology Building	1000
7	PKM	Across PKM	250
8	Hospital	Behind Hospital	2000
9	Medical	Medical Faculty	630

Single line diagram (SLD) of Unand distribution system as show in Figure 2 below:

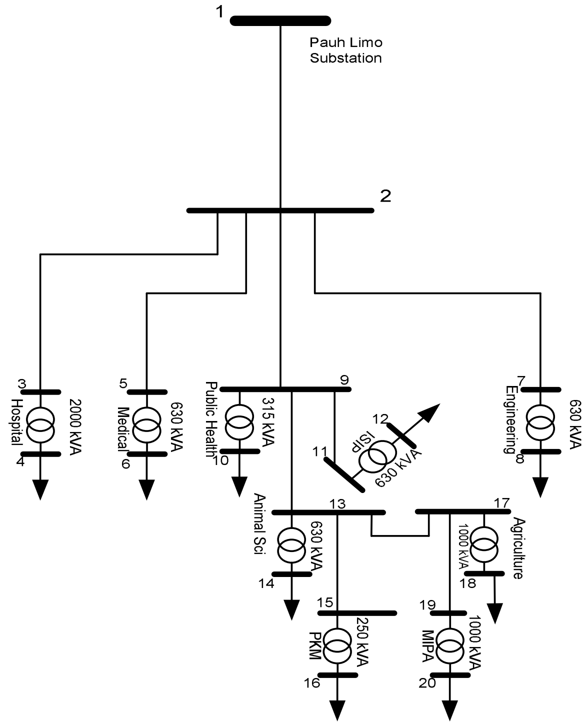

Fig 2. SLD of 20 bus Unand Feeder.

IV. Result and Discussion

Power Flow simulation is a basic analysis used in electrical study of power system installation or expansion. The performance of electrical system is determined by the voltage profile of the main buses and system losses. The value of the voltage profile can be obtained from the calculation of load flow. Based on the standard limits SPLN No. 1 of 1995 [9], the variation in voltage permitted for the distribution system is +5% and -10%. According to SPLN No. 72 of 1987 [10], the allowed distribution network's power loss should not be higher than 10%.

The simulation conducted using four cases:

Case 1: Normal condition

Case 2: With 300 kW separate PV

Case 3: With 300 kW PV in three lowest voltage

Case 4: With 300 kW PV in lowest voltage and longest

The first case is simulated using normal condition of Unand System without PV integration. The Voltage profile for every phase as shown in Table 3 below:

Table 3. Line Voltage Profile of 20 Bus Unand Feeder

Bus ID	Vab		Vbc		Vca	
1	1.00	0.00	1.00	-120.00	1.00	120.00
2	0.9940	-0.05	0.9940	-120.05	0.9940	119.95
3	0.9938	-0.05	0.9938	-120.05	0.9938	119.95
4	0.9771	-1.35	0.9771	-121.35	0.9771	118.65
5	0.9938	-0.05	0.9938	-120.05	0.9938	119.95
6	0.9246	-3.36	0.9246	-123.36	0.9246	116.64
7	0.9939	-0.05	0.9939	-120.05	0.9939	119.95
8	0.9599	-1.33	0.9599	-121.33	0.9599	118.67
9	0.9921	-0.05	0.9921	-120.05	0.9921	119.95
10	0.8579	-4.79	0.8579	-124.79	0.8579	115.21
11	0.9920	-0.05	0.9920	-120.05	0.9920	119.95
12	0.9523	-1.53	0.9523	-121.53	0.9523	118.47
13	0.9915	-0.06	0.9915	-120.06	0.9915	119.94
14	0.9459	-1.73	0.9459	-121.73	0.9459	118.27
15	0.9915	-0.06	0.9915	-120.06	0.9915	119.94
16	0.8802	-3.84	0.8802	-123.84	0.8802	116.16
17	0.9914	-0.06	0.9914	-120.06	0.9914	119.94
18	0.9480	-1.52	0.9480	-121.52	0.9480	118.48
19	0.9913	-0.06	0.9913	-120.06	0.9913	119.94
20	0.9397	-1.90	0.9397	-121.90	0.9397	118.10

The system summary result are:

```
Total Load  Phase A (KVA)  :  602.00     313.00
Total Load  Phase B (KVA)  :  602.00     313.00
Total Load  Phase C (KVA)  :  602.00     313.00
Total Load                 : 1806.00     939.00
Total Generation          : 1888.76    1093.67
System Losses             :    82.76    154.67
```

The lowest voltage bus is bus 10, then bus 16 and bus 6 which this three bus determined as PV system integration bus for case 3 in the simulation. The second case uses a spread PV generator on all load buses based on the weight of each load. This case is very possible because each faculty has land on the roof of the building for laying out solar panels and has a budget for invertase PV systems. For example on a bus the large technique of PV power that is integrated is:

Engineering PV = (Engineering Load/Total load)* 300 kW

= (118/1806)*300 kW

= 19.6 kW

Therefore the 19.6 kW PV system injected to bus 8. The same calculation used for others bus simulated in case 2. The case 4 conducted using two lowest bus i.e: bus 10 and bus 16 and one longest bus is bus 20.

The simulation results for four cases above as shown in Figure 3 below:

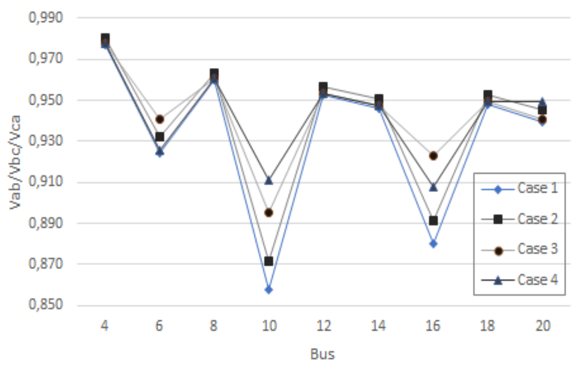

Fig 3. Voltage profile of Load Bus.

While the voltage values for each bus are shown in the following Figure 4.

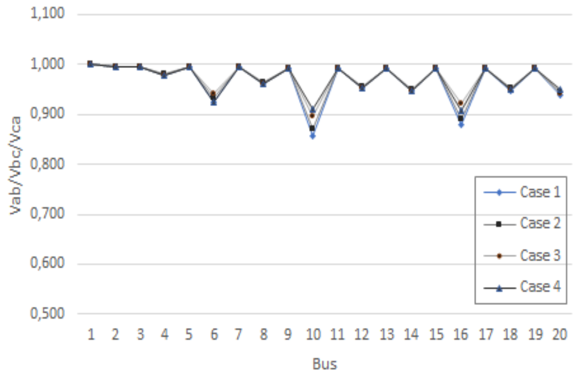

Fig 4 Voltage profile of 20 bus Feeder Unand.

The results of the study in four cases show that the best voltage profile is obtained in conditions where the PV generator is placed on the bus with the lowest voltage and on the load bus which is the farthest from the source i.e. case four. The lowest level of losses of 55 kW is obtained in case three where PV is placed on three buses with have lowest voltage value. Thus the study of PV placement and PV capacity needs to be done before PV integration is carried out on an electricity network to get the best system state.

TABLE 4. SYSTEM LOSSES AND LOWEST VOLTAGE

Cases	Losses (kW)	Lowest Voltage	
		Vphase (pu)	BusID
1	82.770	0.858	10
2	62.631	0.872	10
3	55.429	0.895	10
4	57.525	0.908	16

The simulation results also show that the integration of a PV system has improved the system voltage where in the case 4 all bus loads are greater than 0.9 p.u. The addition of PV system has also reduced power losses as shown in table 4 even though there are large investments in PV development. To get more accurate results it is necessary to consider unbalanced system data such as the amount of load per phase and the presence of one or two phase low voltage lateral that has not been consider in this study.

V. CONCLUSION

The study of power flow in the Unand electrical system with the addition of PV plants has been carried out. Power flow analysis is needed in the feasibility study of the construction of a 300 kW PV system on the Unand network to see the best bus voltage profile and the lowest losses. The results of the study using four cases show that the best voltage profile is obtained in conditions where the PV power plant is placed on the bus with the lowest voltage and on the load bus which is the farthest from the source or case four. All load bus voltages increase above 0.9 p.u in this case. The lowest losses is 55.429 kW is obtained in case three where PV is placed only on buses with the lowest voltage value. Thus the study of PV placement and PV capacity needs to be done before PV integration is carried out on an electrical network to obtain better of system state.

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