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Load Flow Analysis After the Entry of Renewable Power Plants in the Sulselrabar System

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Abstract -- *Power flow analysis in an electric power system is an analysis that reveals the performance of an electric power system and the flow of power (active and reactive) for certain conditions when the system is working. The analysis was carried out using the ETAP 16.00 software, the method used was the newton rapshon by taking a case study of normal conditions. From the results of the study, it can be seen that the power flow that occurs in each channel of the 150 kV system in the South Sulawesi system. The amount of active power (MW) that occurs during normal conditions based on the simulation is 1730.87 MW, where the active power is the largest, which is 171 MW from BUS15_TLASA to BUS13_SGMNSA. For the voltage data, there is a slight comparison of the voltage during the simulation compared to the PLN data.*

Keywords: *Power flow, active power, voltage, simulation, software ETAP 16.*

I. Introduction

In the 1970s Renewable energy was first recognized as a way to offset energy developments with fossil fuels and nuclear. Indonesia's potential for renewable energy for electricity has reached 443 GW, including wind, geothermal, water and micro-mini hydro, solar bioenergy, and ocean waves. One of the renewable energies that the government is now ogling about is wind power or more commonly called wind power. Several eastern regions in Indonesia have the potential to generate electricity due to their wind speed. The wind speeds that have the potential to generate electricity are Oelbuluk, NTT the average speed is 6.1 m/s, Sidrap, South Sulawesi the average speed is 6.43 m/s and Jeneponto, South Sulawesi the average is 7.96 m/s.

South Sulawesi itself, which is an industrial area in Eastern Indonesia, often experiences blackouts due to a power deficit. The blackout that occurs certainly affects the production process of industrial companies. Industries that require large electricity consumption, such as the food processing and plastic industries, sometimes have to experience obstacles due to long hours of blackouts. In addition, the number of electricity consumers continues to grow. From the results of the estimated number of customers, it is known that the amount of power needed or connected power in the following years, the amount of connected power in the household sector in 2015 is 1,296467,311 VA and it is estimated that in 2025 it will increase to 2,597,148,624VA. Therefore, the government is encouraged to build wind power plant installations in the South Sulawesi area which will later affect the distribution of electricity in the Sulserabar system.

After the presence of the Wind Power Plant (WPP), it can increase the stock of available power capacity in the South, Southeast, and West Sulawesi (Sulseltrabar) regions, thus increasing the number of burdens that must be borne. For this reason, it is necessary to conduct a power flow analysis to determine the overall condition of the electric power system in the current Sulselrabar system. Power flow analysis in an electric power system is an analysis that reveals the performance of an electric power system and the flow of power (real and reactive) for certain conditions when the system is working [1]. The main result of the power flow is the magnitude and phase angle of the voltage on each line (bus), the real power and reactive power present in each line

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[2].

In this study, an analysis of the system under normal conditions was carried out. Under normal conditions it will be known how much active power and reactive power occur and the Performance Index (IP) obtained from the calculation. The calculation of the power flow for the electric power system in the Sulselrabar System section after the entry of renewable plants if done manually will be very complicated and requires a lot of time, therefore in this study computer software was used to simplify and speed up the process of calculating the power flow. ETAP (Electrical Transient Analysis Program) Power Station is a software that can be used for calculating the flow of power in an electric power system. By using the ETAP Power Station 16.00 software, you will be able to analyze a very wide electric power system and many conditions [3].

Previously, there have been studies discussing power flow analysis, both the Gauss-Seidel method to the Newton Raphson method, as well as under normal and contingency conditions, among others [4] which discusses power flow analysis in the Sulselrabar system when renewable power has not yet entered, [5] discusses the analysis of the power flow of the electric power system in the texturizing section at PT Asia Pacific Fibers Tbk Kendal, [6] discusses the voltage analysis of each bus in the Gorontalo electric power system through power flow simulation, [7] discusses the study of power flow in the South Sulawesi electrical system, [8] discusses the contingency analysis of the Riau electric power system using the Newton Raphson power flow method, [9] discusses the load flow analysis on the East Kalimantan interconnection system. From this research, the development of power flow analysis needs to be carried out such as an up to date analysis by testing several case studies. The current Sulselrabar system continues to develop [10], especially after the inclusion of several renewable plants. The characteristics of the power flow need to be reviewed to see the characteristics of the system. In this study, a power flow analysis approach will be proposed for the entry of renewable power plants in the Sulselrabar system.

II. Research Method

The research was conducted by simulating the electric power system of the Sulserabar system of PT. PLN AP2B Sulselrabar Region due to the entry of renewable power plants using the ETAP 16.00 application. The modeling of the system to be carried out, adjusts the parameters needed and has been accepted by the researcher when collecting data. The simulated system is designed in such a way as to achieve similarity to the real 150 kV Sulserabar network system.

The initial step of the research is to determine the parameters or technical data supporting the desired value. This data will be obtained when researchers carry out data collection at PT. PLN AP2B for Sulselrabar Region, Makassar. After the data and method analysis have been carried out, the next step is to design a single line diagram of a 150 kV network for the Sulselrabar system on the ETAP 16.00 application which is useful for facilitating the next stage.

Network modeling is the next step by entering data in each installed component with data that is already available, the modeling stage plays an important role for this research because the network is made according to the real conditions of the Sulserabar system. After the design and modeling is complete, the next step is to run load flow on the ETAP 16.00 application to ensure the modeling runs well. After successfully simulating, the results of the power flow are obtained, then identify the parameters of active power and bus voltage under normal conditions.

The next step, the researchers began to simulate contingency by removing one channel installed in the selected system, and conducting a power flow analysis during contingency. Then analyze the power flow generated during contingency by identifying the parameters needed for the calculation of the Performance Index. The active power and bus voltage will be recorded at the time of line disconnection.

III. Results and Discussions

The currently active Sulselrabar electricity system consists of 21 generating units, namely 6 PLTA, 8 PLTU, 1 PLTG, 1 PLTGU, 3 PLTMH and 2 WPP. operating at 150 kV. The Sulselrabar Electricity System is dominated by Steam Power Plants (PLTU) such as PLTU Sengkang, PLTU Barru, PLTU Jeneponto and PLTU Mamuju, each of which has a different generating capacity. The Sulselrabar bus system numbering is shown in Table 1.

III. 1. Power Flow Simulation Results

Analysis using ETAP 16.00 Software was carried out on the Sulselrabar System with normal loading and generation conditions using operating data on

Tuesday, May 21 2019, at 15.00 WITA. As a comparison data, the results of the analysis will be compared with the results of the power flow analysis study from the research [3] as data before the entry of WPP, the results obtained are as follows

The simulation with the ETAP 16.00 software uses the Newton Raphson Method which is completed in the 2nd iteration, resulting in data on Active Power, Reactive Power, Current and Power Factor Efficiency flowing in each channel based on the simulation results of power flow when the Sulselrabar system under normal conditions is given in Table 2.

On the results of the power flow from the 43 Bus interconnection system 150 kV Sulselrabar System, it can produce the following data conclusions,

a) The total active power contained in the channel under normal conditions is 1730.87 MW, where the active power is the largest, which is 171 MW from BUS15_TLASA to BUS13_SGMNSA.
b) The largest reactive power is 25.68 Mvar from BUS8_PANKEP to BUS8_BOSOWA.
c) The highest power factor efficiency reached 100% occurred from BUS21_SENGKANG to BUS16_SIDRAP, while the lowest efficiency occurred on the WPP Sidrap Bus channel to BUS16_SIDRAP which was 19.72%.

TABLE I
BUS NUMBER

ID BUS	kV	ID BUS	kV
BU28_MAROS	150	BUS21_SENGKANG	150
BUS1_BAKARU	150	BUS22_BONE	150
BUS2_POLMAS	150	BUS23_SINJAI	150
BUS3_MAJENE	150	BUS24_BLKMBA	150
BUS4_PINRANG	150	BUS25_JNPNTO	150
BUS5_PARE	150	BUS26_PLTUMmuju	150
BUS6_SUPPA	150	BUS27_PUNAGAYA	150
BUS7_BARRU	150	BUS28_ENRKG	150
BUS8_PNGKEP	150	BUS29_WPP Sidrap	150
BUS9_BOSOWA	150	BUSBNTAENG	150
BUS10_TELLO	150	BusBOLANGI	150
BUS11_TLAMA	150	BUS26_PANGKEP70	70
BUS12_PKANG	150	BUS27_TNASA70	70
BUS13_SGMNS	150	BUS29_MNDAI	70
BUS14_TBNGA	150	BUS30_DAYA	70
BUS15_TLASA	150	Bus31_TELLO70	70
BUS16_SIDRAP	150	BUS32_BRLOE	70
BUS17_MKALE	150	Bus33_TLAMA70	70
BUS18_PALOPO	150	BUS34_BNTLA	70
BUS19_MMUJU	150	Bus35_TELLO30A	30
BUS20_SPPENG	150		

TABLE II
RESULTS OF POWER FLOW SIMULATION OF EACH BUS IN INTERCONNECTION SYSTEM 150 KV SULSELRABAR

ID	Lines		Load Flow	
	From	To	P (MW)	Q (Mvar)
1	BTLA 150	BD_TELLO2	36,04	11,29
		BusBOLANGI	8,64	-1,33
2	BU28	BUS13	0,83	-2,63
		BD_MROS	16,94	6,19
3	BUS1	BUS2	56,59	12,01
		BUS1	57,48	-9,52
4	BUS2	BD_PLMAS	4,75	1,68
5	BUS3	BUS2	4,07	2,86
6	BUS4	BUS1	71,08	-18,71
		BUS8	7,40	-2,68
7	BUS5	BUS4	95,73	-7,35
		BUS2	55,24	-12,57
8	BUS6	BUS5	19,98	5,83
9	BUS7	BUS8	27,27	-4,16
		BUS5	13,31	-1,34
10	BUS8	BUS9	13,97	25,68
11	BUS9	BUS8	13,88	-25,79
12	BUS10	BUS9	31,34	-8,58
		BUS8	16,06	-18,28
		BUS12	32,66	9,69
		BUS11	42,62	8,00
13	BUS11	BONTOALA150	36,10	q11,19
		Bus33	2,99	0,10
14	BUS12	BUS10	32,61	-9,81
		BusBOLANGI	7,82	-0,50
15	BUS13	BUS14	24,90	4,42
		BUS10	124,29	8,68
16	BUS14	BUS13	24,88	-4,51
		BUS_PNAGAYA	131,80	-24,49
17	BUS15	BUS13	171,25	23,11
		BUS5	61,80	-13,31
18	BUS16	ENRKG	13,16	-0,02
		BUS17	20,21	3,38
		BUS18_PALOPO	15,06	4,60
19	BUS17	ENRKG	7,07	-4,32
20	BUS19	BUS3	9,33	3,31
21	BUS20	BUS16	26,39	4,08
22	BUS21	BUS16	59,13	-0,32
		BUS20	17,31	-12,77
23	BUS22	BUS20	5,69	12,93
24	BUS23	BUS22_BONE	9,36	-2,95
25	BUS24	BUS22_BONE	14,76	-1,36
		BUS23_SINJAI	21,68	1,72
26	BUS25	BUSBNTAENG	16,12	-9,82
		BUS24_BLKBA	26,11	-20,06
		BD_JNPNTO	12,80	4,70
27	BusPLTUMa muju	BUS19_MAMUJ U	20,31	5,95
28	BUS_PUNAG AYA	BUS25_JNPNTO	27,55	-12,87
		BUS15_TLASA	132,64	29,62
29	ENRKG	BUS17_MKALE	7,09	1,97
30	WPP Sidrap	BU28_MAROS	13,21	0,29
		BUS16_SIDRAP	2,25	-11,20

If the analysis is compared as data after the entry of the WPP with the analysis before the entry of the WPP using data from, then what happens is that the Active Power (P) that occurs in each channel has increased. The channel that experienced the highest increase in power was BUS7_BARRU to BUS8_PANKEP with an increase in active power (P) of 66.62 MW. This can be seen in Table 3.

TABLE III
RESULTS OF POWER FLOW SIMULATION OF THE 150 KV INTERCONNECTION SYSTEM IN SULSELRABAR BEFORE AND AFTER WIND POWER INSTALLING

LINES		LOAD FLOW BEFORE		LOAD FLOW AFTER	
From	To	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)
BU28	BUS13	37,36	1,53	42,83	-2,63
BUS1	BUS2	11,8	-0,11	56,59	12,01
BUS3	BUS19	3,93	0,52	4,07	2,86
BUS4	BUS5	6,99	0,95	71,08	-18,71
BUS5	BUS8	42,76	-0,5	7,40	-2,68
BUS6	BUS5	28,46	4,3	19,98	5,83
BUS7	BUS8	62,46	-2,79	27,27	-4,16
BUS8	BUS9	27,59	4,17	13,97	25,68
BUS9	BUS10	6,91	-7,26	13,88	-25,79
BUS10	BUS12	14,93	-4,92	32,66	9,69
	BUS11	9,2	-1,72	42,62	8,00
BUS11	Bus33	10,44	-5,14	2,99	0,10
BUS13	BUS14	13,53	6,96	24,90	4,42
	BUS10	40,07	7,35	124,29	8,68
BUS15	BUS13	12,4	9,32	171,25	23,11
BUS16	BUS5	5,6	-4,39	61,80	-13,31
	BUS17	8,41	1,27	20,21	3,38
BUS17	BUS18	8,23	3,11	15,06	4,60
BUS20	BUS16	10,53	3,87	26,39	4,08
BUS21	BUS16	49,8	-1,8	59,13	-0,32
	BUS20	33,65	-10,41	17,31	-12,77

The number of losses obtained is 12,123 kW, where the largest losses are in the BAKARU-PINRANG line, namely 1,662 kW, in addition to transmission losses there are also losses in the transformer. For more details, see the literature. The Table 4 shows the losses that occur in the transmission line.

III. 2. Active Power and Reactive Power on Bus Loading

From the simulation results using ETAP with Newton Raphson method, it can be seen the difference in active power, reactive power and PF that occurs in each channel.

Bus Loading which has the largest active power is found in the BOSOWA Loading bus which is 231.5 MW with 45 Mvar reactive power and 98.16% Power Factor, while the complete results can be seen in Table 5.

Next, compare the results of the power flow analysis simulation on the bus loading before entering and after entering the WPP by taking comparative data from the study [3].

The total active power (P) that occurs at the bus loading before the entry of WPP in the 150 kV interconnection system is 455.61 MW, while the total active power (P) after the entry of the WPP is 610.31 MW, more details can be seen in Table 6.

TABLE IV
LOSSES IN TRANSMISSION LINE IN INTERCONNECTION SYSTEM 150 KV SULSELRABAR

NO	LINES	LOSSES kW	LOSSES kvar
1	TELLOLAMA-BONTOALA4	64,0768	-103,1
2	MAROS-BOLANGI	20,4674	-3423,6
3	MAROS-SUNGGUMINASA1	0,38356	-3577,1
4	SIDRAP-MAROS1	10,8645	-820,25
5	BAKARU-PINRANG	1662,49	5059,31
6	BAKARU-POLMAS	881,497	2489,23
7	POLMAS-MAJENE1	6,93801	-659,33
8	POLMAS-PARE	1152,06	2317,68
9	MAJENE-MAMUJU1	25,6558	-598,79
10	PINRANG-PARE	1261,56	3842,72
11	PARE-BARRU	40,37	-998,27
12	PARE-PANGKEP	26,6489	-2183,2
13	PARE-SIDRAP1	393,773	1186,23
14	SUPPA-PARE1	16,8107	-168,01
15	BARRU-PANGKEP	179,684	-498,15
16	PANGKEP-BOSOWA	93,3184	-114,66
17	PANGKEP-TELLO	137,747	-631,84
18	BOSOWA-TELLO	178,653	-25,277
19	TELLO-PANAKUKKANG1	55,5004	-120,06
20	TELLO-SUNGGUMINASA1	300,038	1831,26
21	TELLO-TELLOLAMA1	69,0172	25,4746
22	MAROS-SGMNSA	17,1501	-3451,2
23	SUNGGUMINASA-TNJUNGBUNGA1	22,7612	-86,716
24	TALLASA-SUNGGUMINASA1	1413,88	9011,84
25	TALLASA-PUNAGAYA	849,596	5122,88
26	SIDRAO-SENGKANG1	358,443	1237,18
27	SIDRAP-ENRKG	53,9369	-2174,6
28	SIDRAP-MAKALE1	132,788	-1679,9
29	SIDRAP-SENGKANG2	358,443	1237,18
30	SIDRAP-SOPPENG1	194,753	-225,06
31	MAKALE-PALOPO1	49,5934	-263,25
32	SIDRAP-ENRKG2	18,931	-2349,8
33	Linemauju	113,131	-295,92
34	SOPPENG-BONE1	45,6797	-783,58
35	SOPPENG-SENGKANG1	46,2633	-651,54
36	BONE-BULUKUMBA	144,859	-1651,9
37	BONE-SINJAI	35,5433	-1069,1
38	SINJAI-BULUKUMBA	136,89	-473,88
39	BNTAENG-BULUKUMBA4	46,9618	-557,06
40	JENEPONTO-BULUKUMBA1	245,555	159,476
41	BNTAENG-JNPNTO	80,1965	-430,04
42	JENEPONTO-PNGYA	29,278	-275,28
43	PANGKEP70-MANDAI1	44,7319	-17,921
44	PANGKEP70-TONASA701	21,0497	-11,209
45	MANDAI-DAYA	16,4574	-20,003
46	MANDAI-TELLO70	56,8898	54,104
47	DAYA-TELLO70	144,823	215,283
48	TELLO70-BORONGLOE	22,1431	-10,251
49	TELLOLAMA-BONTOALA1	1,83994	-44,748
50	TELLO30-BARAWAJA	842,88	1192,8

TABLE V
RESULTS OF POWER FLOW BUS LOADING INTERCONNECTION SYSTEM 150KV SULSELRABAR

NO	ID BUS	P (MW)	Q (Mvar)
1	BD1_BNTLA	5,97	0,00
2	BD1_BONE	6,27	1,97
3	BD1_DAYA	11,63	0,00
4	BD1_MNDAI	7,98	2,56
5	BD1_PLPO	15,47	0,30
6	BD1_PNGAYA	0,74	0,11
7	BD1_PNKNG	16,74	3,14
8	BD1_PNRNG	24,38	6,34
9	BD1_TLAMA	12,22	4,02
10	BD1_TLLASA	16,04	4,58
11	BD2_BONE	6,28	1,97
12	BD2_DAYA	11,86	4,53
13	BD2_MNDAI	11,02	0,00
14	BD2_PLPO	14,52	6,16
15	BD2_PNKNG	17,80	4,14
16	BD2_PNRNG	1,00	0,01
17	BD2_TLAMA	30,74	4,28
18	BD3_PNKNG	30,59	7,69
19	BD_5	95,00	9,50
20	BD_9	89,80	15,00
21	BD_10	231,50	45,00
22	BD_BARRU	4,53	1,35
23	BD_BKRU	1,00	0,00
24	BD_BLKMBA	0,74	1,61
25	BD_BNTAENG	6,17	1,17
26	BD_BOLANGI	16,41	3,79
27	BD_BOSOWA	44,91	9,84
28	BD_BRLOE	6,14	0,85
29	BD_BRWJA	22,67	0,01
30	BD_ENRKG	6,01	0,00
31	BD_JNPNTO	12,79	3,63
32	BD_MJENE	10,45	1,42
33	BD_MKLE	2,97	0,13
34	BD_MMUJU	21,72	2,83
35	BD_MROS	16,93	4,82
36	BD_PARE	17,63	4,07
37	BD_PLMAS	4,75	1,52
38	BD_PNGKEP	24,96	10,98
39	BD_SDRP	17,40	5,68
40	BD_SGMNSA	34,28	0,97
41	BD_SIWA	6,25	1,41
42	BD_SNGKNG	19,49	5,37
43	BD_SNJAI	12,18	4,12
44	BD_SPPENG	6,97	5,41
45	BD_TBNGA	49,64	0,99
46	BD_TELLO	35,31	14,13
47	BD_TELLO2	35,97	8,65
48	BD_TONASA	2,33	21,83

III. 3. Voltage Simulation Results on each Bus

The voltage obtained from the simulation results of the power flow of each bus on the 150 kV Sulselrabar interconnection system after the entry of the WPP can be seen in Table 7. So it can be concluded:

a) Bus 150 kV the largest voltage before the entry of the WPP occurred at BUS22_BONE of 152.31 kV or 101.54%, while the largest voltage after the entry of the WPP occurred at BUS24_BLKMB of 152.31 kV or 104.02%.
b) The smallest voltage value before the entry of the WPP occurred at BUS9_BOSOWA with a value of 147.071kV or 98.05%, while the voltage after the entry of the WPP occurred at BUS18_PALOPO with a voltage of 148.091 kV or 98.72%.
c) The same voltage value with PT. PLN data occurs in BUS1_BAKARU with a value of 150 kV or 100%. The following is a graphic image of the results of the 150 kV analysis. This can be seen in Figure 1 and Table 7.

TABLE VI
RESULTS OF POWER FLOW SIMULATION OF THE 150 KV SULSELRABAR BUS LOADING INTERCONNECTION SYSTEM BEFORE AND AFTER WIND POWER ENTER

BUS	Before		After	
	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)
BD1_BNTLA	7,99	0,00	5,97	0,00
BD1_BONE	4,04	1,71	6,27	1,97
BD1_DAYA	11,45	0,01	11,63	0,00
BD1_MNDAI	7,86	1,52	7,98	2,56
BD1_PLPO	12,78	4,91	15,47	0,30
BD1_PNKNG	3,79	3,08	16,74	3,14
BD1_PNRNG	12,51	2,14	24,38	6,34
BD1_TLAMA	12,08	3,97	12,22	4,02
BD1_TLLASA	0,68	0,10	16,04	4,58
BD2_BONE	10,24	4,09	6,28	1,97
BD2_DAYA	11,68	4,46	11,86	4,53
BD2_MNDAI	10,86	0,01	11,02	0,00
BD2_PLPO	8,72	1,74	14,52	6,16
BD2_PNKNG	13,86	4,06	17,80	4,14
BD2_PNRNG	7,23	4,68	1,00	0,01
BD2_TLAMA	19,40	1,58	30,74	4,28
BD3_PNKNG	26,44	7,54	30,59	7,69
BD_BARRU	4,23	1,25	4,53	1,35
BD_BKRU	2,29	0,19	1,00	0,00
BD_BLKMBA	9,13	2,00	0,74	1,61
BD_BOSOWA	20,56	9,96	44,91	9,84
BD_BRLOE	7,09	9,96	6,14	0,85
BD_BRWJA	5,23	0,00	22,67	0,01
BD_JNPNTO	9,74	3,46	12,79	3,63
BD_MJENE	5,21	1,73	10,45	1,42
BD_MKLE	3,81	1,67	2,97	0,13
BD_MMUJU	7,85	1,91	21,72	2,83
BD_MROS	4,90	2,16	16,93	4,82
BD_PARE	20,00	4,40	17,63	4,07
BD_PLMAS	6,63	2,40	4,75	1,52
BD_PNGKEP	13,38	6,56	24,96	10,98
BD_SDRP	12,21	5,83	17,40	5,68
BD_SGMNSA	11,90	4,30	34,28	0,97
BD_SNGKNG	11,72	5,44	19,49	5,37
BD_SNJAI	5,75	3,33	12,18	4,12
BD_SPPENG	14,00	7,40	6,97	5,41
BD_TBNGA	27,00	11,24	49,64	0,99
BD_TELLO	34,55	13,82	35,31	14,13
BD_TONASA	36,64	21,33	2,33	21,83

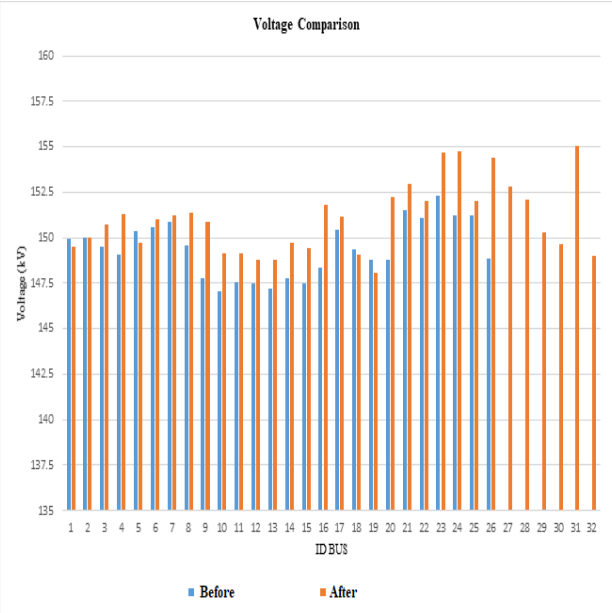

Fig. 1. 150kV voltage comparison graph from Power flow analysis and data from [3]

At Bus 70 kV, the largest voltage before the entry of the WPP occurred at Bus31_TELLO70 of 70.625 kV or 100.89%, while the largest voltage after the entry of the WPP occurred at BUS32_BRLOE with a voltage value of 71.493 kV or 102.13%.

The smallest voltage value before the entry of the WPP occurs at BUS27_TNASA70 with a value of 69.951 kV or 99.93%, while the voltage after the entry of the WPP occurs at BUS34_BNTLA with a voltage value of 69.351 kV or 99.07%. This can be seen in Figure 2.

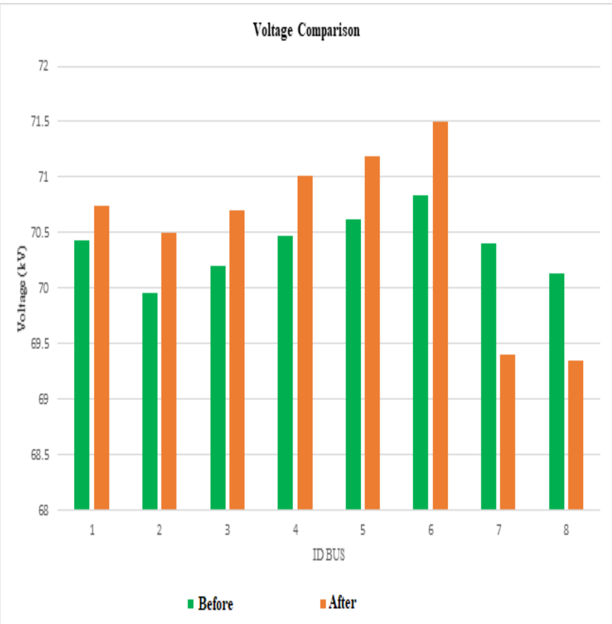

Fig. 2. 70kV voltage comparison graph from Power flow analysis and data from [3]

TABLE VII
RESULTS OF VOLTAGE SIMULATION OF 150KV INTERCONNECTION SYSTEM IN SULSELRABAR

ID BUS	Before		After	
	kV	%	kV	%
BU28	149,895	99,93	149,475	99,65
BUS1	150	100	150	100,00
BUS2	149,511	99,67	150,721	100,48
BUS3	149,086	99,39	151,33	100,89
BUS4	150,38	100,25	149,729	99,82
BUS5	150,572	100,38	151,015	100,68
BUS6	150,831	100,55	151,256	100,84
BUS7	149,536	99,69	151,368	100,91
BUS8	147,783	98,52	150,894	100,60
BUS9	147,071	98,05	149,154	99,44
BUS10	147,537	98,36	149,165	99,44
BUS11	1477,51	98,35	148,775	99,18
BUS12	147,23	98,15	148,805	99,20
BUS13	147,802	98,53	149,679	99,79
BUS14	147,501	98,33	149,404	99,60
BUS15	148,379	98,92	151,836	101,22
BUS16	150,425	100,28	151,189	100,79
BUS17	149,339	99,56	149,041	99,36
BUS18	148,745	99,16	148,091	98,73
BUS19	148,809	99,21	152,199	101,47
BUS20	151,512	101,01	152,917	101,94
BUS21	151,064	100,71	152,022	101,35
BUS22	152,315	101,54	154,696	103,13
BUS23	151,244	100,83	154,735	103,16
BUS24	151,217	100,81	156,031	104,02
BUS25	148,83	99,22	154,396	102,93
BUS26	-	-	153,831	103,37
BUS27	-	-	154,103	102,74
BUS28	-	-	150,27	100,18
BUS29	-	-	149,643	99,76
BUSBNTAENG	-	-	155,048	103,37
BusBOLANGI	-	-	149,014	99,34
BUS26	70,424	100,61	70,744	101,06
BUS27	69,951	99,93	70,493	100,70
BUS29	70,2	100,29	70,702	101,00
BUS30	70,473	100,68	71,012	101,45
Bus31	70,625	100,89	71,189	101,70
BUS32	70,84	101,1	71,493	102,13
Bus33	70,4	100,57	69,396	99,14
BUS34	70,139	100,2	69,351	99,07
Bus35	29,43	98,1	29,411	98,04

While the buses after the entry of the WPP experiencing Critical Voltage Conditions are found in two distribution buses, including:

1. Bosowa 11 kV distribution bus of 9.7475 kV or 88.61% experiencing Under Voltage Condition.
2. Pangkep 20 kV distribution bus with 18,429 kV or 92.14% experiencing Under Voltage Condition. It is described in Table 8.

TABLE VIII
RESULTS OF SIMULATION OF THE 150KV INTERCONNECTION SYSTEM VOLTAGE IN SULSELRABAR AFTER THE INCLUSION OF WIND POWER WITH CRITICAL VOLTAGE CONDITION

ID BUS	VOLTAGE		CONDITION
	kV	%	
BD_BOSOWA	9,7475	88,6136	Under Voltage
BD_PNGKEP	18,4295	92,1475	Under Voltage

Marginal Voltage Condition events can be seen in the Table 9. Where for this condition, the voltage is still within the Standard Voltage, namely +5% and -5% so that it is still allowed to operate. The following is the result of the calculation of the voltage for each bus that experiences Under Voltage or Over Voltage Conditions.

TABLE IX
RESULTS OF SIMULATION OF THE 150KV INTERCONNECTION SYSTEM VOLTAGE IN SULSELRABAR AFTER THE INCLUSION OF WIND POWER WHICH EXPERIENCES MARGINAL VOLTAGE CONDITION

ID BUS	VOLTAGE		CONDITION
	kV	%	
BD1_PLPO	19,5978	97,9889	*Under Voltage*
BD1_PNGAYA	20,5334	102,667	*Over Voltage*
BD1_PNKNG	19,506	97,53	*Under Voltage*
BD1_TLAMA	19,4464	97,2321	*Under Voltage*
BD1_TLLASA	19,5401	97,7006	*Under Voltage*
BD2_PNKNG	19,4102	97,0508	*Under Voltage*
BD3_PNKNG	19,4937	97,4685	*Under Voltage*
BD_9	20,7842	103,921	*Over Voltage*
BD_10	20,8039	104,019	*Over Voltage*
BD_BLKMBA	20,613	103,065	*Over Voltage*
BD_BNTAENG	20,5146	102,573	*Over Voltage*
BD_BOLANGI	19,4795	97,3976	*Over Voltage*
BD_BRLOE	20,5373	102,687	*Over Voltage*
BD_BRWJA	19,0058	95,0288	*Under Voltage*
BD_MROS	19,4486	97,2432	*Under Voltage*
BD_SDRP	19,2944	96,4719	*Under Voltage*
BD_SNGKNG	19,4049	97,0242	*Under Voltage*
BD_SPPENG	20,4878	102,439	*Over Voltage*
BD_TBNGA	19,5604	97,8022	*Under Voltage*
BD_TELLO	19,2802	96,4011	*Under Voltage*
BD_TELLO2	19,3837	96,9186	*Under Voltage*
BD_TONASA	19,3177	96,5885	*Under Voltage*

IV. Conclusion

The conclusion obtained from the results of Power Flow Analysis Power Flow Analysis Due to the Entry of Renewable Energy Plants in the Sulselrabar System Using ETAP 16, is:

1. The Newton-Raphson method used for power flow simulation in this study shows efficiency in terms of computational processing speed in ETAP 16.00 Software.
2. The total active power (P) contained in the channel under normal conditions is 1730.87 MW, where the active power is the largest, which is 171 MW from BUS15_TLASA to BUS13_SGMNSA.
3. The largest reactive power is 25.68 Mvar from BUS8_PANKEP to BUS8_BOSOWA.
4. The highest Power Factor efficiency reached 100% occurred from BUS21_SENGKANG to BUS16_SIDRAP, while the lowest efficiency occurred on the WPP Sidrap Bus channel to BUS16_SIDRAP which was 19.72%.

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