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Real-time voltage stability monitoring model of wind power plant penetration in electrical power system networks

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Abstract. The intermittent output power of wind power plants can affect the stability of the power grid, so a real-time monitoring model is needed. This study uses data from the southern Sulawesi network which is interconnected with wind power plants in real-time, and the IEEE 30 bus data is used as method validation. The method used is the New Voltage Stability Index (NVSI) based on Matlab. The results of the stability index on the IEEE 30 bus data are < 1 or are at the standard of stable criteria, namely 0.95 p.u. The result of the stability index of the South Sulawesi network is line number 49 from Latuppa to Poso has the highest value of 0.0473, the second is line number 18 from Bosowa to Tello is 0.0390, and the third is line number 24 from Tello 30kV to Barawaja is 0.0221, the other bus voltages have lower values. So it can be concluded that the network of South Sulawesi is stable, and intermittent wind power has no effect on voltage stability.

1. Introduction

Voltage instability can cause voltage drops or blackouts so that power flow is not optimal. The non-optimal power flow results in high system operating costs [1, 2, 3, 4, 5, 6]. The optimal power flow is an economic dispatch calculation to calculate the cost of generation and power loss in the network [7, 8, 9]. Previous stability index research used various types of methods including L (L-index), Lmn (Line Stability Index), FVSI (Fast Voltage Stability Index), LQP (Line Stability Factor), Control Design of Automatic Voltage Regulator to Improve the Voltage Stability [10], and the Capital Analysis Method [11].

While the calculation of power flow used methods such as Lambda Iteration [12], Genetic Algorithm [13], Particle Swarm Optimization [14], Artificial Bee Colony algorithm ABC [15], Novel Bat Algorithm (NBA) [16]. This study uses the NVSI method which combines the Lmn and FVSI [17, 18, 19]. Meanwhile, the optimal power flow is calculated using the Novel Bat Algorithm [20], which is compared with the Improved Particle Swarm Optimization IPSO method [21, 22, 23]. The novelty of this research is the calculation of the stability index on the power flow system of the Sulselbar network which is connected to a real-time wind power plant energy.

The basic equation for solving the stability index (Kessel and Glavitsch) [24], the indicator L for the voltage stability in the network index value between 0 (zero loads) and 1 (voltage drop), with the following formula.

1.1 L-Index

$$L = \max_{j\in\alpha_L}\{Lj\} = \max_{j\in\alpha_L}\left\{\left| 1-\frac{\sum_{i\in\alpha_G} F_{ji} * V_i}{V_i}\right|\right\} \qquad (1)$$

$$F_{ji} = |F_{ji}| < \theta_{ji}$$

L is the system on the consumer side and G is the system on the generator, [Lj] a local indicator that determines the bus from which the instability occurs. [F] is calculated by [$[F] = [Y_{LL}]^{-1}[Y_{LG}]$ where $[Y_{LL}]$ and $[Y_{LG}]$ are *Y*-bus matrices. The voltages V_i and V_j represent the voltages on buses *i* and *j*.

1.2 LVSI Method

LVSI is a voltage stability index that discusses the relationship between real power and bus voltage [25] with the following formula

$$LVSI = \frac{4RP_r}{V_s \cos\theta - \delta} \leq 1 \qquad (2)$$

Where $\theta = Tan^{-1}\frac{X}{R}$ is the angle of the transmission network, and R is the resistance of the network.

1.3 NVSI Method

NVSI is a combination of the Lmn method and the FVSI method which aims to increase the accuracy and speed of computation. The line diagram of a two-bus system power model whose parameters and variables are in units as follows (Figure 1).

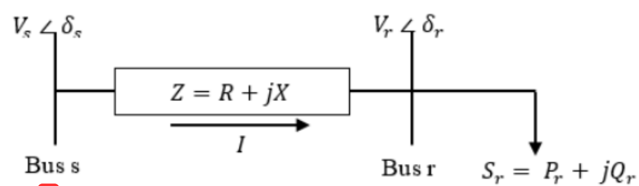

Figure 1. One-line diagram of a model in a two-bus power

$$NVSI = \frac{4Q_r}{|V_s|^2}\left[\frac{(|Z|)^2}{X}\sigma - \frac{X}{sin^2(\theta-\delta}(\sigma - 1)\right] \leq 1 \qquad \sigma = \begin{cases} 1 & \delta < \delta c \\ 0 & \delta \geq \delta c \end{cases} \qquad (3)$$

Where δ is used as the modifying variable, σ is the switching function, the value of which depends on the difference in angle, δ is very small or not.

2. Methods

Table 1 shows the power output of wind power plant 02 march 2020. Tabel 2 shows Bus data of Sulselbar network.

Table 1. The power output of wind power plant 02 march 2020

Sidrap Wind Power Generator				Jeneponto Wind Power Generator			
a.m.	WM	p.m.	WM	a.m.	WM	p.m.	WM
1	1.67	1	12.35	1	0.4	1	0.4
2	1.04	2	17.85	2	16.3	2	16
3	8.26	3	40.12	3	68.5	3	6.9
4	9.66	4	60.27	4	40.3	4	39.2
5	1.98	5	64.91	5	36.2	5	2.5
6	14.33	6	50.72	6	31.1	6	29.2
7	1.86	7	48.42	7	37.6	7	26.8
8	0.00	8	49.26	8	13	8	19.5
9	2.45	9	45.82	9	0	9	22.4

Table 1. (continued)

10	0.50	10	52.17	10	0	10	49.2
11	3.60	11	47.59	11	0	11	41.7
12	3.54	12	45.80	12	0	12	34.7

Table 2. Bus data of Sulselbar network

No	Bus Code	Voltage Mag.	Load		Generator		No	Bus Code	Voltage Mag.	Load		Generator	
			MW	Mvar	MW	Mvar				MW	Mvar	MW	Mvar
1	1	1.03	4.30	0.20	126.00	0.40	23	0	1.00	0.00	0.00	0.00	0.00
2	0	1.00	14.90	3.80	0.00	0.00	24	2	0.97	37.70	9.70	0.00	0.00
3	0	1.00	11.10	2.20	0.00	0.00	25	0	0.99	11.22	20.00	0.00	0.00
4	0	1.03	16.70	3.00	0.00	0.00	26	0	1.00	44.30	0.00	0.00	0.00
5	2	1.00	23.50	7.00	0.43	0.00	27	2	1.00	35.70	8.40	0.00	0.00
6	0	1.00	17.20	4.60	0.00	0.00	28	0	1.00	41.50	12.80	0.00	0.00
7	2	1.00	0.00	0.00	60.00	19.00	29	2	1.00	23.20	5.30	8.00	3.30
8	0	1.00	25.30	9.00	0.00	0.00	30	0	1.00	16.40	4.00	0.00	0.00
9	2	1.00	0.00	0.00	22.93	9.41	31	2	1.00	0.00	0.00	221.10	71.20
10	0	1.00	9.40	2.40	0.00	0.00	32	0	1.00	20.00	4.30	0.00	0.00
11	0	0.97	22.10	8.00	0.00	0.00	33	0	1.00	28.80	7.30	0.00	0.00
12	0	1.01	0.00	-20.00	0.00	0.00	34	2	1.00	14.90	6.90	9.70	-1.51
13	0	1.00	31.10	8.50	0.00	0.00	35	0	1.00	28.80	8.20	0.00	0.00
14	0	1.00	40.78	13.35	0.00	0.00	36	0	1.00	13.10	4.20	0.00	0.00
15	0	1.00	14.10	4.50	0.00	0.00	37	2	1.02	25.00	9.20	216.50	2.30
16	2	0.97	48.50	15.50	8.00	5.00	38	2	1.00	8.80	2.10	13.10	2.89
17	0	1.00	69.20	18.40	0.00	0.00	39	2	1.00	44.60	7.30	8.70	2.50
18	0	0.96	0.00	-20.00	0.00	0.00	40	0	1.00	0.00	0.00	0.00	0.00
19	2	1.00	0.70	0.00	19.30	-0.10	41	2	1.00	0.00	0.00	183.80	19.40
20	0	1.00	17.00	2.10	0.00	0.00	42	0	1.00	0.00	0.00	0.00	0.00
21	0	1.00	25.50	3.90	0.00	0.00	43	0	1.00	4.55	0.20	0.00	0.00
22	0	1.00	0.00	0.00	0.00	0.00	44	0	1.00	6.68	0.00	0.00	0.00

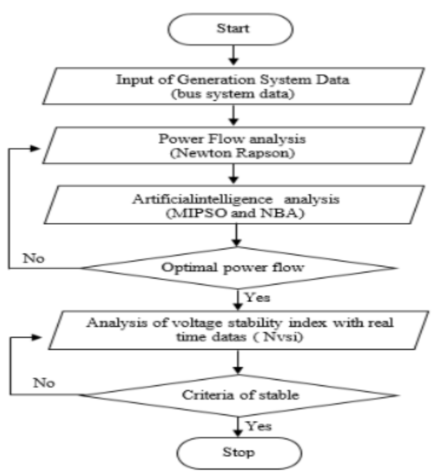

Figure 2. Flowchart of research

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3. Results and Discussion

3.1 Stability Index of IEEE 30 bus data

New Voltage Stability Index analysis performed on IEEE 30 bus data can be seen in Figure below.

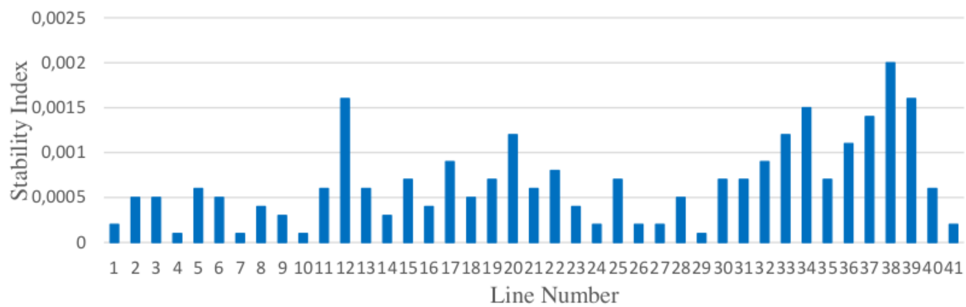

Figure 3. Graph of NVSI Index on IEEE 30 bus data

The test results of the NVSI method used on the IEEE 30 bus data show that the stability index is less than one or below the voltage limit criteria standard of 0.95 p.u, so that it can be used in existing real systems.

3.2 Stability Index of Real-Time Wind Power Plant Injection to Sulselbar Network

The wind power plant does not affect the voltage drop in the power flow of the Sulselbar Network. The graph of the stability index of the South Sulawesi network which is injected with the real power of the wind power plant can be seen as follows.

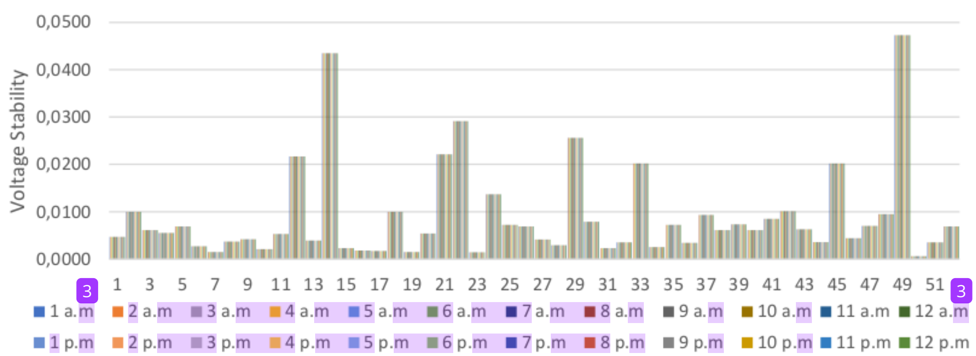

Figure 4. Graph of NVSI at Sulselbar Network of Real-Time wind power plant injection

The results of the New Voltage Stability Index (NVSI) on the Sulselbar network that are injected with wind power in real-time do not affect system stability.

4. Conclusion

The results of the analysis on the South Sulawesi network which is interconnected with the wind power plant in real time are summarized as follows. The results of the stability index on the IEEE 30 bus data are < 1 or are at the standard of stable criteria, namely 0.95 p.u. The result of the stability index of the South Sulawesi network is line number 49 from Latuppa to Poso has the highest value of 0.0473, the second is line number 18 from Bosowa to Tello is 0.0390, and the third is line number 24 from Tello

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