Contingency Analysis on 150 kV Electricity Power System on the Madura Island Based on the 1P1Q Method

Moh Zainul Falah¹ Sujito^{1,*} I Made Wirawan¹

¹ Electrical Engineering Department, Universitas Negeri Malang, Indonesia

*Corresponding author. Email: sujito.ft@um.ac.id

ABSTRACT

A major factor in the power system operation is the desire to maintain system security. System security involves a design to keep the system operating in the event of interference or failure. Interferences in electrical power systems are divided into generator, transmission, and load. Failure or interference of the transmission network results in a contingency of the transmission lines that can cause voltage in the bus and overload in the transmission lines, so it is very necessary to overcome the problem with a contingency analysis simulation to find solutions to problems caused by the disconnection of the transmission line. One of the contingency analysis methods is the 1P1Q (performance contingency index) method where the 1P1Q method lists the worst contingency impact on the electric power system to help engineers to solve problems and determine their next steps when contingencies occur. In the study, the Newton raphson's methods were used to determine the power flow in electrical systems at normal conditions or contingency. Calculating the value of the contingency index in times of interference or failure using the 1P1Q method. The results show that the worst impact or highest-ranking performance index for the Madura 150 kV electric power system occurs in the infinity-base scenario where two lines are overloaded and exceed the maximum value limit of the transmission line power of the infinity-gilitimur channel of 157.5 MW with a maximum value limit transmission line of 92,359 MW and gilitimur-bangkalan of 149 MW with a maximum value limit of transmission line of 88,616 MW. So there is prevention with load shedding of 87,638 MVA with scenario 6 in table 4:24 of load shedding on the bus Sampang, Sumenep, Pamekasan because by shedding loads of 95,528 MVA the power flowing at infinity-gilitimur becomes 72.9 MW.

Keywords: contingency analysis, 1P1Q method, newton raphson method, Madura 150 kV electricity power system

1. INTRODUCTION

Interference in the power system operation is an unavoidable problem. According to PLN data, in 2018 there were 41582 disruptions that occurred, consisting of transmission and distribution disruptions. This data shows the high number of disturbances in Indonesia. In 2017 the island of Madura experienced a disruption in the transmission line of Java Island and Madura which resulted in a part of Madura island outage. The contingency is an unexpected condition that occurs in a short duration in an electric power system [1]. This short duration can cause the elements of the electric power system to be in danger and experience an outage [2]. The release of elements in the electric power system

includes the discharge of generation, transmission, distribution, to load [3].

Based on the data on the number of PLN disturbances, the safety of the electric power system operation is very important to maintain service continuity. So that the power system can survive when an unsettling influence happens [4] - [6]. Interference in the electric power system is the discharge of one or more channels or components [7] - [9]. These disturbances can cause overload so that the electric power system cannot supply the power should the system stack [5], [10], [11].

1P1Q method is one of the strategies utilized to rank possibilities based on their severity. The 1P1Q method comprises of the Power Performance Index and the

Performance Voltage Index [5]. The Power Performance File (PIflow) positions with regard to the stream of dynamic control within the electrical framework whereas the Execution Voltage File (PIV) is based on the voltage on the bus within the electrical system [1], [12] - [22].

This study talks about the contingency analysis of the Madura 150 kV electric power system which was carried out with 8 contingency scenarios. Each scenario comprises a blackout transmission line on the Madura 150 kV electric power system. The Newton Raphson method is utilized to calculate the power flow within the Madura 150 kV electric power system. Performance index analysis is utilized to decide the ranking of the electrical power system severity index. This function is to determine the potential for excess power overload that is generated when one component of the power system outage.

2. MATERIAL AND METHOD

2.1. IP1Q Methode (Performance index)

The solution to select the release case or contingency condition scenario is by using the IP1Q method. The IP1Q method is a ranking of the calculation of two Performance Index (IP), there are the line power performance index and the voltage performance index [23]. First, the line power Performance Index uses the active power value parameter through the following equation:

$$IP_{Flow\ i} = \sum_{i=1}^m \left(\frac{P_i}{P_{maks}} \right)^{2n} \quad (1)$$

Description:

IP flow = performance index contingency power flow i

Pi = active power value of transmission line i at contingency. (MW)

Pl maks = maximum value of active power value of transmission line i at contingency (MW)

n = 1

Second, the voltage performance index uses the bus voltage parameter through the following equation:

$$IP_{V\ i} = \sum_{i=1}^m \left(\frac{V_{j\ min}}{V_{j\ i}} \right) + \sum_{L=1}^m \left(\frac{V_{j\ i}}{V_{j\ maks}} \right) \quad (2)$$

Description :

IP Vi = performance index voltage contingency i

Vj, i = the voltage value on bus j at contingency of line i. (kV)

Vjmin = minimum voltage limit on bus j. (kV) (135kV) (PLN standard -10% + 5%)

Vjmax = maximum limit of the voltage on bus j. (kV) (157.5kV) (PLN standard -10% + 5%)

$$\frac{P_i + jQ_i}{V_i} = V_i \sum_{j=0}^n Y_{ij} - \sum_{j=1}^n Y_{ij} V_j \quad (3)$$

2.2. Flowchart

Model the problem with the help of ETAP 12.6 application to calculate the newton rapson power flow in the 150 kV Madura power system. The research stage of the contingency analysis of the 150 kV Madura electricity network system using the IP1Q method includes the flow chart in Figure 1 below.

Figure 1 Flowchart.

2.3. Research data

This research data is electricity system 150 KV Madura includes a Single line diagram of Madura 150 kV electricity power system with region sub-system Krian 1,2 Gresik, Data transmission line parameters, Data transformer, Bus data, Peak-load data.

3. RESULT AND DISCUSSION

3.1. Madura 150 kV electricity power system

Madura island included in region krian subsystem – 1.2 – gresik consisting of 5 substations (GI) with GI Bangkalan, GI Gilitimur, GI Sampang, GI Pamekasan, GI Sumenep to meet the load needs of Madura island which when peak load happens can reach 200 MW (PT. PLN APB REGION 4). Single line and result is shown in figure 2 below :

Figure 2 Madura Transmission Network Configuration

Power flow at the normal condition (before contingency) shows Madura 150 kV electricity power system in good condition, each bus connected to the system works well to deliver electrical energy according to the demand of each bus without overload or undervoltage. There show the table of results from the simulation of load flow during normal conditions (before contingency) with peak load in table 1:

Table 1. Power Flow result of Madura 150 kV electricity power system Before Contingency (Normal)

No.	Line	Active Power (MW)
1	Infinity – Gilitimur A	84.3
2	Infinity – Bangkalan A	76.8
3	Gilitimur B – Bangkalan B	77.2
4	Bangkalan A – Sampang A	53.3
5	Bangkalan B – Sampang B	53.3
6	Sampang B – Sumenep	23.2
7	Sampang A– Sumenep	49.2
8	Sumenep – Pamekasan	6.7

3.2. Madura 150 kV electricity power system contingency scenario

Contingencies on transmission lines in this study consist of eight outage scenarios. The outages modeled on every transmission line in Madura 150 kV electricity power system. The following contingency scenarios in the study are shown in table 2 below :

Table 2. Scenario contingency

Scenario.	Outage
1	Infinity – Gilitimur A
2	Infinity – Bangkalan A
3	Gilitimur B – Bangkalan B
4	Bangkalan A – Sampang A
5	Bangkalan B – Sampang B
6	Sampang B – Sumenep
7	Sampang A– Sumenep
8	Sumenep – Pamekasan

3.3. IP1Q method (Performance index)

Contingency ranking can be calculated using several methods. One of the methods used is the IP1Q (Performance Index) method. The Index Performance Method consists of two parts, there are the Performance Index Power flow and the Performance Index Voltage.

The index performance ranking aims to sort based on the ranking of index performance from highest to lowest. The following is table 3 ranking the performance index contingency scenario of the 150 kV Madura power system:

Table 3. Performance index of Madura 150 kV electricity power system

Rangki ng	Scen ario	PI flowi	PI V	PI
1	2	6.8794018	9.2767627	16.156164
2	1	4.1894455	9.2810778	13.470523
3	4	4.0020828	9.2788603	13.280943
4	5	4.002082	9.2788603	13.280943
5	3	3.950865	9.2776889	13.228554
6	7	3.832822	9.2800853	13.112908
7	6	3.719607	9.2727083	12.992315
8	8	3.310401	9.2704502	12.580851

Based on the results of the contingency scenario, the 150 kV Madura power system has an impact on the power flow and voltage in the system. Table 4 shows the ranking order of the Performance Index after the contingency scenario 1 to 8 in the 150 kV Madura power grid system. The first ranking for the Performance Index contingency occurs in contingency scenario 2 (Infinity - Bangkalan A). The ranking in the 2nd contingency scenario is worth 16.10830325. This shows that the Infinity -Bangkalan A line plays an important role in the 150 kV Madura power grid system. The greater PI value on the transmission line indicates that has a bad impact such as a blackout in a power system when there is an outage. During contingency scenario 2, the line connecting the Infinity bus and the bus - Bangkalan A is cut off. This resulted in the power supply obtained on the infinite side of Krian 1,2- Gresik Sub-System only transmission line through the Infinity - Gilitimur transmission line.

3.4.Prevention of Contingent Impacts

Based on the index performance value in table 4, the worst impact is when the contingency occurs in the 2 infinity-base scenario which results in an overload of the 150 kv Madura power system. In the scenario 2 infinity-bangkalan where two transmission lines are overloaded and exceed the maximum value limit of the transmission line power, there are the infinity-gilitimur of 157.5 MW with a maximum value limit of channel power of 92,359 MW and the gilitimur-bangkalan channel of 149 MW with a maximum value limit of transmission line power. of 88,616 MW as in table 4 below:

Table 4. Infinity-bangkalan power flow results scenario at madura 150 kv electric power system

Scenario	Pmax	Pline
1	92.359	157.5
2	89.933	0
3	88.616	149
4	84.639	51.2
5	84.639	51.2
6	81.538	22.3
7	82.206	47.3
8	80.939	6.5

Therefore it is necessary to have load shedding (load shedding) on the side of the bus and the amount of load removed is:

- Infinity-gilitimur

$$P = 157.5 - 92.359$$

$$= 65.141 \text{ MW}$$

$$S = \frac{P}{\cos \phi}$$

$$= \frac{65.141}{\cos(\tan^{-1} 0.9)}$$

$$= 87.638 \text{ MVA}$$

- Gilitimur-bangkalan

$$P = 149 - 88.616$$

$$= 60.384 \text{ MW}$$

$$S = \frac{P}{\cos \phi}$$

$$= \frac{60.384}{\cos(\tan^{-1} 0.9)}$$

$$= 81.238 \text{ MVA}$$

Load shedding will be selected based on the sensitivity factor which has the aim of choosing which buses are suitable to be removed. And when the load is removed, it is 87,638 MVA because it is seen from the infinity, which is also a transmission line before the bases, the load shedding scheme and the results of the scenario above, scheme 6 is chosen, there are the load shedding on the sampang, Sumenep, Pamekasan buses because by shedding loads of 87,638 MVA the power flow at the infinity-architecture becomes 72.9 MW. Thus the transmission line becomes safe because the power flow is below the maximum value limit of the channel power of 72.9 MW is shown in table 5 below:

Table 5. Load shedding scheme

Scenario	Bus load	MVA	All load	MW
1	Gili timur	4.332 and 2.932	94.984	81.9
	Bangkalan	21.493 and 31.549		
	Sampang	34.678		
2	Bangkalan	21.493 and 31.549	87.72	84.9
	Sampang	31.678 and 4.185		
3	Bangkalan	21.493 and 31.549	90.841	87.9
	Sumenep	25.817 and 11.982		
4	Bangkalan	21.493 and 31.549	102.125	74.7
	Pamekasan	18.866 and 32.217		
5	Sumenep	25.817 and 11.982	88.882	89.6
	Pamekasan	18.866 and 32.217		
6	Sampang	31.678 and 4.185	95.528	72.9
	Sumenep	25.817 and 11.982		
	Pamekasan	18.866		
7	Sampang	31.678 and 4.185	89.946	87.5
	Pamekasan	18.866 and 32.217		

4. CONCLUSION

The conclusion of this study based on the results of the calculation IP1Q method in each contingency scenario 1 to 8 in the Madura 150 kV Electricity Power System with the highest ranking is 16.10830. The ranking occurs during the contingency scenario 2 (Infinity - Bangkalan A). This highest performance index ranking resulted in overload on two transmission lines, there are Infinity - Gilitimur and Gilitimur - Bangkalan which exceeded the maximum value limit for transmission line power flow, there is infinity-gilitimur transmission line of 157.5 MW with a maximum value limit of transmission line power flow of 92,359 MW and a gilitimur-bangkalan transmission line of 149 MW. with a maximum value limit for transmission line power flow of 88,616 MW. So there is prevention with load shedding of 87,638 MVA with scenario 6 in table 4:24 of load shedding on the bus Sampang, Sumenep, Pamekasan because by shedding loads of 95,528 MVA the power flowing at infinity-gilitimur becomes 72.9 MW.

REFERENCES

- [1] S. Burada, D. Joshi, and K. D. Mistry, "Contingency analysis of power system by using voltage and active power performance index," in 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), Jul. 2016, pp. 1–5, doi: 10.1109/ICPEICES.2016.7853352.
- [2] A. Roy and S. Jain, "CONTINGENCY ANALYSIS IN POWER SYSTEM: Thesis of Master of Engineering in Power Systems & Electric Drives, Thapar University, Patiala,," 2011.
- [3] S. Ghazali and N. Rahmawati, "Analisis Kontingensi Sistem Tenaga Listrik dengan Metode Bounding," J. Rekayasa Elektr., vol. 10, Feb. 2012, doi: 10.17529/jre.v10i2.139.
- [4] J. E. Ruiz-Castro, "Preventive Maintenance of a Multi-State Device Subject to Internal Failure and Damage Due to External Shocks," IEEE Trans. Reliab., vol. 63, no. 2, pp. 646–660, Jun. 2014, doi: 10.1109/TR.2014.2315922.
- [5] W. D. Oliveira, J. P. A. Vieira, U. H. Bezerra, D. A. Martins, and B. das G. Rodrigues, "Power system security assessment for multiple contingencies using multiway decision tree," Electr. Power Syst. Res., vol. 148, pp. 264–272, Jul. 2017, doi: 10.1016/j.epsr.2017.03.029.
- [6] M. Aien, A. Hajebrahimi, and M. Fotuhi-Firuzabad, "A comprehensive review on uncertainty modeling techniques in power system studies," Renew. Sustain. Energy Rev., vol. 57, pp. 1077–1089, May 2016, doi: 10.1016/j.rser.2015.12.070.

- [7] J. V. Canto dos Santos, I. F. Costa, and T. Nogueira, "New genetic algorithms for contingencies selection in the static security analysis of electric power systems," *Expert Syst. Appl.*, vol. 42, no. 6, pp. 2849–2856, Apr. 2015, doi: 10.1016/j.eswa.2014.11.041.
- [8] A. A. Abdelsalam, A. A. Eldesouky, and A. A. Sallam, "Classification of power system disturbances using linear Kalman filter and fuzzy-expert system," *Int. J. Electr. Power Energy Syst.*, vol. 43, no. 1, pp. 688–695, Dec. 2012, doi: 10.1016/j.ijepes.2012.05.052.
- [9] P. Pruski and S. Paszek, "Calculations of power system electromechanical eigenvalues based on analysis of instantaneous power waveforms at different disturbances," *Appl. Math. Comput.*, vol. 319, pp. 104–114, Feb. 2018, doi: 10.1016/j.amc.2017.01.057.
- [10] J. Geeganage, U. D. Annakkage, M. A. Weekes, and B. A. Archer, "Application of energy-based power system features for dynamic security assessment," in 2015 IEEE Power Energy Society General Meeting, Jul. 2015, pp. 1–1, doi: 10.1109/PESGM.2015.7285721.
- [11] M. EL-Shimy, N. Mostafa, A. N. Afandi, A. M. Sharaf, and M. A. Attia, "Impact of load models on the static and dynamic performances of grid-connected wind power plants: A comparative analysis," *Math. Comput. Simul.*, vol. 149, pp. 91–108, Jul. 2018, doi: 10.1016/j.matcom.2018.02.003.
- [12] A. A. Abdulrazzaq, "Contingency ranking of power systems using a performance index," 2015.
- [13] 14524115 Rahmad Syafri Utama, "ANALISIS KONTINGENSI SISTEM TENAGA 30 BUS IEEE BERBASIS METODE ALIRAN DAYA FAST DECOUPLED," Nov. 2018, Accessed: Aug. 16, 2020. [Online]. Available: <https://dspace.uui.ac.id/handle/123456789/12627>.
- [14] J. Venkateswaran, P. Manohar, K. Vinothini., B. T. M. Shree, and R. Jayabarathi, "Contingency analysis of an IEEE 30 bus system," in 2018 3rd IEEE International Conference on Recent Trends in Electronics, Information Communication Technology (RTEICT), May 2018, pp. 328–333, doi: 10.1109/RTEICT42901.2018.9012509.
- [15] S. Rani Gongada, Tegala. S. Rao, P. M. Rao, and S. Salima, "Power system contingency ranking using fast decoupled load flow method," in 2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), Mar. 2016, pp. 4373–4376, doi: 10.1109/ICEEOT.2016.7755544.
- [16] P. Sekhar and S. Mohanty, "Power system contingency ranking using Newton Raphson load flow method," in 2013 Annual IEEE India Conference (INDICON), Dec. 2013, pp. 1–4, doi: 10.1109/INDCON.2013.6725912.
- [17] M. D. M. Putri and A. N. Afandi, "Performance Index Analysis (PIA) for N-1 Contingency Transmission in 150 kV Electricity System," in 2019 International Conference on Electrical, Electronics and Information Engineering (ICEEIE), Oct. 2019, vol. 6, pp. 1–5, doi: 10.1109/ICEEIE47180.2019.8981432.
- [18] 14524003 Ahmad Mursali Arifin, "ANALISIS KONTINGENSI SISTEM TENAGA LISTRIK PADA JARINGAN 150 KV," Universitas Islam Indonesia, 2019.
- [19] K. Gita and A. Kumar, "Contingency Ranking for Security Analysis of Power System Network with Incorporation of STATCOM," in 2020 International Conference on Electrical and Electronics Engineering (ICE3), Feb. 2020, pp. 71–75, doi: 10.1109/ICE348803.2020.9122950.
- [20] B. Krishnakumar and R. Arthi, "Contingency assessment of Indian Utility 62 bus system," in 2012 IEEE International Conference on Engineering Education: Innovative Practices and Future Trends (AICERA), Jul. 2012, pp. 1–8, doi: 10.1109/AICERA.2012.6306712.
- [21] M. Khazaei and S. Jadid, "Contingency ranking using neural networks by Radial Basis Function method," in 2008 IEEE/PES Transmission and Distribution Conference and Exposition, Apr. 2008, pp. 1–4, doi: 10.1109/TDC.2008.4517045.
- [22] A. E. Airoboman, P. James, I. A. Araga, C. L. Wamdeo, and I. K. Okakwu, "Contingency Analysis on the Nigerian Power Systems Network," in 2019 IEEE PES/IAS PowerAfrica, Aug. 2019, pp. 70–75, doi: 10.1109/PowerAfrica.2019.8928883.
- [23] A. Wood and B. Wollenberg, *Power generation, operation, and control*. 2012.