

Newton-Raphson Load Flow Method for Voltage Contingency Ranking

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Abstract—The security assessment is a fundamental task as it provides the knowledge about the system status in case of contingency. This helps in rapidly take the accurate action to maintain the system secure. In the present work, a Newton-Raphson load flow based approach is presented to perform contingency ranking by computing a voltage performance index (PI). The contingencies are classified in secure, insecure and critical classes and then the method proceeds in the decreased order of severity to rank them based on the PI value. The proposed method is applied to the IEEE 39-bus system in MATLAB environment by considering (N-1) contingency for different load conditions.

Keywords— *Load flow; Newton-Raphson; (N-1) contingency; performance index; steady state security assessment.*

I. INTRODUCTION

Power system consists of a variety of equipments like transmission lines and generators which are always prone to undergo a failure. This may harm the security of the system and consequently lead to outages [1]. Therefore, power system has to cope with any possible failure through analysing its consequences and taking the accurate control actions [2, 3]. This task is known as security assessment, the aim of which is to provide information about the behaviour and the condition of the system in the event of an unforeseen contingency [4].

Steady state security assessment (SSA) is a process that concerns the analysis of the steady state performance of the system following an unscheduled contingency. It checks either the operating constraints as voltage limits get violated or not [5]. The assessment of the security revolves around the definition, selection and ranking of the insecure contingencies by considering the degree of their severity [6, 7]. The severity of each contingency may be estimated by computing a performance index (PI). The on-line ranking methods used to measure the PI suffer from large computational time and especially the high cost of the application [8]. For this reason, the use of offline methods still has a great importance in the assessment of system security.

The contingency evaluation and ranking issue have been discussed by several authors [8-11]. In reference [12], the authors studied the dynamic security assessment (DSA) of the IEEE 57-bus system. They opted for an offline method based on numerical simulations to measure two severity indices. Reference [13] proposed a Newton-Raphson load flow

approach to rank line outage. A voltage performance index and an active power index were calculated for each contingency of the selected list. Similarly, this method is used in [14] for the classification of line outage cases using two different test systems. A fast decoupled load flow technique is presented in [15] to estimate the active power index and the voltage performance index. The summation of these indices is considered to order line contingencies according to their severity. Reference [16] deals with the analysis of the transient stability of the IEEE 14-bus system. The authors applied a heuristic method to identify the state of the system and to rank the contingencies. In reference [17], the contingency ranking is given by estimating the performance index. The author concluded the efficiency of the Newton-Raphson load flow method in identifying the most severe contingencies in the IEEE 30-bus test system.

The main focus of this paper is to address the power system static security assessment. Therefore, we propose a Newton-Raphson load flow based method to measure the voltage performance index. By performing (N-1) contingency on the test system IEEE 39-bus system, the PI index is used for the classification of the voltage security level and the ranking of the contingencies in the decreased order of severity. The rest of the paper is structured as follow: section 2 details the proposed methodology. The case study and the simulations results are given in section 3. Finally, the main conclusions are provided in section 4.

II. METHODOLOGY

The main objective of the proposed approach is to rank all the probable contingencies so that we can identify the most severe ones. We propose the Newton-Raphson load flow based approach which is an offline method for solving the non-linear load flow equations. The results of the resolution provide information about the state of the system in particular the post-contingency buses voltages. Using these values, the performance index PI is computed for different conditions. A considerable number of operating conditions is generated by modifying the total load of the power system in large range and for each load pattern; a three-phase short circuit is applied at each transmission line using AC load flow. The contingencies are ranked in the decreased order of severity i.e., higher the PI severe is the contingency.

Table I shows the different classes of the contingencies corresponding to the PI range. When the PI value is below 0.2, the system is said in a secure state and the contingencies are the least severe. The second class corresponds to the insecure state where the PI value is above 0.8 and the contingencies are the most severe. While if $0.2 < PI < 0.8$, the state of the system is deemed critical [18].

TABLE I. CLASSES OF VOLTAGE PERFORMANCE INDEX.

Class	Secure	Insecure	Critical
PI range	< 0.2	> 0.8	$0.2 < PI < 0.8$

A. The index of voltage performance

In this paper the performance index (PI), represented by equation (1), is used to classify the voltage security condition and to rank the contingencies from a well-defined list. Only the voltage violated buses are considered in the computation of the PI.

$$PI = \sum_{i \in S} \left(\frac{w_i}{M} \right) (f_i)^M \quad (1)$$

f_i is a function defined as follows:

$$f_i = \begin{cases} V_i - V_i^{\max}, & \text{for } V_i > V_i^{\max} \\ V_i^{\min} - V_i, & \text{for } V_i < V_i^{\min} \end{cases} \quad (2)$$

Where:

i is the number of the bus which belongs to the set of the violated buses only, V_i is the post-contingency voltage at the i th bus, V_i^{\max} and V_i^{\min} represent the upper limit and the lower limit of the voltage at the i th bus respectively.

M and w_i are the order of the exponent and the weighing coefficient respectively. We started the PI computation by arbitrary using $w_i=1$ and $M=4$. Taking into account that $0 < PI < 1$, it was observed after repeated simulations, that the appropriate values of w_i and M to obtain reasonable results are: $w_i=1$ and $M=6$. Table 2 summarizes the major results of the base case loading condition simulations.

TABLE II. INDEX PI VALUE IN FUNCTION OF M.

Transmission line	PI		
	$M=4$	$M=5$	$M=6$
3-18	1.1093	0.6186	0.3778
16-19	1.4121	0.8446	0.5506
16-21	1.0095	0.5930	0.3818
16-24	1.4121	0.8446	0.5506
8-7	1.8374	1.2781	0.9465

B. Voltage contingency ranking

The algorithm proposed for voltage contingency ranking using Newton-Raphson method is represented in the flow chart of Fig. 1. Various operating conditions must be generated first of all by perturbing the load of all the buses in wide range. Then, for each case of load increase, we perform

(N-1) contingency for all the transmission lines by AC load flow. For all the contingencies, we compute the voltage PIs using equation (1). If the PI value < 0.2 , then the corresponding contingency is filtered out from the contingencies list. Once all the possible cases are considered, rank the selected contingencies in the decreased order of severity.

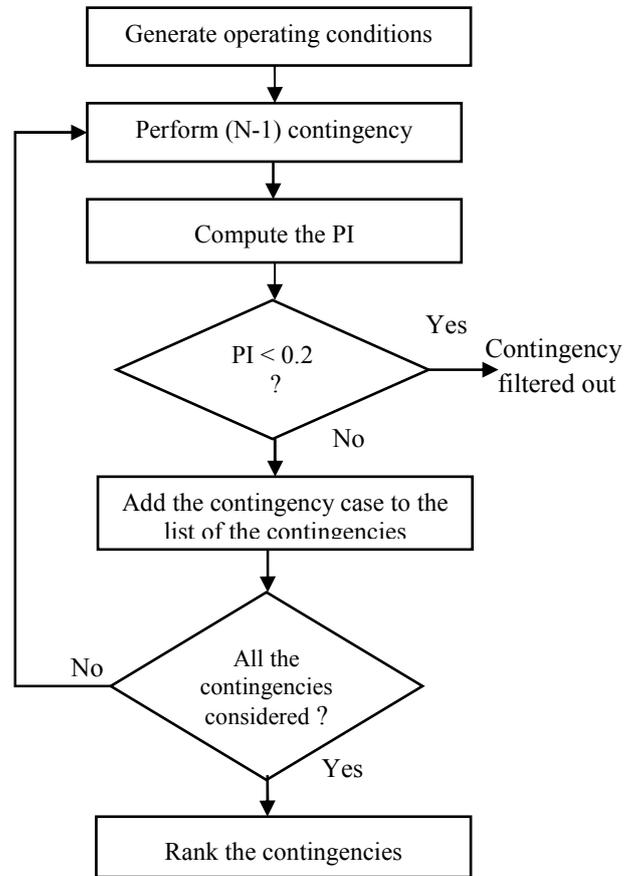


Fig. 1. Flow chart of the proposed method

III. CASE STUDY AND RESULTS

The proposed approach is tested for voltage contingency classification and ranking of IEEE 39-bus New England system [19]. This test system consists of 46 transmission lines, 12 transformers, 19 loads and it has 10 generators. 230 simulation cases were generated corresponding to 5 operating conditions: base case, 10%, 30%, 50% and 70% of load increase. A three-phase short circuit is considered as the contingency and is applied for each load pattern, at all the transmission lines with the following characteristics: fault resistance $r_f = 0.01 \cdot$ and fault duration $t = 100\text{ms}$. In each case, the severity of the contingency is evaluated by computing the PI.

The test results of only some scenarios are shown in Tables III and IV, because of the limited space. Table III presents the classification of the contingencies in secure, insecure and critical classes. During the different load patterns, the PI value in case of a fault at line 1-39 is under 0.2, so the state of the system is classified as secure. However,

a short-circuit at line 8-7 leads to insecure state. In other cases, for example line 14-15, the contingency is critical during the base case and 10% of load increase, but it belongs to insecure class under heavy load conditions.

The ranking phase considers only the contingencies belonging to insecure and critical classes. Thus, after assessing the PI value of all the 46 contingencies, it was found that the system maintains secure operation for the following contingencies: line 1-39, line 9-39, line 11-12, line 26-29, line 13-12 and line 25-26. Therefore, these fault cases are filtered out from the list of credible contingencies i.e. are not

considered to be ranked. Table IV shows the first ten most severe contingencies. The transmission lines 8-5, 8-7 and 9-8 gave the highest PI values and hence are deemed the most critical lines in the test system. However, lines 11-10, 16-24, 15-16 and 10-13 gave the least performance severity levels.

Based on the simulations performed for all the load patterns, it is concluded that the proposed approach can successfully classify all the contingencies in three classes and rank them according to their severities.

TABLE III. CONTINGENCY CLASSIFICATION FOR 5 OPERATING CONDITIONS.

Base case			10%			30%			50%			70%		
Line	PI	State	Line	PI	State	Line	PI	State	Line	PI	State	Line	PI	State
1-39	0.1225	S	1-39	0.1225	S	1-39	0.1225	S	1-39	0.1226	S	1-39	0.1226	S
9-39	0.1227	S	9-39	0.1229	S	9-39	0.1229	S	9-39	0.1233	S	9-39	0.1259	S
2-1	0.2445	C	2-1	0.2807	C	2-1	0.3038	C	2-1	0.3523	C	2-1	0.3728	C
14-15	0.6344	C	14-15	0.7013	C	14-15	0.8063	I	14-15	0.9270	I	14-15	0.9883	I
11-12	0.1227	S	11-12	0.1233	S	11-12	0.1442	S	11-12	0.1585	S	11-12	0.1694	S
25-37	0.2410	C	25-37	0.2565	C	25-37	0.2785	C	25-37	0.2934	C	25-37	0.3045	C
16-19	0.5506	C	16-19	0.5796	C	16-19	0.6357	C	16-19	0.6660	C	16-19	0.6949	C
3-2	0.4004	C	3-2	0.4093	C	3-2	0.4545	C	3-2	0.4799	C	3-2	0.4962	C
26-29	0.1741	S	26-29	0.1800	S	26-29	0.1834	S	26-29	0.1947	S	26-29	0.1951	S
13-12	0.1227	S	13-12	0.1233	S	13-12	0.1442	S	13-12	0.1585	S	13-12	0.1694	S
25-26	0.1741	S	25-26	0.1799	S	25-26	0.1834	S	25-26	0.1945	S	25-26	0.1951	S
6-5	0.9037	I	6-5	0.9206	I	6-5	0.9283	I	6-5	0.9079	I	6-5	0.8582	I
18-17	0.5203	C	18-17	0.5429	C	18-17	0.5880	C	18-17	0.6058	C	18-17	0.6261	C
7-6	0.8597	I	7-6	0.8878	I	7-6	0.8965	I	7-6	0.8594	I	7-6	0.8083	I
8-7	0.9465	I	8-7	0.8706	I	8-7	0.9502	I	8-7	0.9760	I	8-7	0.9365	I

S: Secure; C: Critical; I: Insecure

TABLE IV. CONTINGENCY RANKING FOR 5 OPERATING CONDITIONS.

Base case			10%			30%			50%			70%		
Rank	Line	PI	Rank	Line	PI	Rank	Line	PI	Rank	Line	PI	Rank	Line	PI
1	8-5	0.9467	1	6-5	0.9206	1	8-5 8-7 9-8	0.9502	1	9-8	0.9997	1	14-15	0.9883
2	8-7	0.9465	2	6-31 7-6	0.8878	2	6-5	0.9283	2	8-7	0.9760	2	8-5 8-7 9-8	0.9365
3	9-8	0.9225	3	9-8 8-5 8-7	0.8706	3	7-6 6-31	0.8965	3	8-5	0.9599	3	6-5	0.8582
4	6-5	0.9037	4	5-4	0.7347	4	14-15	0.8063	4	14-15	0.9270	4	6-31 7-6	0.8083
5	6-31 7-6	0.8597	5	4-14	0.7303	5	4-14 13-14	0.7844	5	6-5	0.9079	5	5-4	0.7727
6	5-4	0.7299	6	13-14	0.7017	6	5-4	0.7441	6	7-6 6-31	0.8594	6	13-14	0.7012
7	13-14 4-14	0.6928	7	14-15	0.7013	7	6-11	0.6788	7	13-14 4-14	0.8128	7	4-14	0.7004
8	14-15	0.6344	8	11-10	0.6396	8	11-10	0.6759	8	5-4	0.7118	8	15-16 16-19 16-24	0.6949
9	6-11	0.5991	9	6-11	0.6318	9	15-16 16-19 16-24	0.6357	9	15-16 16-19 16-24	0.6660	9	16-17	0.6264
10	11-10	0.5934	10	16-24 15-16	0.5805	10	10-13	0.6008	10	11-10	0.6571	10	18-17	0.6261

IV. CONCLUSION

This paper has presented an offline method to rank selected contingencies in the decreased order of severity, in accurate manner. The approach is based on the computation of the voltage performance index PI using Newton-Raphson load flow method. The highest values of the index correspond to the most severe contingencies which lead to the violation of voltage limits. During the different load conditions, the ranking of the contingencies are the same, however, there are some misranking due to the fact that the PI values are so close and the variation degree is not always the same. Further works will introduce others methods for comparison purpose.

REFERENCES

- [1] Udaykumar, HRS. Reddy, "Contingency Ranking in Modern Power System by Exact and Precise Method," *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, vol. 3, issue 5, May 2015.
- [2] E.Ciapessoni, D.Cirio, S.Massucco, A.Morini, A.Pitto and F.Silvestro, "Risk-Based Dynamic Security Assessment for Power System Operation and Operational Planning," *Energies journal*, 2017.
- [3] A. Roy, "Contingency Analysis in Power System" Thesis of Master of Engineering in Power Systems & Electric Drives, Thapar Univ., India, July 2011.
- [4] M. Di Santo, N. Ranaldo, D.Villacci, and E. Zimeo, "Performing Security Analysis of Large Scale Power Systems with a Broker-based Computational Grid," *International Conference on Information Technology*, 2004.
- [5] Sunitha R, R. Kumar, and A.. Mathew, "Online Static Security Assessment Module Using Artificial Neural Networks," *IEEE transactions on power systems*, 2013.
- [6] D. Devaraj, J. P. Roselyn, and R. U. Rani, "Artificial neural network model for voltage security based contingency ranking," *Science Direct*, pp 722-727, 2007
- [7] G. Stefopoulos, F. Yang, and APS. Meliopoulos, "An Improved Contingency Ranking Method," *35th North American Power Symposium*, October 2003.
- [8] N. Amjady, "Dynamic voltage security assessment by a neural network based method," *Electric Power Systems Research*, pp 215-226, 2003.
- [9] Manjula B. G., Suma A. P., A. D. Kulkarni, N. Kumar, and T. Ananthapadmanabha, "Contingency Ranking in Power Systems Employing Fuzzy Based Analysis," *International Journal of Electrical and Electronics Engineering Studies (IJEEES)*, June 2012.
- [10] T.Jain, L.Srivastava, and SN.Singh, "Fast Voltage Contingency Screening using Radial Basis Function Neural Network," *IEEE transactions on power systems*, vol. 18, 2003.
- [11] P. Naik, "Power System Contingency Ranking using Newton Raphson Load Flow Method and its Prediction using Soft Computing Techniques," Thesis of Master of Technology in Industrial Electronics, National Institute of Technology, Rourkela, India, May 2014.
- [12] W.A.Oyekanmi, G.Radman and T.O.Ajewole, "Transient stability based dynamic security assessment indices," *Electrical & Electronic Engineering*, 2017.
- [13] P.Sekhar, and S.Mohanty, "Power system contingency ranking using Newton Raphson load flow method," *IEEE India Conference*, 2013
- [14] S. Burada, D. Joshi, and K.D. Mistry, "Contingency Analysis of Power System by using Voltage and Active Power Performance Index," *1st IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems*, 2016.
- [15] S.r. Gongada ,T.S. Rao, P.Mallikarjuna rao, S. Salima, "Power System Contingency Ranking using Fast Decoupled Load Flow Method," *International Conference on Electrical, Electronics, and Optimization Techniques*, 2016.
- [16] A. Meddeb, H. Jmii, and S. Chebbi, "Heuristic analysis and contingencies classification of case Study IEEE 14-bus," *7th International Conference on Sciences of Electronics, Technologies of Information and Telecommunications (SETIT)*, pp 128-133, 2017.
- [17] A. Abdulrazzaq, "Contingency ranking of power systems using a performance index," *International Research Journal of Engineering and Technology (IRJET)*, vol. 2, issue 2, pp 180-183, 2015.
- [18] L. Srivastava, S.N. Singh, and J. Sharma, "A hybrid neural network model for fast voltage contingency screening and ranking," *Electrical Power and Energy Systems*, pp 35-42, 2000.
- [19] L.Lenoir, "Automatic Operator of Electrical Network," Phd. thesis, Univ. Quebec, June 2009.