Contingency Analysis in Power System using Load Flow Solution

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ABSTRACT
In this paper, the objective is to check the real time security. By two kinds of performance indices, i.e., active power index (PI_P) and reactive power index (PI_V) the contingency selection is performed. Using Newton Raphson (NR) iterative method the MATLAB programming code is written for obtaining the solution of load flow equation. Using the algorithm of singular transformation method the MATLAB code for Y_{BUS} is written as the elements of the bus admittance matrix (Y_{BUS}) used here. At last for contingency ranking the performance indices are calculated. On an IEEE 25 Bus, 35 Line test system; the effectiveness of this method has been tested.

Keywords
Contingency analysis, performance index, contingency selection, contingency ranking, security analysis

1. INTRODUCTION
For the power system engineers the maintenance of power system security is one of the most challenging task. In the event of contingency this security assessment is highly essential because it gives the knowledge of the system state. To predict the effect of outages like failure of various power system components such as transformer, generator, transmission line etc. this contingency analysis technique is widely used [10]. It also helps to take necessary action for keeping the power system secure and reliable. As a power system contains large number of components it is a tedious task to predict the effect of individual contingency in offline analysis. In practical basis only selected contingencies will lead to severe conditions in power system [2]. Identifying severe contingencies is a process known as contingency selection which can be done by calculating performance indices for each type of contingency. Contingencies such as single line outages and double line outages are considered in this paper.

2. CONTINGENCY ANALYSIS AND THEIR COMPONENTS
By avoiding system troubles before their occurrence is contingency analysis. This happens by studying the outage events and alerting the operators to any potential over loads or serious voltage violations [3]. Mainly four major components of contingency analysis are there that described as follows.

2.1 Contingency Definition
The main security function contingency analysis is the study of power system by which change in power flow in lines and bus voltage on the system due to any unscheduled outage of a line component or generator or any disturbances such as change in load demand is assessed.

2.2 Contingency Ranking
In descending order contingency ranking is obtained according to the value of a scalar index which is normally called as severity index or performance index (PI). The PI is a measurement of system-wide effect of a contingency event in the system [4]. It is calculated for individual contingency in off line mode using the conventional load flow algorithm. Based on the obtained values contingencies are ranked in such a manner where highest value of PI is ranked first. Basically there are two types of performance indices that are of great use, i.e., active power index (PI_P) and reactive power index (PI_V). PI_P reflects violation of line active power flow and can be calculated using the mathematical expression

$$PI_P = \sum_{i=1}^{L} \left(\frac{P_i}{P_{i\max}} \right)^2 \qquad (1)$$

Where, L = Total number of transmission lines that present in the system
P_i = Active power flow in line i
P_{imax} = Maximum active power flow in line i
$$= \frac{|V_i||V_P|}{|Z|} - \frac{R|V_P|}{|Z|^2}$$

Z = Impedance of the line connecting buses i and p
R = Resistance of the line connecting buses i and p

PI_V reflects bus voltage magnitude violation and can be calculated by the mathematical expression

$$PI_V = \sum_{i=1}^{n-m-1} \left(\frac{2(V_i - V_{inom})}{V_{i\max} - V_{i\min}} \right) \qquad (2)$$

Where, n = Total number of buses present in the system
m = Total number of PV buses present in the system
n-m-1 = Total number of load buses present in the system
V_i = Voltage of bus i after load flow
V_{inom} = Nominal voltage at bus-i. Generally assumed as 1 pu.

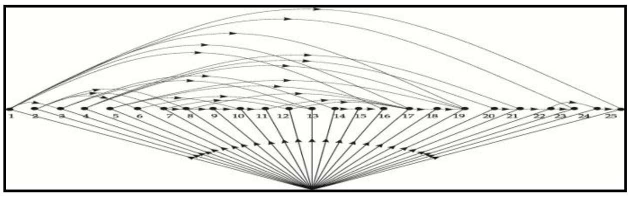

Fig 1: Single line diagram of the system under study

V_{imin} = Minimum voltage limit. Generally assumed as 95% of V_{inom}.
V_{imax} = Maximum voltage limit. Generally assumed as 105% of V_{inom}.

2.3 Contingency Selection

The severe contingencies are then chosen from either of ranked list starting from the top and going down the list until a predefined stopping criteria is reached. These are absolute fixed lists. The process of choosing a subset that containing severe contingencies is called contingency selection [3]. This process consists of selecting the set of most probable contingencies in; they need to be evaluated in terms of potential risk to the system.[10]

2.4 Contingency Evaluation

At last in order of their severity the selected contingencies are ranked, till no violation of operating limits is observed.

3. RESULTS AND DISCUSSIONS

Here the main focus is to perform contingency ranking by determining PI_P and PI_V values. Highest value of performance index is the case with severe contingency. With help of NR iterative method computation of these indices is done under MATLAB environment. Pre and post contingency voltages are determined at various buses. An IEEE 25 bus, 35 line system is considered for the contingency analysis [11]. The bus and line data are provided in Appendix-A. Figure-1 shows the single line diagram of the system.

The system shown in Figure-1, holds 1 numbered slack bus, 4 PV buses (2 to 5) and the rest 20 numbers are load buses. Total 35 transmission lines are connected between various buses in the system. Using NR iterative method load flow is carried out that acts as steady state data. After each contingency case known as post contingency data load flow is again carried out. Performance indices are obtained by the use of equation (1) and (3). Figure-2 shows the graph of the system under study. While developing Y_{BUS} matrix using singular transformation technique it will be useful.

35 single line outage contingency cases are considered. In table-1 and table-2 first 5 severity cases are tabulated (Both for $\%PI_P$ and $\%PI_V$).

Table 1. Single line outage for $\%PI_P$

Contingency Number	From Bus	To Bus	Rank
6	1	25	5
13	4	20	3
15	***5***	***10***	***1***
32	21	22	4
34	22	24	2

In table-1 contingency number 15 is the most severity case and the highlighted one is ranked 1.

Table 2. Single line outage for $\%PI_V$

Contingency Number	From Bus	To Bus	Rank
3	1	17	2
4	1	19	3
6	***1***	***15***	***1***
30	18	19	4
31	20	21	5

In table-2 contingency number 6 is the most severity case and the highlighted one is ranked 1.

Similarly 595 double line outage contingency cases are considered also and first 5 severity cases are tabulated in table-3 and table-4 respectively for both $\%PI_P$ and $\%PI_V$.

Table 3. Double Line Outage for $\%PI_P$

Contingency Number	First Line		Second Line		Rank
	From Bus	To Bus	From Bus	To Bus	
157	1	23	21	22	5
218	2	7	2	08	2
222	***2***	***7***	***4***	***20***	***1***
291	3	13	20	21	8
427	5	19	7	12	4
579	17	18	22	24	3

In table-3 contingency number 222 is the most severity case which is ranked 1 and highlighted.

Table 4. Double Line Outage for $\%PI_V$

Contingency Number	First Line		Second Line		Rank
	From Bus	To Bus	From Bus	To Bus	
100	***1***	***19***	***1***	***23***	***1***
224	2	7	5	10	3
231	2	7	8	17	5
364	4	20	24	25	2
432	5	19	11	17	4

In table-4 contingency number 100 is the most severity case which is ranked 1 and highlighted.

4. CONCLUSION

By calculating performance indices, i.e., active power performance index (PI_P) and reactive power performance index (PI_V) the contingency selection and contingency ranking are made in this paper. These two indices PI_P and PI_V were calculated for an IEEE 25 bus, 35 line test system. The contingency severity cases, i.e., single line outage and double line outage is accurately indicated by the numerical values of PI_P and PI_V respectively. In off line manner the indices are calculated for a single loading condition. From the obtained results it can be concluded that the calculation of performance indices gives a good measure about the severity of all the possible line contingencies occurring in the system. The indices with higher value shows a severe case which has the highest potential to make the system parameters to go beyond their permissible limits.

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7. APPENDIX-A

Table A. Bus Data Of IEEE 25 Bus, 35 Line System

Bus Number	**P_G (in pu)**	**Q_G (in pu)**	**P_D (in pu)**	**Q_D (in pu)**	**|V| (in pu)**	**Angle of V**
1	-	-	0	0	1.030	0
2	0.936	-	0.100	0.030	1.002	-
3	1.153	-	0.500	0.170	1.050	-
4	0.480	-	0.300	0.100	1.015	-
5	1.784	0.500	0.250	0.080	1.007	-
6	0	0	0.150	0.050	-	-
7	0	0	0.150	0.050	-	-
8	0	0	0.250	0	-	-
9	0	0	0.150	0.050	-	-
10	0	0	0.150	0.050	-	-
11	0	0	0.050	0	-	-
12	0	0	0.100	0	-	-
13	0	0	0.250	0.080	-	-
14	0	0	0.200	0.070	-	-
15	0	0	0.300	0.100	-	-
16	0	0	0.300	0.100	-	-
17	0	0	0.600	0.200	-	-
18	0	0	0.150	0.050	-	-
19	0	0	0.150	0.050	-	-
20	0	0	0.250	0.080	-	-
21	0	0	0.200	0.070	-	-
22	0	0	0.200	0.070	-	-
23	0	0	0.150	0.050	-	-
24	0	0	0.150	0.050	-	-
250	0	0	0.250	0.080	-	-

Table B. Line Data Of IEEE 25 Bus, 35 Line System

Sl. No.	From Bus	To Bus	Series line impedance (in pu)	Charging admittance (in pu)
1	1	3	0.8191-3.2719i	0.0089i
2	1	16	1.4604-6.9445i	0.0168i
3	1	17	1.1460-3.1640i	0.0074i
4	1	19	0.8547-2.2399i	0.0112i
5	1	23	1.7451-3.6109i	0.0286i
6	1	25	0.5587-2.6660i	0.0436i
7	2	6	0.6859-3.2629i	0.0093i
8	2	7	0.8209-3.9232i	0.0077i
9	2	8	0.7265-3.4670i	0.0087i
10	3	13	2.2298-5.8791i	0.0042i
11	3	14	0.8351-2.5222i	0.0092i
12	4	19	6.4769-6.9854i	0.0056i
13	4	20	3.2931-8.6812i	0.0110i
14	4	21	1.3058-3.4288i	0.0279i
15	5	10	0.8461-4.0385i	0.0278i
16	5	17	0.8828-7.7800i	0.0667i
17	5	19	1.3608-3.5772i	0.0070i
18	6	13	4.8111-2.6406i	0.0020i
19	7	8	2.1804-6.0385i	0.0039i
20	7	12	1.1569-5.5177i	0.0055i
21	8	9	1.0867-5.1864i	0.0059i
22	8	17	0.8461-4.0385i	0.0286i
23	9	10	1.1882-3.2864i	0.0042i
24	10	11	1.4094-3.7025i	0.0067i
25	11	17	1.1840-3.1120i	0.0080i
26	12	17	0.9137-4.3623i	0.0067i
27	14	15	4.2405-1.5293i	0.0022i
28	15	16	4.9376-2.9806i	0.0074i
29	17	18	1.5681-4.1127i	0.0061i
30	18	19	1.4478-3.8088i	0.0066i
31	20	21	2.0637-5.4127i	0.0177i
32	21	22	3.0599-8.0342i	0.0119i
33	22	23	1.2691-2.0074i	0.0084i
34	22	24	1.2638-3.3811i	0.0283i
35	24	25	2.0097-6.2080i	0.0158i