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Power System Security Analysis

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Abstract: In this paper real time security analysis is carried out. First contingency selection is performed by calculating two kinds of performance indices. They are active power index (PI_P) and reactive power index (PI_V). MATLAB programming code is written to obtain the solution of load flow equations using Newton Raphson (NR) iterative method algorithm. The iterative method uses the elements of the bus admittance matrix (Y_{BUS}). The MATLAB code for Y_{BUS} is written using the algorithm of singular transformation method. Finally the performance indices are calculated for contingency ranking. The effectiveness of the methods has been tested on an IEEE 25 Bus, 35 Line test system.

Index Terms – Security analysis, performance index, contingency selection, contingency ranking.

1 INTRODUCTION

Power system security is one of the challenging tasks for the power system engineers. This security assessment is essential as it gives the knowledge of the system state in the event of contingency. Contingency analysis technique is being widely used to predict the effect of outages like failure of power system components such as generator, transformer, transmission line etc, and to take necessary action to keep the power system secure and reliable. Use of offline analysis to predict the effect of individual contingency is a tedious task as a power system contains large number of components. Practically, only selected contingencies will lead to severe conditions in power system. The process of identifying severe contingencies is referred as contingency selection and this can be done by calculating performance indices for each type of contingency. In this paper contingencies such as single transmission line and double transmission line outages are considered.

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2 CONTINGENCY ANALYSIS

Contingency analysis avoids system troubles before they occur by studying the outage events and alerting the operators to any potential over loads or serious voltage violations. The major components of contingency analysis are:

2.1 Contingency Definition

Contingency definition involves preparing a list of probable contingencies.

2.2 Contingency Ranking

Contingency Ranking in descending order is obtained according to the value of a scalar index, normally called as severity index or performance index (PI). PI is calculated using the conventional load flow algorithm for individual contingency in off line mode. Based on the values obtained contingencies are ranked in a manner where highest value of PI is ranked first. There are basically two types of performance indices that are of great use. These are active power index PI_P and reactive power index PI_V. PI_P indicates violation of line active power flow whereas PI_V indicates bus voltage magnitude violation. PI_P can be calculated using

$$PI_p = \sum_{i=1}^{L} \left(\frac{P_i}{P_{imax}} \right)^2 \quad (1)$$

where

$$P_{imax} = \frac{|V_i||V_p|}{|Z|} - \frac{R|V_p|^2}{|Z|^2} \quad (2)$$

where L = Total number of transmission lines present in the system
P_i = Active power flow in line i
P_{imax} = maximum active power flow in line i

Z = Impedance of the line connecting buses i and p

R = Resistance of the line connecting buses i and p

The second performance index PI_V can be calculated using

$$PI_V = \sum_{i=1}^{n-m-1} \left(\frac{2(V_i - V_{inom})}{V_{imax} - V_{imin}} \right)^2 \qquad (3)$$

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

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

Contingency selection process consists of selecting the set of most probable contingencies in; they need to be evaluated in terms of potential risk to the system.

2.4 Contingency evaluation

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

3 RESULT AND DISCUSSION

In this paper the main focus is to perform contingency ranking by determining performance indices i.e. PI_P and PI_V values. Severe contingency is the case with highest value of performance index. Computation of these indices is done with help of NR iterative method under MATLAB environment. Pre and post contingency voltages at various buses are determined. For the contingency analysis an IEEE 25 bus, 35 line system is considered whose bus and line data are detailed in Appendix-A. The single line diagram of the system is as shown in Fig. 1.

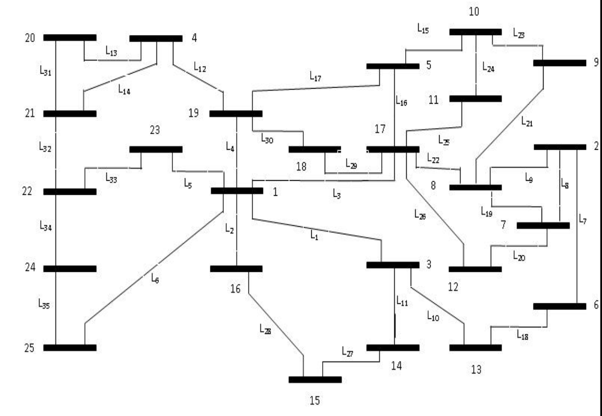

Fig.1. Single line diagram of the system under study.

The system as shown in Fig. 1 consists of a slack bus numbered 1, 4 PV buses numbered from bus number 2 to 5 and remaining 20 are load buses. The system has total number of 35 transmission lines connected between various buses. Load flow is carried out using NR iterative method which acts as the steady state data. Load flow is again carried out after each contingency case which is referred as the post contingency data. Using equations (1) and (3) the performance indices are calculated. The graph of the system under study is as shown in Fig. 2 and it will be useful while developing Y_{BUS} matrix using singular transformation method.

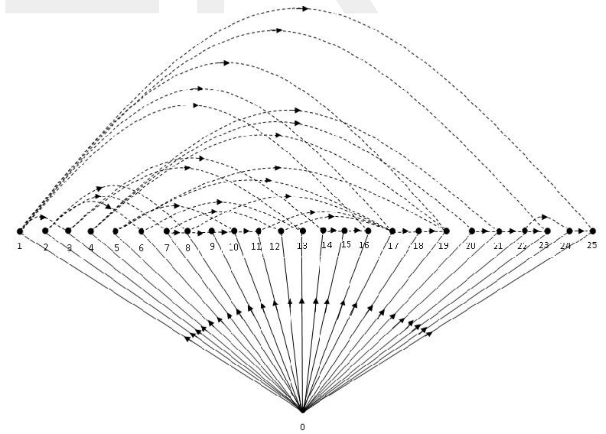

Fig. 2. Graph of the system under study

35 single line outage contingency cases are considered and first 10 severity cases are tabulated both for $\%PI_P$ and $\%PI_V$ in Table-1 and Table-2 respectively.

TABLE 1
SINGLE LINE OUTAGE TABLE FOR %PI_P

Contingency Number	From Bus	To Bus	Rank
6	1	25	5
7	2	6	10
12	4	19	8
13	4	20	3
15	**5**	**10**	**1**
16	5	17	6
17	5	19	7
32	21	22	4
34	22	24	2
35	24	25	9

In Table-1 and Table-2 contingency number 15 and 6 respectively are the most severity cases. They are ranked 1 in the tables and are highlighted.

TABLE 2
SINGLE LINE OUTAGE TABLE FOR %PI_V

Contingency Number	From Bus	To Bus	Rank
1	1	3	8
3	1	17	2
4	1	19	3
6	**1**	**25**	**1**
14	4	21	10
21	8	9	6
26	12	17	9
29	17	18	7
30	18	19	4
31	20	21	5

Similarly 595 double line outage contingency cases are considered and first 10 severity cases are tabulated both for %PI_P and %PI_V in Table-3 and Table-4 respectively.

TABLE 3
DOUBLE LINE OUTAGE TABLE FOR %PI_P

Contingency Number	First Line		Second Line		Rank
	From Bus	To Bus	From Bus	To Bus	
157	1	23	21	22	05
218	2	7	2	08	02
222	**2**	**7**	**4**	**20**	**01**
291	3	13	20	21	08
387	5	10	5	19	10
427	5	19	7	12	04
431	5	19	10	11	09
443	6	13	7	08	06
579	17	18	22	24	03
593	22	23	22	24	07

TABLE 4
DOUBLE LINE OUTAGE TABLE FOR %PI_V

Contingency Number	First Line		Second Line		Rank
	From Bus	To Bus	From Bus	To Bus	
92	1	17	15	16	09
100	**1**	**19**	**1**	**23**	**01**
131	1	23	1	25	07
224	2	7	5	10	03
231	2	7	8	17	05
317	3	14	22	23	10
364	4	20	24	25	02
374	4	21	10	11	08
432	5	19	11	17	04
570	15	16	20	21	06

In Table-3 and Table-4 contingency number 222 and 100 respectively are the most severity cases. They are ranked 1 in the tables and are highlighted.

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4 CONCLUSION

In this paper contingency selection and contingency ranking are made by calculating two important performance indices such as active power performance index (PI_P) and reactive power performance index (PI_V). These two indices were calculated for an IEEE 25 bus, 35 line test system. The severity of contingency cases such as single line outage and double line outage is accurately indicated by the numerical values of PI_P and PI_V respectively. The indices are calculated in off line manner for a single loading condition. From the results obtained 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 reflect a severe case which has the highest potential to make the system parameters to go beyond their permissible limits.

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APPENDIX – A

Table A.1: 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	1.513	-	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	-	-
25	0	0	0.250	0.080	-	-

Table A.2: Line data of IEEE 25 bus, 35 line system

Serial Number	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 - 16.9854i	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- 12.6406i	0.0020i
19	7	8	2.1804- 6.0385i	0.0039i
20	7	12	1.15695- 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- 11.5293i	0.0022i
28	15	16	4.9376- 12.9806i	0.0074i
29	17	18	1.5681- 4.1227i	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