

Static Voltage Stability Analysis Using PSAT

Tejaswini Gawande¹, Komal Kaur Khokhar¹, Naveen Verma¹, Tushar Sahare¹, Bhupesh Metangale¹,
Naved Bakhtiyar¹, Dr. Altaf Badar²

Student, Dept. of EE, Anjuman College of Engineering and Technology, Sadar, Nagpur, Maharashtra, India¹

Assistant Professor, Dept. of EE, Anjuman College of Engineering and Technology, Sadar, Nagpur, Maharashtra,
India²

ABSTRACT: Power System may lose stability and cause blackout when operating under loaded condition. In order to protect the power system it becomes essential to predict and identify the voltage instability. This paper presents the analysis of static voltage stability using continuation power flow method considering the power system contingencies and its effect on Mega Watt Margin (MWM) and maximum loading point (MLP). The weak bus in the system is identified by using contingencies ranking. On the basis of MWM percentage decrease, ranking of the system is done. IEEE 6 and IEEE 30 are simulated using PSAT to verify the results.

KEYWORDS: Voltage collapse, voltage stability, megawatt margin, maximum loading point.

I. INTRODUCTION

The increasing demand of electricity results into overloaded condition of the system. The overloaded condition leads the system to operate in unstable condition. In unstable condition voltages of the buses decreases and can cause voltage collapse [1]. It is a phenomenon that causes severe changes in the power system hence voltage stability analysis becomes necessary. Analysis of voltage stability is also essential from the power system protection point of view [2-3]. Continuation power flow (CPF) is the main analysis tool used for the IEEE 6 and IEEE 30 bus system. CPF technique involves the use of predictor and corrector step for analysing static voltage stability [4]. In this paper, for the analysis of static voltage stability maximum loading point (MLP) and megawatt margin (MWM) are used. Contingency analysis is important factor while considering the power system protection [5]. Operation of system under no contingency gives maximum loading point and maximum megawatt margin. Continuation power flow method is implemented on IEEE 6 and IEEE 30 bus systems for the computation of MLP and its corresponding decrease in MWM. Contingency ranking is obtained by using percentage decrease in MWM [6]. On the basis of ranking system effect of contingencies on the test system and proximity towards voltage collapse can be determined. As a result, weak bus in the system can be determined and corrective action can be taken out before system collapse. Contingency identification can be done by using channel component theorem [7]. Contingency ranking is done by using artificial neural method, using line stability index method and performance index method [8-10]. Exact and precise method can be used to rank the contingency of power system [11]. Analysis of contingency ranking gives the idea about corrective measure that can be taken before system gets collapse [12]. FACTS devices can be used to enhance voltage stability during contingency [13].

II. STATIC VOLTAGE STABILITY AND RANKING CONTINGENCIES

Static voltage stability includes slowly occurring changes in the system which results into the insufficient supply of reactive power and the voltage drop in the buses. This can be determined from $V - \lambda$ curve which gives proximity towards voltage collapse. The $V - \lambda$ curve shows that increase in loading factor (λ) reduces the voltage at receiving end (V) resulting in disturbance of power handling capacity. The main reason behind the voltage drop is the presence of contingencies in the system. Contingency may result into lack of reactive power in the system and smaller MWM causing less voltage in the buses of the system. For the analysis of static voltage stability it becomes essential to rank the contingency on the basis of MLP and percentage decrease in MWM.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

Continuation power flow method is used to rank power system contingency. In the contingency analysis, maximum loading point and corresponding decrease in percentage of MWM is computed. Contingencies ranking is done by arranging the MLP in ascending order and its corresponding MWM decrease in decreasing order. Contingency having lower MLP and higher percentage change in MWM is ranked higher than other contingencies. The values of MMWM and MWM are calculated as:

$$MMWM = P_{i+1max} - P_{base}$$

$$MWM = P_{imax} - P_{base}$$

where, P_{max} is maximum load active power corresponding with MLP and P_{base} is base load active power.

The MWM decrease percent is calculated as:

$$MWM \text{ decrease percent} = 100 \times [1 - (\frac{MMWM}{MWM})]$$

The number of contingencies in the power system depends upon the number of elements subjected to failure. For the event number of L with $NC_L: L=0,1,2,\dots$,

$$NC_L = \frac{N!}{L!(N-L)!}$$

NC_0 means no element is exposed to failure in the system called as zero level contingency. First level contingency NC_1 means only one unique element is subjected to failure. Usually, first and second number of contingency is taken into account. In this paper zero and first level contingency are considered.

$$NC_{0,1} = 1+N.$$

III. SIMULATION RESULTS

The line and bus data for IEEE 6 and 30 bus systems are taken from case6ww and case 30 in Matpower 5.1. The P and Q load powers are voltage independent and its changes can be assumed as:

$$P_L = P_{L0}(1+\lambda) \quad \& \quad Q_L = Q_{L0}(1+\lambda)$$

Where, P_{L0} and Q_{L0} are the active and reactive base loads and P_L and Q_L are the active and reactive loads at bus L for the operating point is given by λ .

A. IEEE 6 bus system

Continuation power flow is executed on IEEE 6 bus system with no contingency, maximum loading point λ_{max} is obtained as 3.3208. The base load active power which is the summation of total active power at the buses during no contingency is computed as 2.94p.u. The maximum load active power is the summation of total active power at the buses during contingency is 6.9735p.u.

(01) SINGLE GENERATION UNIT OUTAGES

In single generation unit outage contingency the values obtained are tabulated in table 1. In generation unit outage the bus number with lowest voltage magnitude is specified with loading factor, real and reactive power in the table 1.

Table 01 GENERATION UNIT OUTAGES

Generation unit outage	Bus no. with lowest voltage magnitude	Magnitude of lowest voltage in MLP(p.u)	λ_{max} (p.u)	P_{load} (p.u)	Q_{load} (p.u)
No contingency	5	0.5603	3.3208	2.3245	2.3245
Bus 2	4	0.6127	2.2893	1.6025	1.6025
Bus 3	6	0.5334	2.2179	1.5525	1.5525

The results obtained of MWM during zero level contingency are 4.0335. The values obtained of MWM and MWM % is tabulated in the table 2 for generation unit outages.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

Table 02 MWM and %MWM FOR GENERATION UNIT OUTAGES

Level of contingency	Generation unit outage	P_{max} (p.u)	P_{base} (p.u)	MWM	MWM%
0	No contingency	6.9735	2.94	4.0335	100
1	Bus 2	4.8075	2.94	1.8675	46.2997
1	Bus 3	4.6575	2.94	1.7175	42.5808

The values obtained of percentage decrease in MWM are tabulated in table 3. In generation unit outage for bus 3 having $\lambda=2.2179$ and MWM % decrease= 57.42 is identified as critical contingency among the remaining contingency of generation unit outage and it is tabulated in table 3

Table 03 CONTINGENCIES RANKING OF SINGLE GENERATION UNIT OUTAGES

Rank of the contingency	Generation unit outage	λ_{max} (p.u)	Percentage decrease in MWM
1	Bus 3	2.2179	57.42
2	Bus 2	2.2893	53.70

In generation unit outage connected to bus 3 is marked as critical contingency in the system. Similarly other generator outages are ranked on the basis of MWM percentage decrease, given in table 3.

(02) LINE OUTAGES

In line unit outage values obtained are tabulated in table 4. The bus number with lowest voltage magnitude is specified with loading factor in the table.

Table 04 SINGLE LINE UNIT OUTAGES

Outage line	Bus no with lowest voltage magnitude	Magnitude of lowest voltage in MLP (p.u)	λ_{max} (p.u)
No contingency	5	0.5603	3.3208
Line 1	5	0.5617	3.2778
Line 2	6	0.6659	1.7218
Line 3	5	0.5085	2.6754
Line 4	5	0.5315	3.1116
Line 5	4	0.6599	1.7263
Line 6	5	0.6874	2.7867
Line 7	4	0.5859	2.6251
Line 8	5	0.5233	2.6981
Line 9	5	0.5785	2.9859
Line 10	5	0.4778	2.7062
Line 11	5	0.5633	3.1927

The result obtained of MWM during zero level contingency is 4.0335. The values obtained of MWM and MWM% is tabulated in the table 5.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

Table 05 MWM and %MWM FOR LINE UNIT OUTAGES

Level of contingency	Generation unit outage	P_{max} (p.u)	P_{base} (p.u)	MWM	MWM%
0	No contingency	6.9735	2.94	4.0335	100
1	Line 1	6.8835	2.94	3.9435	97.7687
1	Line 2	3.6159	2.94	0.6759	16.7571
1	Line 3	5.6184	2.94	2.6784	66.4037
1	Line 4	6.5343	2.94	3.5943	89.1112
1	Line 5	3.6252	2.94	0.6852	16.9877
1	Line 6	5.8521	2.94	2.9121	72.1978
1	Line 7	5.5128	2.94	2.5728	63.7858
1	Line 8	5.6661	2.94	2.7261	67.5865
1	Line 9	6.2703	2.94	3.3303	82.5660
1	Line 10	5.6829	2.94	2.7429	68.0029
1	Line 11	6.7047	2.94	3.7647	93.3359

In line unit outage, line 2 connected between bus 3 and 6 having $\lambda = 1.7218$ and MWM % decrease= 83.24 is identified as critical contingency among the remaining contingencies of line unit outages and it is tabulated in table 6.

Table 06 CONTINGENCIES RANKING OF SINGLE LINE UNIT OUTAGES

Rank of the contingency	Generation unit outage	λ_{max} (p.u)	Percentage decrease in MWM
1	Line 2	1.7218	83.24
2	Line 5	1.7263	83.01
3	Line 7	2.6251	36.21
4	Line 3	2.6754	33.60
5	Line 8	2.6981	32.41
6	Line 10	2.7062	32.00
7	Line 6	2.7867	27.80
8	Line 9	2.9859	17.43
9	Line 4	3.1116	10.89
10	Line 11	3.1927	6.66
11	Line 1	3.2778	2.23

In line unit outage, line 2 connected to bus 3 and 6 is marked as critical contingency in the system. Similarly other lines are ranked on the basis of MWM percentage decrease, given in table 6.

B. IEEE 30 bus system

Continuation power flow is executed on IEEE 30 bus system with no contingency, maximum loading point λ_{max} is obtained as 5.5171. The base load active power which is the summation of total active power at the buses during no contingency is computed as 2.6488 p.u. The maximum load active power is the summation of total active power at the buses during contingency is 10.4383 p.u.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

(01) SINGLE GENERATION UNIT OUTAGES

In single generation unit outage contingency the values obtained are tabulated in table 7. In generation unit outage the bus number with lowest voltage magnitude is specified with loading factor, real and reactive power in the table.

Table 07 RESULTS OF GENERATION UNIT OUTAGES

Generation unit outage	Bus no with lowest voltage magnitude	Magnitude of lowest voltage in MLP (p.u)	λ_{max} (p.u)	P_{load} (p.u)	Q_{load} (p.u)
No contingency	8	0.9649	5.5171	0.3	0.3
Bus 2	8	0.4837	4.1774	1.2532	1.2532
Bus 13	8	0.5528	4.2926	1.2878	1.2878
Bus 22	21	0.5181	3.6892	0.6456	0.4132
Bus 23	8	0.5109	4.8285	1.4486	1.4486
Bus 27	30	0.6374	2.7428	0.2907	0.0521

The results obtained of MWM during zero level contingency are 7.7895. The values obtained of MWM and MWM % is tabulated in the table 8 for generation unit outages.

Table 08 MWM and %MWM FOR GENERATION UNIT OUTAGES

Level of contingency	Generation unit outage	P_{max} (p.u)	P_{base} (p.u)	MWM	MWM%
0	No contingency	10.4383	2.6488	7.7895	100
1	Bus 2	7.9036	2.6488	5.2548	67.4606
1	Bus 13	8.1215	2.6488	5.4727	70.2578
1	Bus 22	6.9799	2.6488	4.3312	55.6028
1	Bus 23	9.1356	2.6488	6.4868	83.2759
1	Bus 27	5.1893	2.6488	2.5405	32.6146

The values obtained of percentage decrease in MWM are tabulated in table 9. In generation unit outage connected to bus 27 having $\lambda = 2.7428$ and MWM % decrease = 67.39 is identified as critical contingency among the remaining contingencies of generation unit outage.

Table 09 CONTINGENCIES RANKING OF SINGLE GENERATION UNIT OUTAGES

Rank of the contingency	Generation unit outage	λ_{max} (p.u)	Percentage decrease in MWM
1	Bus 27	2.7428	67.39
2	Bus 22	3.6892	44.40
3	Bus 2	4.1774	32.54
4	Bus 13	4.2926	29.74
5	Bus 23	4.8285	16.72

In generation unit outage connected to bus 27 is marked as critical contingency in the system. Similarly other generator outages are ranked on the basis of MWM percentage decrease, given in table 3.

(02) LINE OUTAGES

In line unit outage values obtained are tabulated in table 10. The bus number with lowest voltage magnitude is specified with loading factor in the table.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

Table 10 SINGLE LINE UNIT OUTAGES

Outage line	Bus no with lowest voltage magnitude	Magnitude of lowest voltage in MLP (p.u)	λ_{max} (p.u)
No contingency	8	0.9649	5.5171
Line 1	8	0.6196	4.8899
Line 2	8	0.5042	4.9981
Line 3	8	0.5023	4.8611
Line 4	8	0.5054	5.0676
Line 5	7	0.5129	4.5952
Line 6	8	0.5102	4.5042
Line 7	8	0.5208	4.3307
Line 8	7	0.4879	4.541
Line 9	7	0.5701	3.7153
Line 10	8	0.5069	2.0345
Line 11	8	0.5089	5.2937
Line 12	8	0.4877	5.4031
Line 13	8	0.5029	5.5172
Line 14	8	0.5073	5.2941
Line 15	8	0.5008	5.4244
Line 17	8	0.5003	5.4373
Line 18	8	0.5053	5.3496
Line 19	8	0.5166	5.3469
Line 20	8	0.5026	5.5146
Line 21	8	0.5042	5.4483
Line 22	18	0.4853	4.6828
Line 23	8	0.5012	5.3736
Line 24	19	0.4735	4.1476
Line 25	20	0.4886	3.5987
Line 26	17	0.4733	3.8712
Line 27	8	0.4980	5.2389
Line 28	8	0.5004	5.3691
Line 29	21	0.5015	4.5867
Line 30	8	0.5205	5.2848
Line 31	8	0.5013	5.4947
Line 32	8	0.5149	5.3756
Line 33	8	0.4967	5.495
Line 35	8	0.5116	5.3685
Line 36	8	0.4880	5.1482
Line 37	29	0.5334	3.2365
Line 38	30	0.6899	2.4635
Line 39	30	0.5563	4.2177
Line 40	8	0.4979	5.2915
Line 41	8	0.5035	5.498

The result obtained of MWM during zero level contingency is 7.7895. The values obtained of MWM and MWM% is tabulated in table 11.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

Table 11 MWM and %MWM FOR LINE UNIT OUTAGES

Level of contingency	Generation unit outage	P _{max} (p.u)	P _{base} (p.u)	MWM	MWM%
0	No contingency	10.4383	2.6488	7.7895	100
1	Line 1	9.2517	2.6488	6.6029	84.7671
1	Line 2	9.4564	2.6488	6.8076	87.3946
1	Line 3	9.1971	2.6488	6.5483	84.0663
1	Line 4	9.5879	2.6488	6.9391	89.0830
1	Line 5	8.6942	2.6488	6.0454	77.6099
1	Line 6	8.5219	2.6488	5.8732	75.3986
1	Line 7	8.1936	2.6488	5.5448	71.1833
1	Line 8	8.5915	2.6488	5.9427	76.2905
1	Line 9	7.0294	2.6488	4.3806	56.2372
1	Line 10	3.8492	2.6488	1.2004	15.4107
1	Line 11	10.0156	2.6488	7.3668	94.5739
1	Line 12	10.2227	2.6488	7.5739	97.2318
1	Line 13	10.4385	2.6488	7.7897	100.0028
1	Line 14	10.0164	2.6488	7.3676	94.5836
1	Line 15	10.263	2.6488	7.6142	97.7494
1	Line 17	10.2873	2.6488	7.6385	98.0614
1	Line 18	10.1215	2.6488	7.4727	95.9326
1	Line 19	10.1164	2.6488	7.4676	95.8673
1	Line 20	10.4336	2.6488	7.7848	99.9395
1	Line 21	10.3082	2.6488	7.6594	98.3301
1	Line 22	8.8600	2.6488	6.2112	79.7384
1	Line 23	10.1669	2.6488	7.5181	96.5153
1	Line 24	7.8473	2.6488	5.1985	66.7371
1	Line 25	6.8087	2.6488	4.1599	53.4044
1	Line 26	7.3243	2.6488	4.6755	60.0235
1	Line 27	9.9119	2.6488	7.2632	93.2428
1	Line 28	10.1583	2.6488	7.5095	96.4059
1	Line 29	8.6780	2.6488	6.0292	77.4022
1	Line 30	9.9989	2.6488	7.3501	94.3592
1	Line 31	10.3959	2.6488	7.7471	99.4552
1	Line 32	10.1706	2.6488	7.5218	96.5631
1	Line 33	10.3965	2.6488	7.7477	99.4635
1	Line 35	10.1571	2.6488	7.5083	96.3905
1	Line 36	9.7405	2.6488	7.0917	91.0414
1	Line 37	6.1234	2.6488	3.4746	44.6066
1	Line 38	4.6608	2.6488	2.0120	25.8302
1	Line 39	7.9798	2.6488	5.3310	68.4386
1	Line 40	10.0114	2.6488	7.3626	94.5198
1	Line 41	10.4023	2.6488	7.7535	99.5383

In line unit outage, line 10 connected between bus 6 and 8 having $\lambda = 2.0345$ and MWM % decrease = 84.59 is identified as critical contingency among the remaining contingencies of line unit outages and it is tabulated in table 12.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

Table 12 CONTINGENCIES RANKING OF SINGLE GENERATION UNIT OUTAGES

Rankof the contingency	Generation unit outage	λ_{\max} (p.u)	Percentage decrease in MWM
1	Line 10	2.0345	84.59
2	Line 38	2.4635	74.17
3	Line 37	3.2365	55.39
4	Line 25	3.5987	46.60
5	Line 9	3.7153	43.76
6	Line 26	3.8712	39.98
7	Line 24	4.1476	33.26
8	Line 39	4.2177	31.56
9	Line 7	4.3307	28.82
10	Line 6	4.5042	24.60
11	Line 8	4.541	23.71
12	Line 29	4.5867	22.60
13	Line 5	4.5952	22.39
14	Line 22	4.6828	20.26
15	Line 3	4.8611	15.93
16	Line 1	4.8899	15.23
17	Line 2	4.9981	12.61
18	Line 4	5.0676	10.92
19	Line 36	5.1482	8.96
20	Line 27	5.2389	6.76
21	Line 30	5.2848	5.64
22	Line 40	5.2915	5.48
23	Line 11	5.2937	5.43
24	Line 14	5.2941	5.42
25	Line 19	5.3469	4.13
26	Line 18	5.3496	4.07
27	Line 35	5.3685	3.61
28	Line 28	5.3691	3.59
29	Line 23	5.3736	3.48
30	Line 32	5.3756	3.44
31	Line 12	5.4031	2.77
32	Line 15	5.4244	2.25
33	Line 17	5.4373	1.94
34	Line 21	5.4483	1.67
35	Line 31	5.4947	0.54
36	Line 33	5.495	0.54
37	Line 41	5.498	0.46
38	Line 20	5.5146	0.06
39	Line 13	5.5172	0

In line unit outage, line 10 connected to bus 6 and 8 is marked as critical contingency in the system. Similarly other lines are ranked on the basis of MWM percentage decrease, given in table 12.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

IV.CONCLUSION

In this paper, we have analysed static voltage stability by using power system contingencies like generator outage and line outage. Ranking of contingencies is done on the basis of percentage decrease in MWM and MLP by using continuation power flow method in PSAT. The results obtained during contingencies shows that reduction in voltage drop in the buses of the system, hence it gives reduce value of MWM and percentage decrease in MWM. Contingency having higher percentage decrease in MWM is placed at the top. The weak bus in the system can be found out by this method and corrective action can take place before system gets collapse.

REFERENCES

- [01] PrabhaKundur, "Power System Stability and Control", New York: McGraw-Hill, 1994.
- [02] K. B Hemalatha, S.T Jayachristra, "Power System Analysis", SCI TECH Publication, 2010.
- [03] R. K. Rajput, "A Textbook of Power System Engineering", Laxmi publication, 2012.
- [04] MostafaAlinezhad and MehrdadAhmadiKamarposhti, "Static Voltage Stability Assessment Considering the Power System Contingencies using Continuation Power Flow Method", InternationalJournal of Electrical and Electronics Engineering, 2010.
- [05] ArthitSode-Yome, NadarajahMithulananthan and Kwang Y. Lee, "A Maximum Loading Margin Method for Static Voltage Stability in Power Systems", IEEE Transactions on Power Systems, Vol. 21, Issue 2, May 2006.
- [06] KusumVerma, K.R. Niazi, "Supervised Learning Approach to on Line Contingency Screening And Ranking In Power System," Electrical Power and Energy Systems, 2012.
- [07] IrajRahimiPordanjani, YunfeiWang and WilsunXu, "Identification of Critical Components for Voltage Stability Assessment Using Channel Components Transform" IEEE Transactions on Smart Grid, Vol. 4, Issue 2, pp: 1122-1132, June 2013.
- [08] Sidhu T.S., Cui L., "Contingency screening for steady-state security analysis by using FFT and artificial neural networks", IEEE Transaction on Power System, Vol. 15, Issue 1, pp. 421-26, 2000.
- [09] Subramani C., SubhransuSekhar Dash,Vivek Kumar and Harish Kiran, "Implementation of Line Stability Index for Contingency Analysis and Screening in Power Systems", Journal of Computer Science Science Publications, pp: 585-590, 2012.
- [10] Ali Abdulwahhaband Abdulrazzaq, "Contingency ranking of power systems using a performance index", International Research Journal of Engineering and Technology, Vol 02, Issue 02, May 2015.
- [11] Udaykumar and Udaykuma, "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.
- [12]MoussaReda Mansour, Lufís Fernando Costa Alberto and Rodrigo Andrade Ramos, "Preventive Control Design for Voltage Stability Considering Multiple Critical Contingencies" IEEE Transactions on Power systems, Vol. 31, Issue 2, pp: 1517-1525, March 2016.
- [13]M Reddy Prasanna and C N Arpitha, "Voltage Stability Enhancement in Contingency Conditions Using Shunt Facts Devices" International journal of electric and electronic engineering and telecommunication, Vol. 2, Issue 1, 2001.