IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 3, March 2019

Voltage Stability Indices Calculation of Large Bus Power System

Swati S. Pande[1], Sagar T. Telrandhe[2], Dr. Shrikant D. Naik[3]

Student, Electrical Engineering Department, Ramdeobaba College of Engineering and Management, Nagpur, India[1,2]

Associate Professor, Electrical Engineering Department, Ramdeobaba College of Engineering and Management, Nagpur, India[3]

Abstract: This work deals with the study and calculation of Voltage Stability Indices for large bus power system which is performed using Power System Analysis Toolbox (PSAT). MATLAB offers flexible simulation environment for static voltage stability analysis using PSAT. This paper describes static voltage stability analysis with calculation of two voltage stability indices for American Electric Power Service Corporation network which comprises of 30 bus system.

Keywords: Power system; Static Voltage Stability; CPF; PSAT***;*** CPF; BPF.

I. INTRODUCTION

The worldwide increment of electricity usage tends to diverge the giant monopoly company into the section of three companies like Generation Company, Transmission Company and Distribution Company. The advancement in methods used for analysis and software improvement makes the problem solving time control of large power system reliable and secure operation of power systems. In the past, there were many incidences of blackouts due to power system instability because of which researchers shifts their focus to power system stability phenomenon. [1]

PSAT is a MATLAB toolbox for electric power system analysis and control. PSAT can do the power flow analysis and power system stability analysis with the help of continuation power flow method, optimal power flow method. All operations of PSAT can be assessed by means of Graphical User Interfaces (GUIs) and a Simulink-based library provides a user friendly tool for network design. [5]

II. POWER FLOW ANALYSIS

The prerequisite for conducting power system stability analysis is Power flow analysis. The power flow analysis is the numerical algorithms required to determine the steady state operating characteristics of a power system network from the data given by the lines and buses. The need of power flow studies is to plan power future expansions. For example, if in a case of emergency, it is mandatory to separate the transmission line from the power system, in that case is it taken into consideration that whether the remaining lines in the system handle the required loads without exceeding their rated values.[2]

A. Methods for power flow analysis

There are three methods of power flow analysis:
1. Newton-Raphson Method (N-R)

2. Gauss-Seidel Method (G-S)

3. Fast-Decoupled Method

Among these methods, we used N-R method because of its advantages over the other method which is discussed in next section. [3]

B. Newton Raphson method

N-R method is an important method for solving non-linear equations of large power system network. As it converges fast as compared to G-S method. The only disadvantage of this method is that it requires large computer memory which overcomes through a compact storage scheme. Figure 1 shows the flowchart of N-R method.[4]

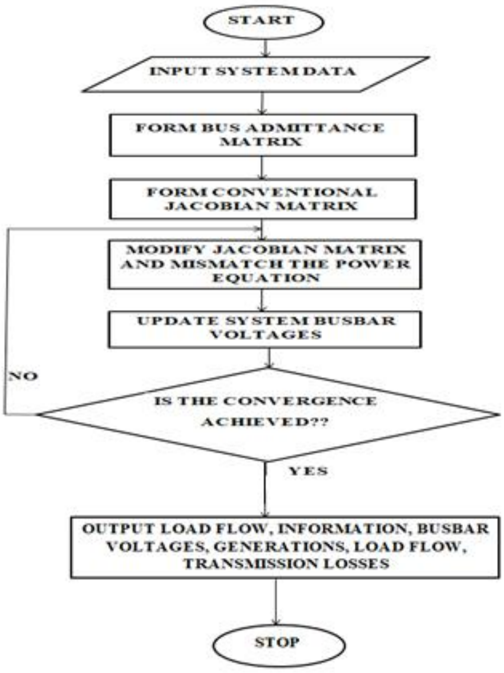


Figure 1 Flowchart of N-R Method

III. POWER SYSTEM STABILITY

The major requirement of power system is that it should operate stably at any point of time meeting all operational criteria under normal as well as emergency conditions. The emergency conditions may arise due to the credible contingencies in power system. Due to economic and environmental constraints today's power systems operate closer to their stability limits. The phenomenon of Voltage instability is associated with the overloaded power systems. Voltage instability may cause the increased transaction level leading to more stress on the power system. The dominant need of today's energy scenario is to address the voltage stability problems for keeping the voltage profile under control levels. In past few years, voltage stability is getting attention of researchers and electrical engineers as it is one of the main causes to threat power system security.[3]

A. Voltage Stability Analysis Tools

Different types of conventional methods for analysis of static voltage stability are classified into following types:-

1. P-V Curve method.
2. Q-V curve method and reactive power reserve
3. Modal analysis method based on the singularity of power flow Jacobian matrix at the point of voltage collapse.
4. Continuation power flow method (CPF)

Among these methods we have chosen CPF method considering the advantages over other methods.

B. Continuation power flow method (CPF)

CPF is the method that finds successive load flow solutions according to a load scenario. Method comprises of two steps i.e. prediction and correction step. Predictor step is used to estimate solution for designated pattern of load enlargement with a known base solution. The corrector step determined by the N-R method. After that a next predictor step based upon the next tangent vector after that the corrector step is applied on load. This process goes till the critical point reached. Once the tangent vector becomes null, then critical point is reached. The curve of predictor-corrector scheme is depicted in Figure 2.

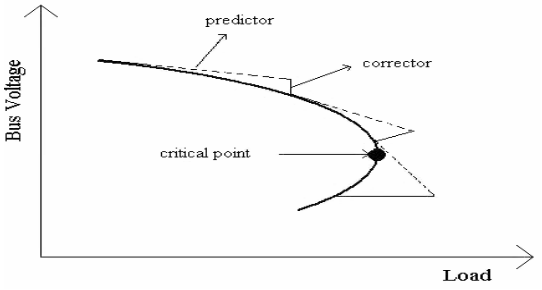


Figure 2 P-V Curve

Figure 3 represents the flowchart of continuation power flow.

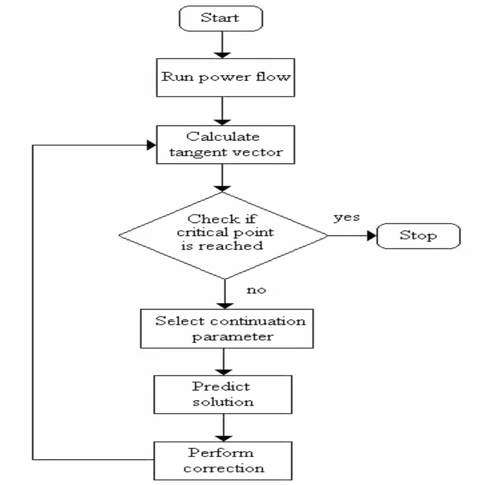


Figure 3 Flowchart of CPF

IV. VOLTAGE STABILITY INDICES

The voltage stability indices are introduced in order to evaluate the stability limit. Voltage stability indices are invaluable tools for gauging the proximity of a given operating point to voltage instability. The objective of the voltage stability indices is to quantify how close a particular point is to the steady state voltage stability margin. These indices can be used on-line or offline to help operators in real time operation of power system or in designing and planning operations. These indices will be presented to demonstrate how close to voltage instability a system can be operated and which could lead to blackout in large parts of the interconnected power system.

A. *Indices Formulation*

The condition of voltage stability in a power system can be known using voltage stability indices. These indices can either reveal the critical bus of a power system or the stability of each line connected between two buses in an interconnected network or evaluate the voltage stability margins of a system. For the paper work, we have chosen two voltage stability indices to formulate. One is the Bus Participation Factor (BPF) and another one is Voltage Sensitivity Factor (VSF).

B. *Bus Participation Factor (BPF)*

BPF gives the information on how effective reactive power compensation at a bus is required to increase the modal voltage at that bus. It is given by,

$$P_{ki} = \xi_{ki}\eta_{ik}$$

Thus, P_{ki} determines the contribution of λ_i of mode i to V-Q sensitivity at bus k. A bus with high participation factor indicates that it has large contribution to this mode. The size of bus participation in a given mode indicates effectiveness of remedial action applied at that bus. The advantage of modal analysis is that it clearly identifies groups

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 3, March 2019

of buses which participate in the instability so that reactive power compensation can be provided at less number of buses.

C. *Voltage Sensitivity Factor (VSF)*

VSF is a voltage stability index used to identify the voltage instability prone buses in a large system. Voltage stability factor for bus k is given by,

$$VSF = \frac{\text{Change in voltage for bus k}}{\text{Sum of change of voltages for all buses}}$$

Its value depends on how much drop in the voltage of affected bus is. While performing load flow analysis one of the buses (here, Bus 1) is taken as slack bus. The slack bus thus supplies the difference between the total system losses plus load and the complex powers specified at the other buses. Normally the bus connected to the largest generating station is selected as a slack bus.

V. IEEE 30 BUS SYSTEM SIMULATION

A. Characteristics of IEEE 30 bus system

The ratings of lines and buses of American Electric Power Services Corporation network which is being made available to the electric utility industry as a standard test case for evaluating various analytical methods and computer programs for the solution of power system problems is taken as the reference for constructing the model. The model comprises of 30 buses, 37 lines, 5 transformers and 20 loads. Figure 4 represents the IEEE 30 Bus system. [7]

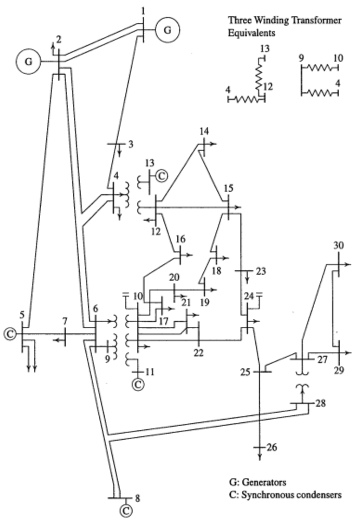


Figure 4 IEEE 30 Bus Systems

Table 1, 2, 3 and 4 shows the data given to the transformers, shunt capacitors, lines and buses respectively.

TABLE 1 DATA FOR TRANSFORMERS

Transformer Data	
Transformer Designation	Tap Setting pu
4 – 12	0.932
6 – 9	0.978
6 – 10	0.969
28 – 27	0.968

TABLE 2 DATA FOR SHUNT CAPACITORS

Injected Q due to Capacitors	
Bus No.	Mvar
10	19
24	4.3

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 3, March 2019

TABLE 3 DATA FOR LINES

BUS NL	BUS NR	R(pu)	X(pu)	1/2B(pu)
1	2	0.0192	0.0575	0.0264
1	3	0.0452	0.1852	0.0204
2	4	0.057	0.1737	0.0184
3	4	0.0132	0.0379	0.0042
2	5	0.0472	0.1983	0.0209
2	6	0.0581	0.1763	0.0187
4	6	0.0119	0.0414	0.0045
5	7	0.046	0.116	0.0102
6	7	0.0267	0.082	0.0085
6	8	0.012	0.042	0.0045
6	9	0	0.208	0
6	10	0	0.556	0
9	11	0	0.208	0
9	10	0	0.11	0
4	12	0	0.256	0
12	13	0	0.14	0
12	14	0.1231	0.2559	0
12	15	0.0662	0.1304	0
12	16	0.0945	0.1987	0
14	15	0.221	0.1997	0
16	17	0.0824	0.1923	0
15	18	0.1073	0.2185	0
18	19	0.0639	0.1292	0
19	20	0.034	0.068	0
10	20	0.0936	0.209	0
10	17	0.0324	0.0845	0
10	21	0.0348	0.0749	0
10	22	0.0727	0.1499	0
21	22	0.0116	0.0236	0
15	23	0.1	0.202	0
22	24	0.115	0.179	0
23	24	0.132	0.27	0
24	25	0.1885	0.3292	0
25	26	0.2544	0.38	0
25	27	0.1093	0.2087	0
28	27	0	0.396	0
27	29	0.2198	0.4153	0
27	30	0.3202	0.6027	0
29	30	0.2399	0.4533	0
8	28	0.0636	0.2	0.0214
6	28	0.0169	0.0599	0.065

TABLE 4 DATA FOR BUSES

				LOAD		GENERATOR				INJECTED
BUS NO.	BUS CODE	|V|	δ	MW	MVAr	MW	MVAr	Qmin	Qmax	MVAr
1	1	1.06	0	0	0	0	0	0	0	0
2	2	1.043	0	21.7	12.7	40	0	-40	50	0
3	0	1	0	2.4	1.2	0	0	0	0	0
4	0	1.06	0	7.6	1.6	0	0	0	0	0
5	2	1.01	0	94.2	19	0	0	-40	40	0
6	0	1	0	0	0	0	0	0	0	0
7	0	1	0	22.8	10.9	0	0	0	0	0
8	2	1.01	0	30	30	0	0	-10	40	0
9	0	1	0	0	0	0	0	0	0	0
10	0	1	0	5.8	2	0	0	0	0	19
11	2	1.082	0	0	0	0	0	-6	24	0
12	0	1	0	11.2	7.5	0	0	0	0	0
13	2	1.071	0	0	0	0	0	-6	24	0
14	0	1	0	6.2	1.6	0	0	0	0	0
15	0	1	0	8.2	2.5	0	0	0	0	0
16	0	1	0	3.5	1.8	0	0	0	0	0
17	0	1	0	9	5.8	0	0	0	0	0
18	0	1	0	3.2	0.9	0	0	0	0	0
19	0	1	0	9.5	3.4	0	0	0	0	0
20	0	1	0	2.2	0.7	0	0	0	0	0
21	0	1	0	17.5	11.2	0	0	0	0	0
22	0	1	0	0	0	0	0	0	0	0
23	0	1	0	3.2	1.6	0	0	0	0	0
24	0	1	0	8.7	6.7	0	0	0	0	4.3
25	0	1	0	0	0	0	0	0	0	0
26	0	1	0	3.5	2.3	0	0	0	0	0
27	0	1	0	0	0	0	0	0	0	0
28	0	1	0	0	0	0	0	0	0	0
29	0	1	0	2.4	0.9	0	0	0	0	0
30	0	1	0	10.6	1.9	0	0	0	0	0

VI. SIMULATION RESULTS

Figure 5 represents the simulated model IEEE 30 Bus System. In the model, Bus no. 26, 29 and 30 are assumed to be instable so load power directions are given to these buses. To maintain the stability the generator bus is provided with generator direction which is equal to the load direction given to bus number 26, 29 and 30. The P-V data with increment of loading parameter λ of bus no.26, 29 and 30 are given in table 5 and P-V curves of the same are shown in figure 6.

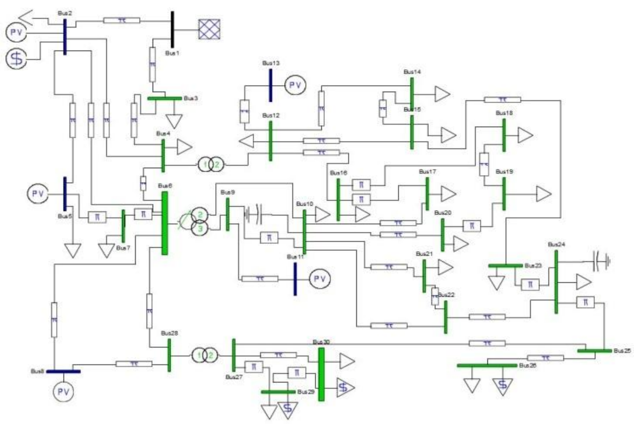


Figure 5 Simulated Model Of IEEE 30 Bus Systems

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 3, March 2019

TABLE 5 DATA OF BUS 26, 29 AND 30

CPF Results						
	BUS 26		BUS 29		BUS 30	
LAMBDA	PD (IN PU)	V (IN PU)	PD (IN PU)	V (IN PU)	PD (IN PU)	V (IN PU)
0	0.015	0.992147	0.014	0.999927	0.106	0.989607
0.349431	0.032	0.963377	0.031	0.968571	0.123	0.956283
0.698661	0.05	0.932226	0.049	0.934393	0.141	0.919919
1.04756	0.067	0.898014	0.066	0.896536	0.158	0.879577
1.395855	0.085	0.859658	0.084	0.853595	0.176	0.833721
1.742859	0.102	0.815203	0.101	0.80297	0.193	0.779492
2.086237	0.119	0.76036	0.118	0.738699	0.21	0.710287
2.410071	0.136	0.680285	0.135	0.638338	0.226	0.600963
2.442519	0.137	0.666306	0.136	0.619412	0.228	0.580088
2.469953	0.138	0.649819	0.137	0.596184	0.229	0.554311
2.483617	0.139	0.634293	0.138	0.573114	0.23	0.528503
2.48372	0.139	0.620043	0.138	0.550496	0.23	0.502959
2.470915	0.138	0.607253	0.137	0.528468	0.229	0.477797
1.896934	0.11	0.568647	0.109	0.370295	0.201	0.275442
1.542405	0.092	0.584146	0.091	0.338178	0.183	0.21567
1.191249	0.075	0.605371	0.074	0.323528	0.165	0.170711
0.841436	0.057	0.628763	0.056	0.319709	0.148	0.135664
0.492636	0.04	0.652495	0.038	0.322112	0.131	0.107846
0.145392	0.022	0.675607	0.021	0.327751	0.113	0.085492
0.110443	0.021	0.677887	0.019	0.328426	0.112	0.083493
0.075498	0.019	0.680157	0.018	0.329115	0.109	0.081536
0.040557	0.017	0.682417	0.016	0.329817	0.108	0.079621
0.005622	0.015	0.684666	0.014	0.330531	0.106	0.077747
0.002122	0.015	0.684891	0.014	0.330603	0.106	0.077562
0.001772	0.015	0.684914	0.014	0.33061	0.106	0.077544
0.001422	0.015	0.684936	0.014	0.330618	0.106	0.077525
0.001072	0.015	0.684959	0.014	0.330625	0.106	0.077507
0.000722	0.015	0.684981	0.014	0.330632	0.106	0.077488
0.000372	0.015	0.685004	0.014	0.330639	0.106	0.07747

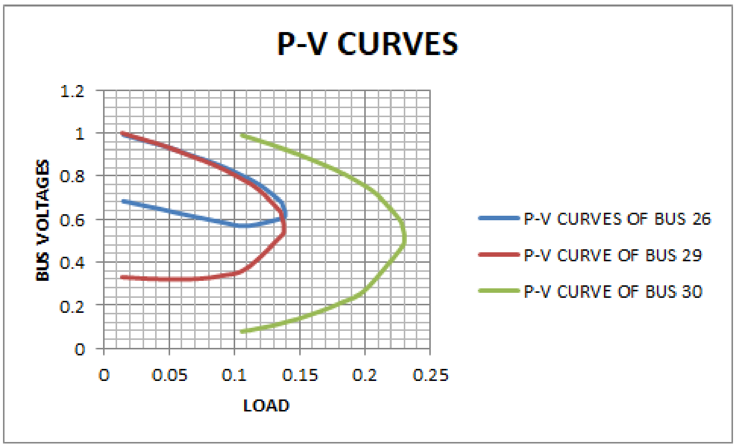


Figure 6 P-V Curves of Bus 26, 29 And 30

After conducting the CPF, BPF and VSF are needed to be found out. Results of BPF and VSF are shown in the table 6.

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

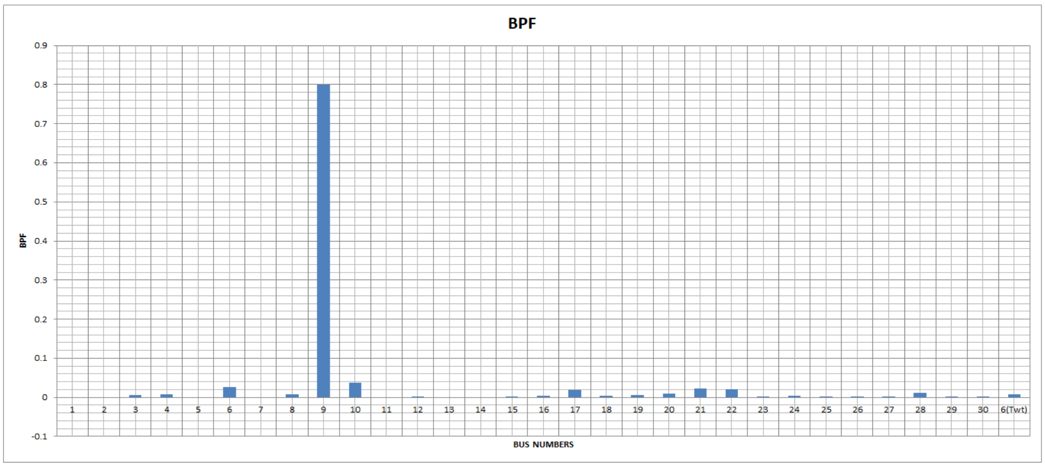
International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 3, March 2019

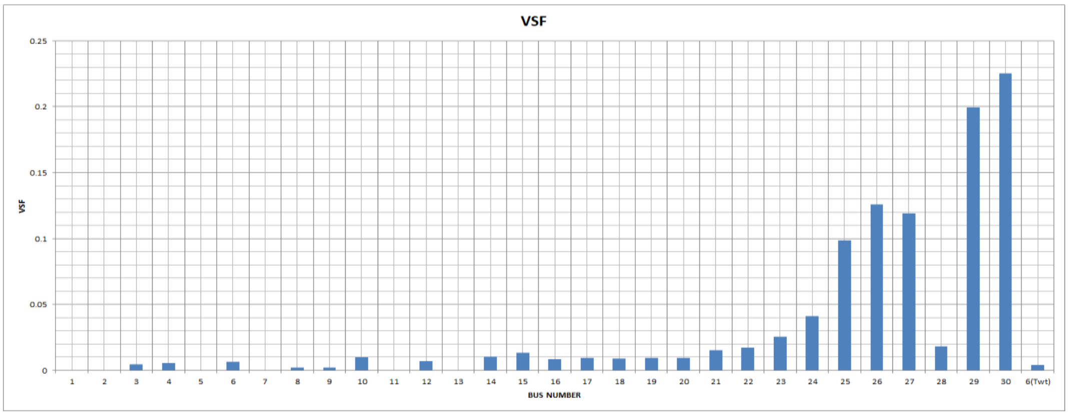
TABLE 6 BPF AND VSF RESULTS

BUS	BPF	VSF
1	0	0
2	0	0
3	0.005	0.005
4	0.009	0.005
5	0	0
6	0.026	0.007
7	0	0
8	0.007	0.002
9	0.801	0.002
10	0.038	0.01
11	0	0
12	2.00E-05	0.007
13	0	0
14	-9.34E-08	0.01
15	2.31E-05	0.014
16	0.004	0.009
17	0.019	0.009
18	0.004	0.009
19	0.007	0.009
20	0.01	0.01
21	0.023	0.016
22	0.021	0.017
23	0.0006	0.025
24	0.004	0.041
25	2.00E-05	0.099
26	7.77E-06	0.126
27	0.0009	0.119
28	0.012	0.018
29	0.0003	0.199
30	0.0002	0.225
6(Twt)	0.008	0.004

Figure 7 shows the bar graph of BPF and VSF.



A. BPF Result Bar graph



B. VSF Result Bar graph

DOI 10.17148/IJIREEICE.2019.7316

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 3, March 2019

CONCLUSION

Power system stability analysis is the main method in power system. The methods like CPF can give the prominent results that can give the information regarding voltage instability prone region. Once we get the information about which buses are most likely to get affected by the voltage instability we can make the arrangements of power compensator devices to reduce the voltage instability. Several voltage stability indexes derived from static power flow analysis were proposed for a utility power system. Loads are the driving force for voltage instability. Voltage regulators restore power that can be consumed by loads in case disturbances. It is possible to know, with modal analysis, which bus of the tested system contribute more to the voltage collapse. Figure 1 shows that the critical bus of this system is bus 9 because bus bars with high participation factors are considered the most vulnerable.

REFERENCES

[1]. You-Jie Ma, Shao-Feng, Xue-Song ZHOU, Zhi-Qiang GAO, *"Review of Static Voltage Stability Analysis of Power System",* International Conference on Mechanical Engineering and Control Automation (ICMECA 2017), Electronic ISSN: 2152-744X, August, 2017.

[2]. Lalit Kumar Gautam, Mugdha Mishra, Tanuj Bisht, *"A Methodology for Power Flow & Voltage Stability Analysis",* International Research Journal of Engineering and Technology (IRJET), 2015, Volume: 02, Issue: 02, ISSN: 2395-0072, pp. 321-326.

[3]. David Sarussi, Raul Rabinovici, *"Developing and analysis of power systems using PSAT software",* 2008 IEEE 25th Convention of Electrical and Electronics Engineers in Israel, Date of Conference: 3-5 Dec. 2008, INSPEC Accession Number: 10442752.

[4]. Federico Milano, Luigi Vanfretti, Juan Carlos Morataya, *"An Open Source Power System Virtual Laboratory: The PSAT Case and experience"*, IEEE Transactions on Education, Volume: 51, Issue: 1, Feb. 2008, pp.:- 17-23.

[5]. Antonino Barberi, Luigi Francesco Solarino, Diego La Cascia, Rosario Miceli, Gaetano Zizzo, *"Distribution grid analysis through PSAT open source tools",* 2015 International Conference on Renewable Energy Research and Applications (ICRERA), Date of Conference: 22-25 Nov. 2015.

[6]. *Power System Stability and Control* by Prabha Kundur.

[7]. *Power System Analysis* by Hadi Sadat.

[8]. *PSAT Software Manual* by Federico Milano.

[9]. G. Anderson, P. Kundur, and V. Vittal, *"Causes of the 2003 Major Grid Blackouts in North America and Europe, and Recommended Means to Improve System Dynamic Performance",* IEEE Transactions on Power Systems, Vol. 20, No. 4, November 2005.

[10]. *Computer methods in power system analysis* by Glenn W. Stagg.

[11]. Gao B, Morison G K, Kundur P, *"Voltage stability evaluation using modal analysis"*, J. IEEE Trans.on Power Systems, 1992,7 (4):1529-1541.

[12]. Abs S, Hamadan, *"Power Flow Convergence In The Vicinity Of a Voltage Stability Limit",* J. IEEE Trans. on Power Apparatus and Systems, 1978, 97(6):1983-1993.

[13]. Saba Akram, Qurrat ul Ann, " *Newton Raphson Method",* International Journal of Scientific & Engineering Research, Volume 6, Issue 7, July-2015; ISSN 2229-5518.