International Journal For Technological Research In Engineering
Volume 1, Issue 9, May-2014 *ISSN (Online): 2347 - 4718*

VOLTAGE STABILITY ANALYSIS OF POWER SYSTEM USING CONTINUATION POWER FLOW METHOD

Satish D. Patel[1] (P.G. Student), H.H. Raval[2] (Assistant Professor), Amit G.Patel[3] (P.G. Student)
Electrical Engineering Department, Merchant Engineering College
Basna, Mehsana, India.

Abstract: Growing rate of consumption of power in power systems, power plants and transmission lines usually works on the edge of stability, and it is possible that with a little increase in load or occurrence of a contingency, the system goes out of control. In such systems, maximum loading condition is almost determined in such a way that static stability of the system will be maintained not only in normal operation of the system but also in emergency conditions and in case of the occurrence of a contingency for at least one of the components of the system. In this paper, using a continuation power flow method and using change in load parameter, we analyze maximum loading of the system. We performed simulations on IEEE 14-bus test systems. Power system analysis toolbox (PSAT) is used as simulation environment for analyzing voltage stability performance of sample 14 bus system. Continuation power flow method is used as theoretical base for carrying out voltage stability performance analysis of the 14 bus system. It is used to obtain P-V curve of power system. In P-V curve Continuation power flow starting with initial operating point and increasing load to the maximum loading point.

Keywords: voltage stability, continuation power flow method, predictor –corrector step, power system analysis toolbox (PSAT).

I. INTRODUCTION

Increasingly growth of electricity consumption adds to the complexity of power systems then the system works at the proximity of instability. In specific terms, voltage stability is defined as the ability of a power system to maintain steady voltages at all the buses in the system after being subjected to a disturbance from a given initial operating condition. It depends on the ability to retain equilibrium between load demand and load supply from the power system. Instability that may affect appears in the form of a progressive go down or increase of voltages of a number of buses. [1], [2], [3]. Voltage stability problems mainly occur when the system is heavily stressed beyond its capability. While the disturbance leading to voltage collapse may be initiated by a variety of causes, the main problem is the inherent weakness in the power system. In most of the research work the voltage stability has been considered as static phenomenon. This is due to slow variation of voltage over a long time observed in most of the incident until it reaches to the maximum loading point and then it decreases rapidly to the voltage collapse. There are different types of voltage stability analysis methods say saddle node bifurcation theory, static and dynamic approach, and modal analysis. Singularity in the Jacobian can be avoided by vaguely reformulating the power flow equations and applying a locally parameterized continuation technique. So continuation power flow method gives the reformulated set of equations remains well conditioned so that divergence and error due to a singular Jacobian are not encountered.

II.CONTINUATION POWER FLOW METHOD

The common principle behind the continuation power flow is simple and easy. It employs a predictor-corrector scheme to find a solution path. It adopts locally parameterized continuation technique. It includes state variable load parameter, and step length for load parameter [1].

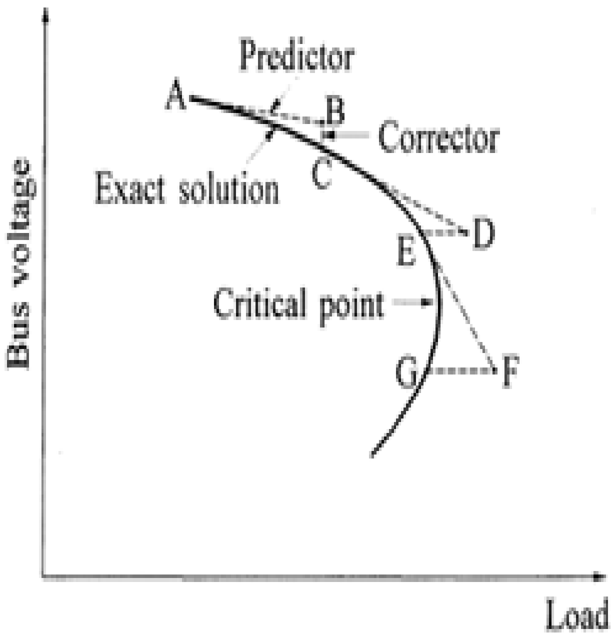

Fig. 1 An illustration of Prediction – correction step [2].

In this method mainly two modes is local parameterized and perpendicular iteration. Local parameterization allows not only the added load parameter, but also the state variables to be used as continuation parameters. Continuation power flow finds successive load flow solutions according to a load scenario. From a known base solution, a tangent predictor is used so as to estimate next solution for a specified pattern of load increase. The corrector step then determines the exact solution using Newton-Raphson technique employed by a conventional power flow. After that a new prediction is made for a specified increase in load based upon the new tangent vector [1]. Then corrector step is applied. This process goes until critical point is reached. The critical point is the point where the tangent vector is zero.

III. MATHEMATICAL REFORMULATION OF POWER FLOW EQUATION

To find successive load flow solution using continuation power flow, the load flow equation is reformulated by inserting load parameter λ. So, locally parameterization technique can apply. Using constant power load, the general form of power flow equation is:

$$P_i = \sum_{k=1}^{n} |V_i||V_k|(G_{ik}cos\theta_{ik} + B_{ik}sin\theta_{ik})$$

$$Q_i = \sum_{k=1}^{n} |V_i||V_k|(G_{ik}cos\theta_{ik} - B_{ik}sin\theta_{ik})$$

$$P_i = P_{Gi} - P_{Di},$$

$$Q_i = Q_{Gi} - P_{Di}$$

Where, The subscript G and D denote generation and load demand respectively on the related bus. In order to simulate a load change, a load parameter λ is inserted into demand power Pdi and Qdi.

$$P_{Di} = P_{Dio} + \lambda(P_{\Delta base}),$$

$$Q_{Di} = Q_{Dio} + \lambda(Q_{\Delta base})$$

Pdio and Qdio are original load demand on ith bus whereas P^{Δ}base and Q $^{\Delta}$base are given quantities of powers chosen to scale λ appropriately. The basic equations are similar to those of a standard power flow analysis except that the increase in load is added as a parameter. The reformulation power-flow equation, with provision for increases generation as the load increases, may as follows:

$$F(\theta, V) = \lambda K$$

Where,

λ Is the load parameter, Ɵ Is the vector of bus voltage angles, V is the vector of bus voltage magnitudes is the vector representing present load change at bus. The above set of nonlinear equation is solved by specified a value for λ such as that 0 ≤ λ ≤ λ critical.

IV. PREDICTOR STEPS

In the predictor step, a linear to approximation is usual to estimate the next solution for a change in one of the state variable [2]. Taking the derivation of both sides with state variable corresponding to the initial solution, will results in Following equations,

$$F_{\theta}d\theta + F_{V}dVF_{\lambda}d\lambda = 0$$

$$[F_{\theta} F_{v} F_{\lambda}] \begin{bmatrix} d\theta \\ dv \\ d\lambda \end{bmatrix} = 0$$

Since the intersection of λ in the equation added an unknown variable. This is satisfied by setting one of the components of the tangent vector to +1 or -1.

V. CORRECTOR STEP

In the corrector step, the original set of equations $F(\theta, V, \lambda) = 0$ is augmented by one equation that specifies the state variable selected as the continuation parameter [2]. Thus new set of equations is,

$$\begin{bmatrix} F(\theta, V, \lambda) \\ x_k \quad -\eta \end{bmatrix} = [0]$$

In above, xk is the state variable selected as continuation parameter and η is the equal to the predicted value of xk. The basic introduction of the additional equation specifying xk makes jacobian non-singular at the critical operating point.

VI. APPLICATION OF CONTINUATION POWER FLOW TO IEEE-14 BUS SYSTEM

Continuation power flow method is applied to following sample systems using matlab based power system analysis tools.IEEE-14 bus system consists of 3 generators, 20 transmission lines and 11 loads. IEEE-14 bus test system shown in Fig.2. The continuation power flow is run in different loading condition. Initially load parameter is one then plot P-V curve for all buses and find the weakest bus, then gradually increase the load parameter (λ). Continuation power flow is run up to bifurcation point, that means when maximum loading point reaches power flow will stop. Slack bus is used so all transmission losses distributed among all buses. At base case loading point lambda is taken 1 and load increasing at each bus proposional to base load. MATLAB and PSAT software's were used for simulation. To examine static voltage stability under different loading conditions, at first we performed continuation power flow, using PAST software, for normal condition of the system which all the component of the system are employed accurately. Then upon power plant unit outage, continuation power flow program is executed for the new structure and the obtained results are evaluated. The simulation is evaluated for different cases.

Case: I the results of continuation power flow analysis without considering load parameter variation.

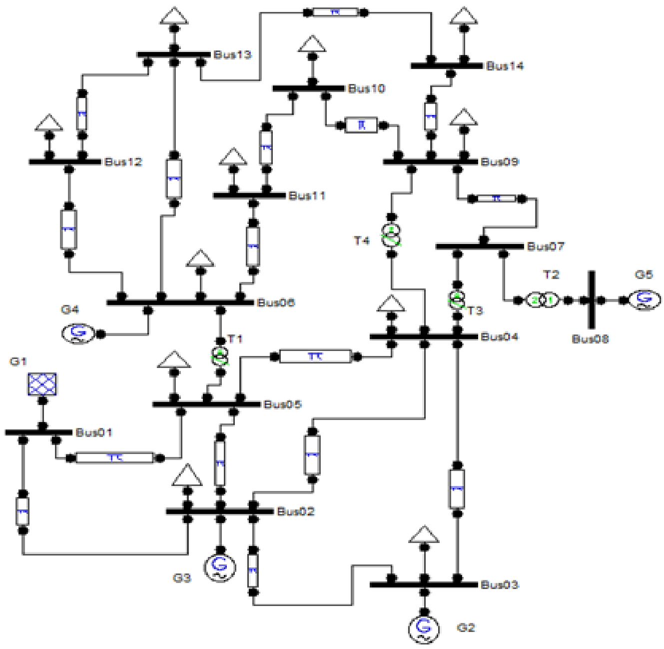

Fig: 2 Diagram of IEEE 14- bus systems simulated with PSAT

It is shown as well in Fig. 3 that buses 3, 4, and 14 have the most loading and hence, have less security margin than other buses. Bus 3 with the voltage of magnitude 0.91 p.u. identified as the weakest bus. In this system, we have 6.56 p.u. active power consumption and 3.45 p.u. reactive power consumption at maximum loading point, which is distributed over load's buses. Continuation power flow is applied again on IEEE 14-bus test system and critical regions are identified. In Figs. 3 and 4 it is shown that buses 14, 4 and 3 have the most loading compared to other buses.

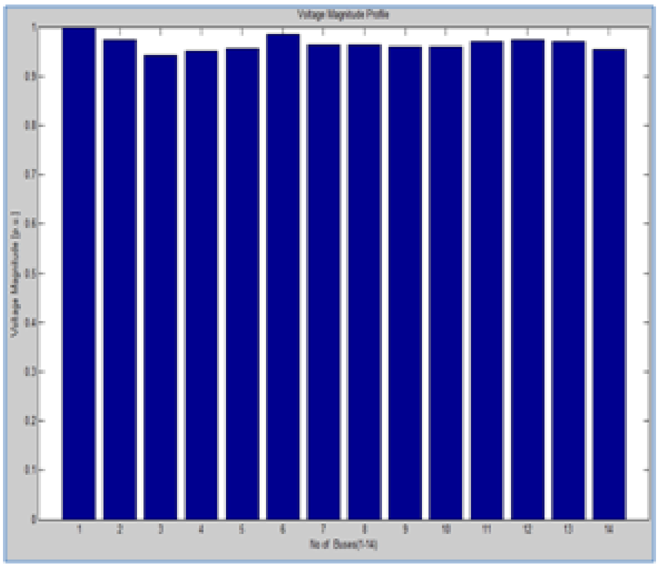

Fig. 3 Voltage Magnitude Profile

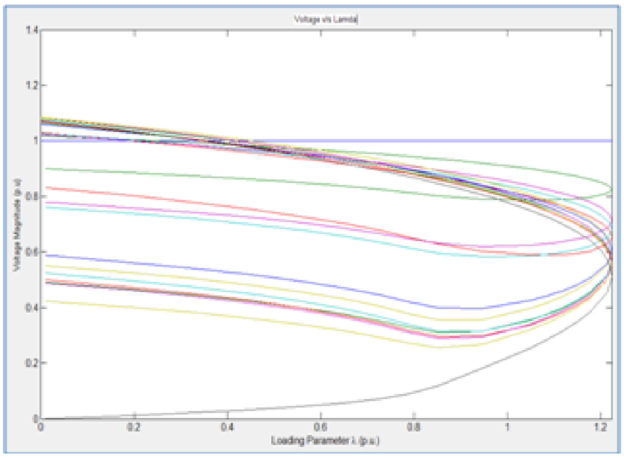

Fig. 4 V- λ curves for IEEE 14-bus test system

Case: II the results of continuation power flow analysis with considering load parameter variation.

It is shown as well in fig.5.7 that buses 3,9,10, and14 have the most loading and hence, have less secure then other buses. Bus 14, with the voltage of magnitude 0.8 p.u. identified as the weakest bus. The maximum loading parameter λ=1.2208. The real power is 247MW and reactive power is 97Mvar,and CPF is completed in 1.2243 second. So at this time system is much disturb as compeered to before scenario. By to this if demand is increase beyond its limit then more reactive power is drawn and losses are increase and real power is 2.47 p.u & reactive power is 0.97 p.u.

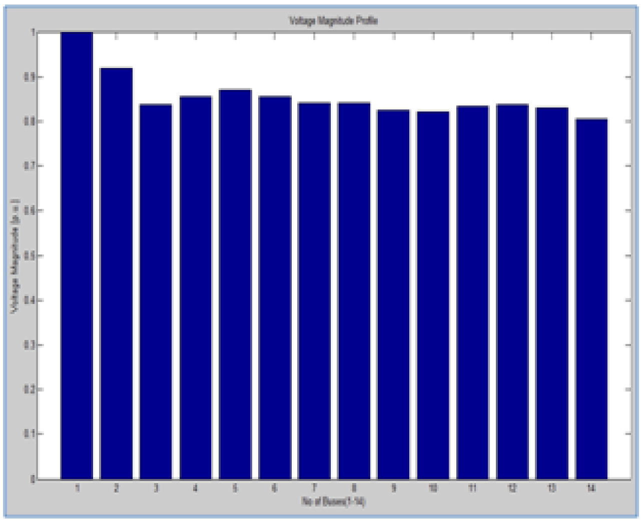

Fig. 5 Voltage Magnitude Profile

In fig. 7 shown bus 14 voltages to lambda is weakest bus in IEEE-14 system. When value of λ=1.25 is peak limit, so gradually increase and at end goes to down. So if we put compensation device then improve the voltage stability of the system.

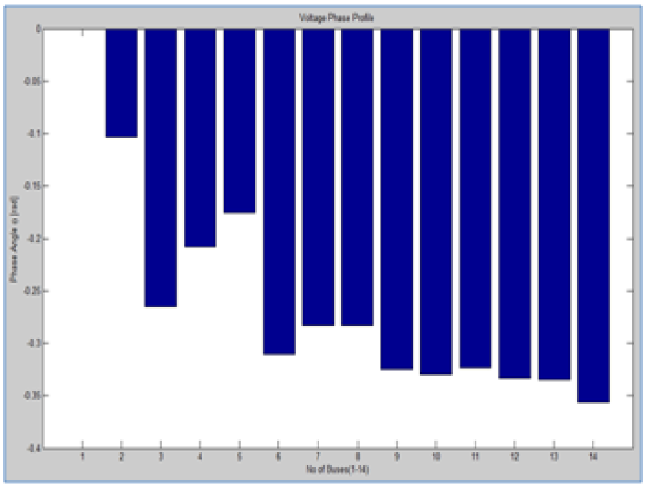

Fig. 6 V-ϴ Profile at change lambda

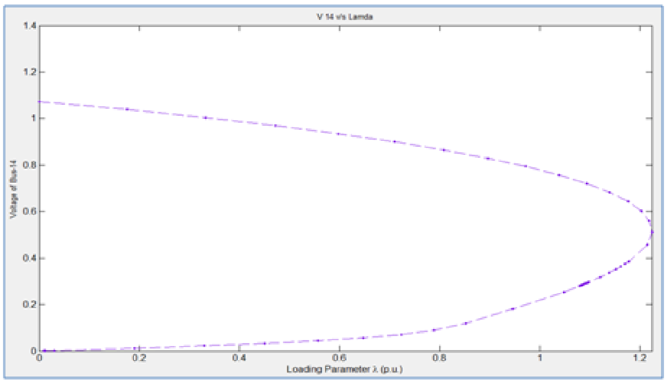

Fig. 7 V14-λ curves for IEEE 14-bus test system

In fig.7 is the weakest bus in IEEE-14 bus system. In this, When value of λ=1.25 is peak limit, so gradually increase and at end goes to down. So if we put compensation device then improve the voltage stability of the system.

VII. RESULTS

Table: I power flow results

POWER FLOW RESULTS						
Bus	V	Phase	P gen	Q gen	P load	Q load
	[p.u.]	[rad]	[p.u.]	[p.u.]	[p.u.]	[p.u.]
Bus01	1	0	1.4183	0.1387	0	0
Bus02	0.97473	-0.0577	0	0	0.11465	0.0671
Bus03	0.94294	-0.13405	0	0	0.49768	0.10038
Bus04	0.95169	-0.10863	0	0	0.25254	0
Bus05	0.95632	-0.0932	0	0	0.04015	0.00845
Bus06	0.98426	-0.15365	0	0	0.05917	0.03962
Bus07	0.9641	-0.1402	0	0	0	0
Bus08	0.9641	-0.1402	0	0	0	0
Bus09	0.9597	-0.15705	0	0	0.15585	0.0877
Bus10	0.95984	-0.15948	0	0	0.04755	0.03064
Bus11	0.96995	-0.15786	0	0	0.01849	0.00951
Bus12	0.97483	-0.16293	0	0	0.03223	0.00845
Bus13	0.97093	-0.16319	0	0	0.07132	0.03064
Bus14	0.95447	-0.17068	0	0	0.07872	0.02642

Table: II line flow results

LINE FLOWS						
From Bus	To Bus	Line	P Flow	Q Flow	P Loss	Q Loss
			[p.u.]	[p.u.]	[p.u.]	[p.u.]
Bus01	Bus05	1	0.42598	0.06205	0.01047	-0.05096
Bus01	Bus02	2	0.99236	0.07669	0.01941	-0.0437
Bus14	Bus13	3	-0.0339	-0.02887	0.00037	-0.00018
Bus04	Bus02	4	-0.27653	-0.06024	0.00495	-0.05439
Bus04	Bus03	5	0.13275	-0.01725	0.0013	-0.02772
Bus04	Bus05	6	-0.33241	-0.00824	0.00163	-0.01816
Bus07	Bus09	7	0.14163	0.03927	0	0.00164
Bus09	Bus10	8	0.0227	-0.01057	0.00005	-0.00086
Bus05	Bus02	9	-0.20079	-0.06318	0.00257	-0.05554
Bus14	Bus09	10	-0.04482	0.00245	0.00028	-0.00032
Bus10	Bus11	11	-0.02487	-0.04035	0.0002	-0.00047
Bus11	Bus06	12	-0.04356	-0.04939	0.00043	-0.00005
Bus03	Bus02	13	-0.36623	-0.08991	0.00723	-0.05012
Bus13	Bus06	14	-0.09561	-0.05094	0.00082	0.00066
Bus12	Bus06	15	-0.04225	-0.01594	0.00026	-0.00041
Bus13	Bus12	16	-0.00998	-0.0084	0.00005	-0.00091
Bus05	Bus06	17	0.2421	0.17767	0	0.02159
Bus08	Bus07	18	0	0	0	0
Bus04	Bus07	19	0.14163	0.04413	0	0.00486
Bus04	Bus09	20	0.08202	0.04161	0	0.00488

In table no.1 has shown the basic power flow results in detail. IEEE-14 bus system with voltage magnitude which in limit with different phase angle. Bus 01 is slack bus so its voltage is 1.0 p.u. and angle is zero. Real and reactive power for generation and load is also given. By to this we can easily understand total generation and load from global reports. At initial lambda the active power is 141MW demand and reactive power is 59Mvar. So system is work with in limit, there is no any unstable condition appear. If any change in load parameter then power flow result is also change. In table no.2 has shown the details of each bus report with its line number. The real power and reactive power for each bus is given. So we can identify weakest bus and also getting losses of both powers.

VIII. CONCLUSION

In this paper, for analyzing the greatest loading from the static point of view, we calculated the effects of change in load parameter by applying continuation power flow method in 14-bus test systems. The results reveal that the occurrence of emergency for the power plant unit in a power system, together with gradual increase of load, causes increasing voltage drop in buses, decreasing maximum loading point and more closeness of buses to instability and finally collapsing the system. Of course it must be emphasized that the effect of this incident on various points of the system that the occurrence of each one of these factors, causes a shift in the location of critical buses in the power system, so identification of those system regions that come under the influence of this Contingency has a special importance in the power systems. This CPF method is more accurate and simple for Voltage stability analysis.

REFERENCES

[1] Venkataramana Ajjarapu Computational Techniques for Voltage Stability Assessment and Control‖ E-Book— Library of Congress Control Number: 2006926216, Iowa State University, Department of Electrical and Computer Engineering. 1122 Coover Hall, Ames Iowa 50011, U.S.A.
[2] P. Kundur, ―Power System Stability and Control‖ McGraw-Hilll, 1994.
[3] J. Paserba, V. Ajjarapu, G. Andersson, A. Bose, C. Canizares, N. Hatziargyriou, D. Hill, A. Stankovic, C. Taylor, T. Van Cutsem, V. Vittal
[4] Satish Joshi, ―A Thesis on Voltage stability and contingency selection studies in electrical power system‖, Department of electrical engineering. Indian institute of technology Kanpur. December 1995.

