Volume 4, Issue 2
April 2015

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

Voltage Stability Evaluation using Model Analysis

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ABSTRACT

This paper analyses the voltage stability analysis of large power systems using a modal analysis technique. This method makes use of the power system Jacobian matrix to determine the eigenvalues necessary for the evaluation of the voltage stability of the power system. It identifies if the eigenvalues are positive or negative which is an indicator of the system stability. For a steady state power system, a positive eigenvalue shows that the system is stable while a negative eigenvalue indicates that the system is unstable. The analysis is performed for IEEE 14 Bus system. Then, the most critical mode is identified for each system. After that, the weakest bus, which contributes the most to the critical mode, are identified using the participation factor.

Keywords: Voltage Stability, Modal Analysis,Reduceed Jacobian Matrix ,Eigen value, Participation factor.

1. INTRODUCTION

The increasing number of power system blackouts in many countries in recent years; is a major source of concern. Power engineers are very interested in preventing blackouts and ensuring that a constant and reliable electricity supply is available to all customers. Incipient voltage instability, which may result from continues load growth or system contingencies, is essentially a local phenomenon. However, sequences of events accompanying voltage instability may have disastrous effects, including a resultant low-voltage profile in a significant area of the power network, known as the voltage collapse phenomenon. Severe instances of voltage collapse, including the August 2003 blackout in North - Eastern U.S.A and Canada, have highlighted the importance of constantly maintaining an acceptable level of voltage stability. The design and analysis of accurate methods to evaluate the voltage stability of a power system and predict incipient voltage instability, are therefore of special interest in the field of power system protection and planning.

The voltage stability of a power system refers to its ability to properly maintain steady, acceptable voltage levels at all buses in the network at all times, even after being subjected to a disturbance or contingency. A power system may enter a condition of voltage instability when the system is subjected to a steady increase in load demand or a change in operating conditions, or a disturbance (loss of generation in an area, loss of major transformer or major transmission line).

This causes an increased demand in reactive power. Voltage instability is characterized by gradually decreasing voltage levels at one or more nodes in the power system. Both static and dynamic approaches are used to analyze the problem of voltage stability. Dynamic analysis provides the most accurate indication of the time responses of the system [1]. Dynamic analysis is therefore extremely useful for fast voltage collapse situations, following large disturbances such as loss of generation and system faults, when specific information concerning the complex sequence of events leading to instability, is required. Dynamic simulations however, fail to provide information such as the sensitivity or degree of stability. More importantly, dynamic simulations are extremely time consuming in terms of CPU and engineering resources required for the computation and analysis of the several differential and algebraic equations needed for quantification of the phenomenon.

In most cases, the system dynamics affecting voltage stability are usually quite slow and much of the problem can be effectively analysed using the static approaches that examine the viability of a specific operating point of the power system. Static analysis methods, in addition to providing information such as sensitivity or degree of stability, involve the computation of only algebraic equations and are much more efficient and faster than dynamic approaches. The static analysis approach is more attractive than the dynamic method, and well suited to voltage stability analysis ofpower systems over a wide range ofsystem conditions [1-4].

Many static approaches for voltage stability analysis are presented in the literature, most utilizing a variation of the same common principle. Some popular static methods are summarized and contrasted in this document. The modal analysis of the load flow Jacobian presented by Gao, Morisson and Kundur in 1992, is of particular interest. This method, in addition to providing an accurate estimate of the system proximity to instability using the system eigenvalues, identifies the elements of the power system contributing the most towards incipient voltage instability (critical load buses, branches and generators). A prototype package for predicting incipient voltage stability is developed incorporating modal.

2.MODAL ANALYSIS

A.The Reduced Matrix Jr

In the Newton Raphson power flow there is the linear system model to represent the injected power in buses as shown in equation (1).

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{P\theta}\, J_{PV} \\ J_{Q\theta}\, J_{QV} \end{bmatrix} \begin{bmatrix} \Delta\theta \\ \Delta V \end{bmatrix} \qquad (1)$$

When the power is kept constant the above equation will become as shown as in the equation (2)

$$\begin{bmatrix} 0 \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{P\theta}\, J_{PV} \\ J_{Q\theta}\, J_{QV} \end{bmatrix} \begin{bmatrix} \Delta\theta \\ \Delta V \end{bmatrix} \qquad (2)$$

Q-V modal analysis method is proposed in [5] follows the reduced Jacobian matrix Jr to analyze eigenvalue and eigenvector of the power system. The relation between Jr, ΔQ and ΔV can be seen in equation (3).

$\Delta Q = Jr\Delta V$ (3)

The reduced Jacobian Matrix Jr can be found by solving the equation (4) below

$J_r = [J_{QV} - J_{Q\theta} J_{P\theta}^{-1} J_{PV}]$ (4)

$J = \xi\Lambda\eta \Leftrightarrow J - = \xi\Lambda - \eta$ (5)

B.The Global VSI value

Voltage Stability Indexes (VSI) is needed to give the system security of the power system. Modal analysis is one of the global VSI that can measure the voltage stability [5-6].

Incremental change in reactive power will affect the incremental voltage by substituting equation (3) with equation (5) we can get equation (6):

$\Delta V = \xi\, \Lambda^{-1}\eta\Delta Q$ OR $\Delta V = \sum_i \frac{\xi_i \lambda_i}{\eta_i} \Delta Q$ (6)

Where

λi is ith eigen value

ξi is the ith column right eigenvector

ηi is the ith row left eigenvector

Therefore, the ith modal reactive power variation is

$\Delta Q_{mi} = k_i \xi_i$

where k_i is a normalization factor such that

$k_i^2 \Sigma \xi_{ji}^2 = 1$

The ith modal variation can be written

$$\Delta V_{mi} = \frac{1}{\lambda_i} \Delta Q_{mi} \qquad (7)$$

The voltage stability can be defined by the mode of eigenvalue λi. The minimum eigenvalue in a power system is the global VSI value. Larger value of λi will give smaller changes in the voltages when the small disturbance happen. When the system is weaker, the voltage becomes weaker. A system is stable when the eigenvalue of Jr is positive. The limit is reached when one of the eigenvalue reach zero. If one of the eigenvalue is negative the system is unstable.

C.Bus Participation

Left and right eigenvectors corresponding to the critical modes in the system can provide information concerning the mechanism of voltage instability. The bus participation of the bus can be defined as

$$P_{ki} = \xi_{ki} \eta_{ki} \qquad (8)$$

Bus participation factors show the voltage stability of nodes in the power system. Bus participation factors show in a matrix form called participation matrix. The row of the matrix indicates the bus number and the matrix column indicate the system mode. The bigger value of the bus participation factor indicates the more affecting bus to the power system.

D. Voltage Stability Assessment

It is useful to establish and facilitate a systematic and complete method for voltage stability analysis and prediction of incipient voltage instability in the power network. As seen previously P-V/Q-V curves cannot be used alone in large practical networks since there is no way to precisely determine beforehand, for many different operating points and contingencies, exactly which nodes and areas are susceptible to instability. Methods such as minimum singular value do not readily provide information in to the main factors contributing to voltage instability.

The modal analysis technique however can be seen as extremely useful since it provides a relative proximity of the system to voltage instability as well as the key contributing factors to instability such as the weakest or critical buses and transmission branches. A simple systematic technique for initial assessment of modal analysis for voltage stability prediction can be done as follow:

1. Initiate the normal operating condition using the load flow analysis
2. Perform the modal analysis to get the global VSI (minimum eigenvalue)
3. Find the weakest bus in the power system
4. Repeat the step 2 and 3 to do the real time monitoring

3. SIMULATION AND EXPERIMENTAL VERIFICATION

A) Circuit Diagram And Discription

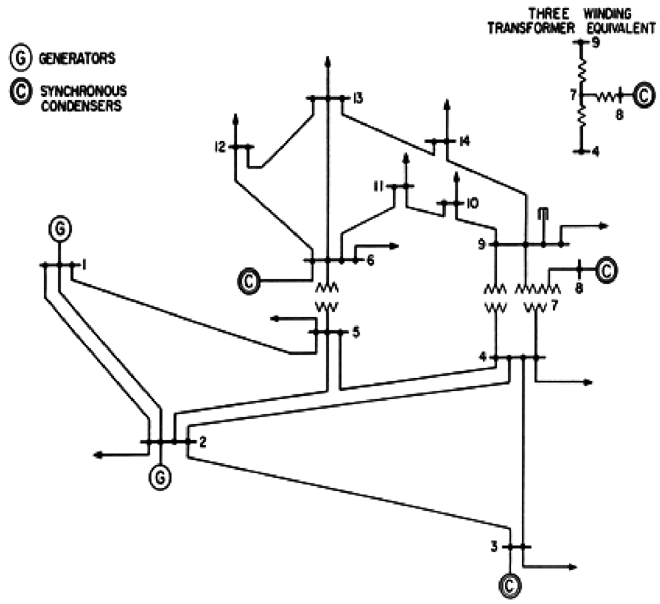

FIG 1: The IEEE 14-bus test system

B) Circuit Discription

A IEEE 14-bus test system as shown in Fig. 3 is used for voltage stability studies. The test system consists of five generators (bus no. 1,2,3,6 and 8) , eleven PQ bus or load bus(bus no. 4,5,7,9,10,11,12,13 and 14) and 20 transmission lines. The Modal analysis method has been successfully applied to the IEEE 14 bus power system. The eigen value analysis are done for selected buses in order to identify the weakest bus. A power flow program based on Matlab is developed to:

1. Calculate the load flow solution.
2. Analyze the voltage stability based on modal analysis.

The modal analysis method is applied and the voltage profile of the buses is presented from the load flow simulation. Then, the minimum eigenvalue of the reduced Jacobian matrix is calculated. After that, the weakest load buses, which are subject to voltage collapse, are identified by computing the participating factors. The results are shown as follows.

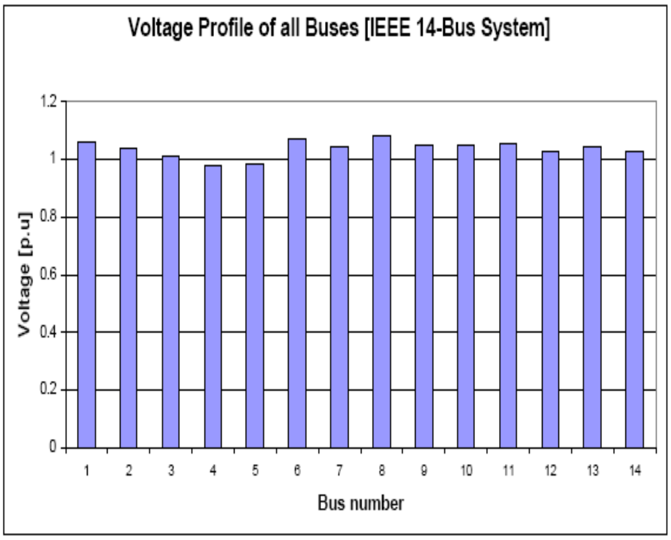

FIG 2: Voltage profile of all buses

Figure 2 shows the voltage profile of all buses of the IEEE 14 Bus system as obtained from the load flow. It can be seen that all the bus voltages are within the acceptable level (± 5%). Since there are 14 buses among which there is one swing bus and 4 PV buses, then the total number of eigenvalues of the reduced Jacobian matrix *JR* is expected to be 9 as shown in table

Bus	1	2	3	4	5	6	7	8	9
Eigen value	65.1	39.2	21.6	18.8	16.2	11.2	2.69	5.52	7.59

TABLE 1: IEEE 14 Bus system eigenvalues

Note that all the eigenvalues are positive which means that the system voltage is stable. From Table 1, it can be noticed that the minimum eigenvalue λ = 2.6943 is the most critical mode. The participating factor for this mode has been calculated and the result is shown in Figure 3.

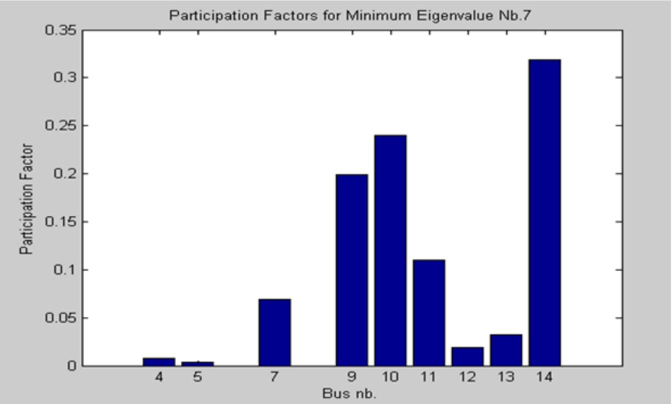

FIG 3: Participating factor for most critical mode

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

The result shows that, the buses 14, 10 and 9 have the highest participation factors for the critical mode. The largest participation factor value (0.327) at bus 14 indicates the highest contribution of this bus to the voltage collapse.

Therefore it is identified that the weakest bus on the IEEE 14 bus power system is bus no.14.

4. CONCLUSION

In this paper, The Modal analysis technique is applied to investigate the stability of the power systems and that method computes the smallest eigenvalue and the associated eigenvectors of the reduced Jacobian matrix using the steady state system model. The magnitude of the smallest eigenvalue gives us a measure of how close the system is to the voltage collapse. Then, the participating factor can be used to identify the weakest node or bus in the system associated to the minimum eigenvalue. The obtained results agreed about the weakest buses that contribute to voltage instability or voltage collapse. The modal analysis feature was tested on IEEE-14 bus test system. The technique was demonstrated as an extremely useful method for steady state voltage stability analysis, providing relative measure of the system to the stability limit, and correctly predicting the critical buses and weak transmission branches in the power network.

5.REFERENCES

[1] B. Gao, G. K. Morison, and P. Kundur," **Towards the development of a systematic approach for voltage stability assessment of large-scale power systems**", IEEE transactions on power systems, vol. 11 , no. 3, pp 1314-1319, (August 1996).(3)

[2]P. Kundur, "**Power System Stability and Control**", New York, NY: McGraw-Hill, 1994

[3] **C.W. Taylor, "Power System Voltage Stability",**
McGraw-Hill, 1993.

[4] Qiu Xiaoyan; Li Xingyuan; Xu Jian; Xia Lili; , "AC/DC Hybrid Transmission System Voltage Stability Analysis Based on Singular Value Decomposition Method," *Power and Energy Engineering Conference (APPEEC), 2010 Asia-Pacific* , vol., no., pp.1-4, 28-31 March 2010.

[5]B. Gao, G. K. Morison, and P. Kundur, **"Voltage stability evaluation using modal analysis, "** IEEE Trans. Power Syst.7: 1529-1536, 1992

[6]Chandrabhan Sharma, Senior Member, IEEE and Marcus G Ganes. Determination of the Applicability of using Modal Analysis for the Prediction ofVoltage Stability. Transmission and Distribution Conference and Exposition, 2008. T&D. IEEE/PES

[7]M. Begovic, D. Fulton, M.R. Gonzalez, J. Goossens, E.A. Guro, R.W. Haas, C.F. Henville (Chairman), G. Manchur, G.L. Michel, R.C.. Pastore, J. Postforoosh, G.L,

[8]- IEEE Committee report. "Voltage stability ***of*** power systems: Concepts. Analytical tools. and Industn experience, IEEE publication **90TH0358-2** PUR

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