Voltage Stability Study of IEEE 14 Bus System Using MATLAB simulation

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Abstract- **The paper discusses voltage Stability as a major concern in planning and operations of power systems. It is well known that voltage instability and collapse have led to major system failures: with the development of power markets, more and more electric utilities are facing voltage stability –imposed limits. The problem of voltage stability may be explained as inability of the power system itself. It is understood as a reactive power problem and is also a dynamic**
phenomenon. The objective of this work is to developed a fast and simple method which can be applied in the power system online, to estimate the voltage stability margin of the power system.

Key words- **Voltage stability- power system- planning –operation P-Q and P-V Curves- MATLAB- IEEE-14 Bus System- voltage stability indicator**

I. INTRODUCTION

In general, the analysis of voltage stability problem of a given power system should cover the examination of the following aspects:

- How close is the system to voltage instability or collapse?
- When does the voltage instability occur?
- Where are the vulnerable spots of the system ?
- What are the key contributing factors?
- What areas are involved?

Voltage Stability analysis often requires examination of lots of system states and many contingency scenarios. For this reason, the approach based on the steady state analysis is more feasible, and it can also provide insights of the voltage reactive power problem. The following methods have been proposed to be used in the work for voltage stability analysis:

1. Repeated load flow studies of IEEE 14 Bus test system
2. Sensitivity analysis approach
3. Measurement based voltage stability analysis

The above methods have been proposed using static approach. Voltage stability indeed is dynamic phenomenon. Some utilities use Q-V curves at some load buses to determine the proximity to voltage –instability. One problem with Q-V curve method is that by focusing on a small number buses, the system –wide problem will not be properly unveiled. This work explores the on-line monitoring index of the voltage Stability, which is derived from the basic power flow and Kirchoff's law. A derivation will be given. The index of the voltage stability predicts the voltage problem of the system with sufficient accuracy. This voltage stability index works well in the static state as well as during dynamic process. It can also be used to find vulnerable spots of the system, the stability margin based on the collapse point, and the key factors for the voltage stability problem, etc. This work uses MATLAB for programming for the solution of the problem

It is desirable that voltage at different buses in a power system is equal to the nominal value (i.e. 1 p.u.) at all times. Many phenomena tend to make the actual voltage different from the nominal value. An unacceptable voltage level means voltage instability. If the voltage departs too much from the nominal value, the phenomenon is known as voltage collapse. Large system disturbances may lead to voltage instability or even voltage collapse. The system voltage may decline progressively leading to unacceptable voltage level. Sometimes voltage instability may be oscillatory in nature. Power systems must be planned, designed, installed and operated in such a manner so as to avoid voltage instability and voltage collapse. Voltage stability is a major concern in planning and operations of power systems. It is well known that voltage instability and collapse have led to major system failures; with the development of power markets, more and more electric utilities are facing voltage stability-imposed limits.

The problem of voltage stability may be simply explained as inability of the power system to provide the reactive power or the egregious consumption of the reactive power by the system itself. It is understood as a reactive power problem and also is a dynamic phenomenon.

The objective of this dissertation is develop a fast and simple method, which can be applied in the power system on line, to estimate the voltage stability margin of power system. For this P-V curve and Q-V curve are plotted using Gauss-Seidel method. Voltage stability analysis often requires examination of lots of system states and many contingency scenarios. Hence in this work V-Q sensitivity analysis is done considering the line outage contingency along with base case using Newton- Raphson method. In addition to above two approaches, this work explores the on-line monitoring index of the voltage stability, which is derived from the basic static power flow and Kirchoff's law. The index of the voltage stability predicts the voltage problem of the system with sufficient accuracy. This voltage stability index can work well in the static state as well as during dynamic process. It can also be used to find the vulnerable spots of the system , the stability margin based on the collapse point, and the key factors of the voltage stability problem.

II CLASSIFICATION OF METHODS OF VOLTAGE STABILITY ANALYSIS:-

A.. Introduction

Many algorithms have been proposed for voltage stability study. Most of the utilities have a tendency to depend regularly on conventional load flows. For such analysis, the study of voltage stability for planning and operation of a power system mainly involves the examination of how close the system is to voltage instability (i.e., proximity) can provide information regarding voltage security.

Many techniques have been proposed in the literature for evaluating and predicting voltage stability using steady state analysis methods.

The voltage stability analysis can be accomplished by any or all of the following methods as:

1) Using P-V and P-Q curves
2) V-Q sensitivity analysis
3) Q-V Modal analysis
4) Measurement based static and dynamic approach using voltage stability indicator

B. Using P-V and P-Q curves The P-V curves, active power – voltage curves are the most widely used method of predicting voltage security. They are used to determine the MW distance from the operating point to the critical voltage.

Q-V curve technique is a general method of evaluating voltage stability. Q-V curve gives, how much reactive power injection at a bus is required to obtain a certain voltage for a constant real power. It mainly presents the sensitivity and variation of bus voltages with respect to the reactive power injection. V-Q or Voltage–Reactive power curves are generated by series of power flow simulation. They plot the voltage at a test bus or critical bus versus reactive power at the same bus, the bus is considered to be a PV bus, where the reactive output power is plotted versus scheduled voltage. Most of the times these curves are termed as Q-V curves rather than V-Q curves. Scheduling reactive load rather than voltage produces Q-V curves. These curves are more general method of assessing voltage stability.

C. V-Q sensitivity analysis

System voltage stability is affected by both P and Q. However at each operating point we may keep P constant and evaluate voltage stability by considering the incremental relationship between Q and V this is analogous to the Q-V curve approach. Although incremental changes in P are neglected in the formulation, the effects of changes in system in load or power transfer level taken into account by studying the incremental relationship between Q and V at different operating conditions.

Based on above considerations, let $\Delta P = 0$

Then $\Delta Q = J_R \, \Delta V$

Where $J_R = [J_{qv} - J_{q\theta} J_{p\theta}^{-1} J_{pv}]$

And J_R reduced jacobian matrix of the system $\Delta V = J^{-1} \Delta Q$

The matrix is reduced V-Q jacobian. Its diagonal element is V-Q sensitivity at bus i. For computational efficiency, this matrix is not explicitly formed. The V-Q sensitivities are calculated by solving. The V-Q sensitivity at a bus represents the slope of the Q-V curve at the given operating point.

♦A positive V-Q sensitivity is indicative of stable operation.

♦The smaller the sensitivity, more stable the system.

♦As stability decreases, the magnitude of sensitivity increases, becoming infinite at the stability limit.

♦conversely a negative V-Q sensitivity is indicative of unstable operation.

♦A small negative sensitivity represents a very unstable operation.

D. Measurement based static and dynamic approach using voltage stability indicator

This is a fast and simple method, which can be applied in the power system online to estimate the voltage stability margin of the power system. In general, the analysis of voltage stability problem of a given power system should cover the examination of these aspects: how close is the system to voltage instability? Where are the vulnerable spots of the system? What are the areas involved? This method is based on static power flow and Kirchoff's law. The indicator of voltage stability calculated in this method predicts the voltage problems of the system with sufficient accuracy. The voltage stability indicator can work well in static state as well as during dynamic process. It can also be used to find the vulnerable spots of the system, the stability margin based on the collapse point, and the key factors of the voltage stability problem etc.

III CASE STUDY Using IEEE 14 bus system:-

The IEEE 14 Bus system data was used to carry out study of the voltage stability. First of all load flow solution was obtained using Gauss- sediel method. Then P-V and Q-V curves were obtained at bus 5. Secondly the Jacobian Matrix was obtained to find the V-Q sensitivity of the system. Third par t of the work voltage curve at bus 2 and voltage stability indicator curve were obtained in MATLAB environment.

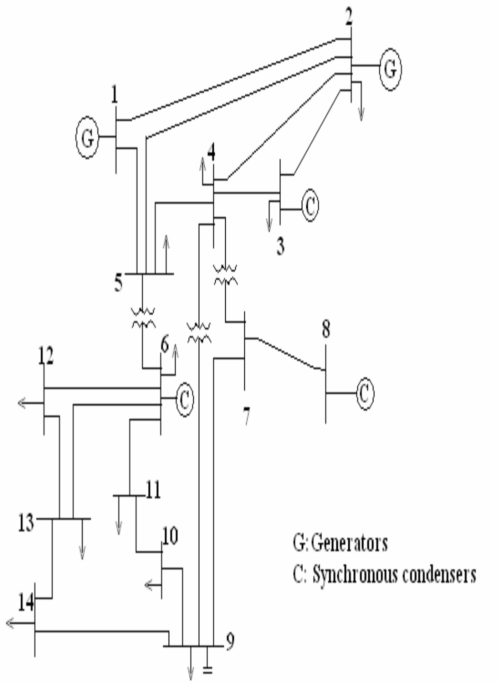


Fig. .1 : 14-bus IEEE sample system

III RESULTS

The results obtained by various methods are as shown below:

III (a) By P-Q and PV Curve Method

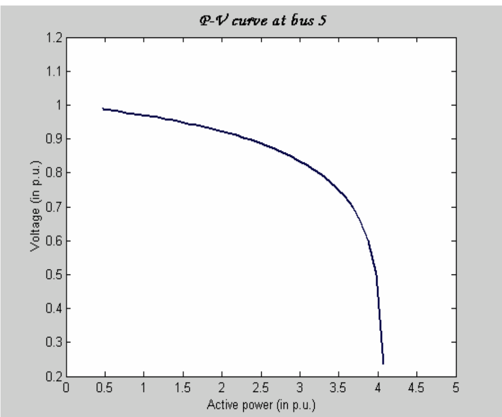


Fig. .2 P-V Curve at bus No.5

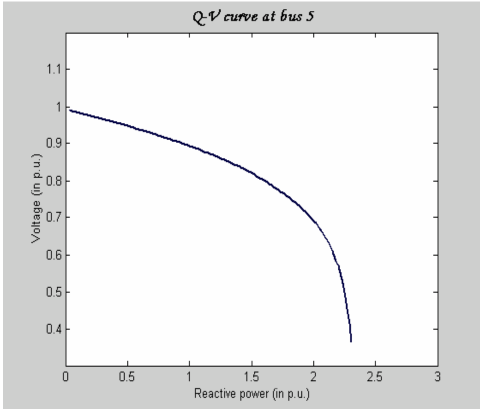
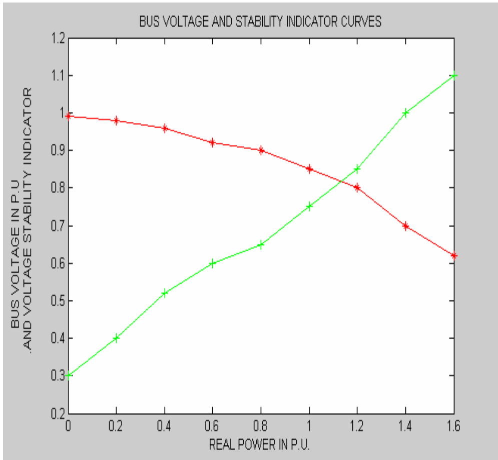


Fig. .3 Q-V Curve at bus No.5

II (b) By voltage stability index/ indicator Method



Bus Voltage curve at bus 2

Voltage Stability Indicator curve

Fig 4 Bus Voltage Curve and Voltage Stability Indicator curve

CONCLUSION

From the case study following conclusions can be made:

1] The maximum loading point for each bus can be found by plotting the P-V and Q-V curves.

2] It can be concluded that to ensure the voltage stable operation of the system, care should be taken not to allow the load on the system to exceed the critical or maximum loading point. In general an indicator of the voltage stability is defined as:

$$VSI_b = (1+V_{oj}/ V_j) =| S_j/ Vj^2*Y_{jj} \;| \text{ ------------ } (1)$$

3] When Sj = 0 , the indicator will be zero and this indicates that there will be no voltage problem.
4] When the load at the bus changes, it will influence the indicator VSI_b.
5] From the fig. 4 it is seen that the voltage at the bus 2 is decreasing as the voltage stability indicator curve is rising. Hence it can be concluded that as voltage stability indicator value increases; that denotes the voltage at that bus collapses if indicator curve is showing continuous and sharp rise. It can also be concluded that the voltage at the bus is stable if the indicator (VSI_b) is small. In other words it can be said that there is no voltage problem at the bus if VSI_b is negligible.
6] From the equation:

$$\acute{S}_j = S_j + \sum_{i \neq j \text{ and } i \rightarrow L} (Z_{ji} * S_j / Z_{jj} * V_i) * V_j \quad \text{-------------} \ (2)$$

Thereby it is clear that the indicator of the voltage stability at a load bus is mainly influenced by the equivalent load $\acute{S}_j$, which has two parts: the load at bus j itself, and the 'contributions' of the other load buses, shown by equation (2) above.

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BIOGRAPHY

Yogesh Yashawant Pundlik, was born in Yeotmal on 23rd December 1974. He graduated from Nagpur University. He has done post graduation from JNTU (Jawaharlal Nehru Technological University) College of Engineering Kakinada. Presently he is pursuing part time PhD in JNTU, Kakinada and working as associate professor and Head of Department of EEE, KITS, Singapur (Andhra Pradesh).

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