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Enhancement of Voltage Stability on IEEE 14 Bus Systems Using Static VAR Compensator

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Abstract: **This paper investigates the effects of Static Var Compensator (SVC) on voltage stability of a power system. One of the major causes of voltage instability is the reactive power limit of the system. Improving the system's reactive power handling capacity via Flexible AC transmission system (FACTS) devices is a remedy for prevention of voltage instability and hence voltage collapse. The effects of Static Var Compensator (SVC) in static voltage stability margin enhancement will be studies. Prediction of the stability margin or distance to voltage collapse is based on the reactive power load demand. The load is connected to several selected buses. The analysis is performed for IEEE 14 Bus system. Then, the most critical mode is identified for each system. IEEE standard test system has been considered and Load flows were computed by using Newton Raphson method with the help of MATLAB and a weak bus is identified.**

Keywords: **IEEE 14 bus system, SVC, MATLAB (PSAT).**

1. INTRODUCTION

As a result of ever-increasing demand of electric power, the electricity supply industry is undergoing profound transformation worldwide. This makes the existing power transmission system highly complex. The basic power flow equation through a transmission line shows that modulating the voltage and reactance influences the flow of active power. In principle, a thyristor-controlled series capacitor (TCSC) and a static-var system (SVC) could provide fast control of active power through a transmission line. The possibility of controlling the transmittable power implies the potential application of these devices for damping of power system electromechanical oscillations. SVCs are mainly used to perform voltage or reactive power regulation. However, there has been a growing trend to use SVCs to aid system stability. In general, a compensator maintaining constant terminal voltage is not effective in damping of power oscillations. Flexible Alternative Current Transmission System (FACTS) devices are used in order to minimize voltage instability problems. FACTS devices generally consist of Static Synchronous Compensator (STATCOM), Static VAR Compensator (SVC), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Control (UPFC). Examining the studies on FACTS devices in the literature shows that these devices have helped solve negative situations in signal stability analysis caused by static and dynamic loads in multi bus power systems [1]. It was also seen that voltage instability problems caused by deactivation of lines can be successfully managed by FACTS devices.

2. VOLTAGE STABILITY ANALYSIS

PV and QV curves - Voltage profiles shown in the well-known PV and QV curves are of the practical use for determining the proximity to collapse so that operators can take proper preventive control actions to safeguard the system.

Q-V curve technique is a general method of evaluating voltage stability. It mainly presents the sensitivity and variation of bus voltages with respect to the reactive power injection. Q-V curves are used by many utilities for determining proximity to voltage collapse so that operators can make a good decision to avoid losing system stability. In other words, by using

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Q-V curves, it is possible for the operators and the planners to know the maximum reactive power that can be achieved or added to the weakest bus before reaching minimum voltage limit or voltage instability. The P-V curves, active power-voltage curve, 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.

Singular value decomposition:

The main idea of the method is to find "How close is the Jacobian matrix to being singular"? One issue with this index is that it does not indicate how far in Mvars it is to the bifurcation point (singular Jacobian value). The more important use of the index is the relationship it provides for control. That is, if VAR compensation through capacitors, excitation control or other means is available, the index provides the answer to the problem of how to distribute the resource throughout the system for maximum benefit. A disadvantage of using the minimum singular value index is the large amount of CPU time required in performing singular value decomposition for a large matrix.

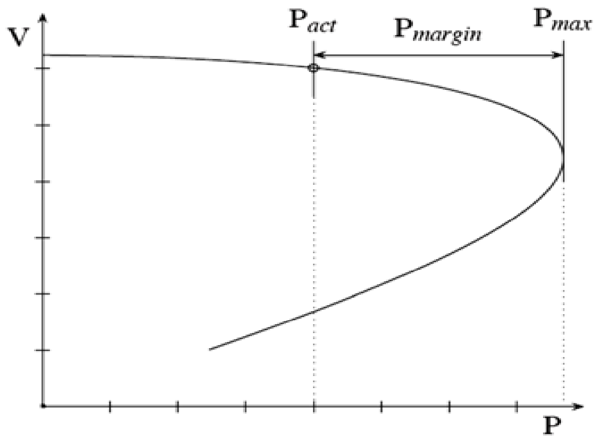

Fig.1.Power margin

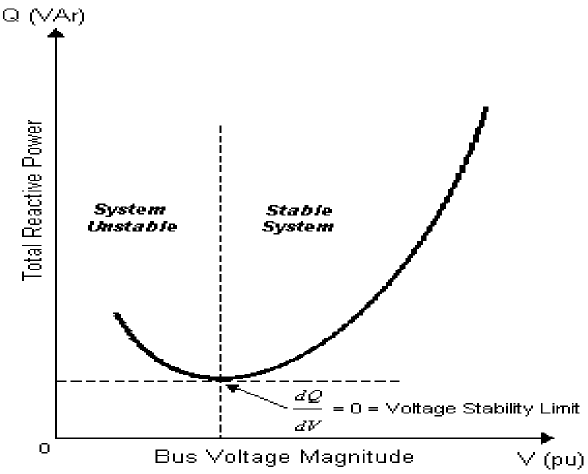

Fig. 2. Q-V curve

3. STATIC VAR COMPENSATOR (SVC)

SVC can be defined as a shunt connected static var generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system (typically bus voltage). SVCs are primarily used in power systems for voltage control or for improving system stability. The main job of a SVC is to inject a controlled capacitive or inductive current so as to maintain or control a specific variable, mainly bus voltage [8]. A well-known configuration of a SVC are the Fixed Capacitor (FC) with Thyristor Controlled reactor (TCR), and Thyristor Switched Capacitor (TSC) with TCR. SVCs are mainly used to perform voltage or reactive power regulation. However, there has been a growing trend to use SVCs to aid system stability.

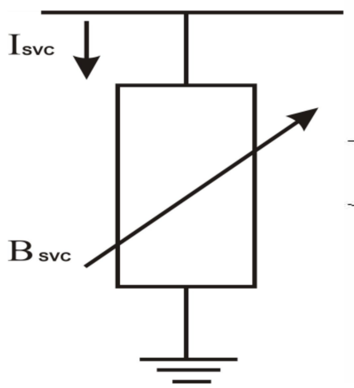

Fig: 3. Schematic Diagram of SVC

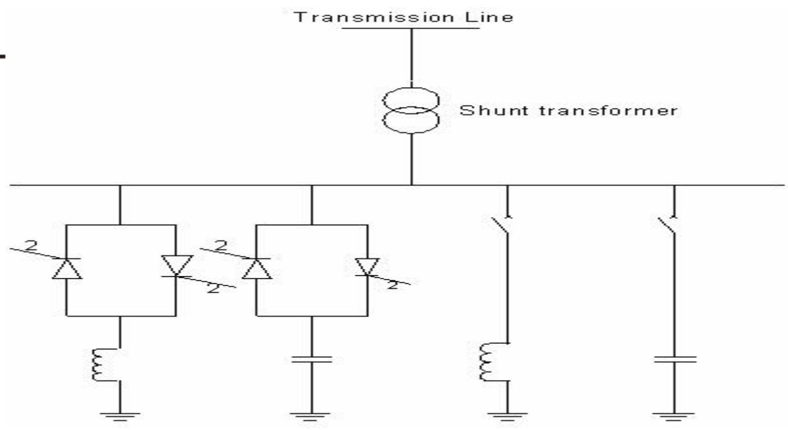

Fig: 4. Functional diagram of SVC

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4. CIRCUIT DIAGRAM AND DESCRIPTION

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

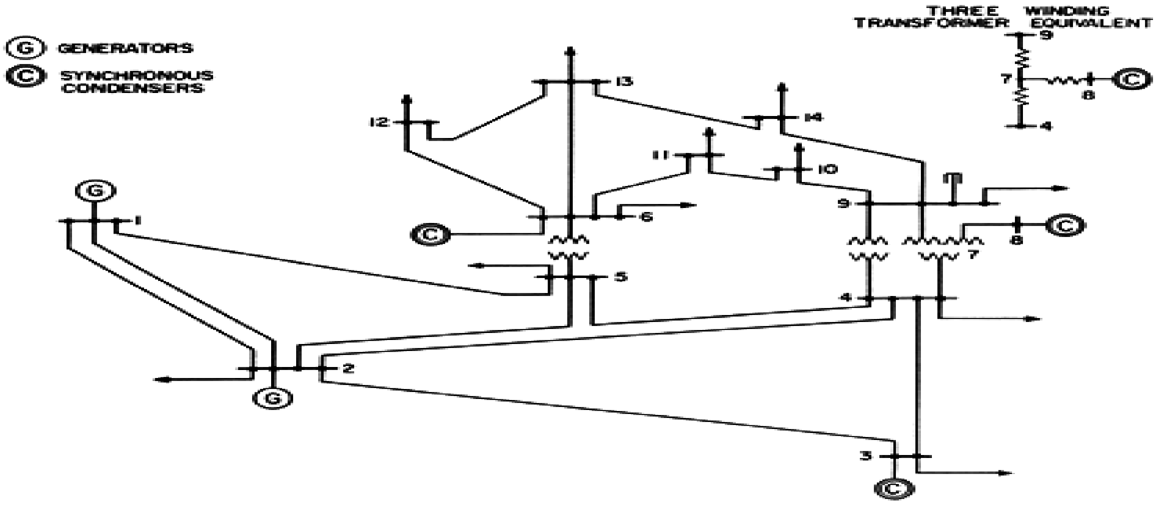

Fig. 5. The IEEE 14-bus test system

5. LITERATURE REVIEW

Bruno Leanardo et al.[1] presented a man –in-loop control method to boost the reactive power reserves while maintaining a minimum amount of voltage stability margin bus voltage limits . To select the the most effective control action the sensitivity of reactive power reserve with respect to control actions is evaluated. With the evaluation of reactive power reserve sensitivities the system operator identifies the most effective control action to restore the critical reactive power reserves. C.W.Taylor et al.[5] describes the importance of reactive power reserves in system operations and planning. The reserves viewed from the load‘s perspective are the measure of the maximum load the system can supply. The reserves viewed from the generator‘s prospective serves as a measure of the usefulness of the generator‘s reactive capability. The load and generation reactive reserves are heavily dependent on network, load, generation and system load characteristics. Feng Dong et al. [3]relates the reactive power reserves with the voltage stability. Reactive reserves are beneficial for maintaining and improving voltage stability. Voltage collapse typically occurs on power systems which are heavily stressed. Voltage collapse is associated with reactive power demands not being met because of limitations on the production, transmission, and consumption of reactive power. Y.H.Choi [7] introduces the concept of Effective reactive power reserves with respect to a particular bus using linear sensitivity. Voltage collapse typically occurs on the power systems which are heavily loaded. All reactive power sources must not affect the entire power system when severe contingency occur. Thus, generators must be evaluated as to whether or not they will have an impact on the maximum permissible loading of buses. This shows that some generators still have reactive power reserves when the system faces voltage collapse

A new line stability index was formulated and used to identify the critical line outages and sensitive lines in the system. Line outage contingency ranking was performed on several loading conditions in order to identify the effect of an increase in loading to critical line outages that line outages in weak lines would cause voltage instability conditions in a system. Subsequently, using the results from the contingency ranking, weak areas in the system can be identified and preventive measures can be taken. By evaluating the line voltage stability index we can identify the weakest line in the system.

Ismail Musirin et al. presents a new voltage stability index refers to a line namely fast voltage stability index (FVSI). The values of the line indices indicate the voltage stability condition in the system and it is used to rank the line outage contingency. The information from the contingency ranking denotes the severity of the voltage stability condition in a power system due to line outage. The line that exhibits the highest rate of change of FVSI is considered as the critical line referred to a bus while the value of maximum reactive load at FVSI value closed to 1.00 is assigned as the maximum permissible load. Á.L. Trigo et al.[8] presents a new heuristic technique to control the reactive power flows through boundary transformers between transmission and sub transmission or distribution networks. Its main advantage against a classical OPF lies in minimizing the number of control variables to modify in order to have all variables between limits.

6. CONCLUSIONS

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.SVC is used as the compensator so as to improve the voltage profile after the prediction of the voltage collapse. PV curves are plotted for the bus more sensitive to voltage collapse both before and after compensation and the improvement is verified using PSAT and the result shows that the maximum loading point improves with SVC thereby the system stability is enhanced.

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