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IMPROVEMENT OF VOLTAGE PROFILE USING SVC WITH IEEE 30 BUS SYSTEM

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Abstract**—** Modern power systems are becoming more endangered to voltage instability problems due to various conditions.So in order to prevent this problem a research has been proposed on advanced technologies like FACTS which improve the power quality and compensate the reactive power. A static VAR compensator is selected to replace the conventional capacitor banks, thus allowing continuous and flexible nodal voltage adjustment. Therefore improving voltage profile and stability by incorporating it in NR load flow model using MATLAB

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Index Terms— **SVC, NR Method,**

I. INTRODUCTION

The sudden inflation of population had made the electrical power systems to expand enormously in size. As the size of the system got increased the complexity also got increased.The main motto of this paper is to maintain the load voltage in limits. Load voltage of a system gets deviated due to many reasons such as environmental issues, unloading, increase in population and etc.. Above mentioned problems cause higher losses in generated power (5-13%). In order to reduce this problem load voltage should be maintained in limits for safety operation and to provide power to the load consumers. As the voltage collapse problem is associated to reactive power including the contingency analysis, as these should be considered for the secure operation of the power system. During the breakdown conditions of some critical lines, generators are capable of delivering limited reactive power even sometimes the delivered reactive power cannot be used to fulfill the obligation of the network because the location is far from the generator point. Further, the flow of real power in transmission lines reduces the supply of reactive power demand of the system and creates voltage problems. Hence, the reactive power compensators are used to maintain the voltage profile and thereby to improve the performances of the power system.

Present day developments in power electronic devices have introduced flexible AC transmission systems (FACTS) that include Thyristor controlled series compensator (TCSC), Static VAR compensator (SVC), Unified power flow controller (UPFC) etc. These devices can alleviate the control of power flow, improve the power transfer, and reduce the voltage magnitude deviations at the load buses by providing flexibility to the operation of power systems. Compared with other FACTS device SVC is more advantageous and very economical. Therefore it is important to find the optimal location and its size in a power system, so that voltage profile may be improved effectively. SVC models and their implementation in Newton-Raphson load flow and optimal power flow algorithms is been developed.

This paper focuses on the placement of SVC, for improving the voltage profile. SVC is a shunt FACTS device which is designed to maintain the voltage profile in a power system under normal conditions. In practical power systems, all buses have different sensitivity to the power system stability, some buses are more and some are less. If SVC is allocated at more sensitive buses, it will effectively improve the voltage profile/stability.

2.BASIC FUNCTIONS OF SVC:

The following basic requirements of a power transmission system can be performed by static VAR compensators

- Maintaining the system voltage profile under dynamic load conditions such as line Switching or load rejection.
- Improving the power transfer capability of the system, thereby increasing the dynamic and transient stability of the system.
- Suppression of power systems oscillations thereby improving the system damping.
- Suppression of voltage fluctuations caused by disturbing loads such as rolling mills arc furnaces and single phase traction loads.
- Controlling the reactive power flow and thereby minimising the system losses.
- Limiting the voltage rise at the AC bus of a HVDC terminal on load rejection Or Converter blocking

3.Static VAR Compensator: There are two models of SVC which are usually implemented for load flow analysis of power system.

- SVC susceptance model
- SVC firing angle model

3.1 SVC susceptance model

It is a shunt-connected device composed of several modules built of a fixed capacitance in parallel with a thyristor controlled reactor. The equivalent susceptance B_{eq} is determined by the firing angle α of the thyristors which is defined as the delay angle measured from the peak of the capacitor voltage to the firing instant. The fundamental frequency equivalent neglecting the harmonics of the current results in

$$B_{eq} = B_L(\alpha) + B_C$$

$$B_L(\alpha) = -\frac{1}{\omega L}\ 1 - \frac{2\alpha}{\pi} - \frac{\sin(2\alpha)}{\pi}$$

The total susceptance of the SVC is composed of the parallel equivalent susceptances of the modules, each controlled separately. Thus, the SVC can be modeled as a shunt-connected variable susceptance with a lower bound B_{SVC} and an upper bound B_{SVC} . In the power flow equations this is accounted for by including the reactive power into the reactive power balance at bus k subject to This range normally includes positive as well as negative values.

$$Q_{svc} = -V_k^2 . B_{SVC}$$

3.2 SVC Firing Angle Model (B =B$_{eq}$)

In this model, it is possible to consider the firing angle to be the state variable provided the SVC can be represented by the structure shown in Fig.1. In this case, the linearized SVC equation is given as,

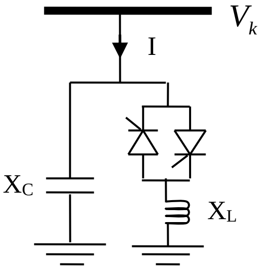

Figure 1. SVC structure.

$$\begin{bmatrix} \Delta P_k \\ \Delta Q_k \end{bmatrix}^i = \begin{bmatrix} 0 & 0 \\ 0 & \dfrac{\partial Q_k}{\partial \alpha} \end{bmatrix}^i \begin{bmatrix} \Delta \theta_k \\ \alpha \end{bmatrix}^i$$

where

$$\frac{\partial Q_k}{\partial \alpha} = \frac{2V_k^2}{X_L}\left(\cos(2\alpha) - 1\right).$$

At the end of iteration *i*, the variable firing angle α is updated

$$\alpha^{i+1} = \alpha^i + \Delta\alpha^i$$

and the new SVC susceptance $\underline{B_{eq}}$ is calculated.

It should be noted that models, the total susceptance model and the firing angle model observe good numerical properties

4. LOAD FLOW ANALYSIS

4.1 NEWTON RAPHSON METHOD:

Newton raphson method is most proficient method for determining the voltage values for larger power systems. Through this method the complexity in calculating the voltages at each bus gets reduced. The proposed work involves NR method for determining the voltages and to identify the bus which is more affected by voltage fluctuations. The number of iterations required to obtain a solution is independent of system size.

Let us consider a exemplary bus from a large power system network as shown below.

Let I_i be the current entering into the bus bar

$$\text{i.e.,}\quad I_i = \sum_{j=1}^{n} |Yij||Vj| \angle \theta ij + \delta j$$

Complex power at bus bar is given by

$$P_i\text{-}jQ_i = |V_i| \angle -\delta_i \ \sum_{j=1}^{n} |Yij||Vj| \angle \theta ij + \delta j$$

Separating the real and imaginary parts ;

$$P_i=\sum_{j=1}^{n} |Vi||Vj||Yij| \cos(\theta ij - \delta i - \delta j)$$

$$Q_i=\sum_{j=1}^{n} |Vi||Vj||Yij| \sin(\theta ij - \delta i - \delta j)$$

In NR method the iteration starts from second bus as the first bus is the slack but Above given matrix is a Jacobian matrix which gives the relationship between small change in voltage magnitudes and load angles with small change in mismatch powers.

Elements in Jacobian matrix are the partial derivatives of real and reactive power equations given above. This can be written as

$$\begin{matrix} \Delta P \\ \Delta Q \end{matrix} = \begin{pmatrix} J1 & J2 \\ J3 & J4 \end{pmatrix} \begin{matrix} \Delta\delta \\ \Delta|V| \end{matrix}$$

For every PV bus voltage and load angle are known if x buses are v controlled buses then x equations involve mismatch reactive power and change in voltage ‘then those corresponding columns of J matrix are eliminated

Real power constraints are in order (n-1) and Reactive power constraints are in order (n-m-1)

Where m= generator bus, n= number of buses

Order of J matrix is (2n-2-m)*(2n-2-m)

Order of element is J matrix is

J_1=(n-1)*(n-1) J_2=(n-1)*(n-m-1)

J_3=(n-m-1)*(n-1) J_4=(n-m-1)*(n-m-1)

The diagonal and the off-diagonal elements of J_1 are

$$\frac{\partial\, Pi}{\partial\, \delta i} = \sum j \neq i |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j)$$

$$\frac{\partial\, P_i}{\partial\, \delta_i} = -|V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \qquad j\neq i$$

The diagonal and off diagonal elements of J2 are

$$\frac{\partial P_i}{\partial |V_j|} = 2|V_j||Y_{ii}| \cos\theta_{ii} + \sum i \neq i\, |V_j||Y_{ij} \cos(\theta_{ij} - \delta_i + \delta_j))$$

$$\frac{\partial P_i}{\partial |V_i|} = |V_i||Y_{ij} \cos(\theta_{ij} - \delta_i + \delta_j) \qquad j\neq i$$

The diagonal element and off diagonal elements of J4 are

$$\frac{\partial Qi}{\partial |Vi|} = -\ 2|V_i||Y_{ii}|\sin\theta_{ii} + \sum j \neq i|Vj||Yij|\sin(\theta ij\text{-}\delta i+\delta j)$$

$$\frac{\partial Qi}{\partial |V\, i|} = -\ |V_i||Y_{ij}|\sin(\theta_{ij} - \delta_i + \delta_j) \qquad j\neq i$$

alculated

$$\Delta P_i^{(k)}=P_i^{sch}\text{-}P_i^{(k)}$$

$$\Delta Q_i^{(k)}=Q_i^{sch}\text{-}Q_i^{(k)}$$

The next iteration for the voltage is given by

$$\delta_i^{(k+1)}=\delta_i^{(k)}+\Delta\delta_i^{(k)}$$

5.COMPUTATIONAL ALGORITHM:

- STEP 1: Initial step is to identify the problem of voltage instability.
- STEP 2: Choosing the best method for determining the voltage values.
- STEP 3: Newton Raphson method is used to find the voltages, load angles of respective buses for a standard IEEE 30 bus test system.
- STEP 4: Run the MATLAB program with Newton Raphson load flow model and observe the values of voltage magnitude as well as load angles for all 30 buses.
- STEP 5: Identify the bus number which is more affected by voltage fluctuations (it can be identified by observing the PU values of each and every bus if voltage falls below 0.95 or above 1.05) .
- STEP 6: Incorporate the static var compensator device in NR load flow model and execute it
- STEP 7: Now again observe the values of voltages as well as load angles , now the values of voltage will get improved at that fault bus as well as its surrounding buses too.

$$P_i - jQ_i = |V_i|\angle{-\delta_i} \sum_{j=1}^{n} |Y_{ij}|\,|V_j|\angle\theta_{ij} + \delta_j$$

$$P_i - jQ_i = |V_i|\angle{-\delta_i} \sum_{j=1}^{n} |Y_{ij}|\,|V_j|\angle\theta_{ij} + \delta_j$$

$$P_i - jQ_i = |V_i|\angle{-\delta_i} \sum_{j=1}^{n} |Y_{ij}|\,|V_j|\angle\theta_{ij} + \delta_j$$

$$\frac{\partial Q\mathrm{i}}{\partial \delta i} = \sum j \neq i|Vi||Vj||Yij| \cos(\theta ij - \delta i + \delta j)$$

$$\frac{\partial Pi}{} = -|V_i||V_j||Y_{ij}|\cos(\theta_{ij} - \delta_i + \delta_j) \qquad j\neq i$$

6.SIMULATION RESULTS:

IEEE 30 BUS SYETEM WITH OUT AND WITH SVC SYSTEM

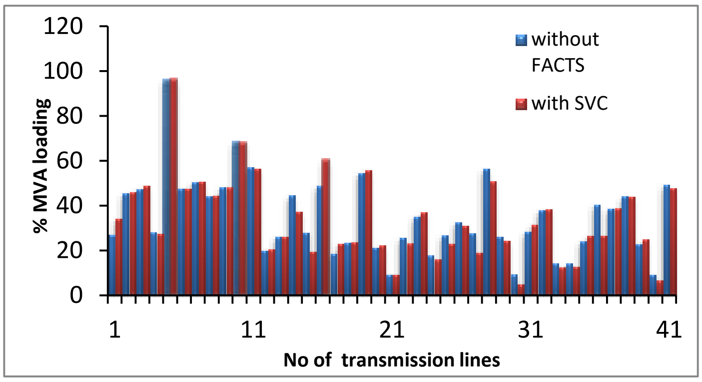

Figure 2 Percentage MVA line loadings of IEEE 30-bus system after optimization without and with SVC

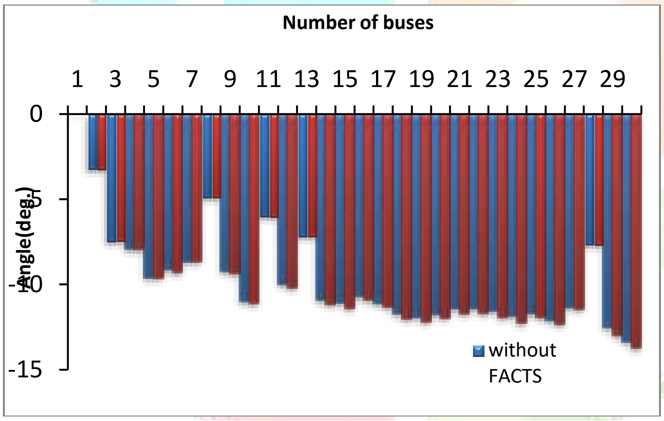

Figure 3 Voltage angles of IEEE 30-bus system after optimization without and with SVC

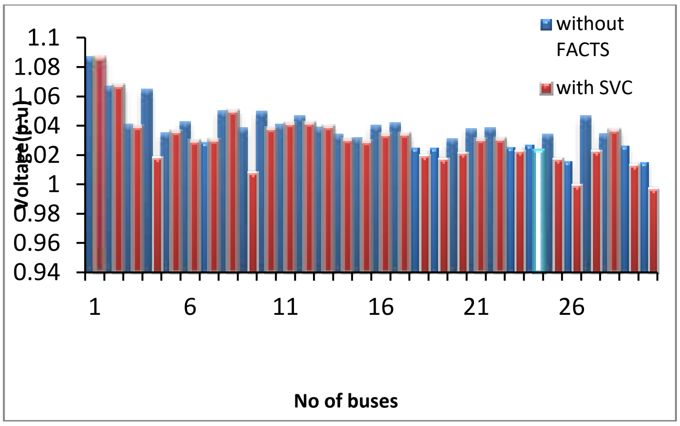

Figure 4 Voltage profiles of IEEE 30-bus system after optimization without and with SVC

7.CONCLUSIONS:

- The load flow solution is carried out for IEEE 30 BUS SYSTEM with and without svc and the results are compared with each other and graphs are plotted as in above slides.
- A simple and efficient load flow technique i.e., Newton Raphson Method has been used for solving IEEE 30 bus system. Static VAR compensator has been applied to the load flow method at optimal load bus and tested that the method has good and fast convergence characteristics.
- Using SVC the voltages, load angles are enhanced and real power losses are reduced and there by improves efficiency of the system. So this controller is used to get optimum solution for improved transmission system.

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