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Optimal Placement of SVC Using Voltage Sensitivity Approach

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***Abstract:* - Voltage is always the most important part of the power system response and it is an important aspect of system stability and its security. The voltage instability generally results in monotonically decreasing voltages. So that Flexible AC transmission system (FACTS) devices play an important role in improving the performance of the power system, but these devices are very costly and so need to be placed optimally. During a large disturbance improving the systems voltage by upgrading the reactive power handling capacity of the system by using SVC is the area of study. Thus the effect of Static VAR Compensator (SVC) in voltage stability enhancement will be studied in this paper and a technique is based on line stability index, real power performance index and reduction of total system VAR power losses has been intended to decide the optimal location of SVC.**

***Keywords* - Voltage stability, FACTS, SVC, IEEE 5 bus system, L-index.**

I. INTRODUCTION

Today, Electricity demand is increased as number of industries is increasing day by day. As the volume of power transmitted and distributed increases, hence do the requirements for high quality and reliable supply. Thus the Transmission networks of present power systems are becoming progressively more stressed because of increasing requirement and limitations on building new lines. Maintaining system stable and secure operation of a power system is a challenging task. Voltage instability is the One of the major concerns of power system stability. It causes the system voltage collapse, which makes the voltage of system to decrease to a level that is unacceptable. Voltage instability occurs because of lack of reactive power. This problem is reduced by Flexible AC Transmission System (FACTS) devices.

FACTS are the power electronics based devices, which can change parameters like impedance, voltage and phase angle. FACTS devices also helps to minimize flows in heavily loaded lines, developing in an increase loadability,low system loss, improved stability of the network, decreased cost of production and satisfied contractual requirement by controlling the power flows in the network. They give control facilities, both in steady state power flow control and dynamic stability control. FACTS devices can be connected to a transmission lines in various ways, such as in series, shunt or a combination of series and shunt. Each one of those has their own characteristics and limitations.

II. STATIC VAR COMPANSATOR (SVC)

Static Var Compensator is shunt connected FACTS device. Means it is installed in parallel with a bus. Diagram of SVC is shown in fig.1.1. SVC is made up of mechanically switched reactor, Thyristor controlled reactor (TCR), Thyristor Switched Capacitor (TSC), Harmonic Filter and mechanically switched capacitor. If load is capacitive, TCR consume VARs and lower system voltage. If load is inductive, capacitor banks are switched on to supply VARs and higher system voltage.

Thyristor switched reactor (TCR) and Thyristor switched capacitor (TSC) are made up of thyristor valve. Thyristors are controlled power electronic switch. As per firing angle thyistors can be ON and OFF. Comparing TCR with TSC, TSC have same operating mode of thyristors as TCR, but the reactor is replaced by capacitor. Combination of TCR, TSC, mechanically switched capacitor and mechanically switched reactor work to supply and absorb reactive power. Hence SVC is advantageous to use because it independently and simultaneously control the below two parameters.

1. Reactive power
2. Bus voltage to where it is installed

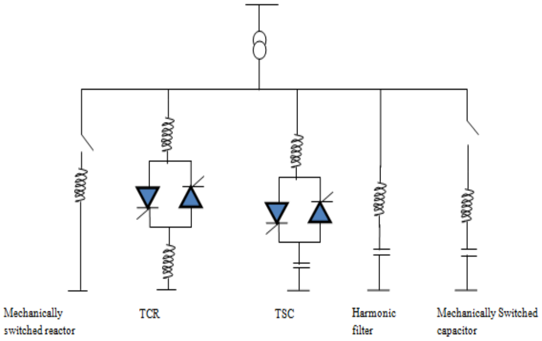


Fig:1.1: Static VAR Compensator (SVC)

III. MODELLING OF SVC

In general the SVC can be seen as an adjustable reactance with either firing-angle limits or reactance limits.

With reference to fig.1.2 ,the transfer admittance equation for the variable shunt compensator is,

$$I = jB_{svc}V_k$$

and the reactive power equation is,

$$Q_k = -V_k^2 B_{svc}$$

For this model the total susceptance Bsvc is taken to be the state variable. The linearized equation of the SVC is given by , where the susceptance Bsvc is taken to be the state variable.

$$\begin{bmatrix} \Delta P_k \\ \Delta Q_k \end{bmatrix}^i = \begin{bmatrix} 0 & 0 \\ 0 & Q_k \end{bmatrix}^i \begin{bmatrix} \Delta \theta_k \\ \Delta B_{svc}/B_{svc} \end{bmatrix}$$

At the end of iteration i, the variable shunt susceptance Bsvc is upgraded according to,

$$B^{i+1}svc = B^{i}svc + \left(\frac{\Delta Bsvc}{Bsvc}\right)^{i} B^{i}svc$$

This changing susceptance represents the total SVC susceptance necessary to keep the nodal voltage magnitude at the specified value. Once the level of compensation has been resolved, the firing angle required to achieve such compensation level can be calculated.

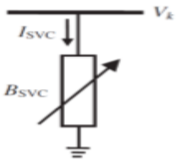
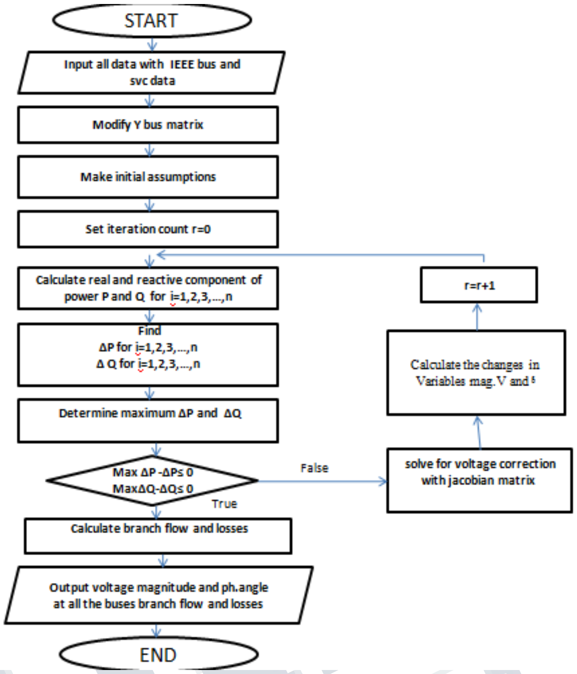


Fig.1.2.Variable Susceptance model of SVC

IV. FLOWCHART FOR NEWTON RAPHSON METHOD WITH SVC



V. OPTIMAL PLACEMENT OF SVC USING VOLTAGE SENSITIVITY APPROACH

Voltage stability is becoming enlarging source of concern in secure operating of present-day power systems. The problem of voltage instability is mainly examined as the incapability of the network to meet the load demand imposed in terms of poor reactive power support or active power transmission capability or both. It is mainly concerned with the analysis and the enhancement of steady state voltage stability depends on L-index. This L-Index determines how any system is close to its instability limit. The line stability index is expressed by Lmn, proposed by Moghavvemi and Omar (1998) is formulated depend on a power transmission concept in a single line fig.1.3

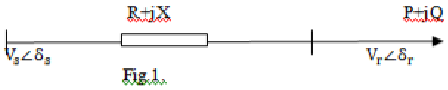


Fig.1.

Where,

- $V_s\angle\delta_s$, $V_r\angle\delta_r$ = The sending end and receiving end voltages.
- R+jX = The impedance of the transmission line.
- P+jQ = The receiving end apparent power.

Current flowing through the branch,

$$I = \frac{Vs\angle\delta_1 - Vr\angle\delta_2}{R + jX}$$

P-jQ=Vr*I

$$P - jQ = \frac{VsVr\angle(\delta_1 - \delta_2) - Vr^2}{R + jX}$$

$$(P - jQ)(R + jX) = VsVr\angle(\delta_1 - \delta_2) - Vr^2$$

The real term of above equation is,

$$VsVr\cos(\delta_1 - \delta_2) = Vr^2 + (RP + XQ)$$

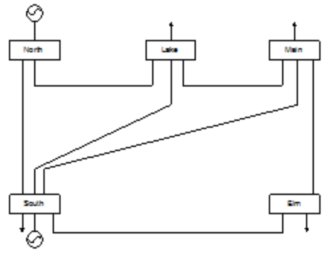
The imaginary term of above equation is,

$$VsVr\sin(\delta_1 - \delta_2) = XP - RQ$$

After simplifying the above equation, we obtain the equation for the stability index can be written as,

$$Lmn_{(p.u.)} = 4\left[\left[\frac{PX - RQ}{Vs^2}\right]^2 + \left[\frac{RP + XQ}{Vs^2}\right]\right]$$

VI. TEST SYSTEM



IEEE 5 BUS SYSTEM

Where,
Bustype 1=slack or swing bus
Bustype 2=PV bus
Bustype3=load PQ bus
Bustype 4=Generator PQ bus

Bus Data

Bus No	Voltage Magnitude (P.U.)	Angle (Degrees)
1	1.06	0
2	1.00	0
3	1.00	0
4	1.00	0
5	1.00	0

Generator Data

Bus No	P_G (MW)	Q_G(MVAR)	Qmin	Qmax
1	0	0	50	50
2	40	0	30	30

Load Data

Bus No	Load	
	P_L (p.u)	Q_L (p.u)
2	0.2	0.1
3	0.45	0.15
4	0.4	0.05
5	0.6	0.1

Transmission line Data

Branch No.	Sending end Bus	Receiving end Bus	Resistance (p.u.)	Reactance (p.u.)	Line charging (p.u.)
1	1	2	0.02	0.06	0.06
2	1	3	0.08	0.24	0.05
3	2	3	0.06	0.18	0.04
4	2	4	0.02	0.18	0.04
5	2	5	0.04	0.12	0.03
6	3	4	0.01	0.03	0.02
7	4	5	0.08	0.24	0.05

VII. L-INDEX FOR IEEE 5 BUS

BUS 1	BUS 2	BUS 3	BUS 4	BUS 5
L=0	L=0.624	**L=1.62**	L=0.964	L=1.248

Here L = stability index.
For stable system, L< 1.
It can be seen that when a load bus reaches a steady state voltage collapse situation, the L-index closes to the numerical value 1.0.

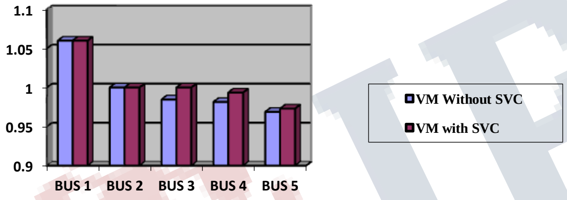
So for an overall system voltage stability condition, the index evaluated at any of the buses should be less than unity. Thus the index value L gives a demonstration of how far the system is from voltage collapse.
Here, bus 3 has highest L index so compensation is to be provided there.

VIII. RESULTS

BUS	Before placement of SVC	After placement of SVC
	VM(p.u.)	VM(p.u.)
1	1.06	1.06
2	1	1
3	0.9847	1
4	0.9815	0.9936
5	0.9688	0.9730

IX. CONCLUSION

The idea behind this work is to improve the voltage magnitude profile of the system and increase more loading capacity by applying reactive power compensation at the buses, which is to be satisfied.



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