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OPTIMAL LOCATION OF FACTS DEVICES ON POWER SYSTEM FOR VOLTAGE CONTROL

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Abstract

In this paper the modelling of the load has a significant effect in the electrical power systems. This paper presents the effect of different static load models on the location of Static VAR Compensator (SVC). The static load types, in which active and reactive powers vary with voltage as an exponential form, are used. The effect of appropriate location of the SVC on voltage control for variable load conditions is investigated. For this purpose each load is varied as a stair-case and voltages are controlled at the desired levels by using minimum number of Static VAR Compensator (SVC). Modelling and simulation of the system are performed using Matlab Sim Power Systems Block sets. PI controllers are used to control SVC firing angles. The studied power system is a simple five-bus system.

INTRODUCTION

The area of voltage stability and control for power systems has yielded an extensive and diverse array of analytical contributions. It is now well-accepted that the basic problem is under influence of static and dynamic aspects of system equipments. The voltage stability and control are dynamic phenomenon's. Accordingly, these led to dynamic modeling and formulation of the system. Consequently one of the most important issue states itself as the modeling requirement, and adequacy of the various system components.

In electric power systems, load models may be classified into two categories; static and dynamic models. The distinguishing feature of the static load model is that, it is not dependent on time; therefore, it describes the relation of the active and reactive powers at any time with the voltage and/or frequency at the same instant of time. On the other hand, dynamic load model expresses these relations as a function of time. In some cases voltage stability studies requires that static load models be replaced with dynamic ones, since the load models have critical effects on the voltage profile of the system.

The improvements in the field of power electronics have major impact on the development of the Flexible AC Transmission Systems (FACTS) devices, These devices are based on Thyristor Controlled Reactor (TCR) and Voltage-Source Inverters (VSI) such as; Static Var Compensator (SVC), Thyristor Controlled Series Capacitor (TCSC) and Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), Unified Power Flow Controller (UPFC). These devices are used for controlling the power flows and for compensation of reactive power in the network**.** In addition of this, they can help to reduce the flows in heavily loaded lines resulting in an increased load ability to reduce system losses to improve stability of the network and to reduce cost of production.

It is a well known fact that the SVCs are generally used as load balancing and power factor correcting devices by adjusting the susceptance in each phase by controlling the conducting angles of the TCR. SVC is basically a shunt connected static var generator/load whose output is adjusted to exchange capacitive or inductive current. So the SVC maintains or controls the specific power system variables; typically, the controlled variable is the bus voltage.

This paper consists of two case studies. In case study I, SVC is modelled as a fixed shunt capacitor and connected to different load buses in a five-bus system to show the effect of different location of this device on system voltage profile for different static load types. Six static load types in which active and reactive powers vary with the voltage as an exponential form are used to show the effect of voltage dependent load models on voltage profile and location of the SVC in power systems. In case study II**,** each load is modelled as a stair-case dynamic load (SCDLM), in which active and reactive powers are varied at a chosen time around the base value with desired step size and realized by simultaneous switching of static loads. To keep the bus voltages at the desired level and to show the capability of the SVC on voltage control, the load voltages are controlled by using two SVCs controllers. From the simulation results, it is obtained that bus voltages for different load models have approximately the same variation with the different location of the SVC for different static load models and the location of the SVC doesn’t depend on the load models.

MODELING OF SVC AND POWER SYSTEM

In this paper, a single-phase SVC is modelled using Mat lab Sim Power Systems Block set as shown in Figure 1 and three SVC blocks are connected in Delta configuration in the three-phase system. The device is represented by a fixed capacitor in parallel with a thyristor controlled reactor (TCR). The TCR consists of a fixed reactor of inductance L and a bi-directional thyristor. The thyristors are fired symmetrically in an angle control range of 90° to 180° with respect to the capacitor voltage.

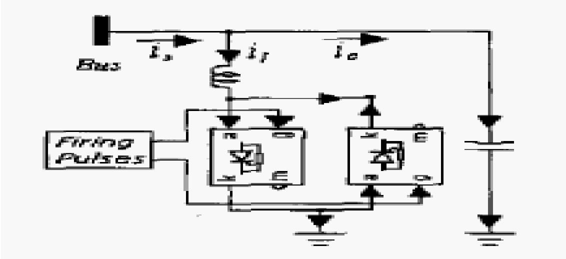


Figure 1 A Single Phase SVC Mat lab Model

The control structure of the SVC consists of Regulator Circuit Model (RCM**)** and Switching Circuit Model (SCM). In the RCM as shown in Fig. 2, RMS voltage measured at the load bus is compared with a reference voltage and the difference between them is used as the input of a PI controller. The resulting output is then transferred in angle values and added constant firing angle, and then limited by a saturation block. The SCM shown in Figure 3 provides firing pulses to thyristors converting the angle signal that comes from the regulator circuit model. The thyristor 2 receives the pulse delayed of 180 degrees for each phase.

For the static load models, it is generally assumed that voltage dependency of active and reactive power could be represented by exponentional load models given by

$P=P_o (V/V_o)^{np}$

$Q=Q_o (V/V_o)^{nq}$

Where *np, nq* are load indices and Po and Q, are the values at the initial condition o f the system. In this paper six types of static load are used and the voltage dependencies of these models are given in Table 1. The composed loads are realized by using the other five static load models at the same ratio.

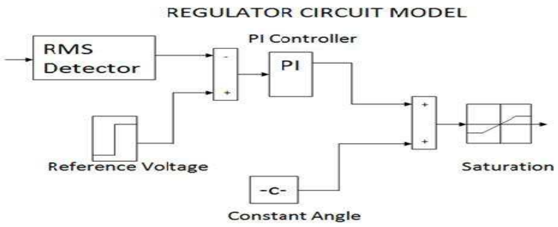


Figure 2 Regulator Circuit Model (RCM)

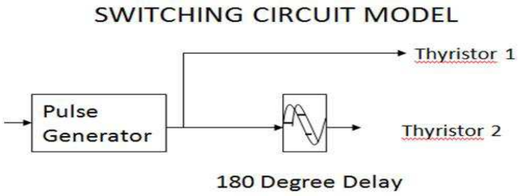


Figure 3 Switching Circuit model (SCM)

Table 1

Common values for the exponents of different static load models

	Load component	***np***	***nq***
1	Battery charge	2.59	4.06
2	Flurescent Lamps	2.07	3.21
3	Constant Impedance	2	2
4	Constant current	1	1
5	Constant power	0	0
6	Constant Load	-	-

Stair-case dynamic load model (SCDLM) in which active and reactive POWERS are varied at chosen times around the base value with desired step sizes is used. The SCDLM is realized by switching three constant impedance loads to obtain the three sizes of total load. Fig. 4 shows the SCDLM model in Mat lab using Sim Power Systems Block set.

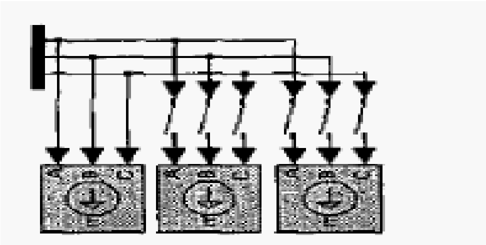
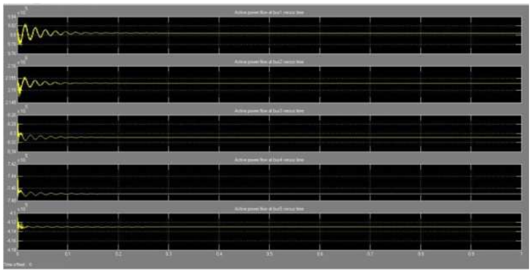


Figure 4 Stair-case dynamic load model (SCDLM)

Transmission lines are modelled as a series R-L branch and the line capacitances are neglected. Generators are modelled using constant three-phase voltage source with internal impedances.



III.SIMULATION RESULTS

Case study I:

The effect of different locations of the SVC on the voltage magnitude for different static load models are analysed on a generic five-bus power system as shown in Fig. 5. For the static load, six load models given in Table .1 are used to show the effect of different load models on the location of the shunt compensators for system voltage profile.

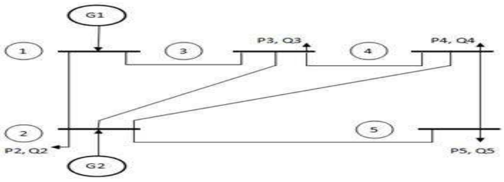
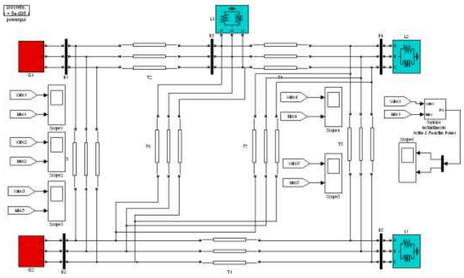


Figure 5 Single phase circuit of the five-bus power System



SIMULATION FOR GENERIC FIVE BUS SYSTEM WITHOUT SVC

(i)ACTIVE POWER FLOW IN FIVE BUS SYSTEM USING WITHOUT SVC

Figure 6(I).Active power (P) at five buses on X-axis versus time on Y-axis

(ii)REACTIVE POWER FLOWS IN FIVE BUS SYSTEM WITHOUT SVC

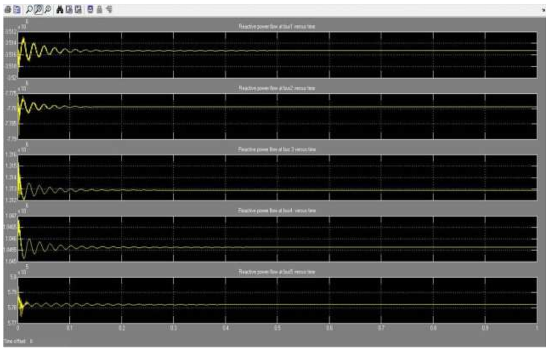


Figure 6(II).Reactive power (Q) at five buses on X-axis versus time on Y-axis

Different load characteristics cause to different voltage level in the system. Locations of the 20 MVAr shunt capacitor at the different bus are caused to different voltage level at each bus and bus voltages for different load models have approximately the same variation with the different location of the shunt capacitor. We can see that locations of shunt capacitors for VAr compensation are independent from the load characteristics if all loads have the same voltage dependence. But different load models require different shunt capacitor sizes. To keep the bus voltages around the desired level, the system with the constant power loads would be needed the maximum MVAr rating, on the other hand the system with the battery charge load would be needed the minimum MVAr rating for the same system.

Case study II

In this case study, the effect of appropriate locations of the SVCs on voltage control for variable load conditions is investigated. All loads of the system are changed as a stair-case load. Each load in the system is changed at every 0.75 second as given in Equation (8) with a base load Po .Constant impedance load type is used for each load. After the simulation, variations of the each bus voltage with the load variation are given in Figure 6(I).

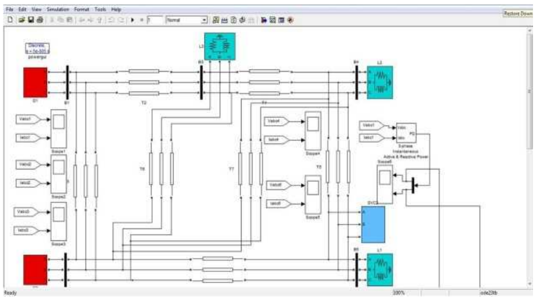
$P, Q=P_O-Q_{0,}$ 0 t 0.75,3 t 3.75

$=1.3P_o-1.3Q_o$, 0.75 t 1.5, 2.25 t 3 --→8

$= 1.6P_o-1.6Q_{o,}$ 1.5 t 2.25

From Figure 6(i) bus 5 is targeted as the location for the SVC, because it has the lowest voltage level with the load variations. To keep the bus 5 voltage at 1.015 Pu**,** parameters of the SVC are chosen as C= 170 F and L=25mH. The firing angle limits of the SVC are defined as 100^0 and svc 175^0 and the PI controller parameters are chosen as K_P= 10 and K_i=*300.* Variation of bus voltages after the location of the first SVC are given in Figures 6(I) and (II).

SIMULATION FOR GENERIC FIVE BUS SYSTEM WITH SVC



(iii) ACTIVE POWER FLOW IN FIVE BUS SYSTEM USING SVC

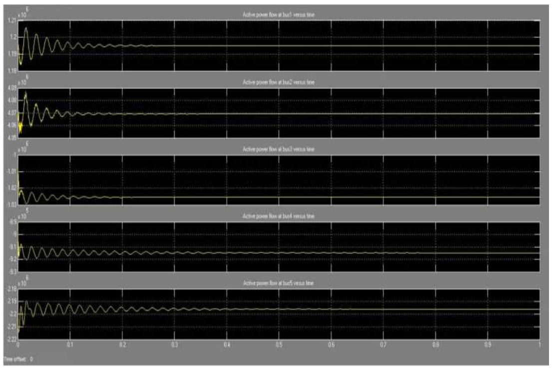


Figure 7 (I). Active power (P) at five buses on x-axis versus time on y-axis.

(iv) REACTIVE POWER FLOW IN FIVE BUS SYSTEM USING SVC CONTROLLER

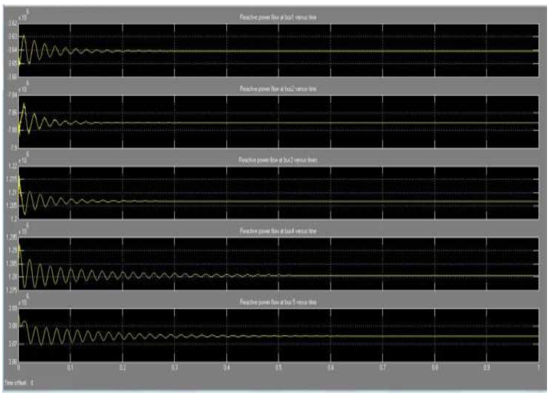


Figure 7(II).Reactive power (Q) power flow at five buses on X-axis versus time on Y-axis.

After locating of the 1st SVC at the bus 5, the bus voltage is kept at 1.015 pu for each load level, but this is not enough to keep the other load voltages at desired level. For this reason, 2nd SVC is located at the bus 3 to control the bus voltage at 1.025 pu. The second SVC parameters are chosen as C=120 F and L=20mH and the firing angle limits are defined as 900 svc 1750 The firing angle of the second SVC is controlled by a PI controller which have Kp=7 and K_i=300 .The results 0btained by using two SVC controllers are given in Figure. Controlling of bus 3 and bus 5 voltages by using two SVC controllers are enough to keep of the other bus voltages at desired level. As can be seen from Figure7 (i) and (ii), both SVCs located at bus 3 and bus 5 provide the enough reactive powers for loads variation around their base values, in order to keep the bus voltage at acceptable levels.

CONCLUSION

Svc is main commercially available shunt facts controller for voltage control in power systems. The small deviation in load may affect the voltage profile of the system. Hence, the dynamic performance of SVC on voltage control with variable load is analyzed and the effect of different locations of shunt compensators on voltage magnitude is investigated for six static load types.

Simulation results show that the appropriate location of the SVC provides to control of the system voltage at the desired level under the variable load conditions by using minimum number of SVCs. In this five bus system optimal location of fact devices is made at fifth bus for voltage control

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