Modeling and Simulation of Static Var Compensator for Voltage Control Using MATLAB/SIMULINK

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Abstract— **Electricity has now been Interconnected power system has been an inherent part of the todays electrical generation. It has becoming more and more complex as there are multiple ways of generations, transmission and distribution. So there is great challenge for proper flow of power and ensuring the system stability. Despite the various use of classical controllers (mechanical switching devices), the implementation of high performance devices is encouraged. The modern system that has the ability of varying the power flow parameters like voltage, impedance, admittance, power angle, damping oscillation etc. in order to enhance the power flow capability is FACTS (Flexible Alternating Current Transmission). Among various FACTS devices, SVC is one of the most popular, reliable and economic controller used in modern power system. It is acquired to have very good design and performance analysis of the SVC device for its better working in the power network. Static Var Compensators are being increasingly applied in electric transmission systems to economically improve voltage control and post-disturbance recovery voltages that can lead to system instability. An SVC provides such system improvements and benefits by controlling shunt reactive power sources, both capacitive and inductive, with power electronic switching devices.**

I. INTRODUCTION

The SVC, a FACTS device has become one of the leading controller devices in the present power system network. So the effective design and the performance analysis of the SVC devices are very important for its desired work in the power system network for the proper power flow control and stability maintenance. The SVC uses the solid semiconductor devices like Thyristor as the switching device and the reactor and capacitors as the VAR absorbers and generators respectively. The amount of the reactive power injection and absorption in the system is controlled by the controlling unit which provides the necessary firing pulses for the thyristors. The effective voltage control and the reactive power control in the system is accompanied by the implementation of the special compensator (Static VAR Compensator) in the desired location in the system. The detail modelling and analysis of the compensator before implementation in the real field is extremely required.

II. STATIC VAR COMPENSATOR

A. Introduction to Static Var Compensator

A static VAR compensator is a set of electrical devices for providing fast-acting reactive power on high-voltage electricity transmission networks. SVCs are part of the Flexible AC transmission system device family, regulating voltage, power factor, harmonics and stabilizing the system. Unlike a synchronous condenser which is a rotating electrical machine, a static VAR compensator has no significant moving parts. Prior to the invention of the SVC, power factor compensation was the preserve of large rotating machines such as synchronous condensers or switched capacitor banks. The SVC is an automated impedance matching device, designed to bring the system closer to unity power factor. SVCs are used in two main situations:

1) Connected to the power system, to regulate the transmission voltage ("Transmission SVC")
2) Connected near large industrial loads, to improve power quality ("Industrial SVC")

B. Mathematical Model of Static Var Compensator

The mathematical modelling of any physical system begins with the development of the relevant relationship between the constraints and variables. Basically, SVC being a control system mathematical modelling is an important aspect of the design. The general control loop system of the SVC is shown in fig 1. Each of the blocks shown above is the representation of the transfer function of the components of the SVC. The individual components of the SVC can be modelled as developing the transfer function:

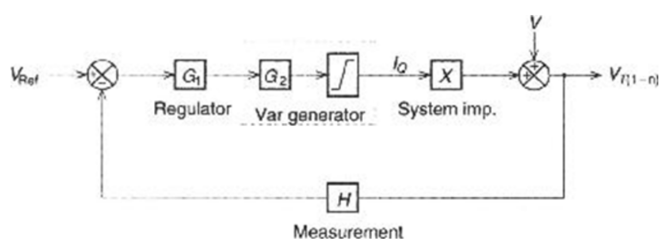

Fig. 1. Block Diagram of SVC

III. MATHEMATICAL MODELLING

Each of the components shown in block diagram above and be modelled in mathematical way individually. The following are the components and their model

1) Measurement System: These systems provide the necessary inputs to the SVC controller for performing its control operations. The different inputs required by an SVC depend on the function that the SVC controller is intended to perform. The SVC controller performance and its robustness largely depend on the authenticity of the measured signals. However, the

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measurement units, together with their transducers, operate in environments that cannot be predicted from simulation studies of power-system component models but can only be witnessed in the field. The voltage, current, power, and frequency transducers can potentially produce spurious outputs from the effects of extraneous dynamics present in the input signals. The general transfer function of the measurement can be treated as the black box system with first order transfer function as given below:

$$H(s) = \frac{1}{1 + T_m s} \tag{1}$$

where T_m is time constant of measurement system.

2) Voltage Regulator: The SVC voltage regulator processes the measured system variables and generates an output signal that is proportional to the desired reactive-power compensation. Different control variables and transfer functions of the voltage regulator are used, depending on the specific SVC application. The measured control variables are compared with a reference signal, usually Vref, and an error signal is input to the controller transfer function. The output of the controller is a per-unit susceptance signal Bref, which is generated to reduce the error signal to zero in the steady state. The susceptance signal is subsequently transmitted to the gate pulsegeneration circuit. The block G represent the voltage regulator in the above block diagram of the SVC. Generally, the use of the proportionate integral voltage regulator is used for the generation of the control signal. The transfer function for the system is given below:

$$G(s) = \frac{\kappa}{1 + T_1 s} \tag{2}$$

where κ is regulation scope and T_1 is time constant of regulator.

3) Gate-Pulse Firing The susceptance reference output from the voltage regulator is transmitted to the gate pulsegeneration (GPG) unit, which produces appropriate firing pulses for all the thyristor-controlled and thyristor-switched devices of the SVC so that the desired susceptance is effectively made available at the SVC bus to achieve the specified control objectives. The transfer function can be written as:

$$T(s) = e^{-T_d s} \tag{3}$$

Where, T_d is delay time of gate pulse firing system.

IV. SIMULATION

A. Simulation of SVC

The block diagram of SVC shown above can be simulated in MATLAB/SIMULINK by direct setting the transfer functions and assainging appropriate values for the time constants and other values. Simulink block diagram can be shown as below:

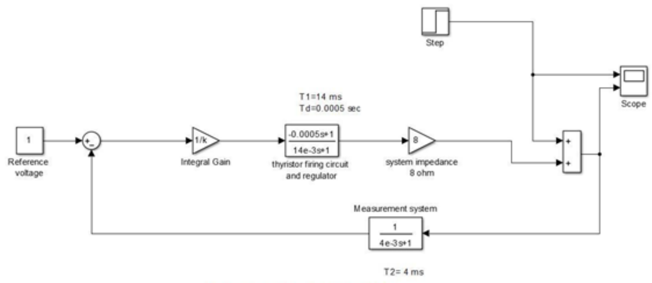

Fig. 2. SVC Model Simulation Blocks

The values taken for optimum operation of SVC is given in table below:

TABLE I
VALUE USED IN THE SIMULATION

Variables	Values
Reference Voltage	1 p.u
Measurement time constant	4 milisecond
Integral Gain	2
Gate Cicuit Delay	0.5 milisecond
System Impedance	8 Ohm

The simulation of SVC with values above has an underdamped response as shown below. The values need to be selected optimally otherwise the result could be over-damped or lead to instability.

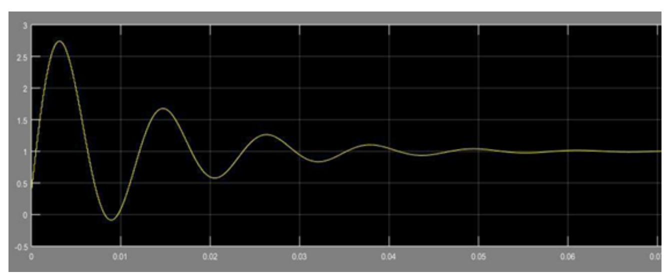

Fig. 3. SVC Model Simulation Result (Voltage-time)

B. System Implementation Without Using SVC

It is a two bus system whose performance is studied without using svc and results are observed in MATLAB/SIMULINK. It consists of a slack bus, transmission line and load bus. SVC can be used in both transmission line and in load bus. Here we dealt with the implementation of SVC in load bus. Simulation is done on phasor as powergui. The effcet of transmission line on reactive power flow is almost neglected. The simulation block in SIMULINK of the two bus system is shown below and value used is shown in table below:

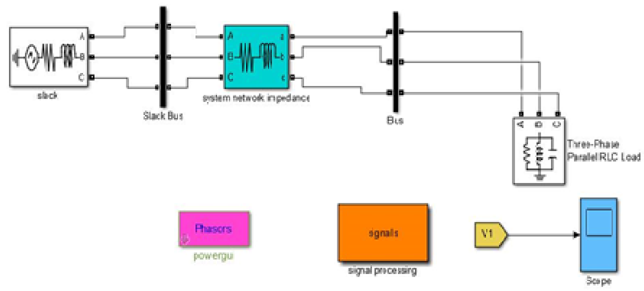

Fig. 4. Two Bus System for Analysis

TABLE II
VALUE USED IN THE SIMULATION

Variables	Values
Nominal slack bus voltage	132 kv
Line Resistance	10 Ohm
Line Inductance	12 mH
System Frequency	50 Hz
Base MVA	100 MVA
Load Active Power	90 MW

C. System Implementation Using SVC

In two bus system mentioned above, SVC block is connected in load bus as shown in SIMULINK block diagram below:

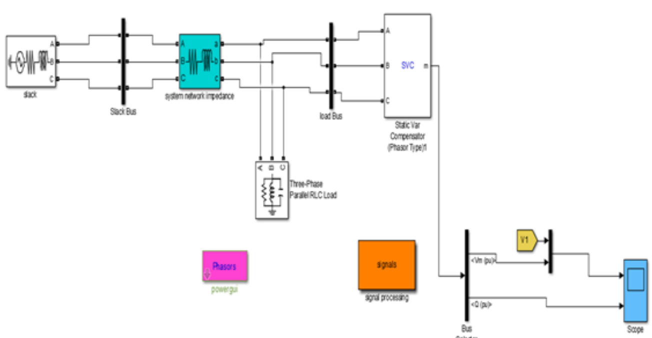

Fig. 5. Two Bus System for Analysis

D. Comparison of Both Conditions

The effect of application of static var compensator in system can be easily understood by comparing the conditions where the compenstaor is used and where it isn't. Application of static var compensator imporves the voltage of the system despite of the nature of load connected in the bus. The lagging load demand reactive power and if supplied by compensator on bus the voltage on system wouldn't drop and the excess reactive var spplied by load (this is in the case of ferranti effect during light loads), var compensator consumes that power and balances the voltage.

As the table shows, in the absence of var compensator there is variation of voltage level, during inductive loads, voltage dropped and during capacitive load voltage raises up. But with the use of static var compensator voltage in bus alomost remained in rated value. The oscillation in graph is due to the energy stord in compensator and is a transient response shown by compensator.

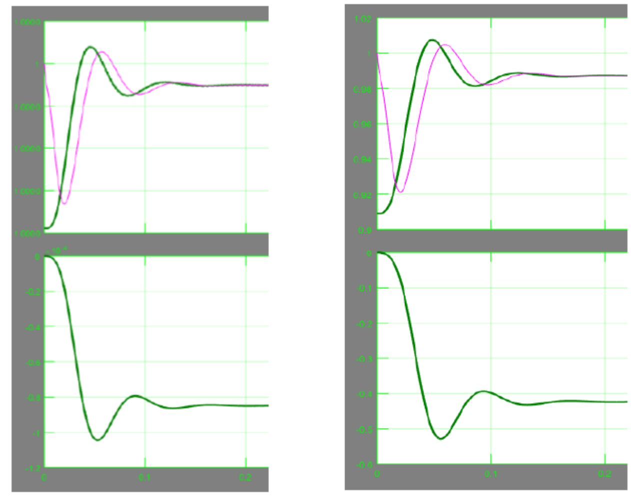

Fig. 6. Above, response of SVC for different loading, left for capacitive and right for inductive loading. Figure at bottom shows reactive power supplied or consumed by SVC.

TABLE III
COMPARSION ANALYSIS OF VOLTAGES

Active Power	Reactive Load	without SVC	with SVC
90 Mw	0 Var	1 pu	1 pu
90 Mw	-50 Var	1.11 pu	1.0132 pu
90 Mw	50 Var	0.9090 pu	0.987 pu

V. CONCLUSIONS

In this paper, Static Var Compensator, a FACT device is modelled on mathematical basis and simulated in MATLAB/SIMULINK. The use of static var compensator has shown an improvement in voltage profile in two bus system. It consumes or supplies reactive power that is either excess or deficient in the system bus so regulates the voltage.

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