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Linear Modeling of STATCOM with Design of Current and Voltage Controllers with Variation of DC-Link Voltage

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Abstract—The STATCOM is a shunt connected voltage source converter using self-commutating device and can be effectively used for reactive power control. Its principle of operation is similar to that of a synchronous condenser. This paper describes the linear modeling of STATCOM along with design of current and voltage controllers. The designed controllers with variation of DC-link voltage have been applied to the STATCOM and suitable DC-link voltage has been selected on basis of spike and over shoot of the responses. The values of the passive parameters decided on basis of selected DC-link voltage are used for the design and fabrication of a STATCOM. All responses are obtained through MATLAB SIMULINK tool box and presented here for clarity of the control strategy.

Index Terms-: Linear model, Controller design, PI Controller, STATCOM

I. INTRODUCTION

Power Generation and Transmission is a complex process, requiring the working of many components of the power system in tandem to maximize the output. One of the main components to form a major part is the reactive power in the system. It is required to maintain the voltage to deliver the active power through the lines. Loads like motor loads and other loads require reactive power for their operation. To improve the performance of ac power systems, we need to manage this reactive power in an efficient way and this is known as reactive power compensation. There are two aspects to the problem of reactive power compensation: load compensation and voltage support. Load compensation consists of improvement in power factor, balancing of real power drawn from the supply, better voltage regulation, etc. of large fluctuating loads. Voltage support consists of reduction of voltage fluctuation at a given terminal of the transmission line. Two types of compensation can be used: series and shunt compensation. These modify the parameters of the system to give enhanced VAR compensation. In recent years, static VAR compensators like the STATCOM have been developed. These quite satisfactorily do the job of absorbing or generating reactive power with a faster time response and come under Flexible AC Transmission Systems (FACTS). This allows an increase in transfer of apparent power through a transmission line, and much better stability by the adjustment of parameters that govern the power system i.e. current, voltage, phase angle, frequency and impedance. In this paper, first, a popularly accepted mathematical model is derived for the STATCOM. Then, the control strategy of the model which been proposed and described. The controller for this model has also been derived. This model has been simulated with designed controller by variation of pre-charge voltage on dc-link of the STATCOM.Finally simulation results are presented and demonstrated

II. MODELING OF THE STATCOM

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A. Operating Principles

The STATCOM is, in principle, a static (power electronic) replacement of the age-old synchronous condenser. Fig.1 shows the schematic diagram of the STATCOM at PCC through coupling inductors. The fundamental phasor diagram of the STATCOM terminal voltage with the voltage at PCC for an inductive load in operation, neglecting the harmonic content in the STATCOM terminal voltage, is shown in Fig.2. Ideally, increasing the amplitude of the STATCOM terminal voltage Voa above the amplitude of the utility voltage Vsa causes

B. Modeling

The modeling of the STATCOM, though well known, is reviewed in the lines below, for the sake of convenience. The modeling is carried out with the following assumptions:

1) All switches are ideal

2) The source voltages are balanced

3) Rs represent the converter losses and the losses of the coupling inductor

4) The harmonic contents caused by switching action are negligible.

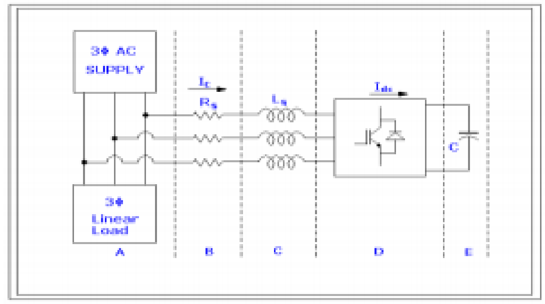

Fig.1: Schematic Diagram of STATCOM

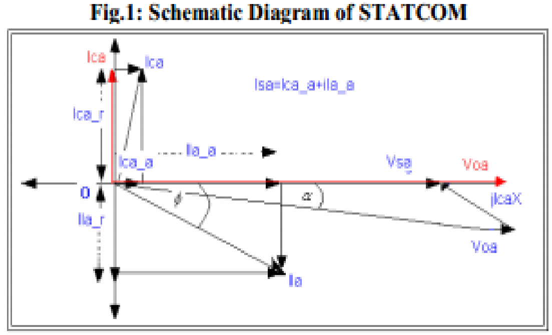

Fig.2: Phasor Diagram for Inductive Load Operation

C. Steady State and Transient Analysis

The detailed steady state and transient responses with the Table.1 are given in Fig.3-4 and responses suggest the static and dynamic conditions of the STATCOM. It can be seen that the transient responses take about one and half power cycle to reach at their steady state values.

Sl	Parameters	Symbol	Values
1	Frequency	f	50 Hz
2	Angular Frequency	w	314 rad/sec
3	RMS line-to-line Voltage	V_s	415V
4	Coupling Resistance	R_s	1.0 Ω
5	Coupling Inductance	L_s	5.0mH
6	DC-link capacitor	C	500 μF
7	Modulation Index	M	0.979
8	Phase angle	α	$\mp 5^0$
9	Load Resistance	R_L	52Ω
10	Load Inductance	L_L	$126mH$
11	Load Power factor	ϕ	0.79

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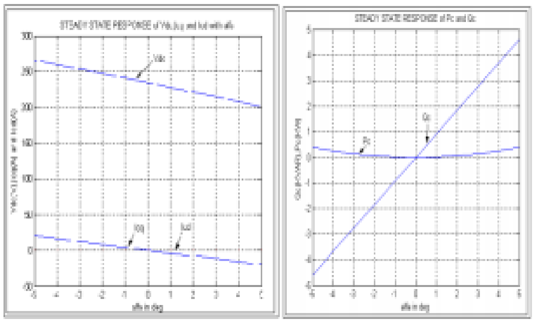
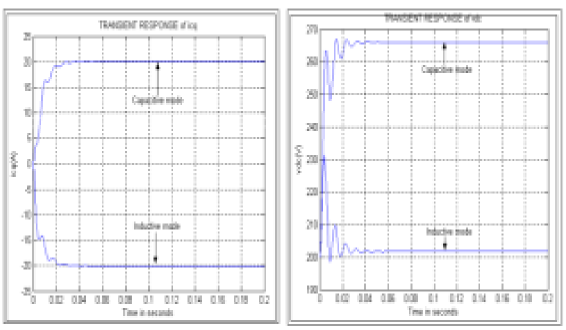


(a) (b)

Fig.3: Steady state responses: (a) Icq , Icd , Vdc and (b) Pc and Qc



(a) (b)

Fig.4: Transient responses in capacitive and inductive mode: (a)cq I and (b)dc

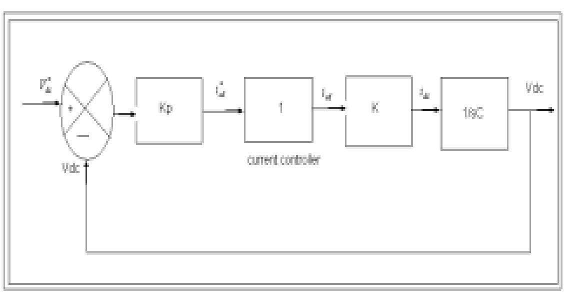


Fig.5: DC-link voltage control loop

The DC bus voltage is maintained at 400 volts. With Vdc as the reference, the voltage control loop is shown in Fig.5 and it consists of inner d - axis current control loop. The active power is supplied by the d -axis current which is nothing but the ripple current of the capacitor. To make the steady state error of the voltage loop zero Proportional control is adopted here and it produces the reference d -axis current for the control of the d - axis current. The design of voltage controller is as follows: Then Proportional Integral controller is considering for the voltage control. Hence, the transfer function of PI controller in (25) is associated with the transfer function on dc side is

IV. SIMULATIONS RESULTS

The control scheme for controlling DC link voltage as well as d and q axes current of STATCOM simultaneously as shown in Fig.6 is implemented with MATLAB SIMULINK with the parameters given in Table. I.

A. Simulation of Linear Load

The grid phases a voltage and current with linear load is shown in Fig.7. This Fig.6 depicts the lagging power factor of 0.7. The proposed control strategy will help for improving the power factor from 0.7 to nearly unit and this logic will also derive the conclusion for using DC link voltage.

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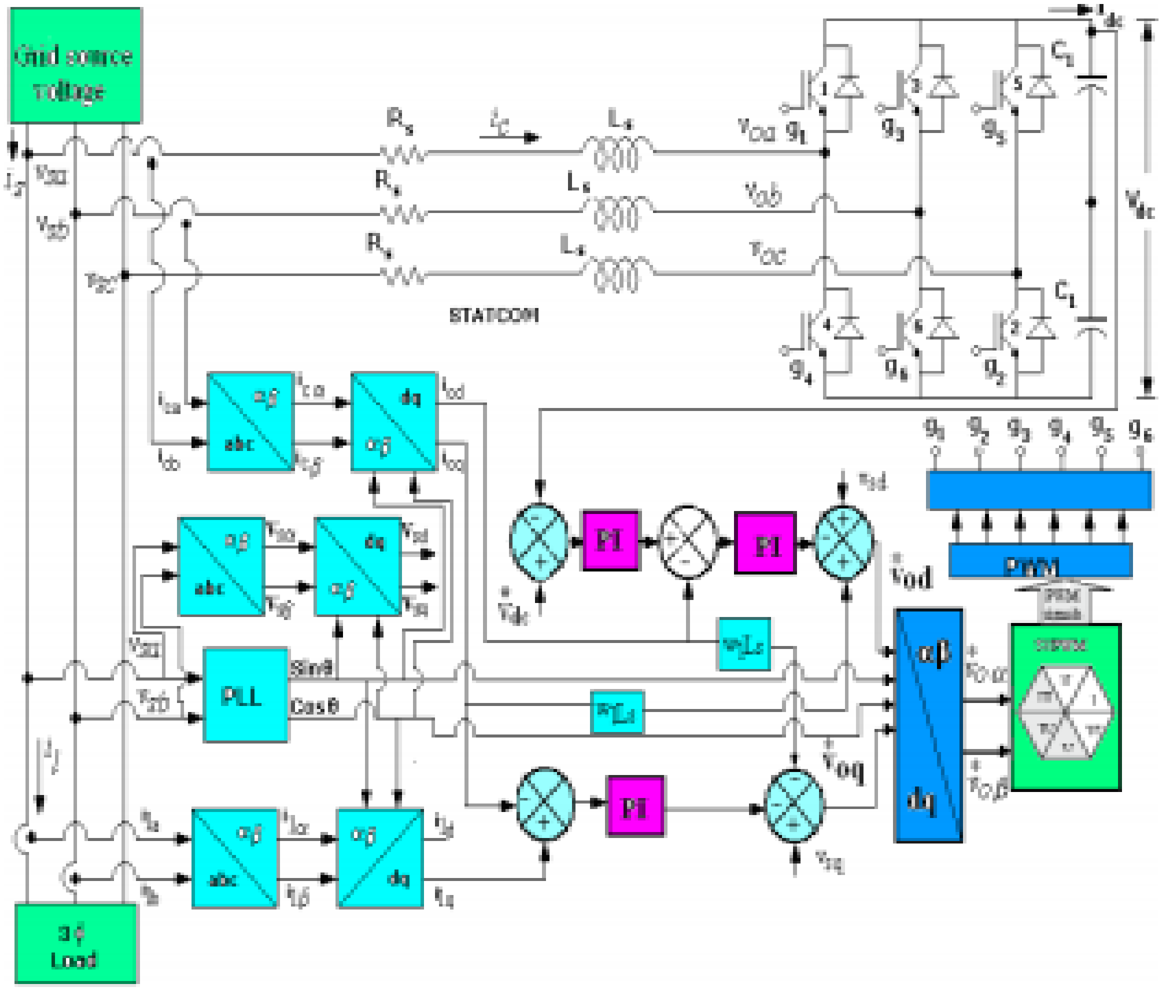

Fig.6: Implementing Scheme of STATCOM

B. Dc Link Capacitor Charged To 100v

These controllers work and STATCOM functions at initial value of DC link voltage of 100V with larger current peak as shown in Fig.8.

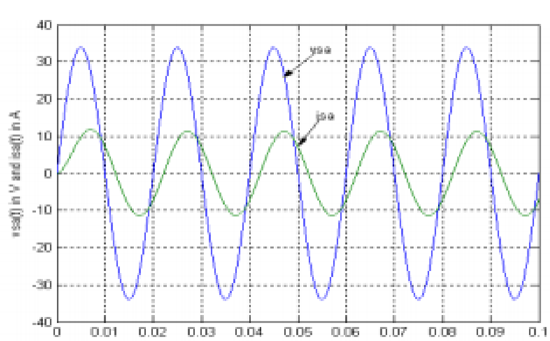

Fig.7: Grid Phase a Voltage and Phase a Load Current

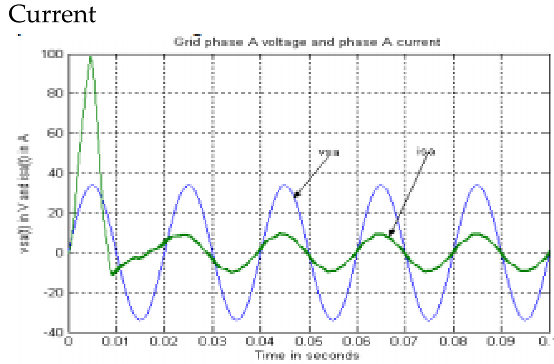

Fig.8: Grid Phase a Voltage and Phase a Current shows the dynamics of active and reactive components of the STATCOM current. The dynamics of active and reactive power of

STATCOM.DC link voltage with over shoot of 640V and settles at two power cycles 8.The zero phase angle and unity modulation index. The grid phase A voltage and the STATCOM phase A output voltage are shown in Fig.16 and both are in phase as it signifies for linear model and no spike8 change of STATCOM phase A current and DC link bus voltage due to change of reference current (reactive current of load).

V. CONCLUSION

The complete analysis and models of reactive current and voltage controllers of the STATCOM application are presented. The controllers are designed on the basis of parameters of the STATCOM and time constant. The simulated figures with designed controllers and on variation of DC link voltages are given which have been controlled the desired values. The settling time of the system by using the PI controller is faster than other controllers. In this paper, the proposed scheme is easier to implement compared to [14] and [19].However, in practice the issue of the charging the DC link voltage to the required value is quite significant. On increasing the magnitude of DC link voltage, the overshoot of all signals decreases. DC link voltage at 600V is suitable for proper operation of the STATCOM. In most cases, there is a separate charging circuit for the DC link voltage. The authors are working on a plausible method of eliminating such an extra starting arrangement, so that the controller may become operational while the DC link voltage is at a low value.

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