Modeling and Simulation of STATCOM

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***Abstract*:- This paper attempts to model and simulate Flexible Alternating Current Transmission Systems (FACTS) device, namely, Static Synchronous Compensator (STATCOM). The STATCOM a solid-state voltage source inverter and DC side capacitor is tied to a transmission line. A STATCOM injects an almost sinusoidal current, of variable magnitude, at the point of connection. This injected current is almost in quadrature with the line voltage, thereby emulating an inductive or a capacitive reactance at the point of connection with the transmission line. The functionality of the STATCOM model is verified by regulating the reactive current flow through it. This is useful for regulating the line voltage. STATCOM model is verified by regulating reactive power flow and is determined by using 6 pulses (two levels) IGBT based inverter. The mathematical modelling of STATCOM is simulated in MATLAB software for 10kVA rating.**

***Keywords*: STATCOM, IGBT, Voltage Source Inverter, PWM**

I. NOMENCLATURE

FACTS	Flexible Alternating Current Transmission System
STATCOM	Static Synchronous Compensator
VSI	Voltage Source Inverter
VA	Voltage-Ampere
GTO	Gate Turn-offs Thyristor
IGBT	Insulated Gate Bipolar Transistor
P	Active Power
Q	Reactive Power
PWM	Pulse Width Modulation

II. INTRODUCTION

Now a days need of electricity is increasing in tremendous way, hence VA loading is also increasing on power transmission line that resulted into need of reactive power compensation [2]. Most of the critical loads in an industrial low voltage AC system have an unbalanced and/or nonlinear characteristic because it is a single-phase rectifier with a capacitor or thyristor-based three phase rectifier. The unbalanced and nonlinear characteristic of the load has an undesirable effect on the power quality of input utility mains and adjacent load side [1]. Therefore, reactive power should be generated and compensated properly to improve the power quality of input utility and to maintain voltage profile mains by using a FACTS devices such as SVC, STATCOM, UPFC, and IPFC. In this paper STATCOM is used for reactive power compensation and to improve voltage profile.

STATCOM is shunt connected reactive compensation device that is capable of generating and or absorbing reactive power and its output can be varied to control the specific parameters of an electrical power system [4]. Use of self-commutated pulse width modulation (PWM) converters with an appropriate control scheme permits the implementation of STATCOM with a time response faster than the fundamental power cycle. Solid-state IGBT switching device is a relatively new technology in power electronics is employed in medium-to-high power ratings PWM-based FACTS devices[6].

STATCOM can be voltage source inverter type or current source inverter type. This paper discusses the VSI scheme. Basic block diagram of STATCOM is shown in Fig.1. The VSI converts DC voltage across storage device into set of three phase AC output voltage. These voltages are in phase and coupled with A. C. System through resistance and leakage reactance. STATCOM based on switching device can be GTO for high voltage, high power application or can be IGBT for low voltage, low power application. It is necessary to note that the size of dc capacitor in STATCOM is considerably smaller than the general ac capacitor for direct power factor compensation.

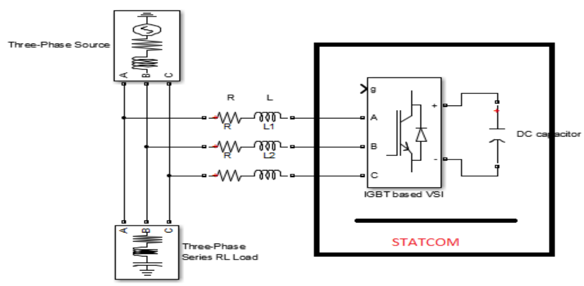

Fig. 1 Basic block diagram of STATCOM

III. PRINCIPLE OF STATCOM OPERATION

STATCOM is to suppress voltage variation and control of reactive power in phase with system voltage. It can compensate for inductive and capacitive current linearly and continuously. The terminal voltage V_{bus} is equal to sum of inverter voltage $V_{STATCOM}$ and voltage across leakage reactance V_L and resistance in inductive and capacitive mode. It means that if output voltage of STATCOM $V_{STATCOM}$ is in phase with bus terminal voltage V_{bus} and $V_{STATCOM}$ is greater than V_{bus} STATCOM provide reactive power to the system. If $V_{STATCOM}$ is smaller thanV_{bus} , STATCOM absorbs reactive power from power system. If $V_{STATCOM}$ and V_{bus} is equal then no power will be exchange, at that time STATCOM will operate in floating mode. Fig. 2 shows operating principle operation of STATCOM.

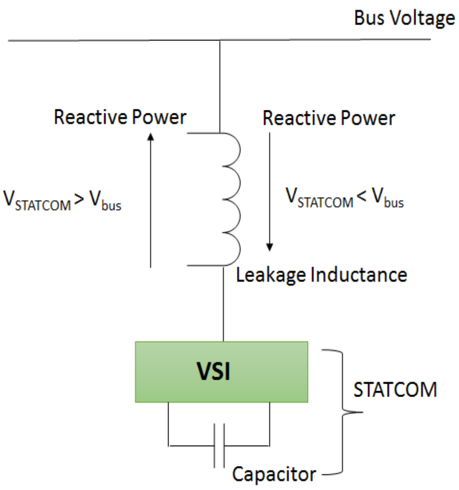

Fig. 2 Operation principle of STATCOM

Terminal voltage V_{bus} (AC side) is equal to sum of statcom output voltage and voltage drop across line reactor and resistance.

$$V_{bus} = bus\ terminal\ voltage$$

$$V_{STATCOM} = output\ voltage\ of\ STATCOM$$

$$R + j\omega L = X_L = Inductive\ Reactance$$

$$V_{dc} = DC\ capacitor\ voltage$$

General mathematical equation of STATCOM for active power, reactive power and statcom output voltage may be given as:

$$P = (V_{bus} \times V_{STATCOM} \div X_L) sin\alpha \quad \text{............... (1)}$$

$$Q = \left(V_{bus} \times \frac{V_{bus}}{X_L}\right) - (V_{bus} \times V_{STATCOM} \div X_L) cos\alpha \quad \text{............ (2)}$$

IV. MATHEMATICAL MODELING OF STATCOM

A typical A. C. System is used in this paper to show performance of STATCOM. The basic configuration of STATCOM is shown in Fig. 1 STATCOM consist of resistance, leakage inductance, and VSI and DC capacitor. Resistance and inductance acts as magnetic coupling to the system. They provide isolation to inverter circuit and grid circuit. DC capacitor provides constant voltage, it acts as source. IGBT with anti parallel diode is used. IGBT performs converter action whereas Diode performs rectification action.

Following equations are used to calculate resistance, leakage inductance and DC side capacitance

First order differential equation for the ac-side circuit of the STATCOM is

$$\frac{dI_{sa}}{dt} = 1/L_s\,(-R_s * I_{sa} + E_{sa} - E_{ta}) \quad \text{....... (3)}$$

$$\frac{dI_{sb}}{dt} = 1/L_s\,(-R_s * I_{sb} + E_{sb} - E_{tb}) \quad \text{........ (4)}$$

$$\frac{dI_{sc}}{dt} = 1/L_s\,(-R_s * I_{sc} + E_{sc} - E_{tc}) \quad \text{......... (5)}$$

These equations are converted on R-I frame of reference (the synchronously rotating frame of reference) as follows

$$\begin{bmatrix} I_{sR} \\ I_{sl} \end{bmatrix} = \begin{bmatrix} \frac{-R_s}{L_s} & w0 \\ -w0 & \frac{-R_s}{L_s} \end{bmatrix} \begin{bmatrix} I_{sR} \\ I_{sl} \end{bmatrix} + 1/L_s \begin{bmatrix} E_{sR} & E_{tR} \\ E_{sl} & E_{tl} \end{bmatrix} \quad \text{.... (6)}$$

STATCOM DC side equation is

$$\frac{dV_{dc}}{dt} = 1/C_s\,(I_{dc} + V_{dc}) \quad \text{......... (7)}$$

Instantaneous powers at the ac and dc terminals of the converter are equal, giving the following power-balance equation:

$$V_{dc} * I_{dc} = 3/2(E_{sR} * I_{sR} + E_{sl} * I_{sl}) \quad \text{.......... (8)}$$

Where the constant 3/2 is reference frame transformation constant. Based on the phasor diagram E_{sR} and E_{sl} is

$$E_{sR} = Es\ cos\theta s = Kcs * Vdc * cos\theta s \quad \text{........ (9)}$$

$$E_{sl} = Es\ sin\theta s = Kcs * Vdc * sin\theta s \quad \text{......... (10)}$$

V. SIMULATION OF STATCOM IN MATLAB

The Voltage Source Inverter (VSI) technique is used to simulate the STATCOM with two level 6 IGBTs. The STATCOM provides the required amount of reactive power to 12.8kW load.

The system parameters are used as follow,

TABLE NO. 1 System Parameters

Sr. No.	Parameters	Values
1	Supply Voltage	440 V
2	Supply frequency	50 Hz
3	Angular frequency	314 rad/s
4	Coupling Resistance	1 Ω
5	Coupling Inductance	5.62 mH
6	DC Capacitor	680uF
7	Modulation Index	0.8
9	Load Resistance	6.83Ω
10	Load inductance	24mH

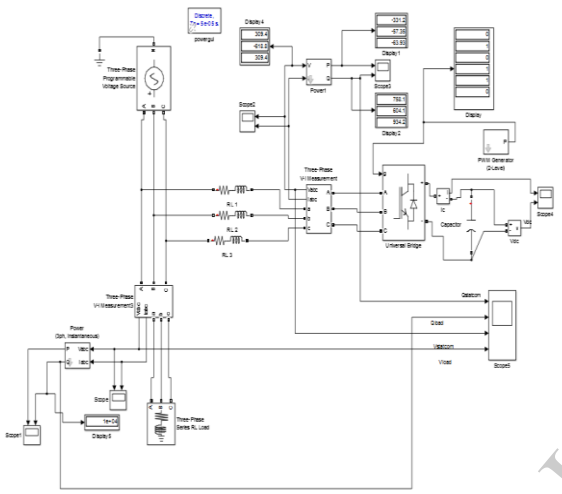

Fig. 3 STATCOM by using 6 pulses IGBT based Inverter

The three phase reference voltages of the STATCOM are generated by multiplying the peak value of the grid voltage and modulation index ($M.I$).The 6 pulses for the switching devices of the STATCOM are generated by using PWM technique. Pulse-width modulation (PWM) is a modulation technique that controls the width (in time) of an electrical pulse, formally the pulse's duration, based on modulator signal information.

Fig. 4 shows the waveform of voltage and current waveform having 3 phase load is directly connected to 3 phase source.

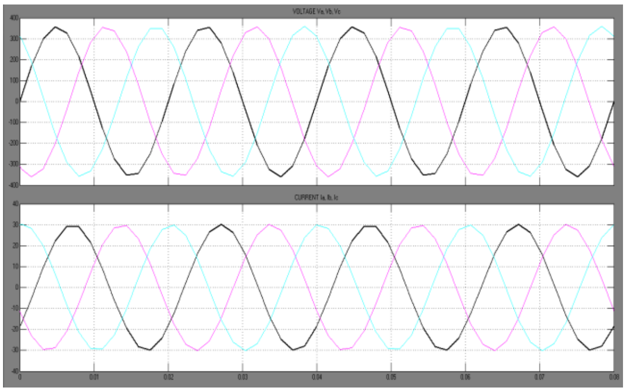

Fig. 4 voltage and current waveform without STATCOM

After inserting the STATCOM in circuit, Fig. 5.1 shows the capacitor current and voltage waveform. As initially capacitor takes large current up to 50A and capacitor is pre-charged with 700V, after that capacitor settle down with voltage 900V.

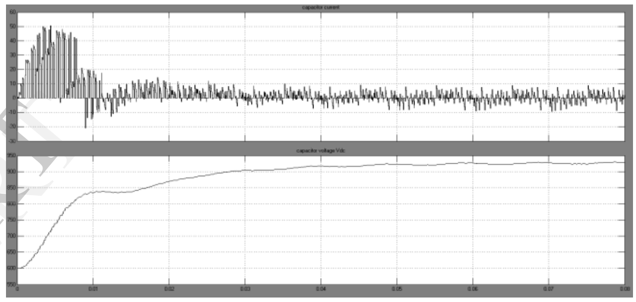

Fig. 5.1 Capacitor voltage and current waveform

Fig. 5.2 shows the waveform of STATCOM voltage and current. By using 6 pulses IGBT STATCOM voltage settle down up to 600V.

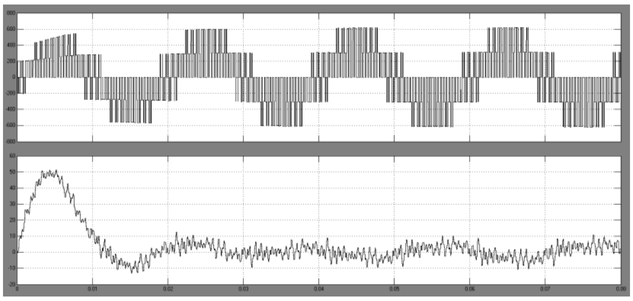

Fig. 5.2 STATCOM voltage and current

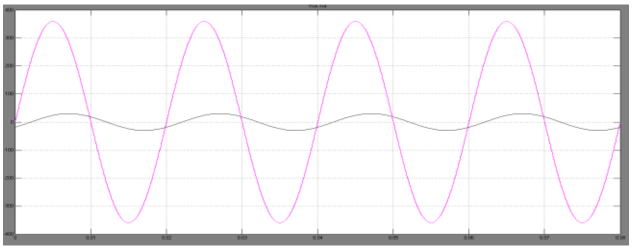

Fig. 5.3 Voltage and Current waveform at load side- Lagging compensation mode

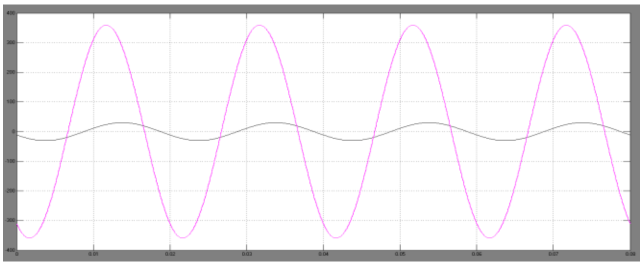

Fig. 5.4 Voltage and Current waveform at load side- Leading compensation mode

Fig. 5.3 and 5.4 shows voltage and current waveform at load side. It is verified that STATCOM being operated as inductive or capacitive load depending on operating mode. Fig. 5.5 shows the active and reactive power response by the load. Total 10kVAr reactive power is compensated. It shows as an inductive load STATCOM generates reactive power and provides constant reactive power to load.

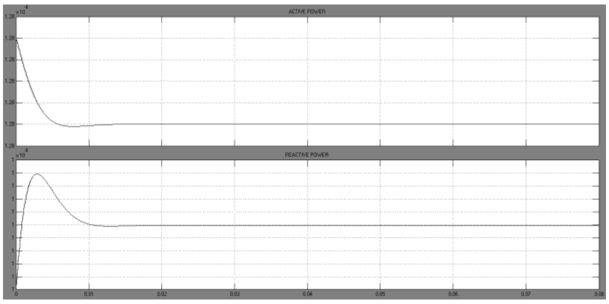

Fig. 5.5 active and reactive power of load

Fig. 5 STATCOM by using 6 pulses IGBT based Inverter

VI. CONCLUSION

In this paper, basic principle of STATCOM operation and the functions of each component are explained. Basic operating characteristics of STATCOM are verified by the simulation. It is observed that by appropriate reactive shunt compensation steady state transmittable power is increased and voltage profile in the line also maintained. The mathematical modelling of STATCOM in MATLAB is simulated and effect of 6 pulse IGBT based STATCOM are discussed. By using the STATCOM 10 kVAr reactive power is supplied to 12.8 kW load.

VII. REFERRANCES

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