Three Phase STATCOM Using Hysteresis Band Current Control Technique

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Abstract—Reactive Power Compensation is an important and indispensable aspect in power system. Most of the loads are inductive in nature and consume reactive power. Hence, the distribution system behaves as the sink of reactive power. When the large amount of lagging current flows through the system, the system voltage goes down. In such situation, VAR compensator brings the voltage back to normal value. STATCOM is a FACTS device based on VSI topology, which generally provides superior performance characteristics compared to conventional compensation methods employing TSCs and TCRs. STATCOM can both supply and consume reactive power. When the system needs reactive power, it acts as a source and supplies reactive power but when there is excess of reactive power in the system, it acts as a sink and consumes reactive power. This paper presents MATLAB simulation of three phase STATCOM. A STATCOM with the Hysteresis Band Current Control is developed in MATLAB/Simulink to observe their performance.

Index Terms—FACTS, Hysteresis Band Current Control, PI controller, Reactive Power Compensation, STATCOM

I. INTRODUCTION

STATCOM is a switching converter type static VAR generator, which generates or absorbs reactive power through several switching pattern within its converter without the use of any capacitor or inductor banks.

Conventionally, capacitor banks are used to compensate the reactive power since capacitor draws a leading current. Power electronics devices are gaining wide popularity nowadays for improving the performance of transmission and distribution systems. The reactive power compensation and control have been recognized as efficient and economic means of increasing power system transmission capability and stability. The FACTS devices, such as STATCOM has been introduced more recently which employs VSI topology with a fixed DC link capacitor as a static replacement of the synchronous condenser.

Functionally, the operation of the STATCOM is similar to that of an ideal synchronous condenser which can generate or absorb the reactive power by varying the excitation in the field winding. In case of STATCOM, the change in gate signal is analogous to the change in excitation of condenser because it causes the change in terminal voltage of STATCOM as in the case of condenser terminal voltage. The reactive power in any line always flows from higher voltage magnitude to lower voltage magnitude.

II. PROBLEM SPECIFICATION

Voltage control and reactive power management are the two aspects of a single activity that both supports reliability and facilitates commercial transactions across transmission networks. In real practice, most of the loads are inductive in nature which consume reactive power. That means, a large amount of lagging current drawn by the load results in voltage sag. At low voltages, electrical equipments perform poorly. For example: light bulb provides less illumination, and induction motor will not operate efficiently and in some case it may not start at all. Reactive power flow from the generation side to the distribution side increases transmission line losses and reduces the power transmission capability of the transmission line. So, we use so many FACTS controller devices to control the flow of reactive power. Since STATCOM provides a fast response and flexible solution to this problem, STATCOM is the most widely use VAR compensator.

III. SYSTEM DESCRIPTION

This system includes voltage source inverter, hysteresis band controller and dc link capacitor. The voltage source inverter consists of three pairs of IGBTs (Insulated-Gate Bipolar Transistor). Each pair consists of two IGBTs which are switched in complementary fashion. If the top device is on then the bottom device is off and vice versa. Hysteresis band controller provides the switching signals to the IGBT by making the actual current follow the reference signal within the limited hysteresis band.

This system is designed in such a way that when the load changes resulting the change in reactive power, the voltage also
changes (voltage increases or decreases), it is sensed by the voltage sensor which is compared with the reference voltage and generates an error signal which when passed through PI controller produces reference quadrature axis current ($I_q$). Similarly, dc link capacitor voltage is compared with the value of voltage that we desire it to be constant and generates an error signal which is fed to the PI controller. It produces reference direct axis current ($I_d$). The reference direct and quadrature axis currents when passed through Parks transformation (dq to abc transform) produces reference abc phase currents. The hysteresis band controller compares the actual current through the STATCOM branch with the reference currents which produces gating signal corresponding to each leg of IGBT (one gating signal can control both the IGBT of the same leg since the top and bottom IGBTs are switched in complementary fashion) by comparing the actual current of the inverter sensed by the current sensor with upper and lower limits of hysteresis band. This gating signal controls the magnitude and phase of the output of the inverter so that the inverter produces the reactive current which compensates the reactive current drawn by the load and maintains the voltage at load terminal. The phase is required to compensate for the active power losses that occur in the inverter and transformer so that the voltage across the capacitor is maintained constant.

**IV. MATLAB SIMULATION**

$I_d$ calculation subsystem gives the active component of current that should flow through STATCOM. This block consists of a closed loop control system with PI controller to maintain the voltage across the dc link capacitor at reference value. It controls the phase angle output of STATCOM voltage. The active power loss in the STATCOM branch should be supplied by the source.

If the active power through the STATCOM branch is greater than the active power loss, the excess of reactive power charges the capacitor and the capacitor voltage increases. Similarly, if the active power through the STATCOM branch is less than the active power loss, the deficient active power is supplied by capacitor and the capacitor voltage decreases. So, to maintain the value of dc link capacitor at constant value, this PI control loop is designed. Thus, designed PI control loop will generate the respective control signal to maintain the capacitor voltage constant. The reactive power demanded by the load should be supplied by the STATCOM branch, which is the main aim of our system.
consists of the closed loop control system which compares with the power supplied by the STATCOM with the reactive power of the load. The error thus obtained is passed through PI controller which will generate the control signal to generate \( I_q \) and compensate the reactive power.

V. HBCC

This is the hysteresis band current control block. This block generates the gating signals for the inverter. In this subsystem, the reference currents and the actual signals through the STATCOM branch are subtracted and passed through a relay block. The relay switches its state when the difference tries to go beyond the two limiting values and the gating signals are generated. The gate signals thus obtained will control the switching of the IGBT and thus make the actual current within the hysteresis band.

VI. DQ TO ABC TRANSFORMATION

In our system dq0 to abc transformation generates the reference signals for the STATCOM currents. dq0 to abc transformation is also known as Inverse Parks Transformation.

\[
\begin{bmatrix}
  u_a \\
  u_b \\
  u_c
\end{bmatrix} = \begin{bmatrix}
  \cos(\theta) & -\sin(\theta) & 1 \\
  \cos(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{2\pi}{3}) & 1 \\
  \cos(\theta + \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) & 1
\end{bmatrix} \begin{bmatrix}
  i_d \\
  i_q \\
  i_0
\end{bmatrix}
\]

VII. RATING OF DIFFERENT PARAMETERS

System voltage: 400 V
De link capacitance: 1000 uF
De link Reference voltage: 600 V

PI for \( i_d \) loop:
\( K_p = 1 \) and \( K_i = 2 \)
PI for \( i_q \) loop;
\( K_p = 0.1 \) and \( K_i = 15 \)
Hysteresis bandwidth: 5% of reference
Coupling parameters
Inductor: 1 mH
Resistor: 1 ohm

VIII. SIMULATION RESULTS

The complete MATLAB model for the simulation of three phase STATCOM is shown in the figures 8 to 19. The horizontal axis indicates time in second and the vertical axis the respective values.

This model consists of three phase voltage source with the rating of 400V connected to three phase RL load of 1000 watts and 1000 VAR. Extra inductive load of 5000 VAR is added after 0.4sec. The STATCOM is switched on after 0.8sec.

The simulation results shown in the fig shows that initially the system is running at 0.953pu. When extra reactive load of 5000Var is switched on after 0.4 sec, the system voltage...
and 1.002 pu. From the plot of $Q_{source}$, $Q_{load}$ and $Q_{stat}$, we can see that initially the source is supplying the reactive power before the STATCOM is switched on and after the switching of STATCOM, the source is relieved of supplying the reactive power as the reactive power for the load is supplied by the STATCOM. Hence the above observation suggests that STATCOM is supplying the reactive power to the load and maintain the system voltage at rated value.

In our STATCOM model there are two closed loops. One loop maintains the voltage across the dc link of the capacitor and the other loop maintains the reactive power injected by the STATCOM. Here, the reference voltage for the dc link is 600 V and the plot of $V_{dc}$ shows that the voltage across the
dc link of the capacitor is maintained at 600V. From the plot of $I_{stat}$, we can see that the current through the STATCOM branch is following the reference current and the actual current is within the 5% of the reference current. The output voltage of the STATCOM is not sinusoidal and is shown in the figure.

IX. Conclusion

In this paper Simulation of STATCOM in MATLAB/SIMULINK with different reactive power load has been studied. The strategy works well for reactive power compensation. For different value of the load our STATCOM branch is generating required amount of reactive power. Also if load is capacitive our system is capable to draw that excess amount of reactive power too. Also performance of STATCOM with various control technique for VSI has been discussed here; PI control technique has been suggested for voltage and reactive power injection followed by the hysteresis band current controller. The hysteresis band current controller is used to control the STATCOM current. The STATCOM is found to be efficient technology compared to the conventional methods of reactive power compensation.

Bibliography


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