CHAPTER 2

STATCOM AND ITS SIMULINK MODEL

2.1 INTRODUCTION

Reactive power compensation is an important issue in the control of electric power systems. Reactive power increases the transmission system losses and reduces the power transmission capability of the transmission lines. Moreover, reactive power flow through the transmission lines can cause large amplitude variations in the receiving-end voltage. This chapter illustrates the effect of STATCOM in power system on reactive power control by proper modelling of simple power system and voltage source converter based STATCOM using simulink and simpower system toolboxes in MATLAB.

Today’s power transmission and distribution systems face increasing demands for more power with better quality and higher reliability at lower cost. Developing countries can apply versatile voltage regulation and system stabilization measures in order to effectively utilize the existing transmission networks. The use of power electronics in the form of SSSC, STATCOM and UPFC is well-established independent of the specific application.

A STATCOM is a controlled reactive-power source. It provides the desired reactive-power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in a VSC. A STATCOM principle diagram is shown in Figure 2.1.
The VSC is connected to a utility bus through shunt transformer. $V_{ac}$ is the bus voltage. $I_{ac}$ is STATCOM injected current. $V_{out}$ is the VSC output voltage. $V_{dc}$ and $I_{dc}$ are the DC capacitor side voltage and current. An IGBT with back to back diode denotes the 3 arm IGBT bridge. Top three IGBTs are called as positive group and bottom three IGBTs are called as negative group IGBTs. The inverter operation takes place, when IGBTs conduct and converter operation takes place, when diodes conduct. Figure 2.2 shows the concept of STATCOM power exchange.
STATCOM is seen as an adjustable voltage source behind a reactance. It means that the capacitor banks and shunt reactors are not needed for reactive-power generation and absorption, thereby it gives the STATCOM, a compact design. The equivalent circuit of the block diagram of VSC based STATCOM is shown in Figure 2.3.

The exchange of reactive power between the converter and the ac system can be controlled by varying the amplitude of the 3-phase output voltage $V_{out}$ of the converter as illustrated in Figure 2.3. If the amplitude of the $V_{out}$ is increased above that of the utility bus voltage $V_{ac}$, the current flows through the reactance from the converter to the AC system and the converter...
generates capacitive-reactive power for the AC system. If the amplitude of the 
$V_{\text{out}}$ is decreased below the utility bus voltage, the current flows from the AC 
system to the converter and the converter absorbs inductive-reactive power 
from the AC system. The reactive-power exchange becomes zero, if the $V_{\text{out}}$ 
equals the ac system voltage, and in this case the STATCOM is said to be in 
a floating state.

In the VSC at the DC side, a relatively small DC capacitor is 
connected. Hence, the STATCOM is capable of only reactive power exchange 
with the transmission system. If the DC capacitor is replaced by some other 
DC energy source, the controller can exchange real and reactive power with 
the transmission system by extending its region of operation from two to four 
quadrants.

The coupling transformer plays two different roles. First, it 
connects the converter to the high voltage power system. Secondly, the 
transformer inductance ensures that DC capacitor is not short-circuited and 
discharged rapidly.

A STATCOM is used for voltage regulation in a power system. 
Under lightly loaded conditions, the STATCOM is used to minimize or 
completely diminish the line overvoltage. On the other hand, it can also be 
used to maintain certain voltage levels under heavy loading conditions.

The real power flowing into the converter supplies the converter 
losses due to switching and charges the DC capacitor to a satisfactory DC 
voltage level. The capacitor is charged and discharged during the course of 
each switching cycle. But in steady state, the average capacitor voltage 
remains constant. In steady state, all the power from the AC system is used to 
provide the losses due to switching. The STATCOM's ability to absorb/supply 
real power depends on the size of DC capacitor and the real power losses due
to switching. Since the DC capacitor and the losses are relatively small, the amount of real power transfer is also relatively small. This implies that the STATCOM's output AC current has to be approximately +90° with respect to AC system voltage at its line terminals.

### 2.1.1 V-I Characteristic of STATCOM

The STATCOM can supply both the capacitive and the inductive compensation and is able to independently control its output current over the rated maximum capacitive or inductive range irrespective of the amount of AC-system voltage. The STATCOM can provide full capacitive-reactive power at any system voltage even as low as 0.15 p.u. and is capable of yielding full output of capacitive generation almost independently of the system voltage. The STATCOM is necessary to support the system voltage during and after faults which otherwise will cause voltage collapse. A typical V-I characteristic of a STATCOM is depicted in Figure 2.4.

![Figure 2.4 The V-I characteristic of the STATCOM.](image)
$V_{pu}$, $I_{min}$ and $I_{max}$ are voltage per unit, minimum current and maximum current respectively. The maximum attainable transient over current in the capacitive region is determined by the maximum current turn-off capability of the converter switches. In the inductive region, the converter switches are naturally commutated. Hence, the transient-current rating of the STATCOM is limited by the maximum allowable junction temperature of the converter switches. In practice, the semiconductor switches of the converter are not lossless, so the energy stored in the DC capacitor is eventually used to meet the internal losses of the converter, and henceforth, the DC capacitor voltage starts decreasing. However, when the STATCOM is used for reactive-power generation, the converter itself can keep the capacitor charged to the required voltage level. This task is accomplished by making the output voltages of the converter lag behind the AC-system voltages by a small angle.

The same mechanism can be used to increase or decrease the capacitor voltage. VAR generation or absorption can be controlled by adjusting the amplitude of the converter output. Figure 2.5 shows the STATCOM AC current and voltage diagram, where phasors $I_Q$ and $I_P$ represent the AC current components that are in quadrature and in phase with the AC system voltage $V_{ac}$ respectively.

At AC terminals

$P = V_{ac}I_{ac}\cos \varphi < 0$
$Q = V_{ac}I_{ac}\sin \varphi > 0$

$P = V_{ac}I_{ac}\cos \varphi > 0$
$Q = V_{ac}I_{ac}\sin \varphi > 0$
At DC terminals

\[
\begin{align*}
-I_{dc} & \quad I_{dc} & \quad V_{dc}
\end{align*}
\]

**Figure 2.5 STATCOM phasor diagrams at AC and DC terminals**

The DC current $I_{dc}$ and voltage $V_{dc}$ are shown in Figure 2.5. If the losses in the STATCOM circuit are neglected, the real power exchange with the AC system is zero. This intern makes the active current component $I_p$ and DC current $I_{dc}$ equal to zero. In this case, the AC current $I_{ac}$ is equal to the reactive component $I_Q$.

In Figure 2.5 the real and reactive power flow are positive means that the power are going into the STATCOM, while negative means that the power are going out of the STATCOM. Varying the amplitude of the converter three-phase output voltage $V_{ac}$, the reactive power generation/absorption of the STATCOM can be controlled. If the amplitude of the converter output voltage $V_{out}$ is increased above the amplitude of the AC system bus voltage $V_{ac}$, the AC current $I_{ac}$ flows through the transformer reactance from the converter to the AC system generating reactive power. In this case, the AC system draws capacitive current that leads the AC system voltage by an angle of $90^\circ$ assuming that the converter losses are equal to zero. The AC current flows from the AC system to the VSC if the amplitude of the converter output voltage is decreased below that of the AC system, and consequently the converter absorbs reactive power.
For an inductive operation, the current lags the AC voltage by an angle of 90°. If the amplitudes of the AC system and converter output voltages are equal, there will be no AC current flow in and out of the converter and hence there will be no reactive power generation/absorption. The AC current magnitude can be calculated using the following Equation (2.1).

\[
I_{ac} = \frac{V_{out} - V_{ac}}{X}
\]  

(2.1)

Assuming that the AC current flows from the converter to the AC system. \(V_{out}\) and \(V_{ac}\) are the magnitudes of the converter output voltage and AC system voltage respectively and \(X\) represents the coupling transformer leakage reactance. The corresponding reactive power exchanged can be expressed as following Equation (2.2).

\[
Q = \frac{V_{out}^2 - V_{out} V_{ac} \cos \alpha}{X}
\]  

(2.2)

where the angle \(\alpha\) is the angle between \(V_{out}\) and \(V_{ac}\).

In Figure 2.5, ‘at DC terminal’, shows the case when the angle \(\alpha\) is equal to zero, there is no real power transfer between the converter and AC system. Thus, the real power exchange between the converter and the AC system can be controlled by phase shifting the \(V_{out}\) with respect to \(V_{ac}\). The converter supplies real power from its DC capacitor to the AC system, if the converter output voltage leads the corresponding AC system voltage and is shown in Figure 2.5, whereas the converter absorbs real power from the AC system, if the converter output voltage is made to lag the AC system voltage.
The amount of exchanged real power is typically small in steady state. Hence, the angle ‘α’ is also small. The real power exchange between the VSC and the AC system can be calculated using the following Equation (2.3).

\[ P = \frac{V_{\text{out}} V_{\text{ac}} \sin \alpha}{X} \]  

(2.3)

The real and reactive power generated or absorbed by the voltage-sourced converter can be controlled independently, provided that the VSC is connected to a DC storage battery, DC voltage source or another VSC instead of a DC capacitor. The real power that is being exchanged by the transmission system must be supplied or absorbed at its DC terminals by the DC energy storage or any other previously mentioned device. In contrast, the reactive power exchange is internally generated or absorbed by the VSC without the DC energy storage device. The converter simply interconnects the three-AC terminals in such a way so that the "reactive" current can flow freely among them.

2.2 EQUIVALENT CIRCUIT MODEL OF STATCOM

The STATCOM consists of 3 phase bus, shunt transformer, VSC and DC capacitor. Figure 2.6 shows the equivalent circuit of the STATCOM.
The loop equations for the STATCOM circuit is written in vector form as Equation (2.5).

$$\frac{dl_{abc}}{dt} = -\frac{\omega_s R_s}{L_s} l_{abc} + \frac{\omega_s}{L_s} (E_{abc} - V_{abc})$$  \hspace{1cm} (2.5)

The output of the STATCOM is given by Equation (2.6).

$$E_a = KV_{dc} \cos(\omega t + \alpha)$$ \hspace{1cm} (2.6)

Here $R_s$ and $L_s$ represent the STATCOM transformer resistance and inductance respectively. $E_{abc}$ are the converter AC side phase voltages, $V_{abc}$ are the system-side phase voltages, and $i_{abc}$ are the phase currents. ‘K’ is the modulation index. $V_{dc}$, $I_{dc}$ and $P_{dc}$ are the DC capacitor voltage, current and DC power. ‘$\alpha$’ is the phase angle between bus voltage and converter output voltage. $R_{dc}$ and $C_{dc}$ are the real power losses in switches and DC capacitor value. $P_{ac}$ and $Q_{ac}$ are the STATCOM injected real and reactive power.
2.3 MODELING OF POWER SYSTEM USING MATLAB/SIMULINK

The effect of STATCOM on the performance of a power system with RL series and RC Load is studied under MATLAB-SIMULINK environment. The real and reactive power flow in the line as well as in the load are observed without STATCOM. The variations of power flow after the introduction of the STATCOM is noted. A PI-based controller is designed for the STATCOM and then its performance is studied using MATLAB-SIMULINK. The real and reactive power flow of the models are analyzed. The power flow with the STATCOM is compared with the power system model without connecting STATCOM and thus its performance is evaluated.

The modelling of STATCOM with power system is done by using the simpower systems toolboxes in MATLAB/SIMULINK. The modelling is done by connecting a three phase source and RL load through a transmission line. The AC voltage at source is maintained at 110V (1.p.u) and the frequency is 50Hz. The load voltage and phase angles are varied and the real and reactive power flow in the bus are observed. Using the active and the reactive power blocks available in Simpower system, the real and the reactive power flow through the line are measured at both the ends. The MATLAB/Simulink diagram of the power system is shown in Figure 2.7.
The simulink diagram of a power system has AC source, load, transmission line and measurement blocks. The source is of 3 phase, 110V and 50 Hz AC supply. The load is RL which has 50W real and 500VAR inductive reactive power at 110V AC. The transmission line is of 100km length.

2.4 MODELLING AND SIMULATION OF STATCOM WITH POWER SYSTEM

The capacitor voltage can be adjusted by controlling the phase angle difference between line voltage and VSC voltage. If the phase angle of line voltage is taken as a reference, the phase angle of VSC voltage is the same as the firing angle of VSC. The DC voltage decreases and reactive power flows into STATCOM, if the firing angles are slightly advanced. Conversely, if the firing angles are slightly delayed, the DC voltage increases and STATCOM supplies reactive power to the bus. By controlling the firing angles of VSC, the reactive power can be generated from or absorbed by
STATCOM and the voltage regulation can be achieved. A DC capacitor is used as a source for the VSC. The DC source sometimes will be connected parallel to the capacitor to give more active power support to the capacitor during transient conditions. This voltage source converter is connected to the transmission line through a shunt transformer, where \( V_{dc} \) is the voltage across the DC capacitor, \( K \) is the modulation gain and \( \alpha \) is the injected voltage phase angle. The STATCOM consists of a VSC and a capacitor.

The VSC in STATCOM is modeled by connecting 3 arm IGBT bridge. Each IGBT is paralleled by a diode. The output of the converter should be a sine wave. In order to get the sine wave output at the converter end, a sine triangular PWM output is given to the IGBT’s gates. When the IGBT is ‘ON’, the converter will act as an inverter and the DC capacitor voltage is inverted to 3 phase AC. During the ‘OFF’ period of the IGBT, the converter will act as a full wave uncontrolled rectifier and the capacitor gets charged to the maximum value of the line voltage.

2.5 PWM GENERATOR

The PWM generator is used to generate the gate pulses for the IGBTs of the VSC. Here, the sine and the triangular waveforms are generated. The sine wave which is of 50Hz is compared with the triangular wave of 20 kHz. According to the comparison, the PWM pulses are produced. These pulses are given to gates of the IGBTs. By varying the modulation index, the magnitude of the converter output will vary and as well as by varying the phase angle of the modulating wave, the converter output voltage phase angle will also vary. Modulation index is defined as the ratio of the magnitude of modulating wave to carrier wave. The simulink model of the PWM generator is shown in Figure 2.8.
Figure 2.8 Simulink model of the PWM Generator

The Modulating signal is of 50Hz sine wave and the carrier wave is of 20 kHz triangular wave. The converter output is in PWM form. In order to bring it to sine wave form, a LC filter is connected to filter out the content of carrier wave with the frequency of 20 kHz. The inductance of shunt transformer will act as ‘L’ for the LC filter. The simulation is done by connecting RL load. Figure 2.9 shows the simulink diagram of power system with STATCOM.

Figure 2.9. Simulink diagram of power system with STATCOM
The converter is the heart of the STATCOM. The ‘NOT’ tool boxes are used to invert the pulses of the positive group IGBTs. The simulink diagram of the converter is shown in Figure 2.10.

![Simulink diagram of IGBT converter](image)

**Figure 2.10. Simulink diagram of IGBT converter**

To find the amount of reactive power to be injected or absorbed by the STATCOM, the 3 phase source currents are transformed to ‘dqo’ form. The $I_q$ component of the source current is strongly correlated to the reactive power which is used as the reference $I_q$ in the PI controller that produces the modulation index of the PWM controller. The STATCOM injected or absorbed $I_q$ is found using the same transformation and is compared with the reference $I_q$ in the above PI controller. The error is given to the PI controller and it gives increased or decreased modulation index (K). The converter output voltage is increased or decreased so that the converter injects or absorbs the reactive power into the bus depending on RL or RC load respectively.
2.6 RESULTS OBTAINED IN POWER SYSTEM MODEL USING MATLAB/SIMULINK

A power system has a 3 phase AC source at the sending end and load at the receiving end and transmission line in between them is created using MATLAB/simulink. The sending end and receiving end details for the power system without STATCOM is given in Table 2.1.

**Table 2.1 Simulation results without STATCOM for RL load**

<table>
<thead>
<tr>
<th>S. NO.</th>
<th>Load Values P(W), Q (VAR)</th>
<th>P&lt;sub&gt;s&lt;/sub&gt; (W)</th>
<th>Q&lt;sub&gt;s&lt;/sub&gt; (VAR)</th>
<th>V&lt;sub&gt;load&lt;/sub&gt; (V)</th>
<th>P&lt;sub&gt;r&lt;/sub&gt; (W)</th>
<th>Q&lt;sub&gt;r&lt;/sub&gt; (VAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>50,500</td>
<td>140</td>
<td>380</td>
<td>93</td>
<td>38</td>
<td>360</td>
</tr>
<tr>
<td>2.</td>
<td>50,400</td>
<td>110</td>
<td>320</td>
<td>96</td>
<td>40</td>
<td>310</td>
</tr>
<tr>
<td>3.</td>
<td>50,300</td>
<td>85</td>
<td>250</td>
<td>99</td>
<td>42</td>
<td>245</td>
</tr>
<tr>
<td>4.</td>
<td>50,200</td>
<td>63</td>
<td>172</td>
<td>109</td>
<td>43</td>
<td>170</td>
</tr>
</tbody>
</table>

As per the Table 2.1 in the first reading, the load is set to absorb 50w real and 500VARs reactive power at a voltage of 110V. It has been observed that the source is supplying real power of 140Watts and 380VARs inductive reactive power but the load is consuming 38 watts of real power and 360 VARs of inductive reactive power. The receiving end voltage has also been reduced to 93V from 110V. Hence, receiving end real and reactive power are also reduced. Remaining 102Watts real and 20VARs reactive power have been absorbed in the transmission line. From the Table 2.1, it is also observed that when the load reactive power is reduced, the sending end real and reactive power is reduced and the load real power is increased. Figure 2.11 shows the simulation result of power system without STATCOM for the first reading of Table 2.1.
In the above figure, from the top, the values are $P_s$, $Q_s$, $P_r$, $Q_r$ and $V_{load}$ respectively. Here, $P_s$ and $Q_s$ represent sending end real and reactive power respectively. $P_r$ and $Q_r$ represent receiving end real and reactive power. $V_{load}$ represents RMS voltage across the load.

2.7 RESULTS OBTAINED IN POWER SYSTEM MODEL WITH STATCOM USING MATLAB/SIMULINK

2.7.1 Case A: RL LOAD

The STATCOM is connected at the middle of the transmission line. The STATCOM injected reactive power ($Q_{stat}$) is measured along with $P_s$, $Q_s$, $P_r$, and $Q_r$ values. Table 2.2 gives the $P_s$, $Q_s$, $P_r$, $Q_r$, and $Q_{stat}$ values, when RL load is connected in the power system with the STATCOM.
Table 2.2 Output results when STATCOM is connected to RL load

<table>
<thead>
<tr>
<th>S. NO.</th>
<th>Load Values</th>
<th>Qs (VAR)</th>
<th>Vload (V)</th>
<th>Pr (W)</th>
<th>Qr (VAR)</th>
<th>Qstat (VAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>50,500</td>
<td>170</td>
<td>108</td>
<td>60</td>
<td>480</td>
<td>520</td>
</tr>
<tr>
<td>2.</td>
<td>50,400</td>
<td>160</td>
<td>109</td>
<td>60</td>
<td>380</td>
<td>410</td>
</tr>
<tr>
<td>3.</td>
<td>50,300</td>
<td>120</td>
<td>109</td>
<td>60</td>
<td>260</td>
<td>330</td>
</tr>
<tr>
<td>4.</td>
<td>50,200</td>
<td>100</td>
<td>109</td>
<td>60</td>
<td>170</td>
<td>250</td>
</tr>
</tbody>
</table>

From the Table 2.2, it can be noted that when the load reactive power decreases, the sending end reactive power also decreases. The load voltage is almost maintained at 109V irrespective of load. The STATCOM is almost injecting the reference (load reactive power) into the bus. Figure 2.12 shows the simulation results of the power system with STATCOM for the first reading of Table 2.2.

Figure 2.12 Simulation results of power system with STATCOM
From the top, the values are $P_s$, $Q_s$, $P_r$, $Q_r$, $V_{\text{load}}$, $P_{\text{stat}}$ and $Q_{\text{stat}}$ respectively. The STATCOM $Q_{\text{ref}}$ value has been set to 500. It is found from the Figure 2.12 that the STATCOM is injecting reactive power of 520VARs. The sending end reactive power is reduced from 380VARs to 170VARs. While comparing the first reading of Table 2.1 and Table 2.2, the load voltage is increased to 108V from 93V and the STATCOM is injecting a reactive power of 520VARs to the system.

Figure 2.13 presents the variation of sending end reactive power, when the load reactive power is varied from 200VARs to 500 VARs with and without STATCOM.

![Figure 2.13 Reactive power comparison chart for with and without STATCOM](image)

From Figure 2.13, it is understood that the sending end reactive power gets reduced, while the STATCOM is introduced for the same load reactive power. So, the power transfer capability of the system gets increased, when STATCOM is connected.
Due to sine triangular PWM, which is given to gate of IGBTs, the inverter side wave forms are sine in shape. Figure 2.14 shows the inverter side outputs, when STATCOM is connected.

![Inverter side outputs when STATCOM is connected.](image)

In Figure 2.14, the first two waveforms show the inverter voltage before and after filtering respectively. The third waveform shows the inverter side RMS voltage and is raised to 120V from 110V. Hence, the reactive power has been injected into the bus. The last two waveforms show the inverter output before and after the shunt transformer.

2.7.2 Case B. RC LOAD

The same power system is now connected with ‘RC’ load instead of ‘RL’ load. Table 2.3 gives the $P_s$, $Q_s$, $P_r$, and $Q_r$ values, when RC load is connected in the power system.
Table 2.3 Simulation results without STATCOM for RC load

<table>
<thead>
<tr>
<th>S. NO.</th>
<th>Load Values</th>
<th>P_s (W)</th>
<th>Q_s (VAR)</th>
<th>V_{load} (V)</th>
<th>P_r (W)</th>
<th>Q_r (VAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>50,500</td>
<td>240</td>
<td>510</td>
<td>130</td>
<td>60</td>
<td>600</td>
</tr>
<tr>
<td>2.</td>
<td>50,400</td>
<td>168</td>
<td>424</td>
<td>120</td>
<td>58</td>
<td>465</td>
</tr>
<tr>
<td>3.</td>
<td>50,300</td>
<td>117</td>
<td>315</td>
<td>118</td>
<td>56</td>
<td>335</td>
</tr>
<tr>
<td>4.</td>
<td>50,200</td>
<td>80</td>
<td>207</td>
<td>114</td>
<td>53</td>
<td>213</td>
</tr>
</tbody>
</table>

From Table 2.3, it is noted that when the load reactive power decreases, the sending end real and reactive power decreases and the load voltage gets reduced, when the load reactive power decreases. Figure 2.15 shows the $P_s$, $Q_s$, $P_r$, $Q_r$ and load RMS voltage for the first reading of Table 2.3.

![Figure 2.15 Simulation results of power system when RC load is connected](image-url)
The STATCOM is connected with ‘RC’ load. The output waveform for the first reading of Table 2.3 is shown in Figure 2.15. Under no load condition, the line voltage is maintained at 110V. From Figure 2.15, it is noted that when RC load is connected, the load voltage is increased to 130V from 110V, and the load reactive power is 600VARs. The actual load is set for 500VARs for 110V. Due to increase in voltage, it is increased to 600VARs. The power system is connected with STATCOM. The obtained values are shown in Table 2.4.

Table 2.4 Simulation results with STATCOM for RC load

<table>
<thead>
<tr>
<th>S. NO.</th>
<th>Load Values P(W),Q (VAR)</th>
<th>Q_s (VAR)</th>
<th>Inverter output voltage in volts</th>
<th>P_r (W)</th>
<th>Q_r (VAR)</th>
<th>Q_stat (VAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>50,500</td>
<td>200</td>
<td>98</td>
<td>140</td>
<td>500</td>
<td>-500</td>
</tr>
<tr>
<td>2.</td>
<td>50,400</td>
<td>200</td>
<td>100</td>
<td>120</td>
<td>390</td>
<td>-390</td>
</tr>
<tr>
<td>3.</td>
<td>50,300</td>
<td>200</td>
<td>103</td>
<td>100</td>
<td>300</td>
<td>-270</td>
</tr>
<tr>
<td>4.</td>
<td>50,200</td>
<td>190</td>
<td>105</td>
<td>90</td>
<td>260</td>
<td>-180</td>
</tr>
</tbody>
</table>

From the first reading of Table 2.4, it is evident that the STATCOM is injecting almost the same reactive power as that of the load reactive power. Comparing Table 2.3 and Table 2.4 for the same load, sending end reactive power is getting decreased, when STATCOM is connected. The inverter side AC voltage keeps on increasing, when load capacitive reactive power decreases in order to absorb less reactive power. Figure 2.16 shows the outputs of P_s, Q_s, P_r, Q_r and Q_stat values for the first reading of Table 2.4.
Figure 2.16 Simulation results of power system when STATCOM is connected

From the first reading of Table 2.4 and Table 2.5, it is identified that the sending end reactive power has been reduced to 200VARs from 510VARs. The inverter voltage is reduced to 98V in order to absorb the reactive power from the bus. Due to absorption of reactive power by the STATCOM, the load voltage is maintained at 110V which was increased earlier to 130V. The STATCOM is absorbing reactive power of 500VAR from the bus. In the last waveform, the negative sign indicates that the power flow is in the opposite direction. The STATCOM is absorbing the reactive power from the bus. Figure 2.17 shows the comparison results obtained for the power system with and without STATCOM.
Figure 2.17 Reactive power comparison chart for with and without STATCOM

From the Figure 2.17, it is clear that the sending end reactive power gets reduced, while the STATCOM is introduced for the same load reactive power. So, the power transfer capability of the sending end generator gets increased, when STATCOM is connected. Figure 2.18 shows the inverter side outputs, when STATCOM is connected with ‘RC’ load.

Figure 2.18 Inverter side outputs when STATCOM is connected
The first two waveforms of Figure 2.18 show the inverter voltage before and after filtering respectively. The third waveform shows that the inverter side RMS voltage is lowered to 98V from 110V. Hence, the reactive power has been absorbed from the bus. Due to sine triangular PWM which is given to gate of IGBTs, the inverter side wave forms are sine in shape. It is also observed that the inverter PWM output has fewer pulses in one cycle. It means that the modulation index has been reduced. The last two waveforms show the inverter output before and after the shunt transformer.

2.8 SUMMARY

A simulink model of the STATCOM based on the VSC is designed. Two types of loads ‘RL’ and ‘RC’ are connected to the power system. The STATCOM is connected at the middle of the transmission line. The results are taken in the power system model with and without the STATCOM for both types of loads. For each type, the readings are taken for with and without the STATCOM and are compared.