Reduction of Losses and Harmonics in Distributed Generation System with the Help of D-STATCOM

Maneesh Yadav, Ankur Chourasiya

Abstract
This paper explains the control methods to reduce the Losses and Harmonics in Distributed Generation System with the Help of Distributed Static Synchronous Compensator (D-STATCOM). D-STATCOM is one of the recent technologies in advanced power electronics in distribution generation system. D-STATCOM is a voltage source converter (VSC)-based device. Negative-sequence compensation may work properly as the imbalanced source is nearby. A harmonic damping active filter was proposed to restore the voltage swell due to distributed generators. The presence of harmonics can result in overvoltage in Distributed Generation System. Harmonic current occur in an electrical system can cause equipment malfunction, data distortion, transformer and motor insulation failure, overheating of network buses, tripping of circuit breakers, and solid-state component breakdown. In recent years, few industries use devices such as rectifiers or converters, power supplies and other devices to improve power quality that is sources of current harmonics. To overcome the above mentioned problem the Space Vector Pulse Width Modulation (SVPWM) control technique is suggested. By using this technique in conjunction with D-STATCOM the voltage stability of the system is improved. Space vector technique is implemented to control the distributed generation system. In this paper, we present extended simulations and discuss the experimental verification by using MATLAB. The proposed D-STATCOM realizes positive-sequence admittance and negative-sequence conductance to regulate positive-sequence voltage as well as suppress negative-sequence voltage.

Keywords: Voltage Regulation, Distributed generation System, D-STATCOM, SVPWM.

Introduction
In the modern era every country mainly concentrates on saving the energy in best and possible way utilizing the limited number of resources to draw maximum output from it. Due to increasing demand in the power sector there are number of non linear loads increasing. There is need of more and more distributed generation system in congestion with Transmission and Distribution system (TDS) and also expansion of Smart Grid System. The expansion of grids requires the generation of electricity in few large units and should be concentrated. If there is any fault in Grids then the effect will be larger and uncontrollable. To avoid this special reserves are developed called “Spinning Reserve”. This protects against any single generating plant to fail, connected in the grid. The energy transmitted from source to consumer end there will be loss of energy during transmission. The loss of energy depends on the configuration of the network connected to the transmission and does not affect the distributed system. The distribution losses are different from the transmission losses and they are separately measured. DGS has the ability to draw the energy from conventional sources as well as Renewable sources. It is also gaining the importance in rural electricity. With the installation of DGS the transmission losses are reduced to a large extent in the case of Renewable energy DGS.
Voltage Regulation

Voltage regulation in the power system could be realized by using an on-load tap changer (OLTC) or a static VAR compensator (SVC) at substations, and a step voltage regulator or a switched capacitor on feeders. With the help of the so-called optimal or intelligent control on all devices, the voltage profile could be improved on a real-time base [5]. The advancement of semiconductor technologies, voltage-source converter-based solutions, such as static synchronous compensator (STATCOM), unified power flow controller (UPFC), distributed STATCOM (D-STATCOM), and active power filter (APF), become viable in practical applications [3], [6] and [13]. STATCOM technology has been extensively studied and developed in transmission systems to regulate voltage by adjusting its reactive power into the power system, whereas UPFC was designed to control real- and reactive-power flows between two substations. On the other hand, D-STATCOM and APF are suitable for power quality improvement of the distributed power system, such as harmonic compensation, harmonic damping, and reactive-power compensation. In [8], fundamental positive-and negative-sequence currents were separately controlled to improve the voltage regulation performances of the D-STATCOM. However, negative-sequence compensation may not work properly as the imbalanced source is nearby. A harmonic damping active filter was proposed to restore the voltage swell due to distributed generators [7]. However, discussions were limited in controlling positive-sequence voltage only. The concept of inverter-based RESs with functionality of VAR supporting was presented to accomplish voltage regulation locally. Compensating voltage fluctuations in DGS by a D-STATCOM was presented in [4]. In this paper, we present extended simulations and discussions as well as experimental verification by using MATLAB. The proposed D-STATCOM realizes positive sequence admittance and negative-sequence conductance to regulate positive-sequence voltage as well as suppress negative-sequence voltage.

Distributed Generation

Due to increasing demand in the power sector there are number of non-linear loads increasing. There is need of more and more distributed generation system in congestion with Transmission and Distribution system (TDS) and also expansion of Smart Grid System. The expansion of grids requires the generation of electricity in few large units and should be concentrated. If there is any fault in Grids then the effect will be larger and uncontrollable. To avoid this special reserve are developed called “Spinning Reserve”. This protects against any single generating plant to fail, connected in the grid. The energy transmitted from source to consumer end there will be loss of energy during transmission. The loss of energy depends on the configuration of the network connected to the transmission and does not affect the distributed system. The distribution losses are different from the transmission losses and they are separately measured. DGS has the ability to draw the energy from conventional sources as well as Renewable sources. It is also gaining the importance in rural electricity. With the installation of DGS the transmission losses are reduced to a large extent in the case of Renewable energy DGS.

Fig. 1: Distributed Generation System

Modeling of Control Strategy

Space Vector PWM (SVPWM)

One of the most popular techniques for pulse width modulation (PWM) is Space Vector Pulse Width Modulation (SVPWM). SVPWM has the highest voltage utilization ratio and is developed from the magnetic flux trajectory control in the speed control of an AC motor. In this technique the space vectors are representing the output voltages of the inverter.
Discontinuous SVPWM (DPWM) methods can be obtained by changing the distribution of the zero vectors through different strategies [5, 12]. DPWM has attracted significant attention because this method minimizes switch loss.

**Realizing Generalized SVPWM**

The numbers of voltage vector and switching state for cascaded multilevel inverters rapidly increases with increasing cascaded number \( N \). If the cascaded number is more than 2, then the SVPWM method becomes extremely complex and difficult to achieve. As a solution to practical applications, the two-level SVPWM method is used for the first single-stage inverter, and then, the PWM control of the rest of the subunits are obtained via the carrier phase shift method. The single-stage structure of cascaded inverters is presented in Fig. 2. A multilevel cascaded inverter is composed of \( N \) series single-stage subunits, which generally form a neutral common point that uses the star connection scheme on one side and is connected to the grid through the reactor on the other side.

**Distribution of Space Vectors**

There are eight possible outputs from which six are active switching states and two are zero switching states. The generalized SVPWM method is used to determine a three-phase reference voltage waveform.

**TABLE 1 Switching States of Space Vector**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Switching States</th>
<th>Phase Voltage</th>
<th>Space Vector Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>000</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>001</td>
<td>( \frac{2}{3} V_{dc} e^{j \pi} )</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>010</td>
<td>( \frac{2}{3} V_{dc} e^{j \pi} )</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>011</td>
<td>( \frac{2}{3} V_{dc} e^{j \pi} )</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>( \frac{2}{3} V_{dc} e^{j \pi} )</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>101</td>
<td>( \frac{2}{3} V_{dc} e^{j \pi} )</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>110</td>
<td>( \frac{2}{3} V_{dc} e^{j \pi} )</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>111</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The above discussed space vectors are represented in the form of hexagon in Fig. 3 spreading over 360 degrees and divided into six sectors displaced by 60 degrees.

**Fig. 2 Single Stage Cascaded Network**

**Fig. 3 Various Sectors of Space Vector**

We can obtain the PWM waveform, which is identical to the PWM waveform based on the SVPWM method, by comparing the waveform with a triangular wave. Active switching state is referred to the state in which power flow from source to load side. Zero switching state is on the other way i.e. no power flow from source to load side. Table 1 shows the phase to neutral six step mode of operation in converter.
MATLAB/SIMULINK Based Power System Model

The simulated model of the 4-bus distributed generation system is shown in fig 4. In this model the supply is given by 3-phase programmable voltage source in which phase and frequency can be pre-programmed. In this test system the supply is 415v, 50Hz and at phase angle of 0 deg is supplied to the primary (source) bus 1. At bus 1 the current waveform of all three phases are observed and sub-transient harmonics are introduced on the current waveform. The bus 1 is connected to bus 2 through distributed line parameters i.e RL branches connected in between the buses 1 and 2, that carries the current and voltage of three phase and are observed at bus 1. The current and voltage of the three phase at the point of common coupling of the distribution system are observed at bus 2 and it is observed that it possess the current harmonics. In between bus 2 and bus 3 the two winding transformer is connected followed by circuit breaker and then by bus 4. The bus 4 contains the pair of DSTATCOM and DG unit to improve the outputs taken by SVPWM from various terminals and then modify it in the form of current pulse to them. The bus 3 is the load bus on which the three phase RL load is connected.

Results and Discussion

The output voltage waveform is shown below in Fig. 5.

Fig. 5: Output Voltage Waveform At Load

The result shows that the voltage profile is improved than the result obtained the point of common coupling (PCC).

The output voltage waveforms at the point of common coupling are shown in Fig 6.

Fig 6: Voltage Waveform At Pcc

The reference voltage and current of phase A is taken at the source terminal which is shown in Fig 7.

Fig. 7 Source Voltage (Va) And Source Current (Ia)
Conclusion

In this paper the simulation results are obtained and the modeling of the test system is done. The performance of the distributed generation system in terms of the voltage stability has been investigated by using the space vector modulation technique. The obtained results are then compared with the relevant references obtained during the Literature Survey. The improvement is the performance is observed and also the reduction of current harmonics at various stages are noted down with the help of SIMULINK.

References


Author’s details

1,2 Assistant Professor, Department of Electrical and Electronics Engineering, Millennium Institute of Technology and Science, Bhopal, M.P. India

1Email: maneesh2t@gmail.com, yadav2208@gmail.com
2Email: ankursati84@gmail.com, ankur070890@gmail.com