



SIMULATION OF SINUSOIDAL PULSE WIDTH MODULATION (SPWM) BASED DSTATCOM FOR COMPENSATION OF REACTIVE POWER

Jadhav Prajakta S. and A. R. Thorat

Rajarambapu Institute of Technology, Sakharale, Maharashtra, India

E-Mail: prajakta.jadhav90@gmail.com

ABSTRACT

A Distribution Static Compensator (DSTATCOM) is a powerful tool for mitigation of the power quality problems. The power quality problem arises due to increasing number of sensitive loads. Hence, in order to maintain power quality the DSTATCOM has been installed. DSTATCOM will provide or absorb the reactive power. In distribution system reactive power is the main reason of power quality problems and system losses. This paper explains the system used to compensate the reactive power, Unbalance load condition and unbalance voltage. The effectiveness and performance of the DSTATCOM to mitigate the power quality problems are analyzed by using SPWM technique. The results are obtained through MATLAB and Simulink software.

Keywords: SPWM, DSTATCOM, VSC, power quality.

1. INTRODUCTION

In power distribution system reactive power is the main reason of increasing power quality problems [1] and system losses. Normally, Static Var Compensators (SVCs) have been used in combination with passive filters at the distribution level for mitigation of power quality problems [5], [6] and reactive power compensation. Although SVCs are very effective controllers used for reactive power compensation at the transmission system, their higher passive element count, limited bandwidth that increases losses and size of the system also slow response make them incompetent for distribution system has been proposed by using a combination of active power filter and SVC, which can compensate the 3 phase loads. Thus, a controller or device which regularly monitors the load voltage and current to decide the accurate amount of compensation required by the system and less response time should be feasible alternative. Distribution Static Compensator (DSTATCOM) [3], [4] has the capability to overcome the above mentioned drawbacks by supplying correct control and fast response with reduced weight.

A DSTATCOM is basically a converter based Distribution Flexible AC Transmission controller [2], [16] which has many similar concepts with that of Static Compensator (STATCOM) used at transmission system. At transmission system STATCOM controls only fundamental reactive power and gives voltage supports, while DSTATCOM is used at distribution system for dynamic compensator. The latter, DSTATCOM can be one of the feasible alternatives to SVC in the distribution system. The DSTATCOM can also act as a shunt active filter, to remove distortion in the source current or voltage. Hence, a DSTATCOM is such a multifunctional device. The main objective of any control technique should be to make it easy and flexible to implement, an inclusion to exploiting its multifunctionality to the maximum. The choice of converter configurations i.e. Voltage Source Converter (VSC) [8] or Current Source Converter (CSC). Usually, VSC are preferred because of their smaller size

and less cost of the capacitor as compared to an inductor for the same rating.

This paper explains, a Voltage Source Converter [9] (VSC) with Sinusoidal Pulse Width Modulation (SPWM) gives a faster control that is essential for mitigation of power quality problems and reactive power compensation. The proposed DSTATCOM system [4] is advantageous for voltage regulation and power factor correction with the neutral current compensation.

2. REACTIVE POWER COMPENSATION

Reactive Power Compensation [10] is defined as management of reactive power to improve the performance of the ac system. The reactive Power Compensation improves the stability of the system by increasing active power.

There are two main features:

Load Compensation [11]: The objectives are:

- To increase the power factor.
- Eliminate harmonics.
- To Balance the real power.
- To compensate the voltage regulation.

Voltage support

- To decrease the fluctuations

Reactive power

Reactive power is required to maintain the voltage to deliver active power (watt) through the system. In other words reactive power supplies a path for actual power flow. It represents the background energy movement in the system arising from the production of magnetic and electric fields. Motor loads and other loads require reactive power to convert the flow of electrons into useful work i.e. reactive power is present where the active power is needed but when there is deficiency in reactive power then the voltage sags down and it is not possible to push the power demanded by loads through the lines.



Hence, reactive power [10] must be properly compensated to maintain stability in the system.

A. Importance of reactive power

- Transformer, transmission lines and motors require reactive power.
- Results from energy storage component in the power grid (mainly inductors and capacitors).
- It has a robust effect on the system voltages.
- It must be balance in the grid to prevent voltage problems.
- Reactive power amount have an effect on voltage collapse.
- Electric motor wants reactive power to produce magnetic fields for their operation.

B. Need of reactive power

- Reactive power is need to maintain the voltage to balance the active power through the system.
- Different loads and electro-mechanical systems needs reactive power.
- Because of reactive power deficiency the voltage sag occurs.

C. Reactive power limitations

- Usually require to produce it close to the location where it is needed, this is very uneconomical.
- A supplier close to the location of the need is in a much better position to provide reactive power than one that is located far from the location of the need.
- Reactive power source are closely tied to the ability to deliver real or active power.

D. Need for reactive power compensation

- Voltage regulation.
- Increased stability of the system.
- Decreases losses related with the system.
- Utilization of machines connected to the system.
- Prevent the system voltage collapse.

3. DISTRIBUTION STATIC COMPENSATOR (DSTATCOM)

A DSTATCOM is a controlled reactive power source, which consist of a Voltage Source Converter (VSC) and DC link capacitor connected in shunt which is able to generate or absorb the reactive power. The DSTATCOM [20] has many similar characteristics like Static Synchronous Compensator (STATCOM). STATCOM is used at transmission system. To achieve the dynamic compensation the DSTATCOM is installed at distribution system.

The AC terminals of the VSC are connected to the Point of Common Coupling (PCC) by the inductance. The inductance should be filter inductance or leakage inductance of the transformer as shown in Figure-1. The DC side of the converter is connected to the DC capacitor. This capacitor carries the ripple current of the converter and it is the reactive power storage element. This DC capacitor should be charged by battery or should be

recharged by converter itself. If the AC terminal voltage is same as that of the input voltage of the VSC no reactive power is distributed to the system and if the output voltage is more than AC terminal voltage the DSTATCOM operates in capacitive mode and vice versa. The amount of reactive power delivered is proportional to the difference between two voltages, but the voltage regulation at point of common coupling and power factor correction should not be obtained simultaneously. The DSTATCOM [24] used for voltage regulation at point of common coupling the compensation can be such that the supply current should lead the supply voltage. Whereas, for the power factor correction the supply current should be in phase with the supply voltage.

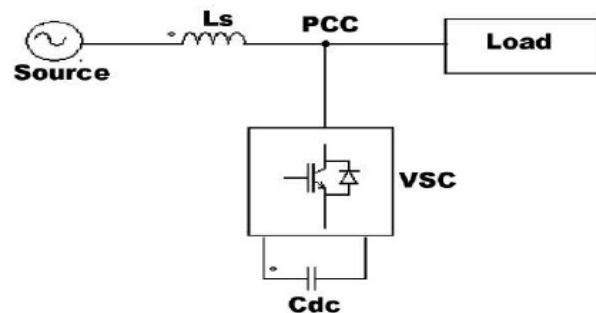


Figure-1. Schematic diagram of DSTATCOM.

Figure-2 shows the single line diagram of the DSTATCOM. The DSTATCOM [20] supplies flexible voltage and reactive power control which can be applied to carry out many power system applications such as, fast voltage recovery, improving system transient stability, improving system reliability, enhancing system voltage stability, minimizing system losses etc.

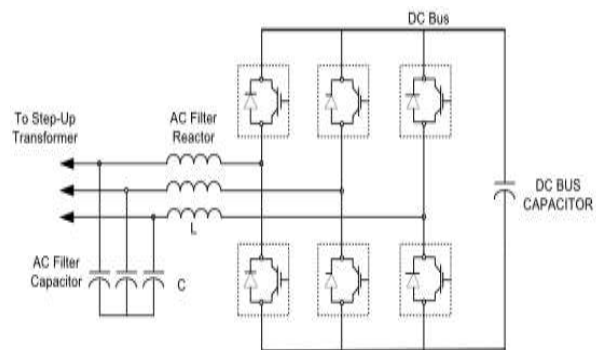


Figure-2. Single line diagram of a DSTATCOM.

A. Voltage source converter

There are two converter types i.e. Voltage Source Converter (VSC) and Current Source Converter (CSC) based on the storage element which are either inductive or capacitive respectively. A Voltage Source Converter (VSC) is a Power Electronics based device [7]. Generally, VSCs are selected due to their less dissipation of heat, smaller size and less cost. A VSC can generate a



sinusoidal voltage with suitable magnitude, frequency and phase angle. VSC are mostly used in adjustable speed drives, also they can be used to mitigate the voltage dips. The VSC [8], [9] is used to inject the 'Missing Voltage'. The difference between nominal voltage and actual voltage is known as 'Missing Voltage'. The main function of VSC is to mitigate the power quality problems.

B. Operating principle of DSTATCOM

STATCOM is the solid-state based power converter type of SVC (Static Var Compensator). The concept of STATCOM [22] was recommended by Gyugyi in 1976 and it is operated as shunt connected SVC. Its output current can be controlled separately from its AC bus voltage. Power converters have fast switching characteristics because of that, STATCOM supplies much faster response as compared to SVC. The capacitor voltage does not change immediately after the event of change in system voltage. Hence, STATCOM effectively acts for the desired response. For example, if the system voltage changes or drops for any reason then the STATCOM can inject the capacitive power to balance the dipped voltages. Basically, a power converter installed in the STATCOM [23] can be either Voltage Source Converter (VSC) or Current Source Converter (CSC).

In practice, VSC [12] is preferred in the system because it has bidirectional blocking capability which is required by the power semiconductor devices used in CSC. To achieve this kind of switching property, a supplementary diode must be connected in series with a conventional semiconductor switch, or the physical structure of the semiconductor must be modified. These alternatives increase the conduction losses and total system value. Usually, a CSC derives its terminal power from a current source (reactor) but a charged reactor has many losses than the charged capacitor. Additionally, the VSC needs a current-source filter at its AC terminals, which is normally supplied by the coupling transformer leakage inductance, while supplementary capacitor banks are needed at the AC terminals of the CSC. Finally, the VSCs can operate with higher efficiency than the CSCs do in high-power applications. A VSC is selected by considering the following factors.

- The voltage rating of the network.
- The current harmonic necessity.
- The complexity of the control system.

Usually, the DSTATCOM system consists of three important parts:

- Voltage Source Converter (VSC)
- Step up transformer or coupling reactor
- Controller

In a high voltage system, the leakage inductance of the transformer can work as a coupling reactor. The STATCOM is added in the system at the Point of Common Coupling (PCC) where the voltage related

problem is the main concern. Hence this DSTATCOM system is more beneficial [24] to overcome the power quality problems. The performance of the system can be increased by using Sinusoidal Pulse Width Modulation (SPWM) technique [25] which provides faster control and mitigates the power quality problems. The fast response, adequate performance, simple implementation are the main considerations of any control technique. The SPWM technique is the most important part of the DSTATCOM control and it has a strong effect on its compensation capability, transient as well as steady state performance.

4. SINUSOIDAL PULSE WIDTH MODULATION

The main goal of this control technique is to maintain constant voltage magnitude at the point where the sensitive load is connected, under the system disturbances. The control technique measures the rms voltage at the load point. The VSC switching technique is based on SPWM control which gives simplicity as well as good response.

The PI controller identifies the error signal and generates the angle δ to drive the error to zero. In the PWM control, the sinusoidal signal $V_{control}$ is compared with a triangular signal in order to generate the switching signal for VSC. The main attributes of the SPWM control are the amplitude modulation index Ma of the signal $V_{control}$ and frequency modulation index Mf of the triangular signal.

Hence, amplitude modulation index Ma is the ratio of $V_{control}$ and V_{tri} . The frequency of modulation index is given by the ratio of switching frequency (F_s) and the fundamental frequency (F_f).

5. MATLAB BASED MODELLING OF DSTATCOM

Figure-3 shows the MATLAB simulation of DSTATCOM. In this model system operates at the frequency of 50 Hz and voltage of 11KV is given through a three phase system. The system for three phases is considered with an internal block diagram and display gives the values of active and reactive power. The main aim of this system is to compensate the reactive power. The graph parameters of each section can be studied through scope provided for each line. Hence, it helps to simplify the calculation of required voltage and current.

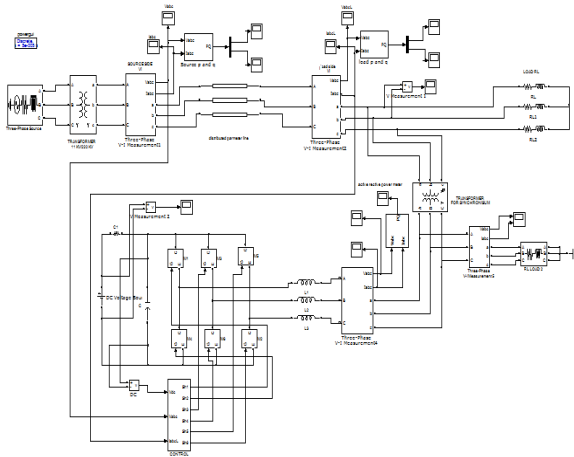


Figure-3. MATLAB simulation of DSTATCOM.

Figure-4 shows the SPWM control which is used to maintain the constant voltage at the sensitive load is connected. The SPWM technique is the most important part of the DSTATCOM control and it has strong effect on its compensation capability, transient as well as steady state performance.

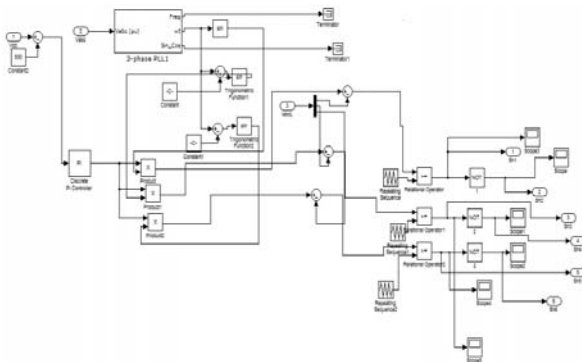


Figure-4. Sinusoidal Pulse Width Modulation (SPWM) controller.

Characteristics of SPWM control:

The objective of using SPWM technique is:

- To control the inverter output voltage
- To reduce the harmonic

Advantages of SPWM technique:

- The average value proportional to duty cycle
- Low power utilized in transistors which is used to switch the signal
- Less heat dissipated versus using resistors for intermediate voltage quantity
- Fast switching feasible due to MOSFETS and power transistors at speeds in excess of 100 kHz

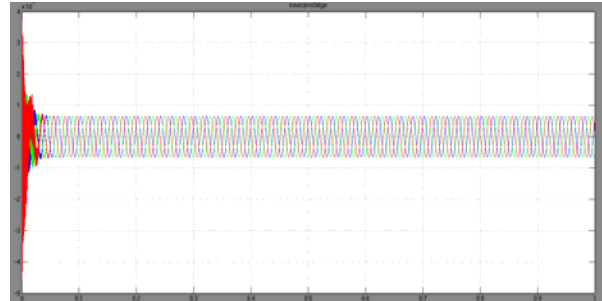


Figure-5. Graph of source side voltage.

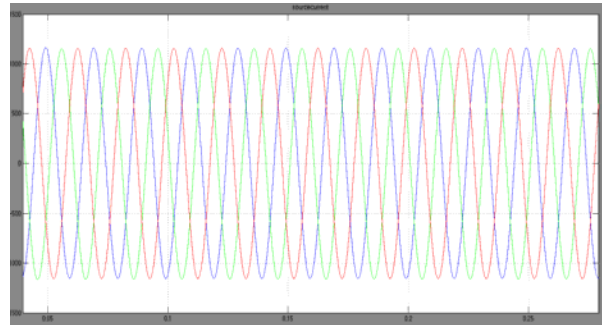


Figure-6. Graph of source side current.

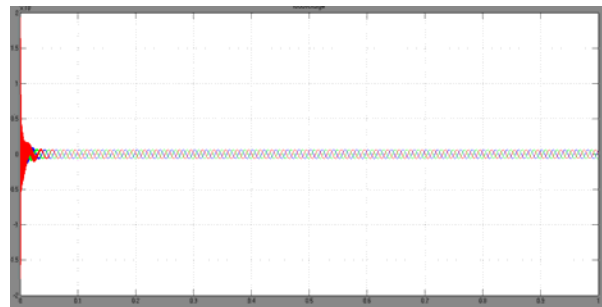


Figure-7. Graph of load side voltage.

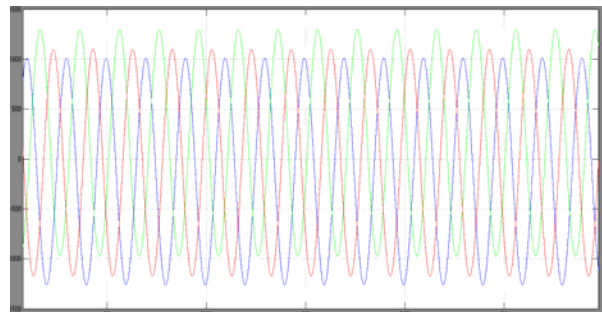


Figure-8. Graph of load side current.

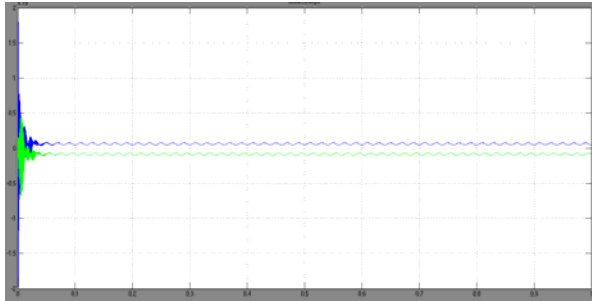


Figure-9. Graph of active and reactive power.

6. CONCLUSIONS

In this paper the DSTATCOM has been modeled and simulated in MATLAB software. The system of Voltage Source Converter (VSC) with SPWM gives the faster control which is required for mitigation of power quality problems and reactive power compensation. The performance of DSTATCOM has been analyzed for non-linear load condition and reactive power compensation has been achieved by this system.

REFERENCES

- [1] Kenneth Price, "Practices for Solving End-User Power Quality Problems", IEEE Transaction on Industry Applications. vol. 29, no. 6, pp. 1164-116, November 1993.
- [2] Narain Hingorani and Laszlo Gyugi, Understanding FACTS, Concepts and Technology of Flexible AC Transmission Systems, IEEE Press Marketing, 2000.
- [3] Masoud Farhoodnea, Azah Mohamed, Hussain Shareef, A Comparative Study on the Performance of Custom Power Devices for Power Quality Improvement. pp. 153-157, 2014 IEEE.
- [4] Saeed Ebrahimi Shah Gholi, Hadi Zayandehroodi, Mohammad Shabani Poor, Javad Alihosseini Hamid Pakari, Simulation of DSTATCOM for Power Quality Enhancement in Distribution Networks under Various Fault Condition, International Journal of Scientific and Engineering Research. Vol. 5, Issue 5, pp. 1425-1434, May-2014.
- [5] Tadashi Fukao, Zhongqing Yang and Mikihiko Matsui, "Voltage Control of Super High-speed Reluctance Generator System with a PWM Voltage Source Converter", IEEE Transaction on. Industry Applications. vol. 28, NO. 4, pp 880-886, JULY / August 1992.
- [6] S. Douangsyla, P. Indarack, A. Kanthee, M. Kando2, S. Kittiratsatcha and V. Kinnares, "Modeling for PWM Voltage Source Converter Controlled Power Transfer", International Symposh on Communications and Information Technologies 2004 (ISCIT 2004) Japan. pp. 875-878, October 2004.
- [7] Jang-Hwan Kim and Seung-Ki Sul, "A Carrier-Based PWM Method for Three-Phase Four-Leg Voltage Source Converters", IEEE Transaction on Power Electronics. vol. 19, no. 1, pp. 66-75 January 2004.
- [8] Guangzhu Wang and Yun Wei Li, "Parabolic PWM for Current Control of Voltage-Source Converters (VSCs)", IEEE Transaction on Industrial Electronics. vol. 57, no. 10, pp. 3491-3496 October 2010.
- [9] Chandan Kumar, Mahesh K. Mishra, "A Control Algorithm for Flexible Operation of DSTATCOM for Power Quality Improvement in Voltage and Current Control Mode", 2012 IEEE International Conference on Power Electronics, Drives and Energy Systems. pp. 16-19, December 2012.
- [10] S. P. Gawande, Nilesh A. Kubde, Manish S. Joshi and B.S. Sudame, "Reactive Power Compensation of Wind Energy Distribution System using Distribution Static Compensator (DSTATCOM)", 2012 IEEE.
- [11] U. Koteswara Rao, Mahesh K. Mishra and Arindam Ghosh, "Control Strategies for Load Compensation Using Instantaneous Symmetrical Component Theory under Different Supply Voltages", IEEE Transaction on Power Delivery. vol. 23, no. 4, pp. 2310-2317, October 2008.
- [12] M. K. Mishra, A. Ghosh and A. Joshi, "Operation of a DSTATCOM in voltage control mode," IEEE Transactions on Power Delivery. vol. 18, no. 1, pp 258-264, January 2003.
- [13] Wenping Qin, Peng Wang, Xiaoqing Han, and Xinhui Du, "Reactive Power Aspects in Reliability Assessment of Power Systems", IEEE Transaction on Power Systems. vol. 26, no. 1, pp. 85-92, February 2011.
- [14] Shahzad Ahsan, Anwar Shahzad Siddiqui, Shagufta Khan, "Reactive Power Compensation for Integration of Wind Power in a Distribution Network", 2012 IEEE.
- [15] Pablo A. Ruiz and Peter W. Sauer, "Reactive Power Reserve Issues", pp 439-445, 2006 IEEE.
- [16] R. Grünbaum, "FACTS to Enhance Availability and Stability of AC Power Transmission", 2009 IEEE.
- [17] S. X. Chen, Y. S. Foo, Eddy, H.B.Gooi, M. Q. Wang and S. F. Lu, "A Centralized Reactive Power Compensation System for LV Distribution Networks", IEEE Transaction on Power Systems, 2014 IEEE.



- [18] V U MINH QUANG, Han Wei, Wang Dazhi, Wang Xuming, "A New Type of PWM Rectifier with Function of Harmonic Suppression and Reactive Power Compensation", 2013 IEEE.
- [19] I. Paptic, "Power Quality improvement using distribution static Compensator with energy storage system," Proceedings of 9th International Conference on Harmonics and Quality Power. pp. 916-920, 2000.
- [20] P. Harsha Vardhana, B. Kalyan Kumar and Mahesh Kumar, "A Robust Controller for DSTATCOM. pp. 546-551, March 2009.
- [21] Bhim Singh, Alka Adya, A.P.Mittal and J.R.P. Gupta, "Modeling, Design and Analysis of Different Controllers for DSTATCOM", 2008 IEEE.
- [22] O. A. Lara, and E. Acha, Modeling and Analysis of Custom power Systems by PSCAD/EMTDC, IEEE Trans, on Power Delivery. Vol.17. no. 1, pp. 266-272, January 2002.
- [23] Alka Singh, Suman Bhowmick, Kapil Shukla, "Load Compensation with DSTATCOM and BESS", 2012 IEEE.
- [24] Jing Wang, Zhiqi Wang, Lingling Xu, Zongli Wang "A Summary of Applications of D-FACTS on Microgrid", 2012 IEEE.
- [25] Juan Segundo-Ramírez and Aurelio Medina, "Modeling of FACTS Devices Based on SPWM VSCs", IEEE Trans, on Power Delivery. Vol. 24, no. 4, pp. 1815-1823, October 2009.