ABHIYANTRIKI
An International Journal of Engineering & Technology
(A Peer Reviewed & Indexed Journal)
Vol. 4, No. 5 (May, 2017) http://www.aijet.in/ eISSN: 2394-627X

Mitigation of Voltage Sag and Swell using Distribution Static Synchronous Compensator (DSTATCOM)

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Abstract
Different types of electrical loads (like highly inductive, capacitive and power electronics loads) are connected in a modern power system. The power system is suffered from different types of problems like voltage sag, voltage swell, stability, frequency deviation, faults etc. Voltage, current and frequency of a power system are continuous varied because of these problems. Power system is mostly disturbed because of rise or drop in voltage. Voltage profile is affected because of the rise and fall in a power system. These problems can be solved by a Distribution Static Synchronous Compensator (DSTATCOM) with a combination of Voltage Source Converter (VSC) and a capacitor. Problem of voltage sag and swell can be mitigated by connecting DSTATCOM in parallel with the power system at load side. DSTATCOM is a shunt type of compensator which utilizes different types of controlling schemes. The problem of voltage sag and swell will be mitigated by phase shift control scheme of DSTATCOM. In this project voltage profiles will be improved with the DSTATCOM. The performance of DSTATCOM for Phase shift control scheme is validated for capacitive load and inductive load by using simulation models in MATLAB/SIMULINK.

Keywords*: Voltage Sag and Swell, Phase Shift Control Scheme, VSC, Voltage Profile, MATLAB Simulink.*

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1. Introduction

In recent years, electric utilities and end users are aware about the power quality. There has been an increased emphasis and concern for the quality of power delivered to factories, commercial establishments and residences. Power systems voltage and current waveforms are becoming worse by the use of power converters and different types of electrical loads. Due to the use of electronic devices the power system is suffering from different types of problems like voltage sag, voltage swell, stability, frequency deviation, faults etc. Voltage, current and frequency of a power system are continuous varied because of these problems. In recent years, electric utilities and end users are aware about the power quality [1]. There has been an increased emphasis and concern for the quality of power delivered to factories, commercial establishments and residences. Power systems voltage and current waveforms are becoming worse by the use of power converters and different types of electrical loads. Due to the use of electronic devices the power system is suffering from different types of problems like voltage sag, voltage swell, stability, frequency deviation, faults etc. Voltage, current and frequency of a power system are continuous varied because of these problems [2].

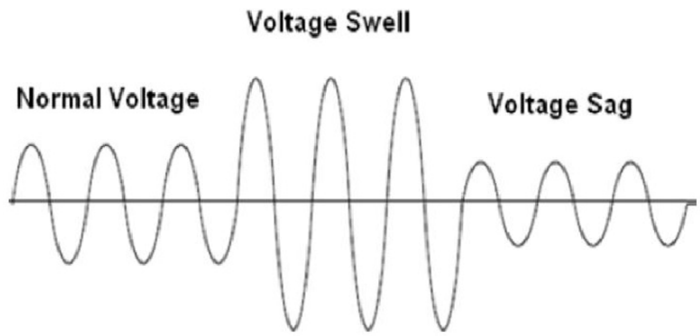

Fig. 1: Voltage waveform

Voltage sag is a decrease in RMS voltage to a value between 0.1 and 0.9 per unit and lasting for duration between half cycles to 1 minute. The magnitudes of the voltages sags caused by faults depend upon the distance of the fault location from the bus where the sag is measured. Starting of large induction motors can result in voltage sags as the motor draws a current up to 10 times the full load current during the starting. Also, the power factor of the starting current is generally poor. Voltage swell is defined as an increase in the RMS voltage from 1.1 to 1.8 per unit for duration from half cycles to 1 minute. A voltage swell (like Sag) is characterized by its magnitude (RMS) and duration. Swells can also Result from energizing a large capacitor bank [3]. The problems like voltage sag and swell can be effectively tackled by the introducing high power electronic controllers for the regulation of power flow and voltage in AC transmission networks.

The performance of the DSTATCOM depends on the control algorithm. For this purpose there are many control schemes which are presented in this paper and some of these are Phase Shift Control, Synchronous Reference Frame Algorithm, Instantaneous Reactive Power Theory, Regulation of AC bus and DC link voltage and FRYZE Power Theory. Among these control schemes instantaneous reactive power theory and synchronous rotating reference frame are most widely used. It is a custom power device which is gaining a fast publicity during these days due to its exceptional features like it provides fast response, suitable for dynamic load response or voltage regulation and automation needs. Both leading and lagging VARS can be provided, to correct voltage surges or sags caused by reactive power demands, DSTATCOM can be applied on wide range of distribution and transmission voltage, overload capability of this provides reserve energy for transients [3].

2. Distributed Static Synchronous Compensator (DSTATCOM)

A DSTATCOM as shown in figure 2 consists of a two level voltage source converter (VSC), a DC energy storage device; a coupling transformer connected in shunt with the AC system, and associated control circuit. The VSC converts the DC voltage across the storage device into a set of three phase AC output voltages. These voltages are in phase and coupled with the AC system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the DSTATCOM output voltages allows effective control of active and reactive power exchanges between the DSTATCOM and the AC system. The VSC connected in shunt with the AC system provides multifunctional topology which can be used for up to three quite distinct purposes:

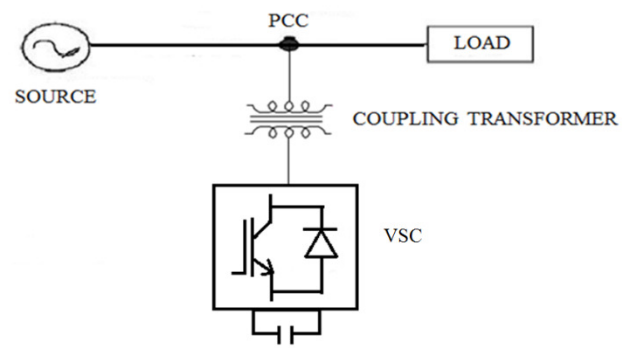

Fig. 2: Schematic diagram of the DSTATCOM

a) Voltage regulation and compensation of reactive power
b) Correction of power factor
c) Elimination of current harmonics

The design approach of the control system determines the priorities and functions developed in each case. In this case, DSTATCOM is used to regulate voltage at the point of connection. The control is based on sinusoidal PWM and only requires the measurement of the RMS voltage at the load point.

DSTATCOM Components

Isolation Transformer: It connects the DSTATCOM to the distribution network and its main purpose is to maintain isolation between the DSTATCOM circuit and the distribution network.

IGBT based Converters: These converters are used to generate the output voltage which is controlled in magnitude and phase angle to generate required lagging or leading reactive current, depends on the load.

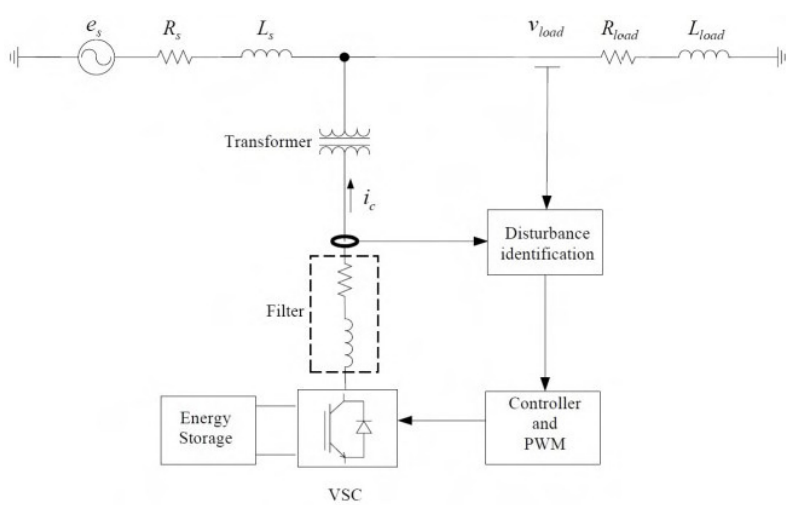

Fig. 3: Components of DSTATCOM

L-C Filter: The L-C filter is generally used to diminish harmonics and correlate converter output impedance to enable multiple parallel inverters to share current. The L-C filter is preferred in according to the type of the system and the harmonics are present at the output side of the converter.

Control Block: Control block is used to generate compensating current as per requirement. It can also control the external devices like manually switched capacitor banks. These control blocks are designed based on the different control theories like IRPT, SRFT, FT etc.

Operating Principle: The operating principles of DSTATCOM are based on the exact equivalence of the conventional rotating synchronous compensator. The converter is connected to a DC capacitor, which carries the input ripple current of the converter and is the main reactive storage element. This capacitor is charged by a battery source. The output voltage of the Thyristor based converter is V_o which is controlled in same way as the source voltage V_s. There are three cases:

- If the output voltage (V_o) of the VSC is equal to the AC terminal voltage (V_s), no reactive power is delivered to the system.
- If the output voltage (V_o) is greater than the AC terminal voltage (V_s), then the DSTATCOM operates in capacitive mode of operation.
- If the output voltage (V_o) is less than the AC terminal voltage (V_s), then the DSTATCOM operates in inductive mode of operation.

Control Algorithms

The main aim of the control algorithm is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The features of any control scheme are fast response, flexibility, robustness and easy to implement. The DSTATCOM control algorithms are implemented in following steps:

- Measurement of the system voltage & current.
- The supply reference current is calculated first.
- The compensating current of the DSTATCOM is then calculated.
- Comparing the load current with the compensating current, the triggering pulses for the IGBTs of the inverter bridge are then produced.
- This causes the inverter to produce the requisite compensating current to perform the load compensation.

Generation of proper triggering pulses for the Thyristor of the VSC is very crucial for proper implementation of the load compensation. The different control algorithms of DSTATCOM which involves above mention steps are as follows:

a) Phase shift control algorithm
b) Regulation of AC bus and DC link voltage
c) Synchronous reference frame algorithm
d) FRYZE power theory

The analysis of DSTATCOM with different control algorithm can be tested through simulations with different parameters.

Phase Shift Control Algorithm: The phase shift control strategy of DSTATCOM involves Sinusoidal PWM based control. The main objective of this type of control scheme is to maintain constant voltage magnitude at the load point. This control scheme only involves the measurement of RMS voltage at the load point and it does not require reactive power measurement [4]. Figure 4 shows the block diagram of Phase Shift Control Scheme. Sinusoidal pulse width modulation technique is used with constant switching frequency. The error signal

E_{error} obtained by comparing the measured system RMS voltage V_{abc} and the reference voltage V_{ref} is fed to the proportional integral (PI) controller, which generates the angle for deciding the necessary phase shift between the output voltage of the VSC and the AC terminal voltage. This angle is summed with the phase angle of the balanced supply voltages, assumed to be equally spaced at 120 degrees, to produce the desired synchronizing signal required to operate the PWM generator.

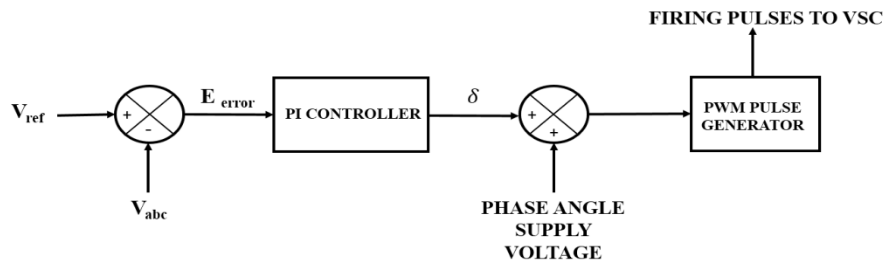

Fig. 4: Schematic diagram for phase shift control

3. Simulation Result and Analysis

The DSTATCOM is commonly used for voltage sags mitigation and harmonic elimination at the point of connection. Here, we have considered two cases to analysis the problem: i) inductive load, and ii) capacitive load.

a) *Inductive Load*

Initially there is a fixed inductive load is connected to the line. After 0.15 second the circuit breaker 2 is closed and the inductive load is added in the system, due to sudden increase of the inductive load, the terminal voltage is decreased to 0.8pu.

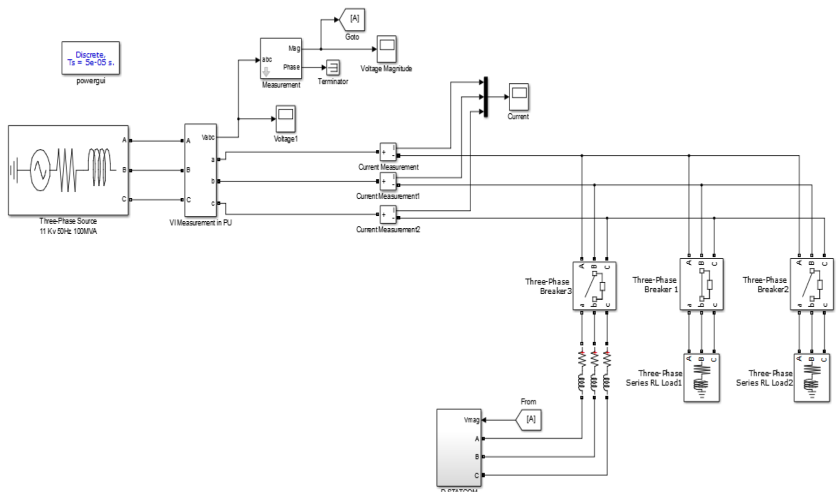

Fig. 5: Simulink model of compensated line with inductive load

Supply voltage = 11Kv (3 Phase)
System frequency = 50Hz
Load 1:2 MVA, Cos ø = 0.9
Load 2:11 MVA, Cos ø = 0.89

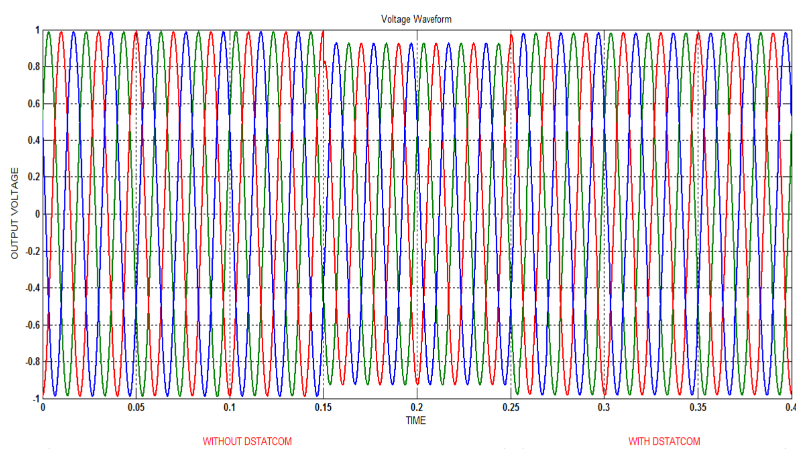

Fig. 6: Waveform of load voltage v/s time for inductive load

b) *Capacitive Load*

Initially there is a fixed inductive load is connected to the line. After 0.15 second the circuit breaker 2 is closed and the Capacitive Load is added in the system, due to sudden increase of the Capacitive Load the terminal voltage is increased to 1.8pu. The design parameters for the simulation are as follows:

Supply voltage = 11Kv (3 Phase)
System frequency = 50Hz
Load 1:2 MVA, Cos ø = 0.9
Load 2:11 MVA, Cos ø = 0.89

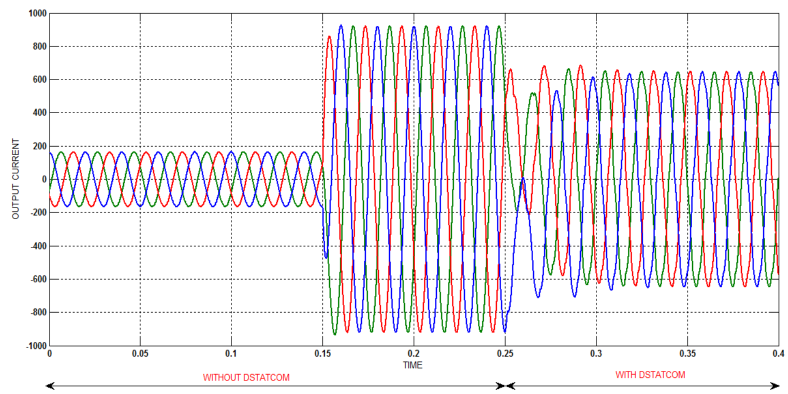

Fig. 7: Waveform of current v/s time for inductive load

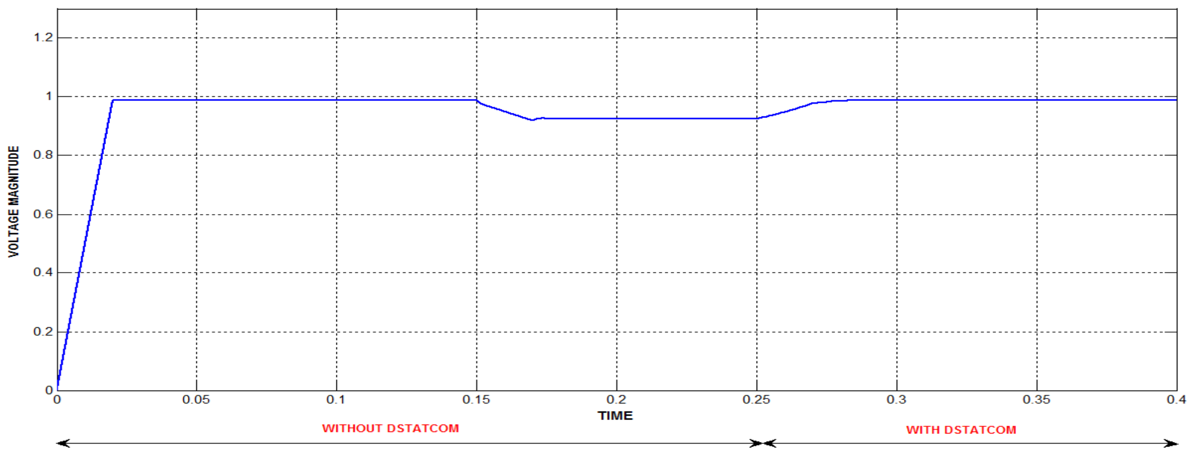

Fig. 8: Waveform of voltage magnitude v/s time for inductive load

When Load 2 (Inductive Load) is connected after 0.15 second there is dip in voltage magnitude which is shown in figure 12. The DSTATCOM can improve the voltage level and supply the reactive power to the load to full fill the reactive power requirement by supplying the current. The DSTATCOM is connected to the line after 0.25 second, due to DSTATCOM the voltage magnitude is improved which is shown in figure 12.

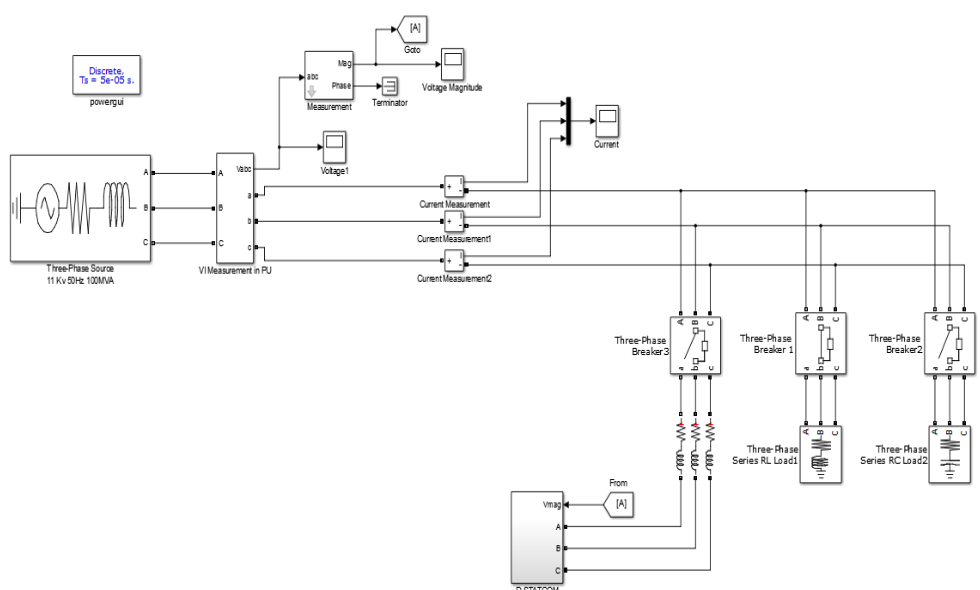

Fig. 9: Simulink model of compensated line with capacitive load

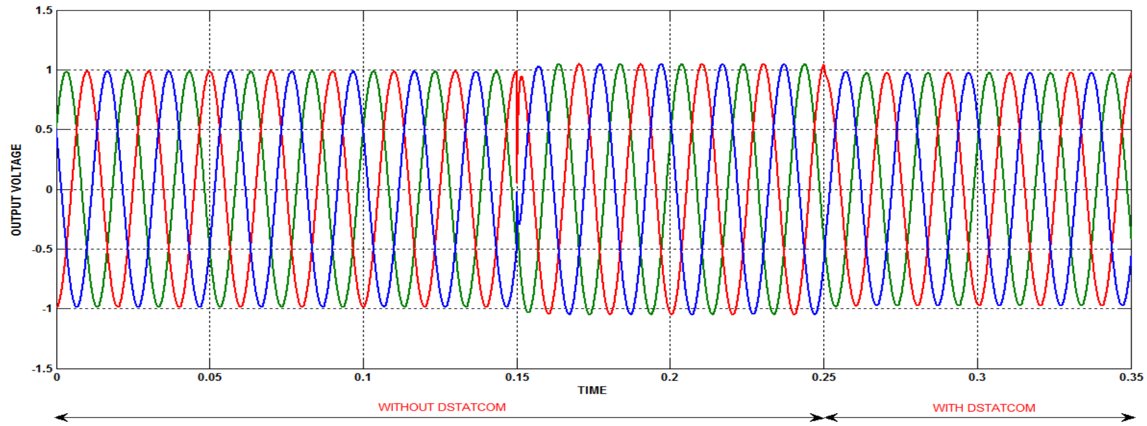

Fig. 10: Waveform of load voltage v/s time for capacitive load

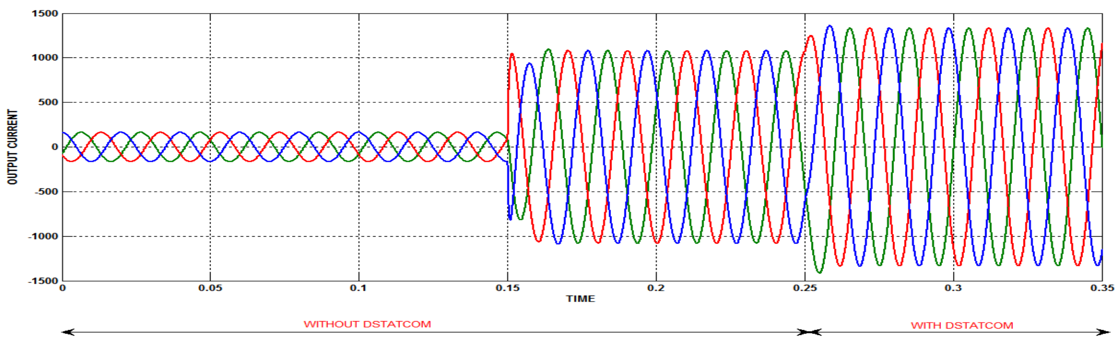

Fig. 11: Waveform of current v/s time for capacitive load

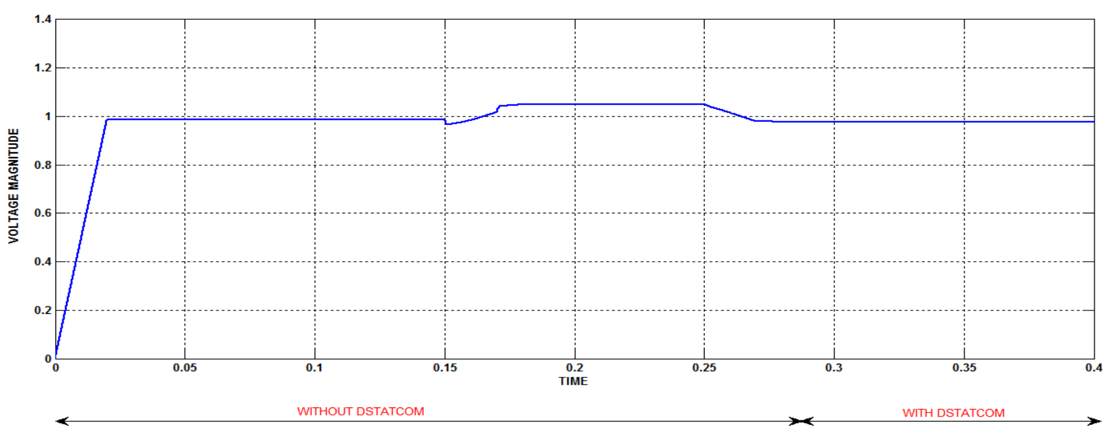

Fig. 12: Waveform of voltage magnitude v/s time for capacitive load

Controller Design

There are basically two types of control scheme which can be implemented are Inner Current Control and Voltage Control. In this system voltage control scheme is proposed. The main aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. In this control scheme, it measures the RMS voltage at the load point, i.e. no requirements of reactive power measurements. Here the sinusoidal PWM technique is used for the switching of VSC as sine PWM offers simplicity and good response compared to other scheme like space vector PWM.

The input of the controller is an error signal which is obtained from the reference voltage and the value RMS of the terminal voltage measured. Now PI controller will process this error signal and then the output is the angle δ, which is provided to the PWM signal generator. In this case it is important to note that in converter, there is active and reactive power exchange with the network simultaneously. Now the error signal is obtained by comparison of the reference voltage with the RMS voltage measured at the load point. The error signal is processed by PI controller which in return generates the required angle to drive the error to zero, i.e., the load RMS voltage is brought back to the reference voltage.

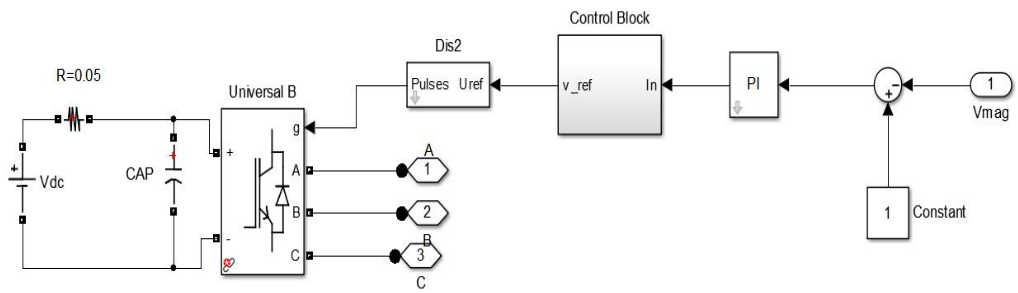

Fig. 13: VSC with control block of phase shift control method

The sinusoidal signal $V_{control}$ is phase-modulated by means of the angle δ i.e.

$V_A = \sin(\omega t + \delta)$

$V_B = \sin(\omega t + \delta - 2\pi/3)$

$V_C = \sin(\omega t + \delta + 2\pi/3)$

Now in order to generate the switching signals for the VSC valves, the modulated signal $V_{control}$ is compared against a triangular signal. The amplitude modulation index of signal and the frequency modulation index of the triangular signal are the main parameters of the sinusoidal PWM scheme.

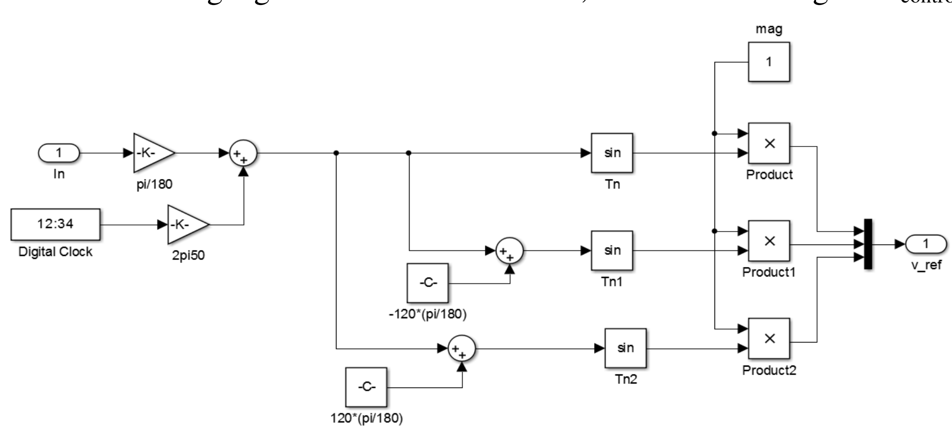

Fig. 14: Phase shift control scheme

4. Conclusion

DSTATCOM operation is mainly depends on its control schemes. The sag and swell in the voltage magnitude is eliminated by DSTATCOM using phase shift control method. The magnitude of voltage is increases or decreases because of presence of capacitive load or inductive load in transmission line. When the DSTATCOM is connected to transmission line, it dynamically releases the reactive power when required to the transmission line or absorbs the extra reactive power from the transmission line with the help of phase shift control method. Thus, the magnitude of voltage waveform can be reduced by absorbing the extra reactive power.

References

[1] Roger C Durgan, Mark F McGranaghan, Surya Santoso, H. Wayne Beaty, "Electrical power system quality" McGraw Hill Publication. 2nd Edition.
[2] L. Pattathurani, Rajat Kumar Dwivedi, P. Sivachidambaranathan, "A voltage controlled DSTATCOM for power quality improvement", IOSR Journal of Electrical and Electronics Engineering, Vol. 10, Issue 6, 2015.
[3] P. Bapaiah, "Power quality improvement by using DSTATCOM", International Journal of Emerging Trends in Electrical and Electronics, Vol. 2, Issue. 4, 2013.
[4] G. Ledwich and A. Ghosh, "A flexible DSTATCOM operating in voltage or current control mode" IEE Proc. Gener. Transm. Distrib. Vol. 149, No. 2, 2002.
[5] Amrita Saraf, Arti Bhandakkar, "Design and simulation of DSTATCOM using phase shift control based on sinusoidal pulse width modulation", Int. Journal of Engineering Research and Applications, Vol.4, Issue 1, 2014.
[6] R. Geetha, M. Aishwariya Devi, "Various control techniques for power quality improvement using DSTATCOM", International Journal of Power Control Signal and Computation, Vol. 4. No. 2, 2012.
[7] Bhim Singh and Jitendra Solanki, "A comparison of control algorithm for DSTATCOM", IEEE Transactions on Industrial Electronics, Vol. 56, No. 7, 2009.
[8] Ankur Gheewala, Jay Chanawala, Nikhil Jadav, Modi Rishit, Chirag Machhi, Jenish Rana, "Load balancing and harmonic elimination using distribution static synchronous compensator", IJET.
[9] M. Koteswara Rao, T. Ganeshkumar and Pappu Pawan Puthra, "Mitigation of voltage sag and voltage swell by using DSTATCOM and PWM switched auto-transformer", International Journal of Emerging Trends in Electrical and Electronics, Vol. 7, Issue. 1, 2013.
[10] Hirak K. Shah, P. N. Kapil, and M. T. Shah, "Simulation & analysis of distribution static compensator (DSTATCOM)", International Conference on Current Trends in Technology, 2011.
[11] K. R. Padiyar, "Facts controllers in power transmission and distribution", NewAge International (P) Limited.