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Mitigation of Power Quality Problems in Distribution Side using D-STATCOM

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Abstract: Power quality problems can be caused by connection/disconnection of heavy equipment, switching operations and different fault conditions. The main objective of this paper is to reduce the power quality problems such as voltage sag and swells and regulate load voltage in distribution side of the system using D-STATCOM. In this technique the distorted load currents are converted into synchronously rotating frame theory to produce the required gate pulses for the control of voltage source inverter (VSI) used in D-STATCOM. The detailed simulation results with required simulation model are provided using MATLAB/Simulink and simpower system toolboxes.

Key words: d-q frame theory, D-STATCOM, Power Quality, Swell and sag.

I. INTRODUCTION

Acceptable level of Power Quality in power systems is the significant issue for all types of customers. The power supply should be of high quality for proper operation of the electrical system. The existence of Power quality problem is defined based on the variation in the electrical supply voltage or current. Voltage sag, swell, interruptions, flicker, unbalancing, harmonics and etc are the different power quality problems [1]. Most of the loads are sensitive loads to the variation in the applied voltage in the distribution system [2]. This causes a failure or malfunctioning of load connected to the system.

The quality of the power supply can be improved by installing the reactive power compensating devices. Among all compensating devices Static synchronous compensator configuration has been used in distribution system widely to regulate the load voltage [3]. With the use of shunt connected voltage source converter known as D-STATCOM, Power Quality can be improved by reactive power compensation method.

In distribution system because of the starting of heavy loads, capacitive loads & faults there may be a dip in the load voltage known as voltage sag. Voltage swells are due to heavy loads and badly regulated transformers.

Voltage sag: The decrease in RMS voltage of the system nominal voltage for duration of few cycles is known as Voltage sag. Voltage swell: The sudden increase of the RMS voltage of the system nominal voltage for a short duration of few cycles [4].

II. D-STATCOM

D-STATCOM is a power electronic compensating device connected in shunt at the load side in the network. A D-STATCOM consists of a 3-φ voltage source inverter (VSI), a large DC link capacitor, filter, a coupling transformer and controller.

The basic operation of D-STATCOM is as similar to the synchronous machine [5].When the synchronous machine is under-excited current is lagging and when the machine is over-excited current is leading. Similarly, D-STATCOM can generate and absorb reactive volt-amperes. If AC system (load bus) voltage is greater than the voltage at PCC then AC system considers D-STATCOM as inductor. Otherwise it is considered as capacitor that is when AC system voltage (load bus) is less than voltage at PCC. If both the voltages are equal then reactive power exchange is equal to zero. Different techniques are proposed for the control of DSTATCOM they are IRPF, SRF theory, power balance theory, Instantaneous symmetrical components and etc [6]. In this technique controlled gate pulses are generated using Synchronous rotating frame (dq0) theory known as instantaneous reactive current control theory for mitigation of voltage sag and swell [7].

III. D-STATCOM OPERATION

A Distribution-STATCOM consists of a three-phase voltage source inverter, a large storage device (capacitor) at DC side of the inverter. D-STATCOM is connected in shunt at the load bus of the system. The model diagram of the D-STATCOM is shown in figure1. The high frequency noise produced by the inverter is mitigated by connecting the ripple filter i.e. RC filter. By the use of this configuration the D-STATCOM can absorb or generate active and reactive power for the reactive power compensation of load voltage under any disturbance. In this control method, a-b-c components of the distorted load currents are transformed into d-q components using the park's transformation method. Fig2 represents the controller of the D-STATCOM, by using this control scheme constant voltage magnitude is maintained at the load bus. This controller employs a three-phase phase locked loop (PLL). PLL can synchronize the inverter outputs with the fundamental voltage components. The PI regulators are provided for the reactive power exchange, to provide reactive and active current reference and to maintain constant DC voltage.

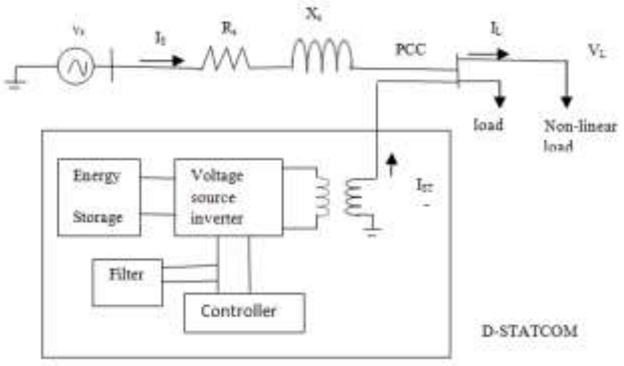

Fig1. D-STATCOM model

The park's transformation:

$$\begin{bmatrix} x_d \\ x_q \\ x_0 \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos\omega t & \cos(\omega t-\frac{2\pi}{3}) & \cos(\omega t+\frac{2\pi}{3}) \\ -\sin\omega t & -\sin(\omega t-\frac{2\pi}{3}) & -\sin(\omega t+\frac{2\pi}{3}) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}\begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix}$$

…. (1)

Where ω is the angular

The complex power is,

$$S = v.i^* = (v_\alpha + jv_\beta).(i_\alpha - ji_\beta) \qquad …. (2)$$

$$P = v_\alpha i_\alpha + v_\beta i_\beta \qquad …. (3)$$

$$Q = -v_\beta i_\alpha + v_\alpha i_\beta \qquad …. (4)$$

Then the d-q axis load currents can be calculated as follows:

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \qquad …. (5)$$

Therefore,

$$i_d = i_\alpha \cos\theta + i_\beta \sin\theta \qquad …. (6)$$

$$i_q = -i_\alpha \sin\theta + i_\beta \cos\theta \qquad …. (7)$$

Inverse Park's transformation:

$$x_{abc} = K^{-1} x_{dq0} \qquad …. (8)$$

$$\begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} \cos\omega t & \sin(\omega t) & \frac{1}{\sqrt{2}} \\ \cos(\omega t-\frac{2\pi}{3}) & -\sin(\omega t-\frac{2\pi}{3}) & \frac{1}{\sqrt{2}} \\ \cos(\omega t+\frac{2\pi}{3}) & -\sin(\omega t+\frac{2\pi}{3}) & \frac{1}{\sqrt{2}} \end{bmatrix}\begin{bmatrix} x_d \\ x_q \\ x_0 \end{bmatrix}$$

….. (9)

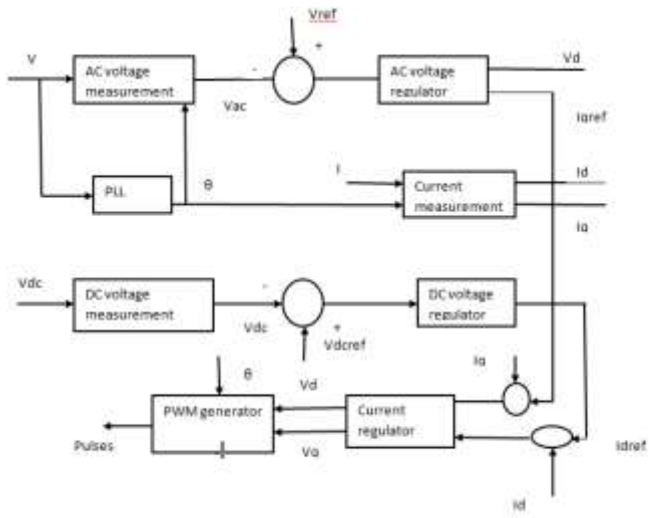

Fig2. D - STATCOM voltage controller.

3- φ **Phase Locked Loop (PLL)**: The 3- φ PLL is used measure the phase angle and this angle is used to calculate the d-q components of voltage and currents they are(V_d, V_q) and (I_d, I_q) respectively.

Current regulator: The current regulator is used to calculate the (V_d,V_q) voltages by using the proportional and integral controller. And these converted V_d , V_q voltages are transformed into(V_a, V_b, V_c). By using this output phase voltages and phase angle the required gate pulses can be produced with the help of PWM generator. By using the PI controllers or regulators the i_q reference and i_d reference are calculated from the DC-link voltage regulator.

Voltage regulator: The terminal voltage of the load bus is regulated by using a PI controller called voltage regulator.

DC voltage controller: To keep the DC link capacitor voltage constant (V_{dc}=2.4 kV).

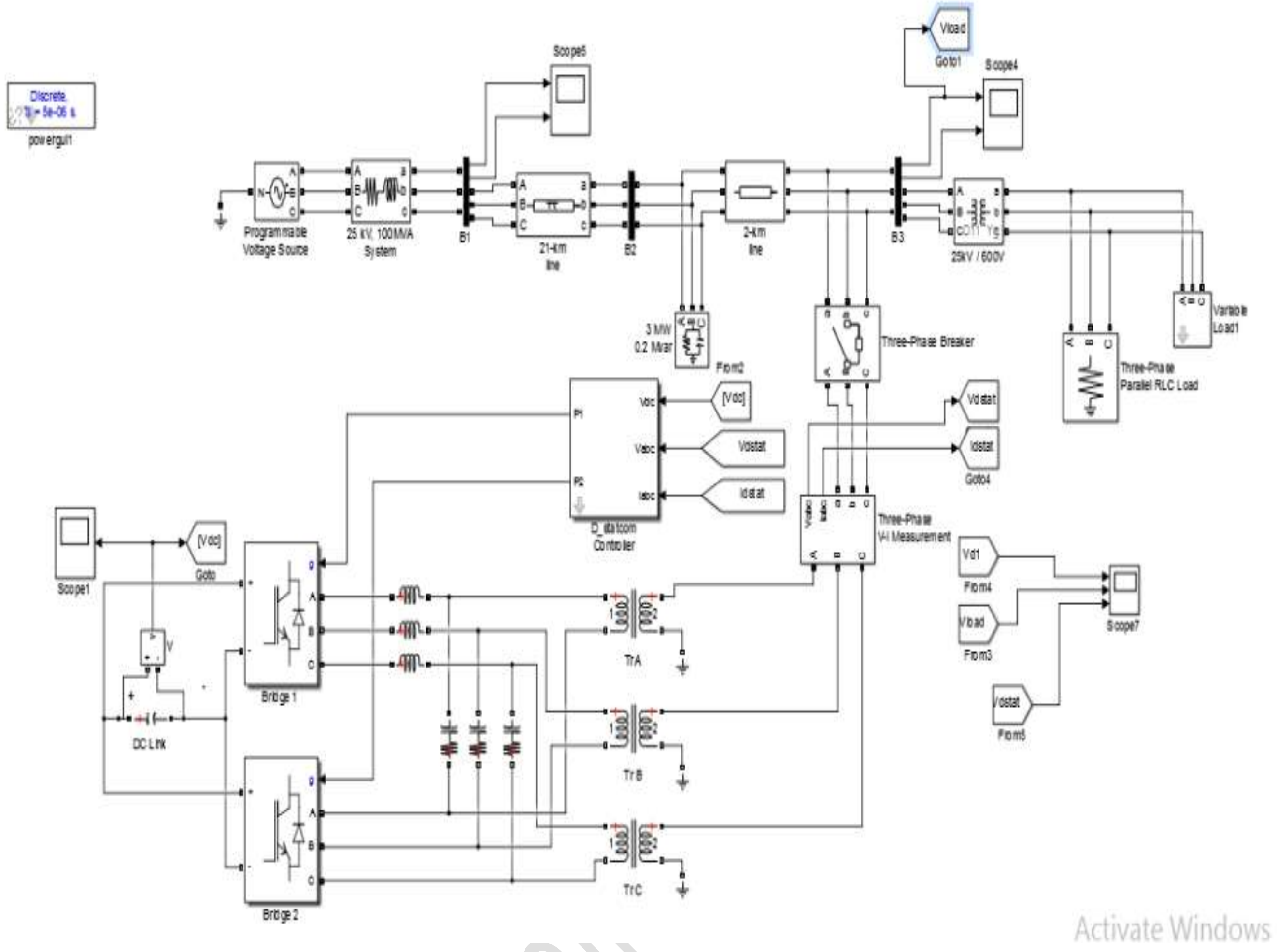

Fig3 MATLAB model of DSTATCOM

IV. SIMULATION MODEL AND RESULTS

The voltage magnitude in the system can be controlled by using the programmable voltage source. That is by varying the source voltage magnitude of the system the voltage sag & swell are created. The source impedance is given and non-linear load is connected at PCC before linear load.

(A) For voltage sag:

Voltage sag is created from 0.2 to 0.4 seconds at the source side. So there is a decrement in load voltage from 1p.u to 0.7p.u. After 0.2 seconds delay the D-STATCOM is connected at the (PCC). And simulation results for the load voltage are provided at different conditions.

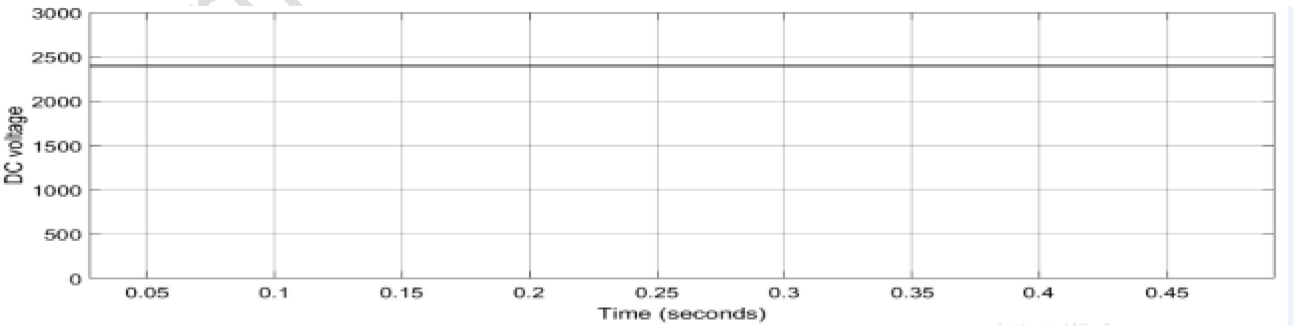

Fig4. DC link voltage.

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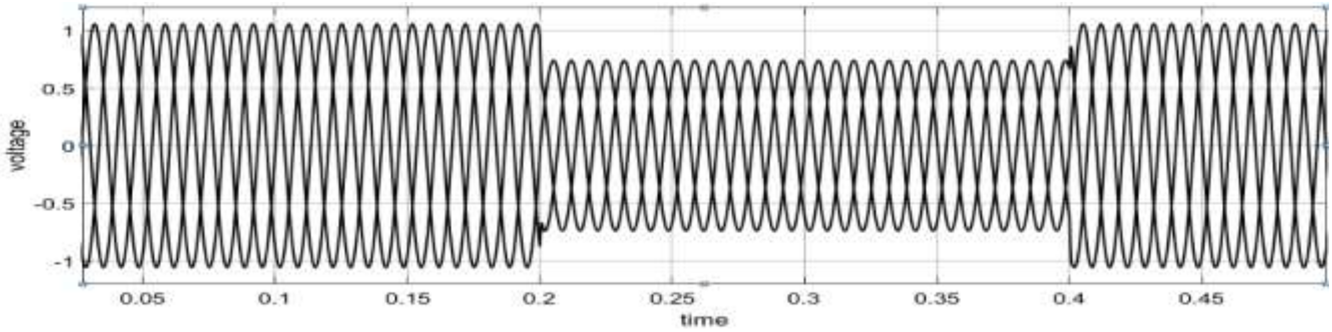
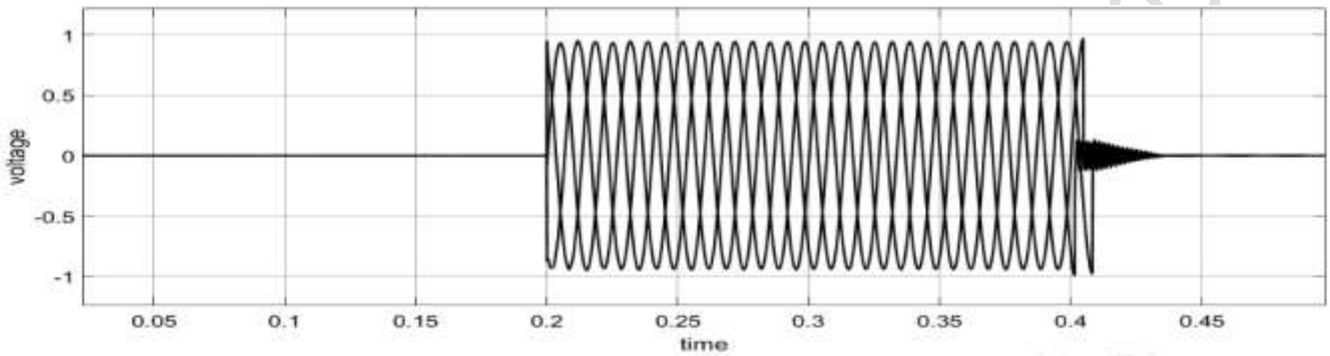
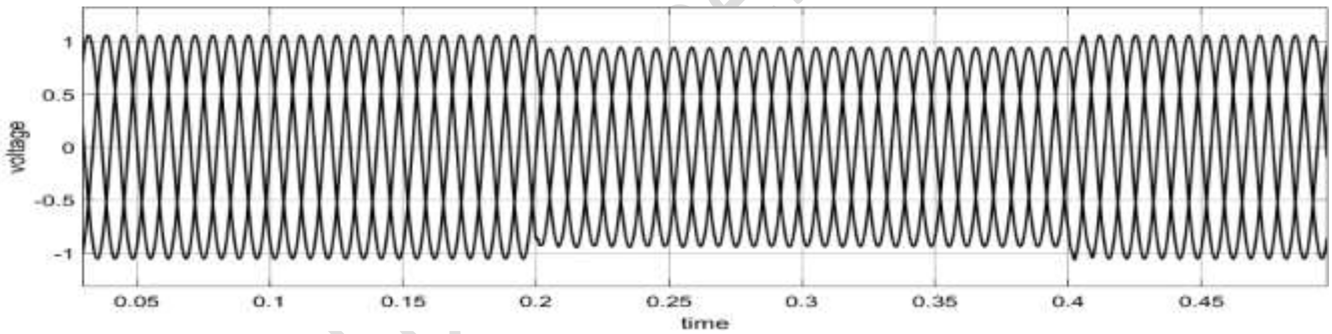


(a)



(b)



(C)

Fig5.(a) Load Voltage without D-STATCOM, (b) D-STATCOM Voltage, (c) Load Voltage with D-STATCOM

Simulation parameters:

AC source, 3 phase 100 MVA, 25KV, 50 HZ system, source resistance 0.625ohm source inductance 9.89mH, load1 (100KW, 100KVAR), Qref is zero, Vdc=2.4KV, Cdc=10000e-06 F.

At voltage sag condition D-STATCOM generates the reactive power to compensate the decreased voltage and DC link capacitor voltage magnitude is constant (2.4Kv). The load voltage is improved to 0.95p.u.

(B) For voltage swell:

Voltage swell is created from 0.2 to 0.4 seconds at the source side. There is an increment in the load voltage from 1 p.u to1.3 p.u. After 0.2 seconds delay the D-STATCOM is operated. And simulation results for the load voltage are provided at different conditions.

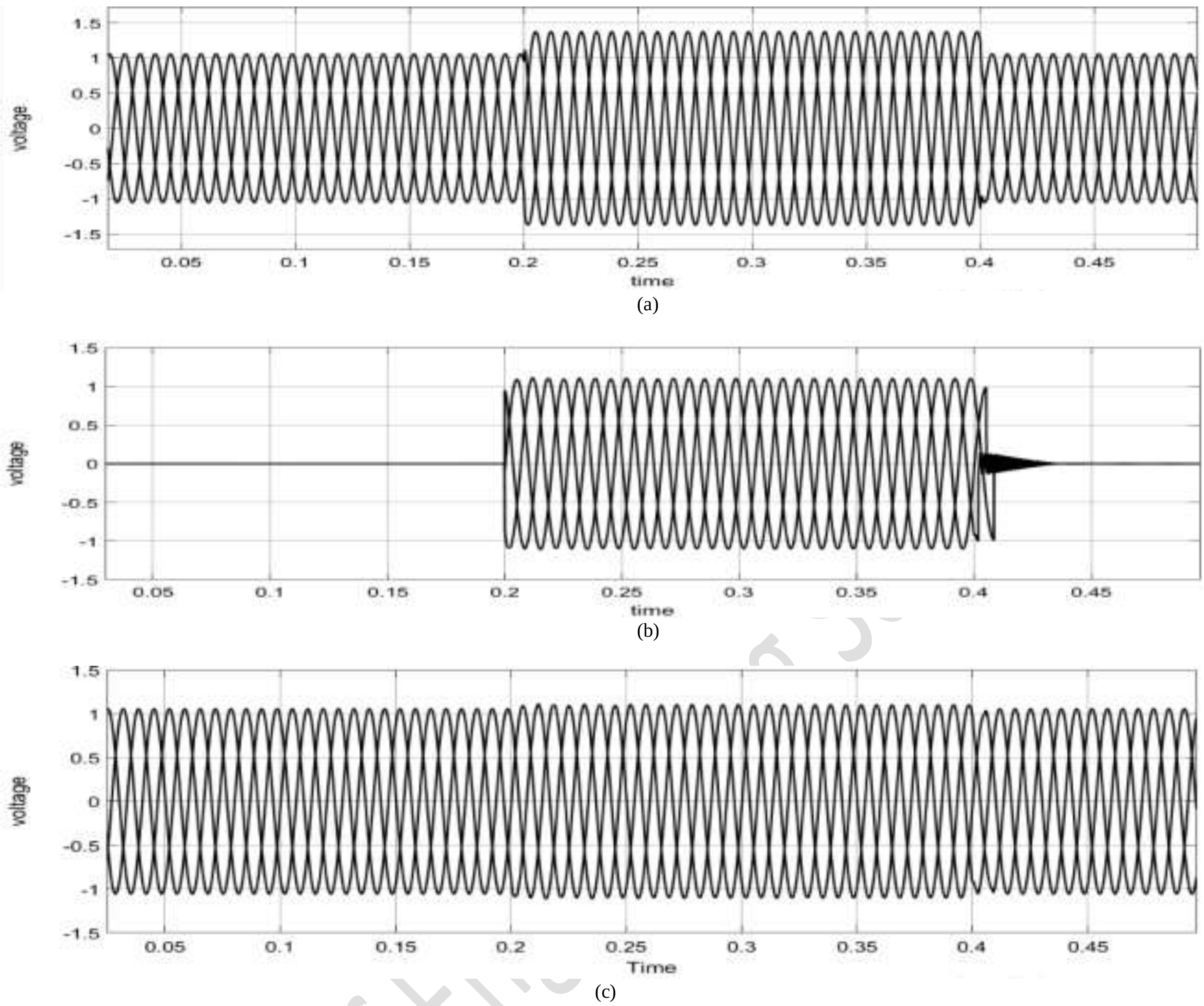


Fig6. (a) Load voltage without D-STATCOM, (b) D-STATCOM Voltage, (c) Load Voltage with D-STATCOM.

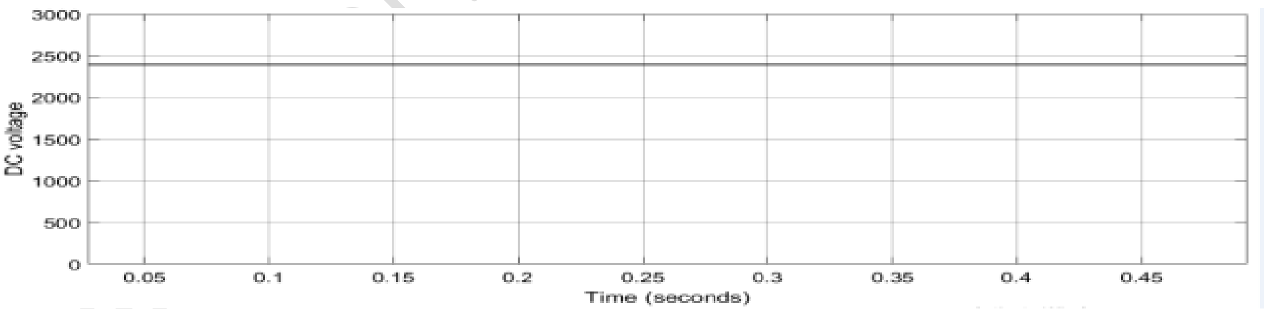


Fig7. DC link voltage

At voltage swell condition D-STATCOM absorbs the reactive power to compensate the increased load voltage. And load voltage magnitude is improved to 1.05p.u.

V. CONCLUSION

The D-STATCOM based on synchronously rotating frame theory is presented in this paper. The required gate pulses are generated by the inverter and the PWM generator. PI controller is employed to regulate the Dc voltage. And MATLAB/Simulink model for voltage sag and swell is developed and the results are presented.

The D-STATCOM regulates voltage at PCC by absorbing or injecting reactive power with respect to the system. When the inverter output voltage is less than the load bus voltage, the reactive power is absorbed by the D-STATCOM. When the inverter or voltage source converter output voltage is more than the load voltage, the reactive power is generated by the D-STATCOM. The voltage level is maintained 1.0 p.u and power quality is improved.

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