

DSTATCOM with L-C-L filter to compensate reactive and non-linear loads

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ABSTRACT

This paper gives Simulink modeling of improved hybrid distribution static compensator (DSTATCOM) methodology to compensate reactive and nonlinear loads with reduced VSI rating, DC link (capacitor) voltage and filter size. An LCL filter with less value of inductor compared to old L filter is used at the front end of a voltage source inverter (VSI), which gives the mitigation of switching harmonics. Voltage of the DSTATCOM can be reduced with capacitor to be connected in series with an LCL filter. The power rating of the voltage source inverter (VSI) has also been decreased. With reduced dc-link voltage, the voltage across the capacitor connected in parallel with the LCL filter will be also less. It will minimize the power losses in the damping resistor as compared with the old LCL filter with passive damping. A systematic procedure of DSTATCOM controlling and filter designing has been presented. The advantages of the proposed DSTATCOM methodology over old methodologies is validated through simulation.

KEYWORDS: Distribution static series compensator (DSTATCOM), Voltage source inverter (VSI), power quality (PQ), point of common coupling (PCC)

(I) INTRODUCTION

Modern power systems are of complex and complicated networks, where number of generating stations and number of load centers are connected to each other through long power transmission lines and distribution networks. Even though the power generation is fairly reliable, the quality of power is not always so reliable. Power distribution system should provide with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency to their customers. PS especially distribution systems, have numerous nonlinear loads, which significantly affect the quality of power.

The STATCOM used in distribution systems is called DSTATCOM (Distribution-STATCOM) and its configuration is the same, but with small modifications. It can exchange both active and reactive power with the distribution system by varying the amplitude and phase angle of the converter voltage with respect to the line terminal voltage. A multilevel inverter can reduce the device voltage and the output harmonics by increasing the number of output voltage levels.

An LCL filter is used at the front end of the VSI which will improve the tracking performance, but requires high value of dc-link voltage as that of L filter. In this paper an LCL filter is used to overcome the aforementioned drawbacks. Capacitor is used in series with the LCL filter to decrease the voltage of DSTATCOM. This proposed model decreases the size of the passive components, rating of dc-link voltage, rating of VSI. It provides good tracking performance.

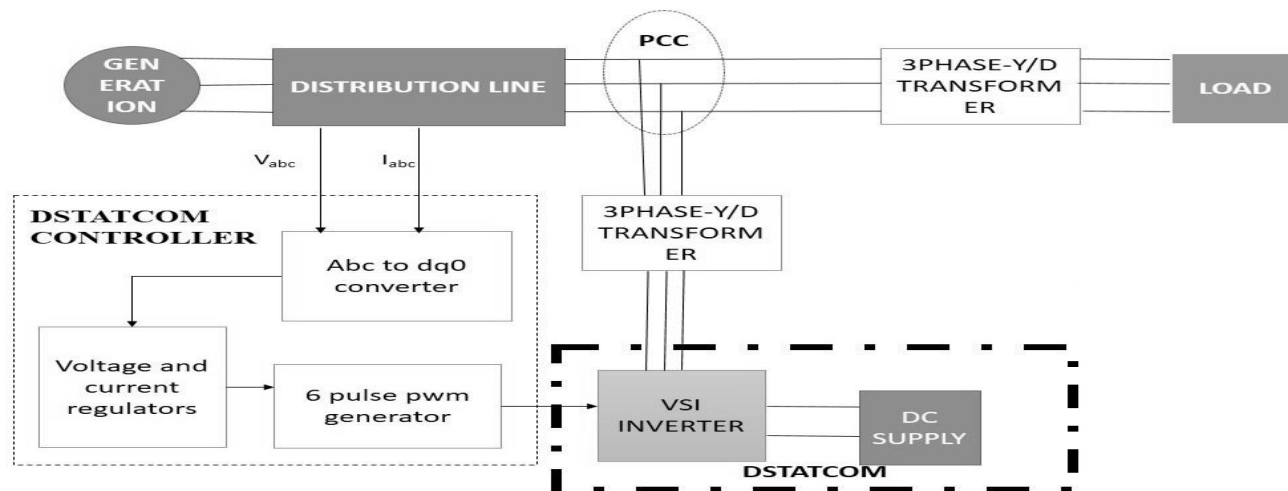


Figure:1 Schematic Diagram of a D-STATCOM

(III) MODELING OF COMPLETE SYSTEM

System consists of a Generation to distribution network, a multi winding transformer block, filters subsystem and a DSTATCOM connected to a system.

Programmable voltage source is used for the variation of voltages and current of the whole system, a DSTATCOM of 11KV ± 2 MVAR is connected to the point of coupling contact (PCC). LCL filters are connected in the filter block as shown in fig. 2. Controlling of DSTATCOM is done in the subsystem of DSTATCOM.

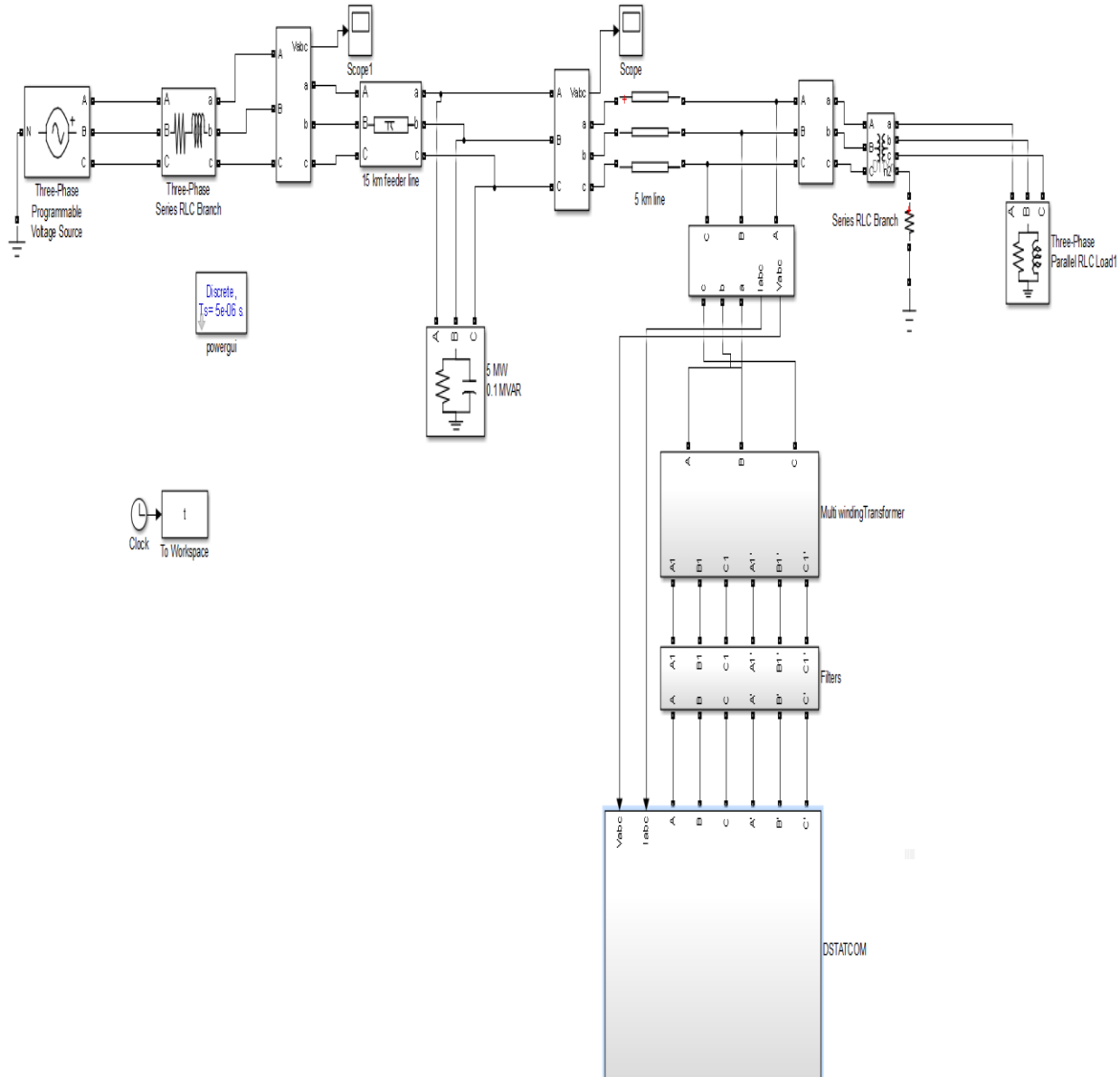


Fig. 2 Complete system Simulink model

(IV) MODELING OF LC FILTER

Fig. 3 shows the modeling of the LCL Filters (subsystem of filters as in the complete model of system) the resistance used in series is the damping resistance,

Value of L and C are provided by

$$L_1 = \frac{V_{dcref}}{(2ha)(2f_{max})} = \frac{V_{dcref}}{4haf_{max}} \quad (1)$$

Where 2ha is allowable ripple in the current, and f_{max} is the maximum switching frequency achieved by the HCC.

If the ripple current is large then the losses will be less. However, it can be seen from that the smaller ripple current results in higher inductance and, thus, more core losses. Therefore, a ripple current of 20% is taken while compromising the

ripple and inductor size, therefore substituting the values of the ripple current and reference dc-link voltage. The expression for resonance frequency will be,

$$F_{res} = \frac{1}{2\pi} \sqrt{\frac{1+b}{kL1C1}} \quad (2)$$

Where $b=L2/L1$

. The value for C is chosen in proportion to the capacitive reactance at F_{res} , i.e., X_{cre} , such that the damping losses are less while assuring system stability. The capacitive reactance at resonance will be

$$X_{cre} = \frac{1}{2\pi f_{res}C} \quad (3)$$

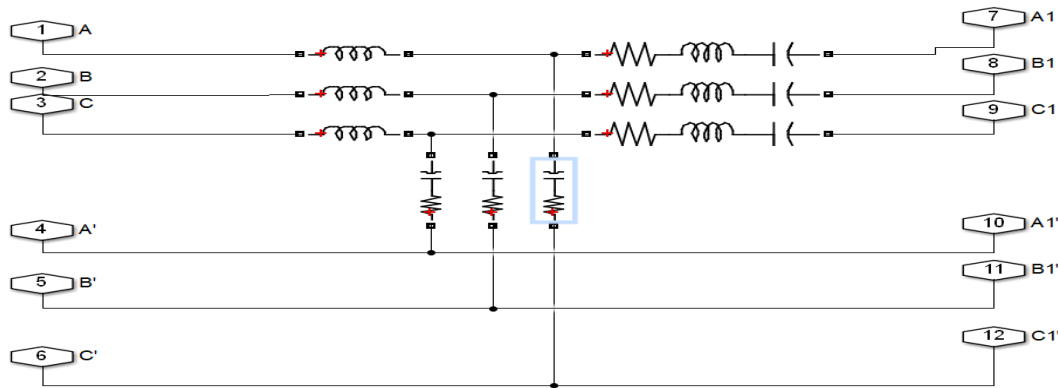


Fig. 3 Modelling of LC filter

(V) DSTATCOM

DSTATCOM subsystem block is modeled in this subsystem, fig. 4 which consists of 2 level bridge inverter and controllers for generating pulses for the inverters. Fig. 5 shows DSTATCOM controller which takes system voltage and current as input and converts it in from of active and reactive component of current and voltages. These components are proceeded further in the pulses subsystem as shown in fig. 6 for generation of pulses P1 and P2 for switching of 2 level bridge inverter.

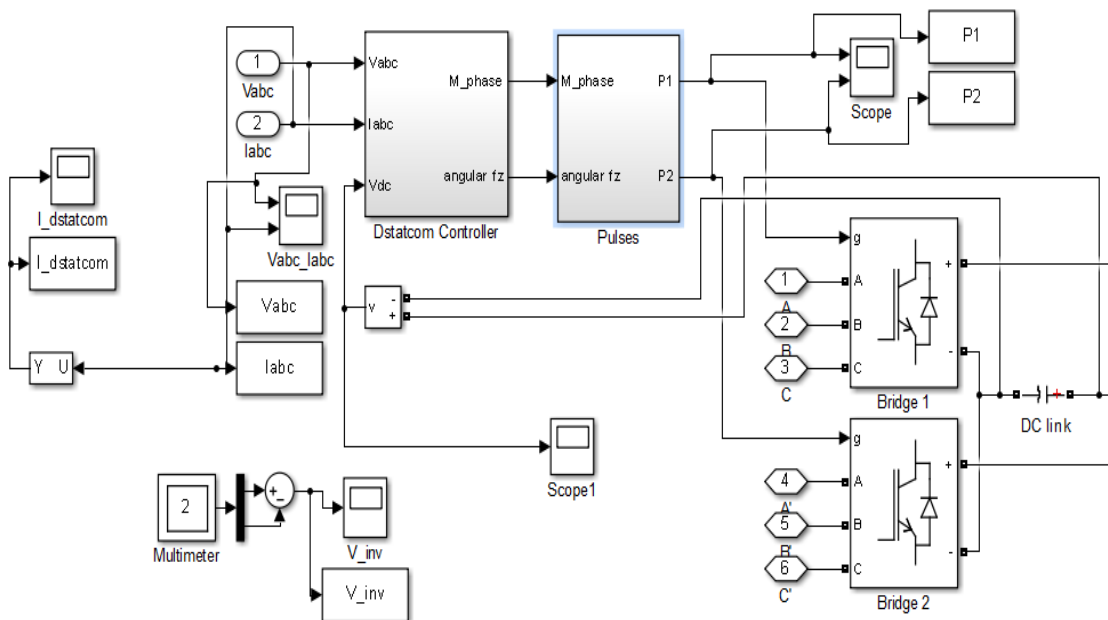


Fig. 4 DSTATCOM

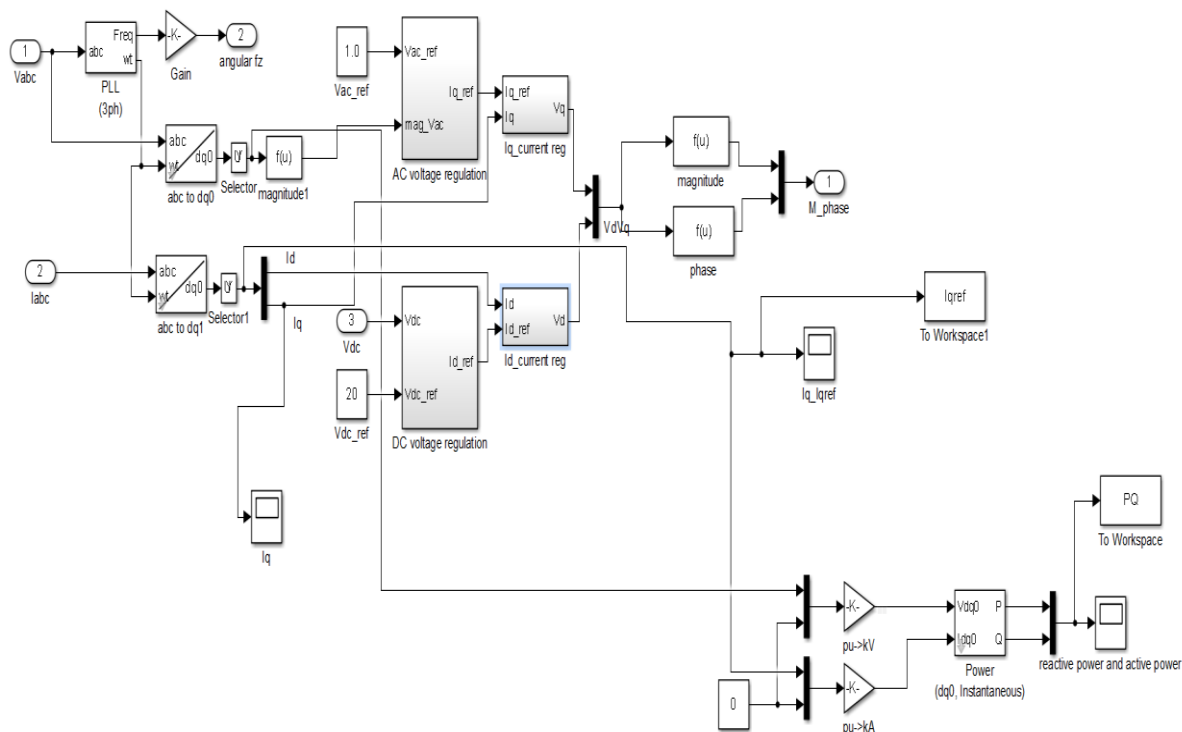


Fig 5 DSTATCOM controller

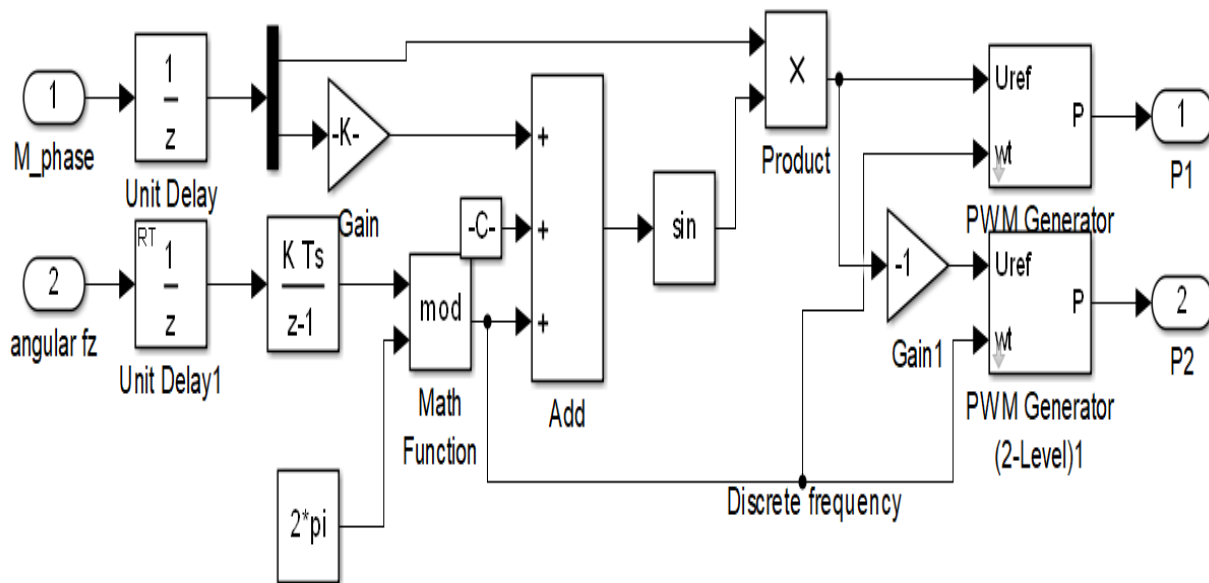


Fig. 6 generation of pulses

(VI) RESULTS

Fig. 7 voltage (11 Kv), different amplitudes are used for different values of time, which shows there is a swell in system voltage at 0.2 sec and sag at 0.4 sec. The simulation is run for 0.5 sec.

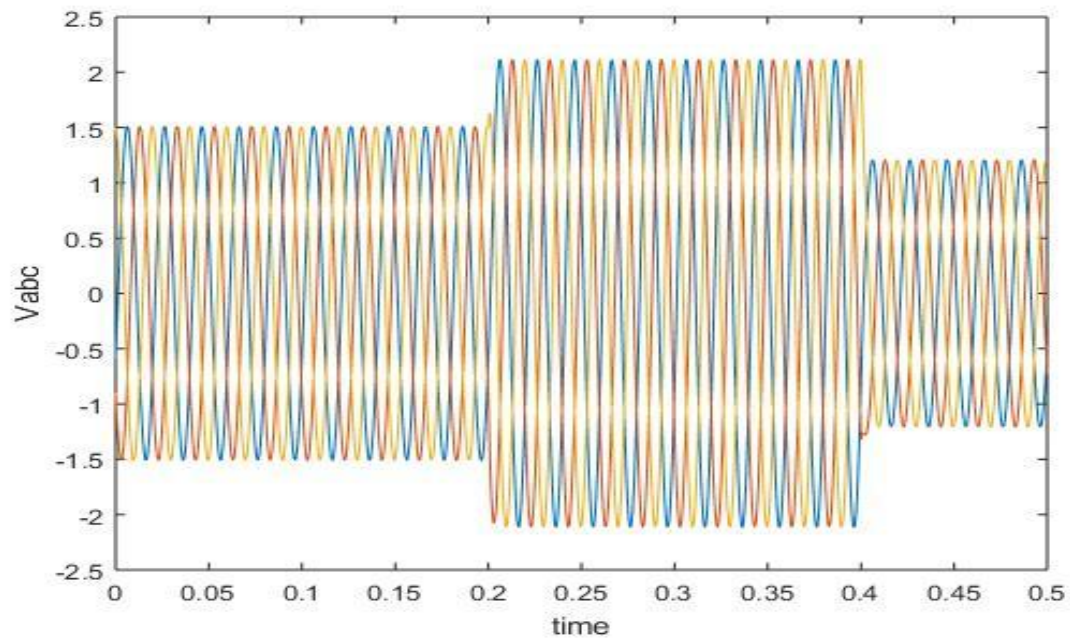


Fig. 7 System voltage V_{abc} (in pu)

Inverter switching pulses are shown in fig. 8, P1 & P2 both are for the different bridge modules

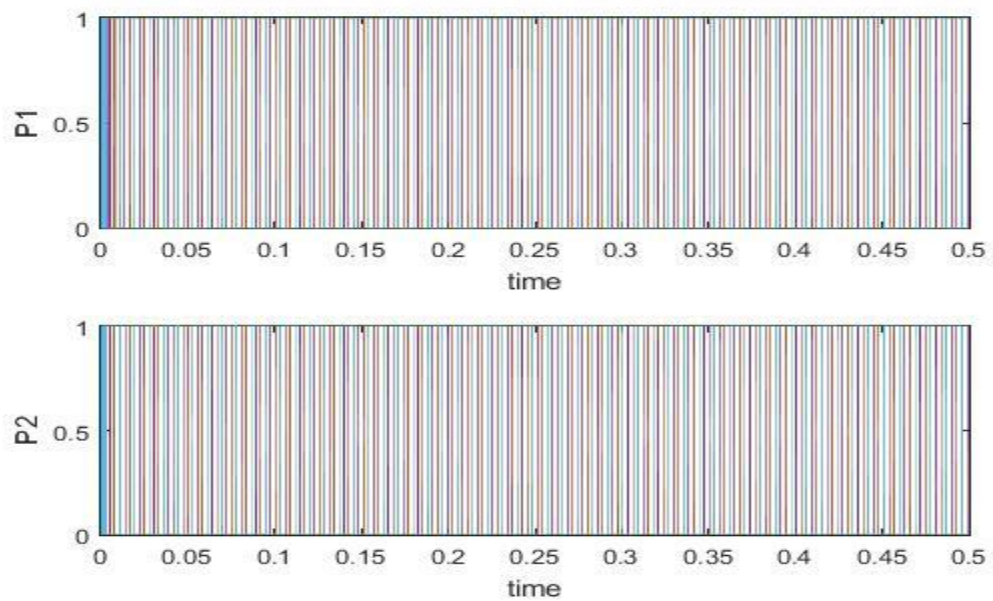


Fig. 8 Inverter Pulses

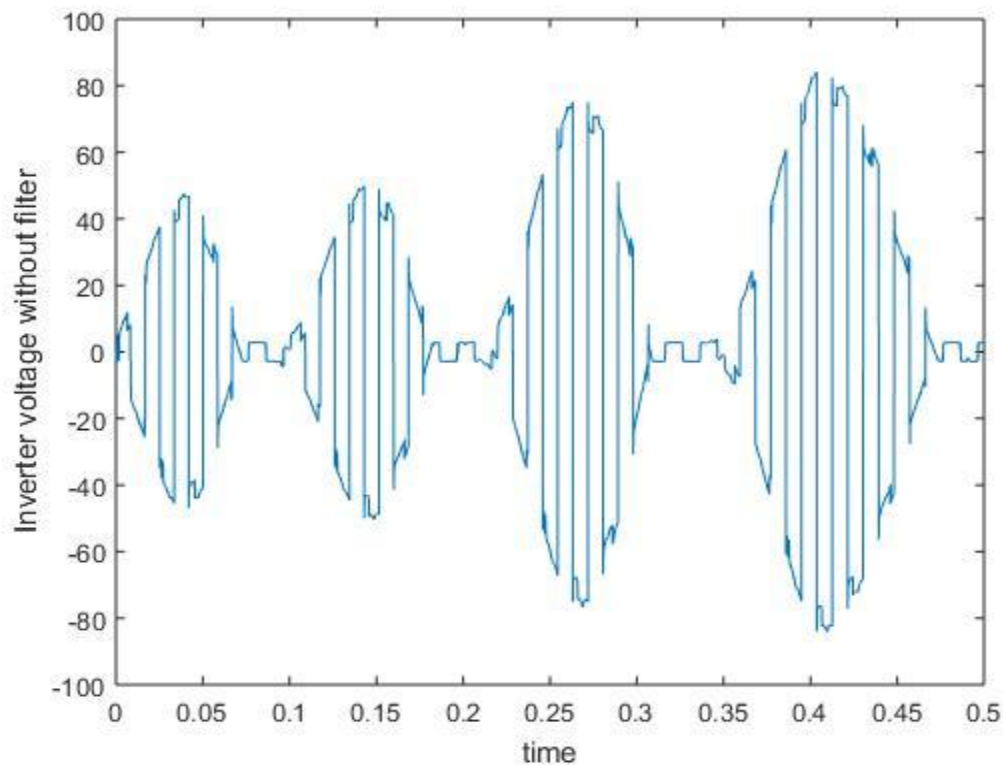


Fig. 9 Inverter Output (Without filter)

Fig. 9 show the inverter output of one phase without filter, it is clear that inverter output changes with corresponding change in the system voltage. Fig. 10 shows the DSTATCOM current of one phase or we can say that the filtered output of inverter, the DSTATCOM current is changing itself with change in the system voltage

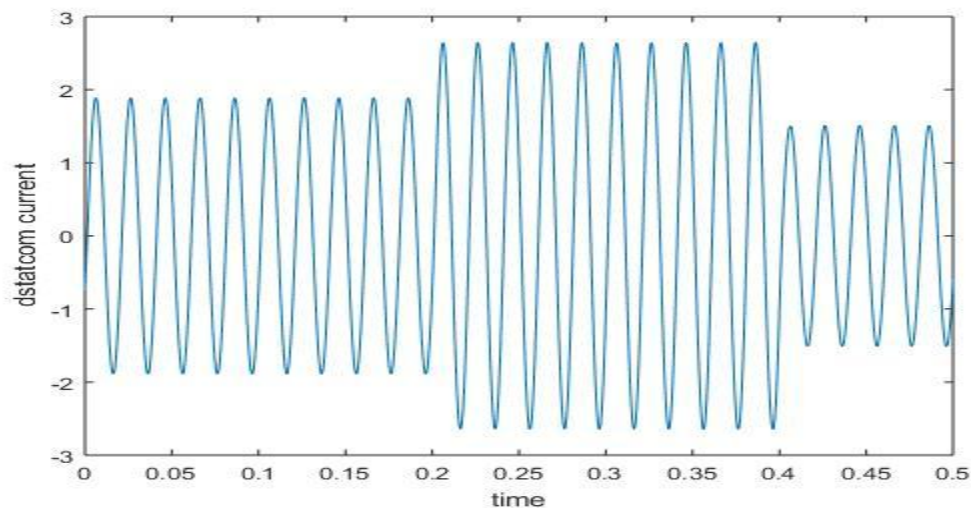


Fig. 10 DSTATCOM CURRENT (in pu)

Fig. 11 shows the comparison of the reactive current and the reference reactive current, at 0.2 sec it shows that with fluctuation in system voltage how i_q (represented by blue) changes itself with respect to i_{qref} (represented by red)

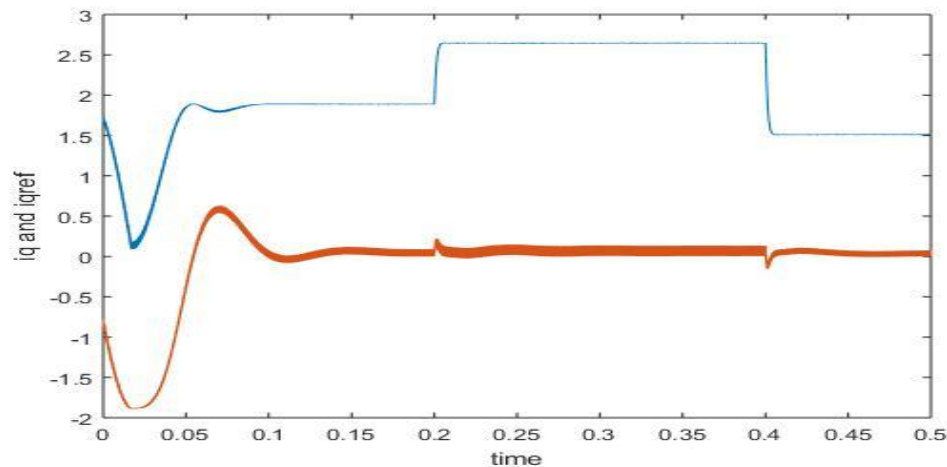


Fig. 11 Reactive currents comparison

(VII) CONCLUSION

This paper has presented the power quality problems such as voltage dips, and mitigation techniques this problem by using DSTATCOM. The design and applications of DSTATCOM for voltage sags result is presented. The voltage at PCC i.e where DSTATCOM is connected when exposed to a swell or sag by using a programmable voltage source for simulation purpose DSTATCOM delivers good compensation. LCL filters which are used with DSTATCOM gives more efficient compensation. Voltage magnitude (p.u.) of DSTATCOM before compensation is 0.01p.u. After compensation voltage magnitude of DSTATCOM becomes 0.86p.u.

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