# Reactive Power Compensation Using DSTATCOM

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*Abstract-* **This paper discusses the mitigation of power quality disturbance in low voltage distribution system due to voltage swells, sags and reactive power compensation using one of the powerful custom power device DSTATCOM. The DSTATCOM normally installed between source voltage and critical or sensitive load. The configuration of DSTATCOM has been proposed for improving voltage regulation and power factor for different types of loads in distribution system.**

***Keywords: Distribution static compensator, Reactive Power, Voltage Sags, voltage swells, distribution system.***

## I. INTRODUCTION

Recently the growth in the use of sensitive loads in all industries has caused many disturbances such as voltage sags, swells, transient and unbalance. These types of disturbances which caused malfunction or shut down and tend to revenue losses. Several methods are available to prevent equipment mal operation due to voltage swells and sags. One of commonly used methods is the use of DSTATCOM in order to mitigate voltage swells and voltage sags. The shunt controller, also known under the name ‘‘Distribution static compensator” or DSTATCOM. [1], [2].

DSTATCOM is an important tool to mitigate disturbances related to power quality problems in the distribution network. One of the crucial disturbances in the electrical network is voltage swells. The existing DSTATCOM as shown in Figure 1 ,consists of a Voltage Source Inverter (VSI), shunt injection transformer, filtering scheme and an energy storage device may that be connected to the dc-link[2-3].
Voltage sags/swells can occurs more frequently than other power quality phenomenon. These sags/swells are the most important power quality problems in the power distribution system. The main objective of this paper is to investigate and propose a configuration of DSTATCOM in order to develop such device for voltage swells, sags mitigation and for reactive power compensation in the network.

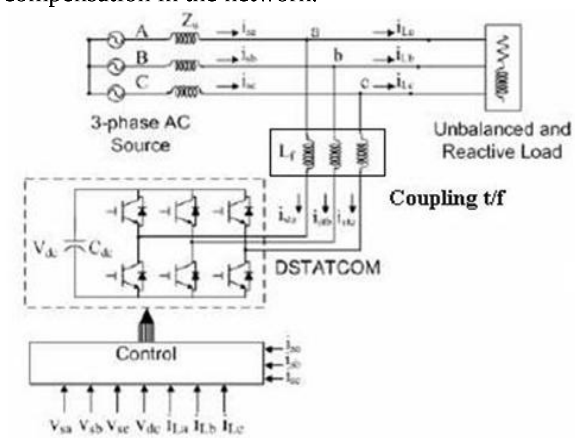



Fig.1 Basic circuit diagram of DSTATCOM

The capacity of the developed device is about 25KVA. This prototype is evaluated and tested in the laboratory and later it will be tested in the industry.

## II. DSTATCOM OPERATING PRINCIPLE

A DSTATCOM is a controlled reactive source which Includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt, capable of generating and /or absorbing reactive power. It is analogous to an ideal synchronous machine, which generates a balanced set of three sinusoidal voltages at the fundamental frequency with controllable amplitude and phase angle. This ideal machine has no inertia, gives an instantaneous response, does not alter the system impedances, and can internally generate reactive (both capacitive and inductive reactive power) [4]. Fig.2 shows the basic structure of a DSTATCOM. If the output voltage of the VSC is equal to the AC terminal voltage; no reactive power is delivered to the system. If the output voltage is greater than the AC terminal voltage, the DSTATCOM is in the capacitive mode of operation and vice versa. The quantity of reactive power flow is proportional to the difference in the two voltages.

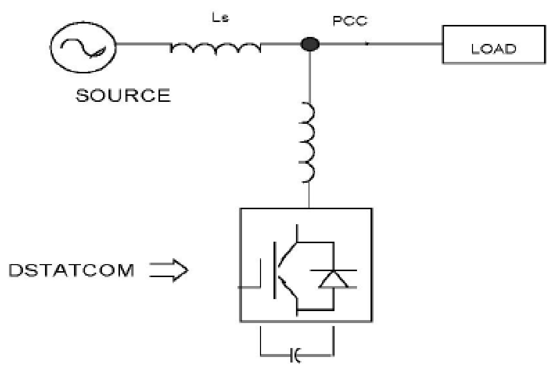



Fig.2 Basic structure of DSTATCOM

It is to be noted that voltage regulation at Point of Common Coupling (PCC) and power factor correction cannot be achieved simultaneously [5]. For a DSTATCOM used for voltage regulation at PCC the compensation should be such that the supply currents should lead the supply voltages and for power factor correction the supply current should be in phase with the supply voltages. The control algorithms studied in this paper are applied with a view to study the performance of a DSTATCOM for reactive power compensation and power factor correction.

## III.DSTATCOM CIRCUIT

The main aim of the DSTATCOM is to provide the voltage regulation at load point .An IGBT based DSTATCOM with voltage source inverter and a capacitor of 10000F as the DC source with a capacity of 25MVA is connected in shunt with the system through a transformer of 11KV/2KV as shown in Fig 3 .The DC capacitor should charge up to a voltage of 4000V in order to invert into an ac voltage of 2000V as the line-line rms voltage is given by

$$VLL=0.612 m_A V_D \quad \text{volt} \qquad (1)$$

Where

VLL= output AC voltage

$m_A$ = Amplitude Modulation ratio

$V_D$ = Input DC Voltage

The base voltage is taken as 11 KV and base MVA is 25 MVA. A filter circuit is connected at the output of the DSTATCOM circuit to eliminate the harmonics produced during switching .The reference PWM signals are given to the PWM generator to generate PWM pulse to the inverter.[6],[7].

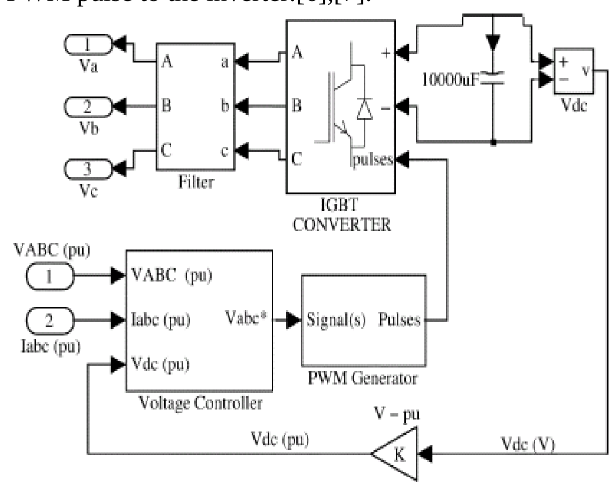



Fig.3 DSTATCOM circuit

## III. THE CONTROL of DSTATCOM

This algorithm requires the measurement of instantaneous values of three phase voltage and current. Fig.3.shows the block diagram representation of the control scheme. The compensation is achieved by the control of $I_d$ and $I_q$. Using the definition of the instantaneous reactive power theory for a balanced three phase three wire system, the quadrature component of the voltage is always zero, the real (p) and the reactive power (q) injected into the system by the DSTATCOM can be expressed under the dq reference frame as:

$$p = V_d I_d + V_q I_q \qquad (2)$$

$$q = V_d I_d - V_d I_q \qquad (3)$$

Since $V_q = 0$, $I_d$ and $I_q$ completely describe the instantaneous value of real and reactive powers produced by the DSTATCOM when the system voltage remains constant. Therefore the instantaneous three phase current measured is transformed by abc_ to_dqo transformation. The decoupled d-axis component $I_d$ and q axis component $I_q$ are regulated by two separate PI regulators. The instantaneous reference $I_d$ and the instantaneous $I_q$ reference are obtained by the control of the dc voltage and the ac terminal voltage measured. Thus, instantaneous current tracking control is achieved using four PI regulators. A Phase Locked Loop (PLL) is used to synchronize the control loop to the ac supply so as to operate in the abc_to_dqo reference frame. The instantaneous active and reactive powers p and q can be decomposed into an average and an oscillatory component. [8], [9].

$$p = \bar{p} + \tilde{p} \qquad (4)$$

$$q = \bar{q} + \tilde{q} \qquad (5)$$

Where $\bar{p}$ and q are the average part and $\tilde{p}$ and $\tilde{q}$ are oscillatory part of real and reactive instantaneous powers. The compensating currents are calculated to compensate the instantaneous reactive power and the oscillatory component of the instantaneous active power. In this case the source transmits only the non-oscillating component of active power. Therefore the reference source currents $i^*_{s\alpha}$ and $i^*_{s\beta}$ in α-β coordinate are expressed as:

$$\begin{bmatrix} i^*_{s\alpha} \\ i^*_{s\beta} \end{bmatrix} = \frac{1}{\Delta}\begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix}\begin{bmatrix} \bar{p} \\ 0 \end{bmatrix} \qquad (6)$$

These currents can be transformed in a-b-c quantities to find the reference currents in a-b-c coordinate.

$$\begin{bmatrix} i^*_{sa} \\ i^*_{sb} \\ i^*_{sc} \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}}\begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix}$$

(7)

Where $i_0$ is the zero sequence components which is zero in 3-phase 3-wire system

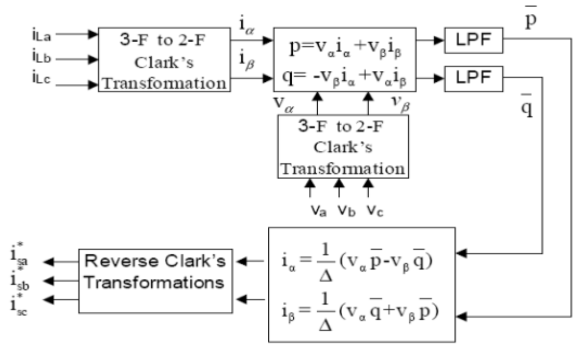



Fig.4 Block diagram of Decoupled theory based control of DSTATCOM

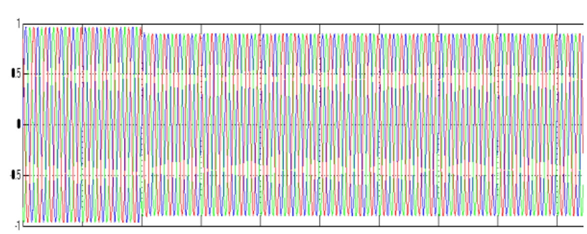
## IV.SIMULATION RESULTS

The DSTATCOM model developed using the mat lab is allowed to run for 0.5 seconds. A fixed inductive load is always connected to the source .the increase or decrease in voltage is performed by using circuit breakers with a delay of 0.2second from the start of the simulation. Simulations were carried out for all the cases where the DSTATCOM is connected was connected into the system and not. The scopes in the following sections show the simulated results with time as the X-axis parameter. The Y-axis parameters are shown on the top of the graphs. The sequence of events simulated is explained as follows.

### *A. Without compensation*

Case: 1

Initially there is a fixed inductive load is connected to the line. After 0.2 second the circuit breaker .is closed and the terminal voltage is decreased to 0.8pu. The top window shows the change in the three phase voltage waveforms, the second window shows the changes in the currents when the inductive load is applied after 0.2seconds and the bottom window shows the magnitude of the voltage.



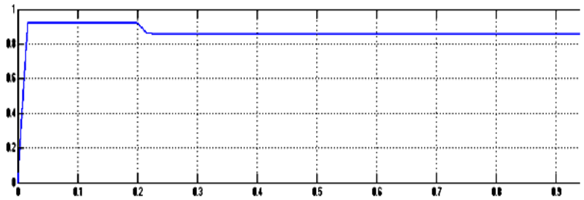


Fig.5 Load voltage in RMS and Pu with inductive load in the uncompensated line

Case: 2

A capacitive load is applied at 0.4seconds after the start of the simulation

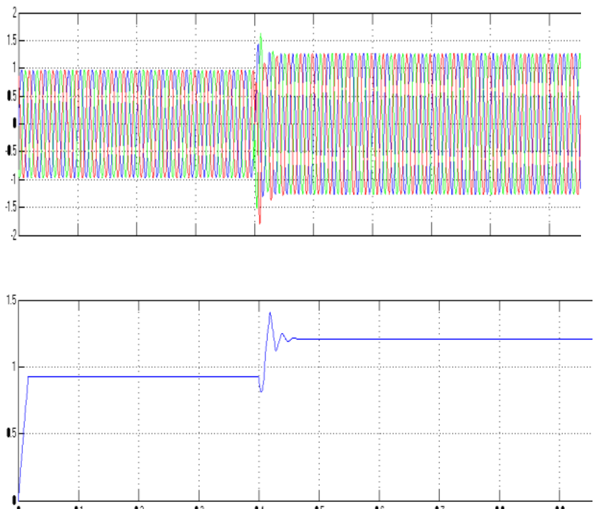
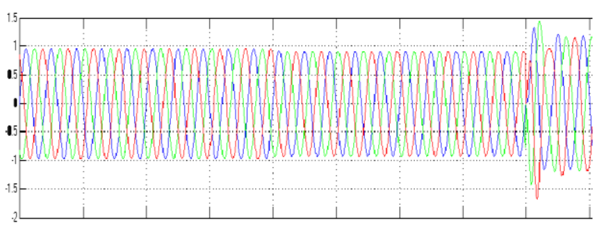


Fig.6 Load voltage in RMS and Pu with capacitive load in the uncompensated line

Case: 3

An inductive load is applied 0.2seconds after the start of the simulation and a capacitive load is applied at 0.4seconds after the start of the simulation



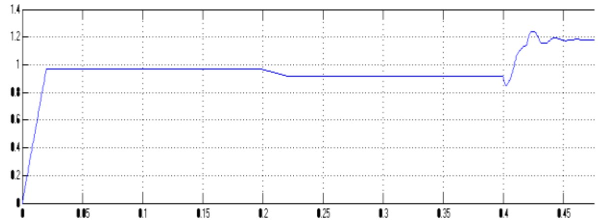


Fig .7 Load voltages in RMS and Pu with inductive and capacitive load in the uncompensated line

*B. With compensation*

Case: 1

An inductive load is applied 0.2seconds after the start of the simulation

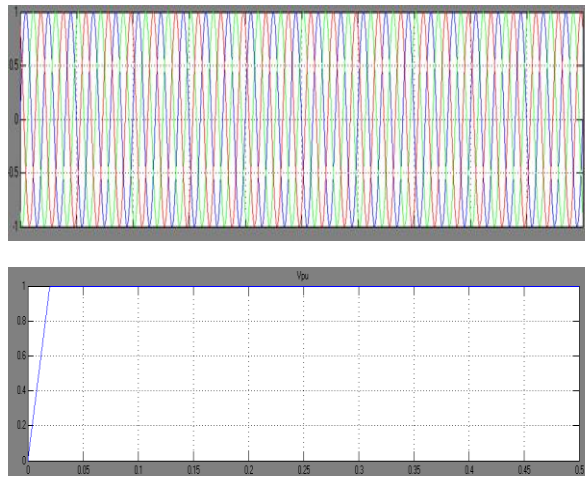
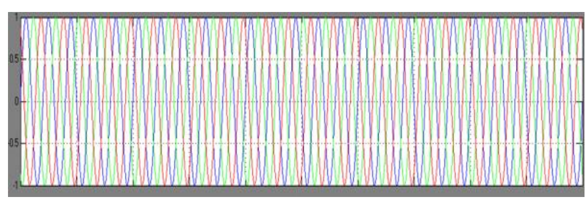


Fig.8 Load voltage in RMS and Pu with inductive in the compensated line

Case: 2

A capacitive load is applied at 0.4 seconds after the start of the simulation



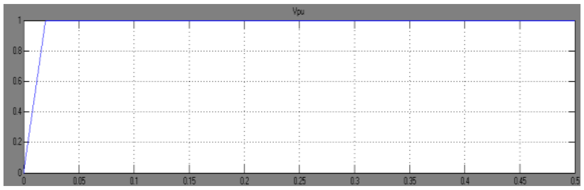


Fig.9 Load voltage in rms and Pu with capacitive load in the compensated line

Case: 3

An inductive load is applied 0.2seconds after the start of the simulation and a capacitive load is applied at 0.4seconds after the start of the simulation

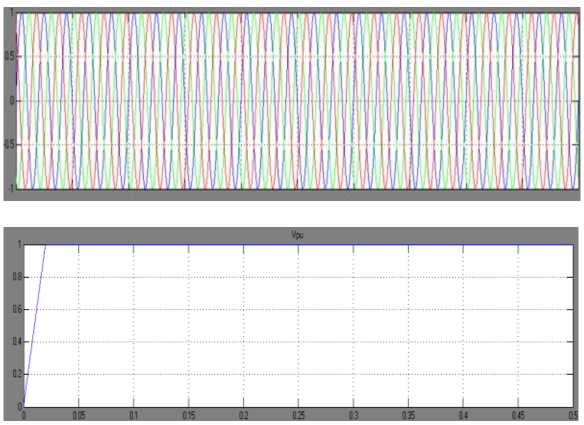


Fig.10 Load voltage in rms and Pu with inductive and capacitive loads in the compensated line

*C. Reactive power compensation*

*Case: 1*

An inductive load is applied 0.3 seconds after the start of the simulation

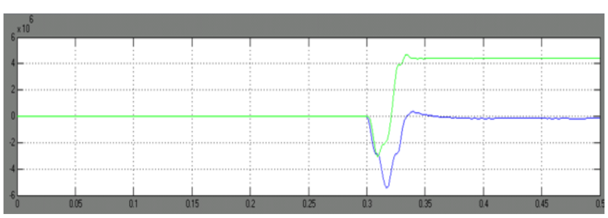


Fig.11 Reactive power improvement for inductive load

*Case: 2*

A capacitive load is applied at 0.2 seconds after the start of the simulation

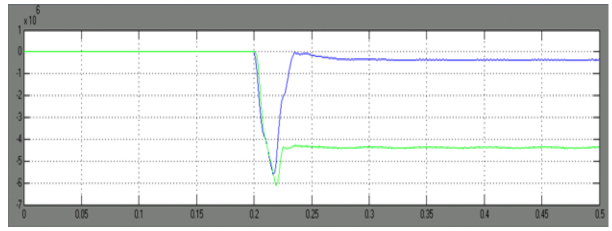


Fig.12 Reactive power improvement for capacitive load

*Case: 3*

An inductive load is applied 0.2seconds and a capacitive load is applied at 0.3seconds after the start of the simulation

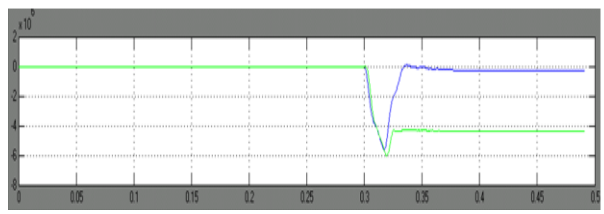


Fig.13 Reactive power improvement for inductive and capacitive load

## V.CONCLUSION

CUSTOM POWER (CP) devices can be used, at reasonable cost, to provide high power quality and improved power service. This project presents the detailed modeling of one of the custom power products, DSTATCOM is presented and also a study of control algorithm, instantaneous P-Q theory, used for the control of DSTATCOM is discussed its relative merits and demerits. This control algorithm is described with the help of simulation results under linear loads. PWM control scheme only requires voltage measurements. This characteristic makes it ideally suitable for low-voltage custom power applications. The control scheme was tested under a wide range of operating conditions, and it was observed to be very robust in every case.

It is concluded that a DSTATCOM though is conceptually similar to a STATCOM at the transmission level. Its control scheme should be such that to achieve reactive power compensation and voltage regulation for achieving improved power quality levels at the distribution end.

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