# Improvement of Power Quality by Enhancing the Voltage Stability by VSC based DSTATCOM

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***Abstract*—This paper investigates the working of a shunt connected Distribution Static Compensator (DSTATCOM) for power quality improvement in the distribution system. The proposed DSTATCOM is employed for the compensation of reactive power, harmonics currents and voltage stability at the point of common coupling. The performance of DSTATCOM is validated by detailed simulations using MATLAB Software with the Simulink and power system toolboxes. The performance of DSTATCOM is found to be satisfactory under time varying and unbalanced loads. The result for voltage compensation validates the effectiveness of DSTATCOM for improving Power Quality.**

***Keywords*—Distribution Static Compensator (DSTATCOM), Power Quality (PQ), Reactive Power Compensation, Voltage Stability.***

## I. INTRODUCTION

Distribution Systems are currently undergoing through lots of problems related to Power Quality ( PQ).Now a day's lots of emphasis is given on the quality of power supplied to the end user. The term Power Quality (PQ) includes all possible situations in which the waveform of the supply voltage (Voltage Quality) or Load Current (Current Quality) deviates from the sinusoidal waveform for all the three phases. The source voltages in distribution system are also encountering PQ problems, such as flicker, voltage sag, voltage swell, unbalance, etc [1-4].In order to limit these problems many standards are proposed such as IEEE 519-1992,IEEE Std.141-1993, etc [ 9-11].At the distribution level ,power electronic controllers also called as custom power devices have been proposed many of which have a Voltage Sourced Converter(VSC) connected to the grid. The solutions to the PQ problems are investigated and discussed in the literature [5 -10].The DSTATCOM is proposed for compensating PQ problems in current.DSTATCOM is a custom power used for mitigating voltage sag and swell, improving power factor and balancing the load. There are many techniques proposed and some have been patented also for elimination of harmonics from source current and for compensation [ 5-8]

The DSTATCOM is a custom power device and it consists of a current source ( VSC) which injects current into the system at the PCC through the interface reactor. The operation of VSC is supported by a dc storage capacitor. The DSTATCOM has a very significant transient response while providing compensation to the system. Basically a DSTATCOM is a device which is used in ac distribution system where harmonic current mitigation, reactive current compensation and load balancing are necessary.

The main benefit of DSTATCOM is that it has very fine and advanced power electronics control [3-6] which can efficiently regulate the current injection into the distribution bus.

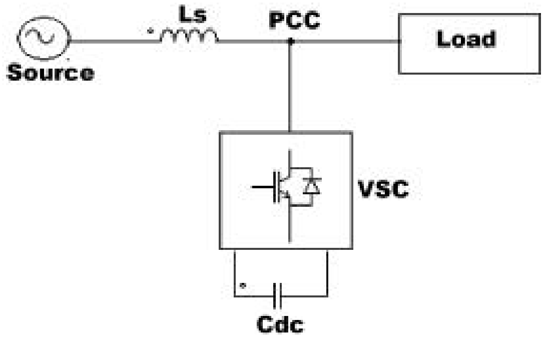

Fig 1.Basic structure of DSTATCOM

Fig.1 shows a basic structure of DSTATCOM. The operating principle of DSTATCOM is based on the exact equivalence of a conventional rotating synchronous compensator. The AC terminals of VSC are connected to the point of common coupling [PCC] through an inductance and the DC side of the converter is connected to the DC capacitor, which carries the input ripple current of the converter. 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. For a given reference operating voltage, a

DSTATCOM can inject current into the system such that it meets the specifications for the utility connection [ 2-6].

Fig 2.shows the operating modes of DSTATCOM.

The two different modes in which DSTATCOM can be operated are :-i) Voltage Regulation Mode ( In which voltage is regulated within limits) ,ii) Volt Ampere Reactive Mode ( In which reactive power is kept constant).

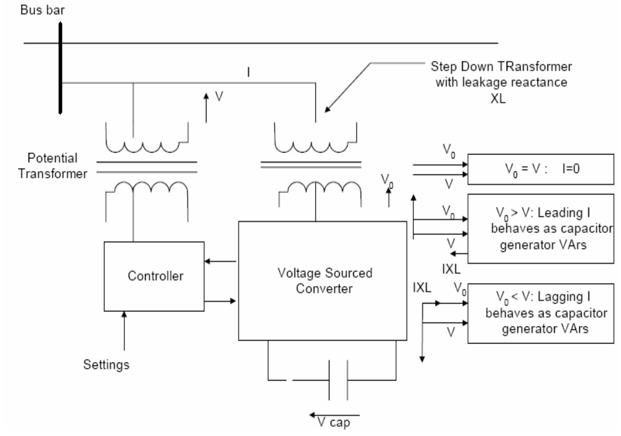

Fig 2.Modes of Operation of DSTATCOM.

## II. COMPENSATION TECHNIQUES

The major PQ problems are due to unbalance phase currents, third harmonic currents produced by the single phase rectifier loads. Even balanced three phase currents produce excessive neutral current with computer loads. The non linear loads are classified into harmonic current source and harmonic voltage source loads. Various methods are used to solve and address PQ problems [ 8 -10].The various methods which are proposed for compensation in the distribution system are :-

- Zig Zag Transformer Based Compensation
- Zig Zag Transformer with Active Filter Based Compensation
- Star / Delta Transformer Based Compensation
- Three Phase Four Wire Active Compensation

## III. PROPOSED COMPENSATION SCHEME

In an average model, the IGBT Voltage-Sourced Converters (VSC) are represented by equivalent voltage sources generating the AC voltage averaged over one cycle of the switching frequency. This model does not represent harmonics, but the dynamics resulting from control system and power system interaction is preserved. This model allows using much larger time steps (typically 40-50 microseconds), thus allowing simulations of several seconds.

## IV. SOFTWARE MODEL DESCRIPTION

A Distribution Static Synchronous Compensator (D-STATCOM) is used to regulate voltage on a 25-kV distribution network. Two feeders (21 km and 2 km) transmit power to loads connected at buses B2 and B3. A shunt capacitor is used for power factor correction at bus B2. The 600-V load connected to bus B3 through a 25kV/600V transformer represents a plant absorbing continuously changing currents, similar to an arc furnace, thus producing voltage flicker. The variable load current magnitude is modulated at a frequency of 5 Hz so that its apparent power varies approximately between 1 MVA and 5.2 MVA, while keeping a 0.9 lagging power factor. This load variation will allow you to observe the ability of the D-STATCOM to mitigate voltage flicker.

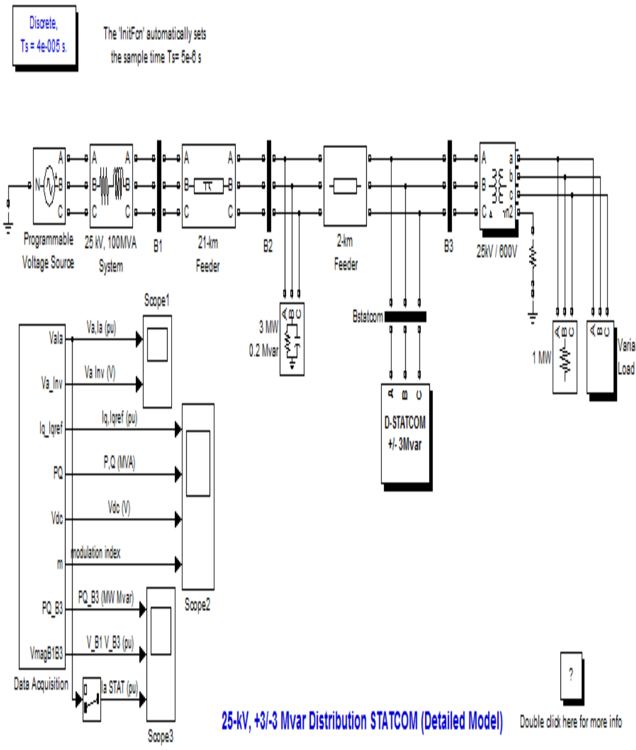

Fig.3 Proposed DSTATCOM Model

The D-STATCOM consists of the following components:

a 25kV/1.25kV coupling transformer which ensures coupling between the PWM inverter and the network. A voltage-sourced PWM inverter. In this demo, the PWM inverter is replaced on the AC side with three equivalent voltage sources averaged over one cycle of the switching frequency (1.68 kHz). On the DC side, the inverter is modeled by a current source charging the DC capacitor. The DC current Idc is computed so that the instantaneous power at the AC inputs of the inverter remains equal the instantaneous power at the DC output (Va*Ia + Vb*Ib + Vc*Ic = Vdc*Idc). LC damped filters are connected at the inverter output.

The D-STATCOM controller consists of several functional blocks:

1) Phase Locked Loop (PLL)-The PLL is synchronized to the fundamental of the transformer primary voltages two measurement systems. Vmeas and Imeas blocks compute the d-axis and q-axis components of the voltages and currents by executing an abc-dq transformation in the synchronous reference determined by sin(wt) and cos(wt) provided by the PLL.

2) Inner current regulation loop-This loop consists of two proportional-integral (PI) controllers that control the d-axis and q-axis currents. The controllers outputs are the Vd and Vq voltages that the PWM inverter has to generate. The Vd and Vq voltages are converted into phase voltages Va, Vb, Vc. The Iq reference comes from the outer voltage regulation loop or from a reference imposed by Qref. The Id reference comes from the DC-link voltage regulator.

3) Outer voltage regulation loop-In automatic mode (regulated voltage), a PI controller maintains the primary voltage equal to the reference value defined in the control system dialog box. A DC voltage controller which keeps the DC link voltage constant to its nominal value (Vdc=2.4 kV).

The electrical circuit is discretized using a sample time Ts=40 microseconds. The controller uses a larger sample time (4*Ts=160 microseconds).

## V. SIMULATION RESULTS

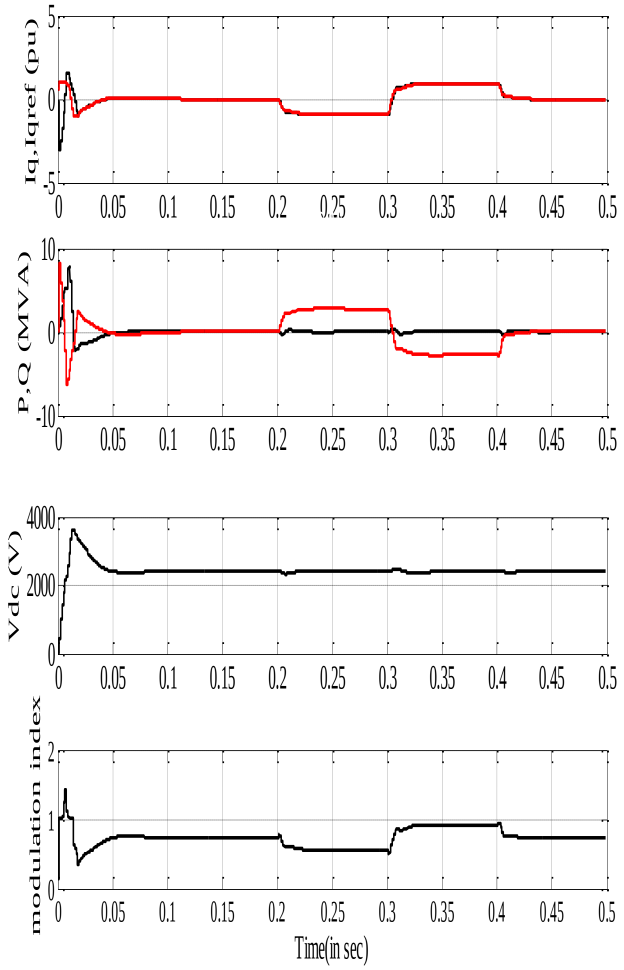

Fig 4. (a) Injected Reactive Current Iq in pu, (b) Active and Reactive Power obtained ( c) Voltage obtained across dc link capacitor (d) Modulation Index .

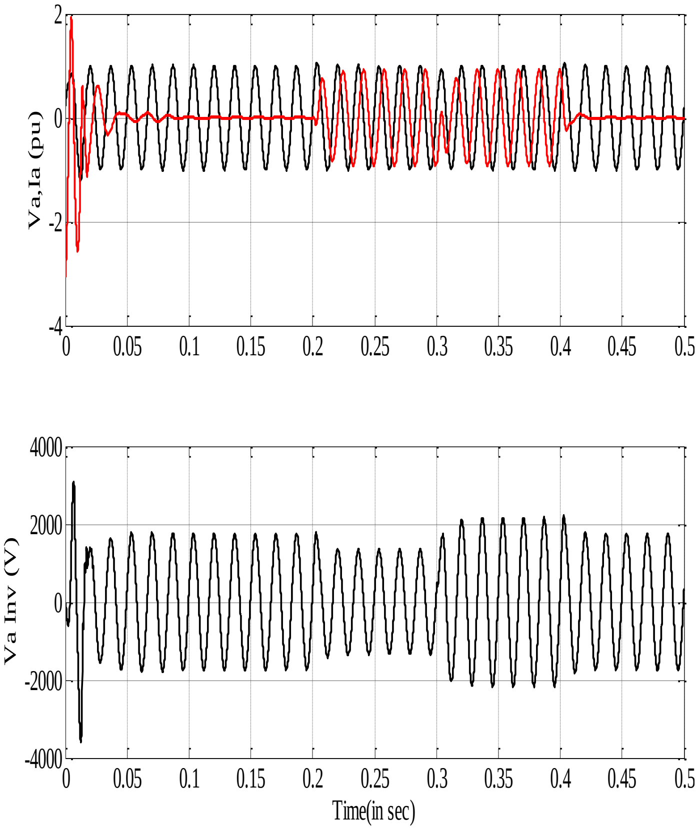

Fig.5 ( a) Voltage and Current Variation in phase a in PU , (b) Voltage obtained in phase a in Volts.

During this test, the variable load will be kept constant and you will observe the dynamic response of a D-STATCOM to step changes in source voltage. Check that the modulation of the Variable Load is not in service (Modulation Timing [Ton Toff]= [0.15 1]*100 > Simulation Stop time). The Programmable Voltage Source block is used to modulate the internal voltage of the 25-kV equivalent. The voltage is first programmed at 1.077 pu in order to keep the D-STATCOM initially floating (B3 voltage=1 pu and reference voltage Vref=1 pu). Three steps are programmed at 0.2 s, 0.3 s, and 0.4 s to successively increase the source voltage by 6%, decrease it by 6% and bring it back to its initial value (1.077 pu).

Start the simulation. Observe on Scope1 the phase A voltage and current waveforms of the D-STATCOM as well as controller signals on Scope2. After a transient lasting approximately 0.15 sec., the steady state is reached. Initially, the source voltage is such that the D-STATCOM is inactive. It does not absorb nor provide reactive power to the network. At t = 0.2 s, the source voltage is increased by 6%. The D-STATCOM compensates for this voltage increase by absorbing reactive power from the network (Q=+2.7 Mvar on trace 2 of Scope2). At t = 0.3 s, the source voltage is decreased by 6% from the value corresponding to Q = 0. The D-STATCOM must generate reactive power to maintain a 1 pu voltage (Q changes from +2.7 MVAR to -2.8 MVAR). Note that when the D-STATCOM changes from inductive to capacitive operation, the modulation index of the PWM inverter is increased from 0.56 to 0.9 (trace 4 of Scope2) which corresponds to a proportional increase in inverter voltage. Reversing of reactive power is very fast, about one cycle, as observed on D-STATCOM current (magenta signal on trace 1 of Scope1).

## VI. CONCLUSION

The modeling and simulation of DSTATCOM in MATLAB SIMULINK toolbox and its detailed simulation analysis indicates DSTATCOM as a effective option for overall compensation. The DSTATCOM can be hence used to address problems related to the Power Quality; this has been validated by extensive computer simulation. The performance of DSTATCOM is found to be satisfactory under nonlinear loads.

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