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Enhancement of Reactive Power Management in Distribution System Using D-STATCOM

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Abstract— In the present era, the quality of the power system should be more precise when it reaches customer ends. Key industrial loads need reactive power for nourishing magnetic field, for example, furnaces, transformers, induction motors etc. Reactive Power Compensation (RPC), a major power quality issue in the distribution system, which affects the performance of the power system. The core fact behind reactive power compensation is the increased system stability, voltage regulation, better utilization of gadgets connected to the systems, dropping system losses associated with the system. The complete pillar of the compensating devices and power electronic application in compensating devices is depicted in this paper. FACTS devices are dynamic reactive power compensator capable of supplying reactive power to the grid and consuming reactive power from the grid. This paper proposes the D-STATCOM, a FACTS device for the compensation of reactive power. The compensation using the D-STATCOM modeling is also discussed in this work. The D-STATCOM normally mounted between source voltage and critical or sensitive load. The configuration of D-STATCOM has been scheduled for improving voltage profile management and power factor performance for different sorts of loads in distribution system. D-STATCOM is an effective measure to sustain voltage stability and improve power quality events of distribution system. The simulation is performed in MATLAB for D-STATCOM and voltage source converter (VSC).

Index Terms— Reactive Power Compensation (RPC), Distribution system, D-STATCOM, VSC, Power Quality events, Voltage Stability, Power Factor.

1 Introduction

In the modern era, most of the AC loads are engrossing reactive power due to the occurrence of reactance. However, tectonic use of reactive power causes poor power quality events such as voltage sag, voltage swell, voltage stability. Present day, these events have even an advanced impact on reliable and stable power supply across the world distribution systems. Major key parameters consume reactive power were reactive loads such as fans, pumps etc. These loads extract lagging power factor currents and leads to reactive power challenge in the distribution system. Reactive power cannot be transmitted across large power angle even with significant voltage magnitude gradient. Reactive power should be produced close to the point of consumption. As a result, extreme reactive power demand surges feeder losses and cuts the active power flow competence of the distribution system. It also affects theoperation of transformers and generators in DG.

For reactive power compensation, D-STATCOM furnish reactive power as desired by the load and therefore the source current keeps the power factor as unity that is Unit Power Factor (UPF). D-STATCOM is an important apparatus to mitigate disturbances related to power quality events in the distribution network. The reference source current used to establish the exchanging of the D-STATCOM has a real fundamental frequency component of the load current which is mined by these techniques. A STATCOM at the transmission level handles only fundamental reactive power and provides voltage support while as a D-STATCOM is engaged at the distribution level as well as the load end for power factor improvement and voltage stability. A D-STATCOM can also perform as a shunt active filter, to abolish unbalance or distortions in the source current or the supply voltage.

Thus, a D-STATCOM is such a multioperational device, the main objective of any control algorithm should be to make it malleable and easy to execute. DSTATCOM can be effectively employed to improve the quality of power supplied to the customers. We can make several reasons to attenuate reactive power transfers and are listed below:

- It is ineffective during high real power transfer and entail substantial voltage magnitude.
- It roots high real and reactive power losses.
- It can prime to damaging temporary overvoltage's following load rejections.
- It requires higher equipment size for transformer and cables.

2 D-STATCOM

The Distribution Static Compensator (D-STATCOM) is a three phased voltage source converter based static compensator. D-STATCOM is a controlled reactive source which comprises a Voltage Source Converter (VSC) and a DC link capacitor coupled in shunt, capable of producing and /or engrossing reactive power. It also applied for the correction of bus voltage sags. Fig 1 shows the basic diagram of D-STATCOM.

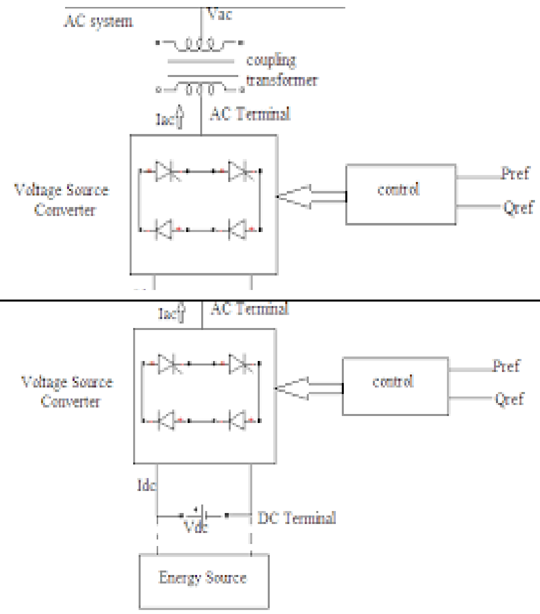

Figure 1 Basic Diagram of D-STATCOM

The D-STATCOM mainly comprises of DC voltage source behindhand self-commutated inverters using IGBT and coupling transformer. A three phase IGBT based current controlled voltage source converter with a dc bus capacitor is habituated as a D - STATCOM.

The key parameters of D-STATCOM are capable to provide load balancing & improve load terminal voltage improves supply power factor. D-STATCOM confines the short circuit current, increases the load ability of the system and transient stability limit.

Apparently, D-STATCOM controller is highly operative in enhancing the power quality at the distribution level by assembling the voltage stable.

To clarify, fig. 2 displays a schematic art of a D-STATCOM coupled to a typical distribution network represented by an equivalent network. As a result, the control system ensures the regulation of the bus voltage and the dc link voltage. The

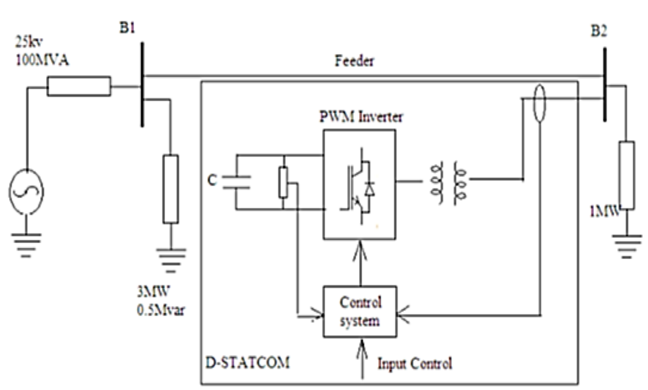

Fig.2 Schematic Art of D-STATCOM

principle operation of the D-STATCOM depends upon reactive current generation.

3 Modes of Operation

D-STATCOM operates in two modes namely, capacitive and inductive.The schematic representation of both capacitive and inductive modes of operation shown in fig.3 and fig.4 respectively.

When,

$$V_d < V_b \qquad (1)$$

The D-STATCOM acts like an inductance consume reactive power from the bus.

When,

$$V_b < V_d \qquad (2)$$

The DSTATCOM acts like a capacitor generating reactive power to the bus.

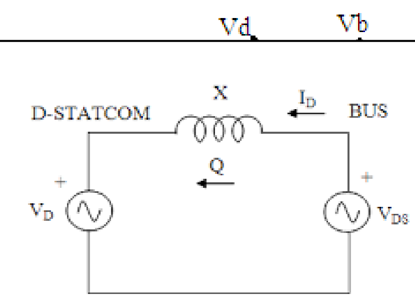

Fig.4 Inductive Mode of Operation

4 Control Schemes for D-STATCOM

A basic block diagram of the internal control for a converter with internal voltage control capability is shown in Fig.5.
The block diagram illustrates, the bus voltage V, I_Q represent the converter output current and the reactive current reference, IQ Ref plus the dc voltage reference, Vdc converter output current. Fig.6 denotes the voltage source converter decayed to the external reactive current component. These components are related to the external reactive current reference determined from compensation concerns and the internal real current reference derived from the dc voltage regulation loop. After an apt amplification, the real and reactive current error signals are transformed into the magnitude and angle of the wanted converter output voltage from which the proper gate drive signals, in proper relationship with the phase-locked loop (PLL) provided phase reference, are derived.

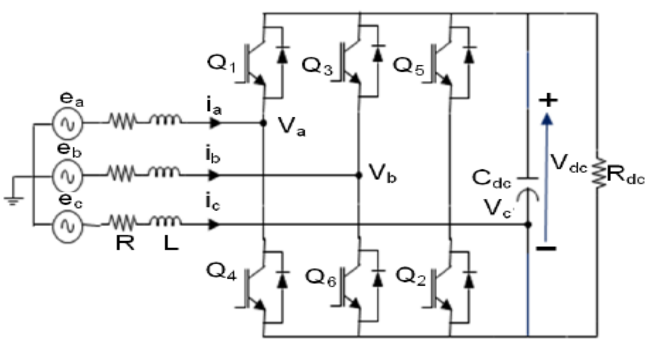

Fig.6 Voltage Source Converter

In fact, $\alpha\beta 0$-Transformation theory (Clarke theory) is accustomed in this presented probe which embraces of a real matrix that converts three phase voltages and current into $\alpha\beta 0$ stationary references frames using $p-q$ theory. It supposes the entire three-phase system as a unit, not a superposition. It split zero sequence component employing a real matrix rather than symmetrical component transformation that uses a complex matrix to resolve. The $\alpha\beta 0$-Transformation theory is employed in both transient and steady state. It is steady in nature of power term. The Clark Transformation and inverse Clark Transformation for instantaneous voltages are given in Equations (3) and (4).

$$|V_\alpha| = \ldots |V_b| \quad (3)$$

$$|V_b| = \ldots |V_\alpha| \quad (4)$$

The real and reactive power is expressed in matrix form in Equation (5).

$$\left|\begin{matrix} P \\ q \end{matrix}\right| = \left|\begin{matrix} V_\alpha & V_\beta \\ \ldots \end{matrix}\right| \left|\begin{matrix} i_\alpha \\ i_\beta \end{matrix}\right| \quad (5)$$

5 SIMULATION AND RESULT DISCUSSION

Modeling the D-STATCOM includes the power network and its controller in Simulink platform demand electrical block from power system block set. The D-STATCOM of ±3 Mvar is connected to a 25-kV distribution network as shown in figure 7.

TABLE 1
SIMULATION PARAMETERS

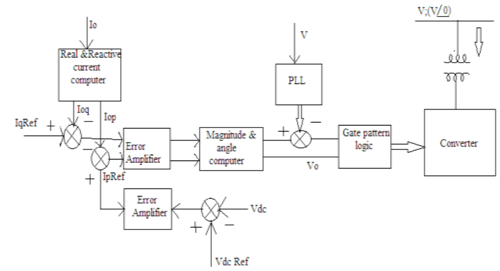

Fig.5 Control of D-STATCOM

Parameter	Numerical Value
Three-Phase Source Voltage	25kV
Frequency	50Hz
Cut-off frequency of Butterworth LPF of 5th order	2*pi*50 rad/sec
Capacitor for D-STATCOM	10000 µF
Reference Voltage	580V

Consequently, the feeding network represented by bus B1 followed by21- km feeder which is displayed by a pi- equivalent circuit coupled to bus B2. As a result, the D-STATCOM output is coupled in parallel with the network through a step-up 1.25/25-kV delta-star transformer. A filter bank is provided at the output of D-STATCOM to consume harmonics. The prime of this transformer is fed by a voltage-source PWM inverter consisting of two IGBT bridges.

Additionally, a capacitor of 10000 µF is used as a dc voltage source for the inverter. A Distribution Static Synchronous compensator

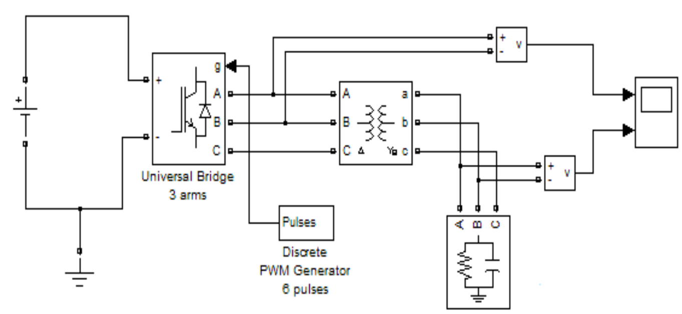

Fig.8 Simulink model of voltage source converter.

(DSTATCOM) is used to regulate voltage on a 25-kV distribution network. The DSTATCOM legalizes bus B3 voltage by absorbing or generating reactive power. This reactive power transmission is done through the leakage reactance of the coupling transformer by generating a secondary voltage in phase with the primary voltage. This voltage is contributed by a voltage-sourced PWM inverter. When the secondary Voltage is lesser than the bus voltage, the DSTATCOM perform like an inductive absorbing reactive power. When the secondary voltage is more than the bus voltage, The D-STATCOM perform like a capacitor producing reactive power.

For the voltage compensation,

$$Q_L = Q_G + Q_{statcom} \quad (6)$$

Where,

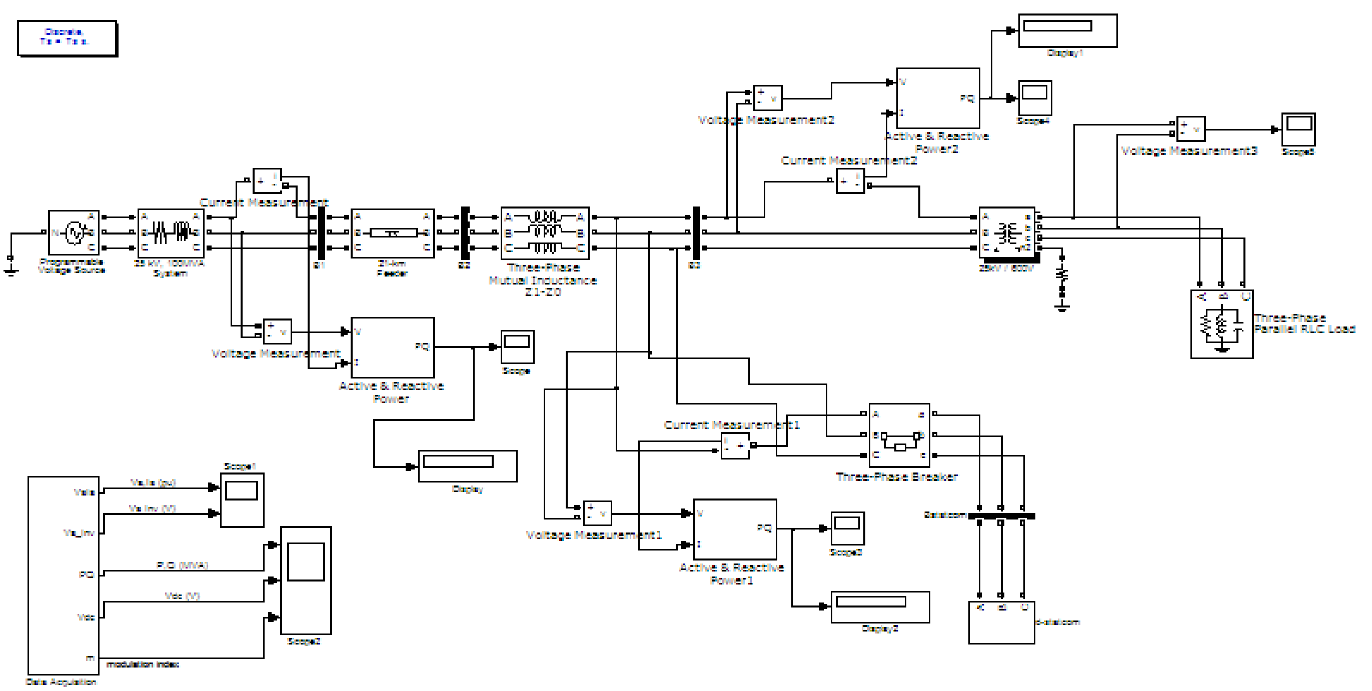

Fig.7 Simulink model of D-STATCOM.

Q_L- reactive power at load side,

Q_G-reactive power at generating side (sending end),

$Q_{statcom}$-reactive power generated by D-STATCOM.

Consequently, by relating results, we can show that the equation (6) can be approximately satisfied which shows that voltage compensation has been done with the aid of DSTATCOM. Operational characteristicsof DSTATCOM in distribution system is given below.

The Simulink model of VSC is shown in fig.8. The Simulink output are depicted below for voltage, power factor and harmonics as well as the current performance. The simulation results are depicted through fig.9 to fig16.

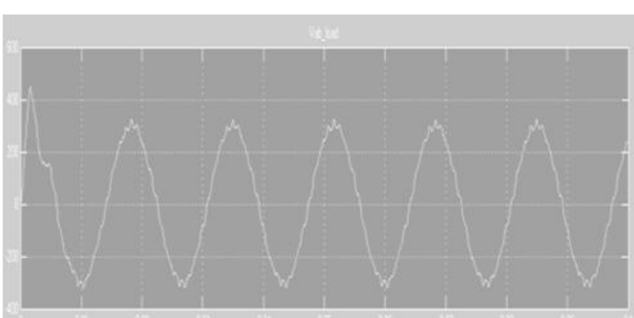

Fig.9 Vab, Inverter load voltage.

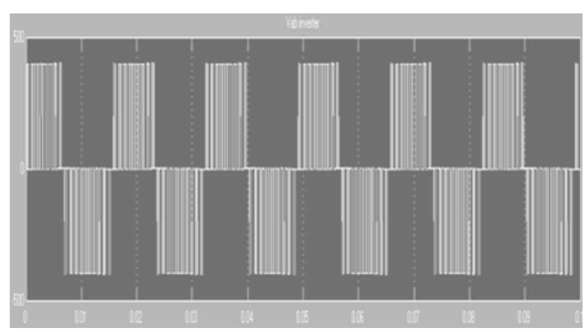

Fig.10 Vab, Inverter voltage.

Fig.11 Phase Voltage and Current.

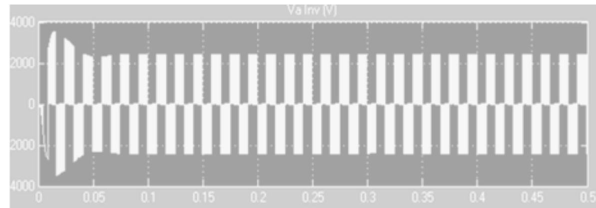

Fig.12 Inverter Waveform.

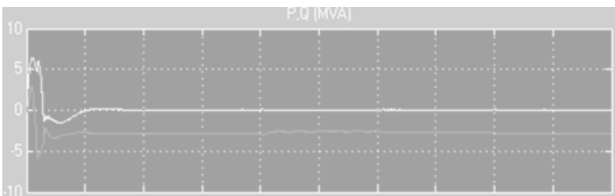

Fig.13 Real and Reactive power.

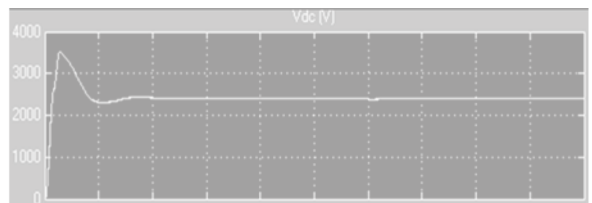

Fig.14 DC Linkage Voltage.

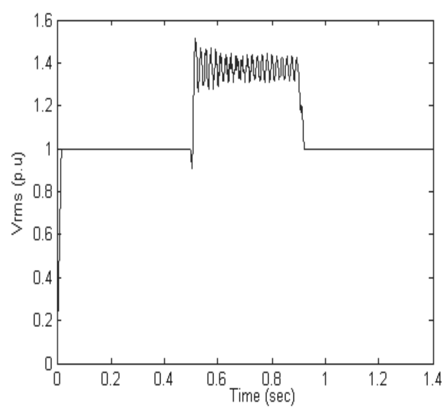

Fig.15Voltage at the load point: Without D-STATCOM.

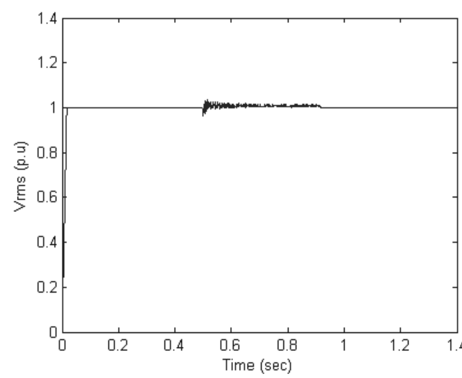

Fig.16 Voltage at the load point: With D-STATCOM

TABLE 2
Voltage Mitigation using D-STATCOM

Without DSTATCOM	With DSTATCOM
V_{B1}=1.064 p. u	V_{B1}=1.02 p. u
V_{B3}=0.936 p. u	V_{B3}=0.96 p. u

6 CONCLUSION

In brief, the simulation and modeling of D-STATCOM in MATLAB SIMULINK toolbox and its detailed simulation analysis directs D-STATCOM as an active decision for overall compensation. The D-STATCOM can be hence used to tackle problems associated to the Power Quality events. Moreover, this has been authorized by extensive computer simulation. The concert of D-STATCOM is found to be satisfactory under nonlinear.In a nutshell, D-STATCOM can regulate reactivepower and also adjust the bus voltage.

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