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Enhancement In Voltage Stability And Reactive Power Compensation Using D-Statcom

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Abstract: This paper deals with performance, analysis and operating principle of a power electronics based device called D-STATCOM, which is used for voltage stability and compensation of reactive power and make the system stable. The D-STATCOM contains an insulated gate bipolar transistor (IGBT) based voltage source converter principle. D-STATCOM is an effective measure to maintain voltage stability and improve power quality of distribution system. The simulation is done in MATLAB for D-STATCOM and voltage source converter (VSC).

Keywords: D-STATCOM, distribution system, line voltage, voltage stability, voltage source converter.

I. INTRODUCTION:

Power quality is set of electrical boundaries that allow the piece of equipment to function in its intended manner without significant loss of performance or life expectancy. The electrical device like electric motor, a transformer, a generator, a computer, a printer, communication equipment, or a house hold appliance. All of these devices and others react adversely to power quality issues, depending on the severity of problems. Reactive power cannot be transmitted across large power angle even with substantial voltage magnitude gradient. Reactive power should be generated close to the point of consumption. We can make several reason to minimize reactive power transfers.

1) It is inefficient during high real power transfer and require substantial voltage magnitude gradient
2) It causes high real and reactive power losses
3) It can lead to damaging temporary overvoltage’s following load rejections
4) It requires larger equipment size for transformer and cables

Due to this here a D-STATCOM as shunt FACT devices is used. A distribution static synchronous compensator (D-STATCOM) is a fast response, solid-stat power controller that provides flexible voltage control at the point connection to the utility distribution feeder for power quality (PQ) improvements. It can regulate the bus voltage by absorbing or generating reactive power from system to the converter and converter to the system at the point of common coupling.

II. STATIC OF ART:

The D-STATCOM is three phase shunt connected power electronics based device. It is connected near the load at the distribution system. It is also a one type of the voltage-source converter, which converts a DC input voltage into AC output voltage in order to compensate the active and reactive power needed by the system.

The DSTATCOM mainly consists of DC voltage source behind self-commutated inverters using IGBT and coupling transformer. A three phase IGBT based current controlled voltage source inverter with a dc bus capacitor is used as a D -STATCOM. D-STATCOM improves supply power factor, provide load balancing & improve load terminal voltage. DSTATCOM limits the short circuit current, improves the system transient stability limit and increases the load ability of the system. D-STATCOM controller is highly effective in improving the power quality at the distribution level by making the voltage stable. A voltage Source converter is connected to bus via three phase transformer. A voltage source converter is a power electronics device, which can generate sinusoidal

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voltage with required magnitude frequency and phase angle. A 10000 μF capacitor is used as a dc voltage source for the inverter. PCC is the point of common coupling at which the generation or absorption of reactive Power takes Place to and from the system and the device. At the distribution voltage level, the switching device is generally the IGBT due to its lower switching losses and reduced size.

Fig. 1 shows a simplified diagram of a STATCOM connected to a typical distribution network represented by an equivalent network.

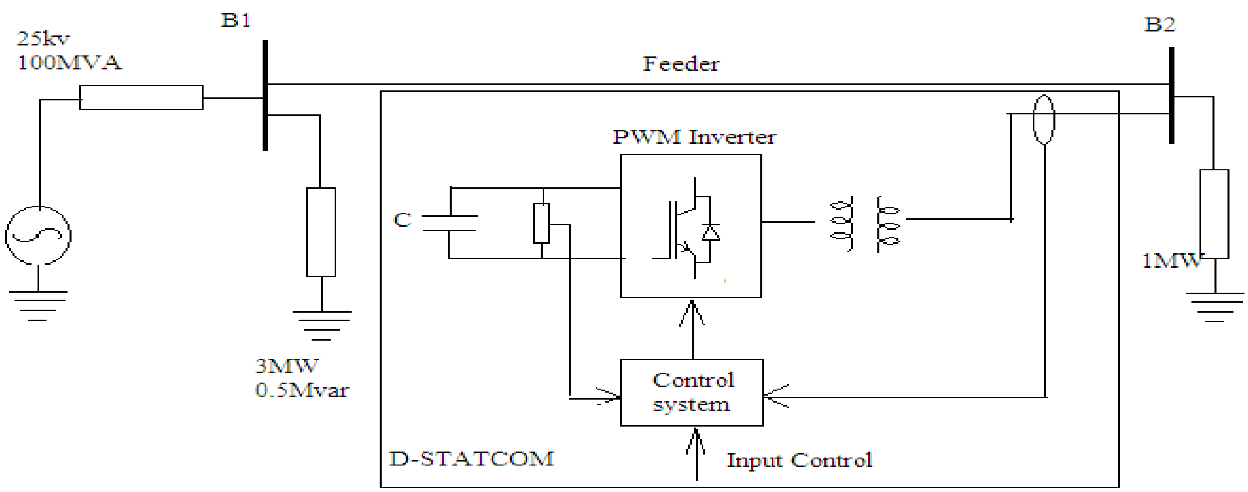

Fig.1 Simplified diagram of a D-STATCOM connected to a distribution network

The control system ensures the regulation of the bus voltage and the dc link voltage. The principle operation of the D-STATCOM depends upon reactive current generation, so (I) varies as,

$$I = \frac{V - V_o}{X} \qquad (1)$$

Where V_o, V, X are the output voltage of the IGBT-based inverter, the system voltage, the total circuit reactance (transformer leakage reactance plus system short circuit reactance) respectively.

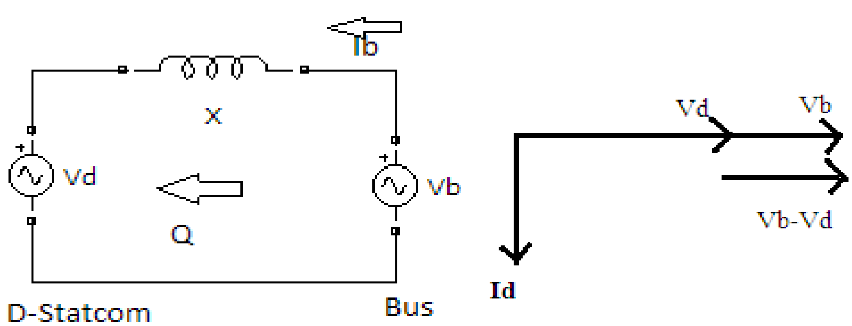

Fig. 2 D-STATCOM operation
(a) Inductive operation, (b) capacitive operation

When the secondary voltage (V_d) is lower than the bus voltage (V_b), the D-STATCOM acts like an inductance absorbing reactive power from the bus. When the secondary voltage (V_d) is higher than the bus voltage (V_b), the DSTATCOM acts like a capacitor generating reactive power to the bus.

III. CONTROL OF D-STATCOM:

Let V_1 be the voltage of power system and V_2 be the voltage produced by the voltage source (VSC). During steady state working condition, the voltage V_2 produced by VSC is in phase with V_1 (i.e.=0) in this case only reactive power is flowing. If the magnitude of the voltage V_2 produced by the VSC is less than the magnitude of V_1, the reactive power is flowing from power system to VSC (the STATCOM is absorbing the reactive power). If V_2 is greater than V_1 the reactive power is flowing from VSC to power system (the STATCOM is producing reactive power) and if the V_2 is equal to V_1 the reactive power exchange is zero. The amount of reactive can be given as,

$$Q = \frac{V_1(V_1 - V_2)}{X} \qquad (1)$$

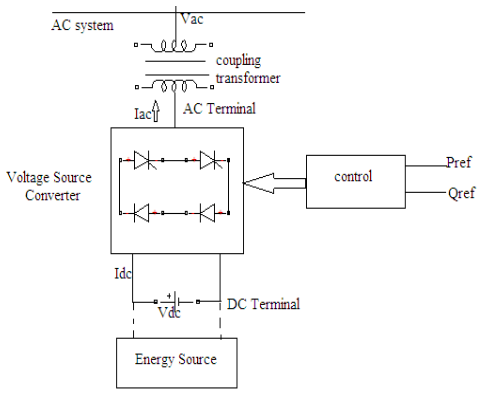

Fig.3 single line diagram of d-statcom

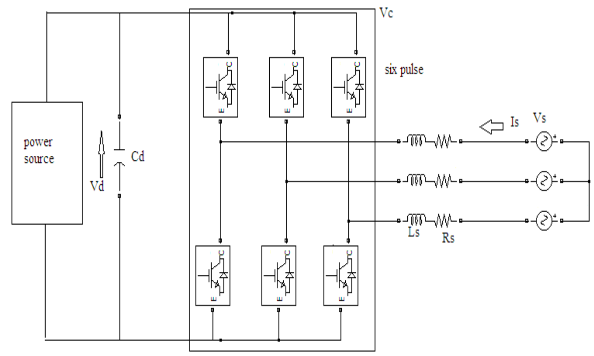

Fig.4 voltage source converter

A simplified block diagram of the internal control for a converter with internal voltage control capability is shown in Fig.5 . The input signals are the bus voltage V, the converter output current io and the reactive current reference, I_Q Ref plus the dc voltage reference, V_{dc} . This dc voltage reference determines the real power. As the block diagram illustrates, the converter output current is decomposed to the external reactive current component These components are compared to the external reactive current reference determined from compensation requirements and the internal real current reference derived from the dc voltage regulation loop. After suitable amplification, the real and reactive current error signals are converted into the magnitude and angle of the wanted converter output voltage from which the appropriate gate drive signals, in proper relationship with the phase-locked loop provided phase reference, are derived.

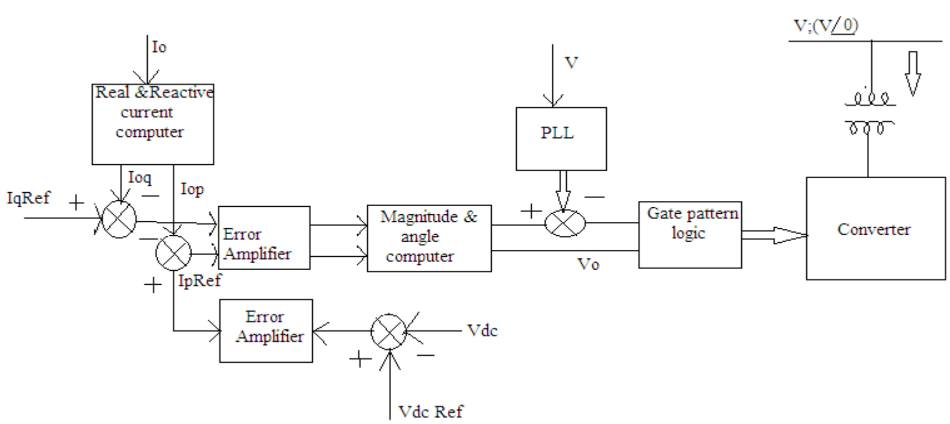

Fig .5.Control of D-STATCOM

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IV. MODELLING OF D-STATCOM:

There are three modeling approach, average modelling, detailed modelling and phase to phase modelling. Generally phase to phase modelling is not used for D-STATCOM. In the average modeling 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 50 microseconds), thus allowing simulations of several seconds. The detailed model includes detailed representation of power electronic IGBT based converters. In order to achieve an acceptable accuracy with the 1680 Hz switching frequency used. the model must be discredited at a relatively small time step (5μs). This model is well suited for observing harmonics and control system dynamic performance over relatively short periods of times (typically hundreds of milliseconds to one second). Here a detailed modeling is used for the D-STATCOM.

V. SIMULATION RESULTS AND DISCUSSION:

Modeling the D-STATCOM includes the power network and its controller in simulink environment require 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 6. The feeding network represented by bus B1 followed by 21- km feeder which is modeled by a pi- equivalent circuit connected to bus B2. The D-STATCOM output is coupled in parallel with the network through a step-up 1.25/25-kV delta-star transformer. At the output of D-STATCOM a filter bank is provided to absorb harmonics. The primary of this transformer is fed by a voltage-source PWM inverter consisting of two IGBT bridges.

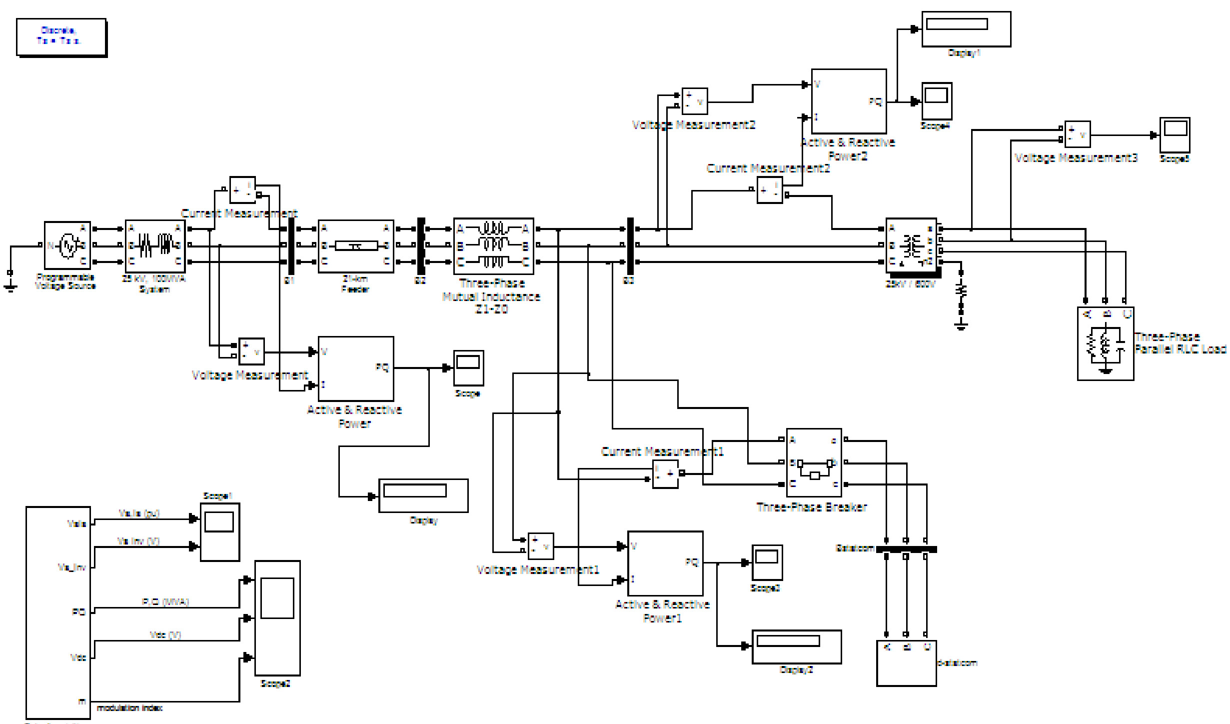

Fig 6. simulink model for D-STATCOM with distribution system.

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10000 µF capacitor is used as a dc voltage source for the inverter. A Distribution Static Synchronous compensator (DSTATCOM) is used to regulate voltage on a 25-kV distribution network. The D-STATCOM regulates bus B3 voltage by absorbing or generating reactive power. This reactive power transfer is done through the leakage reactance of the coupling transformer by generating a secondary voltage in phase with the primary voltage (network side). This voltage is provided by a voltage-sourced PWM inverter. When the secondary Voltage is lower than the bus voltage, the DSTATCOM acts like an inductive absorbing reactive power. When the secondary voltage is higher than the bus voltage, The D-STATCOM acts like a capacitor generating reactive power. For the voltage compensation

QL = QG + Qstatcom (2) Whrer QL is reactive power at load side, QG is reactive power at generating side (sending end), Qstatcom is reactive power generated by D-STATCOM. By comparing results we can show that the equation (2) can be approximately satisfied which shows that voltage compensation has been done with the help of D-STATCOM. Performance characteristics of D-STATCOM in distribution system is given below.

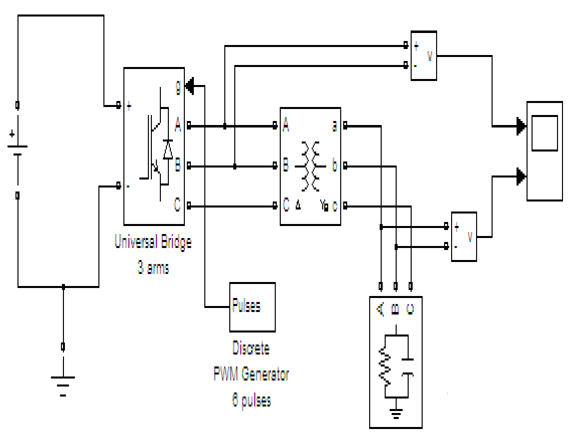

Fig.7 Simulink model of voltage source converter.

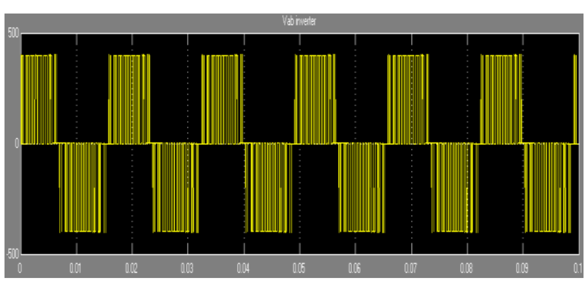

Fig.8 V_{ab}, Inverter voltage

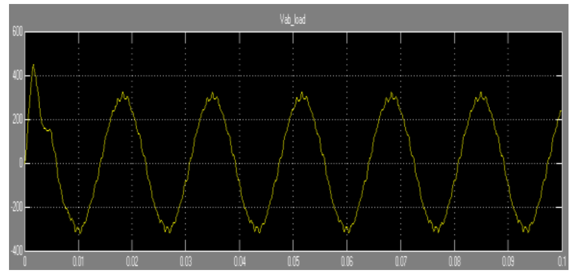

Fig.9 V_{ab} inverter load voltage

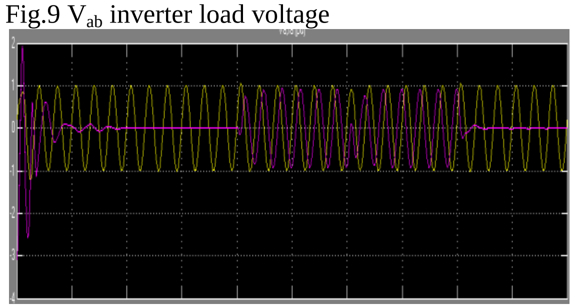

Fig 10 phase voltage and current

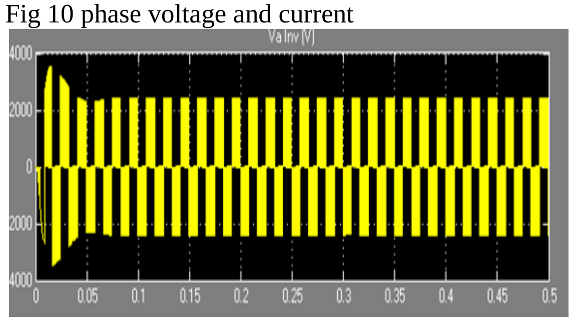

Fig 11inverter waveform

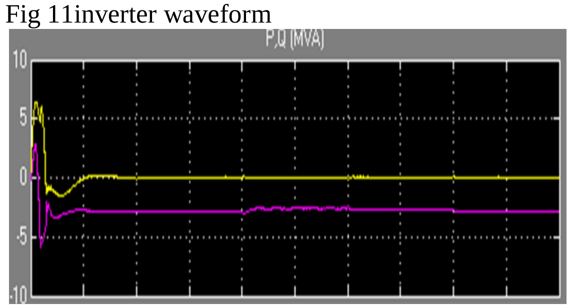

Fig 12 real and reactive power

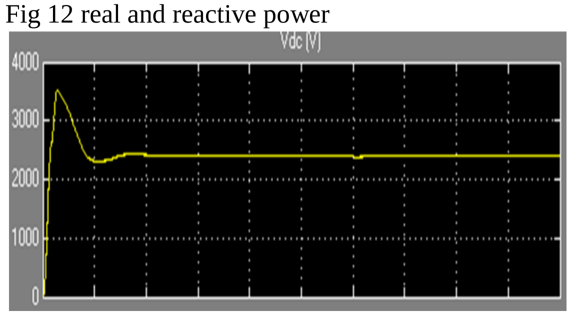

Fig 13 dc link voltage

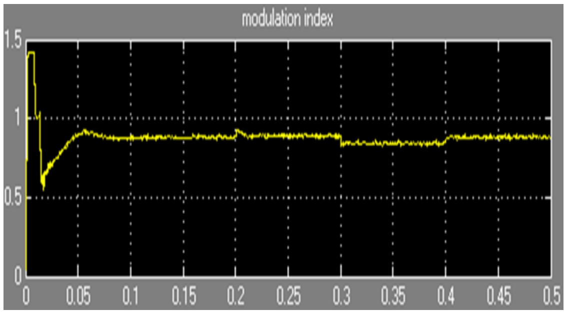

Fig 14 modulation index

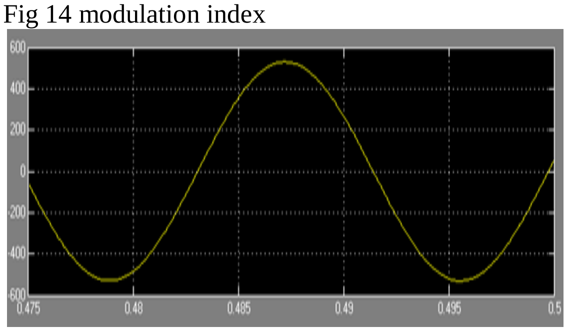
Fig 15line voltage at load side with D-STATCOM

Fig 10 and Fig 11 shows the results for the voltage and current waveform during the change from inductive to capacitive operation. Fig 12 shows the results for the real and reactive power, which shows that D-STATCOM can be work as a capacitive generating reactive power due to an inductive load. Fig 13 shows the DC link voltage and Fig 14 shows the results for the modulation index. Fig 15 shows the line voltage at load side here by varying an inductive load the voltage will remain approximately constant up to certain limit which shows that a D-STATCOM can make voltage stable and it can compensate the voltage.

VI. CONCLUSION

The power quality improvement by using D-STATCOM is presented in this paper.The model of a D-STATCOM was analyzed and developed for use in simulink environment with power system block sets. Here a control system is designed in MATLAB simulink. A D-STATCOM can control reactive power and also regulate bus voltage. It can improve power system performance. Here waveform shows the performance of D-STATCOM in a distribution system. By varying an inductive load at some amount we can observe that D-STATCOM can regulate load side voltage approximately constant which shows the voltage stability of the D-STATCOM.

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