ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2015

Enhancement of Power Quality Using FACTS Devices (D-STATCOM)

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ABSTRACT: Power quality defines the fitness of electric power to consumer devices i.e. Synchronization of the voltage frequency and phase allow electrical system to function without any significant loss in performance. According to Indian standards the rated input current exceeding 16A per phase and low voltage AC distribution system are as follows Nominal voltage up to 240v, Single phase, two or three wire, Nominal voltage up to 600v, three phase, two or four wires and Nominal frequency 50Hz or 60Hz In distribution system the distribution networks and sensitive industrial loads are suffering from different type of outage and interruption which can lead to loss in production and other measurable and non measurable factor. The factors that are affecting power quality are voltage sag, voltage variation, interruption, swells, brownout, distortions, Harmonic, noise, voltage spikes, voltage flicker etc. This causes some deviations in the power when compared with the normal standards.
The above problems may overcome by using compensation devices (custom power devices) either compensate load i.e. correct its power factor, unbalance etc. or improve the quality of the supply voltage. These devices include Distribution static compensator (D-STATCOM), Dynamic voltage restorer (DVR), and unified power quality compensator (UPQC) to obtain Better performance which is simulated by using mat lab.

KEYWORDS: Power quality, source current mitigation, D-STATCOM, Custom power devices, MATLAB/SIMULINK**.**

I. INTRODUCTION

Now a days due to increased power quality problems by using of switch off/on introduction loads, nonlinear load and induction motor etc in domestic and industries, power-quality (PQ) problems, such as harmonics, flicker, and imbalance have become serious concerns. In addition, lightning strikes on transmission lines, switching of capacitor banks, and various network faults can also cause PQ problems, such as transients, voltage sag/swell, and interruption. On the other hand, an increase of sensitive loads involving digital electronics and complex process controllers requires a pure sinusoidal supply voltage for proper load operation. To meet power quality [1] to the standard limits need some sort of compensation. In few years back to mitigate the power quality problems in distribution system by using passive filters like capacitor banks. Now these research going very fast to mitigate the power quality problems [2] with help of power conditioning devices. The power conditioning devices are dynamic voltage restorer (DVR), distribution static compensator (D-STATCOM), and unified power-quality conditioner (UPQC)[3]. A D-STATCOM is a shunt compensation device's that provides an effective solution for reactive power compensation and voltage regulation. It consists of a voltage source converter (VSC), a DC capacitor, a coupling inductor or coupling transformer and a controller. The D-STATCOM, connected to the grid through a coupling inductor at the point of common coupling (PCC), is controlled in such a way that it exchanges only reactive power with the grid. This is achieved by injecting the current in quadrature with the grid voltage. This was done by using hysteresis current control technique [4].

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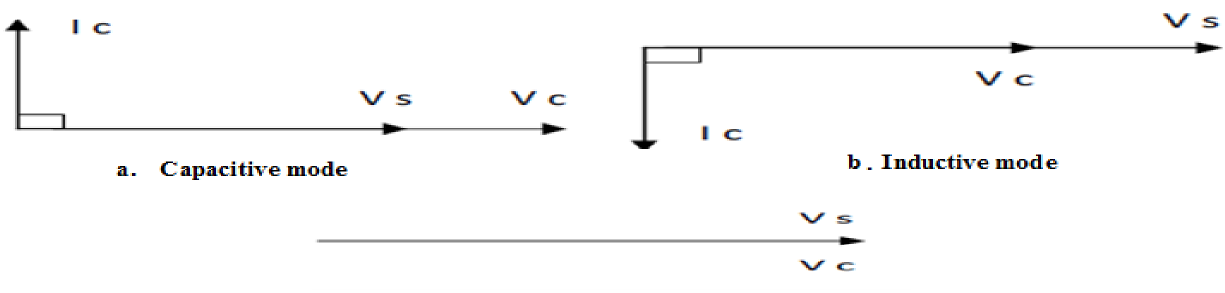
II. RELATED WORK

Power quality problems can be resolved in the power system by using FACT's devices for protecting the sensitive loads in the power system. A **static synchronous compensator** (**STATCOM**)[4], also known as a "static synchronous condenser" ("STATCOM"), is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either **a source** or **sink** of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. In this power quality is enhanced by using D-STATCOM [7] [8] by mitigating the source currents by using a new PWM based control scheme [6] has been implemented to control the electronic valves in the D-STATCOM. A D-STATCOM 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.

The operating principles of DSTATCOM are based on the exact equivalence of the conventional rotating synchronous compensator. The AC terminals of the VSC are not connected to the point of common coupling (PCC) through an inductance, which could be a filter inductance or leakage inductance of the coupling transformer The DC side of the converter is connected to a DC capacitor, which carries the input ripple current of the converter and is the main reactive storage element. This capacitor could be charged by a battery source, or could be pre charged by the converter itself. 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.



a. **Capacitive mode**

b. **Inductive mode**

c. **Floating mode**

If the grid voltage (VS) is greater than the D-STATCOM voltage(VC), the D-STATCOM absorbs reactive power from the grid as shown in Figure (b), and is no exchange of reactive power between the grid and D-STSTCOM, as shown in Figure(c) and the D-STATCOM is said to be in the floating stateThe proposed hysteresis current control technique[4] is instantaneous closed control technique which is used for tracking the command current and maintain the error within the band (δ) and controls the current without crossing upper and lower band. This will be used for maintaining balance between the output current ripple and switching losses and eliminate the harmonics coming from the grid side inverter. The proposed Hysteresis current control method has many advantages such a being robust, having very fast response time and being independent of non linear loads.

III. SOURCES AND EFFECTS OF POWER QUALITY PROBLEMS

The distortion in the quality of supply power can be introduced/ enhanced at various stages; however; some of the primary sources of distortion [2] can be identified as below:
a. Power Electronic Devices
b. IT and Office Equipments
c. Arcing Devices
d. Load Switching

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e. Large Motor Starting
f. Embedded Generation
g. Electromagnetic Radiations and Cables
h. Storm and Environment Related Causes etc.
Some of the common power quality issues and their prominent impact are
Harmonics: Excessive losses and heating in motors, capacitors and transformers connected to the system.
Flicker: Visual irritation, introduction of many harmonic components in the supply power and their associated equipment.
Transients: Tripping, components failures, flashover of instrument insulation hardware booting, software glitches, poor product quality etc.
Voltage sags: Devices /process down time, effect on product quality, failure / malfunction of customer equipments and associated scrap cost, clean up costs, maintenance and repair costs etc.

A. **Control Objectives of D-STATCOM:**

The shunt connected converter has the following control objectives

1. To balance the source currents by injecting negative and zero sequence components required the load.
2. Compensating the harmonics in the load current by injecting the required harmonic current.
3. To control the power factor by injecting the required reactive current (at fundamental frequency).
4. To regulate the DC bus voltage

IV. USE OF CUSTOM POWER DEVICES TO IMPROVE POWER QUALITY:

In order to overcome the problem mentioned above conventional devices such as:

- Line-voltage regulators: Tap changers, buck-boost regulator, CVT (Constant-voltage transformer).
- M-G Sets (Motor-generator Sets)
- Magnetic Synthesizers
- SVC (Static VAR Compensators)
- UPS (Uninterruptible Power Supplies)
- Static Transfer Switch
- Fuel Cell Based Inverter System

Can be used. But present day modem equipments are very sensitive to voltage sags and they need the mitigating device to be very fast in acting, which cannot possible by the above conventional devices. So in order to overcome the above disadvantages, a new category of devices called custom power devices are developed. Custom power devices are the new generation of power electronics-based equipment aimed at enhancing the reliability and quality power flows in low-voltage distribution networks. There are various custom power devices available such a DVR (dynamic voltage restorer),D-STATCOM, UPQC.

In this paper, distribution static compensator (D-STATCOM)is Presented the proposed topology can be used for compensation of current imperfections in both feeders by sharing power compensation capabilities between two adjacent feeders which are not connected.

V. MODELLING OF D-STATCOM AND SIMULATION RESULTS:

The STATCOM consists of a PWM inverter connected to the network through a transformer. The dc link voltage is provided by capacitor C which is charged with power taken from the network. The control system ensures the regulation of the bus voltage and the dc link voltage. The D-STATCOM function is to regulate the bus voltage by absorbing or generating reactive power to the network, like a thyristor static compensator.

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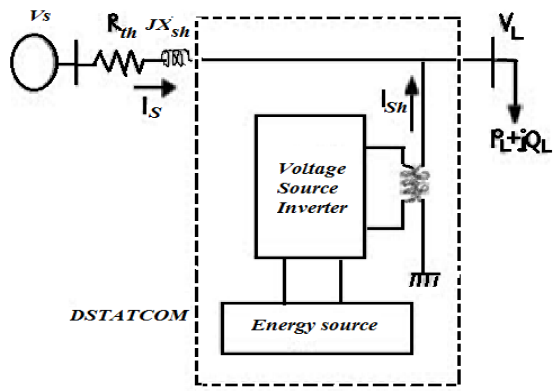

Fig. 1 Block diagram of the proposed model

A D-STATCOM consists of a VSC, a dc energy storage devices, a coupling transformer connected in the shunt with ac system, and associated control circuits. Fig 1Shows the basic configuration of D-STATCOM, Distributed static compensator is presented the proposed topology can be used for compensation of current imperfections.

The SIMULINK model to enhance the performance of distribution system, D-STATCOM was connected to the distribution system shown in fig 2.

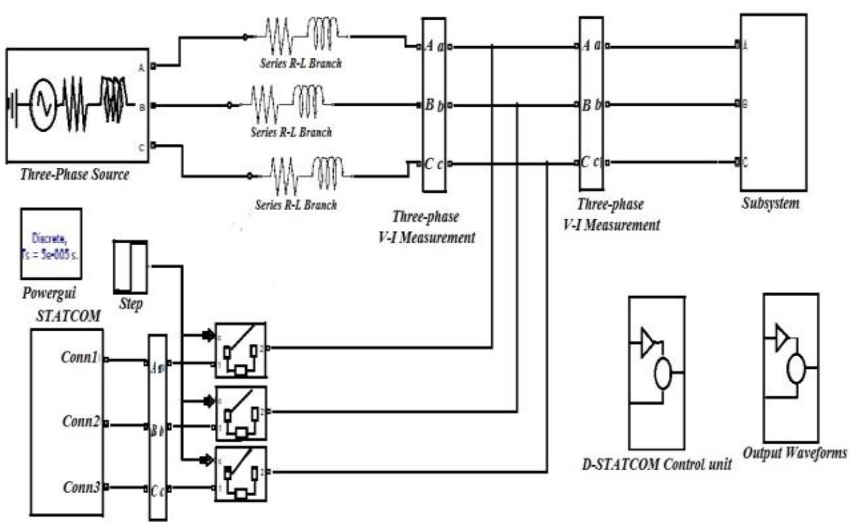

Fig. 2 Simulink model for D-STATCOM

The above figure 2 is a D-STATCOM simulink model is used for compensation of current imperfections at source side. This was done for the non linear R-L load.

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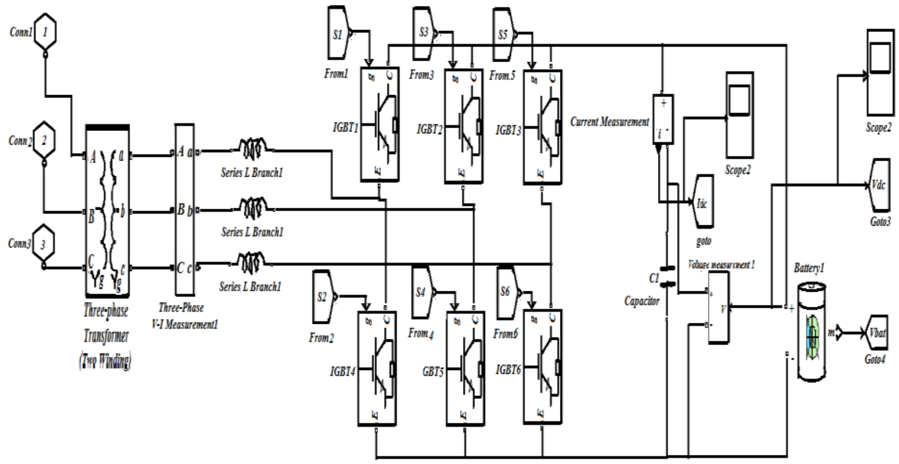

Fig2.1Simulink model of STATCOM subsystem

The above figure 2.1 is a subsystem of STATCOM which is connected in shunt to the transmission line. The IGBT's in the figure receives gate signals from the following control circuit D-STATCOM subsystem.

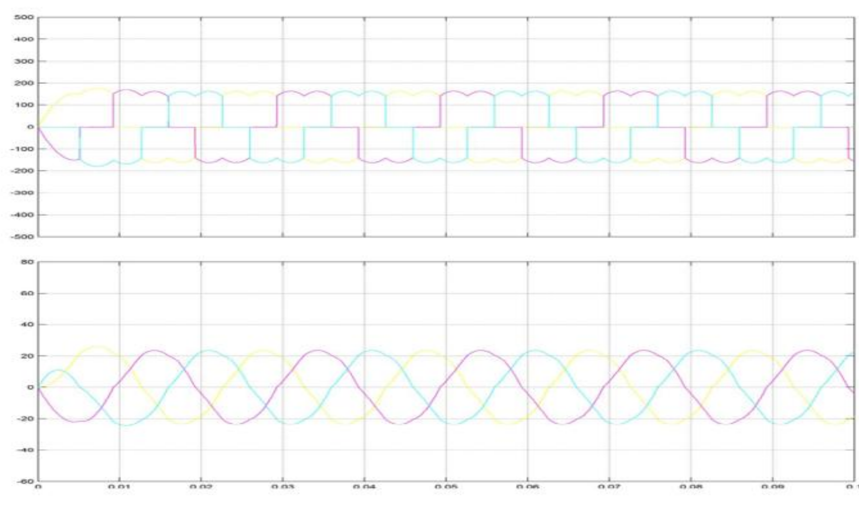

Fig.2.3 Load voltage and current waveforms

From the above figure it shows the load voltage and load sinusoidal current waveforms with D-STATCOM.

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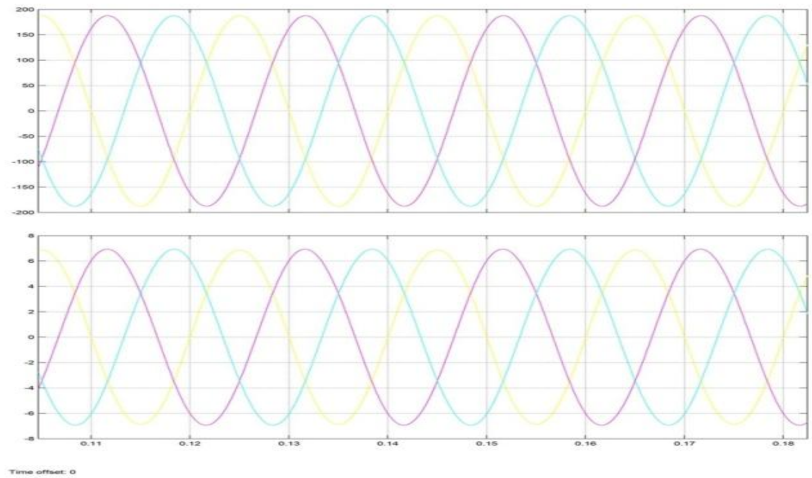

Fig.2.4 Output source voltage and source current waveforms

The figure2.4 shows after mitigation source voltage and source currents waveforms by using D-STATCOM current and voltage becomes sinusoidal by eliminating harmonic contents by using hysteresis current control technique.

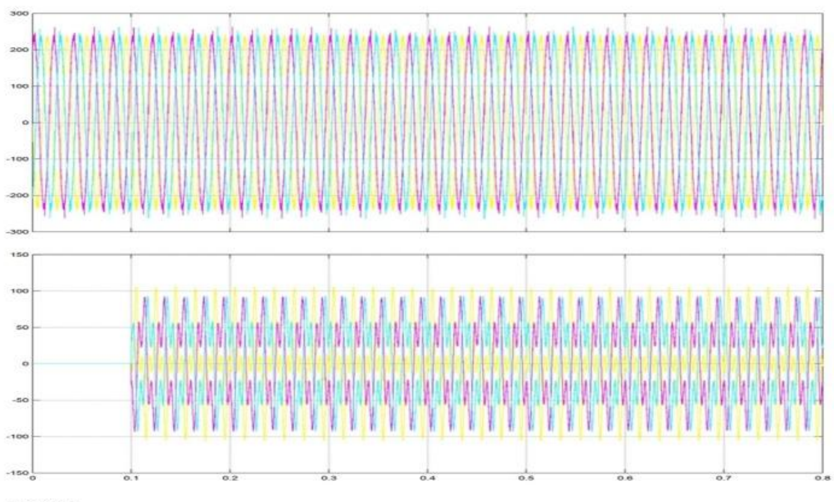

Fig.2.5 STATCOM voltage and current waveforms

These are the STATCOM currents and voltages. Here voltage is sinusoidal and currents are with distortions the distorted currents are injected in the source currents. To make the source current sinusoidal by eliminating harmonics .

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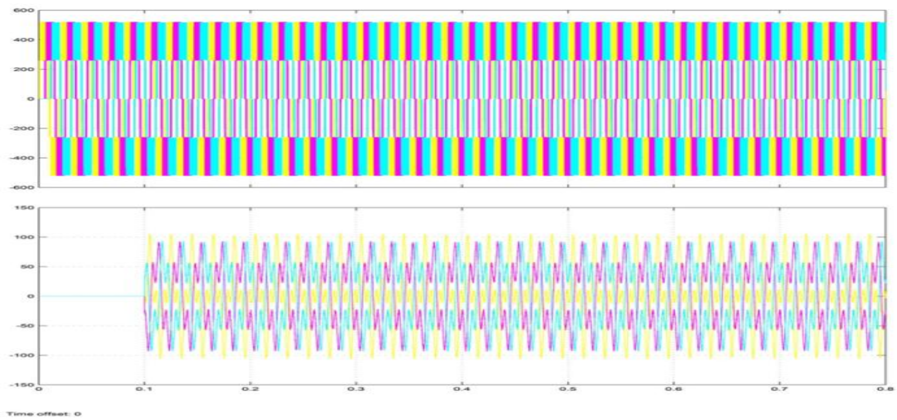

Fig2.6 D-STATCOM voltage and current waveforms

These are the control circuit voltages and a current with ripple contents refers with the actual currents and results the different mode of operations capacitive or inductive mode of operation.

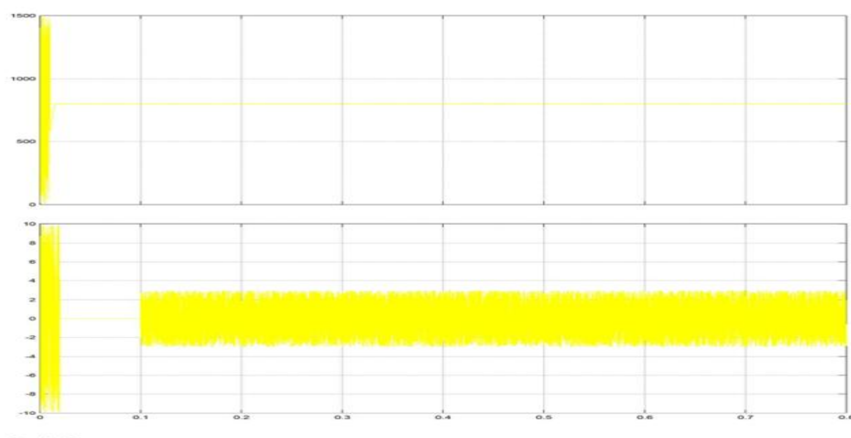

Fig .2.7 Capacitor voltage (V_{dc}) and current (I_{dc}) waveforms

The above waveforms are the capacitor voltage and currents of the inverter block of the STATCOM.

VI. VOLTAGE SOURCE CONVERTERS (VSC):

A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is used to either completely replace the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual.

The converter is normally based on some kind of energy storage, which will supply the converter with a DC

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voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage dip mitigation, but also for other power quality issues, e.g. flicker and harmonics.

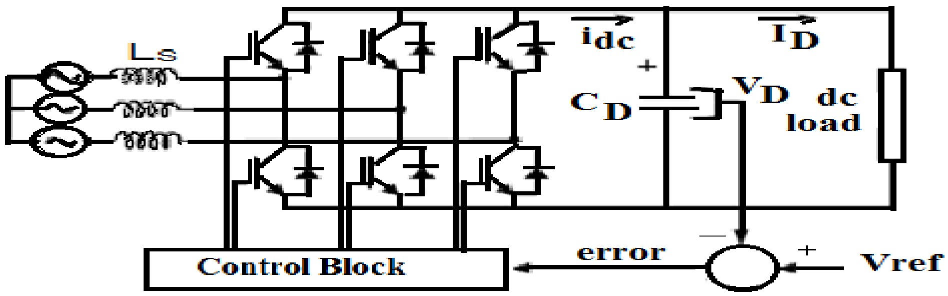

Fig 3 schematic structure of a VSC with closed loop

The voltage source rectifier operates by keeping the dc link voltage at a desired reference value, using a feedback control loop as shown in Fig 4.1. To accomplish this task, the dc link voltage is measured and compared with a reference V_{REF}. The error signal generated from this comparison is used to switch the six valves of the rectifier ON and OFF. In this way, power can come or return to the ac source according to dc link voltage requirements. Voltage V_D is measured at capacitorC_D. When the current I_D is positive (rectifier operation), the capacitor C_D is discharged, and the error signal ask the Control Block for more power from the ac supply. The Control Block takes the power from the supply by generating the appropriate PWM signals for the six valves. In this way, more current flows from the ac to the dc side, and the capacitor voltage is recovered. Inversely, when I_D becomes negative (inverter operation), the capacitor C_D is overcharged, and the error signal asks the control to discharge the capacitor and return power to the ac mains. The PWM control not only can manage the active power, but also reactive power, allowing this type of rectifier to correct power factor. In addition, the ac current waveforms can be maintained as almost sinusoidal, which reduces harmonic contamination to the mains supply. Pulse width-modulation consists of switching the valves ON and OFF, following a pre-established template.

A. BLOCK DIAGRAM OF CONTROLLER:

Proportional-integral controller (PI Controller) is a feedback controller which drives the system to be controlled with a weighted sum of the error signal (difference between the output and desired set point) and the integral of that value. In this case, PI controller will process the error signal to zero. The load r.m.s voltage is brought back to the reference voltage by comparing the reference voltage with the r.m.s voltages that had been measured at the load point. It also used to control the flow of reactive power from the DC capacitor storage circuit. PWM generator is the device that generates the Sinusoidal PWM waveform or signal. To operate PWM generator, the angle is summed with the phase angle of the balance supply voltages equally at 120 degrees. Therefore, it can produce the desired synchronizing signal that required. PWM generator also received the error signal angle from PI controller. The modulated signal is compared against a triangle signal in order to generate the switching signals for VSC valves.

VII. OPERATION OF D-STATCOM:

The three basic operation modes of the D-STATCOM output current I out which varies depending upon V_i. If V_i is equal to V_s, The reactive power is zero and then The D-STATCOM doesn't generate or absorb reactive power. When V_i greater than V_s, The D-STATCOM shows an inductive reactance connected at its terminal. The current I, flows through the transformer reactance from the D-STATCOM to the ac system, and the device generates capacitive reactive power. If V_s is greater than V_i, the D-STATCOM shows the system as a capacitive reactance. Then the current flows from the ac system to the D-STATCOM, resulting in the device absorbing inductive reactive power.

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A. Three-Phase Voltage Source Inverters:

The standard three-phase VSI topology is shown in Fig. 4 and the eight valid switch states. As in single-phase VSIs, the switches of any leg of the inverter (S1 and S4, S3 and S6, or S5 and S2) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity Of the eight valid states, two of them produce zero ac line voltages. In this case, the ac line currents freewheel through either the upper or lower components. The remaining states produce nonzero ac output voltages. In order to generate a given voltage waveform, the inverter moves from one state to another. Thus the resulting ac output line voltages consist of discrete values of voltages that are V_i, 0, and V_i^+ for the topology The selection of the states in order to generate the given waveform is done by the modulating technique that should ensure the use of only the valid states.

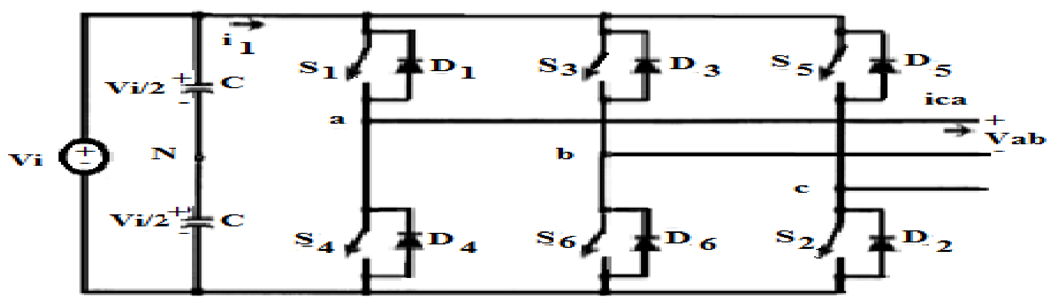

Fig 4 the standard three-phase VSI topology

B. PRINCIPLE OF HYSTERESIS CURRENT CONTROLLER:

Hysteresis current control is an instantaneous closed loop control technique in which the output current I of the inverter is made to track the command current i* and maintain the error within the hysteresis band (δ) .When the error in current (i.e.=i*-i) crosses the error band, inverters are switched to bring the output current within the error band .When the output current exceeds the upper band (i*+ δ/2), it is brought back to within the band of δ by turning ON the lower switch and turning OFF the upper switch of the inverter leg of the phase considered. As a result, the voltage across the load changes from V_{dc} to 0 and the current decreases. Similarly when the output current goes below the lower band (i*- δ/2),the load is connected to V_{dc} by turning OFF the lower switch and turning ON the upper switch. As a result, the output voltage across the load changes from 0to V_{dc} and the output current starts to build up. An optimal value of δ must be chosen to maintain a balance between the output current ripple and the switching losses and thereby eliminate particular harmonics. In this control technique, since each phase is controlled independently, switching frequency goes abnormally high, which increases the switching losses. The instantaneous active power (P*) that is to be supplied by the D-STATCOM can be evaluated from the energy stored in the DC capacitor and is given by:

$$P^* = -\frac{dE}{dt} = \frac{1}{2}C\,\frac{d(V_{DC}^2)}{dt}$$

Where, V_{DC} is capacitor voltage

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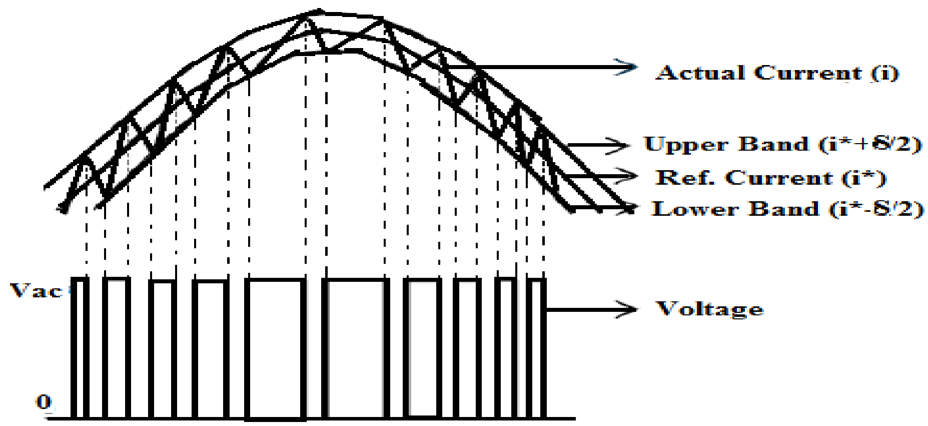

The above figure shows that the voltage level of different band cycles, which shows the difference of actual, reference currents and upper and the lower bands.

VIII. CONCLUSION

In this paper we have modeled and analyzed the power system is being integrated with D-STATCOM at distribution grid at consumer end To compensate the harmonics coming from grid side inverter and different loads in that most of the unbalanced non linear loads injects harmonic currents to source side and effects the source. This can be overcome By using D-STATCOM by connecting as shunt at the distribution side by means of a tie reactance connected to compensate the load current. In this, we have studied and analyzed the operation and performance of D-STATCOM.

This proposed model is implemented by using MATLAB SIMULINK software and the obtained resultant waveforms are evaluated and system stability effectiveness and power system performance have been established.

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