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Application of D-STATCOM to Control Power Flow in Distribution Line

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ABSTRACT: To control the power flow in distribution line D-STATCOM is applied in order to reduce reactive power burden and to mitigate other undesirable effects. The operation of power systems has become complex due to growing consumption and increased number of non-linear loads because of which compensation of multiple power quality issues has become a compulsion. Undesirable effects are caused due to the inductive type load connected at load side hence it is required to control reactive power flow in distribution line. In power system the real power flow is also required to be controlled so as to eliminate the effect of voltage drop. For that purpose, a power electronic based device known by D-STATCOM is useful to control power flow in distribution line because there is no one device is available in India which mitigates the above given effects as well as control the real power. It shows that by using the D-STATCOM based on symmetrical component theory effective reactive power compensation is carried out as well as it also provides real power support to distribution line with battery energy storage.
The substation having distribution voltage 433V of Vega Chemicals is taken for study. The model of distribution system with and without D-STATCOM is modelled in MATLAB/Simulink. From the model it is seen that the power quality as well as power factor improved with the help of D-STATCOM.

KEYWORDS: Distribution Line, Reactive Power, Real Power, D -STATCOM, Instantaneous Symmetrical Component Theory.

I.INTRODUCTION

The electrical load at consumer side consume the large amount of reactive power. The difference between sending end and receiving end voltages is due to increasing load and high R/X of the line which causes voltage drop at load end which may influence on the life of sensitive equipment's at consumer side. Hence it also disturbs the real power flow on transmission line. In order to supply power reliably and continuously, the supply authority should supply power within permissible limits. Voltage, power, frequency should within its tolerated value. Hence it is necessary to control real and reactive power of the transmission line. In past the power flow control can achieve by conventional method which cannot give effective control. Hence In order to control power effectively, FACTS devices are introduced. From FACT family, D-STATCOM is a custom power device installed at distribution line which gives effective control on power, voltage and impedance. A Distribution static compensator (DSTATCOM) is voltage source device based on power electronic and it is one of the most advanced, versatile and suitable devices to be used in the distribution line to provide power flow control. The D-STATCOM operated with different control schemes. Different control strategies are developed with D-STATCOM. Some of these are the instantaneous reactive power theory, Instantaneous symmetrical components, instantaneous compensation, synchronous reference frame theory, computation based on per phase basis and scheme based on neural network.

This paper presents that Power flow is control in the distribution line by using D-STATCOM. The instantaneous symmetrical component theory has been used to generate reference currents and hysteresis current control scheme has been used to generate the gate pulses for switching devices of VSC of D-STATCOM. The D-STATCOM with this control strategy can provide desired power flow control under varying load conditions.

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SourceVoltage&Frequency	433V(LinetoLine),50Hz
TotalResistance	0.1234Ω
TotalReactance	0.045Mh
LoadConnected	DifferentCombinationsof Resistive&Inductive(R-L)Loads

Table 1 : Parameters of Base System

II.BASIC PRINCIPAL OF D-STATCOM

The D-STATCOM is power electronic device which consist of dc voltage source, inverter circuit, coupling transformer and associated control strategy. The voltage source converter (VSC) principle specifies D-STATCOM. The STATCOM is generally used in the transmission system but when it is used in distribution system, it is known by D-STATCOM. Quicker response time and compact structure as compare to the SVC is the advantage of using D-STATCOM in distribution line. D-STATCOM is a shunt connected device (connected in parallel) which includes a voltage source converter (VSC) and dc capacitor, which is capable to generate and/or absorbing reactive power. Voltage source inverter is the main block of D-STATCOM which converts dc voltage into the set of three phase output voltage at same frequency.

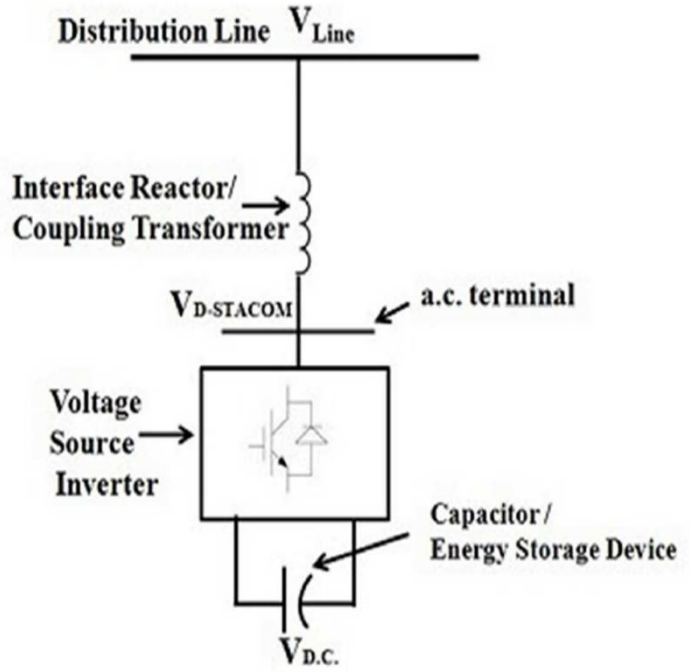

Figure 1: BASIC PRINCIPAL OF D-STATCOM

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IGBT or GTO based dc-to-ac inverters: An output voltage wave produced by these inverters is controlled in magnitude and phase angle which produces either leading or lagging reactive current, depending on the required compensation.

L-C filter: To share the current by connecting multiple inverters in parallel the LC filter is used that reduces harmonics and matches the inverter output impedance. According to the type of system and harmonics at the output of inverter LC filter is chosen.

Control block: To switch Pure Wave DSTATCOM modules as per requirement this control block is used. They can control external devices like mechanically switched capacitor banks also. The design of these control blocks based on the various control theories and algorithms such as instantaneous PQ theory, synchronous frame theory etc. Generation and absorption of reactive power similar to that of synchronous machine is done by D-STATCOM and it can exchange real power too if it is provided with an external device DC source.

Reactive power Exchange: If the system voltage of the voltage source converter is less than the output voltage then the D-STATCOM will act as capacitor and reactive power is generated (i.e. provide lagging current to the system) Real power Exchange: There is a need for the DC capacitor to provide the required real power to the switches as the switching devices are not loss less. To make the capacitor voltage constant in case of direct voltage control hence there is a need for real power exchange with an AC system. In case of fault or in case of very low voltage in distribution system to regulate the voltage the real power exchange with ac system if D-STATCOM id provided with an external DC source. To regulate the system voltage to the 1p.u or to make the capacitor voltage constant when the VSC output voltage leads the system voltage it is necessary that the capacitor or DC source should supply real power to the AC system.

D.C.LinkCapacitor	1000µF
ReferenceD.C.LinkVoltage	800V
CouplingInductance	2.2Mh
BatteryEnergyStorageSystem (forRealPowerCompensationonly)	800V,20Ah

Table 2 : Parameter of D-STATCOM

III.CONTROL STRATEGY

Instantaneous symmetrical component theory is basically the symmetrical component theory (being applied to instantaneous voltages and currents. The unbalanced voltages & currents can be converted into 3-set of balanced voltages & currents i.e. Positive sequence, negative sequence & zero sequence components by using this instantaneous symmetrical component theory. By using this strategy reference current is generated for D-STATCOM. Basic two objectives are making supply current balanced and only positive sequence component of power should be supplied by source.

A. Symmetrical Components:
Positive Sequence Component: Three phase system with same phase sequence known as positive sequence component.

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Negative Sequence Component: Three phase system with opposite phase sequence known as negative sequence component: Three phase with equal in magnitude and with same phase known as zero sequence component.

B. Symmetrical Component Transformation:

Using a as an operator positive sequence component is:

$$V_{b1} = a^2 V_{a1} and V_{c1} = aV_{a1}$$

Negative sequence component is:

$$V_{b2} = aV_{a2} and V_{c1} = a^2 V_{a1}$$

Zero sequence components are:

$$V_{a0} = V_{b0} = V_{c0}$$

Symmetrical component transformation matrix is:

$$C = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \mathrm{a} & a^2 \\ 1 & a^2 & a \end{bmatrix}$$

The original phasors can be obtained by taking inverse transformation

$$V_{abc} = C^{-1} V_{a012}$$

Inverting matrix C

$$\begin{bmatrix} \mathrm{V}_a \\ \mathrm{V}_b \\ \mathrm{V}_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} \mathrm{V}_{a0} \\ \mathrm{V}_{a1} \\ \mathrm{V}_{a2} \end{bmatrix} = C^{-1} \begin{bmatrix} \mathrm{V}_{a0} \\ \mathrm{V}_{a1} \\ \mathrm{V}_{a2} \end{bmatrix}$$

Thus, we can get the equation by symmetrical transformation

$$V_a = V_{a0} + V_{a1} + V_{a2}$$

$$V_b = V_{a0} + a^2 V_{a1} + aV_{a2}$$

$$V_c = V_{a0} + aV_{a1} + a^2 V_{a2}$$

Similarly, unbalance current is as I_{abc} and their symmetrical component as I_{a012}, then we can define

$$I_{a012} = CI_{abc}$$

$$I_{a012} = C^{-1} I_{abc}$$

The unbalanced voltage and current is converted to symmetrical voltage and current, the signal is given to the hysteresis controller to control the output of the D-STATCOM.

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IV.SIMULATION

Sr.No.	Source Voltage	Power Demand		Power Supplied by Source		Power Received by Load		Load Voltage	Current	Source Power Factor
	(V)	P (kW)	Q (kVAR)	P (kW)	Q (kVAR)	P (kW)	Q (kVAR)	(V)	(A)	(PF)
1	433	400	280	350.16	278.67	346.6	275.9	428	558.5	0.527

Table 3 : Effect of Load on Various Parameters of Distribution Line

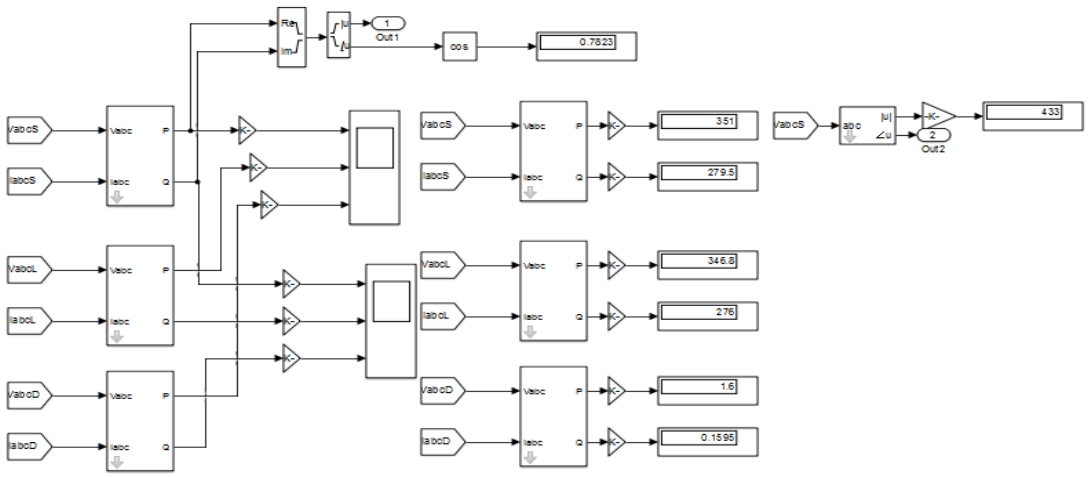

Figure 2 : Simulation model of transmission line with D-STATCOM

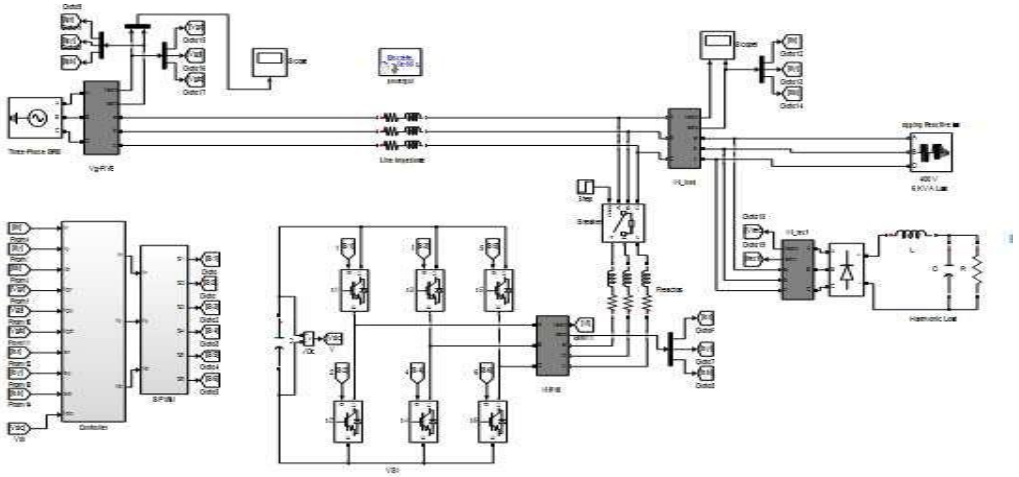

Figure 3 : Simulation model of transmission line with D-STATCOM with non-linear load

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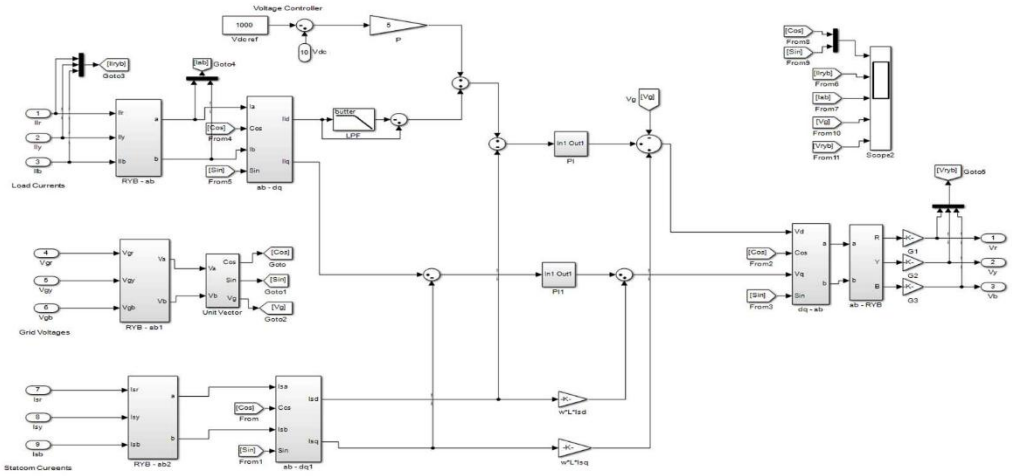

Figure 4 : Control circuit for VSI

V. RESULTS

	Powersuppliedbyload		PowersuppliedbyDSTATCOM		Powerreceivedbyload		Power Factor
	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	
Without D-STATCOM	345	555.3	0	0	213.6	458	0.5277
With D-STATCOM	351	279.5	1.6	0.1595	346	276	0.7823

Table 4 : SIMULATION RESULT

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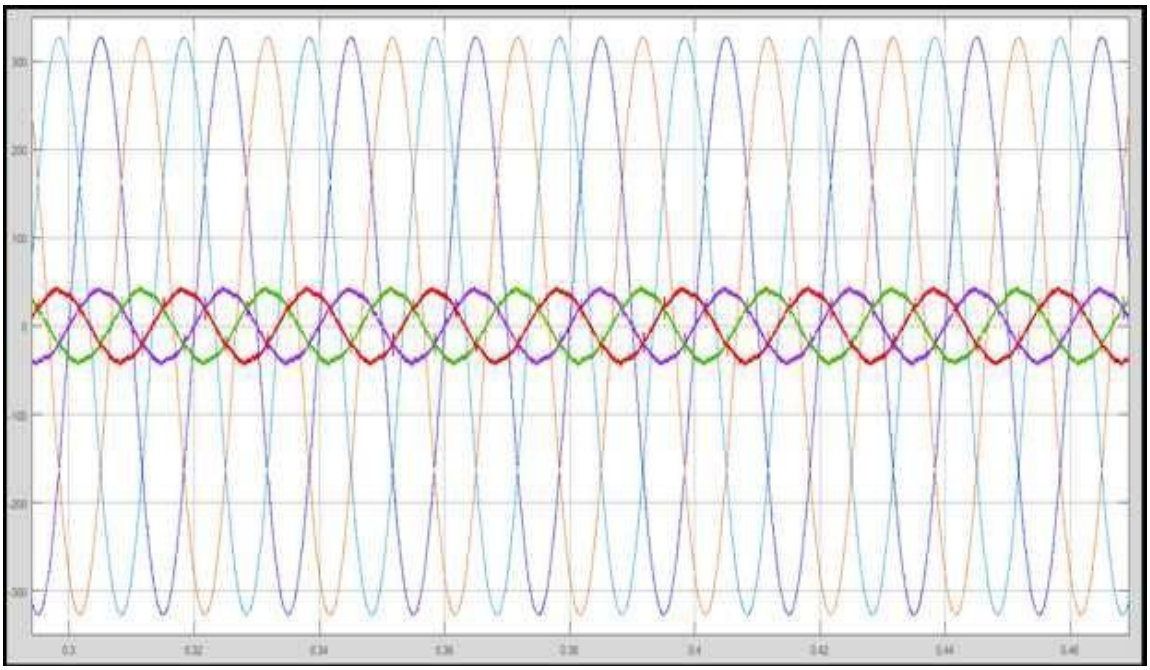

Figure 5 : Waveform of sending end voltage and current

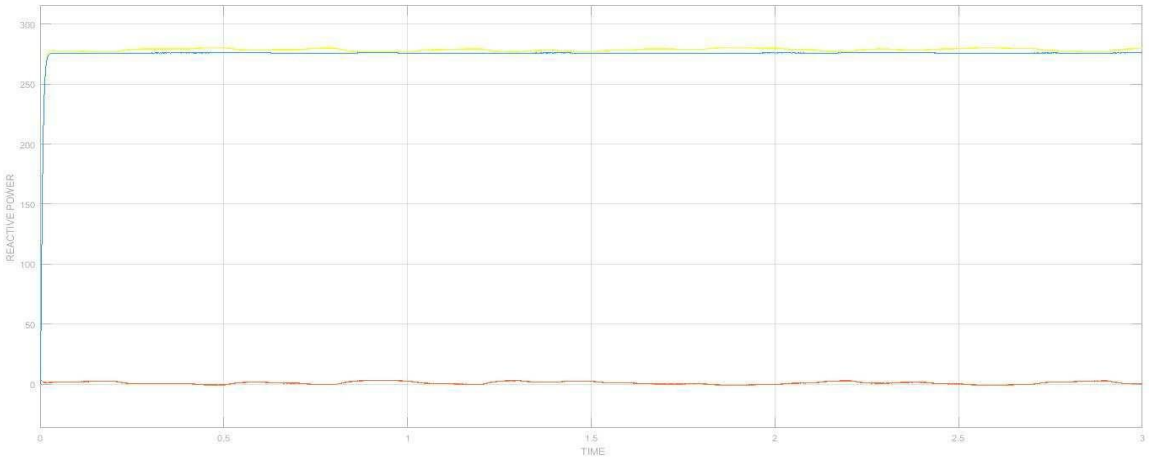

Figure 6 : Waveform of reactive power flow for source, load, D-STATCOM

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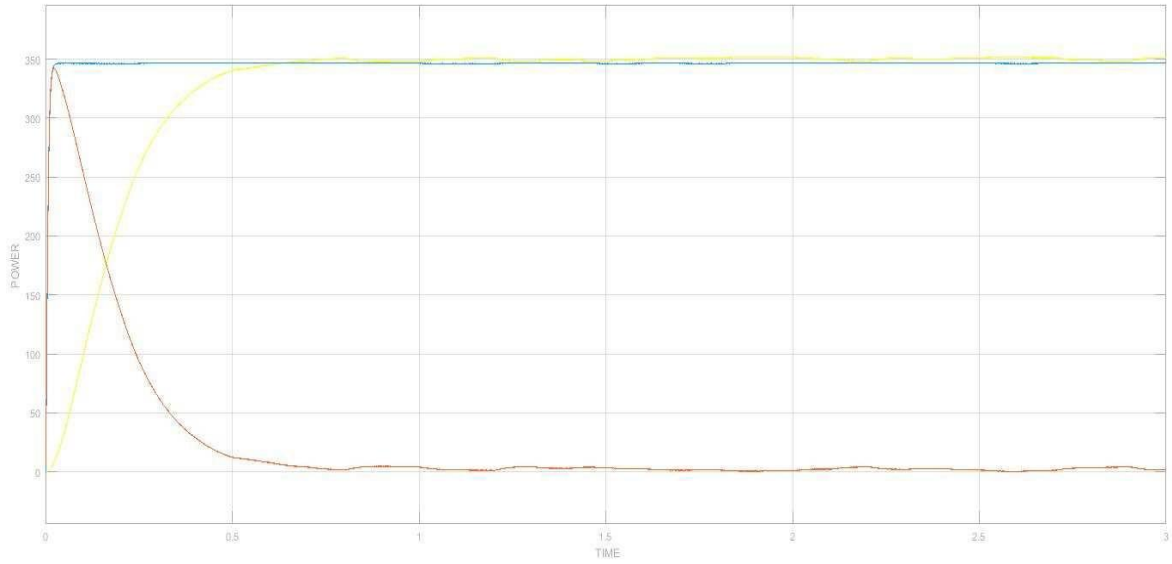

Figure 7 : Waveform of Real Power Flow for Source, Load, D-STATCOM

VI.CONCLUSION

In this work modelling and simulation of D-STATCOM with necessary control strategy is implemented. The simulation results showed clearly the performance of the D-STATCOM in mitigating the voltage sag and swell. The control scheme will measure voltage magnitude, current and power. The source voltage and source current harmonic analysis using FFT are reduced after implementation of D-STATCOM in the system the total harmonic distortions of load side also reduced. D-STATCOM has shown the efficiency and effectiveness on voltage sag compensation hence it makes D-STATCOM to be an interesting power quality improvement device. In this thesis custom power park concept has been studied. Advantages of custom power devices have been pointed out. The original 433V substation was taken for study of with and without D-STATCOM. It is shown that the D-STATCOM gives an acceptable performance in power quality issue mitigation and power flow control. CPP has been modelled by using MATLAB SIMULINK program.

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BIOGRAPHY

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