Power Quality Improvement In RDS Using Instantaneous Power Theory Based DSTATCOM

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Abstract- *this paper stimulates the power quality issue which occur in power system. It has several adverse effects in the electrical power system. This power quality issue is harmful for efficient operation. In the presented study, Distribution Static Compensator is initiated to strengthen power quality in terms of reducing harmonics. The control strategy used is instantaneous power theory. The harmonics annihilation is removed accomplished by providing compensating current accordingly that it produces the sinusoidal wave shape source current no matter what nonlinear load in the distribution line. The harmonic current of source current is curtailed. The switching of nonlinear load yielded in 30 % THD (Total Harmonic Distortion) in source current. The DSTATCOM with instantaneous power theory has improved THD of source current by reducing to 2.5%. The D-STATCOM relies much on the control strategy that is employed to produce the compensating reference current. Besides the numerous control strategy, the instantaneous power theory proves its functionality very well. The amount of compensating current by voltage source inverter to make the source current sinusoidal depends on the switching pattern of IGBT of VSI.*

Keywords- Power quality; D-STATCOM; Instantaneous Power Theory; Clarke Transformation.

I. INTRODUCTION

Now a days most of the load which are connected in load side are inductive in nature. Loads such as UPS, inverters, power electronic devices. So the reactive power burden on the system increases, which will increase losses in the distribution system and capacity of active power flow through the distribution system, gets reduced. Due to advancement of power electronics technology, non linear loads in the system are increasing, such as rectifiers, inverters, uninterruptible power supply (UPS), computers, etc. These Non-linear loads can cause the production of frequency component of the currents in the system which is not fundamental frequency components. So due to such harmonic component of currents the quality of power gets affected. Also, there is the impact of the unbalancing on transformers and generators operation. The solution to power quality improvement is the use of custom power device like DSTATCOM. Control schemes reported in the literature for controlling of the DSTATCOM is instantaneous reactive power theory, current compensation using DC bus regulation, instantaneous reactive power (IRP) theory, a scheme based on the neural network technique. In this paper MATALAB based simulation of the DSTATCOM is carried out using instantaneous reactive power (IRP) theory for compensation of the reactive power, power factor, unbalance, reducing total harmonic distortion (T.H.D) of the system.

II. SYSTEM CONFIGURATION

A power system feeder is connected to unbalanced and nonlinear load is shown in the below Fig. 1. Working performance of the DSTATCOM using instantaneous reactive power theory (IRP) is analysed by the modelling system shown in Fig.1 in MATLAB Simulink tool.

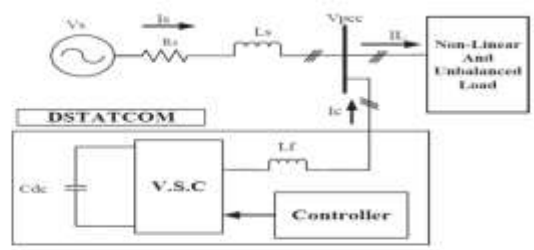

Fig.1. Configuration of DSTATCOM

In the system diagram shown in above Fig. 1, Rs and Ls represents source resistance and source inductance. The nonlinear load is realized by connecting the three phase diode rectifier to a Resistive-Inductive load (R-L). Unbalanced load is realized by connecting different values of impedances in three phases. Three phase voltage source converter (VSC) act as the DSTATCOM which consist of the six insulated gate bipolar transistor (IGBT) and anti-parallel diodes are connected to each IGBT. DC side of the Voltage source converter (VSC) consists of a capacitor which is used to maintain constant voltage for the switching operation of the IGBT switches. The DC capacitor is not used for any reactive power compensation. Interfacing inductor, *Lf* is connected on the AC side of the voltage source converter for compensating high frequency components of the compensating currents. Storage capacitor Cdc does not exchange any active power between DSTATCOM and the load.

III. CONTROL ALGORITHM

DSTATCOM provide the reactive power demand by load. Therefore, with the help of DSTATCOM unity power factor is maintain constant and reactive power burden is also reduce to some extent . Due to the compensation of the reactive power by DSTATCOM source has to supply only real power. Fig. 2. MATLAB Model of IRP Theory. Theory of extracting reference currents using IRP was introduced by Akagi . In this theory the three phase load currents are transformed into two phase coordinate. The co-ordinates are orthogonal to each other. According to the IRP theory the instantaneous real and reactive powers are calculated by using these co-ordinates. Load voltages where load is being connected and load currents are used to generate the reference source currents. The reference currents obtained are then fed to the hysteresis based PWM controller to obtain the pulses to be fed to the IGBT switches of the DSTATCOM.Fig.3 is the MATLAB model of the Instantaneous Reactive Power Theory (for controlling DSTATCOM.

Transformation of the 3 phase current and voltages into the two phase $\alpha - \beta$ transformation as given below

$$\begin{bmatrix} v_\alpha \\ v_B \end{bmatrix} = \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_{La} \\ v_{L_b} \\ v_{Lc} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_\alpha \\ i_B \end{bmatrix} = \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{La} \\ i_{L_b} \\ i_{Lc} \end{bmatrix} \quad (2)$$

The 3 phase instantaneous power in a-b-c axis can be written as

$$_P = v_{La} i_{La} + v_{L_b} i_{L_b} + v_{Lc}\, i_{Lc}$$

Similarly instantaneous active power in $\alpha - \beta$ frame can be Written as

$$p = v_\alpha i_\alpha + v_B i_B \quad (4)$$

Instantaneous reactive power can be written as,

$$q = -v_B i_\alpha + v_\alpha\, i_B \quad (5)$$

Above equations (4) and equation (5) can be written in matrix form as

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_B \\ -v_B & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_B \end{bmatrix} \quad (6)$$

Reference source currents are to be calculated to compensate only instantaneous reactive power theory and some part of active power drawn from source to compensate for switching losses of IGBT devices during operation of VSC. DC link voltage controller play a vital role for maintaining constant dc link voltage. Voltage of the dc link capacitor is to be compared with reference DC voltage and error is processed using PI controller. Output of PI controller is reference d axis component of current so it is added with active power component of source current from source instantaneous active and reactive power . So reference source current in $\alpha - \beta$ can be written as

$$\begin{bmatrix} i^*_\alpha \\ i^*_\beta \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_B \\ v_B & v_\alpha \end{bmatrix} \quad (7)$$

where,

$$\Delta = v^2_\alpha + v^2_\beta \quad (8)$$

Finally reference source current in a-b-c frame can be estimated with the help of Reverse Clark's transformation given as below,

$$\begin{bmatrix} i^*_{sa} \\ i^*_{sb} \\ i^*_{sc} \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i^*_0 \\ i^*_\alpha \\ i^*_\beta \end{bmatrix}$$

Zero sequence component of current is absent in case of three phase three wire system [3] so we can write i^*_0 as 0 in above equation (9)

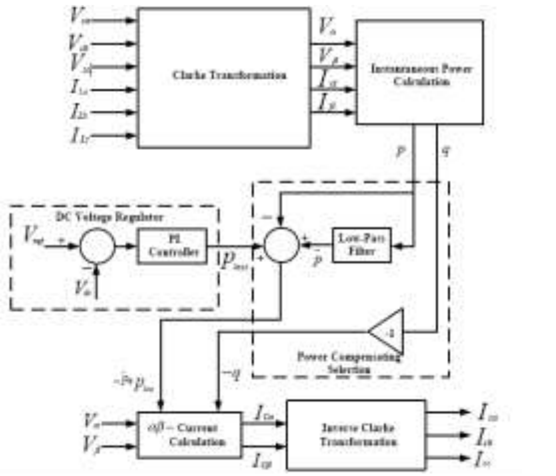

Fig. 2. Control strategy of implemented V D-STATCOM

IV. SIMULATION AND RESULT DISCUSSION

The several parametric quantities involved in the presented simulated study are tabulated in Table I. Parametric quantities of considered evaluated System

Parameters	Numerical Value
Three-Phase Source Voltage	50V
Frequency	50 Hz
Line Parameter	X/R=10
Non-linear load	Three-phase Diode Rectifier with a resistive load of 10 ohms.
Coupling inductor (LC)	1.2 mH
Cut-off frequency of Butterworth LPF of 5th order	2*pi*50 rad/sec
Capacitor for D-STATCOM	$20\mu F$

Using MATLAB tool, the power system network shown in Fig. 3 is simulated to show the consequence of nonlinear load on source current.

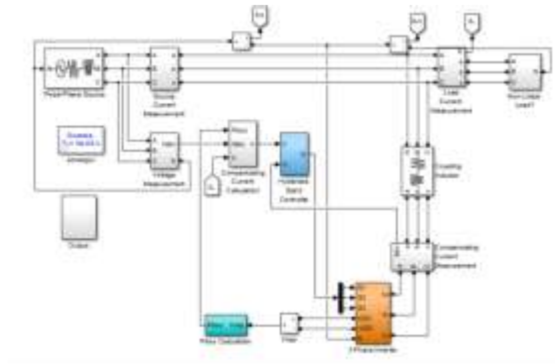

Fig. 3 MATLAB-SIMULINK model of test system

The simulation is carried out with DSTATCOM. The waveform of source current and its harmonic spectrum content analysis are depicted in Fig.4 and for one phase when D-STATCOM is not incorporated.

Zero sequence power, real power and reactive power waveform is depicted in fig.4

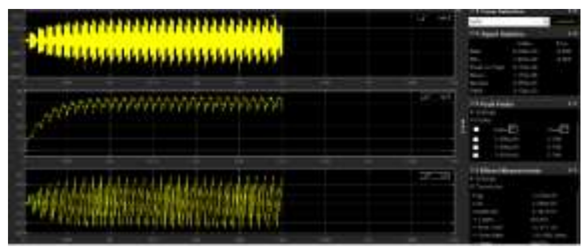

Fig.4 p0, p ,q

The harmonic content load current, compensating Current compensated source current waveform and source voltage of D-STATCOM is depicted in Fig. 5

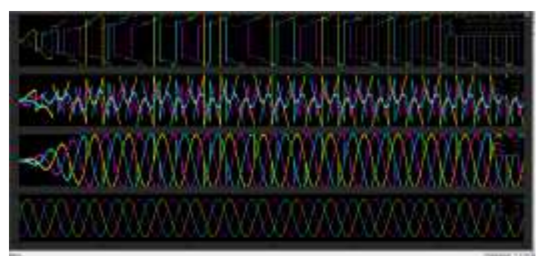

Fig. 5 Il, Ic, Is, Vs

The Variation of the voltage across DC capacitor incorporated in the DSTATCOM which used in control strategy is shown in Fig. 6

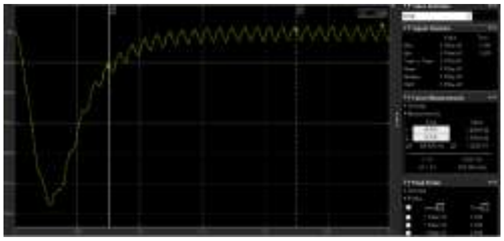

Fig. 6 voltage variation across DC capacitor

From Fig. 5, it is identified that when DSTATCOM is not incorporated then the source current is non-sinusoidal one which is undesirable in the power system scenario for its healthy operation. The total harmonic distortion (THD) of same source current is found to be 30% by fast Fourier transform (FFT) analysis. This numerical value of THD indicated that the source current possesses heavy harmonic content. As a result of which, adverse effects are observed in the system. The simulated result of a power system incorporating D-STATCOM containing non-linear load and its harmonic spectrum content analysis are depicted in Fig. 7 respectively.

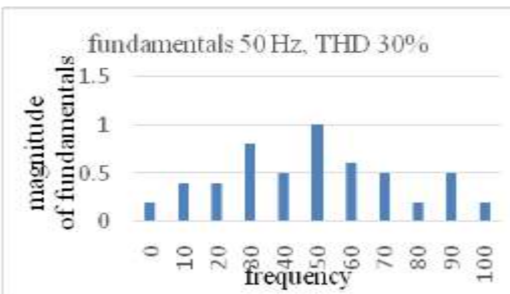

Fig.7 Harmonic Spectrum of Source current without incorporating DSTATCOM

From Fig. 5, it is identified that when DSTATCOM is incorporated then the shape of the waveform is improved and close to a sine wave. The THD of D-STATCOM incorporated source current is found to be 2.5% by Fast Fourier Transform (FFT) analysis which is acceptable and close to desirable THD. This numerical value of D-STATCOM incorporated THD indicated that the source current possesses lesser harmonic content which is desirable.

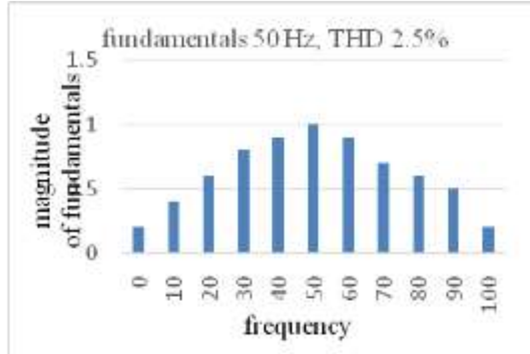

Fig.8 Harmonic Spectrum of Source current with incorporating DSTATCOM

V. CONCLUSION

Custom power devices can be used for power quality improvement in the distribution system IRP theory for controlling the DSTATCOM reduce the unbalance in the system, harmonic components are also reduced. Power factor of the system is improved and maintained equal to unity. The response of the DSTATCOM is fast for compensation of the reactive power as compared to conventional reactive power control devices.

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