Performance control of DSTATCOM by P-Q theory with Power factor correction of Polluted Grid

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ABSTRACT

This paper investigated and simulates the modeling and design of Instantaneous Reactive Power Theory for control of DSTATCOM P-Q theory with Polluted Grid Power Factor Correction. This paper presents results using a sinusoidal grid as well as non-sinusoidal voltages. The compensator can improve power factor, manage voltage, lower supply current harmonics, and support load balancing. In a three-phase, three-wire system with a sinusoidal grid and a non-sinusoidal voltage grid, several features of control are analyzed.

Keyword: - *DSTATCOM, power quality, power system grid, voltage regulation.*

I. INTRODUCTION

Since the invention of power electronics in the late 1800s, its use of non-linear loads has accelerated. Reactive power imbalanced is causing more and more problems, such as voltage variation during load changes and power transmission limitations. Due to the presence of reactance, most AC loads consume reactive power. Voltage quality suffers as a result of excessive reactive power usage. These issues have now had a far greater influence on the reliability and security of the power distribution system [1]. Maintaining electric power quality ("PQ") in an electrical distribution system is a major challenge right nowadays.

The phrase "power quality" requires monitoring of good power quality during the generation; transmission, distribution, and use of electric power [2].Harmonics are a major contributor to poor power quality and can cause a variety of problems in the distribution system, including electromagnetic interference, cable overheating, and low power factor. Because it is connected to a growing number of loads, the electrical power system is becoming increasingly sophisticated. As a result, when compared to the supply system, it will use more power. Consumers utilize controllers to manage their reactive power. These controllers are made up of a number of solid-state switches. When inductive loads, which generate greater reactive power, are connected to the system, these sorts of switches, which are included in practically all electrical equipment, will cause power quality problems in the system. Due to the power factor, a substantial amount of lagging current is drawn from the supply in this instance. This can be resolved by producing power just

when and where it is needed, reducing line losses. Filters can be used to remedy these power quality issues. Active, passive, and hybrid filters are available [2]. In comparison to the other two types of filters, active filters are more commonly utilized because of their quick response, small size, and light weight. are the most effective in resolving power quality issues. There are several compensating devices for reactive power compensation, such as UPFC, DVR, SSSC, STATCOM, DSTATCOM, SSTS, and so on [3][4]. DSTATCOM is a well-known facts device that has fast and reliable control over transmission characteristics such as voltage, impedance, and phase angle between the transmitting and receiving end voltages. When changing system parameters, DSTATCOM is a power electronic device that maintains dynamic stability and controls power flow. The control mechanism used to extract reference current components has an impact on DSTATCOM's performance. The Instantaneous Reactive Power (IRP) theory and the Synchronous Reference Frame (SRF) theory are compared to a new adaline-based control algorithm presented by B. Singh and J. Solanki in [4] for compensating reactive power and unbalancing in loading.

In 2009, L.S. Czarnecki proposed employing Instantaneous Reactive Power (IRP) p-q theory to create reference current for Shunt Switching Compensator (SSCs) regulation in [5]. J. Bangarraju, V. Rajagopal, and A. Jayalaxmi, on the other hand, created and used the Instantaneous Reactive Power (IRP) theory control method for three-leg VSC used it for Dynamic Voltage Regulator (DVR) in [6].

This new research shows how the performance of DSTATCOM controlled by instantaneous reactive power theory (IRPT) or P-Q theory is influenced by different control algorithms utilised to generate reference quantities and gate pulses to the VSC. To extract reference current, DSTATCOM will perform according to gate pulses given by a control algorithm. When the distribution system grid voltages are sinusoidal and polluted and feed non-linear loads, these currents have been used to accomplish load management. In the distribution system, the performance of DSTATCOM was tested in Power Factor Correction (PFC) mode for both ideal (sinusoidal) and practical (non-sinusoidal) voltages.

II. DESIGNING OF DSTATCOM

Figure 1 show a schematic representation of a DSTACOM that is shunt linked to the line via a coupling transformer [7]. DSTATCOM's DC side is connected to an energy storage device, such as a capacitor. There's still no batteries connection in a DSTATCOM, thus the energy stored in a capacitor with the assistance of VSC. DSTATCOM is a controller for Alternating current devices.

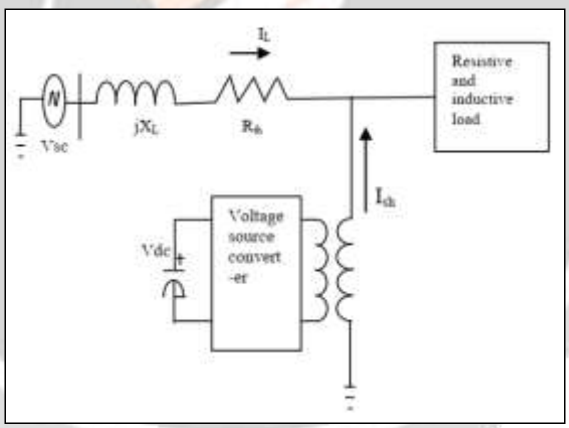

Fig-1 Block model of DSTATCOM

The load current and load voltage are inputs for the inverter in this DSTATCOM. To generate a reference quantity, DSTATCOM can be controlled using a variety of control mechanisms. Use different PWM ways to get the pulses for the converter. The converter will switch to operation based on those pulses. When it comes to DSTACOM in order to provide active and reactive power to the line The VSC changes DC energy stored in the capacitor it in to a three-phase Ac output voltage. The basic block diagram of Dstatcom connected to grid is shown in Fig 2. In MATLAB/SIMULINK R2015a, the effectiveness of DSTATCOM was assessed in Power Factor Correction (PFC) in this system.

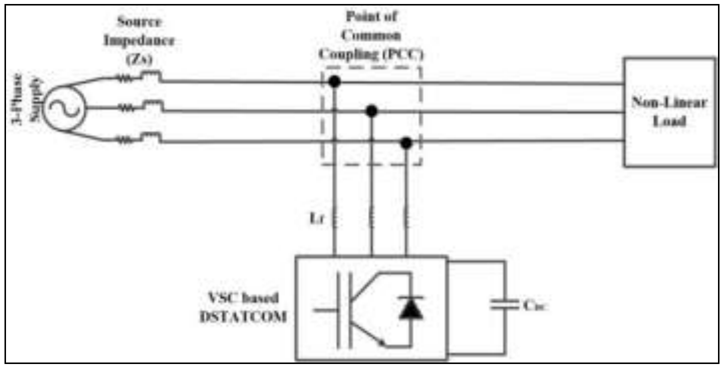

Fig-2 Block diagram of DSTATCOM connected to grid

III. CONTROL SCHEME OF DSTATCOM

This paper deals with the instantaneous reactive power theory (IRPT) or P-Q theory for controlling the DSTATCOM This hypothesis was first proposed in 1983. This method necessitates the use of both real and reactive power components. This control technique is used to estimate reference signals, and the reference signals are utilized to generate pulses, which are then used for switching. 3-phase signals are transformed to 2-phase components using the Clarke transform, and the 2-phase current and voltage components are utilized to estimate P&Q components. Use the inverse Clarke transform to acquire the reference signal.[8],[9].

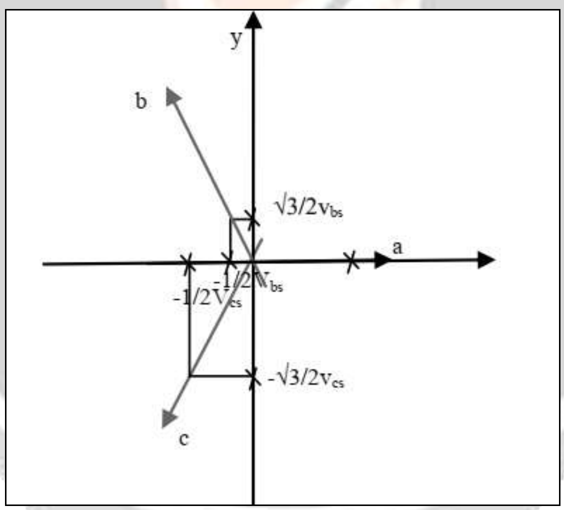

Fig-3 Clarke transformation

Three phase load currents and three phase voltages at the point of common coupling (PCC) will be Clarke converted using this technique. Real and reactive powers are calculated using these two quantities. Clarke transformation signals can be filtered fast and reference current values computed as a result of this. Using the inverse Clarke transformation, these reference signals are converted back into three phase values. When these reference values are compared to the DSTATCOM injected currents, the error is sent on to the hysteresis band PWM current controller, which generates suitable pulses based on load fluctuation.

$$\begin{bmatrix} i_x \\ i_y \end{bmatrix} = (A_c)^{-1} * \begin{bmatrix} i_{al} \\ i_{bl} \\ i_{cl} \end{bmatrix} \quad \ldots\ldots (1)$$

i_x, i_y are Clarke transform components.
I_{al}, i_{bl}, i_{cl} are three phase load currents.
A_c is the Clarke transformation matrix

Using the below equation, these 2-D currents were transformed to 3-D components for the reference quantity.

$$A_c = \sqrt{\frac{2}{3}} * \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \quad \ldots\ldots (2)$$

$$\begin{bmatrix} i_{al} \\ i_{bl} \\ i_{cl} \end{bmatrix} = (A_c)^{-1} * \begin{bmatrix} i_x \\ i_y \\ i_0 \end{bmatrix} \quad \ldots\ldots (3)$$

$$(A_c)^{-1} = \sqrt{\frac{2}{3}} * \begin{bmatrix} 1 & 0 & 1/\sqrt{2} \\ -1/2 & \sqrt{3}/2 & 1/\sqrt{2} \\ -1/2 & -\sqrt{3}/2 & 1/\sqrt{2} \end{bmatrix} \quad \ldots (4)$$

Where Ac^{-1} is inverse Clarke transformation matrix.

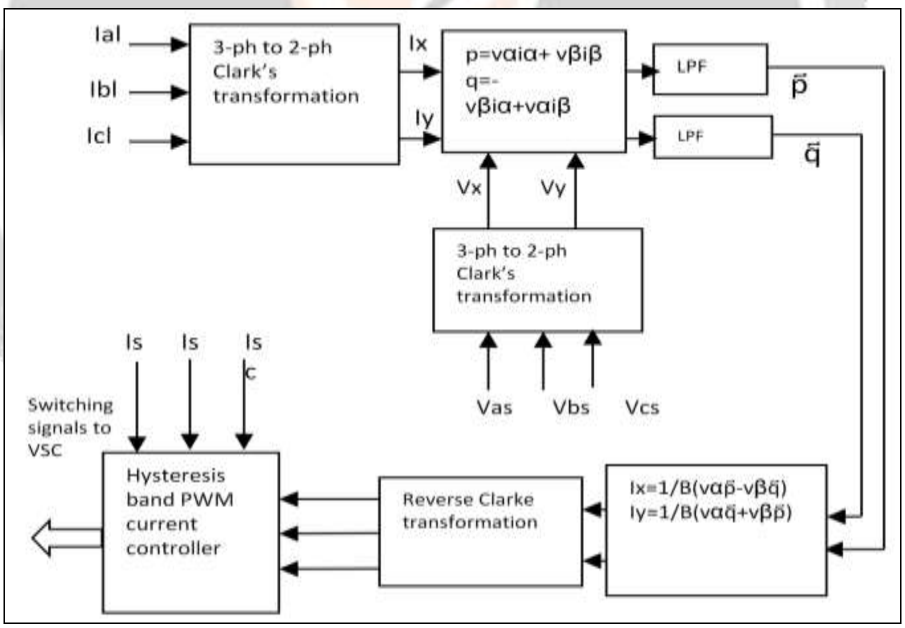

Fig-4 IRPT control algorithm

Similarly, at the PCC, voltage is Clarke transformed, generating voltage elements vx, vy. From such voltage and current elements, real and reactive powers are computed. P and Q represent the total real and reactive power consumed by the load at a certain predefined location.

$$B = v_x{}^2 + v_y{}^2 \quad \ldots\ldots (6)$$

Where vx, vy andix, iy are 2-ph terminal voltages and load current components.

$$P = v_x * i_x + v_y * i_y \quad ..... (7)$$
$$P = \hat{p} + \tilde{p} \quad ..... \quad (8)$$

Where $\hat{p}$ the fundamental element of real is power and $\tilde{p}$ is the oscillating element of real power
There is also a computation for reactive power in addition to real power.

$$Q = -v_y * i_x + v_x * i_y \quad ..... (9)$$
$$Q = \hat{q} + \tilde{q} \quad ..... (10)$$

Where, $\hat{q}$ fundamental component of reactive power,
$\tilde{q}$ oscillating component of reactive power.

IV. MODELLING AND SIMULATION

In this chapter The Sim power system (SPS) toolbox is being used to design sophisticated models in MATLAB/SIMULINK . For the modified version of IRPT, the simulations were run in Discrete mode with the ode 23tb (stiff/TR-BDF2) solver with a sampling time of (5e-6) sec shown in fig 5 The acquisition of PCC voltages (v_{sa}, v_{sb}, v_{sc})and load voltages ($i_{La,}$ i_{Lb}, i_{Lc}) into α-β Frame using Clarke Transformation and inverse Clarke Transformation for inductive load using DSTATCOM is shown in Fig. 4

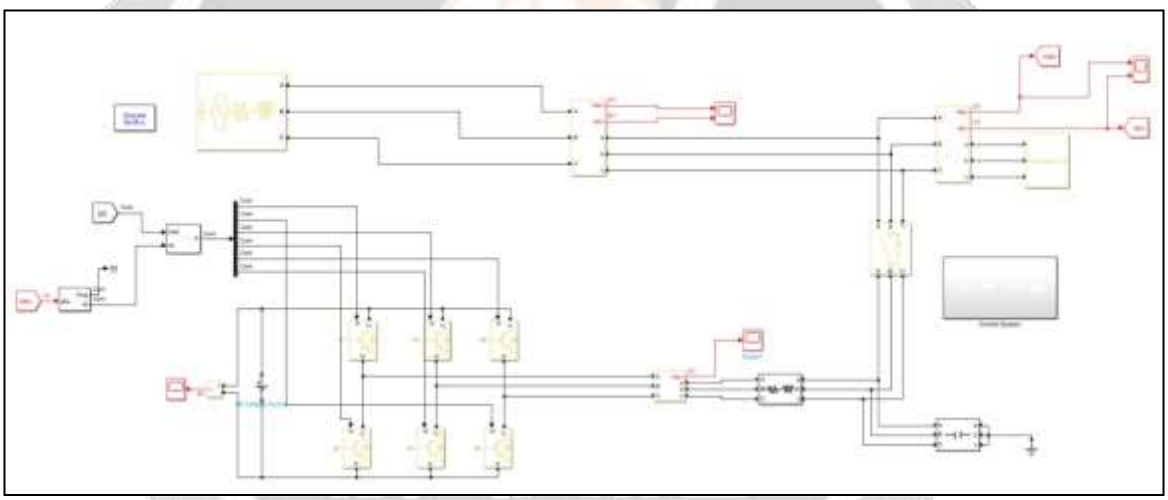

Fig-5 Simulink model for inductive load with DSTATCOM

Figure 6 depicts the improvements proposed to the control algorithm to produce results in power factor correction (PFC) mode. In this situation, the reactive power has been set to zero.

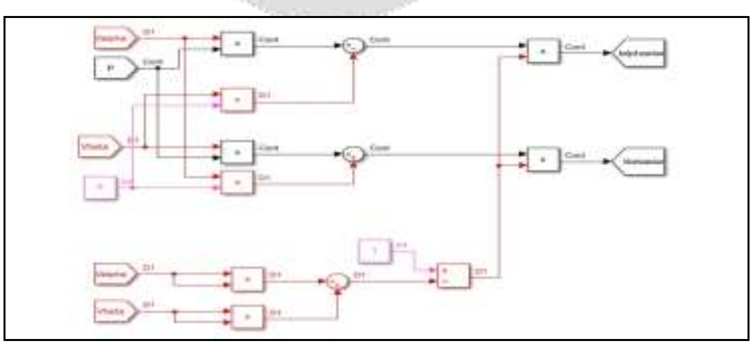

Fig- 6 Fundamental Source Currents in α-β Frame in PFC mode

V. Result & discussion

The Sim power system (SPS) toolbox was used to create control algorithms in MATLAB/SIMULINK. The simulations were run in Discrete mode with a sampling time of (5e-6) seconds using the ode 23tb (stiff/TR-BDF2) solver.[10] The load and supply currents in PFC/ZVR mode for sinusoidal and non-sinusoidal voltage distribution network are analyzed using fast Fourier Transform under different modes.

A. FFT Analysis under Sinusoidal Grid Voltages

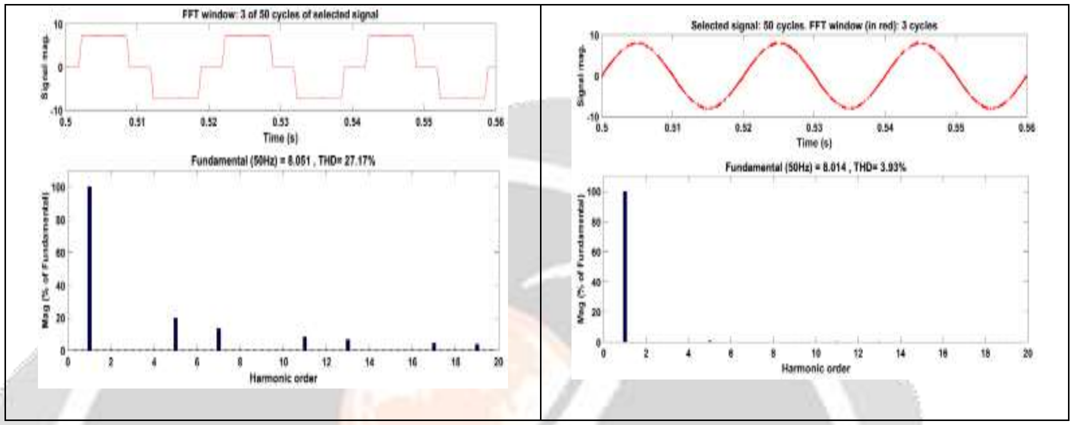

Fig-7 FFT Analysis of load and source current in PFC mode

The total harmonic distortion (THD) in load current is shown in Fig.7. The value of THD in Load current is 27.17 % and the supply current is 3.93 %. When the voltages in phase-a in PFC mode are inadequate, compensation is made in phase-a. With module of Sinusoidal network elements are used. The voltage is sinusoidal in nature. It has a THD of only 0.04 cent.

B. FFT Analysis under Non-Sinusoidal Grid Voltages

FFT evaluation of PCC voltage, load, and source currents non-sinusoidal voltage distribution network in PFC mode as seen in Fig 8 The THD values of load current, PCC voltage and in-supply current are 24.75 % and 6.4 cents, respectively., 8.52% in PFC mode after mitigation in phase-a of proposed techniques[11],[12].

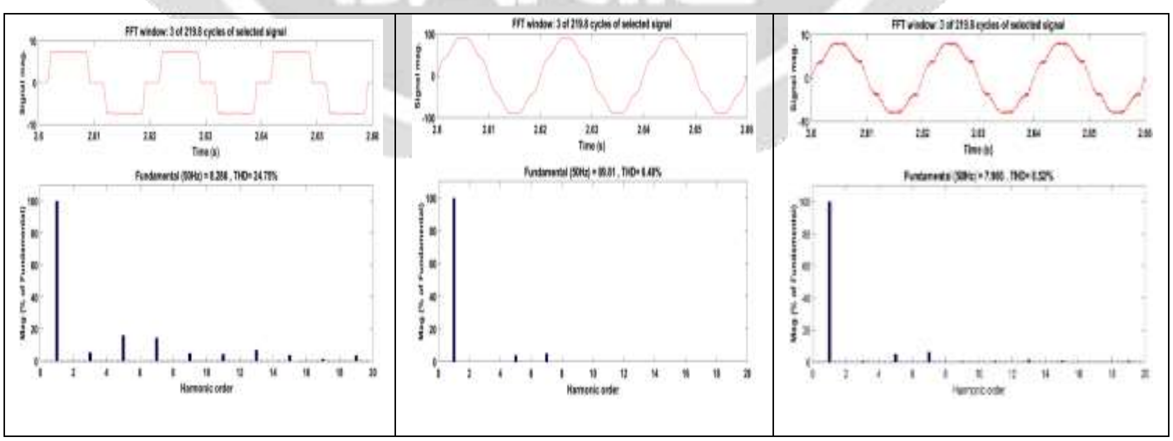

Fig-8 FFT Analysis of load current, PCC voltage and source current in PFC mode with distorted voltages

C. Performance of DSTATCOM using p-q theory in PFC mode

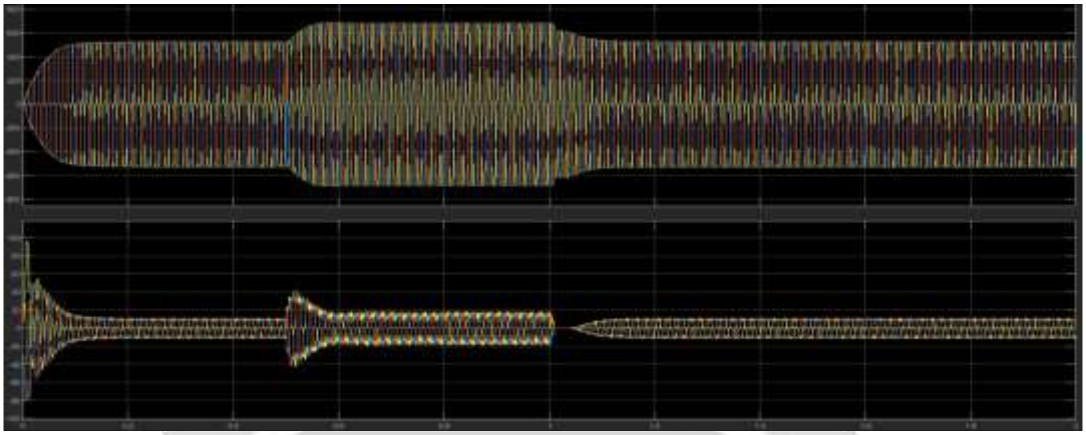

Fig- 9: Supply Side Performance of DSTATCOM using p-q theory in PFC mode

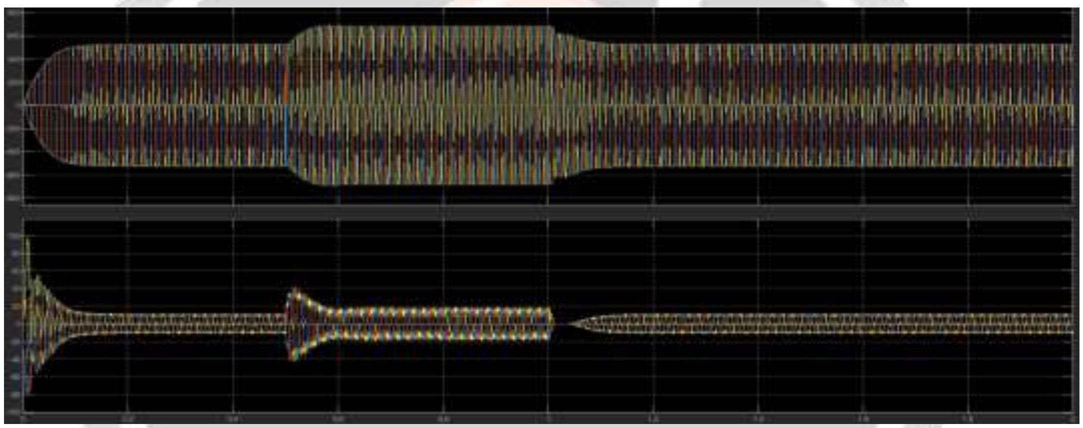

Fig- 9: Load side Performance of DSTATCOM using p-q theory in PFC mode

The performance of DSTATCOM in PFC mode when the distribution network has non-sinusoidal voltage is demonstrated in Fig 9 To analyze the impact of an imbalanced load, phase "a" of the load is disconnected at time t= 0.5 sec, and we're seeing the dc link voltage rises briefly before settling down to 440V, as shown in figure. The supply current and voltage have been seen to be affected.

VI. CONCLUSION

In this paper a detailed discussion given on compensating power device i.e DSTATCOM with a control scheme of Instantaneous reactive power theory (IRPT) method in PFC when distribution system supplies sinusoidal and non-sinusoidal voltage. By using this adaptive approach of IRPT with PFC method on DSTATCOM supplies reactive power to the line for reactive power compensation to lower down the total harmonic distortions below 6%. This compensating device placed on load side in order to improve the voltage stability of system and minimize power losses within the system.

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