Review on Performance Control of DSTATCOM by p-q theory with Power Factor correction of Polluted Grid

Rupali Gadhawe[1]
Student , BIT Ballarpur, Maharashtra India

Prajakta Kasulkar[2]
Assistant Professor, BIT Ballarpur, Maharashtra India

ABSTRACT

This paper reviewed the modelling and design of Instantaneous Reactive Power Theory for control of DSTATCOM P-Q theory with Polluted Grid Power Factor Correction. Several aspects of control are investigated using a sinusoidal grid and non-sinusoidal voltages. In this post, we'll look at how a compensator can help with power factor, voltage management, supply current harmonics, and load balancing. A three-phase, three-wire system with a sinusoidal grid and a non-sinusoidal voltage grid has a sinusoidal grid and a non-sinusoidal voltage grid.

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.

Ever since power electronics was introduced in the late 19th century, the use of non-linear load has increased significantly. Increasingly, problems like voltage deviation during load change and power transfer limitation are observed due to reactive power unbalancing. Most AC loads consume reactive power due to presence of reactance.[1] Heavy consumption of reactive power results in poor voltage quality. Today these problems have caused a substantially higher impact on reliable and secure power distribution system. Maintaining the electric power quality „PQ" in an electrical distribution system is presently a matter of great concern. The term power quality generally refers to maintaining good quality of power at generation, transmission, distribution and usage of electric power supply.

Harmonics are a key factor influencing poor power quality and lead to a lot of disturbances in the distribution system such as electromagnetic interference, overheating if cables and low power factor. 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]. Distribution Static Compensator (DSTATCOM) is used to compensate the current based power quality disturbances like reactive power, neutral currents, fluctuations, harmonics and unbalanced currents. An insulated gate bipolar transistor (IGBT) based current controlled 3-phase, 3leg voltage source converter (CC-VSC) with a DC bus capacitor is used as DSTATCOM. In general, a DSTATCOM has a VSC connected to a DC bus and AC side is connected across the consumer end of the power distribution system in shunt. A control algorithm is used to generate reference currents that are compared to the supply currents in indirect current control of the VSC; these are then used to generate gating pulses which are fed directly to the DSTATCOM. [6]-[9]

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].

To extract reference current, this review study analyzed the impact of DSTATCOM controlled by instantaneous reactive power theory (IRPT) or p-q theory in PFC (Power factor correction) mode. When the distribution system grid voltages are contaminated and non-linear loads are fed, these currents are used to execute load correction. In Power Factor Correction (PFC) mode, the performance of DSTATCOM employing this method is tested and verified.

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.

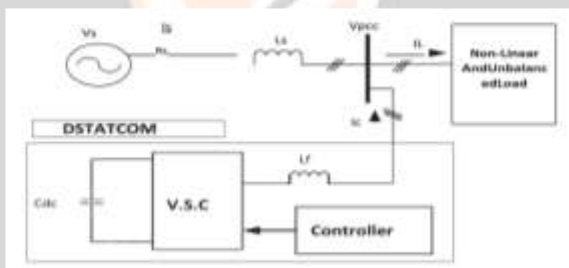

Fig-1 Simplified representation of DSTATCOM

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.

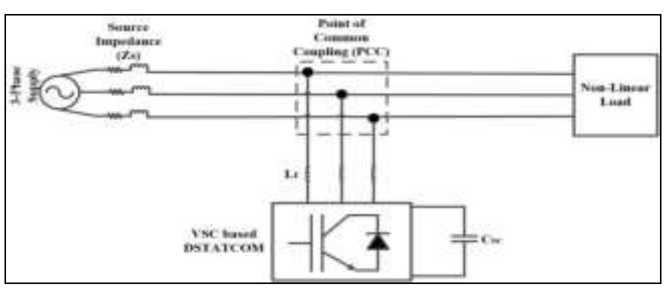

Fig-2 Block diagram of DSTATCOM connected to grid

A three phase source feeds a three phase non linear load. DSTATCOM is connected in shunt at distribution side. It is modeled as an IGBT base current controlled VSC that connected to DC link capacitor. DSTATCOM is capable of absorb and delivering reactive power in the system. It take reference current from load side and compensate the harmonic current and injects filter current into the system.

III. CONTROL SCHEME OF DSTATCOM

For the control of DSTATCOM Instantaneous reactive power theory is used in three different mode, are as follows:

1) Power factor correction mode (PFC)

2) Zero voltage regulation (ZVR)

3) Complete harmonic elimination (CHE)

This paper is focused to discuss the two very much used control strategies for DSTATCOM which are IRPT or p-q theory and SRF or d-q theory. Both these theory are used to generate the reference source current which is used to generate the pulses for the switches of the VSC of the DSTATCOM. The IRPT uses the Clarke transform and SRF uses the Park transform whose basic concept and vector diagram is shown in the fig. 2. For park transformation the abc quantities are first Clark transformed and then Park transformed to get the dqo components.[10] Similarly for getting abc components from thedqo components these are first inverse park transformed and then inverse Clark transformed

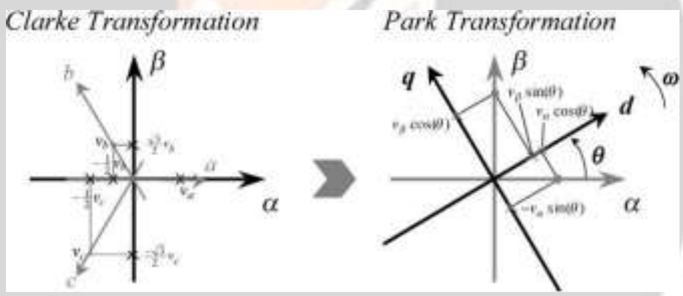

Fig- 3 Clarks and Parks transformation

A) IRPT (Instantaneous Reactive Power Theory) or p-q theory

This theory was discovered in 1983 and used since then for controlling which focus on the two forms of power component which are active and reactive power. [11]

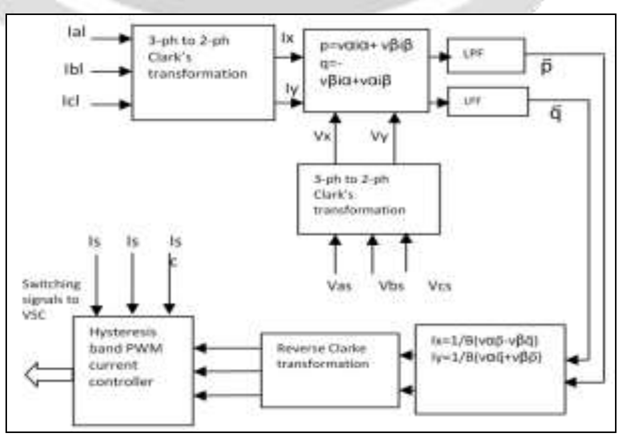

Fig-4 IRPT control algorithm

$$\begin{bmatrix} \alpha \\ \beta \\ o \end{bmatrix} = Tc * \begin{bmatrix} a \\ b \\ c \end{bmatrix} \tag{2}$$

Where Tc is the Clark transformation matrix which is given by

$$Tc = \sqrt{\frac{2}{3}} * \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \tag{3}$$

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = Tc^{-1} * \begin{bmatrix} \alpha \\ \beta \\ o \end{bmatrix} \tag{4}$$

$$Tc^{-1} = \sqrt{\frac{2}{3}} * \begin{bmatrix} 1 & 0 & 1/\sqrt{2} \\ -1/2 & \sqrt{3}/2 & 1/\sqrt{2} \\ -1/2 & -\sqrt{3}/2 & 1/\sqrt{2} \end{bmatrix} \tag{5}$$

The total instantaneous active and reactive power can be calculated by

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} v\alpha & v\beta \\ -v\beta & v\alpha \end{bmatrix} \begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} \tag{6}$$

Where, $\Delta = v\alpha 2 + v\beta 2$ (7)

P is the total instantaneous real power absorbed by load,

Q is the total instantaneous reactive power absorbed by the load

$v\alpha$ and $i\alpha$ is the alpha component of terminal voltage and load current

$v\beta$ and $i\beta$ is the beta component of terminal voltage and load current

$$P = v\alpha * i\alpha + v\beta * i\beta \tag{8}$$

$$\check{q} + \bar{q} = q \tag{9}$$

Active power can also be calculated by P = Va*Ila +Vb*Ilb + Vc*Ilc (10)

Where Va, Vb and Vc are the three phase source voltage And Ila, Ilb and Ilc are the three phase load current

The (9) shows that the active power P contain both fundamental Pdc and oscillating component Pac active power component. This instantaneous active power can also be calculated using the actual three phase quantities as shown in (10).Similarly the instantaneous reactive power can be calculated by the equation

$$Q = -V\beta * I\alpha + V\alpha * I\beta \tag{11}$$

The instantaneous reactive power (Q) absorbed by the load contains both fundamental (qdc) and scillating component (qac) which can be given by the (12).

$$Q = \bar{q} + \check{q} \tag{12}$$

B) SRF (synchronous reference frame) theory or d-q theory

In SRF or d-q theory the load current quantities are clark-park transformed to dq0 components and the transformation sin and cos components used for that are extracted from the supply voltage. The significance of dqo is the direct, quadrature and zero axes. In park transformation the three phase components are rotated at the reference frame with fundamental frequency thus the fundamental frequency component seems to be stationary while the signals other than the fundamental frequency seems to be oscillating signals. Now in the dqo current quantities are low pass filtered to get the fundamental current quantities. The filtered current quantities are transformed back into the phase quantities using inverse park-clark transformation which are the reference source current.

The d current component shows the current responsible for active power, similarly q component of current show the current responsible for reactive power and o component current shows the unbalance in the supply. The system considered here is balanced for simplicity.

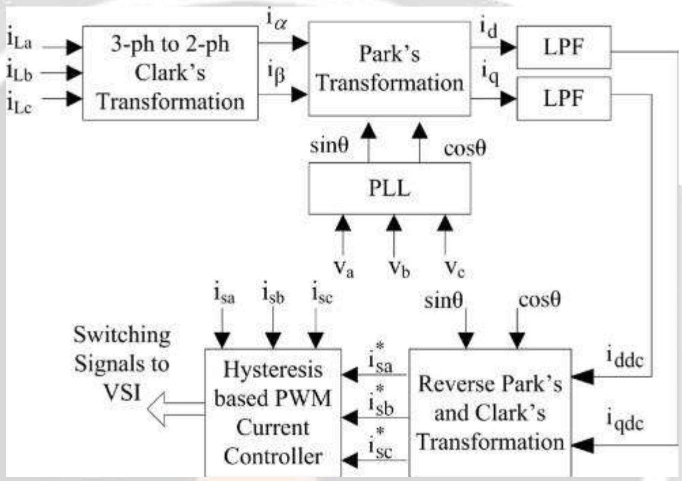

Fig- 5 Basic SRF control algorithm

Tp and Tc are the park and clark transformation matrixes, and Tpc is the product of them

$$\begin{bmatrix} d \\ q \\ o \end{bmatrix} = Tp * Tc * \begin{bmatrix} a \\ b \\ c \end{bmatrix} = \text{Tpc}* \begin{bmatrix} a \\ b \\ c \end{bmatrix}$$

$$\begin{bmatrix} d \\ q \\ o \end{bmatrix} = Tp * Tc * \begin{bmatrix} a \\ b \\ c \end{bmatrix} = \text{Tpc}* \begin{bmatrix} a \\ b \\ c \end{bmatrix}$$

$$Tpc = \sqrt{\frac{2}{3}} * \begin{bmatrix} cos\theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ -sin\theta & -\sin\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta + \frac{2\pi}{3}\right) \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \quad (13)$$

After simplification

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = Tcp^{-1} * \begin{bmatrix} d \\ q \\ o \end{bmatrix} \quad (14)$$

Where, is the inverse transformation matrix of Tpc and is given by the

$$Tcp^{-1} = \sqrt{\frac{2}{3}} * \begin{bmatrix} cos\theta & -sin\theta & 1/\sqrt{2} \\ \cos\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta - \frac{2\pi}{3}\right) & 1/\sqrt{2} \\ \cos\left(\theta + \frac{2\pi}{3}\right) & -\sin\left(\theta + \frac{2\pi}{3}\right) & 1/\sqrt{2} \end{bmatrix} \quad (16)$$

IV. Proposed Control Model Strategy

Under this condition the grid is considered to be polluted and has 5th and 7th order harmonics in grid voltage along with the fundamental. The conventional p-q algorithm will not work well in such conditions; hence modification have been suggested in the literature. Three such modification have been modeled, viz. power factor correction (PFC) mode, Zero voltage regulation (ZVR) mode and complete harmonic elimination (CHE). Strategy using p-q theory, in which we tested PFC mode using p-q theory.

Both PFC and ZVR mode are incapable of completely eliminating the harmonics currents, so a modification of the PFC mode for harmonic elimination in the distribution system is considered. So in Complete Harmonic Elimination strategy, the three phase voltages and load currents are transformed into αβ0 stationary reference frame by Clarke Transformation as shown in Eq 1.The instantaneous value of load active power is calculated by:

$$P=iLaVsa+iLaVsa+iLaVsa = PLac+PLdc \quad (17)$$

The DC component of load active power is filtered out using a low pass filter. The fundamental value of "Va" and "VB " "Va*" and "V *" obtained by using two band-pass filters tuned to extract the fundamental components of these voltages. The reference currents generated using these components in α-β frame known as "Ia *" and "Ib *".

The reference source currents in a-b-c frame can be calculated using Eq.13.The essence of PFC strategy focuses on filtering the distorted current first and using filtered PL . Once the reference source currents are generated, these are compared with the sensed source currentsto generate gating pulses of VSC based DSTATCOM.

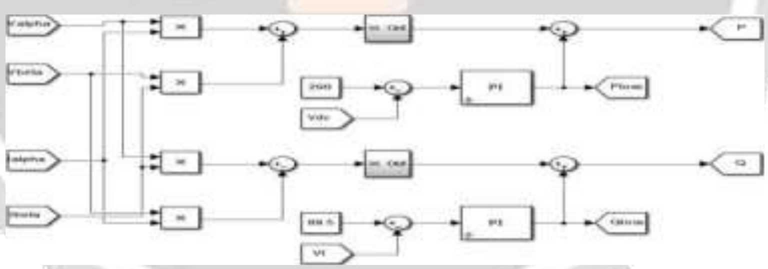

Fig 6 calculation of fundamental component of real and reactive powers

Figure 7 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.

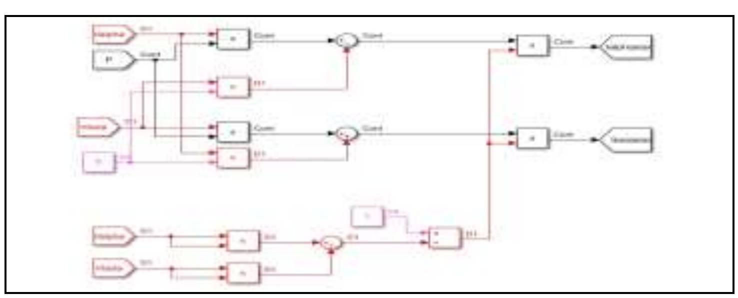

Fig- 7 Fundamental Source Currents in α-β Frame in PFC mode

In this review of this paper the overall system of DSTATCOM controlled by p-q theory, in which three phase source is connected with the three phase non-linear load. DSTATCOM is connected in shunt at distribution side. VSC based DSTATCOM having three leg IGBTs with antiparallel dc source. By using control logic fundamental current is generated for gate pulse for IGBTs the VSC based DSTATCOM work and inject compensating current into the system. The calculation of fundamental component of real and reactive powers are shown in below fig.

VI. CONCLUSION

In this paper a detailed review 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. In this literature the performance of DSTATCOM controlled by p-q theory in PFC and ZVR mode when distribution system supplies sinusoidal voltage has been studied. 2. The performance of DSTATCOM controlled by p-q theory in PFC, ZVR mode and using complete harmonic elimination strategy when distribution system supplies non-sinusoidal voltage has been studied. This compensating device placed on load side in order to improve the voltage stability of system and minimize power losses within the system.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.

VII. REFERENCES

[1]. Olimpo Anaya-Lara and E. Acha, “Modelling and analysis of custom power systems by PSCAD/EMTDC”, IEEE TRANSACTIONS ON POWER DELIVERY, VOL.17, NO. 1, JANUARY 2002.

[2]. Saidi Amara and Hadj Abdallah Hasn, “Power system stability improvement by FACTS Devices: Comparision between STATCOM, SSSC, and UPSC”, 2012 IEEE first international conference on renewable energies and vehicular technology.

[3]. J. Ganesh Prasad redy, K. Ramesh Reddy, “Design and Simulation of cascaded H-Bridge Multilevel inverter based DSTATCOM for compensation of reactive and harmonics”, 1st international conference on Recent Advances in information technology (RAIT) 2012, IEEE.

[4]. Anand Ahirwar, Alka Singh, “Performance of DSTATCOM control with instantaneous reactive power theory under ideal and polluted grid”, IEEE 2016 second international innovative Application of computational intelligence on power, Energy and controls with their impact on humanity (CIPECH).

[5] Akagi, Hirofumi, Watanabe, Edson Hirokazu and Aredes, Mauricio (2007), *Instantaneous Power Theory and Applications to Power Conditioning*, IEEE Press, John Wiley and Sons Ltd. 2007.

[6] Singh, Bhim, Chandra, Ambrish, Al-Haddad, Kamal (2015), *Power Quality: Problems and Mitigation Techniques*, John Wiley and Sons Ltd 2015.

[7] Singh, B. and Solanki, J. (2009), “A Comparison of Control Algorithms for DSTATCOM”, *IEEE Trans. Ind. Electron*., Vol. 56, No. 7, pp. 2738–2745.

[8] Czarnecki, L.S. (2009), “Effect of Supply Voltage Harmonics on IRP-based Switching Compensator Control”, *IEEE Trans. Power Electron*., Vol. 24, No. 2, pp. 483–488.

[9].Bangarraju, J. and Rajagopal, V. (2014), “Implementation of Three-Leg VSC based DVR using IRPT Control Algorithm”, *IEEE 6th India International Conference on Power Electronics* (IICPE).

[10].Kumar, S., Singh, B. and Member, S. (2009), “Control of 4-Leg VSC based DSTATCOM using Modified Instantaneous Symmetrical Component Theory”, *Third International Conf.on Power System*, India, Dec, 2009.

[11]. H. Akagi, Y. Kanazawa, and A. Nabae, “Instantaneous Reactive power compensators comprising Switching Devices without Energy Storage Components,” IEEE Transactions on Industry Applications,vol.IA-30 , no. 3, pp. 625-630, 1984.