OPTIMIZATION OF ELECTRICAL POWER QUALITY USING UNIFIED POWER QUALITY CONDITIONER: A REVIEW

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Abstract : Unified Power Quality Conditioner (UPQC) is combination of shunt and series active power filter which are used in distribution system to control the voltage related problem such as voltage harmonics, voltage flicker, voltage sag-swell and current related problem such as current harmonics, Reactive current and current unbalance. By Studying the performance of UPQC using Instantaneous active and reactive power theory (p-q) for shunt active power filter and synchronous reference frame theory (d-q) for series active power filter to generate the reference signal for voltage and current. The hysteresis controller is used to generate the gating signal for shunt voltage source inverter connected to the sensitive load and non-liner load. The sinusoidal pulse width modulation techniques (SPWM) are used to generate the gating signal for series voltage source inverter which is connected to the feeder through series injection transformer. The PI controller are used to generate signal to compensate the errors. Energy storage element such as battery is not required for unified power quality conditioner. The MATLAB/SIMULATION model of unified power quality conditioner (UPQC) is used to improvement of power quality problem at distribution network**.**

***Index Terms* - Power Quality, Unified Power Quality Conditioner (UPQC), Active Power Filter (APF), p-q theory, d-q theory, voltage sag, voltage swell, current harmonics.**

I. INTRODUCTION

Power quality is defined as the ability of electrical equipment to consume the energy being supplied on it. The power quality has been important issues for consumers of electricity at entire level of usages in electrical power system. Power quality problem demonstrated in frequency, voltage or current deviation and may result into increased power losses, failure of equipment and malfunctioning of equipment. The wide use of non-liner load such as power electronics based equipment such as switch mode power supplies (SMPS), frequency converters, arc welding machines, variable frequency drives (VFD), single phase converter and three phase converter-rectifier has been substantial effect on power quality in electrical power system. When non-linear load are connected to the power system it produce voltage or current harmonics, reduce power factor, reactive power related problem, Voltage sag and swell in distribution system. Voltage sag, voltage swell and current harmonics are the most common PQ problem. Voltage sag and swell can cause equipment failure, malfunctioning and data loss. Current harmonics can harm the live system and other customers connected to the system [1-4].

Development of the FACTS devices such as STATCOM, SVC, TCSC and Custom power devices such as dynamic voltage restorer (DVR), distributed static compensator (D-STATCOM), distributed static-var compensator (D-SVC) and unified power quality conditioner (UPQC) are used to improve the power quality of the electrical power system. APFs are the best solution to mitigate the major power quality problems effectively. Although all devices can be improve the power quality problems but in this paper the focus is only on UPQC.

The Unified Power Quality Conditioner (UPQC) is one of the APF family members where shunt and series APF interconnect with the common dc link formed by capacitor [1]. The shunt APF is the most suitable to handle the current-related problems, where the series APF is the most suitable to handle the voltage-related problems [1]. The performance of UPQC is observed with a nonlinear load and simulation studies using MATLAB/Simulink verify the satisfactory performance of UPQC.

II. SYSTEM CONFIGURATION

The main component of unified power quality conditioner are given below which is shown in fig 1.

- Shunt voltage source inverter
- Series voltage source inverter
- Shunt coupling inductor
- Low pass filter(L-C)
- Common D.C link energy system
- Series injection transformer

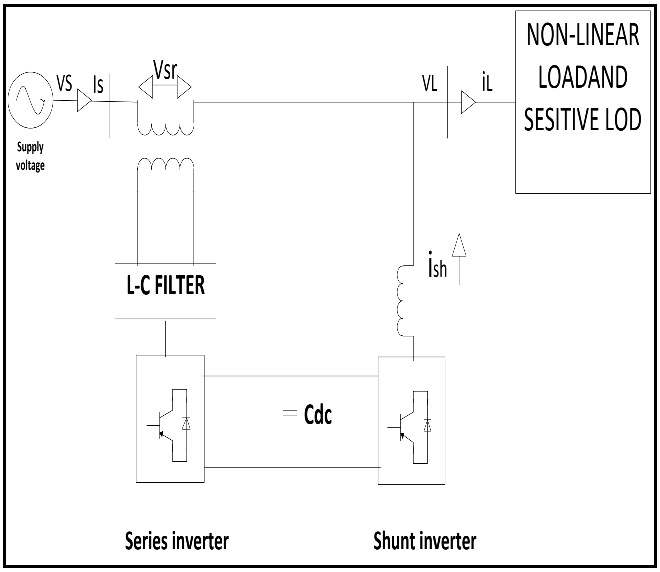

Fig. 1 General block-diagram of UPQC

1. Shunt voltage source inverter :

The Shunt voltage source inverter (VSI) is made by the insulated gate bipolar transistor (IGBT) and which is connected to the load through Shunt coupling inductor and it is act as current source to mitigation current related problem like load current harmonics and current unbalance and maintain the D.C link voltage at desired reference voltage. The Shunt voltage source inverter (VSI) is controlled by output of the adjusted dynamic hysteresis band controller.

2. Series voltage source inverter :

The series voltage source inverter (VSI) is made by the insulated gate bipolar transistor (IGBT) and which is connected to the feeder line through series injection transformer and it is act as voltage source to mitigation voltage related problem like voltage harmonics, voltage unbalance, voltage flicker, voltage-sag and voltage-swell. Control of the series voltage source inverter by output of the sinusoidal pulse-width modulation (SPWM).

3. Shunt coupling inductor :

Shunt coupling inductor is a High-pass filter which is used to interface shunt voltage source inverter and distribution network. It is installed at the output of shunt voltage source or shunt converter to smoothing the current switching ripples or switching frequency harmonics or smoothing the current waveform [1].

4. Passive low pass (L-C) filter :

Passive Low pass filter (LPF) is employ between series injection transformer and it is installed at the output of the series voltage source inverter. Series VSI which is used to eliminate the high frequency switching ripple. High-frequency switching ripple generated by series VSI.

5. Common D.C link energy system :

A common D.C link energy system is made by using capacitor and inductor which is connected in between series voltage source inverter and shunt voltage source inverter. Main important thing is the performance of the UPQC is mainly depending on the common D.C link energy system because it supported to the compensating voltage of the series voltage source inverter and also supported related to compensating current of the shunt voltage source inverter. Shunt active power filter is maintain the voltage of common D.C link energy system at reference level [2].

6. Series injection transformer :

The Series injection transformer is used to connect the series voltage source inverter (VSI) in the electrical network and suitable turn ratio of the transformer is selected to reduce the voltage and current rating of the series voltage source inverter. It is inject the compensation voltages and currents, and for also provide electrical isolation of UPQC converters.

III. EXTRACTION TECHNIQUE FOR UPQC

This section describes the extraction technique of current and voltage for shunt active power filter and series active power filter in UPQC.

A. P-Q current control theory:

The p-q theory i.e. instantaneous active and reactive power theory which is based on shunt APF have been designed. The Purpose of p-q theory is to compensate the distortive condition produced due to the non-linear load by using active power filter (APF).The p-q control theory is based on conversion of the co-ordinates from a-b-c axes into α-β-0 axes. The compensate reference current to be calculated in α-β-o axes.

Firstly, p-q control theory was established only for three-phase three wire systems without neutral conductor and being far ahead worked, p-q control strategy was developed for three-phase four wires power systems by Watanabe and Aredes and 0 axes is requirement to presenting three phase four wire system [4].

The p-q control strategy is well-defined in time domain. In instantaneous active and reactive power theory, the co-ordinate of the three phase supply voltage Va,Vb, Vc and supply current Ia, Ib, Ic are transform into the Vα,Vβ and Iα, Iβ, Io co-ordinate axes. These transformations have been realized by using three phase axes variable into two axes reference frame.
The Clarke transformation for the variables of the voltage and current quantities is given in equation (1) and (2),

$$\begin{bmatrix} Vo \\ V\alpha \\ V\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} Io \\ I\alpha \\ I\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Ia \\ Ib \\ Ic \end{bmatrix} \quad (2)$$

By taking inverse transformation such that the coordinate of the Vα,Vβ,Vo and supply current Iα, Iβ, Io are transformed into three phase variable Va, Vb, Vc the and Ia, Ib, Ic co-ordinate axes in equation (3) and (4),

$$\begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Vo \\ V\alpha \\ V\beta \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} Ia \\ Ib \\ Ic \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Io \\ I\alpha \\ I\beta \end{bmatrix} \quad (4)$$

Three phase Instantaneous real power is expressed by,

$$P = V\alpha I\alpha + V\beta I\beta \quad (5)$$

Three phase Instantaneous reactive power is expressed by,

$$Q = V\alpha I\beta - V\beta I\alpha \quad (6)$$

In matrix form it is written as,

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} V\alpha & V\beta \\ -V\beta & V\alpha \end{bmatrix} \begin{bmatrix} I\alpha \\ I\beta \end{bmatrix} \quad (7)$$

The reference current in alpha-bita coordinates are calculated by given equation,

$$\begin{bmatrix} Ic\alpha \\ Ic\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} V\alpha & V\beta \\ -V\beta & V\alpha \end{bmatrix} \begin{bmatrix} P_{loss} \\ Q \end{bmatrix} \quad (8)$$

Instantaneous reactive power to be set into opposite vector to cancel the reactive component in feeder line current which is given in equation (9).

$$\begin{bmatrix} Ia \\ Ib \\ Ic \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I\alpha \\ I\beta \end{bmatrix} \quad (9)$$

Compensation current of each phase calculated by inverse Clarke transformation. The output to be Occupied from the reference current calculation block so taking the inverse transformation the coordinate of the Vαβo and supply current Iαβo transformed into three phase voltage and current variable Vabc the and Iabc co-ordinate axes. The reference current to be mitigated the load harmonics current and reactive current of the load and this reference current is compare source current and generate the error which is given to the hysteresis controller. The hysteresis controller is generating the gating signal for IGBT switches of shunt active power filter [4].

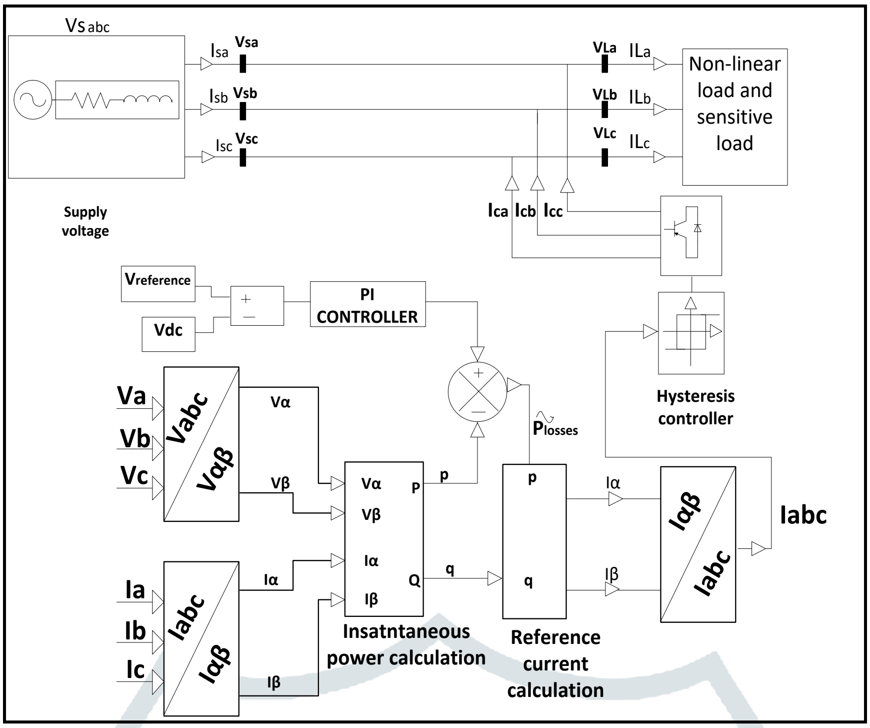

Fig. 2 Instantaneous active and reactive power control strategy for UPQC

Hysteresis controller is the most appropriate for current control techniques for shunt APF because of it is simple, response time fast, switching frequency is variable and no delay time. It has fast dynamic and automatic current limited characteristic. The PI controller is used for regulating the D.C link voltage and second low pass filter is used for separate the average value and oscillatory value which passed only fundamental value and high pass filter is passes only average or higher frequency value.

B. Synchronous Reference Frame Method (d-q theory):

In this technique, the voltage or current is transferred from the a-b-c frame to the d-q synchronous reference frame. The fundamental component of the voltage or current in the d-q frame represents DC quantities, which can be eliminated by the Low Pass Filter. The d-q theory has limitations when the voltage supply is unbalanced. Hence, in this paper the unbalanced voltages in the a-b-c frame are decomposed into the three symmetrical components, which are positive sequence, negative sequence and zero sequence as in Fig. 3 The positive sequence and negative sequence components are balanced in three phase. Therefore, the d-q theory is used to extract the fundamental components of the both sequence components. For now, all zero sequence component are in phase with each other, so the single phase d-q theory is used to extract the zero sequence instead of the conventional d-q theory .After extraction of the fundamental components of the three symmetrical components, they are transformed back to the a-b-c frame.

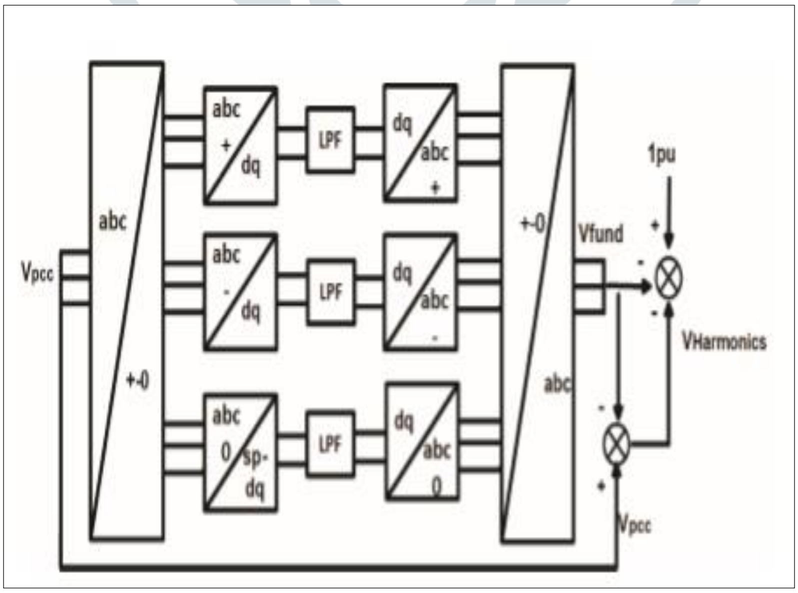

Fig. 3 Extraction of unbalanced voltage sag and swell using d-q theory

The extracted fundamental voltages and harmonics are subtracted from the reference voltage, which is 1pu for positive-sequence voltage and zero for negative and zero sequence voltage. So, the reference signal is developed to derive the switching of the series part of the UPQC for mitigating the unbalanced voltage sag and swell.

$$\begin{bmatrix} Vd \\ Vq \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin(\theta - \frac{3\pi}{3}) \\ -\sin\theta & \cos(\theta - \frac{3\pi}{3}) \end{bmatrix} \begin{bmatrix} V\alpha \\ V\beta \end{bmatrix} \quad (10)$$

IV. CONCLUSION:

This paper presented system configuration of UPQC and different types of controlled strategy of the UPQC to enhancing power quality and after the studied I have concluded that synchronous reference frame theory (d-q) and instantaneous active and reactive power theory (p-q) is the best method to controlling the series active power filter and shunt active power filter of UPQC respectively.

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