Controlling Technique for Unified Power Quality Conditioner (UPQC) For Mitigation of Power Quality

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Abstract - *In this Paper the controlling methods of a FACTS controller device UPQC has been discussed, UPQC is a bipolar device, UPQC consists of two inverters, one is series connected and another one is shunt connected. UPQC used in electrical power to mitigate the power quality issues in power system, the main of power quality is variation of voltage, frequency, transients etc. The increased use of nonlinear loads in power system leads to distortion in voltage & current waveforms and injecting harmonics and thus the system inherently gets unbalanced. Harmonics generation becomes a grave concern in distribution system. Besides this, the voltage sag-swells and power factor also create the power quality problem at the utility side.*

Key Words: Unified Power Quality Controller (UPQC), Flexible AC Transmission System (FACTS), Power Quality, Harmonics etc.

1. INTRODUCTION

UPQC plays a very vital role. It provides blessings of parallel and series active power filter both. Being a multitasking power conditioner UPQC can be utilized for compensation of numerous voltage disturbances, voltage flicker and it also provides prevention to the harmonics in the load current and doesn't allow them to enter into the power system and contaminate the quality of power. This custom power equipment has the ability of mitigation of the problems affecting the working of sensitive equipment or loads. UPQC provides compensation to harmonics in current (shunt part) as well as that to the voltage (series part), controls the flow of power and also overcomes the disturbances in voltage like voltage swell, sag etc. The essential parts of unified power quality conditioner are shunt inverter, series inverter, Dc link capacitor, Shunt coupling inductor and series transformer. [1]

1.1 UPQC CONFIGURATION:

UPQC mainly consists of following parts-[2]

- Shunt inverter
- Series inverter
- DC link Capacitor
- Shunt coupling Inductor
- LC filter
- Series Transformer

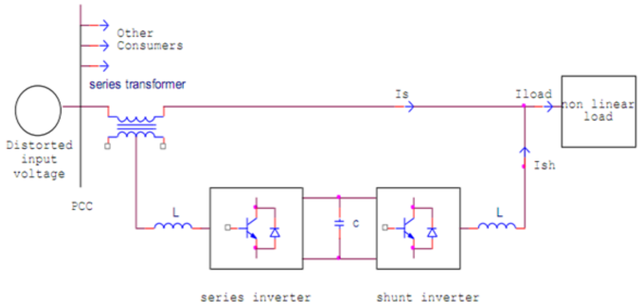

Figure 1: Basic block diagram of UPQC

a. Shunt inverter:

A shunt connected voltage source inverter acts as shunt inverter. It is helpful in cancellation of current distortions i.e. compensates the harmonic current of the load. It also provides assistance in keeping up a steady value for the DC link capacitor voltage and also helps in improvement of system power factor. Furthermore it is also helpful in compensation of load reactive current. Usually hysteresis band controller is employed for controlling of the shunt inverter output current. By adjusting the semiconductor switches reference current can be made to follow the output current and stays within the particular hysteresis band.

b. Series inverter:

It is a series connected VSI (voltage-source inverter) acting as a source of voltage. Its connection is in series with the line by using a series transformer. It helps in overcoming the voltage based distortions. It helps in maintaining a sinusoidal load voltage by eliminating the load voltage imbalances and the flickers in the terminal voltage. PWM techniques are used for controlling the series inverter. Mostly hysteresis band technique of pulse width modulation is used. There are many advantages of using this PWM technique. It provides a better and faster response speed, easy to implement and it can work properly even without having the knowledge about the parameters of the system.

c. DC link Capacitor:

It is used for back to back connection of the series and shunt VSIs. The DC voltage developed across the capacitor acts as a constant voltage and helps in proper operation of both shunt and series inverters. If regulated properly the voltage provided by this capacitor can be used a source for both active and reactive power and the use of any outer DC source e.g. battery etc. can be eliminated.

d. Shunt coupling Inductor:

It is helpful in interfacing of the shunt inverter to the network. The main benefit of this is, by using it we can do the smoothening of the wave shape of the current by elimination of the ripples producing the current.

e. LC filter:

It is present near the series inerter output of UPQC. Acting as a low-pass filter (LPF), it is helpful in attenuation of high-frequency voltage components of the output voltage of the series inverter.

f. Series Transformer:

The series inverter generates a voltage for maintenance of load voltage sinusoidal at a particular required value. Series inverter helps in injection of this voltage through the series transformer. It is required to maintain a particular turn's ratio in order to maintain a low current flow through the series inverter.

2. CONTROL TECHNIQUE FOR UPQC

Various control techniques have been used for the controlling of harmonics in voltage and current by using UPQC. Here mainly two methodology has been described i.e. the unit vector template generation technique and the Synchronous reference frame and PQ theory.-

A. UNIT VECTOR TEMPLATE GNERATION

The control technique used here is Unit vector template generation technique In this case supply voltage is made distorted and Unit Vector Templates are extracted from it. The distorted input source voltage contains harmonic components in addition to the fundamental component. For extraction of these unit vectors, the supply voltage is first measured and the product of this and gain ($1/V_m$) is done, V_m being the peak fundamental supply voltage. After this unit vector templates are generated by using a phase locked loop. [3]

$$V_a = \sin\omega t$$
$$V_b = \sin(\omega t-120)$$
$$V_c = \sin(\omega t+120)$$

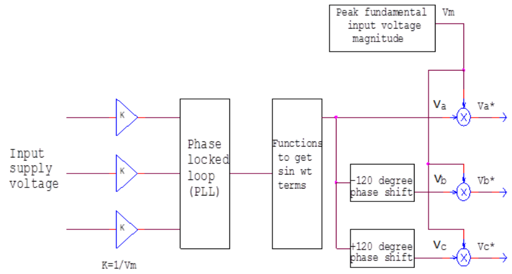

Figure 2: Generation of Unit Vector Templates and reference Load Voltages

Supply voltage is then multiplied with the unit vector templates and reference load voltage is generated. The reference load voltage generated is given by V*abc.

$$V^*_{abc} = V_m * U_{abc}$$

Then the comparison of actual load voltage and reference load voltage is done. Error is calculated and send into a hysteresis band for generating the gate pulse for the series inverter. Shunt Active Power Filter is used for current harmonics compensation. Generation of pulses for the shunt inverter DC link voltage is then measured an it its comparison is done with the reference dc link voltage. After that error is processed by utilizing a PI controller, and to produce the reference current these results are multiplied by unit vector templates. Comparison of reference and actual source current is done and a hysteresis band controller is used for processing the error and production of gate pulses for parallel inerter circuit is completed. [4]

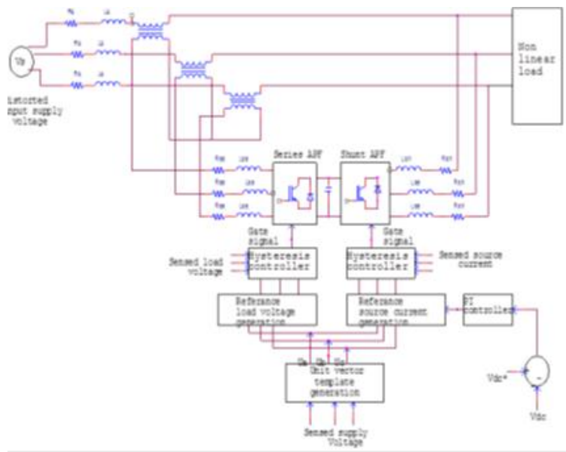

Figure 3: Overall Control Circuit Configuration of UPQC

B. SYNCHRONOUS REFERENCE FRAME AND P-Q CONTROL OF UPQC-

I. Control Method for Series Active Filter

For controlling the source side voltage aggravation SAF is utilized. In this method, the reference voltage that needs to be infused by the series transformers is ascertained by comparison of the positive – sequence component of the source voltage with that of the source voltage. The reference generation calculation for SAF is demonstrated as follows- [5]

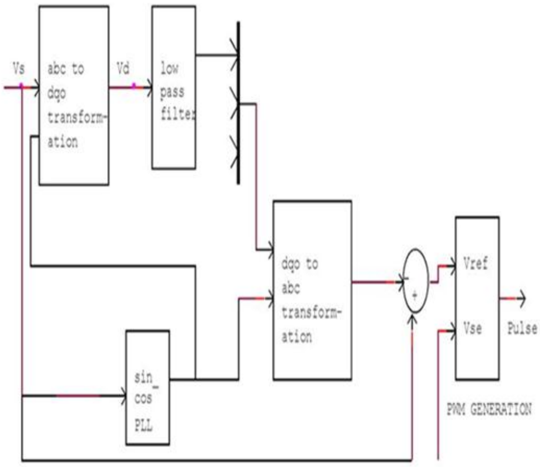

Figure 4: Control algorithm of SAF

Equation depicting transformation of supply voltage and load current into d-q-o coordinate are given below;

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

$$\begin{bmatrix} Vd \\ Vq \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} V\alpha \\ V\beta \end{bmatrix} \text{.......... (2)}$$

Along with the fundamental component harmonics are also present in the d-axes voltage. A second order LPF is used for filtering out the harmonic components. Then the reference voltage Vref is then estimated by utilizing d-q-o to a-b-c transformation. Then the output of series active filter and the reference voltage generated is fed to a hysteresis band controller to generate the gate pulses. [6]

II. Control Method Employed for Shunt Active Filter

For calculating the reference current in this method P-Q methodology has been utilized. Clarke's transformation given in equation (1),(2),(3) and (4) are used for transformation of reference voltages generated at SAF and load current in to α-β-0 coordinates –

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

$$\begin{bmatrix} Id \\ Iq \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} I\alpha \\ I\beta \end{bmatrix} \text{.........(4)}$$

Equation (5) is used for the calculation of real power and imaginary power in the Source side. These are instantaneous power-

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} V\alpha & V\beta \\ -V\beta & V\alpha \end{bmatrix} \begin{bmatrix} I\alpha \\ I\beta \end{bmatrix} \text{..............(5)}$$

For compensating reactive power and the harmonic component, real power is taken as the reference and the source current reference can be calculated by Eq.(6).

$$\begin{bmatrix} Is\alpha\ * \\ Is\beta\ * \end{bmatrix} = \frac{1}{V\alpha 2 + V\beta^2} \begin{bmatrix} V\alpha & -V\beta \\ V\beta & V\alpha \end{bmatrix} \begin{bmatrix} P + \Delta P \\ 0 \end{bmatrix} \text{.................. (6)}$$

Where, $\Delta P = Po + Ploss$

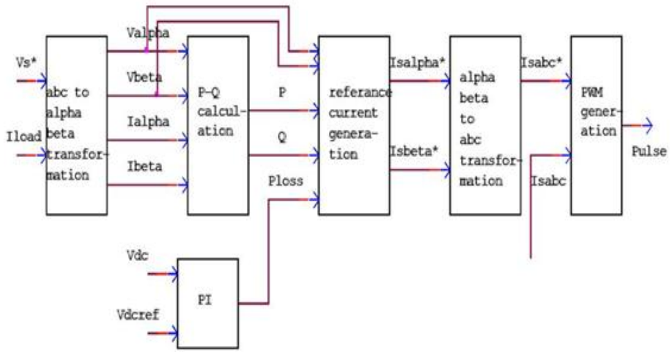

Figure 5: Control algorithm of PAF

Due to the absence of unbalance the power Po is zero. Comparison of measured and reference DC-link voltage is done and a Proportional integral controller is used for processing the error produced. The main reason behind using this controller is that it helps in reducing the steady state error to a zero value. PI controller's yield is termed as Ploss. Then the reference source current is converted to a-b-c frame of reference using the Eq. (7)-

$$\begin{bmatrix} Isa\ * \\ Isb\ * \\ Isc\ * \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Is\alpha\ * \\ Is\beta\ * \end{bmatrix} \text{....... (7)}$$

Finally the comparison of these current and actual source current is done by the help of hysteresis band controller and gate pulses for the shunt Active power filter are generated. [8]

3. CONCLUSIONS

It is predictable that, in future, utility service providers will impose more strict power factor and harmonic standards. Therefore, efforts are being made so that power electronic system or any other load drawing reactive volt-amperes is made to appear as linear load drawing current in-phase with the utility voltage. This paper presents a control technique for unified power quality conditioner (UPQC), which is a combination of series APF and shunt APF. A control strategy based on unit vector template generation is discussed in this paper with the focus on the mitigation of voltage harmonics present in the utility voltage. [10]

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