

# **P-Q theory based design of Unified Power Quality Conditioner for tranquillization of voltage and current unbalance under Non Linear Load condition.**

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## **Abstract**

This paper presents unified power quality conditioner (UPQC) which is an integration of shunt and series Active Power Filters and aims to compensate for voltage sag, voltage and current unbalance and other power quality problems [1],[5],[6]. The UPQC helps to improve power quality at the point of installation on power distribution system or industrial power system. This paper deals with design of UPQC by considering a controller based on PQ theory. Reference signal generation for shunt active filter is done by using PQ theory while for series dual PQ theory is used [2], [3]. Reference signals are then applied to pulse generators. Pulse generation is carried out by using hysteresis band controller for each filter. The validation of proposed scheme is carried out by using Matlab/Simulink.

**Keywords** – Unified Power Quality Conditioner, Active Power Filter, hysteresis control, voltage and current unbalance.

## **Introduction**

With tremendous growth of power electronic industry and computer industry, the quality of power has become very poor. The main problem is the distortion of sine wave which causes voltage & current harmonics and thus affecting the performance of the equipment connected to the point of common coupling (PCC). Another problem is, it causes voltage unbalance at both ends of PCC thus affecting the operation of other loads connected to it [6]. The solution is Unified Power Quality Conditioner (UPQC) which is an integration of shunt and series active power filters [1]. The UPQC helps to compensate harmonic currents, imbalance due to non linear load, also harmonic voltages and imbalance of power supply.[5]

This paper focuses on heart of system, UPQC controller which generates pulses. For shunt active filter and series active filter the control (reference) signal is obtained by using instantaneous active and reactive power theory broadly known as P-Q theory. For series active filter dual P-Q theory is used which is converse of P-Q theory used for shunt active filter.[6] These control signals are then applied to pulse generators. Pulse generation is carried out by using separate hysteresis band controller for each filter. The paper represents design of control circuits for both techniques by using Matlab/Simulink. Lastly both filters are integrated to form UPQC which provides compensation for voltage unbalance, voltage sag and voltage harmonics, current harmonics.

## UPQC

### A. Block diagram

The general block diagram of UPQC is shown below which consists of shunt and series active filters with UPQC controller.

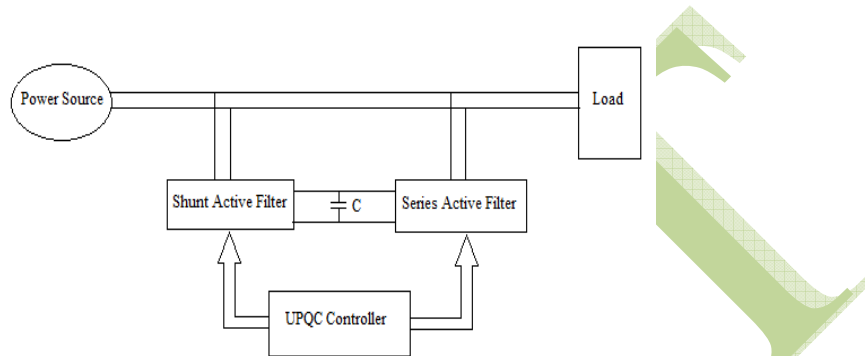


Fig. (a) Block diagram of UPQC

### B. Proposed Scheme of UPQC controller

#### i. modelling equations for shunt and series active filter:

From measured values of phase voltages ( $V_{p1}$ ,  $V_{p2}$ ,  $V_{p3}$ ) and load currents ( $i_{L1}$ ,  $i_{L2}$ ,  $i_{L3}$ ), controller calculates reference currents ( $i_{1r}$ ,  $i_{2r}$  and  $i_{3r}$ ) used to produce compensation currents ( $i_{c1}$ ,  $i_{c2}$ ,  $i_{c3}$ ) and compensation voltages ( $v_{c1}$ ,  $v_{c2}$ ,  $v_{c3}$ ). This is accomplished by calculation of instantaneous active power  $P$  and instantaneous reactive power  $Q$ . This is well known as  $P-Q$  theory as explained below. [2], [3],[6].

#### Step 1:

- Clarke Transformation:

Calculation of  $v_{\alpha}$ ,  $v_{\beta}$ ,  $i_{\alpha}$  and  $i_{\beta}$

$$\begin{bmatrix} v_{\alpha} \\ v_{\beta} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{p1} \\ V_{p2} \\ V_{p3} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_{\alpha} \\ i_{\beta} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{L1} \\ i_{L2} \\ i_{L3} \end{bmatrix} \quad (2)$$

#### Step 2:

- Instantaneous power calculation

Instantaneous real power

$$P = v_{\alpha} \cdot i_{\alpha} + v_{\beta} \cdot i_{\beta} \quad (3)$$

Instantaneous imaginary power

$$Q = v_{\alpha} \cdot i_{\beta} - v_{\beta} \cdot i_{\alpha} \quad (4)$$

**Step 3:**

The compensation signals are derived as follows:

a) Control method for shunt current compensation: [3],[6]

- $\alpha$  &  $\beta$  current calculations.

$$\begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \end{bmatrix} = \frac{1}{v\alpha^2+v\beta^2} \begin{bmatrix} v\alpha & -v\beta \\ v\beta & v\alpha \end{bmatrix} \begin{bmatrix} P \\ Q \end{bmatrix} \quad (5)$$

- Inverse Clarke Transformation : calculation of  $i1r$ ,  $i2r$  and  $i3r$  (Reference current calculation)

$$\begin{bmatrix} i1r \\ i2r \\ i3r \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \end{bmatrix} \quad (6)$$

b) Series voltage compensation Control method by using dual P-Q theory. [6]

$$\begin{bmatrix} v_{c\alpha} \\ v_{c\beta} \end{bmatrix} = \frac{1}{i\alpha^2+i\beta^2} \begin{bmatrix} i\alpha & -i\beta \\ i\beta & i\alpha \end{bmatrix} \begin{bmatrix} P \\ Q \end{bmatrix} \quad (7)$$

- Inverse Clarke Transformation : calculation of  $v1r$ ,  $v2r$  and  $v3r$  (Reference voltage calculation)

$$\begin{bmatrix} v1r \\ v2r \\ v3r \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_{c\alpha} \\ v_{c\beta} \end{bmatrix} \quad (8)$$

**ii. hysteresis controller**

The hysteresis band control technique is used to generate the switching pattern of the inverter. The hysteresis control method is the best among other control methods, as it is quick controllable, easy to implement and unconditioned stability and easy to understand. It gives excellent dynamics and fastest control and requires minimum hardware.

**Two-level hysteresis controller:**

The pulses for both inverters are generated with the help of two level hysteresis controller by applying error signals to it. The error signal is derived by summation of reference signals and load side values. The output is applied to hysteresis controller to generate the pulses. For Positive sum the output switches to high and for negative or zero switches to zero, thus generating positive pulse train. The negation of this positive pulse train is done in order to generate negative pulses [7],[8].

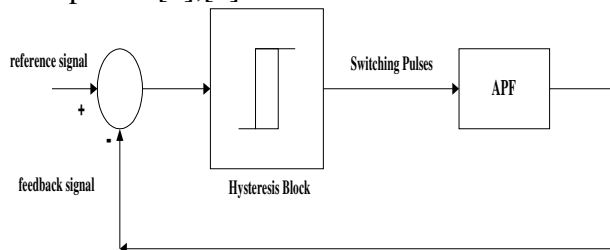


Fig. (b)Hysteresis controller block diagram.

**iii. Shunt controller based on p-q theory**

The matlab/simulink model is shown in Fig. (c)

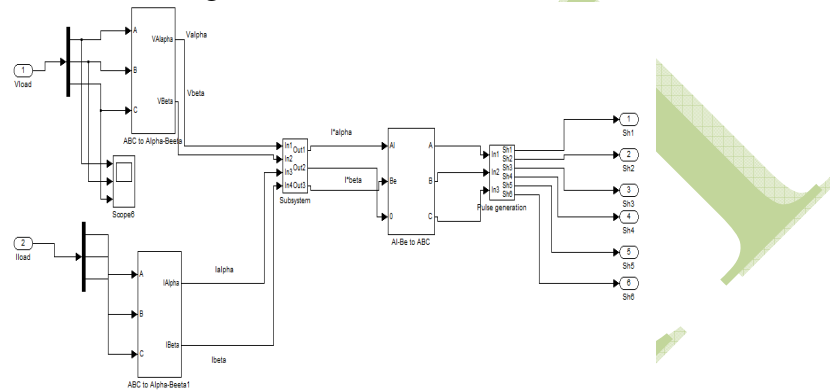


Fig. (c) Simulink model for shunt filter based on p-q theory.

**iv. Series controller based on dual p-q theory**

The matlab/simulink model is shown in Fig. (d)

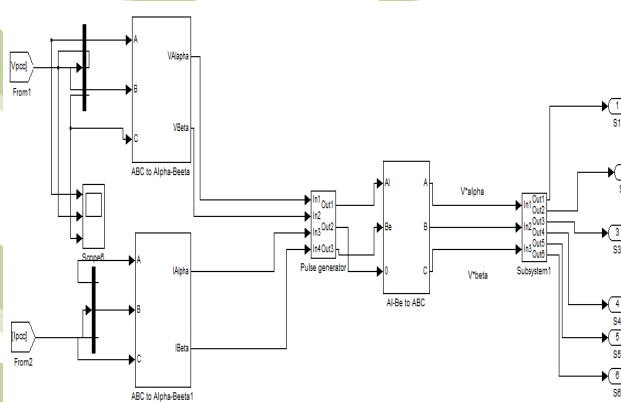


Fig. (d) Simulink model for series filter based on dual P-Q theory.

**C. Simulation Results for UPQC :**

The transition period for both circuit breakers is selected from 0.6 to 0.8. Two cases are considered. In first case when both filters are inactive, there is voltage unbalance and voltage sag at PCC as shown in Fig.(g) and Fig.(h) and when both are operated there is compensation as shown in Fig.(i) .For second case initial status is closed for shunt and series is open. This implies that initially shunt filter active giving load current compensation as shown in Fig. (f) While Fig. (e) Shows load current when shunt filter is inactive.

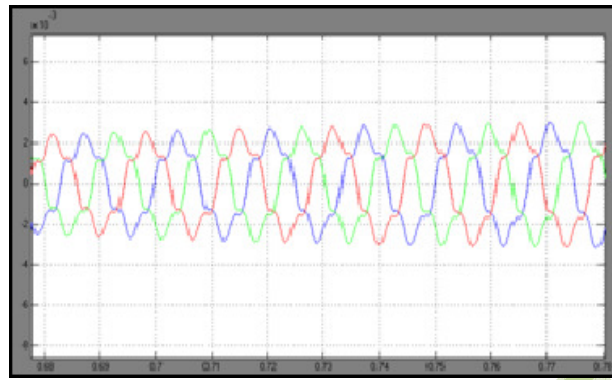


Fig. (e) Load current when shunt filter is inactive.

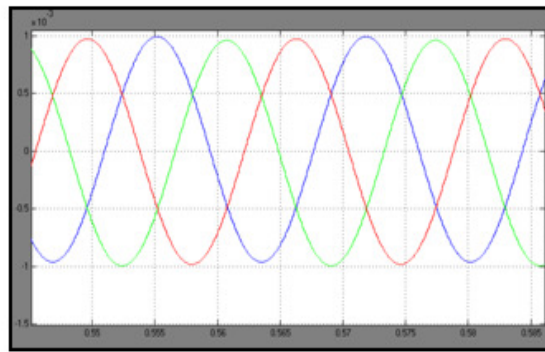


Fig. (f) Load current when shunt filter is operated.

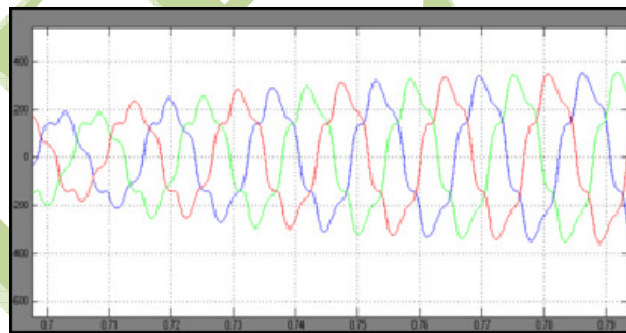


Fig.(g) Voltage at PCC before series filter is operated

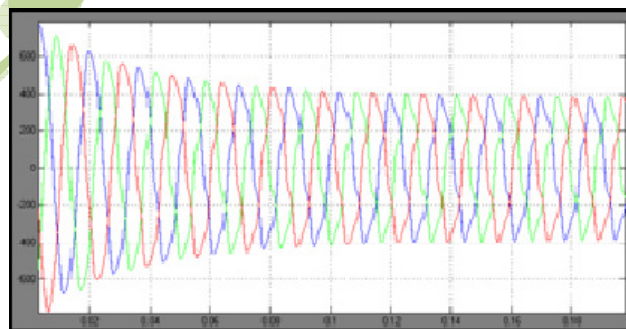


Fig.(h) Voltage sag observed at PCC before operation of series filter.

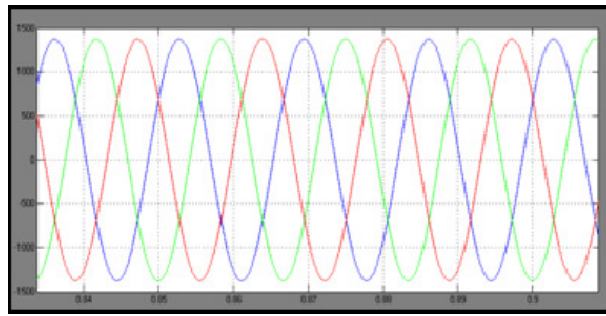


Fig.(i) Voltage at PCC after series filter is operated

## Conclusion

This paper has focused on UPQC which aims at compensating not only current unbalance produced by non linear load but also voltage sag and voltage unbalance appearing at PCC. The control of UPQC is carried out by considering flow of instantaneous active and reactive power which is broadly known as P-Q theory. The simulation can further be modified to eliminate various power quality issues [5], [6].

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