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Harmonic Mitigation in Distribution Network Using Unified Power Quality Conditioner

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Abstract— **This paper presents design, configuration and control of Unified power quality conditioner in distribution network for Harmonic mitigation technique. The d-q-0 and p-q-0 theories are used for controlling of UPQC. The UPQC is a promising custom power device installed in the distribution system to protect the load from PQ distortions and it protects the utility from the penetration of current imperfections. Shunt compensator is used to regulate current distortion and series compensator regulates voltage distortion. The UPQC improves power quality at the point of installation on power distribution systems or industrial power systems. UPQC System is modeled and simulated using the blocks of Simulink**

Keywords: *UPQC, APF and VSI*

I INTRODUCTION

The harmonic voltage and current distortion are strongly linked with each other because harmonic voltage distortion is mainly due to non-sinusoidal load currents. Current harmonic distortion requires over-rating of series components like transformers and cables. As the series resistance increases with frequency, a distorted current will cause more losses than a sinusoidal current of the same rms value. Types of equipment that generate current harmonics are single-phase loads, switched mode power supplies, electronic fluorescent lighting ballasts, small Uninterruptible Power Supply (UPS) units and variable speed drives. Usually for good quality power it is recommended that the THD be less than 3%. The problems caused by current harmonics are overloading of neutrals, overheating of transformers, nuisance tripping of circuit breakers, over-stressing of power factor correction capacitors and skin effect. [1,7]

II UNIFIED POWER-QUALITY CONDITIONER

The Unified Power Quality Conditioner is a custom power device that is employed in the distribution system to mitigate the disturbances that affect the performance of sensitive and/or critical load. UPQC mitigate several power quality problems related with voltage and current simultaneously therefore is multi functioning devices that compensate various voltage disturbances of the power supply, to correct voltage fluctuations and to prevent harmonic load current from entering the power system.[3]

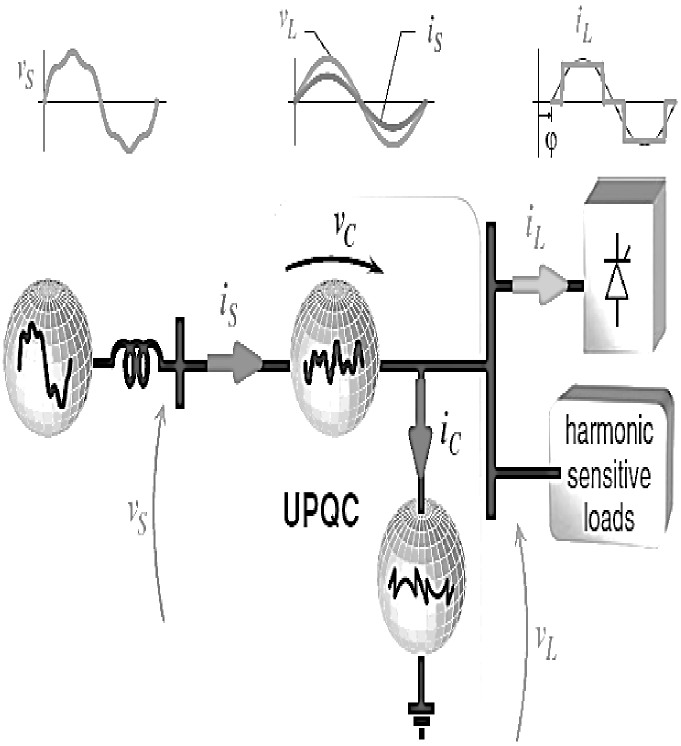

Figure 1. Configuration of the UPQC

The UPQC was constructed from two voltage source inverters, DC link capacitor, series and shunt controllers. The DC link of the two voltage source inverters were connected back to back with a common DC link capacitor. One voltage source inverter (VSI) was connected in series with the source through coupling transformers. Another VSI was connected in parallel between the coupling transformer and load impedance through shunt interfacing impedance known as shunt VSI.[5]

III THE UPQC CONTROLLER

A. INSTANTANEOUS POWER THEORY

Instantaneous power theory is generally preferred for reference current calculation for shunt voltage source inverters. An extended method based on Instantaneous reactive power theory in a rotating reference frame is used to suppress the harmonics and to correct the power factor. p-q Theory is depends on set of instantaneous powers defined in the time domain and applies the Park Transform. It can be applied to

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three-phase systems with or without a neutral wire for three-phase generic voltage and current waveforms. Therefore p-q theory is valid for the steady state and transient state. Also having advantages of efficient and flexible in designing controllers for power conditioners based on power electronics devices.

$$where\ [T] = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}$$

Three phase instantaneous voltages($v_{\alpha\beta 0}$) and currents ($i_{\alpha\beta 0}$) are transformed in to $\alpha\beta 0$ coordinates

$$[v_{\alpha\beta 0}] = [T][v_{abc}]$$

$$[i_{\alpha\beta 0}] = [T][i_{abc}]$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2}\begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix}\begin{bmatrix} p \\ q \end{bmatrix}$$

$$p = \bar{p} + \tilde{p} \quad ; \quad q = \bar{q} + \tilde{q}$$

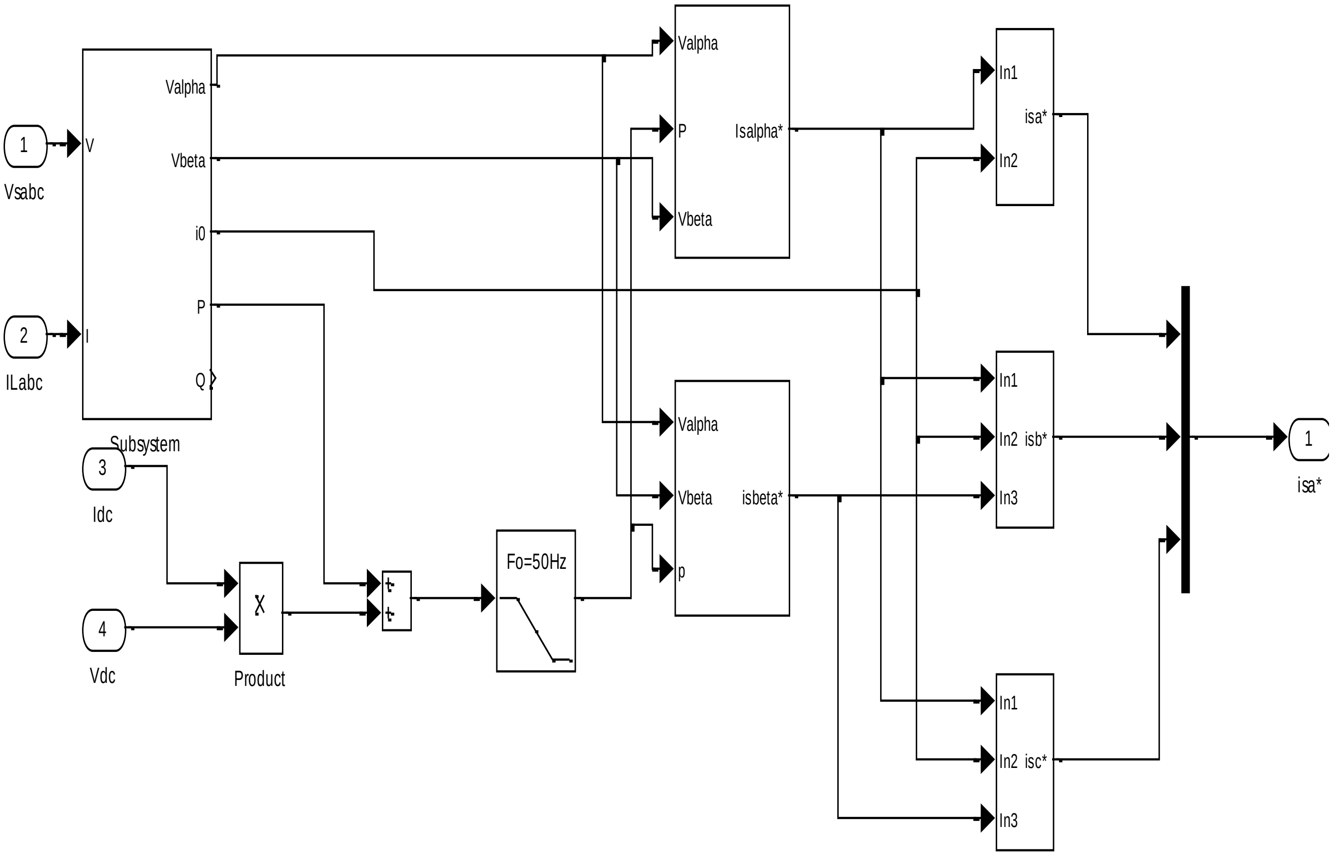

Figure. 2 Instantaneous power theory Simulink model

Where, p and q are the average active and reactive powers originating from the symmetrical fundamental (positive sequence) component of the load current. p is the average active power delivered to the load, and q is the average reactive power drawn by the load. To improve the power factor, q compensated by the shunt active filter. $\tilde{p}$ and $\tilde{q}$ are the ripple active and reactive powers originating from the harmonic and asymmetrical fundamental (negative sequence) components of the load currents. The shunt active filter reference currents in the α-β reference frame will be calculated as[3]

$$\begin{bmatrix} i^*_{\alpha\, ref} \\ i^*_{\beta\, ref} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2}\begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix}\begin{bmatrix} \tilde{p} \\ \bar{q} + \tilde{q} \end{bmatrix}$$

B.d-q-0 THEORY

Series control technique is to regulate series APF in order to compensate voltage related PQ distortions and maintain a rated load voltage. The d-q-0 theory is used to series control technique performing functions of generation of reference voltage signal, capture of voltage related PQ distortions and pulse generation for series APF.

A distorted source voltage for 400V/50 Hz utility system which includes the sag, swell, unbalanced and harmonic distortions are present in the source voltage. Supply voltages

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Vsabc are transformed to d-q-0 coordinates. The voltage in d axes (V_{sd}) consists of average and oscillating components of source voltages.

$$\begin{bmatrix} v_{s0} \\ v_{sd} \\ v_{sq} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \sin wt & \sin(wt - \frac{2\pi}{3}) & \sin(wt + \frac{2\pi}{3}) \\ \cos wt & \cos(wt - \frac{2\pi}{3}) & \cos(wt + \frac{2\pi}{3}) \end{bmatrix} \begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix}$$

$$v_{sd} = \overline{v_{sd}} + \widetilde{v_{sd}}$$

The average voltage is calculated by using second order Low Pass Filter. The load side reference voltages V_{Labc}^{*} are calculated. The switching signals are assessed by comparing reference voltages (V_{Labc}^{ref}) and the load voltages (V_{Labc}).

$$\begin{bmatrix} v_{La}^{ref} \\ v_{Lb}^{ref} \\ v_{Lc}^{ref} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin wt & \cos wt & 1 \\ \sin(wt - \frac{2\pi}{3}) & \cos(wt + \frac{2\pi}{3}) & 1 \\ \sin(wt + \frac{2\pi}{3}) & \cos(wt + \frac{2\pi}{3}) & 1 \end{bmatrix} \begin{bmatrix} v_{sd} \\ 0 \\ 0 \end{bmatrix}$$

Errors are then processed by sinusoidal PWM controller. To generate the required switching signals for series APF IGBT switches

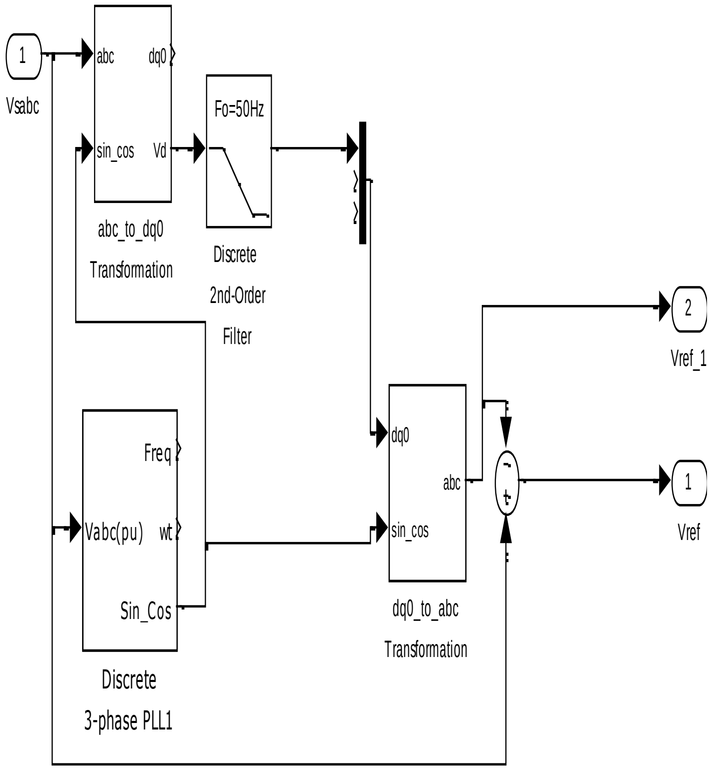

Figure. 3 d-q-0 theory Simulink model

Following results shown FFT analysis for voltage and current.

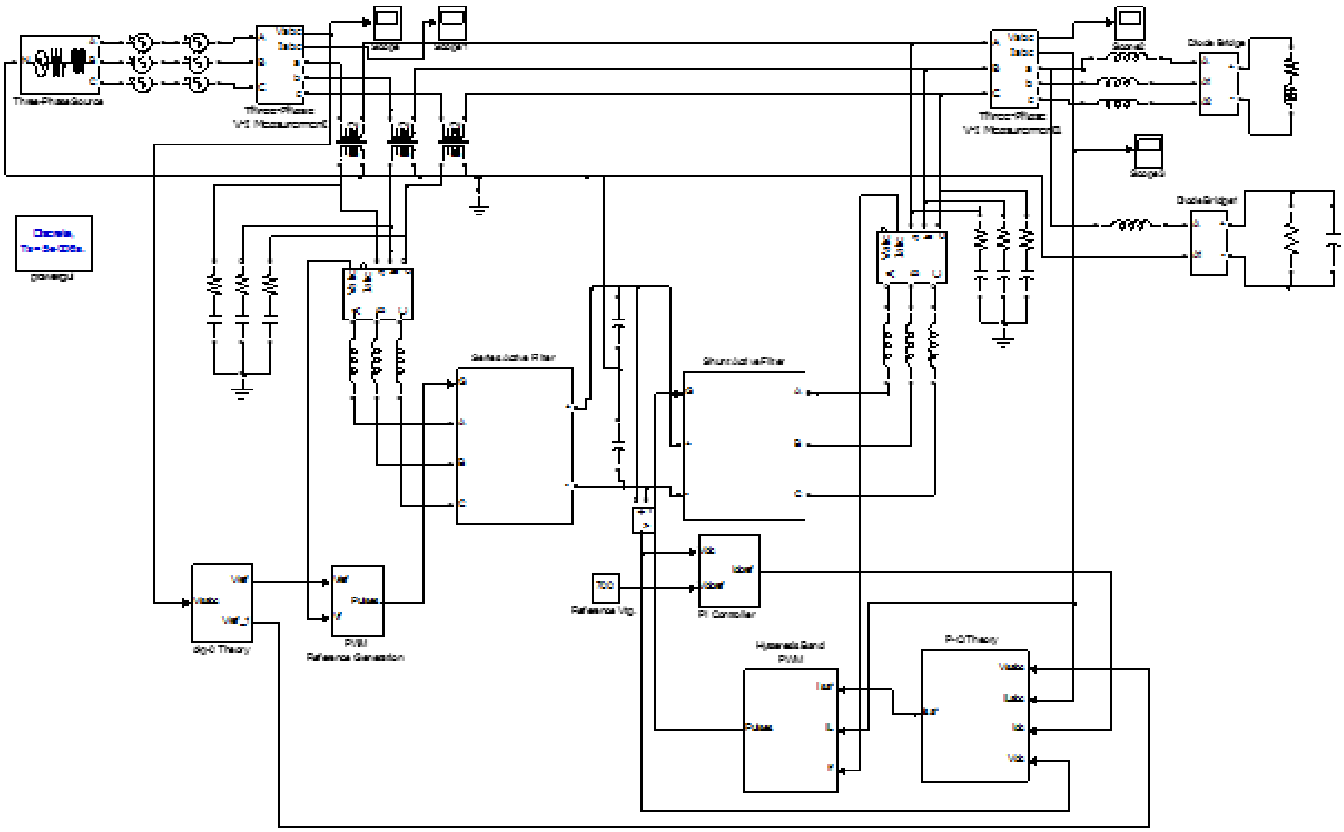

Figure 4 UPQC control Matlab block diagram

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IV SIMULATION RESULTS

In Proposed UPQC matlab/simulink model control methods for UPQC in Distribution network found following results shown FFT analysis for voltage and current.

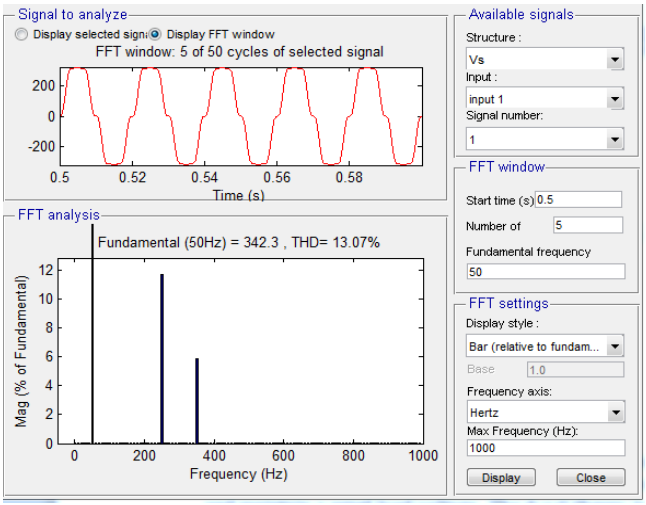

Figure 5 Source voltage (V_S)

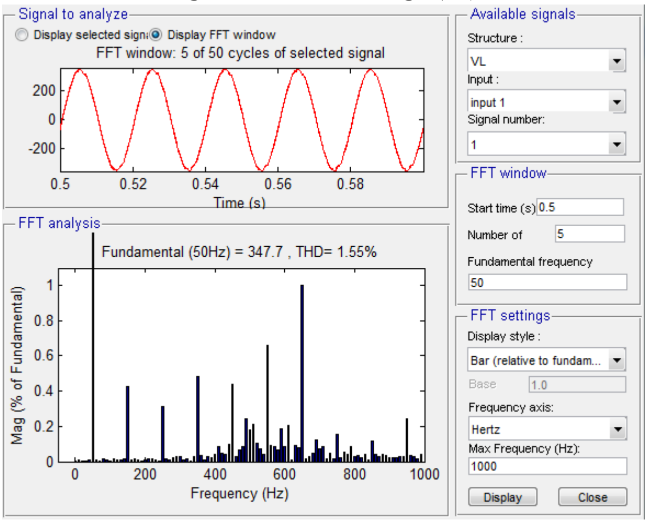

Figure 6 Load voltage (V_L)

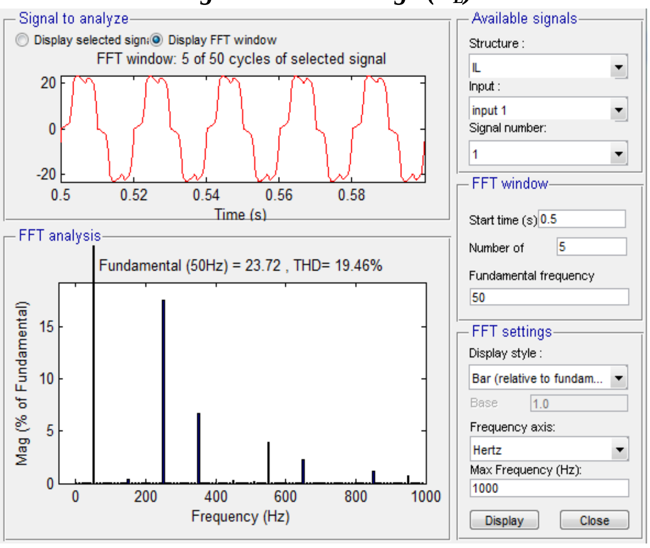

Figure 7 Load current (i_L)

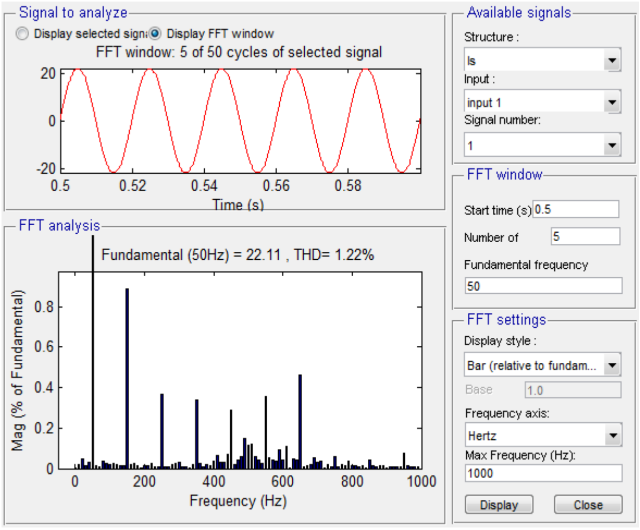

Figure 8 Source current (i_S)

Table 1 Total Harmonic distortion

THD	Vsabc	VLabc	ILabc	Isabc
400V	13.72	0.99	19.33	0.93
420V	13.07	1.55	19.46	1.22
440V	12.48	2.02	19.65	2.06

V CONCLUSION

Distribution network deals with the mainly two problems firstly supply side faults i.e. voltage disturbances and secondly nonlinear load connected to utility side i.e. current harmonics. For different supply proposed system results are observed before compensation, for 440V the THD level of the load voltage was a 12.48% and the source current was 19.65%; after compensation, the THD level of the load voltage is approximately 2.02% and the source current is approximately 2.06%. Future scope is for cost effective and hardware prototype implementation.

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