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Unified Power Quality Conditioner for Current Quality Improvement

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ABSTRACT

Presence of power quality disturbances highly influences the performance of power system. Most modern electrical appliances for example industrial drives, electronic ballast fluorescent lights, switching power supplies and so forth are becoming increasingly power electronics based. Whereas these loads possess certain advantages like, enhanced controllability, high power density and so forth, they also bring with them disadvantages which were not there in the early power distribution systems. Some of these disadvantages include increased sensitivity to supply voltage, harmonics and reactive power requirements. These inherent characteristics of power electronic based loads have helped to raise awareness of power quality issues. Most of the word nowadays moving towards the implementation of renewable energy resources to support the rapid increase in load demand. The integration of renewable energies and their accommodation in the existing electricity networks is often a complex issue and is making the electric power distribution networks more susceptible to power quality problems. There are several methods to illuminate all this problems depending upon their severity. One of the best solution for these all power quality issues i.e. unified power quality conditioner is discuss in this paper. A three phase four wire system is analysed in Simulink with different control algorithm.

Keywords: Series APF, Shunt APF, harmonic compensation, voltage quality improvement, control strategies.

INTRODUCTION

In recent year, there is incredible use of complex systems with technologically advanced component such as non-linear load, Uninterruptable power supply, rectifier loads, power electronics devices in domestic as well as industrial area. These components not only affect the source but also impure the power supply inherently. This will replicate the generation of various power quality disturbances such as noise, voltage harmonics, current harmonics, transients, etc. The effect of all these power quality issues are always depends upon cause of disturbances and its occurrence.IEC and IEEE design various international standards for power quality safety and awareness. The solutions to all the power quality obstacles will also depends upon its causes of occurrences, location, time period effect, frequency of occurrence. These all changes in behaviour of supply system also affect on the end users equipment.

Today's power system is usually as three phase three wire or three phase four wire fetching with significant limit to voltage source with source impedance and having a mixture of various types of loads. As per the IEEE standards and view of ideal condition of power systems a pure and balance three phase voltage of constant magnitude should be provided to consumer with as less as possible power quality problems. However with the use of power electronics devices and several non-linear loads,reactive,single phase and unbalance three phase load making structure of system more complex with several power quality issues. At the same side in recent year several active methods of improving power quality have been highlighted with their fast response and

small structure such as different active power filters and unified power quality conditioner which can be used to remove power quality issues for both series and shunt side of the systems [1].

UNIFIED POWER QUALITY CONDITIONER

Theunified power quality conditioner is the solution for different power quality issues.The ultimate aim of UPQC to solve all these power quality problems with help of series and shunt active power filters which is normally used to compensate the voltage unbalance, reactive power, negative sequence current and harmonics. In another way the UPQC has compatible and satisfied performance for utility as well as consumer side at point of installation on power distribution system or industrial power system. Hence UPQC is expected as one of the highly responsive powerful solution to large capacity loads which is more sensitive to voltage impurities such as flickers or imbalance. The UPQC provides solution to all problems in different ways which is partially divide UPQC in two parts namely series active power filter and shunt active power filter. The series normally nullify the problems on supply side which include illumination of voltage flickers or imbalance, voltage sag and voltage swell. The voltage flickers generally accomplished by low frequency fluctuation of active power flowing into or out of series active filters. The shunt active filter performs dc link voltage regulation thus leading to significant reduction of capacity of DC link capacitor [9].

The UPQC is hybrid combination of series-shunt active power filters. The circuit topology of series and shunt active filter is discuss below.

Also the performance of UPQC classified on the basis of reference to be calculated for the determination of compensation signal such as current or voltage which is normally used for performance of convertor called as current source convertor based UPQC and voltage source base UPQC.In this paper simple structure of UPQC which is union of series and shunt active power filter based on voltage source convertor topology is going to be discuss [2]. In addition to series-shunt filters the energy storage capacitor is also the part of UPQC system which provide constant DC link voltage may be a limb of single capacitor or two capacitor separate by ground.

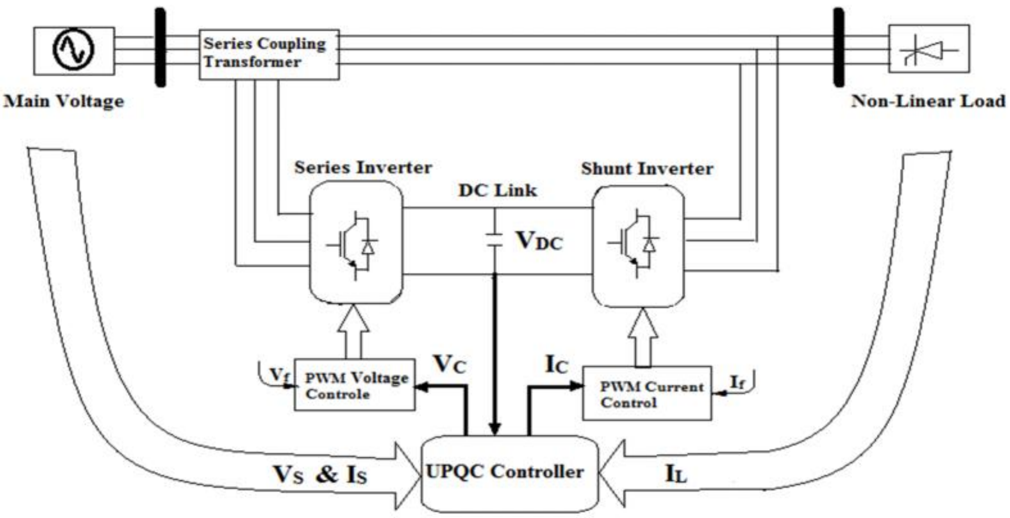

Fig.1 Representation of UPQC

UPQC BASED ON CSC TOPOLOGY

In this topology the UPQC is connected to distribution line through passive filters used to mitigate rate of change of current by switching of power valve current source convertor. The unique identity of this topology is based on the union series active filter and shunt active filter sharing a common DC reactor. The resulting equipment is installed to closed to a critical load at the same side it can compensate simultaneous with PCC voltage and load power factor. The benefits of CSC base UPQC is

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- Rapid response of accommodating disturbance due to existence of first order filters stage.
- Neutral current protection due to short circuit to dc link reactor.

UPQC BASED ON VSC TOPOLOGY

Currently the study of UPQC network topology using VSC is well documented but not using CSC base topology, which is being to be utilised as alternative for UPQC-VSC for a instant in medium voltage drive. In this topology the UPQC is interface to the line by switching the DC capacitor link.

The structural performance of this conditioning device can be well understood by smooth execution of series and shunt active filter for the compensation on both the side of system as discuss below [6].

SERIES ACTIVE POWER FILTER

The series active filter is normally used to reduce the problem related to supply voltage side. This filter protects the consumer from inadequate supply voltage quality. Such type of approach practically used to compensate the voltage sag and voltage flickers from Ac supply and for low power application. This results no energy storage and overall ratings of the component is smaller. The series active filter injects required voltage component depends upon the relevant control algorithem.The series active filter interface to the main system through different resistive and inductive elements also called as passive filters. Also the SAF connect the main system through three phase injected transformer. A voltage source inverter (VSI) is series active power filter. Ultimate aim of this topology is to draw a compensating voltage (Vc).The Vc from or to the supply as per the requrment [4].Normally the control algorithm based Synchronous reference frame theory is used to analysed reference signal generation (Reference voltage signal).This theory based on direct and quadrature axis components of voltage. The execution of SRF theory for the SAF can be as below.

SRF BASED CONTROL ALGORITHM

SRF based UPQC control algorithm can solve power quality problems related with source voltage impurities, unbalance voltage, voltage sag, voltage swell with series active filters also it can moderately use for compensation of few shunt problems which required separate modified PLL (**Reference**).In this method proposed algorithm will calculate the reference to be injected by the series transformer by comparing positive sequence voltage of source (V_{Sabc}) to load side line voltage (V_{Labc}).At first the source voltage component is converted into the D-Q-0 voltage component as illustrate below [3].

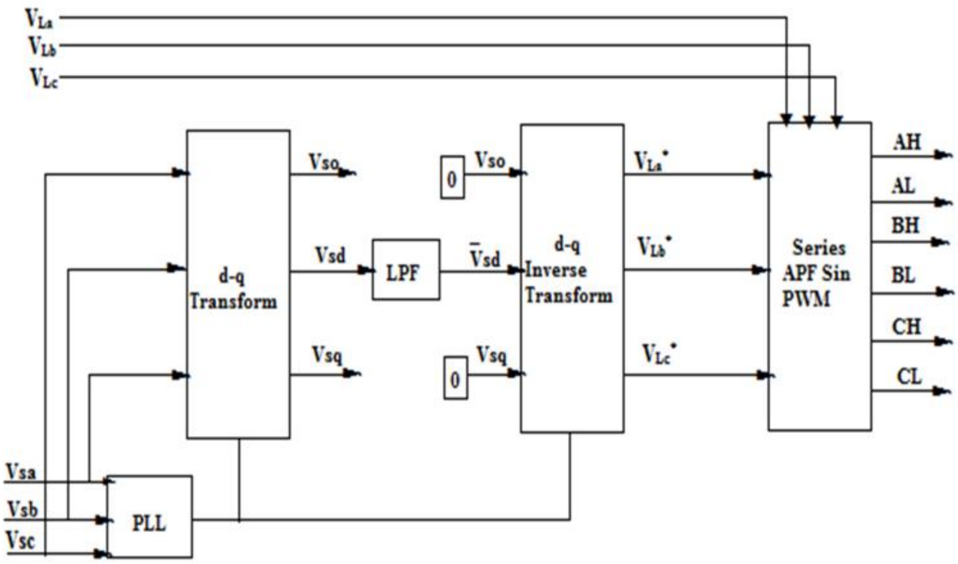

Fig.2 Control Algorithm for SRF Theory

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$$\begin{bmatrix} V_s \\ V_s \\ V_s \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \mathrm{Sin}(wt) & \mathrm{Sin}(wt-\frac{2}{3}) & \mathrm{Sin}(wt+\frac{2}{3}) \\ \mathrm{Cos}(wt) & \mathrm{Cos}(wt-\frac{2}{3}) & \mathrm{Cos}(wt+\frac{2}{3}) \end{bmatrix}\begin{bmatrix} V_s \\ V_s \\ V_s \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} V*_L \\ V*_L \\ V*_L \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \mathrm{Sin}(wt) & \mathrm{Cos}(wt) & 1 \\ \mathrm{Sin}(wt-\frac{2}{3}) & \mathrm{Cos}(wt-\frac{2}{3}) & 1 \\ \mathrm{Sin}(wt+\frac{2}{3}) & \mathrm{Cos}(wt+\frac{2}{3}) & 1 \end{bmatrix}\begin{bmatrix} V_S \\ 0 \\ 0 \end{bmatrix} \quad (2)$$

The obtained stream of D-Q-0 voltage component are consist of DC and AC components of voltages. This newly obtain voltage component are reconverted into the a-b-c component of voltage ($V*_{Sabc}$) by using inverse transformation as shown below. The basic switching signals are resultant of comparison of calculated reference source voltage and load line voltage.

SHUNT ACTIVE POWER FILTER

Normally reactive power theory is effectively used for shunt analysis of UPQC to solve problems related to the current such as current harmonics. In this method instantaneous reactive power theory is used as control algorithm for shunt active power filter in real time. In this algorithm the instantaneous current and voltage are transfer to α-β-0 domain from basic a-b-c coordinate which is illustrate as below by using a-b-c to α-β-0 transformation techniques [5,10].

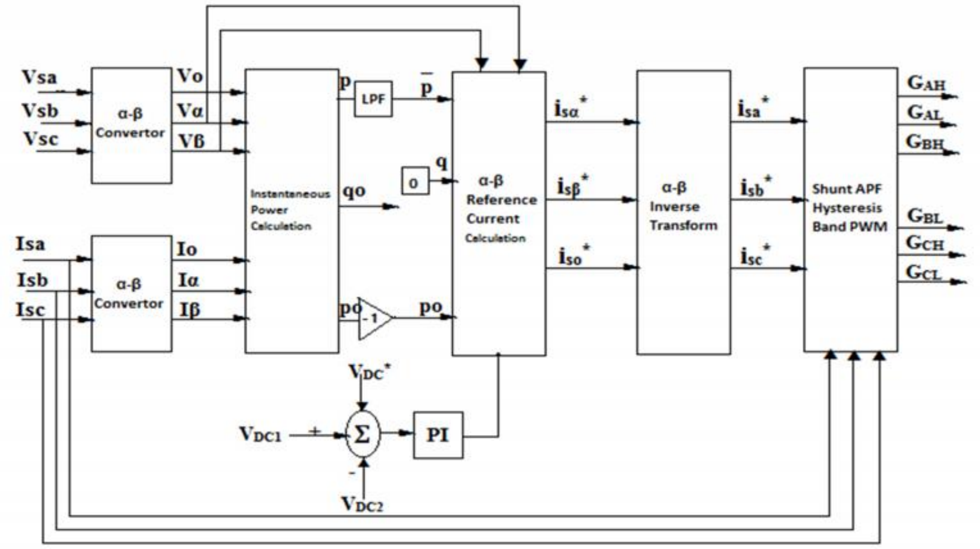

Fig.3 Control Algorithm for PQ Theory

$$\begin{bmatrix} V_0 \\ V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \sqrt{\frac{3}{2}} & -\sqrt{\frac{3}{2}} \end{bmatrix}\begin{bmatrix} V_S \\ V_S \\ V_S \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} I_0 \\ I_\alpha \\ I_\beta \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \sqrt{\frac{3}{2}} & -\sqrt{\frac{3}{2}} \end{bmatrix}\begin{bmatrix} I_S \\ I_S \\ I_S \end{bmatrix} \quad (4)$$

The sin1k side active and imaginary power components are derived by using load current and phase-neutral voltage as given in below expression

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} \qquad (5)$$

Again the instantaneous real and imaginary power includes the content of AC and DC components

$$P_0 = V_0 * I_0 \quad ; \quad p = \overline{p} + \tilde{p} \ (6)$$

DC component of active and reactive power will be derived from positive sequence component ($\overline{p}$ and $\overline{q}$) of load current.AC component ($\tilde{p}$ and $\tilde{q}$) of p and q consist of harmonics and negative sequence component of load current [7].

In order to illustrate neutral current P_0 was calculated by using DC and AC component of imaginary power and AC component of real power as shown below

$$\begin{bmatrix} I_{S\alpha}{}^* \\ I_{S\beta}{}^* \end{bmatrix} = \frac{1}{V_\alpha{}^2 + V_\beta{}^2} \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} + p_0 + \overline{p_{l0}} \\ -q \end{bmatrix} \qquad (7)$$

Here $I_{S\alpha}{}^*$ and $I_{S\beta}{}^*$ are reference current of shunt active power filter in terms of α-β coordinates.Now derived components are transformed into three phase system.All the calculations of currents i.e. $I_S{}^*$,$I_S{}^*$,$I_S{}^*$ are done to neutralised the harmonics and reactive current at load side [10].

MATLAB SIMULATION AND RESULTS

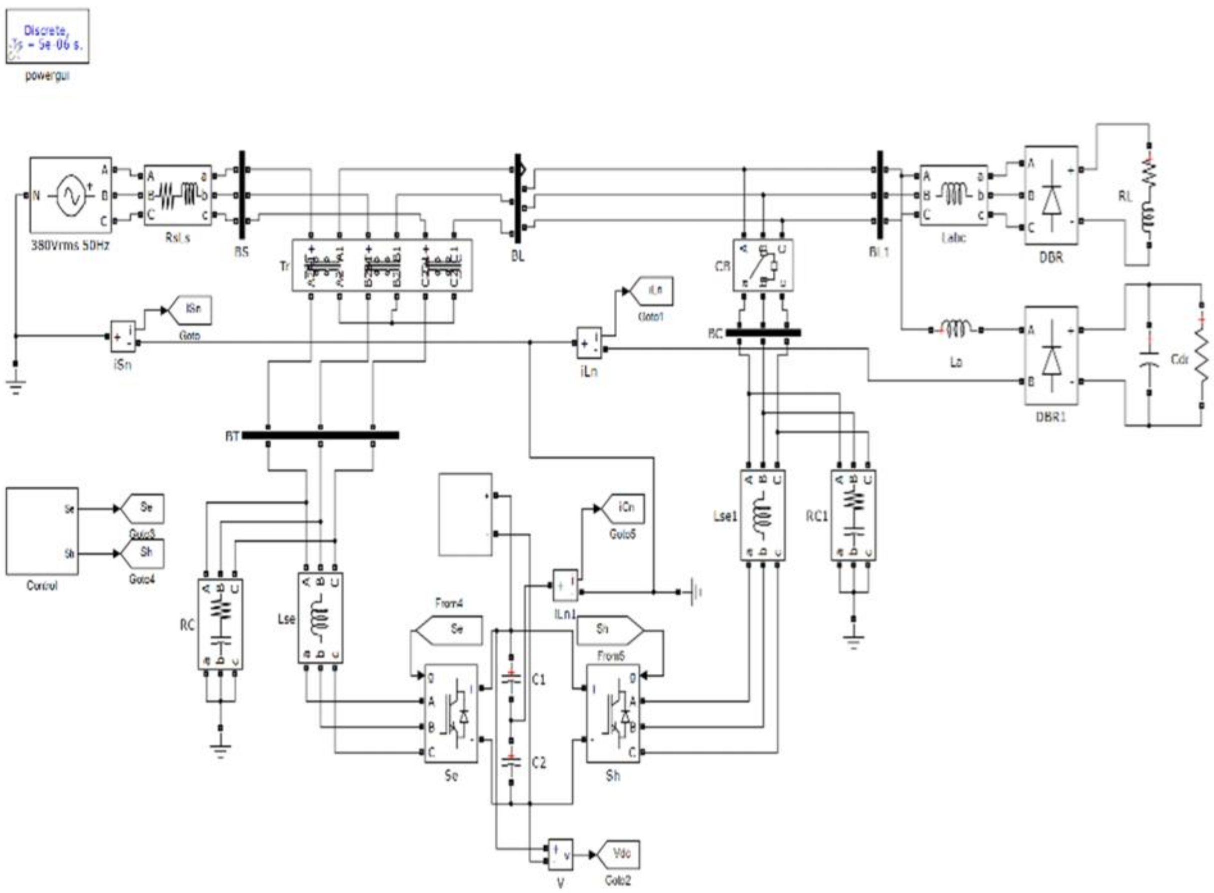

Fig.4 Matlab Simulation of Unified Power Quality Conditioner

	Parameter	Value
Source	Voltage	380 V_r
	Frequency	50 Hz
Load	DC Inductance	10mH
	DC Resistance	30Ω
DC Link	Voltage,Capacitance	700V, 2200µF
PAF	Coupling inductance	3.5mH
SAF	Coupling inductance	1.5mH

Table 1. UPQC System Parameter

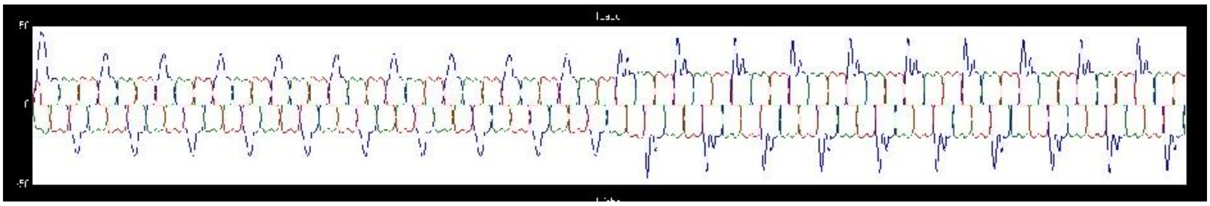

Fig.5 Load Current

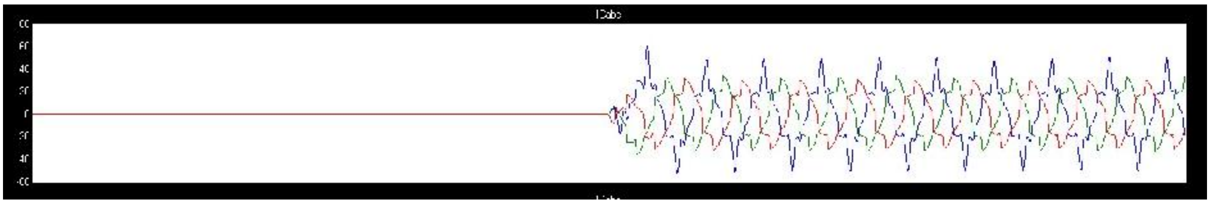

Fig.6 Compensating Current

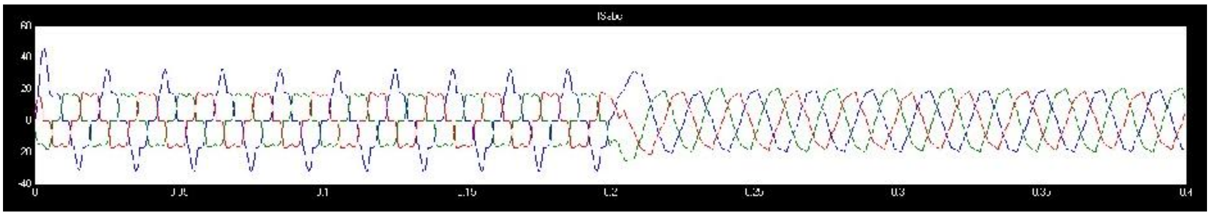

Fig. Source Current before and after Compensation

CONCLUSION

A novel controller for the UPQC is implement and analysed by using both shunt and series converter based on control algorithm and dc-link voltage regulation with synchronous frame reference theory and instantaneous reactive power theory. The SRF algorithm used here to determine series compensating signal and the same side PQ control is used to determine shunt compensating signal. The control scheme of UPQC has been validated for compensation for current harmonics conditions. The simulation results notify the elimination of harmonic component from source current using the Control algorithm. It can also be observed that use of PQ to the shunt APF can compensate the harmonic in terminal current and can maintain desired total harmonic distortion.

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