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Power Quality Management using Unified Power Quality Conditioner

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***Abstract*—In this paper, a unified power quality conditioner (UPQC) is used for simultaneous compensation of current harmonics and voltage variations due to fault conditions in to grid. For improving power quality series and shunt compensation is provided in form of UPQC, in which series APF and shunt APF are connected through a common DC link. Synchronous reference frame theory is used to generate reference signals for both series and shunt active power filters. Series active power filter is used to compensate voltage related distortions and shunt active power filter is used to compensate current related problems. PI controller is used to stabilize the level of DC link voltage.**

***Keywords*—UPQC, Series APF, Shunt APF, PWM, Harmonics, Voltage Regulation**

I. INTRODUCTION

Power quality has become an important issue these days due to degradation of power quality due to increasing non linear loads, and due to increasing use of renewable energy resources in distributed power generation. Some other reasons of poor power quality are arc welding machines, current regulators, switch mode power supplies(SMPS), low power consumption lamps, various types of faults and switching etc. These are the reason for pollution in distribution system. So due to increase in harmonic content in power at distribution side, both electric utilities and power consumer are concerned about the power quality. Active power filters are considered as efficient tool for power quality management. There are two types of active power filters series APF and shunt APF. The series APF is used to compensate all voltage related problems and shunt APF is used to compensate all current related problems. The combined operation of series and shunt APFs is called unified power quality conditioner (UPQC). In this paper a UPQC controlled by SRF theory is used to compensate current harmonics and voltage distortion in line due to nonlinear loads and fault conditions.

II. UNIFIED POWER QUALITY CONDITIONER

The basic circuit of UPQC is shown in Fig.1. It consists of a combination of series active power filter and shunt active power filter connected through a common DC link. In this system the series APF is used to control voltage regulation, flicker and voltage harmonics at utility-consumer point of common coupling (PCC). The shunt APF is used to compensate current harmonics, provide reactive power and is used to regulate DC link voltage between series and shunt APF. So UPQC can compensate all power quality problems at same time. There are various types of circuit topologies used for UPQC like left shunt UPQC, right shunt UPQC, OPEN UPQC, interline UPQC etc, but mostly used circuit is right shunt UPQC. Because the performances of right shunt UPQC is more than other types. The basic structure of right shunt UPQC is shown in Fig.1.

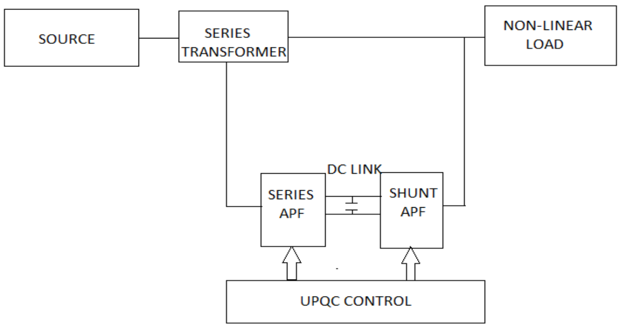

Fig.1. Basic Configuration of UPQC

III. SYNCHRONOUS REFERANCE FRAME THEORY

The proposed system consists of three phase voltage source, a non linear load consisting of bridge rectifier with R-L load, two voltage source converters VSCS connected through a common DC link, A series Transformer and control blocks separately for both shunt and Series Connecters.

The control scheme is based on Synchronous Reference frame theory. The important characteristic of this theory is its simplicity in terms of calculations .In calculation part only algebraic calculations are involve which makes this control simple as compare to other algorithms .SRF works on park's transformation (d-q) and inverse$(d\text{-}q)^{-1}$ park transformation. The transformation is done from three phase a-b-c to direct axis (d) and quadratic axis (q).Phase Locked Loop (PLL) is used to generate sine and cosine functions .which helps to maintain synchronization with supply voltage and current. When the power system is nonlinear then d and q axis currents and voltage include both oscillating ($\tilde{id}$ and $\tilde{iq}$) and average components ($\overline{id}$ and $\overline{iq}$) . A proper balanced three phase system with linear parameters contains the fundamental positive sequence components only. But in case the system is connected with non linear loads and there are some unbalanced conditions then load voltage and current includes positive, negative and zero sequence components. In active power filter the positive sequence components should be separated with the help of LPF in order to compensate the harmonics.

A. Reference signal generation for series APF

To generate reference signal for series Active Power Filter, synchronous reference frame theory (SRF) is used, in which park's transformation and inverse park's transformation are used along with low pass filter .In this control strategy the reference value which is to be injected by series transformer is calculated, for this supply voltages V_{sabc} are transformed to V_{dqo} by transformation matrix T.

$$\begin{bmatrix} Vsd \\ Vsq \\ Vso \end{bmatrix} = T \begin{bmatrix} Vsa \\ Vsb \\ Vsc \end{bmatrix}$$; And T is given as

$$T = \sqrt{2/3} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ \sin(\omega t) & \sin(\omega t\text{-}2\pi/3) & \sin(\omega t\text{+}2\pi/3) \\ \cos(\omega t) & \cos(\omega t\text{-}2\pi/3) & \cos(\omega t\text{+}2\pi/3) \end{bmatrix}$$

Here Vsd and Vsq contains average ($\bar{V}sd$ and $\bar{V}sq$) and oscillating ($\tilde{V}sd$ and $\tilde{V}sq$) components. Here $\tilde{V}sd$ and $\tilde{V}sq$ consists of harmonics and negative sequence components. While the average components consists of fundamental components of supply voltage .The zero sequence component Vso occurs only when the voltage is unbalanced .The source voltage in d-axis Vsd includes both average and oscillating components and is given as .

$$Vsd = \tilde{V}sd + \bar{V}sd$$

The reference voltage V'abc is calculated as,

$$\begin{bmatrix} V'a \\ V'b \\ V'c \end{bmatrix} = T^{-1} \begin{bmatrix} 0 \\ \bar{V}sd \\ 0 \end{bmatrix}$$; And T^{-1} is given as

$$T^{-1} = \sqrt{2/3} \begin{bmatrix} 1/\sqrt{2} & \sin(\omega t) & \cos(\omega t) \\ 1/\sqrt{2} & \sin(\omega t\text{-}2\pi/3) & \cos(\omega t\text{-}2\pi/3) \\ 1/\sqrt{2} & \sin(\omega t\text{+}2\pi/3) & \cos(\omega t\text{+}2\pi/3) \end{bmatrix}$$

The zero sequence and q-axis components are set to zero to compensate load voltage harmonics, distortions and unbalances in voltage. The reference signal will be compared with load voltages to generate the gate pulses with the help of PWM technique. In this calculation the negative and zero sequence components are not considered and the reference signal is generated only with the help of d-axis components so that load voltage harmonics, distortion can be compensated generally gate signals are generated with the help of SPWM or hysteresis band controller.

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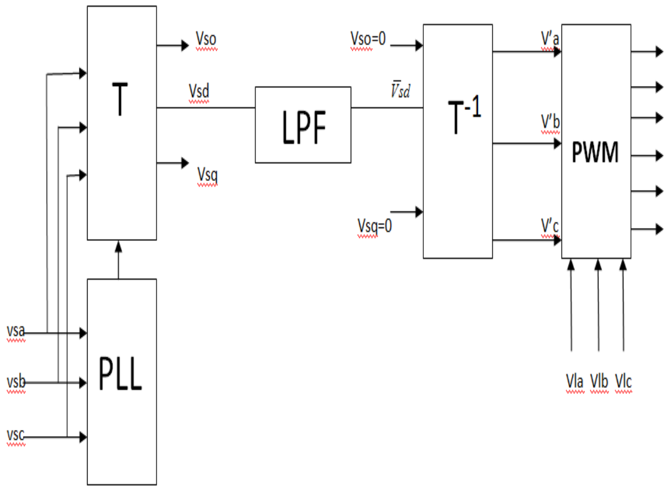

Fig: 1. Control of series APF

B. Reference signal generation for shunt APF

It injects the equal amount of harmonics compensating current in opposite to harmonics current, shifted at 180^0 .The control strategy includes the transfer of source current from a-b-c to d-q-o frame as,

$$\begin{bmatrix} isd \\ isq \\ iso \end{bmatrix} = T \begin{bmatrix} isa \\ isb \\ isc \end{bmatrix}$$

If the load is non linear then source current includes both oscillating ($\tilde{i}sd$ and $\tilde{i}sq$) and average components ($\bar{i}sd$ and $\bar{i}sq$). The average components include positive sequence components only, and the oscillating components include harmonics and negative sequence components. Zero sequence components are absent in balanced system and appear only when there are some unbalanced conditions. To maintain DC link voltage shunt APF will absorb some active power from power system. DC voltage is compared with reference DC voltage and required active current (i_{dloss}) is obtained by PI controller. The reference current is calculated by adding $\bar{i}sd$ and required active current $i_{dloss.}$

$$i'sd = i_{dloss.} + \bar{i}sd$$

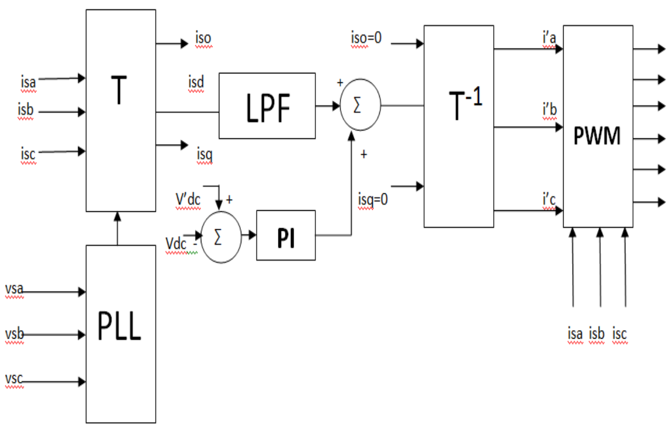

Fig: 2. Control of shunt APF

IV. SIMULATION RESULTS

In this analysis a simplified control algorithm is used for both series and shunt active power filters. The proposed system is simulated using MATLAB software and results of uncompensated and compensated system are compared. First of all system without UPQC is shown below in fig: 3.

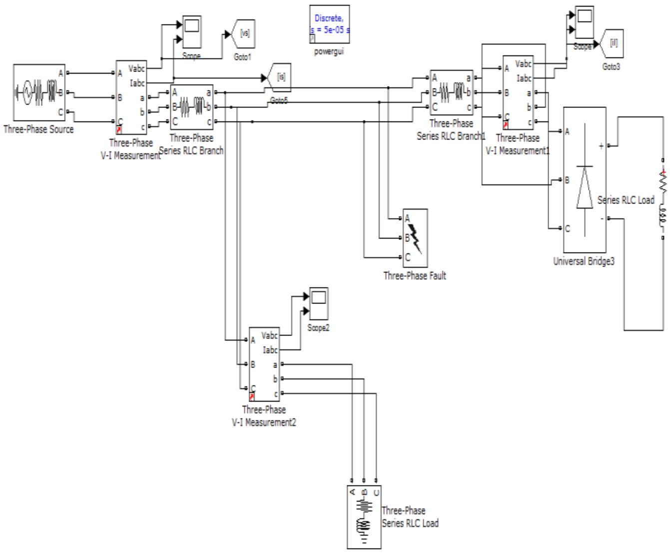

Fig: 3. System without Compensation

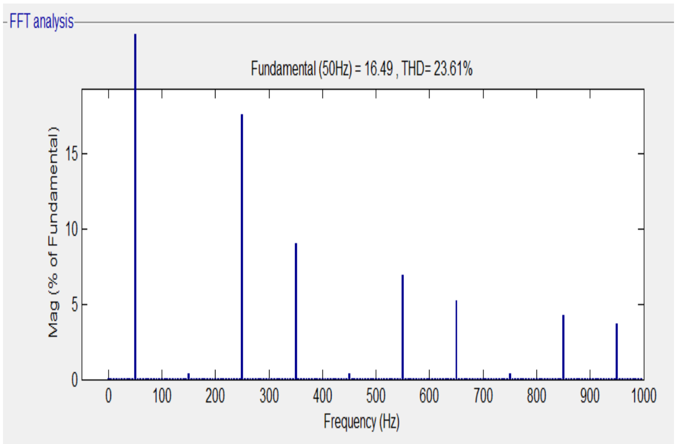

Fig: 4. THD of line current without UPQC

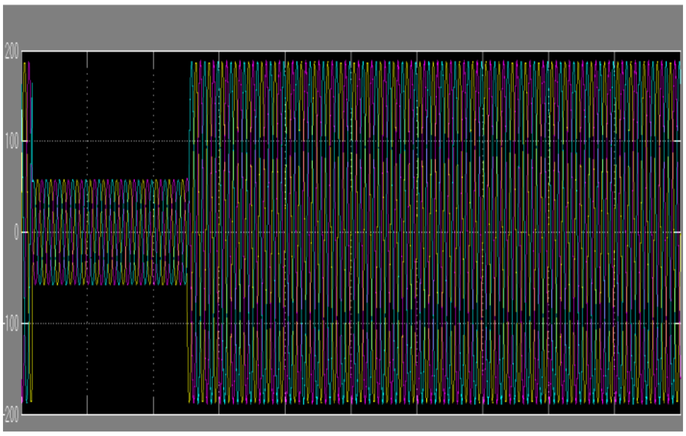

Fig: 5. Line Voltage without UPQC

As the system is connected with nonlinear load and there is no compensation in above case therefore the THD level at point of common coupling is PCC is 23.61% and the voltage level at PCC goes down due to fault ate distribution side. so both current and voltage are not in desired condition for other sensitive loads. In next case the system is studied with UPQC.

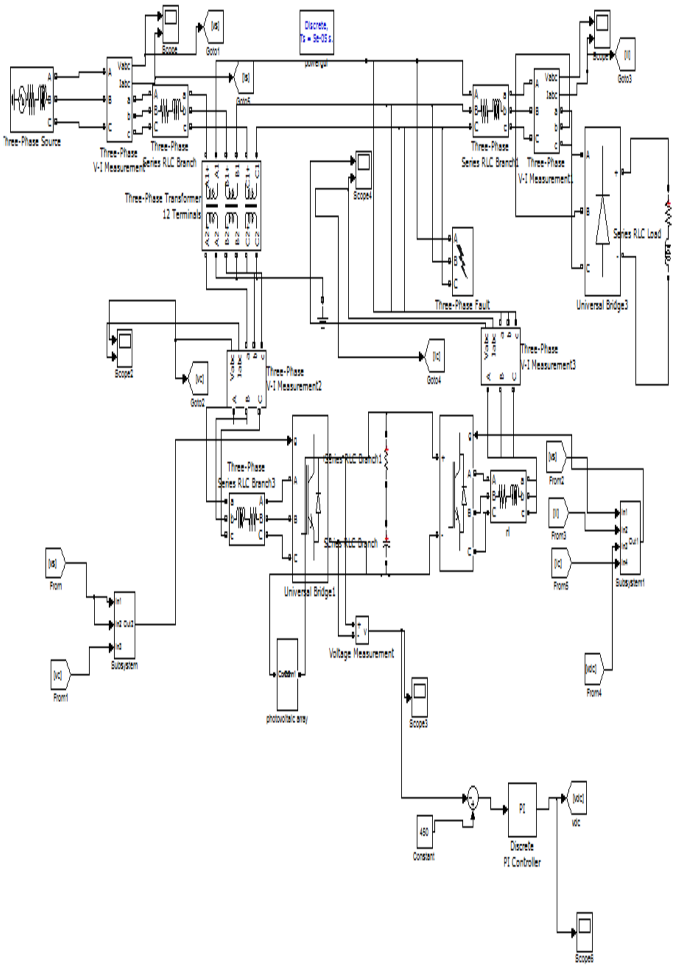

Fig: 6. System compensated with UPQC

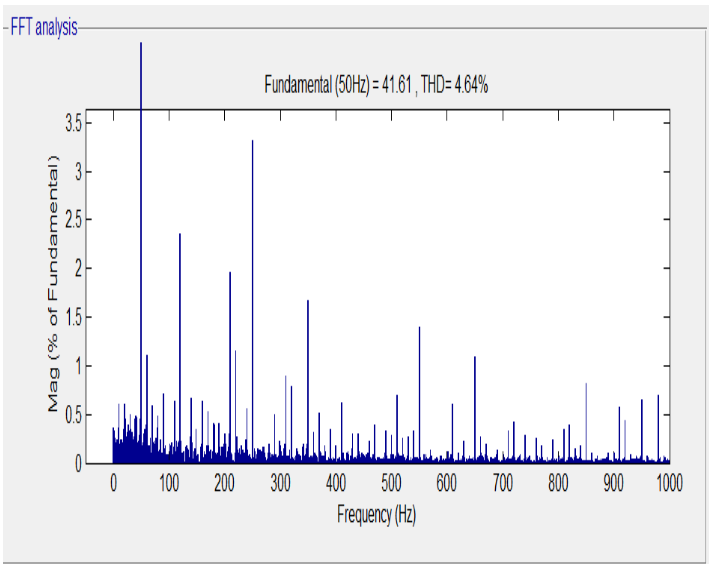

Fig: 7. THD of line current with UPQC

It is clear from above THD analysis that after connecting UPQC with system the THD level at pint of common coupling goes down to 4.64% from 23.61%. Now the voltage form after connecting UPQC is shown below in Fig: 8.

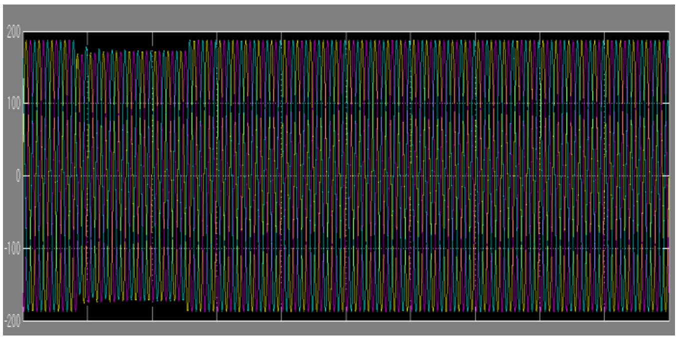

Fig: 8. Line voltage with UPQC

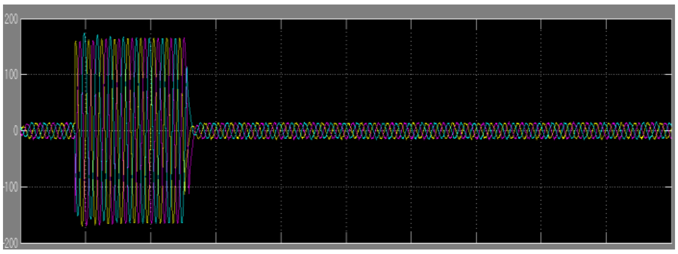

Fig: 9. Voltage Injected by UPQC

It is clear that when voltage decreases due to fault condition in distribution side, then line voltage decreases due to sink created by fault, and UPQC starts providing voltage in series with line voltage to maintain line voltage so that other loads can be protected against low voltage condition.

Design Specifications and circuit Parameters	
Supply voltage	230V
Fundamental Frequency	50HZ
Switching frequency	1080HZ
Non linear load	2KW
Linear load	1KW
Vdc	450V
DC link Capacitor	3000µF
Line parameters	R=0.25Ω,L=1mh

V. CONCLUSION

The main work of this paper is carried to show that by using FACTS devices power quality of circuit can be maintained in prescribed limits. In this paper circuit without UPQC is studied, in that case level of harmonics at PCC was around 23.61% and after applying UPQC harmonics content goes down to 4.64%. Similarly voltage level at PCC also improves, as UPQC in injects voltage in series with line voltage during fault condition. And the DC link voltage is maintained with the help of PI controller. Therefore it is clear that UPQC can improve both voltage and current profiles in a given circuit.

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