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Synchronous Reference Frame and Hysteresis Band Controlled UPQC for Power Quality Improvement

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***Abstract*— in this paper power quality of circuit, consisting of nonlinear loads is improved with the help of unified power quality conditioner. For conditioning of line voltage and current, active power filters are used. Series active power filter is used to improve voltage profile and shunt active power filter is used for reactive power compensation and to improve current profile. Both these series and shunt inverters are connected through a common DC link. PI controller helps to maintain DC link voltage constant. Reference signals are generated with the help of SRF theory and switching signals are generated with hysteresis band controller. Nonlinear loads cause harmonics into grid and harmonics can disturb the functioning of sensitive loads. Also as the power system is becoming more and more complex therefore the power quality at consumer end is becoming big issue. Therefore to manage power quality according to international standards, UPQC is best compensating device, it provide both current and voltage compensations.**

***Keywords*— UPQC, Active Power Filter (APF), Power Quality (PQ), Synchronous Reference Frame (SRF), Harmonics**

I. INTRODUCTION

Power System is becoming more complex with increase in number of consumers and also with increasing distributed power generation. Also with increase in power electronics based devices the non linear loads are increasing which creates harmonics in current waveform. Other reasons of poor power quality are welding machines; switch mode power supplies (SMPS), current regulators, various types of faults and switching etc. These create pollution in distribution system. So due to increase in harmonic content in power at distribution side, both power consumer and electric utilities are concerned about the power quality [2]. Custom power devices are considered as efficient tool for power quality improvement. UPQC is a custom Power device used for improvement of voltage and current condition in a given circuit [4]. It consists of two active power filters, series APF and shunt APF. The series APF is used to reduce all voltage related problems and shunt APF is used to reduce all current related problems [3].

II. UNIFIED POWER QUALITY CONDITIONER

UPQC is a combination of Series and shunt converters connected through a common DC link for improvement of power quality in a given circuit. We can use current and voltage source converters depending on the circuit requirement. Series APF is used for problems related to voltage and shunt APF is used for problems related to quality of line current [1]. Basic configuration of UPQC is shown below in Fig.1.There are various circuit topologies of UPQC, like left shunt UPQC, right shunt UPQC, open UPQC, interline UPQC etc. these can be used according to requirement of circuit. This combination of Series and shunt converters connected through a common DC link can manage the quality of power at point of common coupling (PCC), by injecting voltage in series with line voltage and compensating current opposite to harmonics current [2].

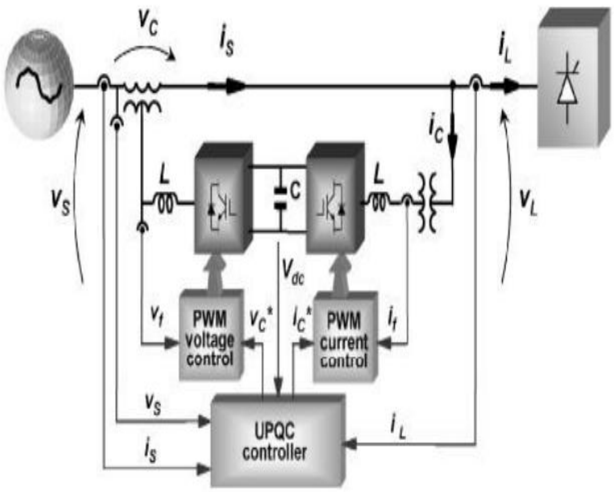

Fig -1: Basic configuration of UPQC

III. CONTROL STRATEGY

Synchronous Reference frame theory is used to control both series and shunt APFs. AS compare to other methods calculation with SRF is comparatively easy. SRF works on park's transformation and inverse park transformation for generation of reference signal [4]. First the transformation is done from three phase a-b-c to direct axis (d) and quadratic axis (q) and then again forms d-q-0 to a-b-c with the help of inverse parks transformation. Phase Locked Loop (PLL) is used to generate sine and cosine functions [9] .which helps to maintain synchronization with supply voltage and current [5]. A low pass filter (LPF) is used to separate average and oscillating components of voltage and current to generate reference signals [6].

In series controller the reference signal is generated by comparing the source voltage with distortion and constant voltage. The source voltage V_{sabc} and constant voltage $V_{\text{ref } abc}$ are converted to d-q-0 frame [6]. Then V_{sdq0} and $V_{\text{ref}dq0}$ are compared to get the error signal which is again converted to V_{labc}.

$$\begin{bmatrix} Vsd \\ Vsq \\ Vso \end{bmatrix} = T \begin{bmatrix} Vsa \\ Vsb \\ Vsc \end{bmatrix} \text{ And } \begin{bmatrix} V'a \\ V'b \\ V'c \end{bmatrix} = T^{-1} \begin{bmatrix} Vsd \\ Vsq \\ Vso \end{bmatrix}$$

Here T is given as

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

And T^{-1} is given as

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

In shunt controller the reference signal is generated by first converting source current from a-b-c to d-q-0 format and then with LPF the average and oscillating components are separated and v_{dc} is added to this to generate reference signal for shunt controller [7]. Then again abc to $dq0$ transform is inversed and converted to abc.that signal is given as the reference signal and the measured signal is given to the hysteresis band controller to generate the pulse signals for the operation of shunt converter. Similarly in case of shunt controller,

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

And reference signal is generated by adding d-q component of source current with V_{dc} and these signals will be compared with actual measured signals with the help of hysteresis controller [8]. Hysteresis band controllers are simple to compare signals as compare to other PWM techniques. The instantaneous value of the output voltage is compared with the reference voltage when the sensed output signal deviates from the reference by more than a prescribed value; the inverter is operated to reduce the deviation. This means that the switching occurs whenever the output voltage crosses the value of HB [2].

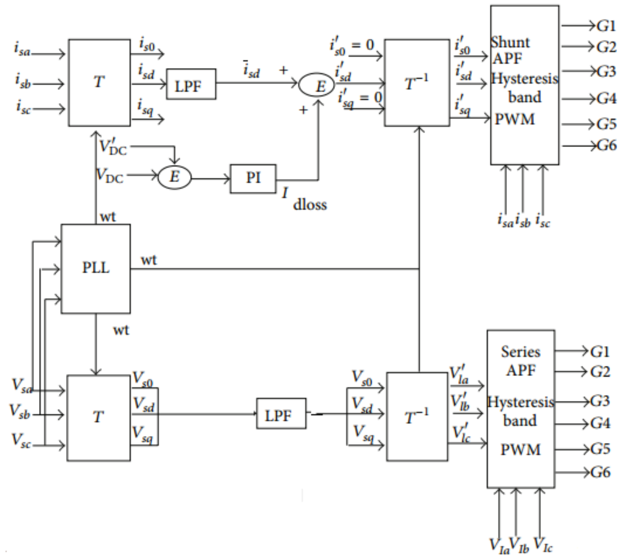

Fig -2: Control of series and shunt APF

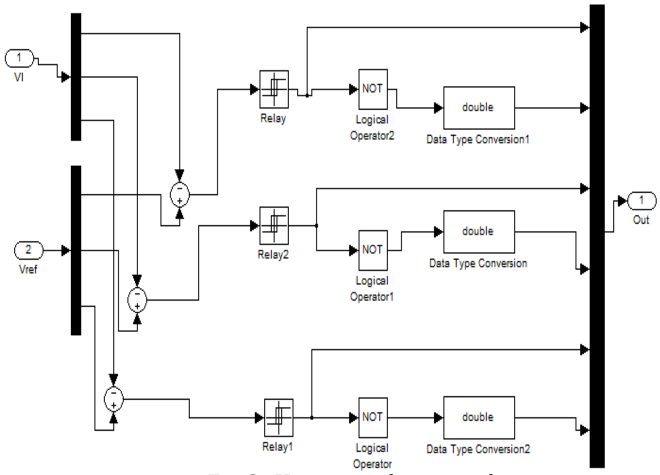

Fig -3: Hysteresis voltage control

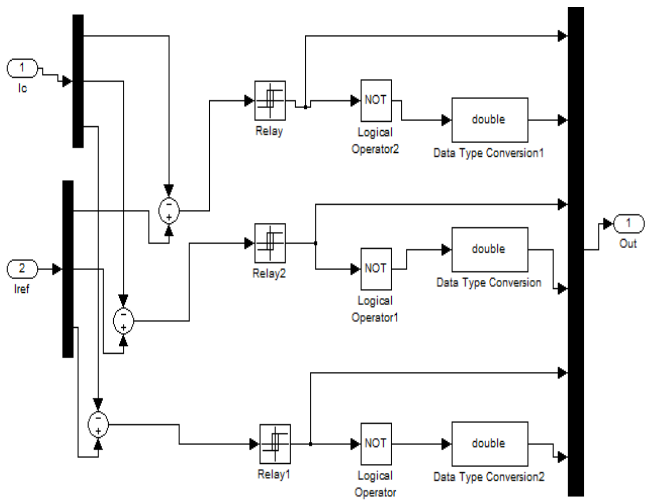

Fig -4: Hysteresis Current control

IV. SIMULATION RESULT

In this analysis a simplified control algorithm based on SRF theory 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: 5

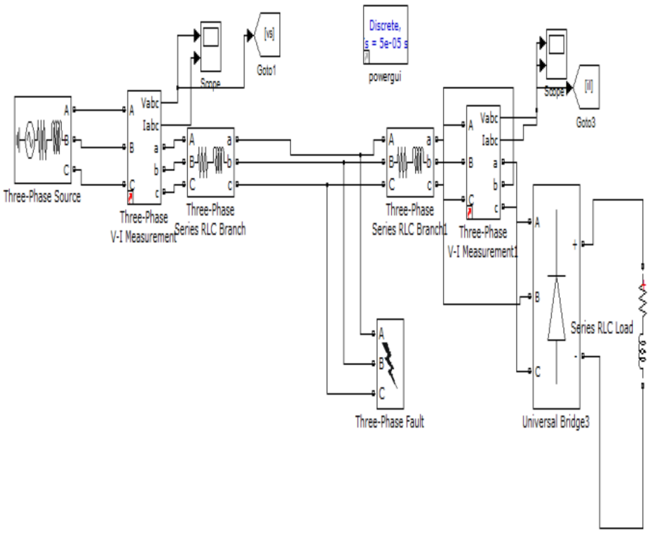

Fig -5: System without UPQC

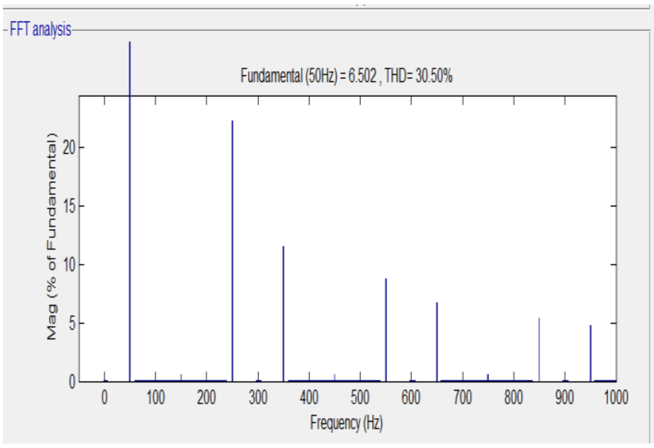

Fig -6: THD of line current without UPQC

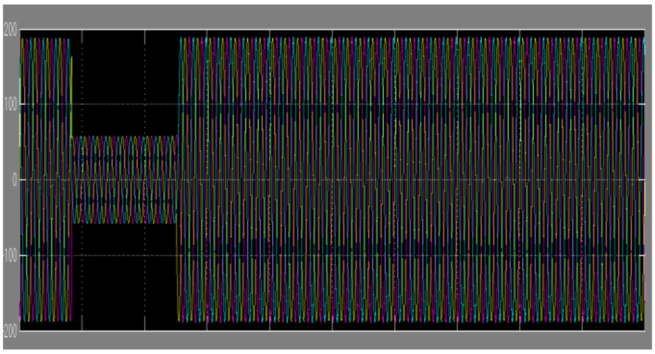

Fig -7: Line voltage without UPQC

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 30.50% and the line voltage goes down due to fault at 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.

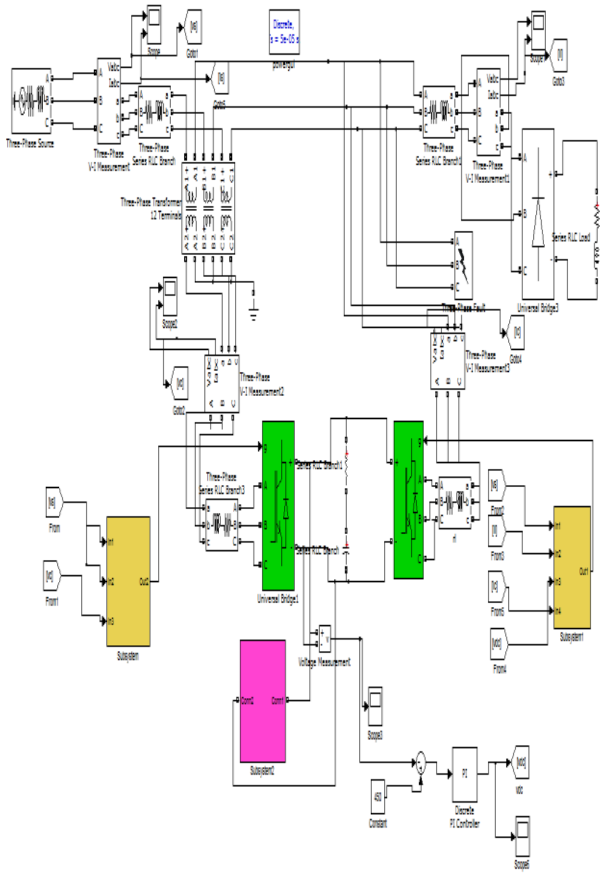

Fig -8: System compensated with UPQC

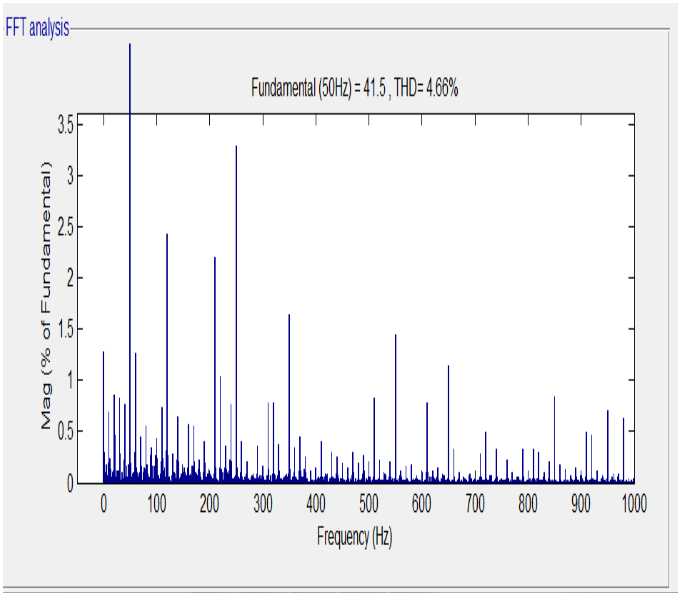

Fig -9: THD of line current with UPQC

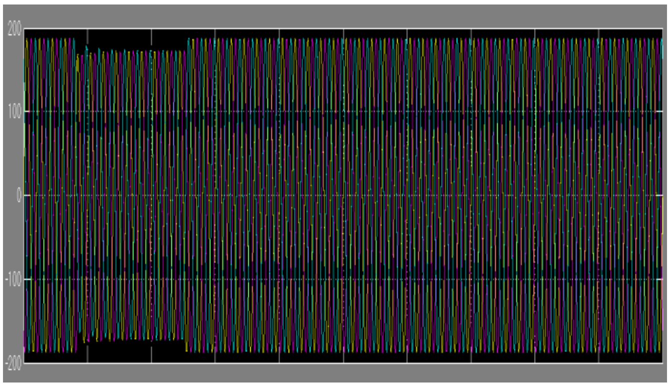

Fig -10: Line voltage with UPQC

It is clear that after connecting UPQC with line the line current THD level reduces to 4.66% from 30.50%. And the voltage sag is reduced to almost negligible value, by injecting voltage in series with line voltage by series APF.

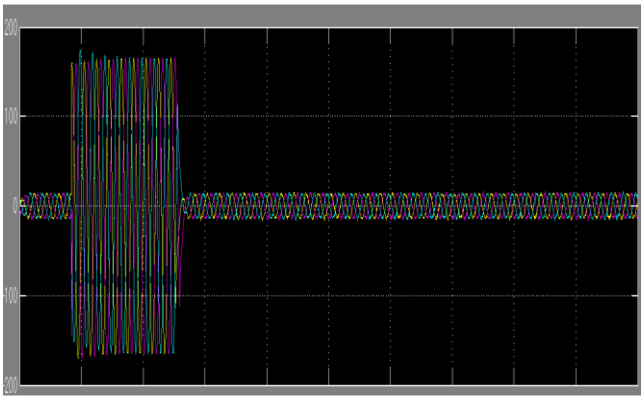

Fig -11: voltage injected by UPQC

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.

Table -1: Name of the Table

Design Specifications and circuit Parameters	
Supply voltage	230V
Fundamental Frequency	50HZ
Switching frequency	1080HZ
Non linear load	2KW
Cut-off frequency	50HZ
Vdc	450V
DC link Capacitor	3000µF
Line parameters	R=0.50Ω,L=1mh

V. CONCLUSION

The main work of this paper is carried to show that by using UPQC power quality of circuit can be improved. In this paper first of all, circuit without UPQC is simulated, in that case level of harmonics at PCC was around 30.50% and after applying UPQC harmonics content goes down to 4.66%. Similarly voltage level at PCC also improves, as UPQC 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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