© 2015 IJEDR | Volume 3, Issue 2 | ISSN: 2321-9939

Unified Power Quality conditioner in Grid connected Photovoltaic System

[1]Sukhjinder Singh, [2]Robinjit Singh, [3]Mukul Chankaya
[1]Student M.Tech, [2]Student M.Tech, [3]Assistant Professor
[1]Department of Electrical Engineering,
[1]Lovely Professional University, Phagwara, Punjab

***Abstract* – in this paper power quality of a distributed generation network consisting of photovoltaic generation as a distributed generation source is improved with the help of unified power quality conditioner. The control strategy which is applied in this paper is based on synchronous reference frame theory. So in this control strategy the reference signal is obtained by SRF theory and the comparison of reference signal is done to find the error signal, and this error signal is used to generate gate pulses with the help of PWM technique.**

***Index Terms* – UPQC, Active Power Filters, PWM, SRF, Photovoltaic Generation, Distributed Generation, power Quality.**

I. INTRODUCTION

The use of non conventional energy sources is increasing as distributed generation; this type of distributed generation can cause several power quality problems in to grid. As the photovoltaic power is connected to grid through inverters so it will inject harmonics into grid supply. The second cause of disturbance can be due to variable solar radiations due to which the output of photovoltaic system will not be steady and this will create fluctuations in line voltage. Third source of disturbance is the faults in DG (Distributed Generation). Whenever any fault occurs in distributed generation system it affects the supply of main line. So these are some power quality problems which can occur in distribution grid due to distributed generation. Custom power devices can be the solution to these power quality problems. There are several custom power devices like D-STATCOM, DVR and UPQC these devices can be used according to requirement of the network. D-STATCOM is used to compensate problems related to quality of current and also provides reactive power to load with lagging power factor [1]. DVR is dynamic voltage restorer and is used for improving voltage profile of line. When both these active power filters are combined then the combination is known as unified power quality conditioner. It has the ability to compensate both voltage and current related problems. In UPQC the D-STATCOM and DVR are connected through a common DC link and share power through this common DC link. In this system UPQC is connected at point of common coupling to stabilize voltage and reduce current harmonics [2]. The proposed system is shown below with the help of block diagram in fig.1.

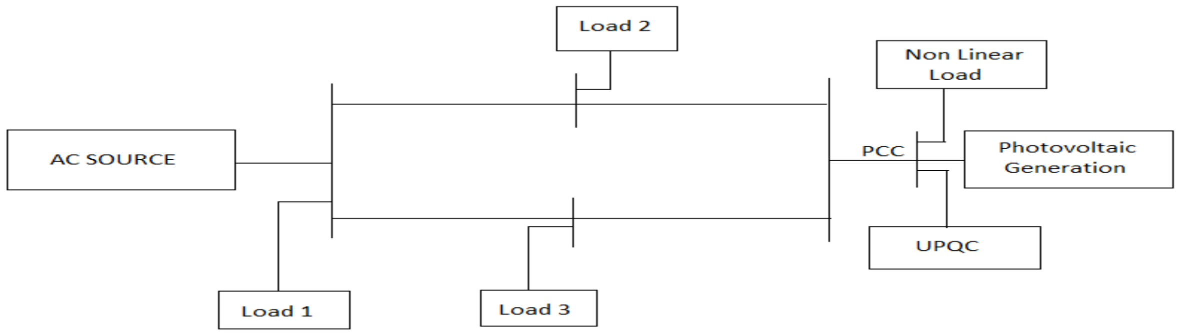

Fig.1UPQC in grid connected PV

The UPQC is already explained above. The second component which is used along with UPQC is photovoltaic array. Now the photovoltaic array containing 6 PV modules is shown below, in this 6 photovoltaic modules are used in series and the design of array is based on structure shown in Fig.2 [ECEN2060]. Photovoltaic array consisting of six modules is shown below and the design of photovoltaic module is based on the structure presented in library [ECEN2060], and is shown in Fig.3

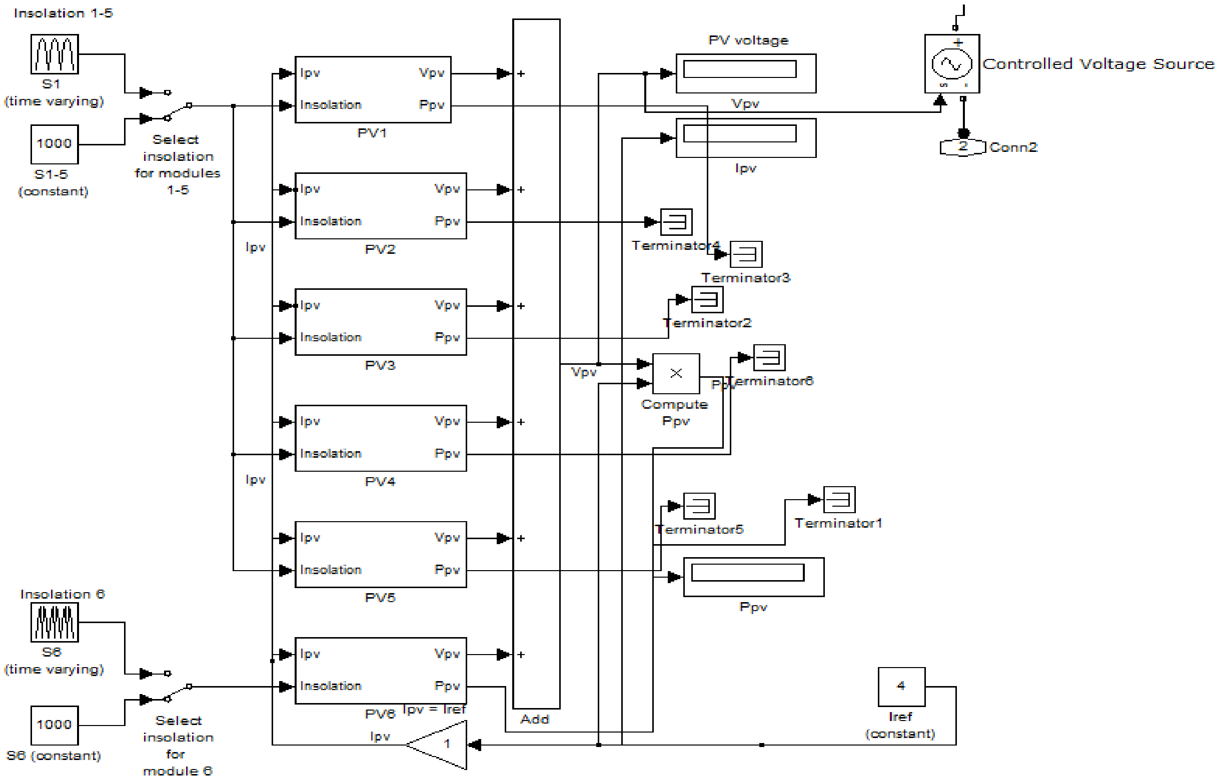

Fig.2 six module PV array

II. Synchronous Reference Frame Theory

In this work both controllers for series and shunt APFs are controlled with the help of theory called synchronous reference frame (SRF) theory. This control scheme is used because it is simple in calculation as compared to other control schemes [12]. This control strategy is based on algebraic calculations so it is less complex as compare to other methods. It uses Park transformation and inverse park transformation to generate of reference signals for both active power filters i.e. series APF and shunt APF [15]. The transformation is done from (a-b-c) to (d-q-o) frame [3]. In this Sine and cosine functions are generated by phase locked loop (PLL) to maintain synchronism of compensated current and voltage with supply current and voltage. Under disturbed conditions the d and q axis voltage and current consists of both average components ($\overline{id}$ and $\overline{iq}$) and oscillating components ($\tilde{id}$ and $\tilde{iq}$) [2]. And if the system is in balanced state then it consist only positive sequence components. But during unbalanced conditions and with non linear load the system will have zero, negative and positive sequence components [14]. The equations given below are used in transformation and inverse transformation of quantities. First equation is used to convert voltage from a-b-c to d-q-0 frame.

$$Vd = 2/3[Va\sin(\omega t) + Vb\sin(\omega t - 2\pi/3) + Vc\sin(\omega t + 2\pi/3)]$$
$$Vq = 2/3[Va\cos(\omega t) + Vb\cos(\omega t - 2\pi/3) + Vc\cos(\omega t + 2\pi/3)]$$
$$V0 = 1/3[Va + Vb + Vc]$$

And to convert these components back to a-b-c frame the equation given on next page is used.

$$Va = Vd\sin(\omega t) + Vq\cos(\omega t) + V0$$
$$Vb = Vd\sin(\omega t - 2\pi/3) + vq\cos(\omega t - 2\pi/3) + V0$$
$$Vc = Vd\sin(\omega t + 2\pi/3) + Vq\cos(\omega t + 2\pi/3) + V0$$

For three phase current same transformations will be used, we have to simply replace Va,Vb,Vc,Vd,Vq and V0 with Ia,Ib,Ic,Id,Iq and Io variables.

III. Control scheme for series APF

For series APF control the reference signal is generated with the help of SRF theory and phase locked loop (PLL). Park transformation and inverse park transformations are used to convert quantities from a-b-c to d-q-0 frame and again from d-q-0 to a-b-c frame to generate reference signal. In this control scheme the reference signal for series APF is obtained and compared with actual load voltage signal to generate gate pulses [6]. First of all three phase supply voltage V_{sabc} will be transformed to V_{sdq0}.

$$\begin{bmatrix} Vsd \\ Vsq \\ Vso \end{bmatrix} = T \begin{bmatrix} Vsa \\ Vsb \\ Vsc \end{bmatrix}$$

Where T represents the park transformation and is used to convert source voltage from a-b-c to d-q-0 frame. In this Vsd and Vsq have both oscillating components ($\tilde{V}sd$ and $\tilde{V}sq$) and average components ($\bar{V}sd$ and $\bar{V}sq$). Here oscillating components consists of harmonics and negative sequence components. But the average component consists of fundamental components of supply voltage only. The zero sequence components exists only in unbalanced state [4]. The reference signal will be compared with actual voltage (load) and gate pulses will be generated. To generate gate pulses we can use either PWM controller or hysteresis band controller [13]. Here in this work PI-PWM is used to generate gate pulses. When the load voltage differs from reference voltage then series controller gives signal to series inverter and it injects same amount of voltage in series with line [8]. The block diagram of series controller is shown below.

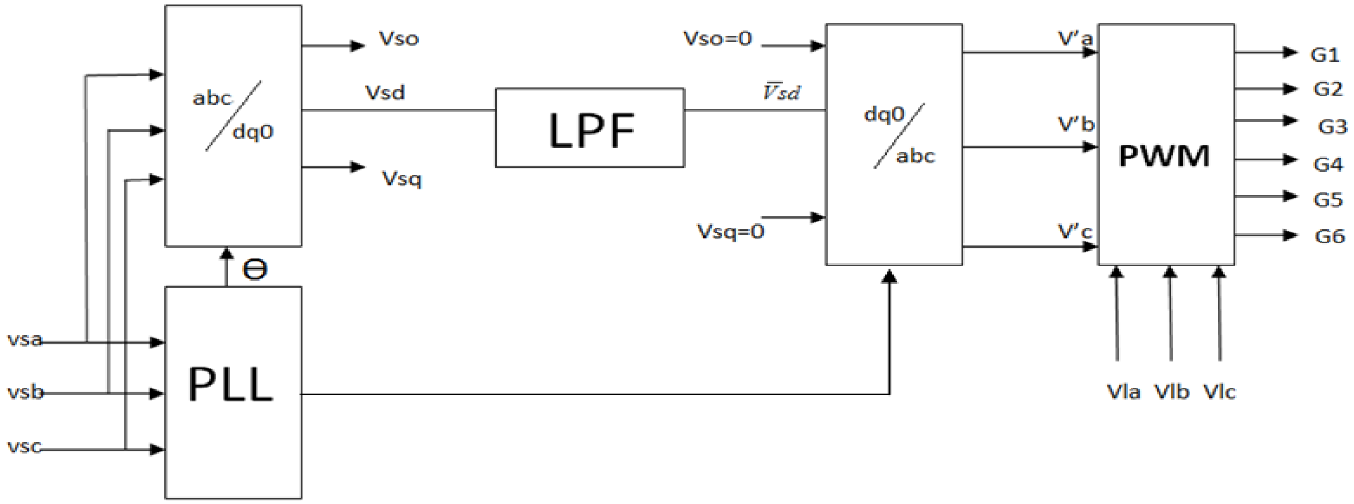

Fig.3 control scheme of series APF

IV. CONTROL SCHEME FOR SHUNT APF

Shunt APF injects the current opposite to harmonics current in equal amount as of harmonics current shifted at 180^0 and provide reactive power compensation for lagging power factor load and maintain DC link voltage at constant level [11]. The control strategy includes the transformation of source current from abc frame to dq0 frame with the help of parks transformation and again back to abc frame from dq0 frame by using inverse parks transformation. These transformations are already explained above. Now the dq0 transformation of source current is shown below [10].

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

When the load is non linear then source current will have both average components ($\bar{i}sd$ and $\bar{i}sq$) and oscillating components ($\tilde{i}sd$ and $\tilde{i}sq$) [7]. We know that shunt APF is used to maintain DC link voltage along with providing compensations. So to maintain DC voltage level constant it absorbs some active power from network. In this actual DC link voltage is compared with a reference signal and the required active current I_{dloss} is calculated using PI controller[6]. And the reference current for APF is calculated by summing $\bar{i}sd$ and I_{dloss} . Therefore $i'sd = I_{dloss} + \bar{i}sd$. In this calculation only d axis components are taken for calculation of reference current and q axis and zero sequence components are set to zero. This is done to compensate harmonics and reactive power at PCC (point of common coupling) [9].

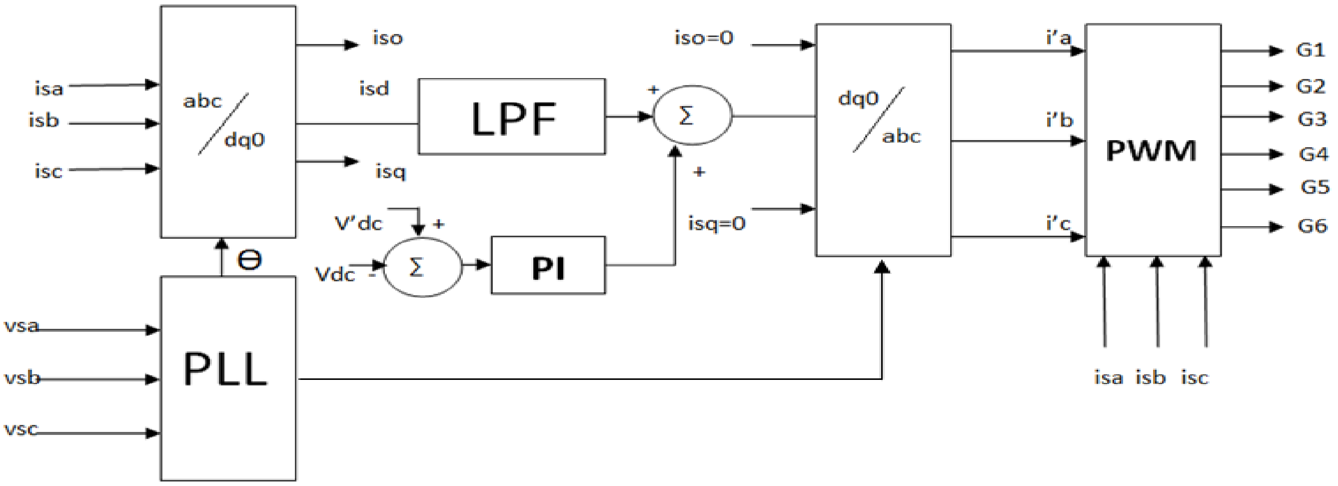

Fig.4 Control Scheme for Shunt APF

V. SIMULATION RESULTS AND CONCLUSION

First of all consider the system with PV- inverter and nonlinear load, both are injecting harmonics in to distribution grid. The simulation consisting of nonlinear load and photovoltaic system without UPQC is shown below.

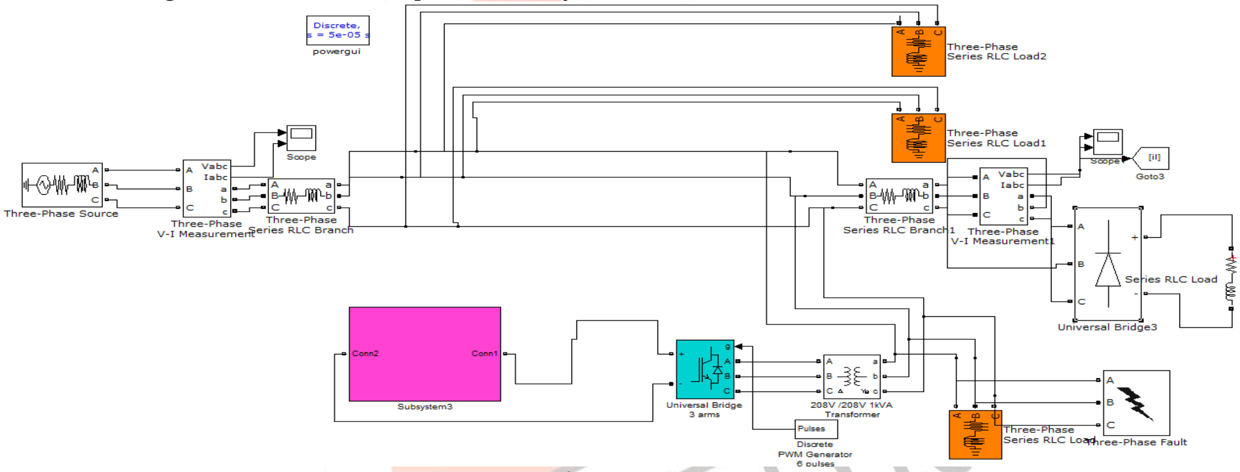

Fig.5. Circuit consisting of PV panel and non linear load without UPQC

Now in this simulation the system is without UPQC therefore inverter connected to PV and non linear load both are injecting harmonics in to grid supply which are shown below with the help of THD measurement and waveform of line current without UPQC.

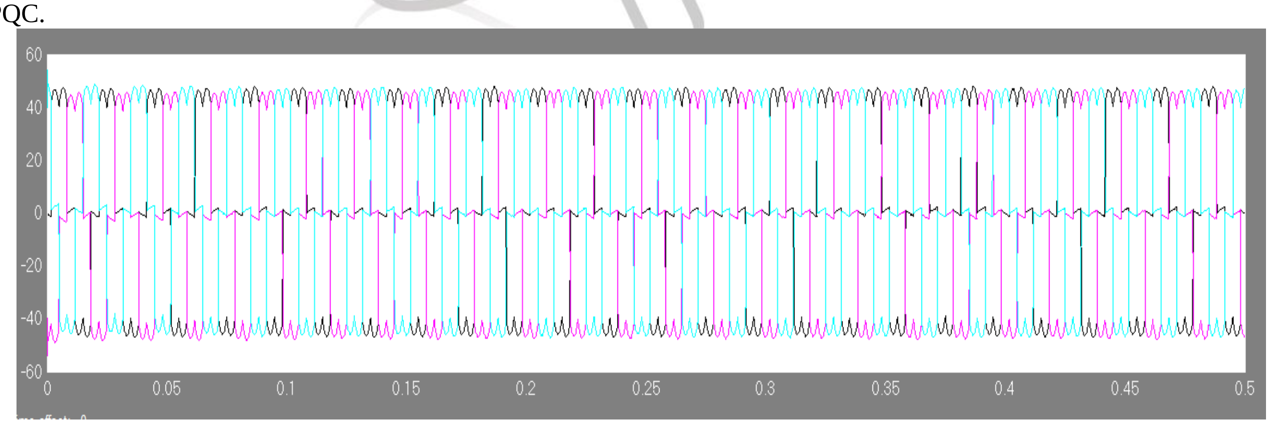

Fig.6 Line current waveform without UPQC

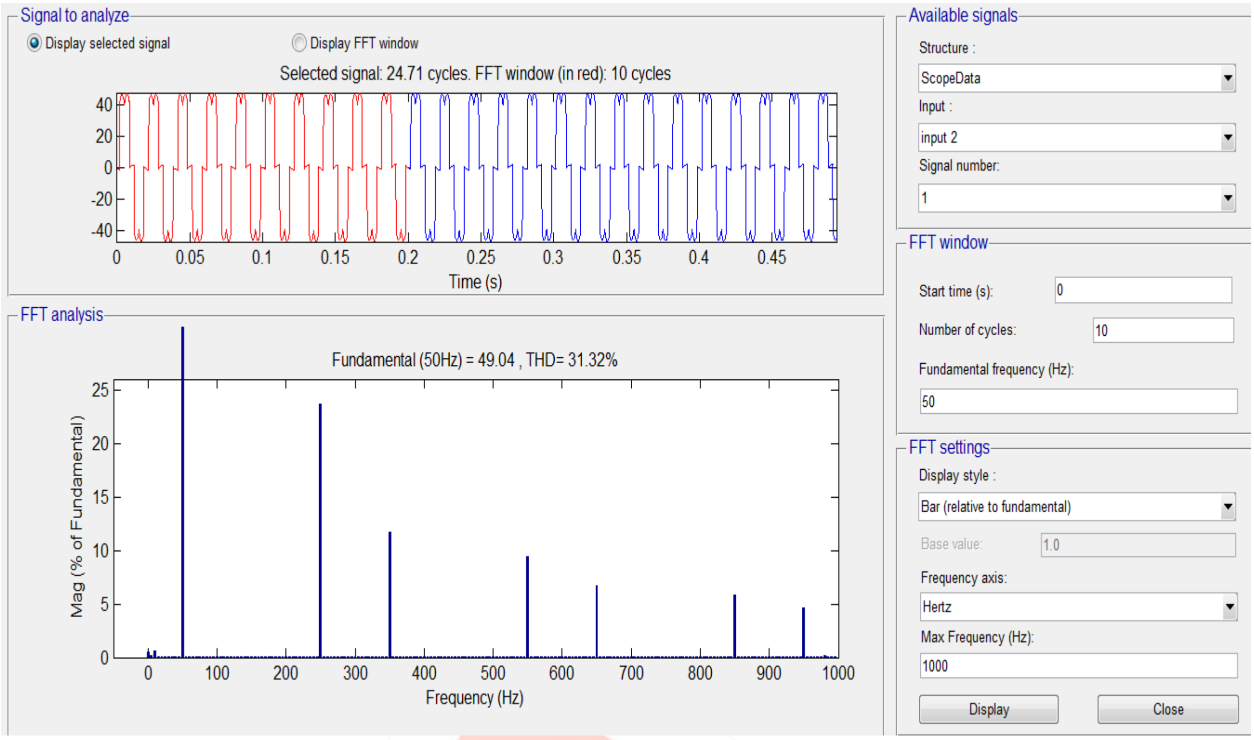

Fig.7 Line current THD without UPQC

Now UPQC is connected at point of common coupling which is shown below with the help of MATLAB simulation diagram.

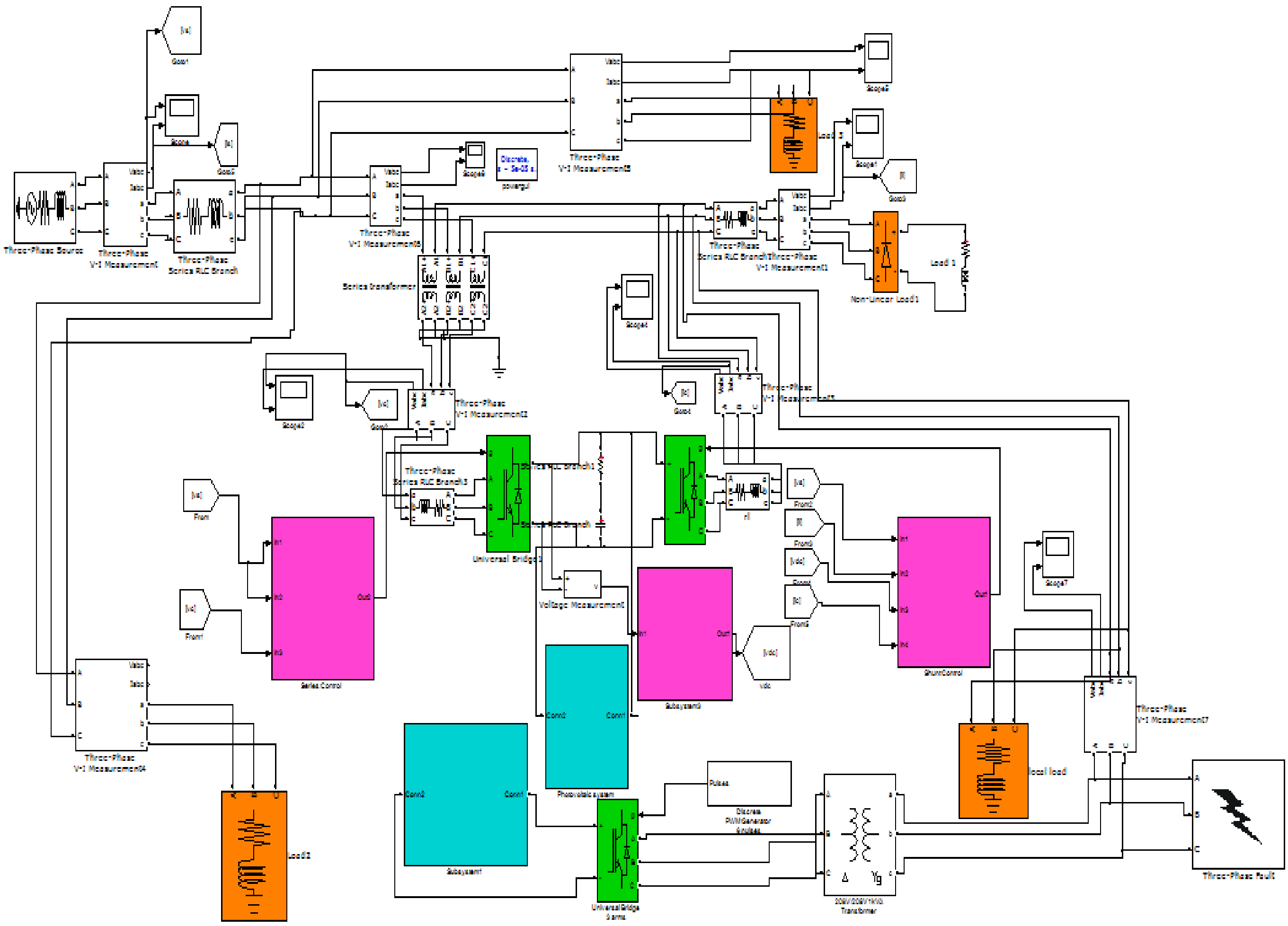

Fig.8 Simulation of circuit with UPQC

Now the fig shown above shows the compensated circuit with UPQC. In this the UPQC is connected to improve the voltage and current profiles of the system. Now after connecting UPQC the THD level of line current is shown below with the help of waveform and THD measurement.

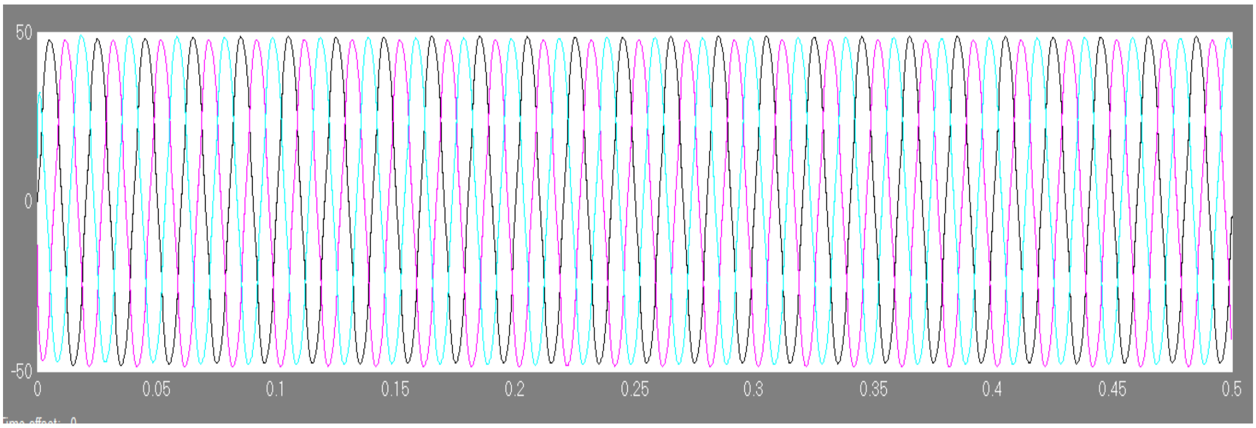

Fig.9 Line current waveform with UPQC

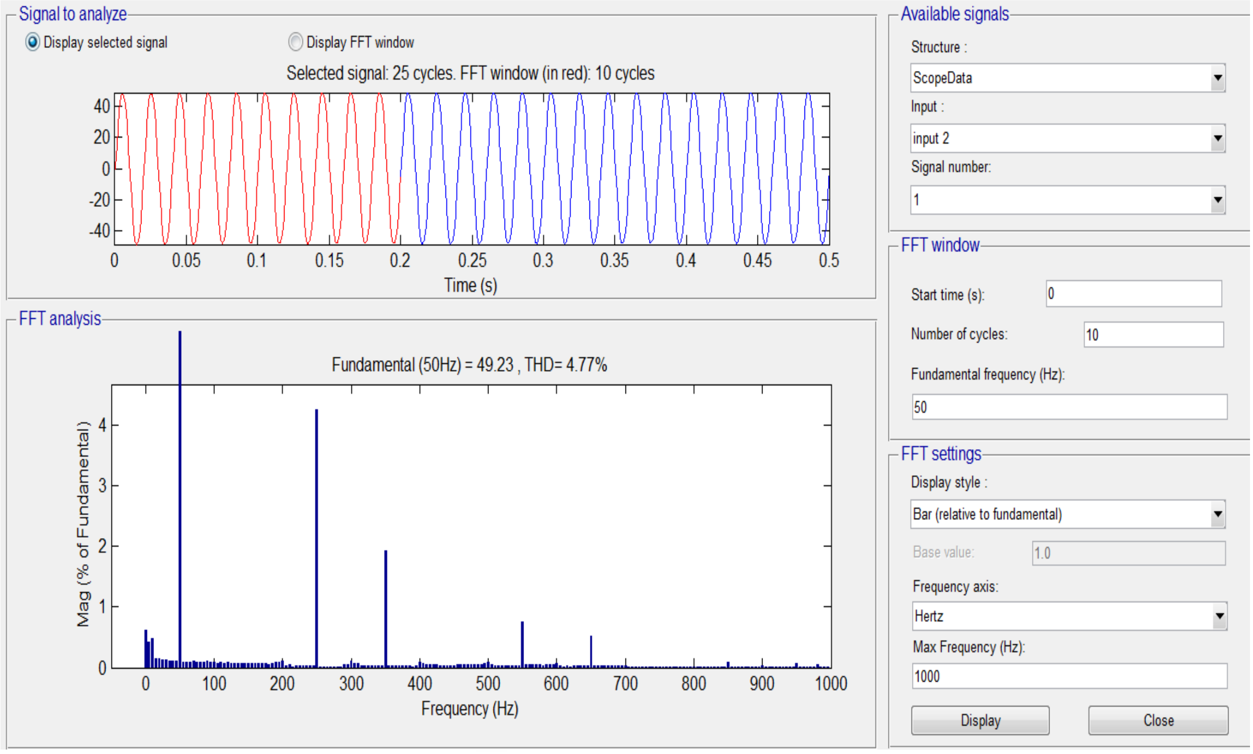

Fig.10 Line current THD with UPQC

It shows that the THD level reduces to 4.77% from 31.32% after connecting UPQC at the point of common coupling. Now if there is any fault occur at distributed generation consisting of PV panel then the voltage profile of line gets disturbed which is shown below with the help of LLLG fault.

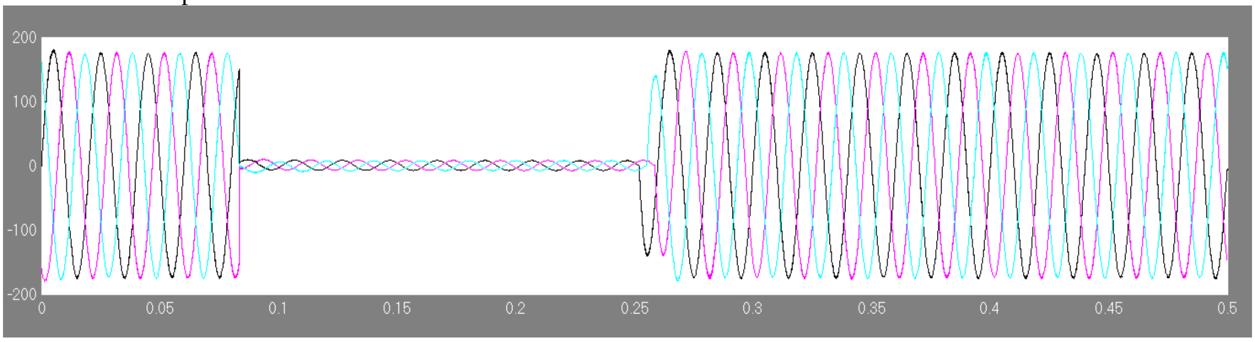

Fig.11 Line voltage waveform during LLLG fault

If we connect UPQC at PCC then series active power filter will inject voltage in series with the line and improve line voltage profile as shown below.

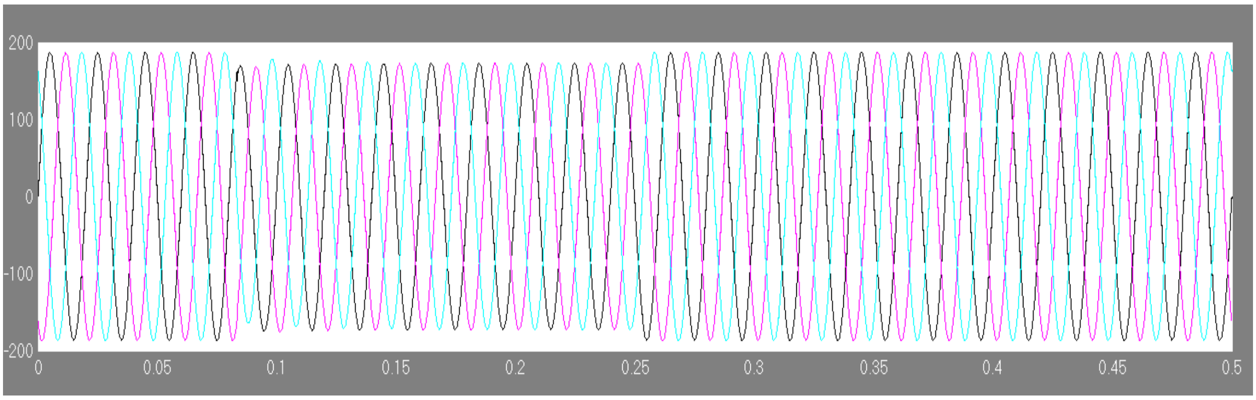

Fig.12 Line voltage waveform during LLLG fault with UPQC

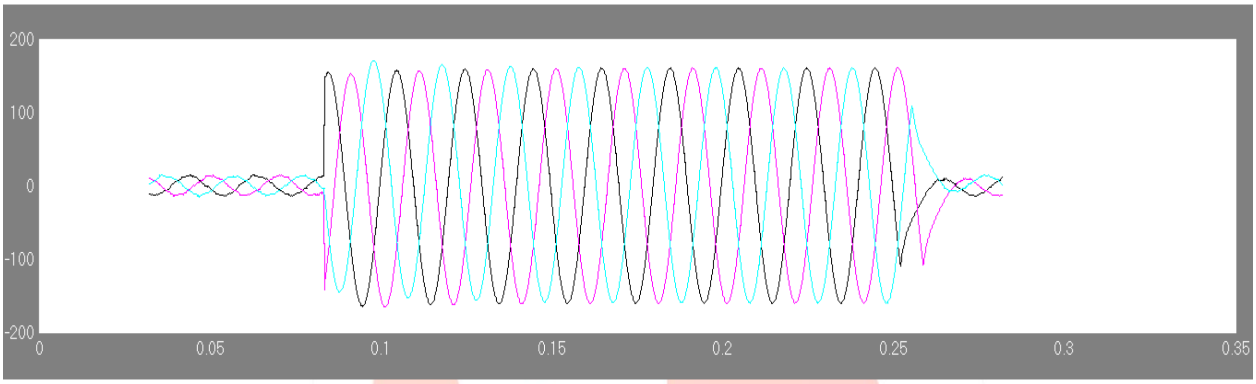

Fig.13 compensation voltage provided by UPQC during LLLG fault

So it shows that UPQC can improve both voltage and current profiles of system, by providing voltage compensation through series APF and current compensation through shunt APF. Therefore it can be effective in maintaining power quality of distribution networks consisting of non linear loads and distributed generation sources.

References

[1] N.G Hingorani, "Introducing Custom Power" IEEE Spectrum, Vol.32, Issue: 6, Page(s): 41-48, June 1995.

[2] V. Khadkikar, A. Chandra, A.O. Barry and T.D Nguyen, "Conceptual Study of Unified Power Quality Conditioner (UPQC),"IEEE International Symposium on Industrial Electronics, Vol. 2, and Page: 1088 –1093, 2006.

[3] Metin Kesler, Engin Ozdemir, "International Conference on Renewable Energies and Power Quality (ICREPQ'09)" Valencia (Spain), 15th to 17th April, 2009.

[4] Bhim singh, V. Verma, A. Chandra and K. Al-Haddad, "Hybrid Filters for Power Quality Improvement", IEE Proceedings- Generation, Transmission and Distribution", Vol.152,Page(s): 365 - 375, 2005.

[5] Luis F.C. Monteiro, Mauricio Aredes and Joao A. Moor Neto "A Control Strategy for Unified Power Quality Conditioner", IEEE International Symposium on Industrial Electronics, vol. 1, Page(s): 391 - 396, 2003.

[6] Y.C.V.Kondaiah, M.Archana, Grid interfacing inverter of renewable energy sources to improve the power quality in distribution system; [IJAREEIE] [ISSN: 6231-4407]

[7] Subramanian Muthu and Jonathan M. S. Kim "Steady-State Operating Characteristics of Unified Active Power Filters", twelfth annual Applied Power Electronics conference and Exposition, 1997, APEC '97 Vol. 1, Page(s): 199 - 205 vol.1, Feb 1997.

[8] S. Angalaeswari, M.G. Thejeswar, R.santhana poongodi, W.valeed Basha, P.Sasikumar, power quality improvement of standalone hybrid solar-wind power generation system using FACTS devices; [IJAREEIE]; [Vol. 1, Issue 1, March 2014].

[9] S.Rajesh Rajan; power quality improvement in grid connected wind energy system using UPQC; [IJRET]; [Vol. 1, Issue 1, June 2013, 13-20].

[10] Chaitanya Marisarla, K. Ravi Kumar; Hybrid wind and solar energy system with battery energy storage for an isolated system; [IJEIT] [ISSN: 2277-3754]

[11] Alka Singh, Suman Bhowmick and Kapil Shukla, "Load Compensation with DSTATCOM and BESS", IEEE 5th International Conference on Power Electronics, December 2012.

[12] V. Khadkikar, A. Chandra, A.O. Barry and T.D Nguyen, "Conceptual Study of Unified Power Quality Conditioner (UPQC),"IEEE International Symposium on Industrial Electronics, Vol. 2, and Page: 1088 –1093, 2006.

[13] Yash Pal, A. Swarup, and Bhim Singh, "Control Strategy for Selective Compensation of Power Quality Problems through Three-Phase Four-Wire UPQC" Journal of Power Electronics, Vol. 11, No. 4, July 2011.
[14] Marcelo C. Cavalcanti, Francisco A.S NEVES, "Unified power quality conditioner in grid connected photovoltaic system" electrical power quality and utilization journal, 2006.
[15] Dr.S. Suresh Kumar," Enhancement for Power Quality in Distribution Side Using Custom Power Devices" Volume 5, Issue 6 (May. - Jun. 2013), PP 81-87.