International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 2, February - 2014

Integration of UPQC with PV Arrays for Power Quality Enhancement

Amit Shrivastava [1], Payal Deshpande [2], Anula Khare [3]
[1.] Department of Electrical & Electronics Engineering, Professor, Oriental College of Technology, Bhopal
[2.] Department of Electrical & Electronics Engineering, PG Scholar. Oriental College of Technology, Bhopal
[3.] Department of Electrical & Electronics Engineering, Associate Prof. Oriental College of Technology, Bhopal

***Abstract*— This paper deals with the importance of UPQC in the power quality improvement of the distribution system with non linear load. The unified power quality conditioner (UPQC) is a power conditioning device, which is an integration of back to back connected shunt active power filter (APF) and series APF to a common DC link voltage. For improvement of power quality (PQ) problems in a distribution system; a dynamic model of the UPQC is developed in the MATLAB/SIMULINK environment and the simulation results demonstrating the power quality improvement in the system are presented for distorted supply and a combination of linear and non-linear load.**

Index Terms- Active Power Filters (APFs), UPQC, Power Quality, Non Linear Load.

I. INTRODUCTION

In the present trend of deregulated power market, providing quality power to consumers has emerged as a figure of merit for the power distribution utilities. Now a- days modern and sensitive power electronic device find wide applications at domestic, industrial and commercial purposes. Devices such as rectifiers, inverters, adjustable speed drives and cyclo-converter draw non-linear currents from the source, which degrade the electric power quality. The quality degradation leads to low power-factor, low efficiency, malfunctions of sensitive devices, overheating of transformers and so on [1].In addition to this, the overall load on a distribution system is hardly balanced. Because of this there is excessive neutral current in a three-phase four-wire distribution system.

Conventionally, passive filters were used to mitigate harmonics, but their limitations such as, fixed compensation, resonance with the source impedance and the difficulty in tuning ,time dependence of filter parameters forced the need of active and hybrid filters[2]-[4]. These filters address some of the power quality problems only. Whereas present electric power distribution systems are facing acute power quality problems like reactive power burden, poor power-factor, load unbalancing, voltage and current harmonics, voltage sag and swells, voltage dip etc.

For enhancing the reliability and quality of the power supply of the distribution systems, a new technology called custom power emerged [5-6]. The compensating type Custom Power Devices mainly include static shunt compensators or a distribution static compensator (D-STATCOM) [7-8], dynamic voltage restorer (DVR) [9-10] and UPQC [11-13].The DSTATCOM is a shunt device, which is responsible for the mitigation of current based distortions, while DVR is a series device, which finds its application for the mitigation of voltage based distortions. The UPQC is a power conditioning device, which is a combination of back to back connected shunt and series APFs to a common DC link voltage. The shunt APF is used to compensate for harmonic contents, unbalance, and reactive components of the load current and to prevent the undesired effect of these distortions on power systems. The series APF is used for compensation of unsymmetrical and harmonic components, flicker, sag, and swell of the source voltage.

This paper deals with the implementation of UPQC with multiple PV Arrays in the distribution system. Generally, UPQC has two voltage-source converters. The main purpose of the series converter is harmonic isolation between a sub transmission system and a distribution system. In addition, the series converter has the capability of voltage flicker/imbalance compensation as well as voltage regulation and harmonic compensation at the utility-consumer PCC. The main purpose of the shunt converter is to absorb current harmonics, compensate for reactive power and negative sequence current, and regulate the dc-link voltage between both converters [14]. But UPQC has no capability in compensating the voltage interruption because it has no energy storage. This paper proposes a new configuration of UPQC.

As UPQC can compensate for almost all existing PQ problems in the transmission and distribution grid, placement of UPQC in the distributed generation network can be multipurpose. As a part of integration of UPQC in DG systems, research has been done on the following two techniques: DC-Linked and Separated DG-UPQC systems. Following figures show the pictorial view of both the techniques.

A structure has been proposed in [2, 4-7], as shown in Figure 1, where DG sources are connected to a DC link in the UPQC as an energy source.

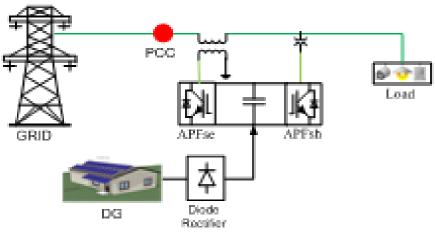

Fig.1.UPQC with DG connected to the DC link

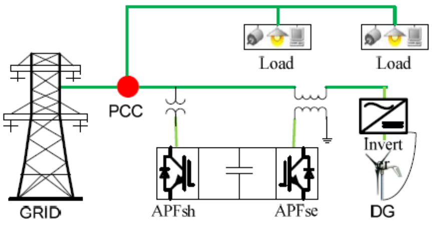

Fig.2.UPQC with DG separated to the DC link

This configuration works both in interconnected and islanded mode (shown in Figure 3.1; 3.2). In Interconnected mode, DG provides power to the source and loads whereas in islanded mode DG (within its power rating) supplies the power to the load only. In Addition, UPQC has the ability to inject power using DG to sensitive loads during source voltage interruption. The advantage of this system is voltage interruption compensation and active power injection to the grid in addition to the other normal UPQC abilities. The system's functionality may be compromised if the DG resources are not sufficient during the voltage interruption conditions. Economical operation of the system can also be achieved by proper controlling of the active power transfer between the supply and DG source through a series APF [7].

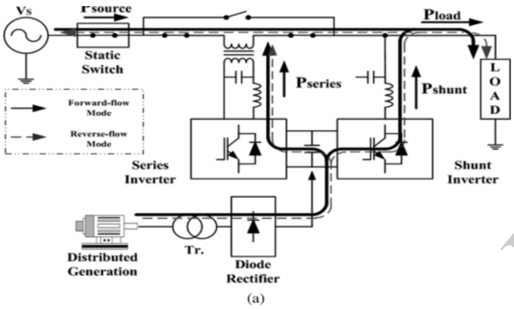

Fig.3 (DG-UPQC) DC- linked System operation concept. (a) Interconnected mode.

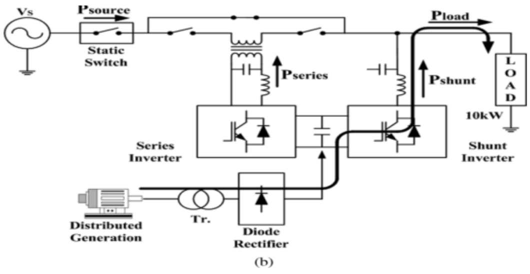

Fig.4. (DG-UPQC) DC- linked System operation concept. (b) Islanding mode

II. MAJOR ADVANTAGES OF WIND POWER AND PHOTOVOLTAIC POWER THAT HAVE ACCELERATED ITS DEVELOPMENT

Major factors that have accelerated the wind-power technology development are as follows:

- High-strength fiber composites for constructing large low-cost blades.
- Falling prices of the power electronics.
- Variable-speed operation of electrical generators to capture maximum energy.
- Improved plant operation, pushing the availability up to 95 percent.
- Economy of scale, as the turbines and plants are getting larger in size.
- Accumulated field experience (the learning curve effect) improving the capacity factor.

Major advantages of the photovoltaic power are as follows:

- Short lead time to design, install, and start up a new plant.
- Highly modular, hence, the plant economy is not a strong function of size.
- Power output matches very well with peak load demands.
- Static structure, no moving parts, hence, no noise.
- High power capability per unit of weight.
- Longer life with little maintenance because of no moving parts.
- Highly mobile and portable because of light weight.

III. UPQC WITH WIND ENERGY GENERATION SYSTEM

In this system combination of UPQC and synchronous generator is used. The synchronous generator is connected to UPQC DC bus through an uncontrolled rectifier. The significant advantage of this configuration when compared with separate operation of UPQC and wind energy generation system, is reduction in using of one inverter and use of shunt inverter for UPQC as a WEGS`s inverter. The UPQC can compensate the voltage interruption in the source, while the WG supplies power to the source and load or the load only. UPQC operates in two operation modes as interconnected mode and islanded mode.

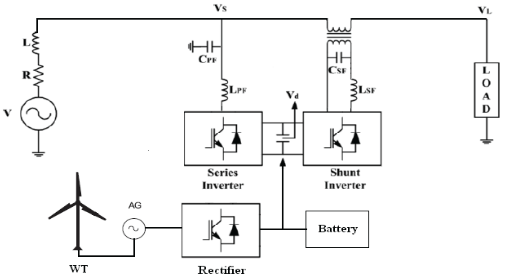

Fig.5. Configuration of UPQC with WECS as DG Network

IV. INTRODUCTION TO UPQC WITH PV ARRAYS

Although DG needs more controls to reduce the problems like grid power quality and reliability, PV energy is one of the distributed generation sources which provides a part of human required energy nowadays and will provide in the future. The greatest share of applying this kind of energy in the future will be its usage in interconnected systems. Nowadays, European countries, has caused interconnected systems development in their countries by choosing supporting policies. Hence, UPQC and PV combined system has been presented. UPQC introduced in has the ability to compensate voltage interruption along with voltage sag and swell, harmonics and reactive power.

Here, PV energy conversion system has high efficiency, low cost and high functionality. Fig. shows the block diagram of proposed system. The converter 1 (PV converter) is responsible to convert the PV energy to the grid as well as to compensate current harmonics and reactive power. The converter 2 (DVR Converter) is responsible to compensate voltage harmonics or voltage sags. Thus, the utilization of two controlled converters makes the system to have the most structure applied as energy conditioner.

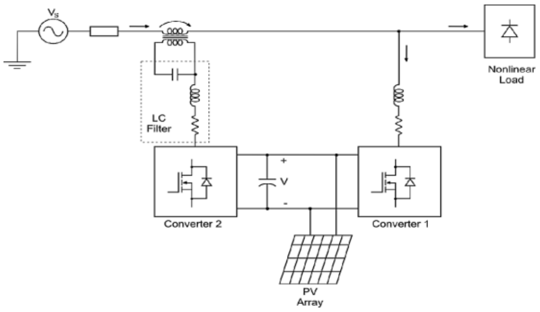

Fig.4. PV generation with UPQC function

V. PROPOSED UPQC SYSTEM

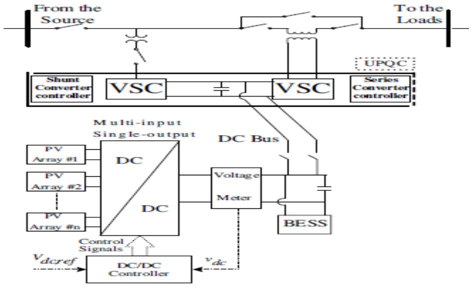

Fig.6. Proposed system of upqc

In this paper the role of Unified power quality conditioner is the power quality improvement of Distributed networks (PV Arrays). Following figure shows the proposed UPQC system. Here, UPQC is integrated with multiple PV Arrays. The input of these multiple PV Arrays is given to the DC-DC converter. This DC-DC converter is Multi Input Single Output DC-DC converter. Brief discussion of various components of the proposed system is given following sub articles.

Following figure shows the proposed UPQC system. Here, UPQC is integrated with multiple PV Arrays. The input of these multiple PV Arrays is given to the DC-DC converter. This DC-DC converter is Multi Input Single Output DC-DC converter. Brief discussion of various components of the proposed system is given following sub articles.

5.1. MISO DC-DC Converter Introduction

Since the DC voltage generated by a photovoltaic array varies and is low in magnitude, a step-up DC-DC converter is essential to generate a regulated higher DC voltage. The DC-DC converter is responsible for absorbing power from the photovoltaic array, and therefore should be designed to match photovoltaic array ripple current specifications and should not conduct any negative current into the photovoltaic array. The MISO DC-DC converter is useful for combining several distributed generation sources whose power capacity and/or voltage levels are different to obtain well-regulated higher output voltage [14]. The converter topology used for the combination of DC output of photovoltaic array units is shown in Fig. 6.

In the control system of MISO DC-DC converter, the output voltage of converter has been compared with a reference value and the error signal is applied to PI-controller.

The output signal of this controller is the one input of PWM switching for adjusting the duty cycle. In this paper, as an example a Triple-Input Single-Output (TISO) DC-DC converter has been designed and studied. The component values of TISO DC-DC converter are listed in Table I.

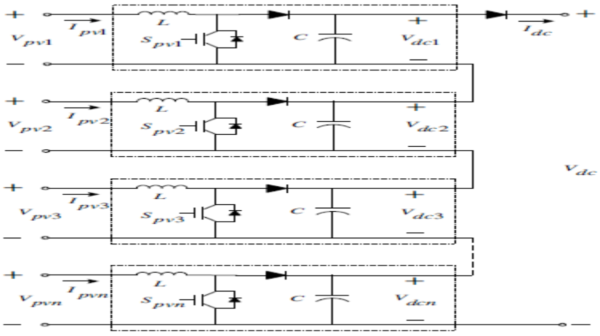

Fig.7. TISO DC - DC Converter

5.2 Control Scheme of the Proposed System

Instantaneous power theory is used to control of the proposed system. This scheme includes Photovoltaic (PV) energy resource to deliver PV power to loads and maintaining DC link voltage as well as other condition tasks. The theory is based on converting three axis parameters into two axes by defining well-known transfer matrix. The active and reactive instantaneous power can be decomposed by DC component and AC harmonic components, which consist of negative sequence component and harmonic component

$$\begin{aligned} p &= \bar{p} + \tilde{p} \\ q &= \bar{q} + \tilde{q} \\ p_0 &= \bar{p}_0 + \tilde{p}_0 \end{aligned} \qquad (1)$$

Because the zero sequence power never produces a constant DC component without its associated AC component, the proposed system should compensate fully power *p0* when it applied to the three-phase four-wire networks, and the additional active power component drawn from supply needs to be injected:

$$\begin{aligned} p_{control} &= p_0 + \tilde{p} \\ q_{control} &= \bar{q} + \tilde{q} \end{aligned} \qquad (2)$$

Where:

p_0 is zero sequence of active power.

$\tilde{p}$ is negative sequence and AC harmonic component of active power.

$\bar{q}$ is direct component of reactive power.

$\tilde{q}$ is alternative component of reactive power associated to the harmonic reactive component.

If shunt inverter is used simultaneously for reactive, negative and harmonic component compensation, the α-β axis current reference is given by the following equation

$$\begin{bmatrix} i^*_{c_\alpha} \\ i^*_{c_\beta} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} -p_{control} \\ -q_{control} \end{bmatrix} \qquad (3)$$

When the series converter of the proposed configuration is used simultaneously for reactive, negative and harmonic compensation, the α-β axis voltage reference is given by equation (4).

$$\begin{bmatrix} v_{c_\alpha}^* \\ v_{c_\beta}^* \end{bmatrix} = \frac{1}{i_\alpha^2 + i_\beta^2} \begin{bmatrix} i_\alpha & -i_\beta \\ i_\beta & i_\alpha \end{bmatrix} \begin{bmatrix} -p_{control} \\ -q_{control} \end{bmatrix} \qquad (4)$$

When the shunt converter of the proposed configuration is used for the charge control of battery, the active reactive power control is becoming the main issue, and the proposed system still satisfy the compensation demand of load such as negative and harmonic compensation. Then the α-β axis current reference is given by equation (5).

$$\begin{bmatrix} i_{c_\alpha}^* \\ i_{c_\beta}^* \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p_{control} + p_{pv} \\ q_{control} \end{bmatrix} \qquad (5)$$

Where, p_{pv} is the PV power delivered to local loads by shunt converter. It should be noted that, it is so difficult to compensate reactive power and harmonic current using series converter only and because the signals from converter output terminals must be passed through the filters, the filter design strongly depends on the system parameters like load size and transformer turns ratio.

Here UPQC with multiple PV arrays is used and results are obtained for UPQC with multiple PV Arrays and MISO DC DC Converter.

VI. SINGLE LINE DIAGRAM OF TEST SYSTEM

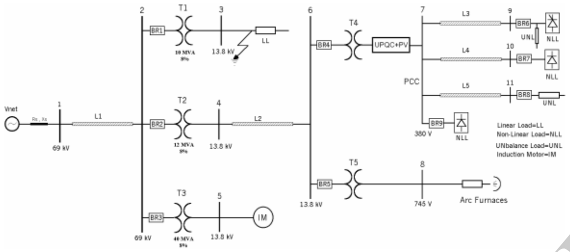

Fig.8. Single line diagram of test system used under consideration

As mentioned earlier this paper focuses on the analyses the feasibility of protecting sensitive loads from power quality problems (voltage sags, flicker, harmonic current compensation, etc) with compensation being performed at the distribution voltage level (13.8 kV in this case)[20]. Above designed new UPQC with PV Array model is installed in the secondary side of transformer between bus bars 6 and 7 near the point of common coupling (PCC). An industrial process which is sensitive to power quality problems was to be protected. Following figures show the single line diagram and MATLAB model of the test system under consideration. Initially working of system is observed in the absence of UPQC and then with UPQC. The effectiveness of the use of UPQC can be observed form the outputs of the system with UPQC.

VII. SIMULATIONS AND RESULTS

Figure shows the MATLAB SIMULINK model of the test system with floating THDs coming during simulation of the system.

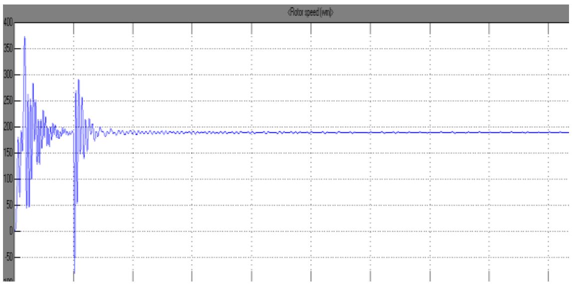

Fig.9.Waveform of speed of nonlinear load (motor)

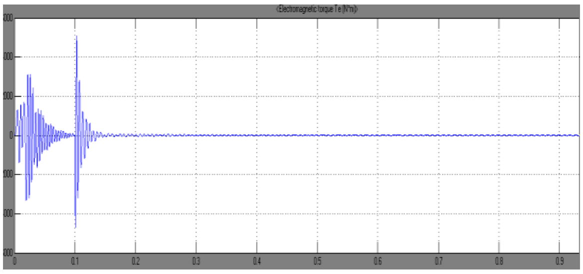

Fig.10.Waveform of torque of nonlinear load (motor)

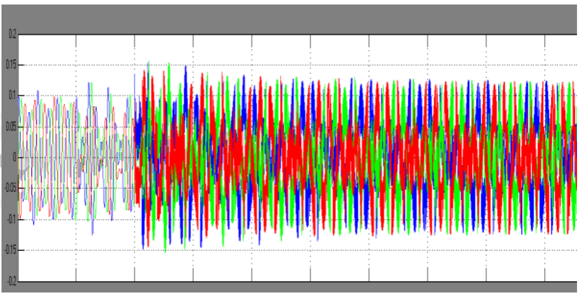

Fig.11.System output without UPQC

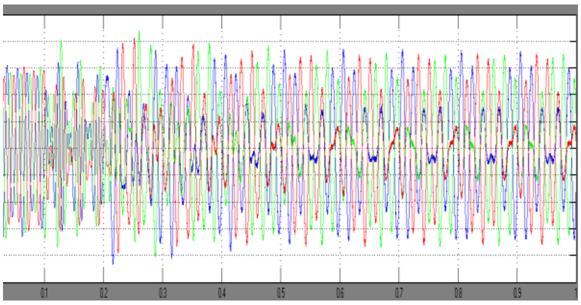

Fig.12.System output with UPQC

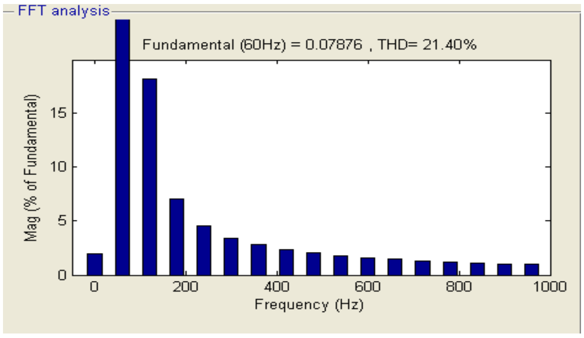

Fig.13.FFT Analysis of system without UPQC

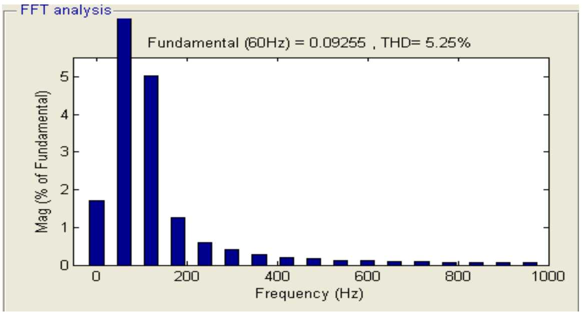

Fig.14.FFT Analysis of system with UPQC

VIII. CONCLUSION & RESULT

This paper proposed the UPQC model with multi input single output DC DC Converter installed on the secondary side if distribution transformer in the test system. Results obtained show the effectiveness of the UPQC. The THD level of the system from 21.40% is reduced to 5.25%.

The performance of the proposed system was analyzed using simulations with MATLAB SIMULINK and validates the improvement of the power reliability of the nonlinear loads.

IX. LIST OF PARAMETERS USED

Table 1.System Parameters

Sr. No.	**System Quantities**	**Standards**
1	Source	3 phase, 69 kV, 60Hz
2	Inverter parameters	IGBT based, 3-arm, 6-Pulse, Carrier Frequency=2000 Hz, Sample Time=5 µs
3	PI Controller	KP=0.5, Ki=1000 for series control Kp=0.5, Ki=1000 for shunt control, Sample time=50 µs
4	RL load	Active Power = 5kW; Inductive Reactive Power = 2kVAR
5	Transformer 1	Δ\Yg, 69/138kV
6	Transformer 2	Δ\ Δ; 69/138kV
7	Transformer 3	Δ\Yg, 69/138kV
8	Transformer 4	Δ\Yg,138\745kV
9	Motor Load (NLL)	Voltage V_{rms} = 138kV, Frequency = 60Hz

Table 2 TISO DC DC Converter Parameters

Quantities	**Standards**
L	0.112 mH
C	138.455 µF
Dpv1 = Dpv2 = Dpv3	0.45
R(Equivalent Load)	50 Ω
ΔVdc	0.015 kV
Fs	10 kHz
Ipv1 =Ipv2 = Ipv3	0.1 kA
Vpv1 = Vpv2= Vpv3	0.14 kV
Vdc1= Vdc2= Vdc3	0.25 kV

REFERENCES

[1] E.W.Gunther and H.Mehta, “A survey of distribution system power quality”,IEEE Trans. on Power Delivery, vol.10, No.1, pp.322-329, Jan.1995.

[2] B. Singh, AL.K.Haddad & A. Chandra, “A review of active filters for power quality improvement,” IEEE Trans. on Ind. Electron, vol.46, pp. 960–971, 1999.

[3] H Akagi, “New trends in active Filters for power conditioning”, IEEE Trans.on Ind. Appl., 1996, 32, pp. 1312–1322

[4] B.Singh,V. Verma,A. Chandra and K. Al-Haddad, “ Hybrid filters for power quality improvement,”Proc. IEE on Generation, Transmission and Distribution, vol.152,pp.365-378,May2005.

[5] Arindam Ghosh, Gerard Ledwich, “*Power Quality Enhancement Using Custom Power Devices*” Kulwer International Series in Engineering and Computer Science, 2002.

[6] N. G. Hingorani, “Introducing custom power,” Proc. IEEE Spectrum, vol.32, pp.41-48, June1995.

[7] P. Jayaprakash, B. Singh and D.P. Kothari, “Star/Hexagon transformer Based Three-Phase Four-Wire DSTATCOM for Power Quality Improvement,” International Journal of Emerging Electric Power Syatem,vol.9,no.8,Article1,Dec.2008.

[8] B. Singh, P. Jayaprakash and D. P. Kothari, “A T-Connected Transformer and Three-leg VSC Based DSTATCOM for Power Quality Improvement,” *IEEE Transactions on Power Electronics*, Vol. 23 , pp.2710-2718,2008.

[9] A.Ghosh and G.Ledwich, “Compensation of distribution system voltage using DVR,” IEEE Trans. on Power Delivery, vol.17, pp.1030-1036, Oct.2002.

[10] J.Praveen, B.P. Muni, S. Venkateshwarlu and H.V. Makthal, “ Review of dynamic voltage restorer for power quality Improvement,” Proc.IEEE on IECON2004, Nov.2004, vol.1, pp.749-754.

[11] M. Aredes, K. Heumann, and E. H. Walandble, “An universal active power line conditioner,” *IEEE Trans. Power Del.*, vol. 13, no. 2, pp. 545– 551, Apr. 1998.

[12] H. Fujita and H. Akagi, “The unified power quality conditioner: the integration of series- and shunt-active filters,” *IEEE Trans. Power Electron.*, vol. 13, no. 2, pp. 315–322, Mar. 1998.

[13] B. Han, B. Bae, H. Kim, and S. Baek, “Combined operation of unified power-quality conditioner with distributed generation,” *IEEE Trans. Power Del.*, vol. 21, no. 1, pp. 330–338, Jan. 2006.

[14] Hideaki Fujita and Hirofumi Akagi,”The Unified Power Quality Conditioner: The Integration of Series- and Shunt-Active Filters” IEEE transaction on power electronics, vol. 13, no. 2, March 1998

[15].Chapter iii custom power devices applications in distribution system prr.hec.gov.pk/Chapters/543S-3.

[16]. M. Davari, S.M. Ale-Emran, H. Yazdanpanahi and G. B. Gharehpetian, “Modeling the Combination of UPQC and Photovoltaic Arrays with Multi-Input Single-Output DC-DC Converter”, IEEE, 2009