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UPQC Based Power Quality Improvement in Distribution System Connected with PV Arrays

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ABSTRACT: With the advancement of technology, the dependency on the electrical energy has been increased greatly. To meet the increased energy demand renewable energy sources (RES) like solar, wind, biomass etc. will be integrated to the distribution system directly. These integration will cause various power quality issues in the system due to extensive use of power electronics converters circuits. On the load side we are using more and more non-linear loads which also cause power quality issues in the system. Hence it is necessary to mitigate the power quality (PQ) issues in the distribution system in the presence of renewable energy source. This paper deals with the mitigation of power quality issues in the presence of unified power quality conditioner (UPQC).

KEYWORDS: Renewable Energy Sources (RES), Unified Power Quality conditioner(UPQC), Power Quality (PQ)

I. INTRODUCTION

Due to the increase in the load demand our conventional generation is not sufficient to meet the growing demand. Therefore we look into an alternate energy sources to meet the growing energy demand Renewable energy sources such as solar, wind, biomass etc. are becoming more and more popular to meet up the growing demand along with the convention supply. Many efforts have been taken by utilities to fulfill consumer requirement, some consumers require a higher level of power quality than the level provided by modern electric networks. This implies that some measures must be taken so that higher levels of Power Quality can be obtained.

Non-linear loads pollute the electric power distribution system by injecting current harmonics and deteriorating the grid voltage. Based on international standards, such as, IEEE519, the power quality should be maintained by limiting the voltage and current distortion. The use of UPQC is increasing as the use of low power efficient high brightness UPQC becomes commercially available. Usually UPQC add harmonics to the system which is unavoidable using uncontrolled rectifier circuits.

In recent years, Unified Power Quality Conditioner which offers customers high quality of power has become an increased concern of engineers. UPQC is a combination of a shunt (APF) and a series compensator (DVR) connected together via a common direct current (DC) link capacitor. These devices compensate the power quality disturbances such as current harmonics and voltage sag/swell to protect sensitive process loads as well as improve service reliability.

II. OBJECTIVES AND POWER QUALITY ISSUES

The main objectives of this project are as follows.

1. To describe the power quality definitions, types of the PQ problems, main sources of the PQ problems, negative influences of the PQ problems, PQ standards, solutions to PQ problems and Custom Power concept.
2. To present literature survey of APF, DVR and UPQC with their control algorithms and power circuit topologies.
3. To find/develop control methods for reference current extraction for APF to describe the modeling of APF, to evaluate the performance of the APF with simulation studies, to describe the experimental setup of APF, to evaluate the performance of APF with experimental analysis.

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To find/develop control methods for reference voltage generation and sag/swell detection for DVR, to describe the modeling of DVR, to evaluate the performance of the DVR with simulation studies, to describe the experimental setup of DVR, to evaluate the performance of DVR with experimental analysis.

Power Quality Issues: Power quality is defined as the concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment in Institute of Electrical and Electronics Engineers (IEEE) Standard 1159-1995 (IEEE Std 519, 1995).

A.POWER QUALITY TERMINOLOGY

1. **Frequency:** Number of complete cycles of a periodic wave in a unit time, usually 1 sec. The frequency of electrical quantities such as voltage and current is expressed in (Hz).
2. **Harmonic:** Sinusoidal component of a periodic wave having a frequency that is an integral multiple of the fundamental frequency. If the fundamental frequency is 60 Hz, then the second harmonic is a sinusoidal wave of 120 Hz, the fifth harmonic is a sinusoidal wave of 300 Hz, and so on.
3. **Harmonic distortion:** Quantitative representation of the distortion from a pure sinusoidal waveform.
4. **Impulse:** Traditionally used to indicate a short duration overvoltage event with certain rise and fall characteristics. Standards have moved toward including the term impulse in the category of transients.
5. **Distortion:** Qualitative term indicating the deviation of a periodic wave from its ideal waveform characteristics. Figure 3.2 contains an ideal sinusoidal wave along with a distorted wave. The distortion introduced in a wave can create waveform deformity as well as phase shift.
6. **Distortion factor:** Ratio of the RMS of the harmonic content of a periodic wave to the RMS of the fundamental content of the wave, expressed as a percent. This is also known as the total harmonic distortion (THD).
7. **Linear loads:** Electrical load which in steady-state operation presents essentially constant impedance to the power source throughout the cycle of applied voltage. A purely linear load has only the fundamental component of the current present.
8. **Nonlinear load:** Electrical load that draws currents discontinuously or whose impedance varies during each cycle of the input AC voltage waveform.
9. **Power factor (total:** Ratio of the total active power (watts) to the total apparent power (volt amperes) of the composite wave, including all harmonic frequency components. Due to harmonic frequency components, the total power factor is less than the displacement power factor, as the presence of harmonics tends to increase the displacement between the composite voltage and current waveforms.
10. **Power disturbance:** Any deviation from the nominal value of the input AC characteristics.
11. **Swell:** RMS increase in AC voltage at power frequency from half of a cycle to a few seconds duration.

III. UNIFIED POWER QUALITY CONDITIONER

Unified Power Quality Conditioner (UPQC) is a multifunction power conditioner that can be used to compensate various voltage disturbance of the power supply, to correct voltage fluctuation, and to prevent harmonic load current from entering the power system. It is a custom power device designed to mitigate the disturbances that affect the performance of sensitive and/or critical loads. UPQC has shunt and series compensation capabilities for (voltage and current) harmonics, reactive power, voltage disturbances (including sag, swell, flicker etc.), and power-flow control.

Normally, a UPQC consists of two voltage-source inverters with a common dc link designed in single-phase, three-phase three-wire, or three phase four-wire configurations. One inverter is controlled as a variable voltage source in the series active power filter (APF). The other inverter is controlled as a variable current source in the shunt active power filter (APF). The series APF compensates for voltage supply disturbances (e.g., including harmonics, imbalances, negative and zero sequence components, sag, swell, and flickers). The shunt APF converter compensates for load current distortions (e.g., caused by harmonics, imbalances) and reactive power, and perform the dc link voltage regulation.

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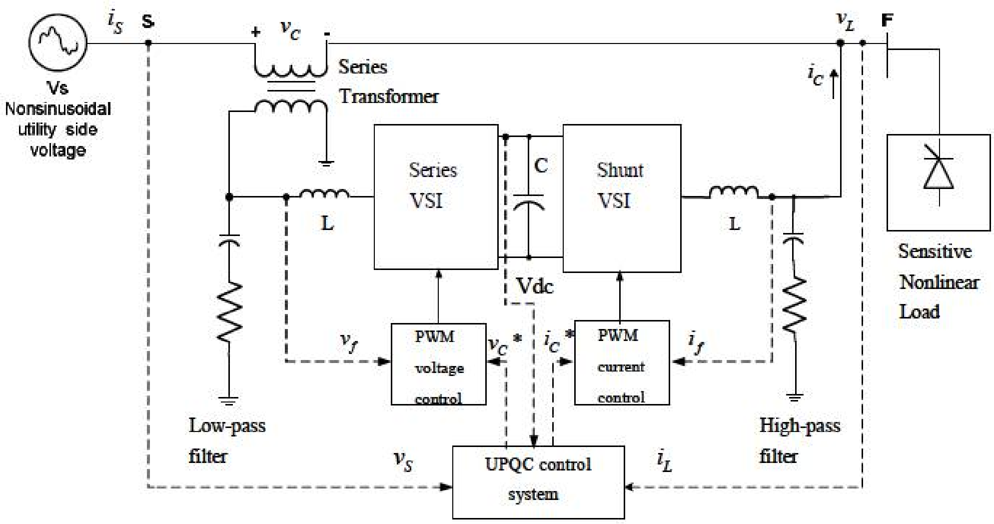

Fig 4.1.1: Shows detailed configuration of UPQC

The key components of UPQC are as follows:

Series Inverter: It is a voltage-source inverter connected in series with AC line through a series transformer and acts as a voltage source to mitigate voltage distortions. It eliminates supply voltage flickers and imbalances from the load terminal voltage. Control of the series inverter output is performed by using pulse width modulation (PWM). Among the various PWM technique, the hysteresis band PWM is frequently used because of its ease of implementation. Also, besides fast response, the method does not need any knowledge of system parameters. In this work hysteresis band PWM is used for the control of inverters.

Shunt inverter: It is a voltage-source inverter connected in shunt with the same AC line which acts to cancel current distortions, compensate reactive current of the load and improve the power factor of the system. It also performs the DC-link voltage regulation, resulting in a significant reduction of the DC capacitor rating. The output current of shunt converter is adjusted using a dynamic hysteresis band by controlling the status of the semiconductor switches such that output current follows the reference signal and remains in a predetermined hysteresis band.

DC link capacitor: The two VSIs are connected back to back with each other through this capacitor. The voltage across this capacitor provides the self-supporting DC voltage for proper operation of both the inverters. With proper control, the DC link voltage acts as a source of active as well as reactive power and thus eliminates the need of external DC source like battery.

Low-pass filter: It is used to attenuate high-frequency components of the voltages at the output of the series converter that are generated by high-frequency switching of VSI.

High-pass filter: It is installed at the output of shunt converter to absorb ripples produced due to current switching.

Series transformer: The necessary voltage generated by the series inverter to maintain a pure sinusoidal load voltage and at the desired value is injected in to the line through these series transformers. A suitable turns ratio is often considered to reduce the current flowing through the series inverter.

IV. MATLAB SIMULINK OF UPQC CONFIGURATION WITH SOLAR PV ARRAY

This chapter discusses the simulation results of shunt active power filter (APF), series active power (APF) filter and the unified power quality conditioner to evaluate the proposed control strategy. The simulation models have been developed MATLAB/SIMULINK environment. The models have been operated for non-linear load. In order to introduce nonlinear load a three phase diode bridge with RL load on dc side is used. The nonlinear load has been used purposely because to compensate the harmonics and the distortion. Here a three phase programmable source is taken as input and is given through the line resistance.

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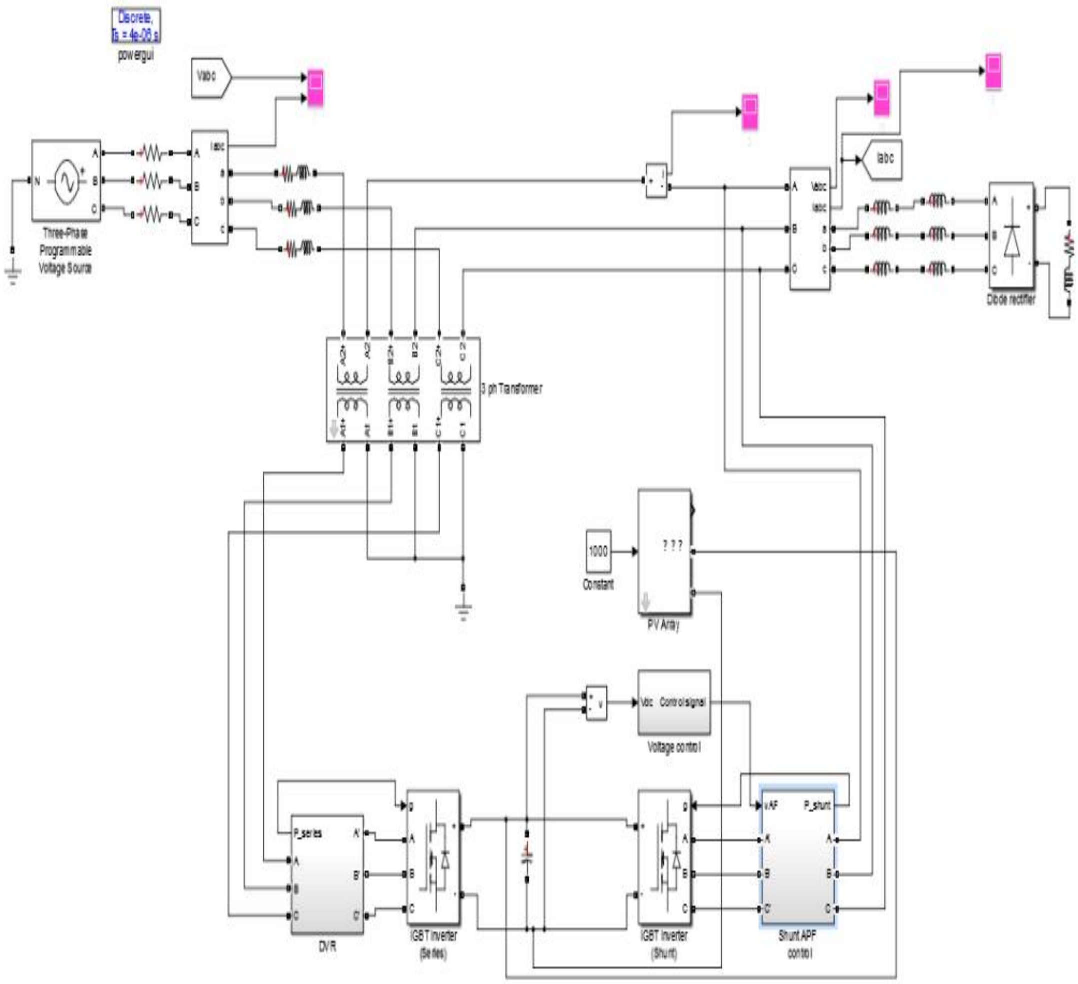

V. CONTROL SCHEME OF THE PROPOSED SYSTEM

The DC voltage generated by a photovoltaic array varies and is low in magnitude. Hence to generate a higher DC voltage, it is necessary to have a step-up DC-DC converter. The DCDC converter will be absorbing power from the photovoltaic array, and therefore should be designed to match photovoltaic array ripple current specifications. Also at the same time it should not conduct any negative current into the photovoltaic array.

A.CLARKE's TRANSFORM

The transformation of stationary circuits to a stationary reference frame was developed by E. Clarke. In electrical engineering, the alpha-beta ($\alpha\beta\gamma$) transformation (also known as the Clarke transformation) is a mathematical transformation employed to simplify the analysis of three-phase circuits. One very useful application of the $\alpha\beta\gamma$ transformation is the generation of the reference signal used for space vector modulation control of three-phase inverters. The stationary two-phase variables of Clarke's transformation are denoted as α and β, α-axis and β-axis are orthogonal.

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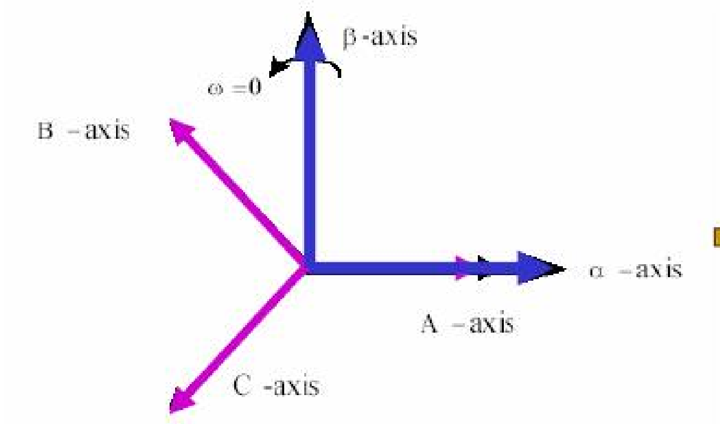
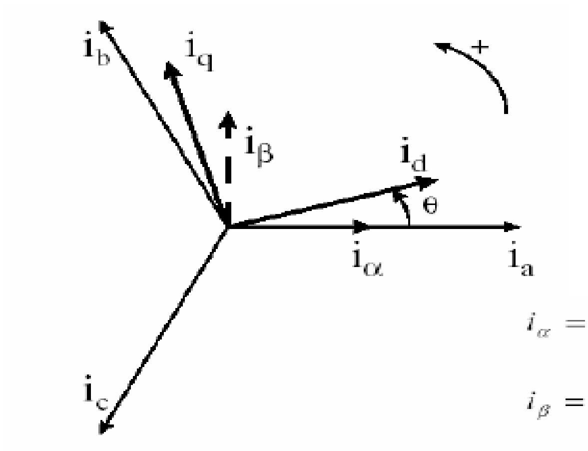


$$v_\alpha = v_a$$
$$v_\beta = \frac{2v_b + v_a}{\sqrt{3}}$$

Fig.5.1: Axis Diagram of Clarke's Transform

In order for the transformation to be invertible, a third variable, known as the zero-sequence component, is added. The representation of clarke's diagram is given as:



$$i_\alpha = \frac{2}{3}\cdot i_a - \frac{1}{3}(i_b - i_c)$$
$$i_\beta = \frac{2}{\sqrt{3}}(i_b - i_c)$$
$$i_o = \frac{2}{3}(i_a + i_b + i_c)$$

$$i_\alpha = i_a$$
$$i_\beta = \frac{1}{\sqrt{3}}\cdot i_a + \frac{2}{\sqrt{3}} i_b$$
$$i_a + i_b + i_c = 0$$

$$i_a = i_\alpha$$
$$i_b = -\frac{1}{2}\cdot i_\alpha + \frac{\sqrt{3}}{2}\cdot i_\beta$$
$$i_c = -\frac{1}{2}\cdot i_\alpha - \frac{\sqrt{3}}{2}\cdot i_\beta$$

Fig 5.2: Representation of Clarke's Diagram

In matrix form clarke's transform is given as:

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

v_o, v_α, v_β are zero sequence voltages, α axis, β axis voltages respectively.

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$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

io, iα, iβ are zero sequence current, α axis, β axis currents respectively.

VI. SIMULATIONS AND RESULTS

The series inverter mainly functions to mitigate voltage harmonics and voltage imbalance. The main function of the DVR is to compensate voltage difference. The shunt APF inverter mainly functions to mitigate current harmonics and current imbalance. The figures below show the simulation results of the proposed system.

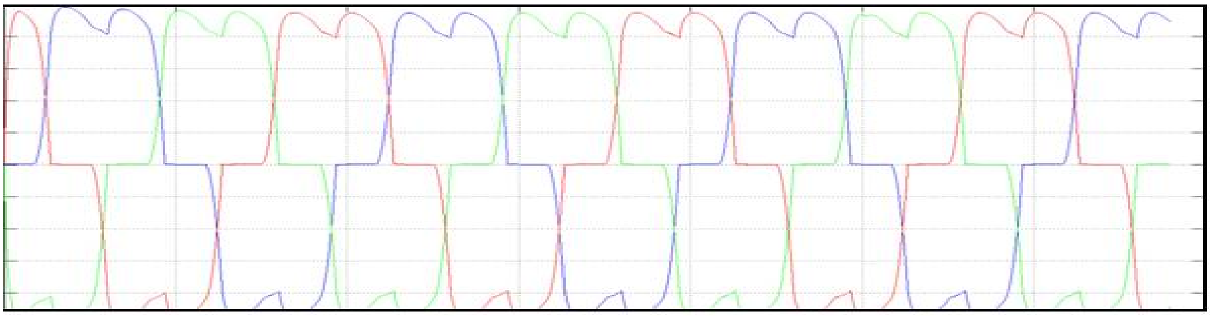

Fig 1: Current before Compensation

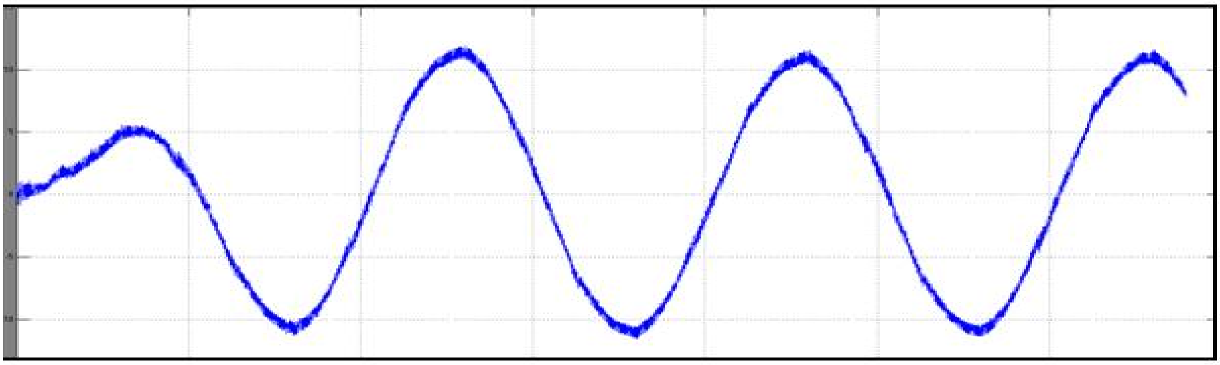

Fig 2: Current after Compensation

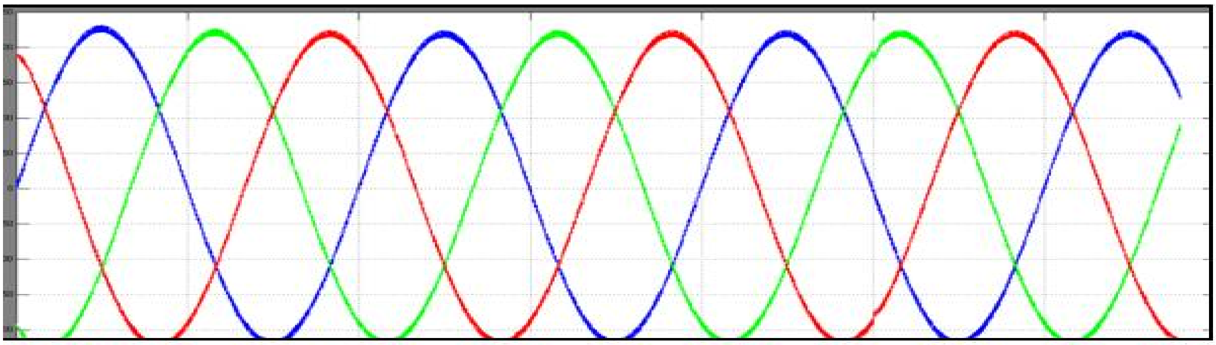

Fig 3: Voltage at source side before Compensation

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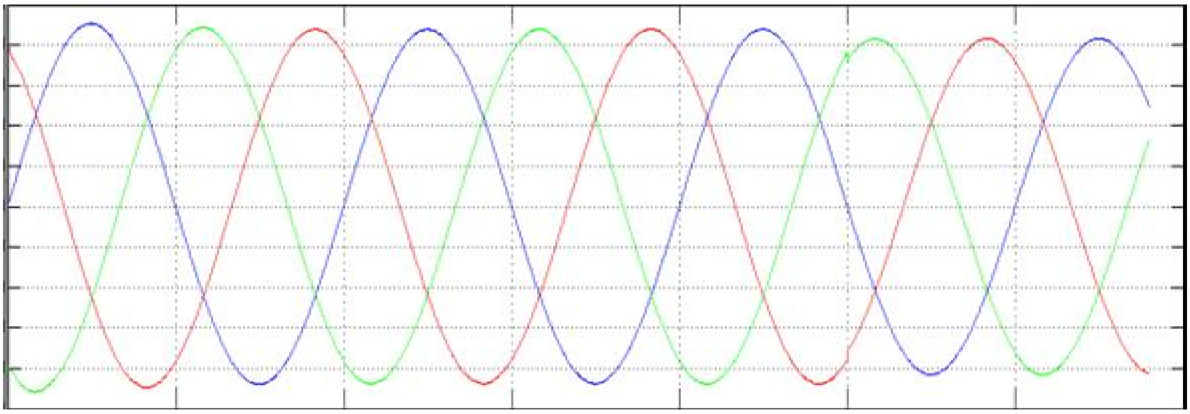

Fig 4: Voltage after Compensation

VII. CONCLUSION

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

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.

[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 System, 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]H. Matsuo, W. Lin, F. Kurokawa,T. Shigemizu and N. Watanabe, “Characteristics of the Multiple-Input DC–DC Converter,” IEEE Trans. On Ind. Electronics, Vol. 51, N0. 3, pp. 625-631, June 2004.

[16] Lorenzo, E. “Solar Electricity Engineering of Photovoltaic Systems”, internationally recognized expert engineers and scientists of IES (Solar Energy Institute), 1994.

[17] Altas, I. H.; Sharaf, A.M: A Photovoltaic Array Simulation Model for Matlab-Simulink GUI Environment, Clean Electrical Power, 2007. ICCEP '07. International Conf. 2007, pp.341 – 345