A Custom Power Device for Power Quality Improvement Unified Power Quality Conditioner (UPQC)

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ABSTRACT:Power Quality (PQ) has long been a source of worry for utilities of all sizes. The development of power electronic devices has had a substantial impact on the quality of electric power supply. The operation of nonlinear loads generates harmonics, which reduces the quality of the distribution system. In such cases, both utilities and end users are concerned about power quality. This suggests that improving power quality requires just a few actions. This research focuses on UPQC, which is a combination of series and shunt active power filters. The series APF is used to decrease voltage-based distortions, while the shunt APF is used to reduce current-based distortions. UPQC concurrently and independently lowers voltage- and current-based aberrations. UPQC improves power quality by correcting harmonics as well as load current, resulting in sinusoidal source current and load voltage at the optimum voltage level. The simulations of the series APF, shunt APF, and UPQC were performed using MATLAB/Simulink.

Keywords: Power System; Power Quality; Unified Power Quality Conditioner (UPQC); Series Active Power Filter; Shunt Active Power Filter;Voltage Source Inverter; Total Harmonic Distortion.

1. INTRODUCTION: To improve power quality in the distribution system, custom power devices such as dynamic voltage restorers (DVR), distribution static synchronous compensators (D-STATCOM), and universal power quality conditioners (UPQC) are employed. Voltage-related concerns like as voltage sag, swell, and interruption are addressed by DVR. D-STATCOM generates or absorbs reactive current and adjusts for it. DVR and D-STATCOM can manage voltage or current problems, however they can not filter harmonics. To do this, active or passive filters are utilised. In contrast, UPQC may solve current and voltage-related power quality issues, as well as filter harmonics. As a consequence, there is no need to install a significant number of devices in the distribution system to handle power quality problems, and UPQC may be considered a complete solution. UPQC is offered in this research as an all-inclusive device to improve power quality due to its operational idea. The UPQC series and shunt compensators were built and managed using the reference frame (dq) theory. The UPQC, its series, and shunt compensator were all simulated using the PSIM environment. FFT analysis is offered to help understand the results [1].

A unified power quality conditioner (UPQC) is a specialist power device that provides a complete power quality solution. The single downside of UPQC is that it cannot maintain voltage in the case of a power interruption. Several UPQC topologies are described. This article examines the design and operating features of two UPQC topologies: (i) UPQC-Multi converter and (ii) UPQC-Distributed Generation. Both of these topologies address UPQC's inability to provide uninterrupted power supply even in the case of a grid outage while adhering to IEEE standard 519. An attempt is made to evaluate the performance of both topologies in terms of harmonic current and reactive power compensation, sag/swell mitigation, number of switches, switch ratings, and so on. In the case of UPQC-Distributed Generation, a subclassification based on energy sources and energy storage components is also available. The behaviour of the two topologies under different operating situations is also compared [2].

The usage of power quality conditioners in distribution system grids has increased in recent years as a result of the continual growth in nonlinear loads linked to the electrical network. It is feasible to provide a balanced and harmonically low modulated voltage for the loads while leaving undistorted current from the utility grid by employing a Dual architecture of unified power quality conditioner. The Dual UPQC has two active filters: a shunt active filter and a series active filter. The Dual UPQC (iUPQC) is a combination of two active filters, one series and one parallel, used to terminate harmonics and unbalances. Unlike standard UPQCs, the iUPQC controls the series filter as a sinusoidal current source and the shunt filter as a sinusoidal voltage source. As a result, the iUPQC's pulse width modulation controls deal with a well-known frequency spectrum since it is supervised using voltage and current sinusoidal standards, as opposed to the normal UPQC, which is supervised using non sinusoidal references. This work might build Dual UPQC (iUPQC) for power quality improvement by taking into account sudden load variations [3].

One of the power quality difficulties is voltage flicker, which is a recurring voltage magnitude change with a low frequency. The use of non-linear load aggravates the problem. The research outlines the use of a Unified Power Quality Conditioner (UPQC) as a voltage flicker solution. A fundamental control method is used to control UPQC. The simulation results show variations in voltage and current at the Point of Common Coupling (PCC). The dynamics of combining Series and Shunt Active Filters is identified to combat flicker soon enough for proper system operation [4].

It is detailed a simpler control strategy for a three-phase Series Active Power Filter (SAPF) as Power Quality Conditioner. SAPF corrects supply voltage distortions/unbalance, as well as supply voltage harmonics, such that they do not reach the load end with exceptionally low THD in load voltage. The series APF is implemented using a three-phase, three-leg VSI. A dynamic model of the SAPF is created in the MATLAB/SIMULINK environment, and simulation results demonstrating system power quality improvement in terms of constant RMS Voltage at load are reported [5].

To alleviate power quality difficulties in terminal voltage, a control algorithm for the dynamic voltage restorer (DVR) is used. The DVR's dc bus voltage and the load terminal voltage are managed by two PI (proportional integral) controllers [6].

The UPQC is created by merging series and shunt active power filters (APFs) that share a dc bus capacitor. The shunt APF is implemented using a three-phase, four-leg voltage source inverter (VSI), whereas the series APF is implemented using a three-phase, three-leg VSI [7].

The instantaneous reactive power theory, also known as p-q theory, is investigated for a 3-phase 4-wire and 4-leg shunt active power filter (APF) based on a new control algorithm to suppress harmonic currents, compensate reactive power, neutral line currents, and balance load currents under unbalanced nonlinear load and non-ideal mains voltage conditions [8].

Unified Power Quality Conditioner (UPQC) is a series and shunt APF hybrid. This paper offers a control approach based on a unit vector template, with a focus on voltage harmonics in utility voltage. The universal power quality conditioner (UPQC) was subjected to a steady-state test. The mathematical analysis is based on the flow of active and reactive power via the shunt and series APFs, where the series APF may absorb or generate active power while the shunt APF handles all reactive power needs [9].

This work describes a software phase locked loop (PLL) for custom power devices. The PLL separates 3-phase utility voltage samples from the past and present into sequence components. The first two stages of the PLL monitor the projected positive sequence component's phase angle and frequency. In the third step, the parameter /spl Delta//spl theta/, which is required by the first stage, is approximated. Simulations of the PLL's performance as well as the performance of a dynamic voltage restorer including the proposed PLL have been shown. The proposed PLL works effectively in unbalanced and distorted utility circumstances. It continuously monitors the utility phase angle and frequency, as well as extracting the utility voltage sequence components. A PLL-enabled DVR may accommodate sensitive loads while also functioning as a harmonic filter [10].

2. UNIFIED POWER QUALITY CONDITIONER (UPQC): The Unified Power Quality Conditioner (UPQC) is a versatile power conditioner that may be used to compensate for a variety of power source voltage disturbances and voltage changes, as well as to prevent harmonic load current from entering the power system. It is a customised power device designed to decrease the impact of disturbances on sensitive load performance. UPQC consists of two voltage-source inverters connected by a common dc connection that may be single-phase, three-phase three-wire, or three-phase four-wire [2]. One inverter is controlled as a variable voltage source in the series active power filter (APF), while another inverter is controlled as a variable current source in the shunt active power filter (APF). In series, the Active Filter compensates for voltage supply anomalies (such as harmonics, imbalances, sag, swell, flickers, negative and zero sequence components). The shunt filter compensates for load current distortions (such as those caused by harmonics or imbalances), reactive power, and regulation of the dc link voltage.

2.1.COMPONENTS OF UPQC: The series inverter (voltage-source inverter) is connected in series with the alternating current line through a series transformer and acts as a voltage source to correct voltage aberrations. Supply voltage flickers and load terminal voltage imbalances are reduced by UPQC. The output of a series inverter (PWM) is controlled by pulse width modulation. Hysteresis band PWM is the most often used PWM technique due to its ease of implementation. In addition to giving a speedy response, the technique does not need any knowledge of system features. The next sections go through the details of the hysteresis control method. Shunt Inverter: A voltage-source inverter that is shunt-connected to the same alternating current line and operates to reduce current distortions, adjust for reactive current in the load, and boost system power factor. It also adjusts the DC-link voltage, which results in a significant reduction in DC capacitor rating. The output current of the shunt converter is adjusted using a dynamic hysteresis band by managing the state of the semiconductor switches so that it follows the reference signal and remains within a preset hysteresis band. The DC link capacitor: links the two VSIs that are coupled back-to-back. The voltage across this capacitor provides self-sustaining DC voltage for the best operation of both inverters. A low-pass filter: is utilised to reduce high-frequency components of voltages at the series converter's output generated by VSI switching at high frequencies. A high-pass filter: is added to the shunt converter's output to absorb waves created by current switching [4]. Through these series transformers: the needed voltage generated by the series inverter to maintain a pure sinusoidal load voltage at the proper value is supplied into the line.

3. PROPOSED SYSTEM FORANALYSIS: Unified power quality conditioning is the process of conditioning the power's components, namely supply voltage and load current. Figure 1 depicts the UPQC Simulink model. Table 1 is used in the test system modelling.

The following are the requirements to meet conditioning or modelling:

- If there is a fluctuation or harmonics in the supply voltage, it shall not impact the load. As a result, we must ensure that the voltage is sinusoidal and regulated at the required value.
- If there is a non-linear load on the load side, it uses non-linear current, resulting in non-linearity in the grid section, which impacts other loads as well. As a result, we must ensure that the current is sinusoidal and that the THD value is as low as possible.
- At the Grid point, reactive power must be kept at zero.

4. MATLAB SIMULATION, RESULTS ANDDISCUSSION

The simulation results for the system under consideration are shown below. The findings obtained with and without the use of UPQC are presented. The simulation was carried out in the MATLAB/Simulink environment.

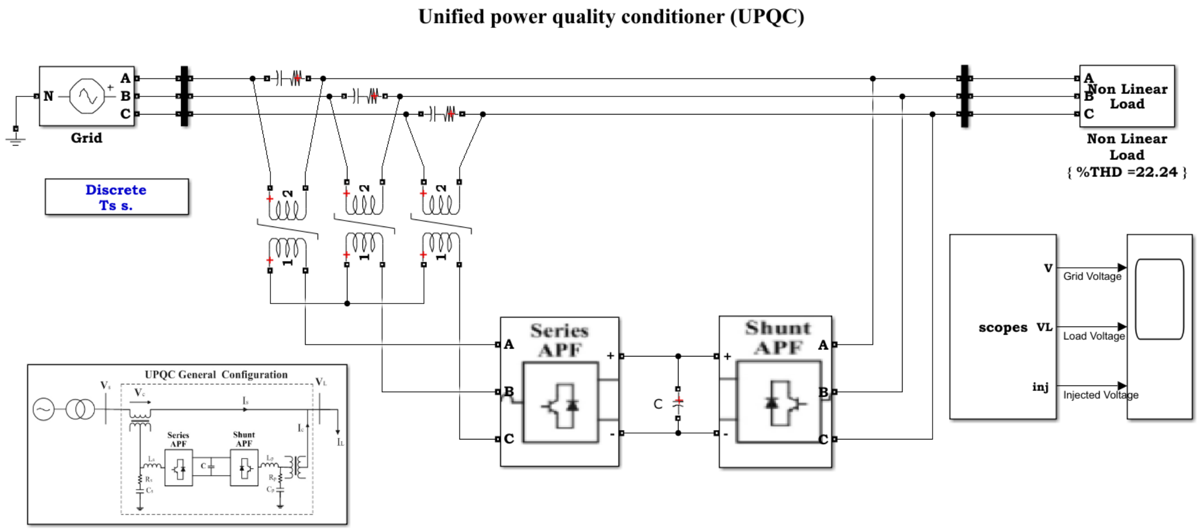

Figure 1: MATLAB Simulink Model of UPQC

The conditions to satisfy conditioning or modelling are as follows:

- Voltage compensation (Series APF)

A series active power filter (APF) may aid with voltage compensation by calculating the voltage inaccuracy in the grid and how much voltage has to be induced in the grid to make the voltage sinusoidal with the appropriate voltage magnitude and frequency. It subtracts the supply voltage from the reference voltage (Vabc*), calculates the voltage error, which is then compared to the voltage error produced in the lines, and then proceeds to PWM control to produce the pulses to minimise the error produced by the difference in calculated error voltage and produced error voltage.

- Current Compensation (Shunt APF)

Current compensation determines how much current error exists in the grid and how much current must be injected into the grid to make the current sinusoidal with the required current magnitude and frequency. The load current must be subtracted by reference currents (Iabc*), which will be sinusoidal where Id and Iq currents are purified by collecting load currents, and it will calculate the error in current which is then compared with error current produced in three lines before proceeding to PWM control to produce pulses to minimise the error produced by the difference in calculated error current and produced error current.

- DC capacitor voltage controller

The DC capacitor voltage must be kept constant at a certain level. The reference value must be subtracted from the measured DC voltage, and the error must be minimised to zero using a transfer function, before the control signal is added to the Id current.

Table 1: Simulation parameters of the proposed system for analysis

Simulation Parameters	Values
Grid Voltage (Phase to Phase) in RMS	440V
Grid Frequency	50 Hz
Rating of the Coupling Transformer	3.3kVA, 1kV/440V
Non-Linear Load	THD = 22.24 %

Figure 2, shows the effect of series active power filter in compensating voltage, the supply voltage is non-sinusoidal. As series active power filter is used it will calculate the error that is present and injects the required amount of voltage to it sinusoidal.

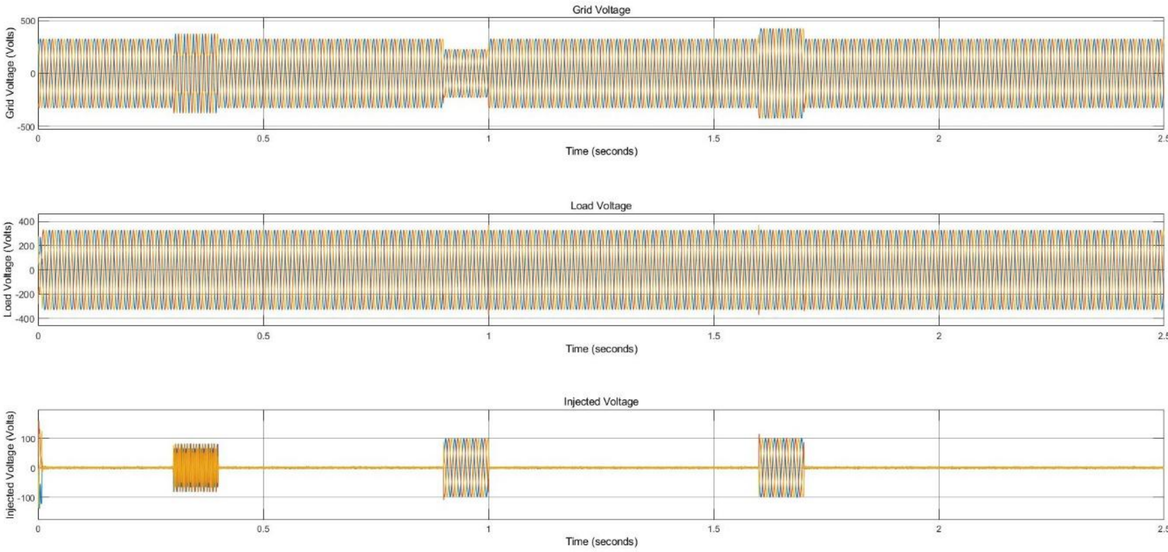

Figure 2: Source voltage before and after compensation

Figure 3, shows the effect of shunt active power filter in compensating current, the load current is nonlinear. As shunt active power filter calculates the error that is present and injects the reference currents to make the current sinusoidal with desired magnitude and frequency.

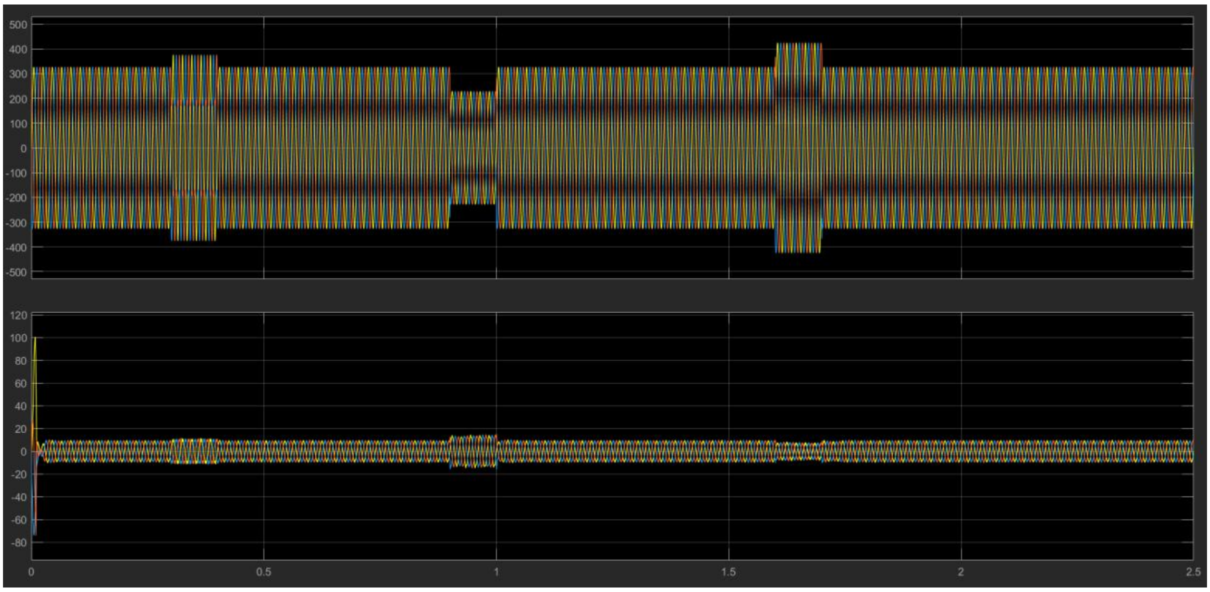

Figure 3: load current before and after compensation

4.1. TOTAL HARMONICDISTORTION

Simulations of the test system using MATLAB/Simulink are done to verify the performance of UPQC. To validate the performance of planned control mechanisms, Total Harmonic Distortion is measured. The shunt active power filter is responsible for reducing current harmonics; figures 4 and 5 show the harmonic spectrum of current harmonics before and after compensation, and the percentage THD is less than the IEEE 519-1992 harmonic limit.

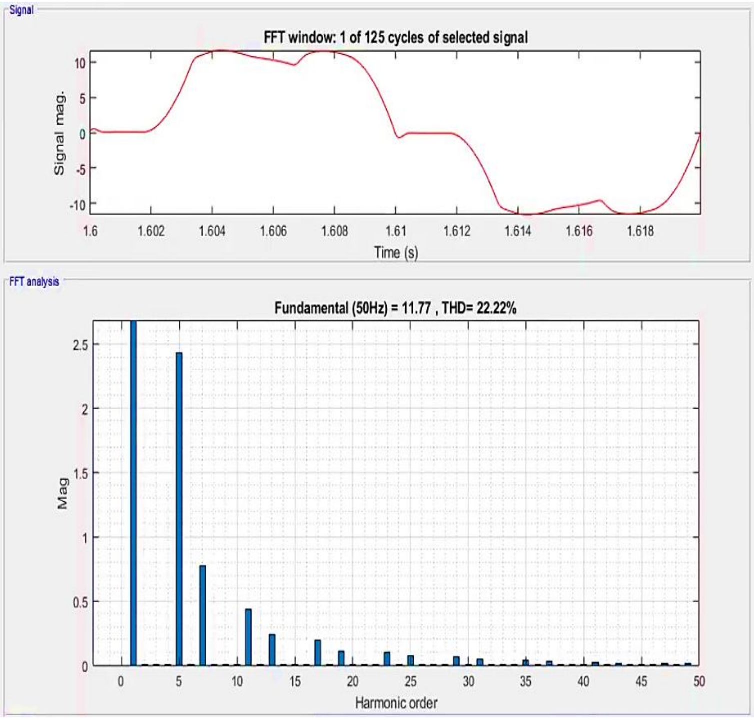

Figure 4: Harmonic spectrum of grid current before compensation

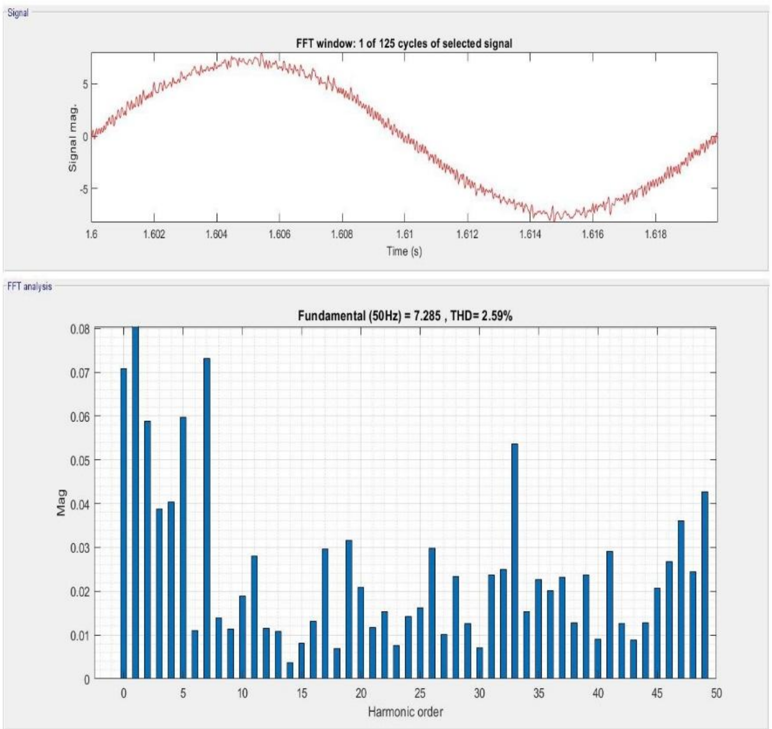

Figure 5: Harmonic spectrum of grid current after compensation

5. CONCLUSION

This article describes how to use series and shunt active power filters as UPQC to adjust for voltage distortions and reduce current harmonics. The primary goal of this project is to develop a mechanism for detecting and classifying power quality incidents. After correction, the source voltage THD is well within the IEEE 519 recommended threshold. The series APF, shunt APF, and UPQC modelling has been completed. A fundamental control strategy known as extraction of unit vector template was used to mimic the control scheme for series APF. In this technique, the reference signals for series APF are created using a phase locked loop (PLL) and a hysteresis band controller. The control mechanism for shunt APF was described using the instantaneous reactive power theory. According to the simulation results, UPQC improves power system quality by correcting harmonic and reactive currents in load current, which makes source current sinusoidal, and it also makes load voltage sinusoidal at the required voltage level by compensating with series APF. The harmonics limit defined by IEEE standard 519-1992 is met by the THD of the source current and load voltage.

This research work's major contributions are summarised below:

- The proposed expert system provides a more accurate categorization of power quality concerns.
- The UPQC addresses power quality issues such as voltage imbalances and total harmonic distortion at the point of common connection. It aids in the successful integration of renewable energy sources while minimising the influence on power quality.

6.FUTURESCOPE

Research is an ongoing activity that brings up new opportunities to continue the work. Further study may be conducted in the following areas.

- Other transformation techniques, including as linear, Walsh, and coordinate approaches, may be used in the expert system's pre-processing step. It is applicable to any industry that requires a power quality monitoring system.
- It may provide a controller that is suitable for mitigating power quality events that may arise as a result of the introduction of renewable energy sources and nonlinear loads.

- A variety of evolutionary algorithms may be used to tune the controller in specialisedpower devices.
- Power quality concerns in microgrids may be analysed and addressed utilising different energy storage devices.
- To improve performance, energy storage methods such as super capacitors and fly wheel storage systems may be included in specialised power devices.

REFERENCES

[1] Dinesh MahendraMatlani; Mehul D Solanki "UPQC: An Exhaustive Solution to Improve Power Quality" 2020 4th International Conference on Electronics, Communication and Aerospace Technology (ICECA).

[2] Nirav Karelia; Amit Vilas Sant; Vivek Pandya "Comparison of UPQC Topologies for Power Quality Enhancement in Grid Integrated Renewable Energy Sources" IEEE 16th India Council International Conference (INDICON) 2019.

[3] Nikhil S. Borse; Suhas M. Shembekar "Power quality improvement using dual topology of UPQC" International Conference on Global Trends in Signal Processing, Information Computing and Communication (ICGTSPICC) 2016.

[4] Arpit Agrawal; Pramod Agarwal; Premalata Jena "Compensation of voltage flicker using Unified Power Quality Conditioner (UPQC)" IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES) 2014.

[5] M. A. Chaudhari; Chandraprakash "Three-phase Series Active Power Filter as Power Quality Conditioner" 2012 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES).

[6] B. Singh, P. Jayaprakash, D. P. Kothari, A. Chandra and Kamal-Al-Haddad,"New Control Algorithm for Capacitor Supported Dynamic Voltage Restorer" Journal of Electromagnetic Analysis and Applications, 2011.

[7] Yash Pal, A. Swarup, Bhim Singh, "A control strategy based on UTT and of three-phase, fourwire UPQC for power quality improvement" International Journalof Engineering, Science and Technology, 2011.

[8] Mehmet Ucar and EnginOzdemir, "Control of a 3-phase 4-leg active power filter under non-ideal mains voltage condition", Electric Power Systems Research (2008).

[9] V. Khadkikar, P. Agarwal, A. Chandra, A.O. Bany and T.D.Nguyen , "A Simple New Control Technique For Unified Power Quality Conditioner (UPQC)," IEEE International Conference on Harmonics and Quality of Power, Sept. 2004.

[10] S. R. Naidu, A. W. Mascarenhas and D. A. Fernandes "A Software Phase-Locked Loop for Unbalanced and Distorted Utility Conditions," IEEE POWERCON Nov.2004.