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# Power Quality Improvement Using Unified Power Quality Conditioner

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**ABSTRACT:** Abstract Power quality (PQ) problem can be defined as the deviations of the voltage And/or current from the nominal sine wave. P-Q problems generally concern with voltage sags/swells and harmonic currents. Custom Power (CP) devices that mitigate these power quality problems have gained more attention in the recent decades. Unified Power Quality Conditioner (UPQC) is one of the CP devices and it mitigates both load current and supply voltage problems, simultaneously.

UPQC is Designed, modelled and setup experimentally to mitigate voltage sag/swells and harmonic currents. UPQC consists of Dynamic Voltage Restorer (DVR) and Active Power Filter (APF). Traditional Instantaneous Reactive Power Theory (IRPT) is optimized for APF control algorithm to compensate harmonic load current under unbalanced and distorted supply voltages. UPQC with proposed controller algorithms effectively compensates the sag/swell in supply voltage by keeping the load voltage amplitude at 0.9-1 per unit and eliminates the load current harmonics by keeping supply current at 5% less than of Total Harmonic Distortion, simultaneously. UPQC can work in zero active power consumption mode, active power absorption mode and active power delivering mode.

The series active power filter (APF) part of UPQC works in active power delivering mode and absorption mode during voltage sag and swell condition, respectively. The shunt APF part of UPQC during these conditions helps series APF by maintaining dc link voltage at constant level. It is found that the UPQC in Three-phase system effectively compensates the important power quality issues, such as the load reactive power, load current harmonics, voltage harmonics, voltage sag, voltage swell and voltage flicker.

**KEYWORDS:** Unified Power Quality Conditioner , Reactive Power , Shunt converter ,Series Converter.

## I. INTRODUCTION

The Power Quality (PQ) has become an important issue to electricity consumers at all levels of usage. The PQ issue is defined as “Any power problem manifested in voltage, current, or frequency deviations that results in failure or disoperation of customer equipment.”

The development of power electronic based equipment has a significant impact on quality of electric power supply. The switch mode power supplies (SMPS), dimmers, current regulator, frequency converters, low power consumption lamps, arc welding machines, etc., are some out of the many vast applications of power electronics based devices. The operation of this loads/equipment generates harmonics and thus, pollutes the modern distribution system.

The growing interest in the utilization of renewable energy resources for electric power generation is making the electric power distribution network more susceptible to power quality problems. In such conditions both electric utilities and end users of electric power are increasingly concerned about the quality of electric power. 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. Active power filters (APF) have been proposed as efficient tools for power quality improvement. Active power filters can be classified as series or shunt according to their system configuration. The series APF generally takes care of the voltage based distortions, while shunt APF mitigates current based distortions. The combination of series and shunt active power filter is called the unified power-quality compensator (UPQC). UPQC mitigates the voltage and current based distortion simultaneously as well as independently. In this thesis the main focus is on UPQC.

## II. LITERATURE SURVEY

The use of unified power quality conditioner (UPQC) was first described by the Hideaki Fujita, Hirofumi Akagi [1] and C. Sankaran in 2002. [2]. However, the unified power quality conditioner technology available today emerged from the early efforts by Vinod khadkikar, Ambrish Chandra [3].

Hideaki Fujita, Hirofumi Akagidemonstrated about the integration of shunt active filters and series active filters which can use for the compensation of the voltage flicker/imbalance, reactive power and harmonics. Fujita and Akegi also demonstrated about the control strategies of unified power quality conditioners (UPQC). A practical approach to harmonic compensation is provided by the Fujita and Akagi to improve the power quality of the distribution and industrial systems [4].

## III. UNIFIED POWER QUALITY CONDITIONER

The Unified Power Quality Conditioner is a custom power device that is employed in the distribution system to mitigate the disturbances that affect the performance of sensitive and/or critical load. It is a type of hybrid APF and is the only versatile device which can mitigate several power quality problems related with voltage and current simultaneously therefore is multi functioning devices that compensate various voltage disturbances of the power supply, to correct voltage fluctuations and to prevent harmonic load current from entering the power system.

Figure shows the system configuration of a single-phase UPQC. Unified Power Quality Conditioner (UPQC) consists of two IGBT based Voltage source converters (VSC), one shunt and one series cascaded by a common DC bus. The shunt converter is connected in parallel to the load. It provides VAR support to the load and supply harmonic currents. Whenever the supply voltage undergoes sag then series converter injects suitable voltage with supply. Thus, UPQC improves the power quality by preventing load current harmonics and by correcting the input power factor.

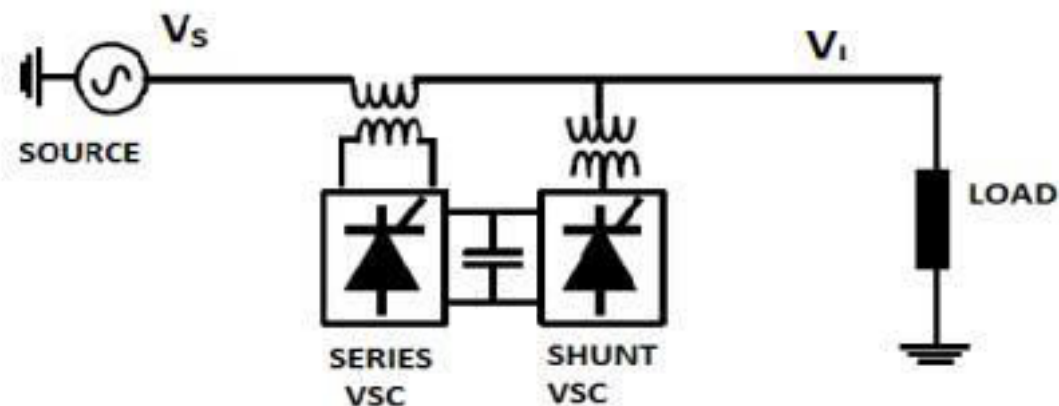


Fig.1 Block Diagram of UPQC

## IV. SHUNT ACTIVE FILTER (SHUNT VSC) AND SERIES ACTIVE FILTERS (SERIES VSC)

### Series converter

It is a voltage-source converter connected in series with the AC line and acts as a voltage source to mitigate voltage distortions. It is used to eliminate supply voltage flickers or imbalance from the load terminal voltage and forces the shunt branch to absorb current harmonics generated by the nonlinear load. Control of the series converter output voltage is usually performed using sinusoidal pulse-width modulation (SPWM). The gate pulses required for converter are generated by the comparison of a fundamental voltage reference signal with a high-frequency triangular waveform.

### Shunt converter

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

## V. BASIC CONFIGURATION AND CONTROL TECHNIQUES OF UPQC

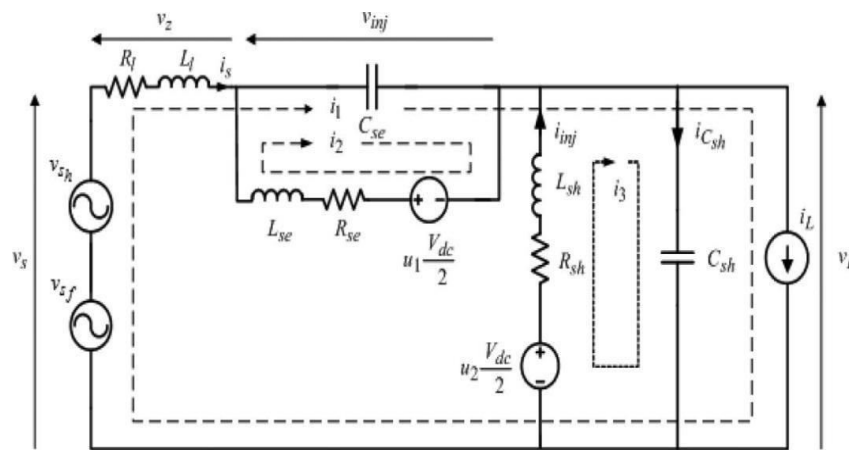


Fig 2. Basic Configuration Of UPQC

The equivalent single-phase representation of the UPQC in a power distribution system is shown in Figure

The distorted supply voltage  $v_s$  at the point of common coupling is modelled by the sum of two voltage sources, namely, its fundamental  $v_{sf}$  and its harmonics  $v_{sh}$ .

The nonlinear load is modelled by a distorted current source  $i_L$ , which is also made up of its fundamental  $i_{Lf}$  and its harmonics  $i_{Lh}$  that will change with different loadings. The supply current and the load voltage are denoted by  $i_s$  and  $v_L$ , respectively. Ideally,  $i_s$  and  $v_L$  should be sine waves of 50 Hz without any harmonic distortions, even though harmonics may exist in  $v_s$  and  $i_L$ . As such, this is one of the tasks to be accomplished by the UPQC.

$v_z$  in Figure models the voltage drop across the line impedance  $R_l + j\omega L_l$ .  $u_1(V_{dc}/2)$  and  $u_2(V_{dc}/2)$  model the series active and shunt active filter respectively. Their associated low-pass interfacing filters and losses are modelled by  $L_{se}$ ,  $C_{se}$ , and  $R_{se}$ , and  $L_{sh}$ ,  $C_{sh}$ , and  $R_{sh}$ , respectively.  $i_{Csh}$  is the leakage capacitor current of the shunt low-pass interfacing filter.  $u_1(V_{dc}/2)$  and  $u_2(V_{dc}/2)$  represent the switched voltages across the series and shunt VSI outputs of the UPQC, respectively.

$v_{inj}$  denotes the injected voltage of the series active filter, while  $i_{inj}$  denotes the injected current of the shunt active filter.  $u_1$  and  $u_2$  will be determined by the ORC to be discussed later; they are supposed to take continuous values between  $-1$  and  $+1$ . These continuous values will be modulated by PWM to become the switching signals for the VSIs.  $V_{dc}/2$  is the desired voltage level of each capacitor unit for the UPQC.

### CONTROL TECHNIQUES OF UPQC:-

The control unit is the most important part of UPQC system. Rapid detection of disturbance signal with high accuracy, fast processing of the reference signal and high dynamic response of the controller are the prime requirements for desired compensation.

The main considerations for the control system of a UPQC include Series inverter control: Sag/swell detection, voltage reference generation, voltage injection strategies and methods for generating of gating signals.



Shunt inverter control: Current reference generation, methods for generating of gating signals and capacitor voltage control

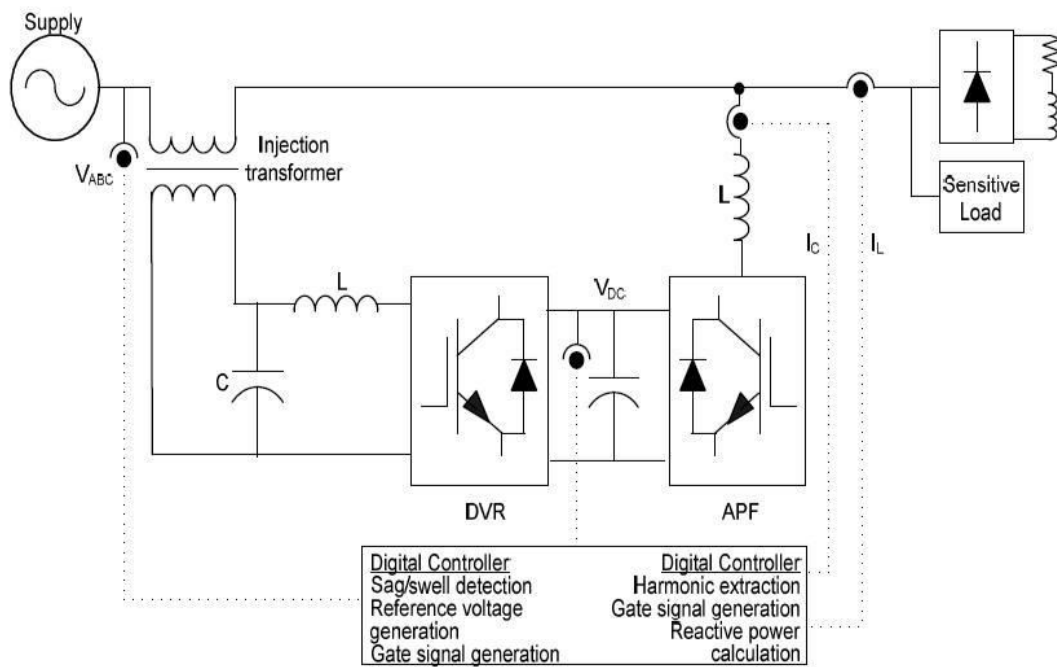


Fig 3. Control Strategies for UPQC

## VI. MATLAB MODELS AND RESULTS

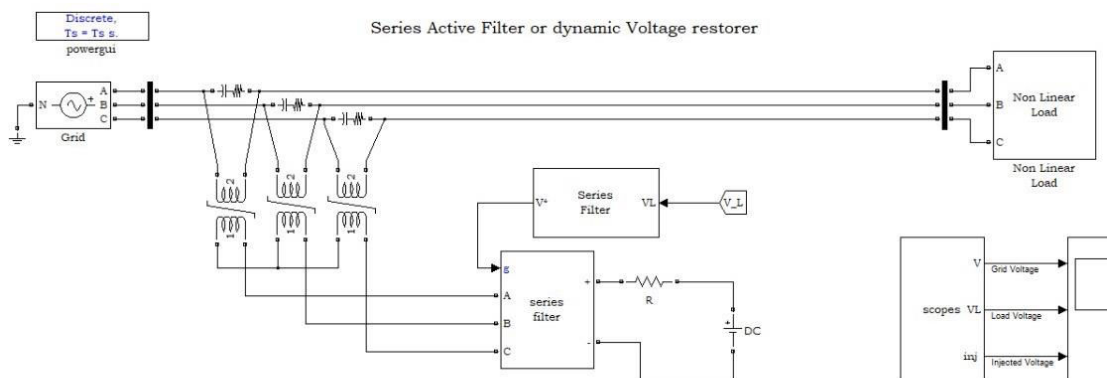


FIG 4. MATLAB SIMULINK MODEL FOR SERIES ACTIVE FILTER

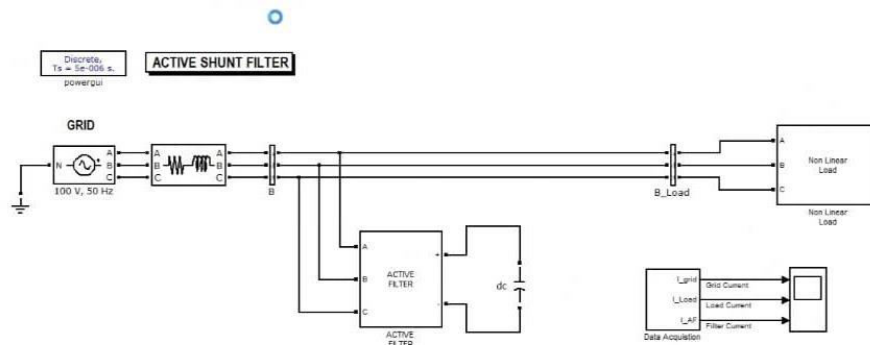


Fig 5. Matlab Simulink Model for Shunt Active Filter

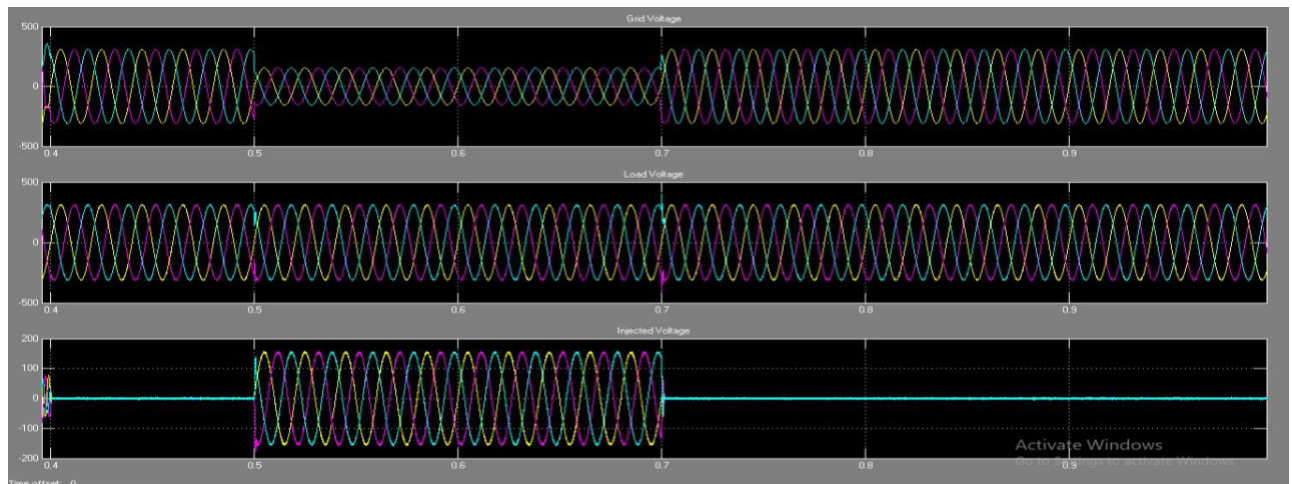


Fig 6. Output Waveform of Series Active Filter showing mitigation of voltage distortions

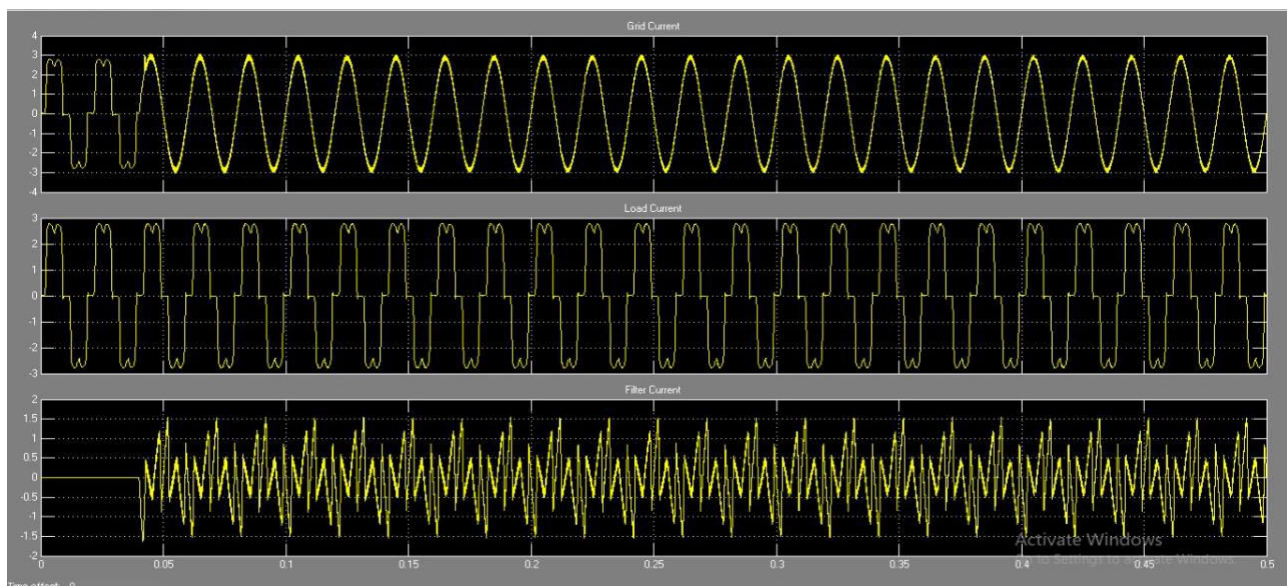


Fig 7. Output Waveform of Shunt Active Filter Showing Mitigation of Current Waveform

## VII. CONCLUSION

Voltage sags and current harmonics are the most important power quality problems in commercial and industrial utility's customers. These power quality problems can cause tripping of sensitive electronic equipment, abnormal operations of facilities and tremendous economic losses.

Custom Power devices have now been of interest for more than a decade that are able to improve the reliability and the quality of power delivered to electric power customers. Unified Power Quality Conditioner consisting of two voltage source inverters with a common DC link is a Custom Power device and can simultaneously perform the tasks of Active Power Filter and Dynamic Voltage Restorer. The power quality problems in distribution systems are not new but customer awareness of these problems increased recently. It is very difficult to maintain electric power quality at acceptable limits.

One modern and very promising solution that deals with both load current and supply voltage imperfections is the Unified Power Quality Conditioner (UPQC). The performance of the UPQC is satisfactory in various power quality improvements, such as load balancing, neutral source current mitigation, power-factor correction, voltage harmonics mitigation, and current harmonic mitigation. Supply currents and load voltage harmonic levels are maintained below IEEE-519 standards under all conditions.

The computational delay is reduced by indirectly controlling the three-phase supply currents/voltages. Moreover, the load and APF neutral currents are not sensed; hence, the number of current sensors is reduced. Therefore, with the help of these topologies can meet required load demand in future, increase the production in industries and increase the economy of the country.

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