# Power Quality Improvement Using UPQC

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**Abstract—**This paper introduces a new concept of optimal utilization of a unified power quality conditioner (UPQC). The series inverter of UPQC is controlled to perform simultaneous 1) voltage sag/swell compensation and 2) load reactive power sharing with the shunt inverter. The active power control approach is used to compensate voltage sag/swell and is integrated with theory of power angle control (PAC) of UPQC to coordinate the load reactive power between the two inverters. Since the series inverter simultaneously delivers active and reactive powers, this concept is named as UPQC-S (S for complex power). A detailed mathematical analysis, to extend the PAC approach for UPQC-S, is presented in this paper. MATLAB/SIMULINK-based simulation results are discussed to support the developed concept. Finally, the proposed concept is validated with a digital signal processor-based experimental study.

**Key Words**—Active power filter (APF), power quality, reactive power compensation, unified power quality conditioner (UPQC), voltage sag and swell compensation.



## I. Introduction

In the early days of power transmission in the late 19th century problems like voltage deviation during load changes and power transfer limitation were observed due to reactive power unbalances. Today these Problems have even higher impact on reliable and secure power supply in the world of Globalization and Privatization of electrical systems and energy transfer. The development in fast and reliable semiconductors devices (GTO and IGBT) allowed new power electronic Configurations to be introduced to the tasks of power Transmission and load flow control. The FACTS devices offer a fast and reliable control over the transmission parameters, i.e. Voltage, line impedance, and phase angle between the sending end voltage and receiving end voltage. On the other hand the custom power is for low voltage distribution, and improving the poor quality and reliability of supply affecting sensitive loads. Custom power devices are very similar to the FACTS. Most widely known custom power devices are DSTATCOM, UPQC, DVR among them DSTATCOM is very well known and can provide cost effective solution for the compensation of reactive power and unbalance loading in distribution system [3].

The performance of the DSTATCOM depends on the control algorithm i.e. the extraction of the current components. For this purpose there are many control schemes which are reported in the literature and some of these are instantaneous reactive power (IRP) theory, instantaneous compensation, instantaneous symmetrical components, synchronous reference frame (SRF) theory, computation based on per phase basis, and scheme based on neural network [4- 11]. Among these control schemes instantaneous reactive power theory and synchronous rotating reference frame are most widely used. This paper focuses on the compensating the voltage sag, swells and momentary interruptions. The dynamic performance is analyzed and verified through simulation.

## II. Unified Power Quality Conditioner

Power quality issues are becoming more and more significant in these days because of the increasing number of power electronic devices that behave as nonlinear loads. A wide diversity of solutions to power quality problems is available for both the distribution network operator and the end use. The power processing at source, load and for reactive and harmonic compensation by means of power electronic devices is becoming more prevalent due to the vast advantages offered by them. The shunt active power

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filter (APF) is usually connected across the loads to compensate for all current related problems such as the reactive power compensation, power factor improvement, current harmonic compensation and load unbalance compensation, whereas the series active power filter is connected in a series with a line through series transformer. It acts as controlled voltage source and can compensate all voltage related problems, such as voltage harmonics, voltage sag, voltage swell, flicker, etc. UPQC is a Custom Power Device and consists of combined series active power filter that compensates voltage harmonics, voltage unbalance, voltage flicker, voltage sag/swell and shunt active power filter that compensates current harmonics, current unbalance and reactive current.Unified Power Quality Conditioner is also known as universal power quality conditioning system, the universal active power line conditioner and universal active filter. UPQC system can be divided into two sections: The control unit and the power circuit. Control unit includes disturbance detection, reference signal generation, gate signal generation and voltage/current measurements. Power circuit consists of two Voltage source converters, standby and system protection system, harmonic filters and injection transformers.

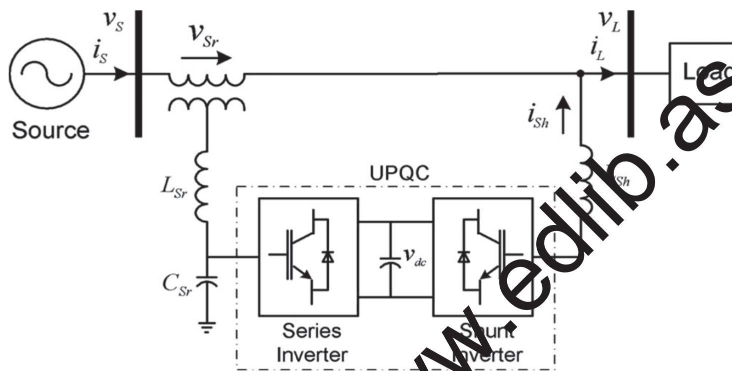


Fig:1. Unified power quality conditioner (UPQC) system configuration.

The voltage sag/swell on the system is one of the most important power quality problems. The voltage sag/swell can be effectively compensated using a dynamic voltage restorer, series active filter, Unified power quality conditioner, etc., among the available power quality enhancement devices, the Unified power quality conditioner has better sag/swell compensation capability. Three significant control approaches for Unified power quality conditioner can be found to control the sag on the system: 1) active power control approach in which an in-phase voltage is injected through series inverter, popularly known as UPQC-P; 2) reactive power control approach in which a quadrature voltage is injected [4], [5], known as UPQC-Q; and 3) a minimum VA loading approach in which a series voltage is injected at a certain angle, in this paper called as UPQC-VAmin.

### III. Results and Analysis

A UPQC is one of the most suitable devices to control the voltage sag/swell on the system. The rating of a UPQC is governed by the percentage of maximum amount of voltage sag/swell need to be compensated. However, the voltage variation (sag/swell) is a short duration power quality issue. The performance of the proposed concept of simultaneous load reactive power and voltage sag/swell compensation has been evaluated by simulation. To analyse the performance of UPQC-S, the source is assumed to be pure sinusoidal. Further more, for better visualization of results the load is considered as highly inductive. The supply voltage which is available at UPQC terminal is considered as three phase, 60 Hz, 600 V (line to line) with the maximum load power demand of 15 kW + $j$ 15 kVAR (load power factor angle of 0.707 lagging).The simulation results for the proposed UPQC-S approach under voltage sag and swell conditions are given Before time $t_1$ , the UPQC-S system is working under steady state condition, compensating the load reactive power using both the inverters. A power angle $\delta$ of 21$^\circ$ is maintained between the resultant load and actual source voltages. The series inverter shares 1.96 kVAR per phase (or 5.8 kVAR out of 15 kVAR) demanded by the load. Thus, the reactive power support from the shunt inverter is reduced from 15 to 9.2 kVAR by utilizing the concept of PAC. In other words, the shunt inverter rating is reduced by 25% of the total load kilovolt ampere rating. At time $t_1 = 0.6$ s, a sag of 20% is introduced on the system (sag last till time $t =$ 0.7 s). Between the time period $t = 0.7$ s and $t = 0.8$ s, the system is again in the steady state. A swell of 20% is imposed on the system for a duration of $t_2 = 0.8–0.9$ s.

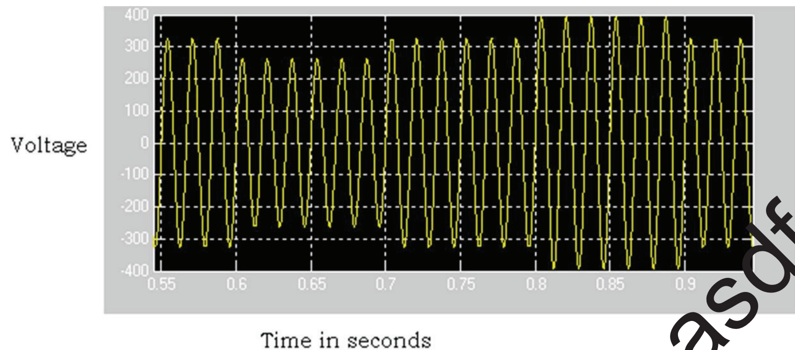


Fig: 2 Supply voltage

In the above Supply Voltage The sag occurs in the time period of 0.6sec to 0.7sec and 07.sec to 0.8sec stead state occurs. 0.8sec to 0.9sec the swell occurs. here voltage decreases current increases.

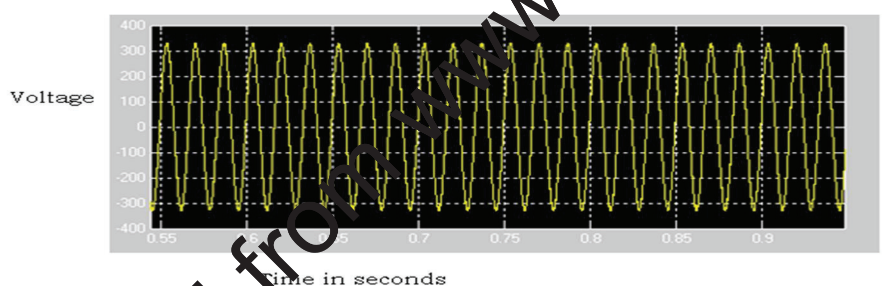


Fig:3 Load voltage

In the above simulation of Load voltage is pure sinusoidal wave form occurs because any faults occurs in the Load side the .UPQC compensate the faults.

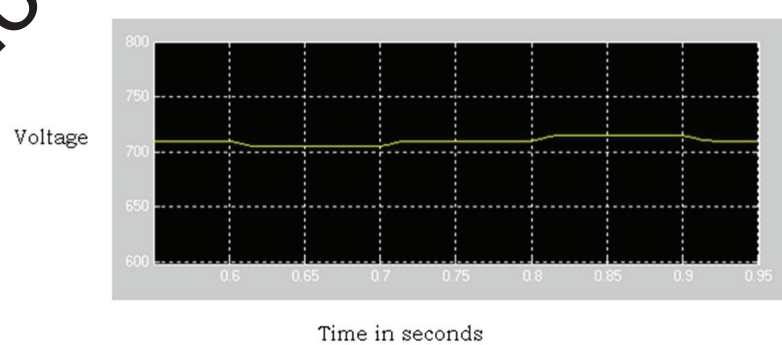


Fig:4 Self supporting dc bus voltage

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In the above dc bus voltage sag occurs 0.6sec to 0.7sec and swell occurs 0.8sec to 0.9sec.

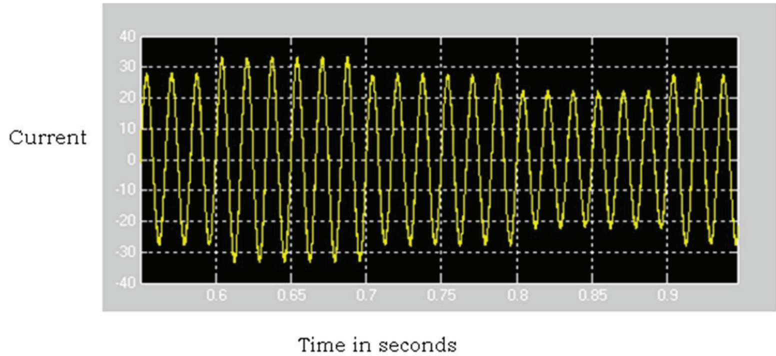


Fig: 5 Supply current

In the supply current swell occurs 0.6sec to 0.7sec.here first swell occurs because voltage decreses and current increases.0.8sec to 0.9sec swell occurs.

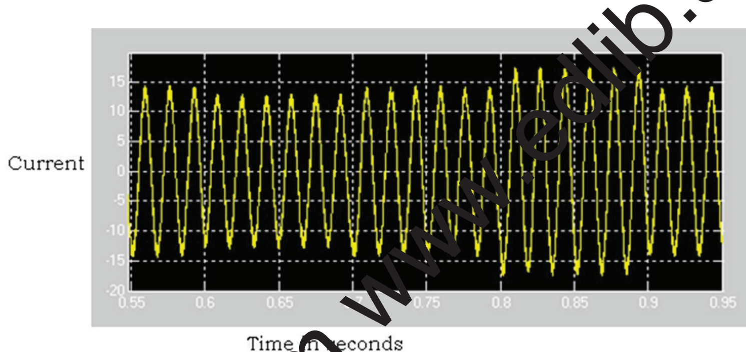


Fig: 6 Shunt inverter injected current

In shunt inverter injected current faults are Occurred.sag occurred in time period of 0.6sec to 0.7sec. swell occurred 0.8sec to 0.9sec.

**With VDC Controller Simulation Results:**

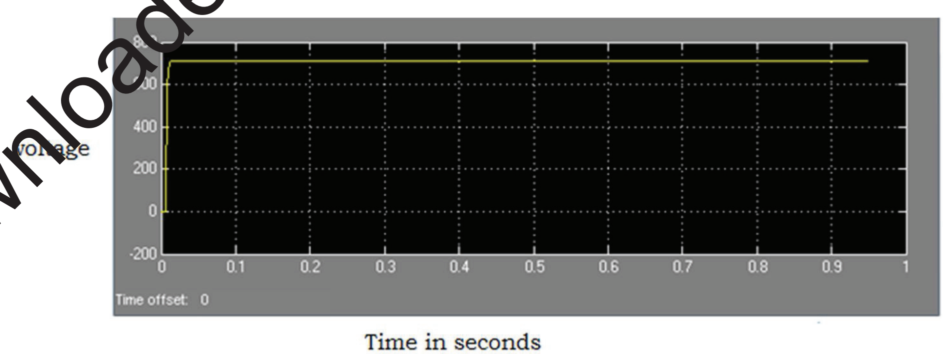


Fig. 7 Self supporting dc bus voltage

In self supporting dc bus voltage using dc regulater transient response is decreased and system dynamic performance increased.

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## IV. Conclusions

A new concept of controlling complex power (simultaneous active and reactive powers) through series inverter of UPQC is introduced and named as UPQC-S. The proposed concept of the UPQC-S approach is mathematically formulated and analyzed for voltage sag and swell conditions. The developed comprehensive equations for UPQC-S can be utilized to estimate the required series injection voltage and the shunt compensating current profiles (magnitude and phase angle), and the overall VA loading both under voltage sag and swell conditions.

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