# SIMULATION OF UPQC FOR VOLTAGE SAG/ SWELL/ SIMULTANEOUS VOLTAGE SAGS/ SWELL PROBLEMS

**R.Ramesh [1], G.Naveen [2]**

*[1] M.Tech Scholar (PS), Nalanda Institute of Engineering and Tech. (NIET), Kantepudi, Guntur, A.P, (India)*

*[2] Assistant Professor (EEE), Nalanda Institute of Engineering and Tech. (NIET), Kantepudi, Guntur, A.P, (India)*

## ABSTRACT

*Here in this paper presents a new concept of maximum utilization of a unified power quality conditioner (UPQC). The series inverter of UPQC is maintained to operate simultaneous 1) voltage sag/swell and in the case of only sag and swell compensation and 2) load reactive power allocation with the shunt inverter. The active power control accession is utilized to compensate voltage sag/swell and individual sag and swell and interconnected with theory of power angle control (PAC) of UPQC to coordinate the load reactive power between the two inverters. Hence the series inverter simultaneously produces active and reactive powers; this approach is called as UPQC-S (S for complex power). An accurate mathematical analysis, to enhance the PAC concept for UPQC-S is discussed in this paper. The platform used as MATLAB/SIMULINK based simulation results is analyzed to support the developed approach. Finally the recommended approach is approved with a digital signal processor based experimental study.*

***Keywords- Active Power Filter (APF), Power Angle Control (PAC), Power Quality, Reactive Power Compensation, Unified Power Quality Conditioner (UPQC), Voltage Sag And Swell Compensation.***

## I. INTRODUCTION

Now a day's power distribution system is becoming highly vulnerable to the various power quality issues. The vast usage of nonlinear loads is further contributing to improved current and voltage harmonics problems. Moreover the penetration stage of small/large scale renewable energy systems based on wind energy, solar energy, fuel cell, etc., established at distribution as well as, transmission stage is improving significantly. This interconnection of renewable energy sources in a power system is further imposing new challenges to the electrical power industry to contain this newly arriving distributed energy system. To maintain the controlled power quality regulations, few kind of compensation at all the power stages is becoming a common practice. At the distribution stage UPQC is a most interesting solution to compensate several major power quality problems. The schematic block diagram representation of a UPQC based system is depicted in this paper. It is generally consist of two voltage source inverters integrated back to back utilizing a common dc link capacitor. Here in this paper presents a new approach of optimal usage of a UPQC. The sag and swell on the power system is one of the most important power quality issues. The voltage sag/swell and only sag and only swell can be accurately compensated using a dynamic voltage restorer, active filter connected in series manner, UPQC etc. Among the available power quality extensive devices, the UPQC has better sag/swell compensation capability. Three significant control strategies for UPQC can be found to eliminate the sag on the system: 1) active power control strategy in which an in-phase voltage is supplied through series inverter, widely known as UPQC-P 2) reactive power compensation strategy in which a quadrature voltage is injected is known as UPQC-Q and 3) a minimum VA loading strategy in which a series voltage is supplied at a certain angle, in this paper called as UPQC-$VAmin$. Among the aforementioned three accessions, the quadrature voltage injection requires a maximum series injection voltage, whereas the in-phase voltage injection desires the minimum voltage supply magnitude. In a minimum VA loading strategy the series inverter voltage is supplied at an optimal angle with respect to the source current. In addition the series inverter supplies, the current strained by the shunt inverter, to control the dc link voltage and the overall power balance in the power system interconnected network, plays an important aspect in calculating the overall UPQC VA loading. Here in this paper on UPQC-$VAmin$ is focused on the optimal VA load of the series inverter of UPQC especially during voltage sag condition. Since an out of phase component is desired to be applied for voltage swell compensation, the recommended VA loading in UPQC-$VAmin$ resolved on the basis of voltage sag , may not be at excellent value. A comprehensive investigation on VA loading in UPQC-$VAmin$ considering both voltage sag and voltage swell schemes is important. Here in this paper the authors have recommended a concept of power angle control (PAC) of UPQC. The PAC approach of suggests that with proper control of series inverter voltage with the series inverter successfully supports part of the load reactive power requirement, and hence reduces the desired VA rating of the shunt inverter. Most importantly this equalized reactive power allocation feature is accomplished during normal steady state condition without affecting the resultant load voltage magnitude. The excellent angle of series voltage injection in $UPQC - Vmin$ is calculated using lookup table or particle swarm optimization strategy. On the other hand the PAC of UPQC concept determines the series injection angle by estimating the power angle $\delta$ is calculated in adaptive by computing the instantaneous load active/reactive power and thus, ensures fast and exact estimation.

Comparable to PAC of UPQC the reactive power flow control using shunt and series inverters is also done in a unified power flow controller (UPFC). A UPFC is used in a power transmission system where as UPQC is utilized in distribution system to perform the shunt and series compensation simultaneously. The power transmission systems are basically opened in balanced and distortion free environment, contrary to power distribution system. That may consist of dc component, distortion, and unbalance. The main objective of a UPFC is to control the flow of power at essential frequency. Also while carrying out this power flow controls in UPFC the transmission network voltage may not be controlled at the rated value. Even though in PAC of UPQC the load side voltage is accurately maintained at rated value while performing load reactive power allocation by shunt and series inverters.

## II. EXISTED SYSTEM

Here in this paper the approach of UPQC is further expanded for voltage sag and swell conditions. This altered concept is utilized to compensate voltage sag or swell while allocating the load reactive power between two inverters. Because the series inverter of UPQC in this case delivers both active and reactive power, it is given the name UPQC-S (S for complex power). The key addition of this paper is outlined as follows.

1) The series inverter of UPQC-S is take advantage for simultaneous voltage sag or swells compensation and load reactive power compensation in coordination with shunt inverter.

2) In UPQC –S the available VA loading is making used to its maximum capability during all the operating conditions contrary to $UPQC - VAmin$ where major focus is to minimize the VA loading of UPQC during voltage sag condition.

3) The approaches of UPQC-S covers voltage sag as well as swell condition.

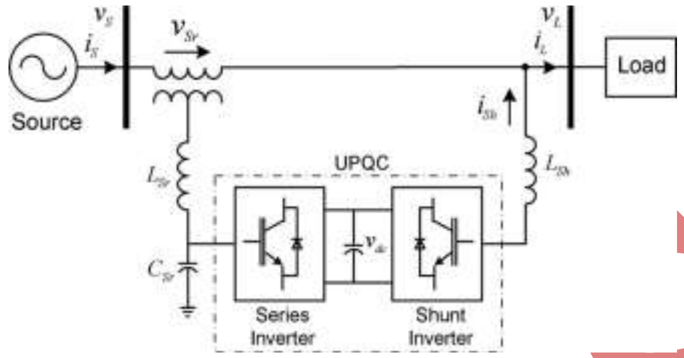


**Fig.1 Unified Power Quality Conditioner (UPQC) System Configuration**

Here in this paper an accurate mathematical formulation of PAC for UPQC-s is carried out. The availability and effectiveness of the proposed UPQC-S concept are validated by simulation as well as experimental response.

## III. FUNDAMENTALS OF PAC CONCEPT

A UPQC is one of the most convenient devices to control the voltage sag or swell on the system. The rating of a UPQC is directed by the percentage of maximum amount of voltage sag are swell need to be compensated. Even though the voltage fluctuations (sag or swell) is a short duration power quality problem. Hence under normal operating condition the series inverter of UPQC recommends that with proper control of the power angle between the source and load voltages, the load reactive power demand can be allocated by both shunt and series inverters without disturbing the overall UPQC rating. The phase representation of the PAC concept under a rated steady state condition as depicted in fig 2. According to this theory a vector $V_{Sr}$ and phase angle $\varphi_{Sr}$ when supplied through series inverter gives a power angle $\delta$ boost between the sources $V_S$ and resultant load voltage $V_L'$ controlling the same voltage magnitudes. This power angle shift causes relative phase advancement between the supply voltage and resultant load current$I_L'$. In other words with PAC concept the series inverter supports the load reactive power requirement and hence reducing the reactive power requirement allocated by the shunt inverter.

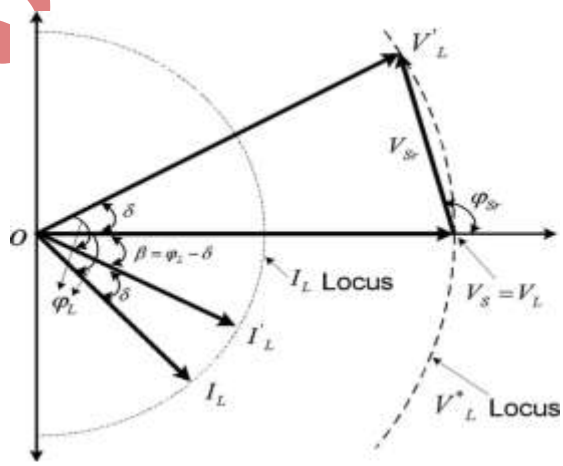


**Fig.2. Concept of PAC of UPQC**

## IV. VOLTAGE SAG OR SWELL COMPENSATION UTILIZING UPQC-P AND UPQC-Q

The voltage sag on a system can be mitigated through active power control and reactive power control approaches. The UPQC-Q concept is limited to compensate the sag on the system. Even though the UPQC-P control strategy can effectively compensate both voltages sag and swell on the system. Moreover to compensate an equal percentage of sag, the UPQC desires larger magnitude of series supplying voltage than the UPQC-P. Interestingly UPQC-Q also gives a power angle shift between resultant load and source voltages but this shift is a function of effect of sag on the system. Hence the phase shift in UPQC-Q cannot be maintained to vary the load reactive power support. In addition the phase shift in UPQC-Q is valid only during the voltage sag condition. Hence here in this paper PAC concept is interconnected with active power control approach to accomplish simultaneous voltage sag or swell compensation and the load reactive power support using the series inverter of UPQC operates multi functionality is named as UPQC-S. The important benefits of UPQC-S over the other control techniques are given as follows.

1) The inverter which connected in series of UPQC-S can support both active power (for voltage sag or swell compensation) and reactive power (for load reactive power compensation) simultaneously and therefore the name UPQC-S (S for complex power).
2) The feasible VA loading of UPQC is used to its maximum capability and thus, compared to general UPQC operation for equal amount of sag mitigation; the desired rating of shunt inverter in UPQC-S will be smaller.

## V. PROPOSED SYSTEM

Consider that the UPQC system is already working under PAC control strategy, i.e., both the inverters are mitigating the load reactive power and the supplied series voltage gives a power angle $\delta$ between resultant load and actual source voltages. If a sag or swell and only sag and only swell condition occurs on the system, both the inverters should continuously supplying the load reactive power as they were before the sag. In addition with the series inverter should also compensate the voltage sag or swell and only sag and swell by injecting the proper voltage component. In other words irrespective of the fluctuation in the supply voltage the series inverter should maintain same power angle $\delta$ between both the voltages. Even though if the load on the system varies during the voltage sag condition, the PAC control strategy will give a different $\delta$ angle. The increase or decrease in load reactive power.

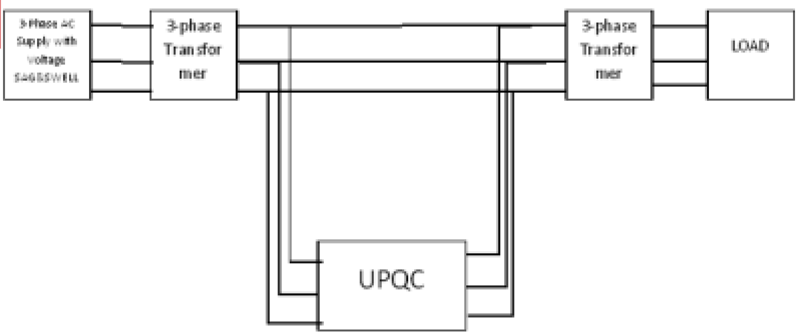


**Fig 3. Schematic Diagram of Proposed System**

Let us represent a vector $\vec{V}_{sr1}$ responsible to compensate the load reactive power using PAC approach and vector $\vec{V}_{sr2}$ responsible to compensate the sag on the system using active power control strategy. For simultaneous compensation as observed in this paper. The series inverter should now supply a component which would be the vector sum of $V_{sr1}$ and $V_{sr2}$. This resultant series inverter voltage will control the load voltage magnitude at a required level such that the drop in source voltage will not appear present at the load side. Moreover the series inverter will maintain allocating the load reactive power requirement. Series inverter and shunt Inverter parameter Estimation Under Voltage Sag and Voltage Swell. In this section the desired series inverter parameters to accomplish simultaneous load reactive power and voltage sag compensations are analyzed. The voltage variation factor $k_f$ which is defined as the ratio of the difference of instantaneous supply voltage and rated load voltage magnitude to the rated load voltage magnitude is given as follows.

$$k_f = \frac{V_L - V_L^*}{V_L^*} \quad (1)$$

The desired current supplied by the shunt inverter in order to operate the UPQC-S under voltage sag compensation mode is analyzed. The pharos diagram based on different currents is discussed in this paper. Mainly voltage sag on the system, the UPQC is assumed to be compensating for load reactive power using PAC control strategy, supplying the current $I'_{sh}$ through shunt inverter. The current $Ish$ represents the desired current if the shunt inverter is utilized to alone to compensate the total load reactive power requirement.

## VI. UPQC-S CONTROLLER

A detailed controller for UPQC based on PAC control strategy is explained. Here in this paper the generation of reference signals for series inverter is discussed. The series inverter controls the load voltage at the required level; the reactive power demanded by the load remains constant irrespective of changes in the source voltage magnitude. Moreover the power angle $\delta$ is maintained at constant value under various operating conditions. Therefore the reactive power allocated by the series inverter and hence by the shunt inverter changes. The reactive power allocated by the series and shunt inverters can be fixed at constant values by allowing the power angle to change under sag or swell and only sag and swell conditions.

## VII. CONCLUSION

Here in this paper a novel approach of controlling complex power (simultaneous active and reactive powers) through series inverter of UPQC is represented and named as UPQC-S. The suggested approach of the UPQC-S concept is mathematically formulated and analyzed for voltage sag and swell and only voltage sag and voltage swell conditions. The developed extensive equations for UPQC –S can be utilized to estimate the desired series supplied voltage and shunt compensating current profiles (magnitude and phase angle), and the overall VA loading under voltage sag and swell in both the conditions. The simulation and experimental results demonstrate the effectiveness of the recommended approach of simultaneous voltage sag or swell and only sag and swell and load reactive power allocating features of series part of UPQC-S. The significant benefits of UPQC-S applications are: 1) the multifunction capability of series inverter to compensate voltage variation (sag, swell, etc.) while supporting load reactive power 2) better utilization of series inverter rating of UPQC and 3) reduction in the shunt inverter rating due to the reactive power allocation by the inverters.

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## AUTHOR DETAILS

***R.RAMESH,***

pursuing M.Tech (PS) from Nalanda Institute of Engineering and Technology (NIET), Kantepudi, sattenapalli(M),Guntur Dist,A.P, INDIA.

***G.NAVEEN***,

working as Assistant Professor (EEE) from Nalanda Institute of Engineering and Technology (NIET), Kantepudi, sattenapalli(M),Guntur Dist,A.P, INDIA.