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A Novel Concept of Simultaneous Voltage Sag/Swell and Load Reactive Power Compensations Utilizing Series Inverter of 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) volt- age 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 re- active 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 mathemati- cal 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 experi- mental study.

Index Terms—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

The Modern power distribution system is becoming highly vulnerable to the different power quality problems [1], [2]. The extensive use of nonlinear loads is further contributing to increased current and voltage harmonics issues. Furthermore, the penetration level of small/large-scale renew- able energy systems based on wind energy, solar energy, fuel cell, etc., installed at distribution as well as transmission levels is increasing significantly. This integration of renewable energy sources in a power system is further imposing new challenges to the electrical power industry to accommodate these newly emerging distributed generation systems [3]. To maintain the controlled power quality regulations, some kind of compensation at all the power levels is becoming a common practice [5]–[9]. At the distribution level, UPQC is a most at- tractive solution to compensate several major power quality problems [7]–[9], [14]–[28].

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The general block diagram representation of a UPQC-based system is shown in Fig. 1. It basically consists of two voltage source inverters connected back to back using a common dc bus capacitor. This paper deals with a novel concept of optimal utilization of a UPQC.

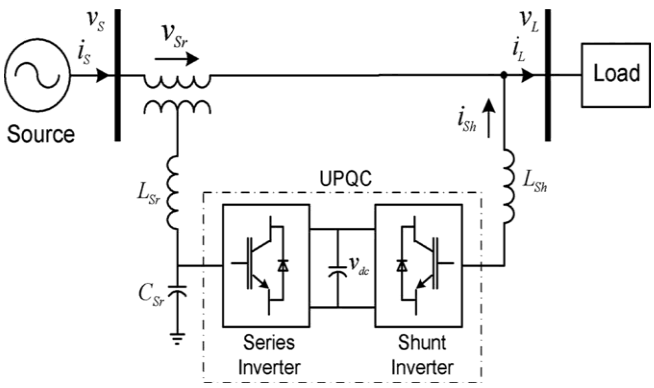

Fig. 1. Unified power quality conditioner (UPQC) system configuration.

The reported paper on UPQC-VA_{min} is concentrated on the optimal VA load of the series inverter of UPQC especially during voltage sag condition [25]–[28]. Since an out of phase compo- nent is required to be injected for voltage swell compensation, the suggested VA loading in UPQC-VA_{min} determined on the basis of voltage sag, may not be at optimal value. A detailed investigation on VA loading in UPQC-VA_{min} considering both voltage sag and swell scenarios is essential. In the paper [15], the authors have proposed a concept of power angle control (PAC) of UPQC. The PAC concept suggests that with proper control of series inverter voltage the series inverter successfully supports part of the load reactive power demand, and thus reduces the required VA rating of the shunt inverter. Most importantly, this coordinated reactive power sharing feature is achieved during nor- mal steady-state condition without affecting the resultant load voltage magnitude. Similar to PAC of UPQC, the reactive power flow control utilizing shunt and series inverters is also done in a unified power flow controller (UPFC) [4], [5]. In this paper, the concept of PAC of UPQC is further expanded for voltage sag and swell conditions. This mod- ified approach is utilized to compensate voltage sag/swell while sharing the load reactive power between two invert- ers. Since the series inverter of UPQC in this case delivers both active and reactive powers, it is given the name UPQC-S (S for complex power). The key contributions of this paper are outlined as follows.

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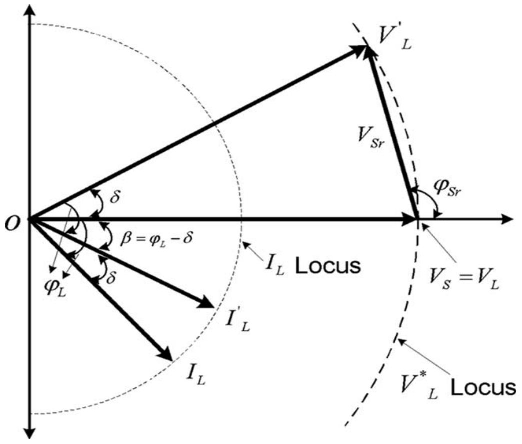

Fig. 2. Concept of PAC of UPQC.

II. FUNDAMENTALS OF PAC CONCEPT

A UPQC is one of the most suitable devices to control the volt- age 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 [19].

For a rated steady-state condition

$$|V_S| = |V_L| = |V_L^*| = |V_L'| = k \quad (1)$$

Using Fig. 2, phasor V_{Sr} can be defined as [15]

$$\vec{V}_{Sr} = V_{Sr}\angle\varphi_{Sr}$$

$$= \left(k.\sqrt{2}.\sqrt{1-\cos\delta}\right)\angle\left\{180^{\theta} - \tan^{-1}\left(\frac{\sin\delta}{1-\cos\delta}\right)\right\}$$

$$= \left(k.\sqrt{2}.\sqrt{1-\cos\delta}\right)\angle\left(\frac{90^{\theta}+\delta}{2}\right) \quad (2)$$

Where

$$\delta = \sin^{-1}\left(\frac{Q_{Sr}}{P_L}\right) \quad (3)$$

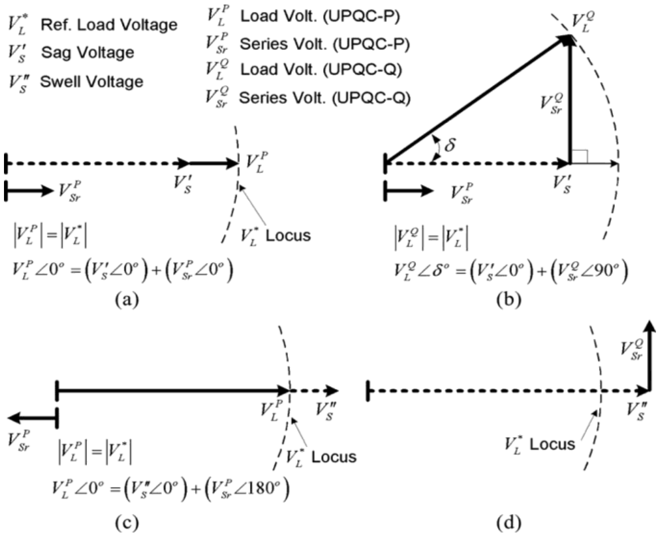

Fig.3. Voltage sag and swell compensation using UPQC-P and UPQC-Q: phasor representation. (a) Voltage Sag (UPQC-P). (b) Voltage Sag (UPQC-Q). (c) Voltage Swell (UPQC-P). (d) Voltage Swell (UPQC-Q).

III. VOLTAGE SAG/SWELL COMPENSATION UTILIZING UPQC-P AND UPQC-Q

The voltage sag on a system can be compensated through active power control [16]–[22] and reactive power control [23], [24] methods. Fig. 3 shows the phasor representations for volt- age sag compensation using active power control as in UPQC-P [see Fig. 3(a)] and reactive power control as in UPQC-Q [see Fig. 3(b)]. Fig. 3(c) and (d) shows the compensation capability of UPQC-P and UPQC-Q to compensate a swell on the system. For a voltage swell compensation using UPQC-Q [see Fig. 3(d)], the quadrature component injected by series inverter does not intersect with the rated voltage locus.

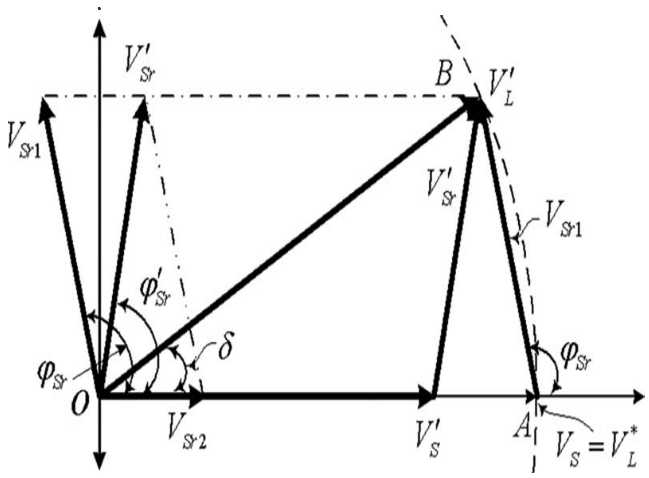

Fig. 4. Phasor representation of the proposed UPQC-S approach under voltage sag condition.

IV. PAC APPROACH UNDER VOLTAGE SAG CONDITION

Consider that the UPQC system is already working under PAC approach, i.e., both the inverters are compensating the load reactive power and the injected series voltage gives a power angle δ between resultant load and the actual source voltages. If a sag/swell condition occurs on the system, both the invert- ers should keep supplying the load reactive power, as they were before the sag. Additionally, the series inverter should also com- pensate the voltage sag/swell by injecting the appropriate volt- age component.

For load reactive power compensation using PAC concept

$$\vec{V}_{Sr1} = \overrightarrow{V_L'} - V_S' \quad (4)$$

$$V_{Sr1}\angle\varphi_{Sr} = V_L'\angle\delta - V_S\angle 0^{\circ} \quad (5)$$

For voltage sag compensation using active power control approach

$$\vec{V}_{Sr2} = \overrightarrow{V_L^*} - V_S' \quad (6)$$

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$$V_{sr2}\angle 0^\circ = V_L^{*}\angle 0^\circ - V_s^{'}\angle 0^\circ \text{ -} \qquad (7)$$

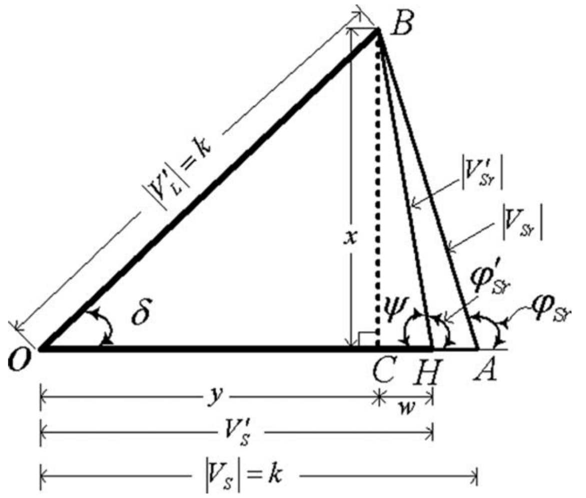

Fig. 5. Detailed phasor diagram to estimate the series inverter parameters for the proposed UPQC-S approach under voltage sag condition.

For simultaneous load reactive power and sag compensation

$$\vec{V'}_{Sr} = \vec{V}_{Sr1} + \vec{V}_{Sr2} \qquad (8)$$

$$V'_{Sr}\angle\varphi'_{Sr} = V_{Sr1}\angle\varphi_{Sr1} + V_{Sr2}\angle 0 \qquad (9)$$

A. Series Inverter Parameter Estimation Under Voltage Sag

In this section, the required series inverter parameters to achieve simultaneous load reactive power and voltage sag compensations are computed. Fig. 5 shows the detailed phasor dia- gram to determine the magnitude and phase of series injection voltage.

$$k_f = \frac{V_s - V_L^*}{V_L^*} \qquad (10)$$

Representing (10) for sag condition under PAC

$$k_f = \frac{V_S^{/} - V_L^{/}}{V_L^{/}} = \frac{V_S^{/} - k}{k} \qquad (11)$$

Let us define

$$1 + k_f = \eta o \qquad (12)$$

To compute the magnitude of $\vec{V_{Sr}^{/}}$, from ΔCHB in Fig. 5

$$w = l(CH) = \eta o.k - y \qquad (13)$$

$$|V_{Sr}^{/}| = \sqrt{(k.\sin\delta)^2 + (\eta_o.k - k\cos\delta)^2} \qquad (14)$$

$$|V_{Sr}^{/}| = k.\sqrt{(1+\eta_o^2) - 2.\eta_o.\cos\delta} \qquad (15)$$

To compute the phase of $\vec{V_{Sr}^{/}}$

$$\angle CHB = \angle\psi = \tan^{-1}\left(\frac{x}{w}\right) = \tan^{-1}\left(\frac{\sin\delta}{\eta o - \cos\delta}\right) \qquad (16)$$

Therefore,

$$\angle\varphi_{Sr}^{/} = 180^\circ - \angle\psi \qquad (17)$$

Equations (15) and (17) give the required magnitude and phase of series inverter voltage of UPQC-S that should be injected to achieve the voltage sag compensation while supporting the load reactive power under PAC approach.

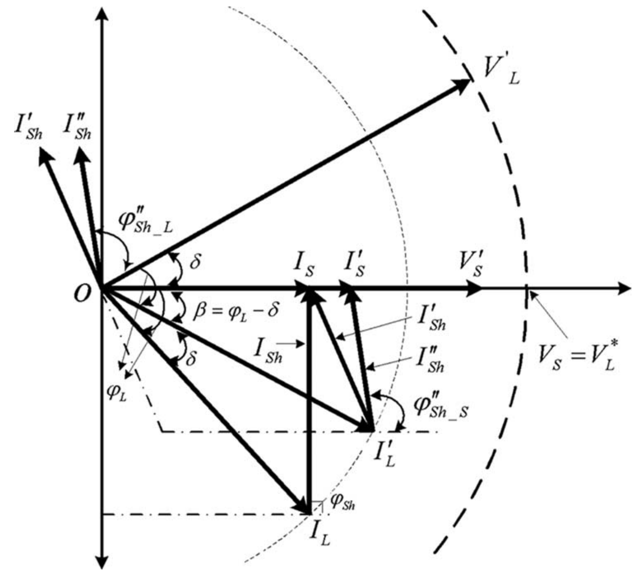

Fig. 6. Current-based phasor representation of the proposed UPQC-S approach under voltage sag condition

B. Shunt Inverter Parameter Estimation Under Voltage Sag.

The required current injected by the shunt inverter in order to operate the UPQC-S under voltage sag compensation mode is computed. The phasor diagram based on different currents is represented in Fig. 6.

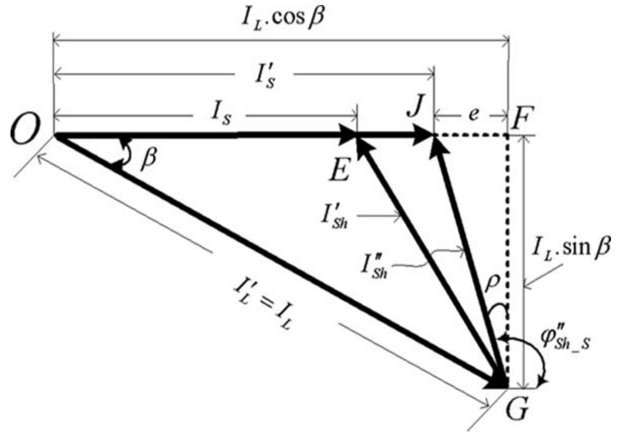

Fig. 7. Detailed phasor diagram to estimate the shunt inverter parameters for the proposed UPQC-S approach under voltage sag condition

Fig 7 represents the phasor diagram to complete the shunt inverter injected current magnitude and its phase angle.

To support the active power required during voltage sag condition, the source delivers the extra source current.

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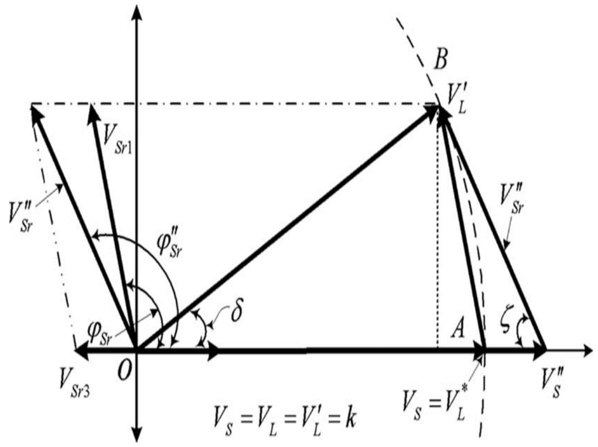

Fig. 8. Phasor representation of the proposed UPQC-S approach under voltage swell condition.

During voltage sag [19]

$$I_S' = \frac{I_L}{1+k_f}.\cos\varphi_L \qquad (18)$$

Let

$$\frac{1}{1+k_f} = ko \qquad (19)$$

Therefore,

$$I_S' = ko.I_L.\cos\varphi_L \qquad (20)$$

In ΔGFJ (see Fig. 7)

$$I_{sh}'' = \sqrt{\left(I_L'.\sin\beta\right)^2 + \left[I_L'.(\cos\beta - ko.\cos\varphi_L)\right]^2} \qquad (21)$$

$$I_{sh}'' = I_L'.\sqrt{1+k_o^2.\cos^2\varphi_L - 2.ko.\cos\varphi_L} \qquad (22)$$

$$\rho = \tan^{-1}\left(\frac{\cos\beta - ko.\cos\varphi_L}{\sin\beta}\right) \qquad (23)$$

$$\angle\varphi_{Sh\_S}'' = \angle\rho + 90^\circ \qquad (24)$$

$$\angle\varphi_{Sh\_L}'' = (\angle\rho + 90^\circ) - \delta \qquad (25)$$

Equations (22) and (25) give the required magnitude and phase angle of a shunt inverter compensating current to achieve the desired operation from the UPQC-S.

V. PAC APPROACH UNDER VOLTAGE SWELL CONDITION

The phasor representation for PAC of UPQC-S during a voltage swell on the system is shown in Fig. 8. Let us represent a vector V_{Sr3} responsible to compensate the swell on the system using active power control approach. For simultaneous compensation, the series inverter should supply the V_{Sr1} component to support the load reactive power and V_{Sr3} to compensate the swell on the system. The resultant series injected voltage V would maintain the load voltage magnitude at a desired level while supporting the load reactive power.

For voltage swell compensation using active power control approach.

$$\vec{V}_{Sr3} = \vec{V}_L^{\,*} - \vec{V}_S^{\,//} \qquad (26)$$

$$V_{Sr3}\angle 180^\circ = V_L^*\angle 0^\circ - V_S^{//}\angle 180^\circ \qquad (27)$$

For simultaneous load reactive power and voltage swell compensations

$$\vec{V}_{Sr}^{\,//} = \vec{V}_{Sr1} + \vec{V}_{Sr3} \qquad (28)$$

$$V_{Sr}^{//}\angle\varphi_{Sr}^{//} = V_{Sr1}\angle\varphi_{Sr} + V_{Sr3}\angle 180^\circ \qquad (29)$$

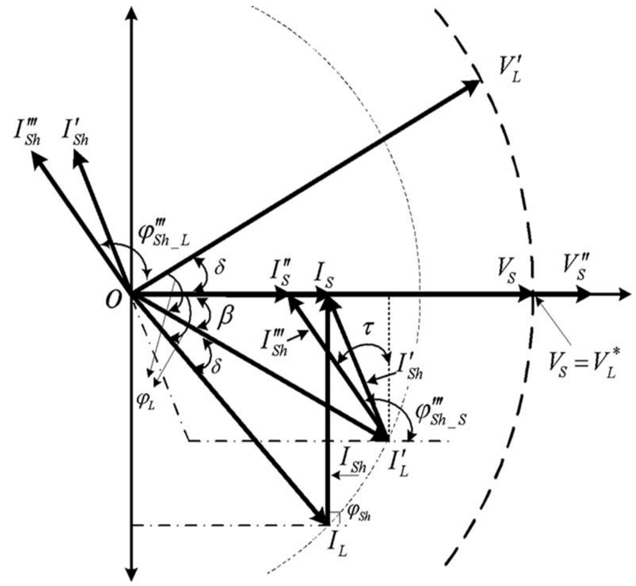

Fig. 9. Current based phasor representation of the proposed UPQC-S approach under voltage swell condition.

For series inverter (see Fig. 8)

$$|\,V_{Sr}^{//}\,| = k.\sqrt{1+\eta_O^2 - 2.\eta_O.\cos\delta} \qquad (30)$$

$$\angle CLB = \angle\varsigma = \tan^{-1}\left(\frac{\sin\delta}{\eta_O - \cos\delta}\right) \qquad (31)$$

$$\angle\varphi_{Sr}^{//} = 180^\circ - \angle\varsigma \qquad (32)$$

Fig. 9 shows the phasor representation for different currents under PAC of UPQC-S under a voltage swell condition. Utilizing the active power control to compensate voltage swell, the source current magnitude reduces from its normal steady-state value [19]. This reduced shunt inverter current is represented as I . The procedure to determine the series and shunt inverter parameters for PAC of UPQC-S during voltage swell is similar to the one illustrated for the voltage sag condition in Section IV. The important equations are given here. For shunt inverter (see Fig. 9)

$$I_{Sh}^{//} = I_L'.\sqrt{1+k_O^2.\cos^2\varphi_L - 2.k_O.\cos\beta.\cos\varphi_L} \qquad (33)$$

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$$\tau = \tan^{-1}\left(\frac{\cos\beta - k_O.\cos\varphi_L}{\sin\beta}\right) \quad (34)$$

$$\angle\varphi^{//}_{Sh\_L} = \left(\angle\tau + 90^\circ\right) - \delta. \quad (35)$$

VI. ACTIVE–REACTIVE POWER FLOW THROUGH UPQC-S

The per-phase active and reactive powers flow through the UPQC-S during the voltage sag/swell is determined in this section. As the performance equations for series and shunt inverters are identical for both sag and swell conditions, only sag condition is considered to determine the equations for active and reactive power.

A. Series Inverter of UPQC-S

For active power

$$P^{/}_{Sr} = V^{/}_{Sr}.I^{/}_{S}.\cos\varphi^{/}_{Sr} \quad (36)$$

From Fig. 5

$$P^{/}_{Sr} = V^{/}_{Sr}.I^{/}_{S}.\cos(180^\circ - \psi) \quad (37)$$

$$P^{/}_{Sr} = V^{/}_{Sr}.I^{/}_{S}.(-\cos\psi) \quad (38)$$

$$P^{/}_{Sr} = -V^{/}_{Sr}.I^{/}_{S}.\left(\frac{w}{V^{/}_{Sr}}\right) \quad (39)$$

$$P^{/}_{Sr} = -I^{/}_{S}.k.\left(\eta_O - \cos\delta\right) \quad (40)$$

The increase in $I^{/}_{S}$ or decrease in $I^{//}_{S}$ in the source current magnitude during the voltage sag or swell condition respectively is represented as

$$I^{/}_{S} = I^{//}_{S} = k_O.I_L.\cos\varphi_L \quad (41)$$

Therefore ,

$$P_{Sr.PAC} = P^{/}_{Sr} = -k_O.\left(\eta_O - \cos\delta\right).\left(P_L\right)$$

$$\left\{\because P_L = k.I_L.\cos\varphi_L\right\} \quad (42)$$

For reactive power

$$Q^{/}_{Sr} = V^{/}_{Sr}.I^{/}_{S}.\sin\varphi^{/}_{Sr} \quad (43)$$

From Fig.5

$$Q^{'}_{Sr} = V^{'}_{Sr}.I^{'}_{S}.\left(180^0 - \psi\right) \quad (44)$$

$$Q^{'}_{Sr} = V^{'}_{Sr}.I^{'}_{S}.\psi \quad (45)$$

$$Q^{'}_{Sr} = V^{'}_{Sr}.I^{'}_{S}.\left(\frac{x}{V^{'}_{Sr}}\right) \quad (46)$$

There fore

$$Q_{Sr,PAC} = Q^{'}_{Sr} = k_0.(\sin\delta).(P_L) \quad (47)$$

Using (42) and (47), the active and reactive power flow through series inverter of UPQC-S during voltage sag/swell condition can be calculated.

B. Shunt Inverter of UPQC-S

The active and reactive power handled by the shunt inverter as seen from source side is determined as follows.

For active power

$$P^{'}_{Sh} = V^{'}_{S}.I^{''}_{Sh}.\cos\varphi^{''}_{Sh-S} \quad (48)$$

From Fig 7

$$P^{'}_{Sh} = -n_0.k.I^{''}_{Sh}.(-\sin\rho) \quad (49)$$

$$P^{'}_{Sh} = -n_0.k.I^{''}_{Sh}.\left(\frac{e}{I^{''}_{Sh}}\right) \quad (50)$$

$$P_{Sh,PAC} = -\frac{(k_{,}I_L).(\cos\beta - k_0\cos\varphi_L)}{k_0} \quad (51)$$

$$Q^{'}_{Sh} = V^{'}_{S}.I^{''}_{Sh}.\sin\varphi^{''}_{Sh-S} \quad (52)$$

$$Q^{/}_{Sh} = \eta_O k.I^{//}_{Sh}.\cos\left(\rho\right) \quad (53)$$

$$Q_{Sh.PAC} = \frac{(k.I_L).(\sin\beta)}{k_O} \quad (54)$$

Using (51) and (54), the active and reactive power flow throughshunt inverter of UPQC-S during voltage sag/swell condition can be calculated and utilized to determine the overall UPQC-S VA loading.

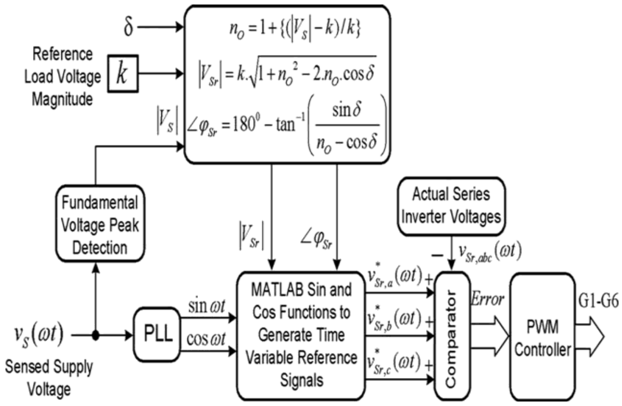

Fig. 10. Reference voltage signal generation for the series inverter of the proposed UPQC-S approach

VII. UPQC-S CONTROLLER

The control block diagram for series inverter operation is shown in fig 10. The instantaneous power angle δ is determined using the procedure given in [15]. Based on the system rated specification, the value of the desired load voltage is set as reference load voltage k. The instantaneous value of factors k_f and n_O is computed by measuring the peak value of the supply voltage in real time. The error signal of actual and reference series voltage is utilized to perform the switching operation of series inverter of UPQC-S. The control diagram for the shunt inverter is as given in [15].

VIII. SIMULATION RESULTS

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).

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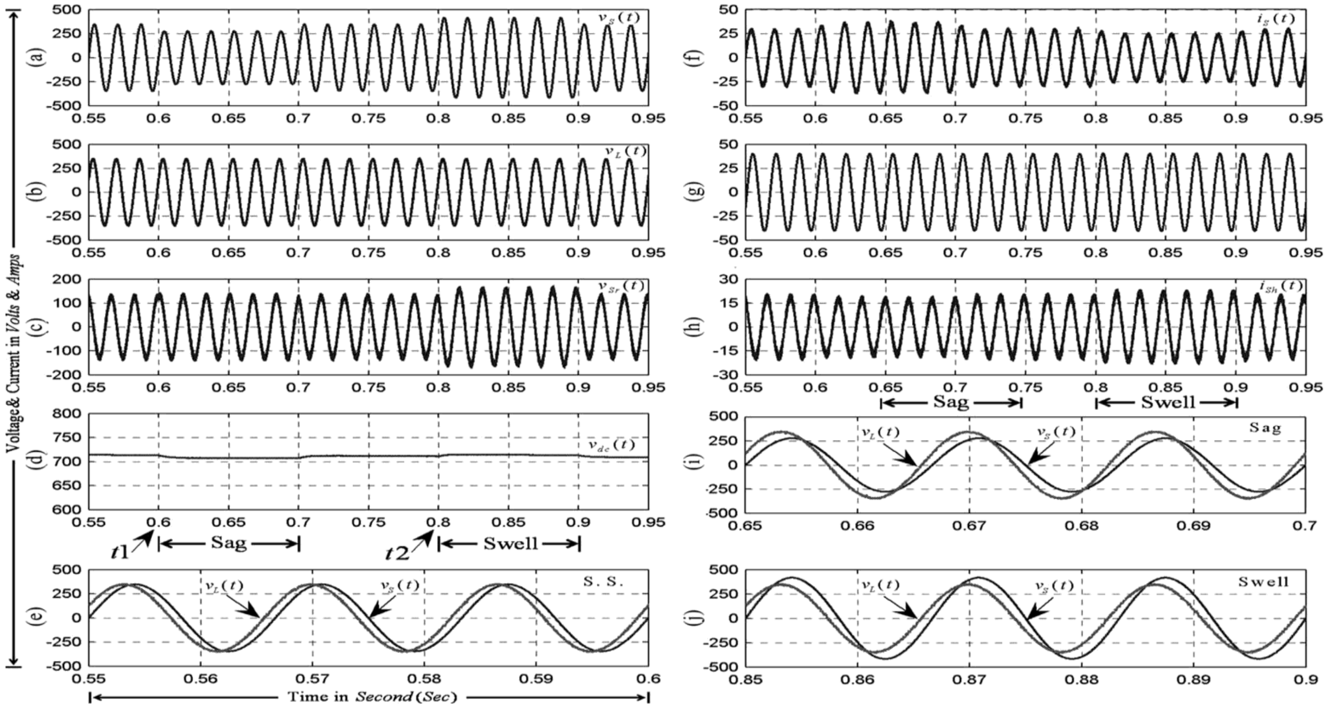

Fig.11. Simulation results: performance of the proposed UPQC-S approach under voltage sag and swell conditions. (a) Supply voltage. (b) Load voltage. (c) Series inverter injected voltage. (d) Self-supporting dc bus voltage. (e) Enlarged power angle δ relation between supply and load voltages during steady-state condition. (f) Supply current. (g) Load current. (h) Shunt inverter injected current. (i) Enlarged power angle δ during voltage sag condition.(j) Enlarged power angle δ during voltage swell condition

The simulation results for the proposed UPQC-S approach under voltage sag and swell conditions are given in Fig. 11. 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 δ of 21° 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 kilovoltampere 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. The active and reactive power flows through the source, load, and UPQC are given in Fig. 12. The distinct features of the proposed UPQC-S approach are outlined as follows.

1) From Fig. 11(a) and (b), the load voltage profile is maintained at a desired level irrespective of voltage sag (de- crease) or swell (increase) in the source voltage magnitudes. During the sag/swell compensation, as viewed from Fig. 11(f), to maintain the appropriate active power balance in the network, the source current increases during the voltage sag and reduces during swell condition.
2) As illustrated by enlarged results, the power angle δ between the source and load voltages during the steady state [see Fig. 11(e)], voltage sag [see Fig. 11(i)], and voltage swell [see Fig. 11(j)] is maintained at 21°.
3) The UPQC-S controller maintains a self-supporting dc link voltage between two inverters [see Fig. 11(d)].
4) From Fig. 12(c) and (d), the reactive power supplied by the series inverter during the voltage sag condition increases due to the increased source current. As load reactive power demand is constant, the reactive power supplied by the shunt inverter reduces accordingly. On the other hand, during the voltage swell condition, the reactive power shared by the series inverter reduces and the shunt inverter increases. The reduction and increment in the shunt compensating current magnitude, as seen from Fig. 11(h), also confirm the aforementioned fact. Although the reactive power shared by the series and shunt inverters is varied, the sum of their reactive powers always equals the reactive power demanded by the load.

Thus, the aforementioned simulation study illustrates that with PAC of UPQC-S, the series inverter can compensate the load reactive power and voltage sag/swell simultaneously. The shunt inverter helps the series inverter

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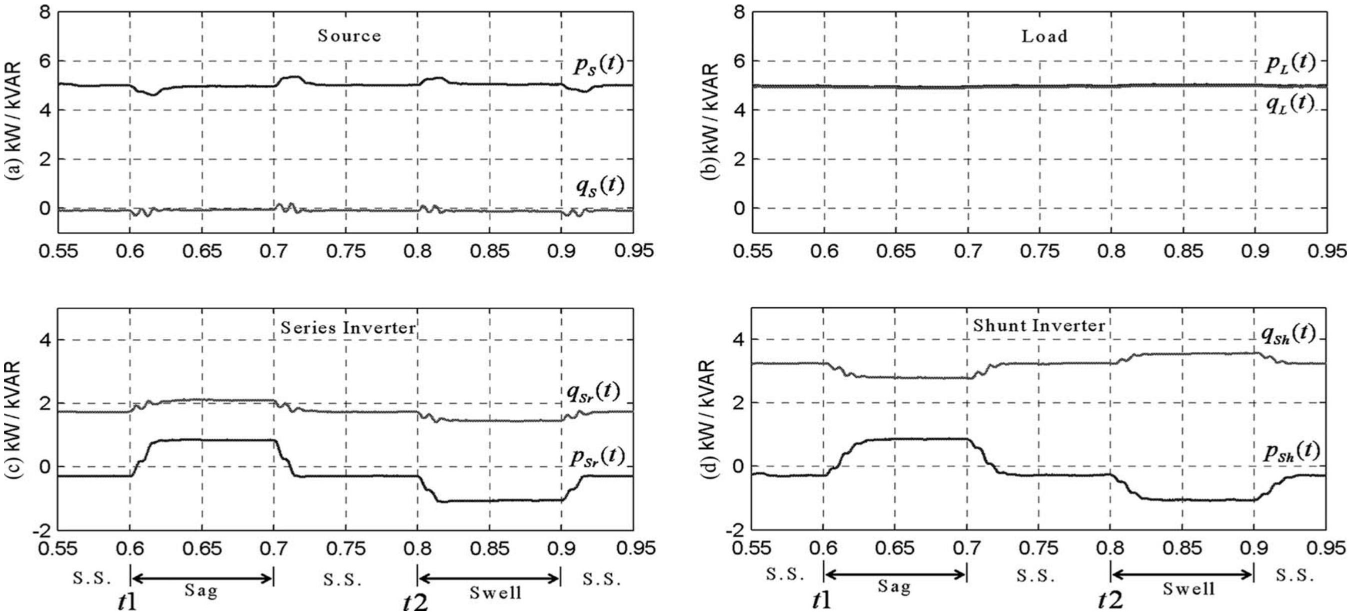

Fig. 12. Simulation results: active and reactive power flow through source, load, shunt, and series inverter utilizing proposed UPQC-S approach under voltage sag and swell conditions. (a) Source P and Q. (b) Load P and Q. (c) Series inverter P and Q. (d) Shunt inverter P and Q.

to achieve the desired performance by maintaining a constant self-supporting dc bus. The significant advantage of UPQC-S over general UPQC ap- plications is that the shunt inverter rating can be reduced due to reactive power sharing of both the inverters.

IX. EXPERIMENTAL VALIDATION

The performance of the proposed concept of UPQC-S is validated through experimental study. The pictorial view of the UPQC experimental setup is shown in Fig. 13 and prototype . Details are given in the Appendix.

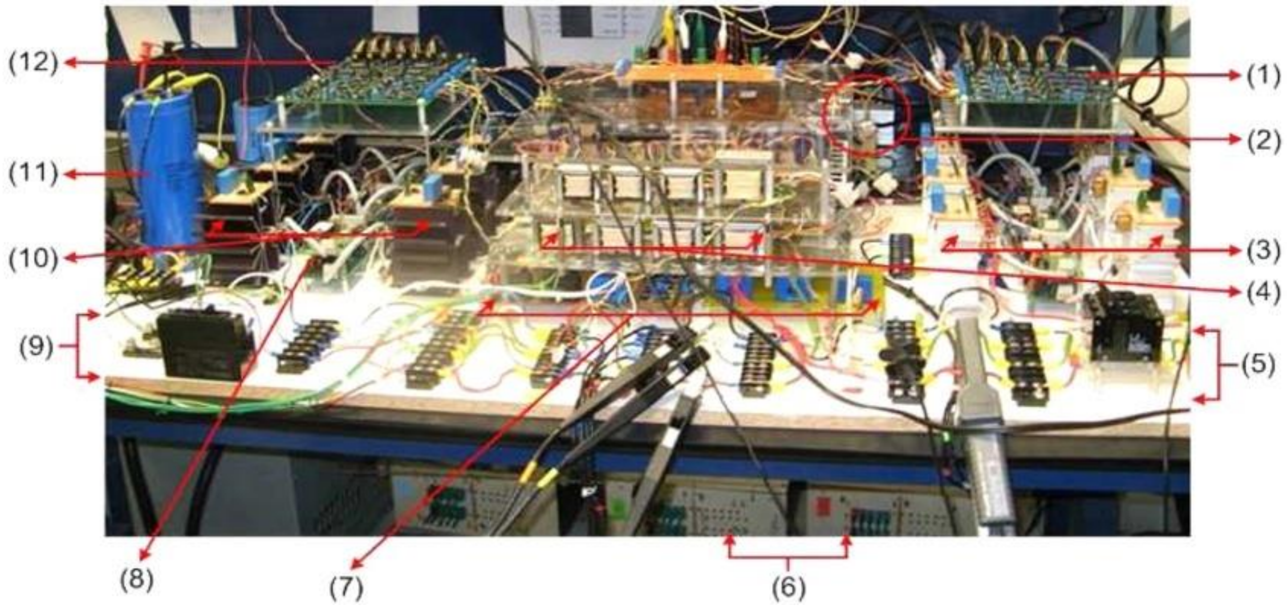

Fig. 13. Pictorial view of UPQC laboratory prototype. (1) Analog triangular carrier signal-based PWM controller for series inverter, (2) dSPACE, (3) in- sulated gate bipolar transistor (IGBT)-based series inverter, (4) voltage sensing circuitry, (5) source side, (6) series injection transformers, (7) current sens- ing circuitry, (8) IGBT driver circuitry, (9) load side, (10) IGBT- based shunt inverter, (11) dc bus, and (12) analog hysteresis current controller for shunt inverter

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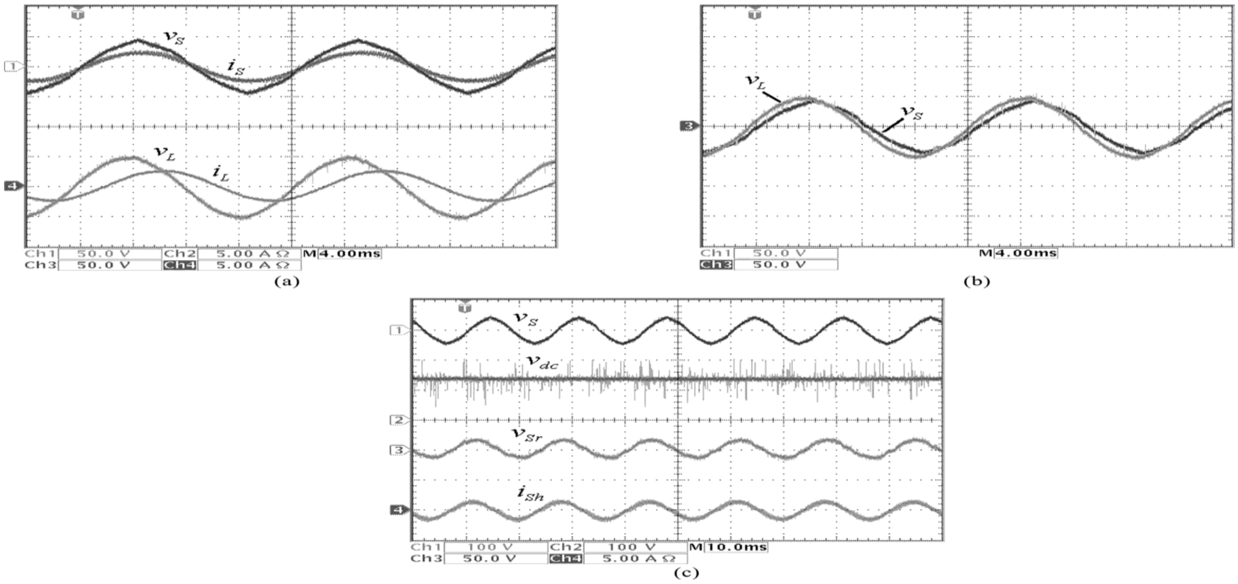

Fig. 14. Experimental results: Performance of proposed UPQC-S approach under voltage sag condition (voltage sag = 17%, δ = 10°). (a) Source and load *v–I* profiles. (b) Power angle δ shift between resultant load and source voltages. (c) UPQC-S injected *v–i* and self-supporting dc bus profiles

Performance of UPQC-S under Voltage Sag Condition. The experimental results during the voltage sag on the system are shown in Fig. 14. It is considered that the UPQC already working under PAC shares the load reactive power (load power factor 0.6 lagging) between both the inverters. The power angle δ between the load and source voltages is 10°. Under this condition, the voltage sag of 17% is introduced on the system. The reduced source voltage profile can be noticed from Fig. 14(a) (upper trace). The UPQC-S with the proposed approach maintains the load voltage at a set reference value while supporting the load reactive power using both the inverters. Furthermore, the UPQC-S effectively achieves a unity power factor operation at source side, which can be noticed from Fig. 14(a) (upper two traces). The resultant load and source voltage profiles are com- pared in Fig. 14(b). The power angle δ of 10° between the two voltages is noticeable in the figure. The voltage injected by the series inverter and the shunt inverter current during the voltage sag compensation mode of operation are given in Fig. 14(c). The presence of in-phase voltage component (for voltage sag compensation) in addition to the load reactive power component can be observed from the series injected voltage profile (trace-3). The self-supporting dc bus of UPQC-S is also shown in Fig. 14(c) (trace-2).

X. CONCLUSION

In this paper, 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. The simulation and experimental studies demonstrate the effectiveness of the proposed concept of simultaneous voltage sag/swell and load reactive power sharing feature of series part of UPQC-S. The significant advantages of UPQC-S over general UPQC applications are: 1) the multifunction ability 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 sharing by both the inverters.

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