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SYNCHRONOUS-REFERENCE – FRAME BASED CONTROL METHOD FOR UPQC UNDER DIFFERENT LOAD CONDITIONS

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ABSTRACT

A new synchronous-reference-frame (SRF)-based control method is proposed in this project .It compensate power-quality (PQ) problems through a three-phase four-wire unified PQ conditioner (UPQC) under unbalanced and distorted load conditions. The proposed UPQC system can improve the power quality at the point of common coupling on power distribution systems under unbalanced and distorted load conditions. The main problem in the power distribution system is voltage sag, voltage swell and load reactive power compensation, to compensate these problems we are using in this project a power electronic device i.e., UPQC-S(Unified power quality conditioner). S means complex power. i.e., vector sum of active and reactive power. UPQC is a flexible ac transmission system. It is combination of series and shunt converters.

INDEX TERMS:- UPQC, Power angle control, shunt and series circuit

NOMENCLATURE—Active power filter (APF), harmonics, phase-locked loop (PLL), power quality (PQ), synchronous reference frame (SRF), unified power-quality (PQ) conditioner (UPQC).

1.INTRODUCTION

The modern power distribution system is becoming highly vulnerable to the different power quality problems. The main problem in the power distribution system is voltage sag, voltage swell and load reactive power compensation, to compensate these problems we are using in this project a power electronic device i.e., UPQC-S(Unified power quality conditioner). S means complex power. i.e., vector sum of active and reactive power. UPQC is a flexible ac transmission system. It is combination of series and shunt converters.

The series converter is SSSC (static synchronous series compensator), and shunt converter is STATCOM. The STATCOM is a combination of TCR&TSC (thyristor capacitor reactance& thyristor switched capacitor).

- The series compensator which can injects the voltage and controls the current.
- The shunt compensator which can injects the current and controls the voltage.

The extensive use of nonlinear loads is further contributing to increased current and voltage harmonics issues. Furthermore, the penetration level of small/large-scale renewable 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. To maintain the controlled power quality regulations, some kind of compensation at all the power levels is becoming a common practice. At the distribution level, UPQC is a most attractive solution to compensate several major power quality problems.

2.BLOCK DIAGRAM OF UPQC

The general block diagram representation of a UPQC-based system is shown in Fig: 2.1. It basically consists of two voltage source inverters connected back to back using a common dc bus capacitor. This thesis deals with a novel concept of optimal utilization of a UPQC.

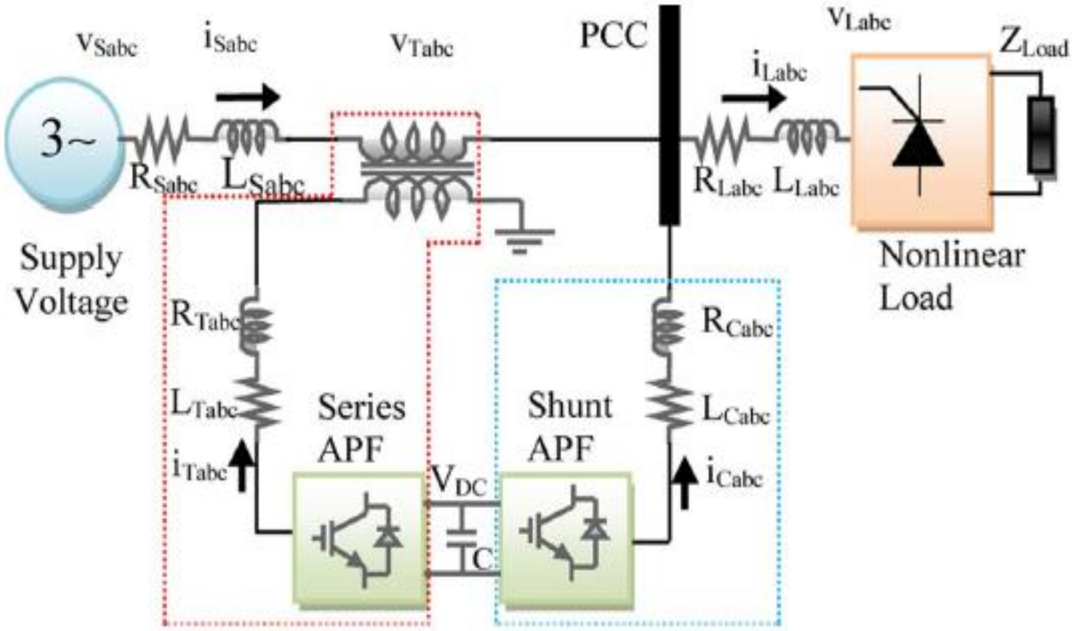


Fig. 1.: Block diagram representation of Unified power quality conditioner (UPQC).

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, UPQC, etc. Among the available power quality enhancement devices, the UPQC has better sag/swell compensation capability.

Three significant control approaches for UPQC 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, known as UPQC-Q.
3) A minimum VA loading approach in which a series voltage is injected at a certain angle, in this paper called as UPQC-VA min.

Among the aforementioned three approaches, the quadrature voltage injection requires a maximum series injection voltage, whereas the in-phase voltage injection requires the minimum voltage injection magnitude. In a minimum VA loading approach, the series inverter voltage is injected at an optimal angle with respect to the source current.

Besides the series inverter injection, the current drawn by the shunt inverter, to maintain the dc link voltage and the overall power balance in the network, plays an important role in determining the overall UPQC VA loading. 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.

Since an out of phase component 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 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 normal steady-state condition without affecting the resultant load voltage magnitude.

The optimal angle of series voltage injection in UPQC-VA min is computed using lookup table or particle swarm optimization technique. These iterative methods mostly rely on the online load power factor angle estimation, and thus may result into tedious and slower estimation of optimal angle. On the other hand, the PAC of UPQC concept determines the series injection angle by estimating the power angle δ. The angle δ is computed in adaptive way by computing the instantaneous load active/reactive power and thus, ensures fast and accurate estimation.

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). A UPFC is utilized in a power transmission system whereas a UPQC is employed in a power distribution system to perform the shunt and series compensation simultaneously. The power transmission systems are generally operated in balanced and distortion-free environment, contrary to power distribution systems that may contain dc component, distortion, and unbalance.

The primary objective of a UPFC is to control the flow of power at fundamental frequency. Also, while performing this power flow control in UPFC the transmission network voltage may not be maintained at the rated value. However, in PAC of UPQC the load side voltage is strictly regulated at rated value while performing load reactive power sharing by shunt and series inverters. In this project, the concept of PAC of UPQC is further expanded for voltage sag and swells conditions. This modified approach is utilized to compensate voltage sag/swell while sharing the load reactive power between two inverters.

Since the series inverter of UPQC in this case delivers both active and reactive powers, it is given the name UPQCS (S for complex power). The key contributions of this paper are outlined as follows.

1) The series inverter of UPQC-S is utilized for simultaneous voltage sag/swell compensation and load reactive power compensation in coordination with shunt inverter.
2) In UPQC-S, the available VA loading is utilized to its maximum capacity during all the working conditions contrary to UPQC-VA min where prime focus is to minimize the VA loading of UPQC during voltage sag condition.
3) The concept of UPQC-S covers voltage sag as well as swell scenario.

In this thesis, a detailed mathematical formulation of PAC for UPQC-S is carried out. The feasibility and effectiveness of the proposed UPQC-S approach are validated by simulation as well as experimental results.

A: Configuration of UPQC:

The provision of both DSTATCOM and DVR can control the power quality of the source current and the load bus voltage. In addition, if the DVR and STATCOM are connected on the DC side, the DC bus voltage can be regulated by the shunt connected DSTATCOM while the DVR supplies the required energy to the load in case of the transient disturbances in source voltage. The UPQC configuration is shown in fig.2..

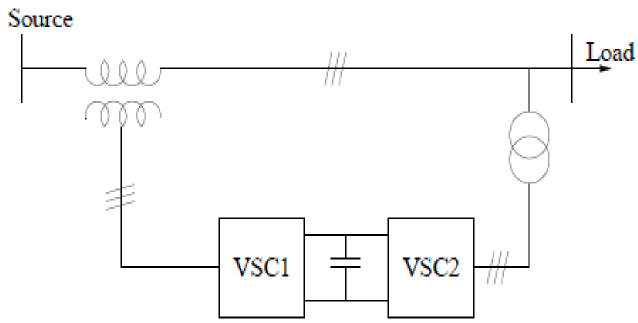


Fig. 2: UPQC Configuration.

The configuration of such a device (termed as Unified Power Quality Conditioner (UPQC)) is shown in Fig: 2. This is a versatile device similar to a UPFC. However, the control objectives of a UPQC are quite different from that of a UPFC.

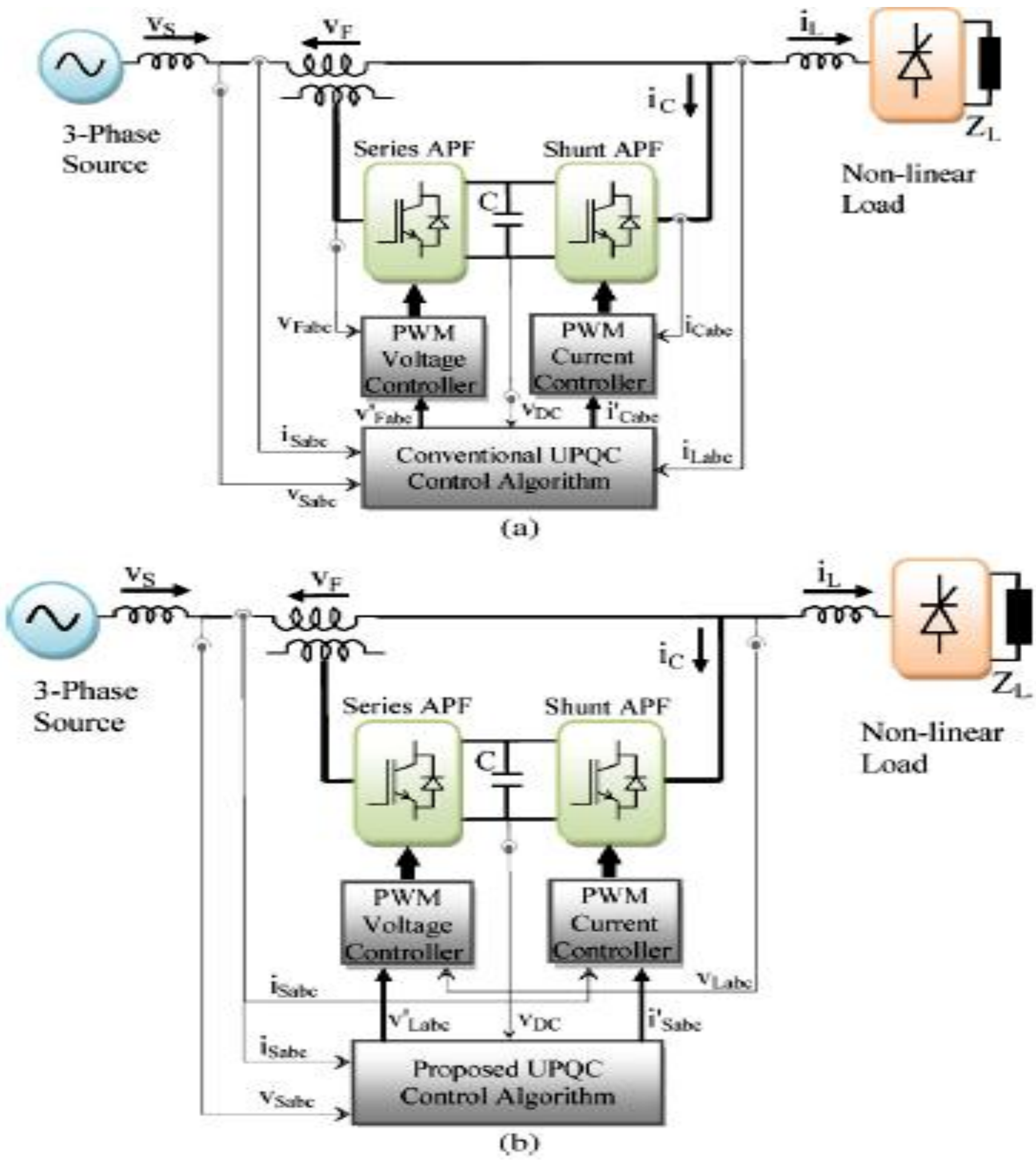


FIG 2a) Conventional UPQC b) Proposed UPQC

B: CONTROL OBJECTIVES OF UPQC:

The shunt connected converter has the following control objectives,

1. To balance the source currents by injecting negative and zero sequence components required by the load.
2. The compensate for the harmonics in the load current by injecting the required harmonic currents.
3. To control the power factor by injecting the required reactive current (at fundamental frequency).
4. To regulate the DC bus voltage.

The series connected converter has the following control objectives,

1. To balance the voltages at the load bus by injecting negative and zero sequence voltages to compensate for those present in the source.
2. To isolate the load bus from harmonics present in the source voltages, by injecting the harmonic voltages.
3. To regulate the magnitude of the load bus voltage by injecting the required active and reactive components (at fundamental frequency) depending on the power factor on the source side.
4. To control the power factor at the input port of the UPQC (where the source is connected. Note that the power factor at the output port of the UPQC (connected to the load) is controlled by the shunt converter.

C: Operation of UPQC:

The operation of a UPQC can be explained from the analysis of the idealized equivalent circuit shown in Fig: 2.4. Here, the series converter is represented by a voltage source VC and the shunt converter is represented by a current source IC.

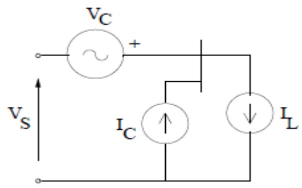


Fig. 3: Operation of UPQC.

Note that all the currents and voltages are 3 dimensional vectors with phase coordinates. Unlike in the case of a UPFC (discussed in chapter 8), the voltages and currents may contain negative and zero sequence components in addition to harmonics. Neglecting losses in the converters, we get the relation

(VL, IC) +(VC, IS)=0

Where X, Y denote the inner product of two vectors, defined by

$$\langle X, Y\rangle = \frac{1}{T}\int_0^T X^t(\tau)Y(\tau)d\tau.$$

Let the load current IL and the source voltage VS be decomposed into two Components given by

$$I_L = I_L^{1p} + I_L^r$$

$$V_S = V_S^{1p} + V_S^r$$

Where I1p L contains only positive sequence, fundamental frequency components. Similar comments apply to V 1pS. IrL and V rS contain rest of the load current and the source voltage including harmonics. I1pL is not unique and depends on the power factor at the load bus. However, the following relation applies for I1p L.

$$P_L = \langle V_L, I_L\rangle = \langle V_L, I_L^{1p}\rangle$$

This implies that hIrL; VLi = 0. Thus, the fundamental frequency, positive sequence component in IrL does not contribute to the active power in the load. To meet the control objectives, the desired load voltages and source currents must contain only positive sequence, fundamental frequency components and

$$P_L = |V_L^* \; I_S^*|\cos\phi_l = |V_S^{1p} I_S^*|\cos\phi_s$$

Where V ¤ L and I¤S are the reference quantities for the load bus voltage and the source current respectively. All is the power factor angle at the load bus while Ás is the power factor angle at the source bus (input port of UPQC). Note that V ¤ L (t) and I¤S (t) are sinusoidal and balanced. If the reference current (I¤C) of the shunt converter and the reference voltage (V ¤ C) of the series converter are chosen as

$$I_C^* = I_L^*, \quad V_C^* = -V_S^r + V_C^{1p}$$

With the constraint

$$\langle V_C^{1p}, I_S^*\rangle = 0$$

We have,

$$I_S^* = I_L^{1p}, \quad V_L^* = V_S^{1p} + V_C^{1p}$$

Note that the constraint (14.30) implies that V 1p C is the reactive voltage in quadrature with the desired source current, I¤S. It is easy to derive that

$$\langle V_C^*, I_S^*\rangle = 0 = \langle I_C^*, V_L^*\rangle$$

The above equation shows that for the operating conditions assumed, a UPQC can be viewed as a inaction of a DVR and a STATCOM with no active power °ow through the DC link. However, if the magnitude of V ¤ L is to be controlled, it may not be feasible to achieve this by injecting only reactive voltage. The situation gets complicated if V 1p S is not constant, but changes due to system disturbances or fault. To ensure the regulation of the load bus voltage it may be necessary to inject variable active voltage (in Phase with the source current). If we express

$$V_C = V_C^* + \Delta V_C, I_C = I_C^* + \Delta I_C$$

$$I_S = I_S^* - \Delta I_C, V_L = V_S^{1p} + V_C^{1p} + \Delta V_C$$

$$\langle I_S, \Delta V_C\rangle + \langle V_L, \Delta I_C\rangle = 0$$

In deriving the above, we assume that

$$\langle I_S, V_C^*\rangle = 0 = \langle V_L, I_C^*\rangle$$

This implies that both ¢VC and ¢IC are perturbations involving positive sequence, fundamental frequency quantities (say, resulting from symmetric voltage sags). the power balance on the DC side of the shunt and series converter. The perturbation in VC is initiated to ensure that

$$|V_C^* + \Delta V_C + V_S| = |V_L| = \text{constant}.$$

Thus, the objective of the voltage regulation at the load bus may require exchange of power between the shunt and series converters

III.UPQC CONTROLLER

A detailed controller for UPQC based on PAC approach is described. In this project, the generation of reference signals for series inverter is discussed. Note that, as the series inverter maintains the load voltage at desired level, the reactive power demanded by the load remains unchanged (assuming load on the system is constant) irrespective of changes in the source voltage magnitude. Furthermore, the power angle δ is maintained at constant value under different operating conditions.

Therefore, the reactive power shared by the series inverter and hence by the shunt inverter changes as given by (47) and (54). The reactive power shared by the series and shunt inverters can be fixed at constant values by allowing the power angle δ to vary under voltage sag/swell condition.

The control block diagram for series inverter operation is shown in Fig:4 The instantaneous power angle δ is determined using the procedure given. Based on the system rated specifications, the value of the desired load voltage is set as reference load voltage k. The instantaneous value of factors kf and nO is computed by measuring the peak value of the supply voltage in real time.

The magnitudes of series injected voltage VSr and its phase angle ϕSr are then determined using (15) and (17). A phase locked loop is used to synchronize and to generate Instantaneous time variable reference signals $v*$Sr,a , $v*$Sr,b , $v*$Sr,c .

The reference signals thus generated give the necessary series injection voltages that will share the load reactive power and compensate for voltage sag/swell as formulated using the proposed approach. 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.

A: UPQC CONTROL STRATEGY

The control system has three major elements, which are a positive sequence detector, a shunt inverter control, and a series inverter control [3], [5]. The positive-sequence detector extracts the positive sequence of component from the disturbed and unbalanced three-phase source voltage with series of steps as given in the Fig. 4 sub block.

The transformed positive sequence reference voltage Vsα′, Vsβ′,based on the αβ0 transform are found out as explained below. The measured source voltage passes through the three phase PLL (Phase-Locked Loop) and the sine wave generator to calculate the Fig.4 shunt inverter control. fundamental component of the α-β transformed current, (iα′=sinω1$t)$ and (iβ′=cosω1$t)$ [5]. And in Fig.4, the Vsabc divided by k(=(Vrms/sqrt(3))*sqrt(2)) for getting unit magnitude voltage signals.

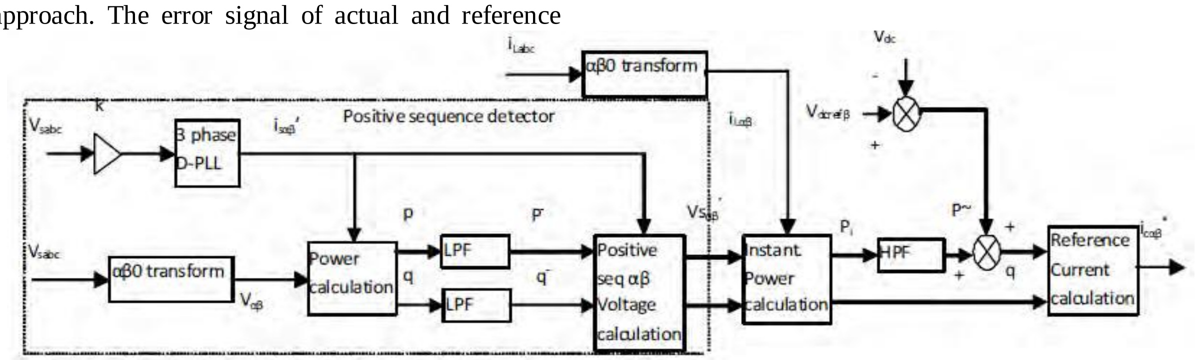


Fig. 4: shunt inverter control.

To positive sequence fundamental component are calculated as active power ps ′ and reactive power qs ′ from the of the source voltage VS and fundamental current components i α′ and i β′ [3],[5].

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}}\, X \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} \quad \ldots(1)$$

$$\begin{bmatrix} p_s' \\ q_s' \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha' \\ i_\beta' \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

So, the instantaneous value of the positive-sequence component voltage is calculated using the expression (3).

$$\begin{bmatrix} V_{s\alpha}' \\ V_{s\beta}' \end{bmatrix} = \frac{1}{{i_\alpha'}^2 + {i_\beta'}^2} \begin{bmatrix} i_\alpha' & i_\beta' \\ i_\beta' & -i_\alpha' \end{bmatrix} \begin{bmatrix} p_s' \\ q_s' \end{bmatrix} \quad \ldots\ldots\ldots\ldots(3)$$

B: Shunt Inverter Control:

The functions of the shunt inverter are to compensate the current harmonics, the reactive power, and to regulate the DC link capacitor voltage. Fig.2 shows the configuration of shunt inverter control, which includes the current control for harmonic compensation, and the DC voltage control. Shunt control calculates the reference value of the compensating current for the harmonic current, the load reactive power, real power demand of series inverter to compensate sag / swell in terms of DC link voltage regulation and considering the power loss ploss due to the inverter operation. This loss should be compensated to maintain the dc link voltage constant. The instantaneous power is calculated using α-β components of positive sequence voltage and load current iL.

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_{s\alpha}' & v_{s\beta}' \\ v_{s\beta}' & -v_{s\alpha}' \end{bmatrix} \begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots(4)$$

$$\begin{bmatrix} i^*_{c\alpha} \\ i^*_{c\beta} \end{bmatrix} = \frac{1}{\upsilon} \begin{bmatrix} V_{s\alpha}' & -V_{s\beta}' \\ V_{s\beta}' & V_{s\alpha}' \end{bmatrix} \begin{bmatrix} -p\sim + p_{loss} \\ -q \end{bmatrix} \quad \ldots(5)$$

Where,

Power corresponds to harmonic content is calculated by separating oscillating power and fundamental power by passing throw 5th order butter-worth high pass filter. Using these active powers (oscillating power and system power loss) and reactive power the reference value of the compensating current is derived as (5).

C: Series Inverter Control:

Fig.5.,shows the control circuit of series converter. The function of the series inverter is to compensate the voltage disturbance such as voltage harmonics, sag/ swell on the source side, which is due to the fault and/or line drop because of over load in the distribution line. Fig.5.. Control circuit for Series converter. The function of the series inverter is to compensate the voltage disturbance such as voltage harmonics, sag/ swell on the source side, which is due to the fault and/or line drop because of over load in the distribution line.

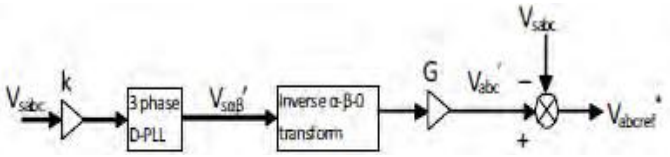


Fig. 5: Control circuit for Series converter.

The series inverter control calculates the reference voltage to be injected by the series inverter, comparing the positive-sequence component (Vabc') with the disturbed source voltage (Vsabc). The sag / swell compensation may involves supplying / absorbing real power from the supply line, so there must be real power balance between series and shunt inverters.

The instantaneous real power absorbed / delivered by the series inverter must be equal to the real power delivered / absorbed by the shunt inverter so as to maintain DC link capacitor voltage constant. In the Fig: 5., k=(Vrms/sqrt(3))*sqrt(2) and G=desired maximum phase voltage value.

IV.SIMULATION RESULTS

The performance of the proposed concept of simultaneous load reactive power and voltage sag/swell compensation has been evaluated by simulation. To analyze the performance of UPQC-S, the source is assumed to be pure sinusoidal. Furthermore, 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).

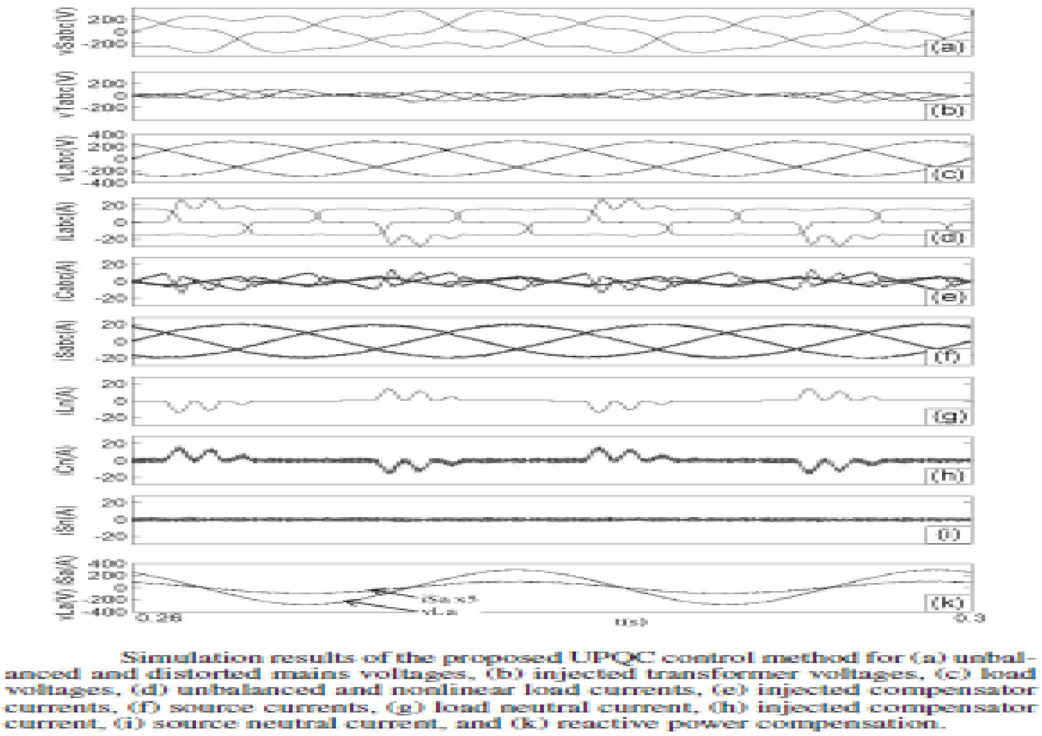


Fig. 6: Simulation results: Performances of the proposed UPQC-S approach under voltage sags and swell conditions. (a) Supply voltage. (b) Load voltage. (c) Series inverter injected voltage. (d) Self-supporting dc bus voltage. (e) Enlarged power angle δ relation between supply and load voltages during 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. 6.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 kilo volt ampere rating. At time $t1$ = 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 $t2$ = 0.8–0.9 s. The active and reactive power flows through the source, load, and UPQC are given in Fig: 6.. The distinct features of the proposed UPQC-S approach are outlined as follows.

1) From Fig: 6.1(a) and (b), the load voltage profile is maintained at a desired level irrespective of voltage sag (decrease) or swell (increase) in the source voltage magnitudes. During the sag/swell compensation, as viewed from Fig: 6., 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:6)], voltage sag [see Fig:6 (i)], and voltage swell [see Fig: 5] is maintained at 21◦.

3) The UPQC-S controller maintains a self-supporting dc link voltage between two inverters [see Fig: 6].

4) From Fig: II(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: I(h), also confirm thforementioned 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 to achieve the desired performance by maintaining a constant self-supporting dc bus.

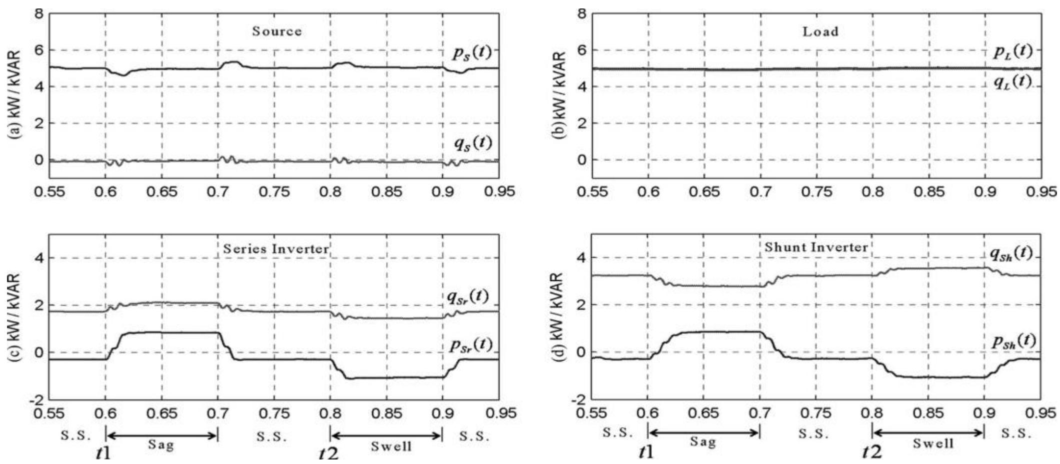


Fig. 7: Simulation results: active and reactive power flow through source, load, shunt, and series inverter utilizing proposed UPQC approach under voltage sag and swell conditions. (a) Source P and Q. (b) Load P and Q. (c) Series inverter P and Q. (d) Shunt inverter P and Q.

The power loss is computed as the ratio of losses associated with UPQC to the total load power. The rms values of current flowing through shunt and series inverters and series injection voltage are also given in Table 6.1. Initially, it is considered that the shunt inverter alone supports the load reactive power and the series inverter is assumed to be in OFF condition. The series injection transformer is also short circuited. This operating condition gives the losses in the shunt part of UPQC, which are found as 0.74% of the rated load power. In the second condition, the series inverter is turned on as well.

The percent power losses, when both the inverters of UPQC are in operation, are noticed as 1.7%. Under this condition when UPQC is controlled as UPQC-S to support the load reactive power using both shunt and series inverters, controlled by the PAC approach, losses are observed as 1.2%. The power loss in the UPQC system with PAC approach thus is lower than the normal UPQC control.

This is an interesting outcome of the PAC approach even when the series inverter deals with both active and reactive powers due to δ shift between source and load voltages. One may expect to increase the power loss with the UPQC-S system.

The reduction in the power loss is mainly due to the reduction in the shunt inverter rms current from 20.20 A (without PAC approach) to 13.18 A (with PAC approach). Second, the current through the series inverter (which is almost equal to the source current) remains unchanged. Similarly from the Table I, the power losses utilizing the PAC approach, during voltage sag and swell conditions, are observed lower than those without PAC approach.

This study thus suggests that the PAC approach may also help to reduce the power loss associated with UPQC system in addition to the previously discussed advantages. The significant advantage of UPQC-S over general UPQC applications is that the shunt inverter rating can be reduced due to reactive power sharing of both the inverters.

V: SIMULATION CIRCUITS:

: Main Circuit model:

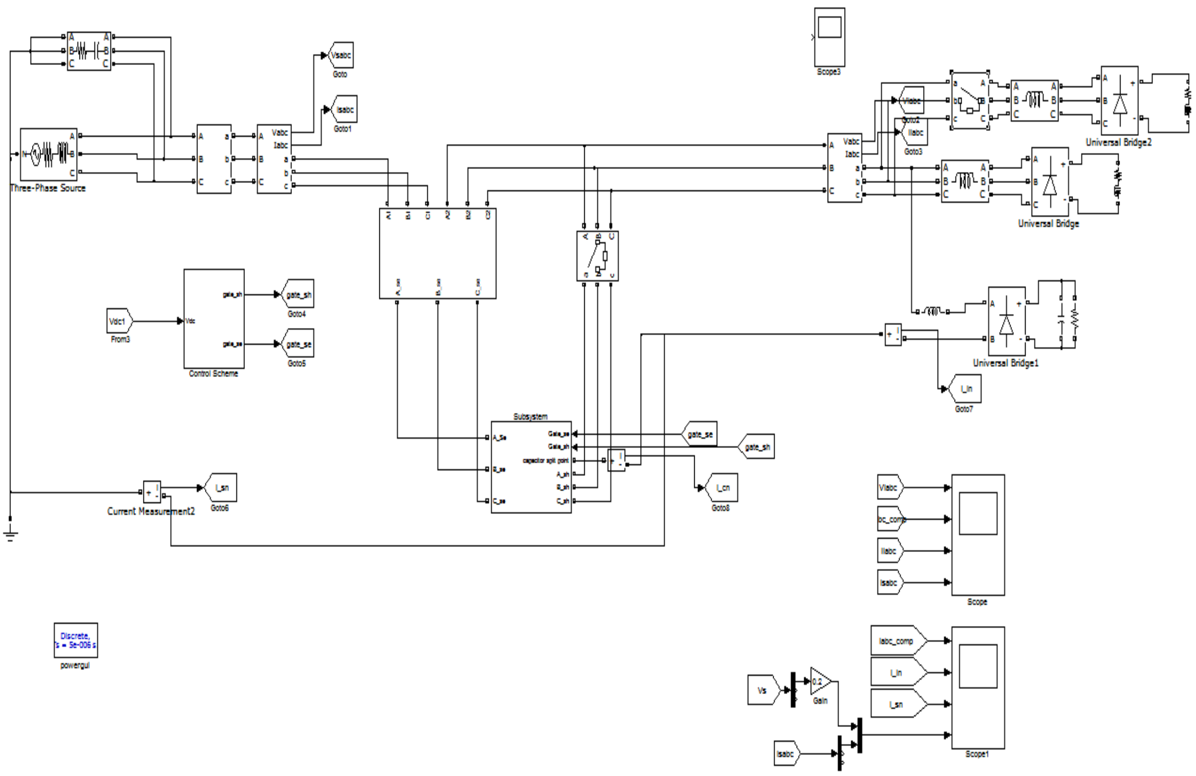
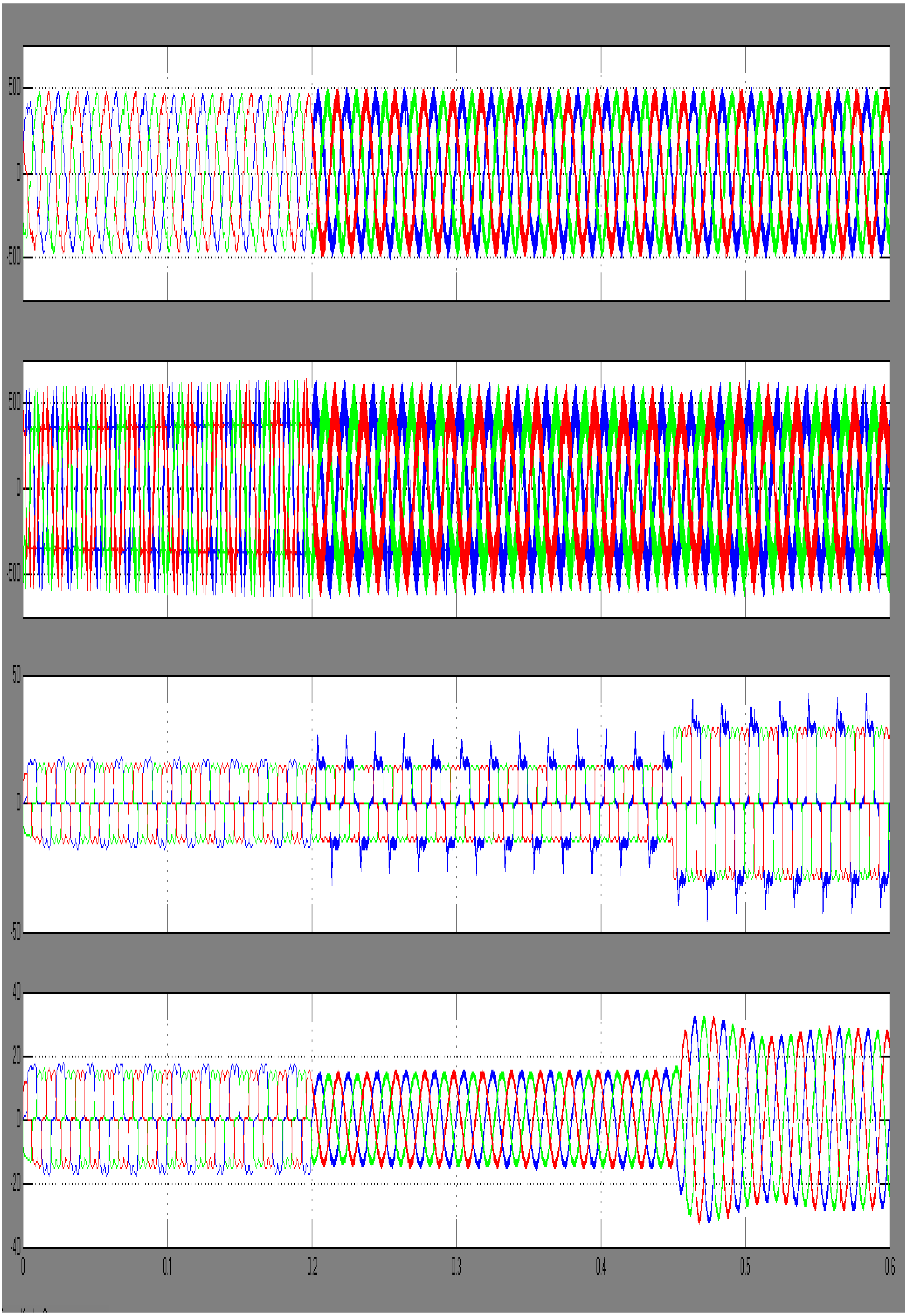


FIG:8 Simulation Circuit

VI:OUTPUTS



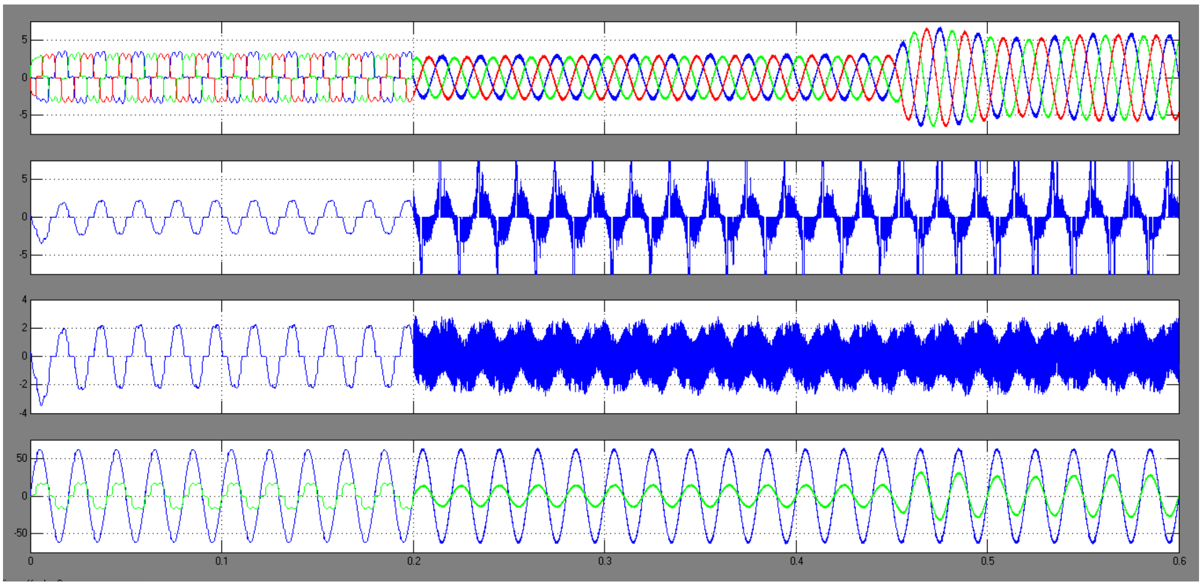


Fig. 9: Simulation results: Performances of the proposed UPQC-S approach under voltage sags and swell conditions. (a) Supply voltage. (b) Load voltage. (c) Series inverter injected voltage. (d) Self-supporting dc bus voltage. (e) Enlarged power angle *δ* relation between supply and load voltages during steady-state condition. (f) Supply current. (h) Shunt inverter injected current.

I. CONCLUSION

This paper describes a new SRF-based control strategy used in the UPQC, which mainly compensates the reactive power along with voltage and current harmonics under nonideal mains voltage and unbalanced load-current conditions. The proposed control strategy uses only loads and mains voltage measurements for the series APF, based on the SRF theory. The conventional methods require the measurements of load, source, and filter currents for the shunt APF and source and injection transformer voltage for the series APF. The simulation results show that, when under unbalanced and nonlinear load-current conditions, the aforementioned control algorithm eliminates the impact of distortion and unbalance of load current on the power line, making the power factor unity. Meanwhile, the series APF isolates the loads and source voltage in unbalanced and distorted load conditions, and the shunt APF compensates reactive power, neutral current, and harmonics and provides three-phase balanced and rated currents for the mains.

REFERENCES

[1] R. C. Dugan, M. F. McGranaghan, and H. W. Beaty, *Electrical Power Systems Quality*.. New York: McGraw-Hill, 1996, p. 265.

[2] C. Sankaran, *Power Quality*. Boca Raton, FL: CRC Press, 2002, p. 202.

[3] R. A. Walling, R. Saint, R. C. Dugan, J. Burke, and L. A. Kojovic, "Summary of distributed resources impact on power delivery systems," *IEEETrans. Power Del.*, vol. 23, no. 3, pp. 1636–1644, Jul. 2008.

[4] L. Gyugyi, "Unified power-flow control concept for flexible AC transmission systems," *IEE – C Gene. Trans. Distr.*, vol. 139, no. 4, pp. 323–331, Jul. 1992.

[5] N. G. Hingorani and L. Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*. New York: IEEE Press, 2000, p. 432.

[6] V. K. Sood, *HVDC and FACTS Controllers – Applications of Static Convertersin Power Systems*. Boston, MA: Kluwer, 2004, p. 295.

[7] A. Ghosh and G. Ledwich, *Power Quality Enhancement Using Custom Power Devices*. Boston, MA: Kluwer, 2002, p. 460.

[8] B. Singh, K. Al-Haddad, and A. Chandra, "A review of active power filters for power quality improvement," *IEEE Trans. Ind. Electron.*, vol. 45, no. 5, pp. 960–971, Oct. 1999.

[9] M. El-Habrouk, M. K. Darwish, and P. Mehta, "Active power filters: A review," *IEE Electr. Power Appl.*, vol. 147, no. 5, pp. 403–413, Sep. 2000.

[10] Doncker, C. Meyer, R. W. De, W. L. Yun, and F. Blaabjerg, "Optimized control strategy for a medium-voltage DVR—Theoretical investigations and experimental results," *IEEE Trans. Power Electron.*, vol. 23, no. 6, pp. 2746–2754, Nov. 2008.

[11] C. N. Ho and H. S. Chung, "Implementation and performance evaluation of a fast dynamic control scheme for capacitor-supported interline DVR," *IEEE Trans. Power Electron.*, vol. 25, no. 8, pp. 1975–1988, Aug. 2010.

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