VOL. 10, NO. 8, MAY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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IMPROVEMENT OF POWER QUALITY USING CUSTOM POWER DEVICES

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ABSTRACT

There are many custom power devices and they are divided in two groups: network-reconfiguring type and compensating type. The network reconfiguring group includes the following devices: solid-state current limiter (SSCL), solid-state breaker (SSB) and solid-state transfer switch (SSTS). These devices are much faster than their mechanical counterparts. The compensating devices either compensate a load, correcting its power factor, unbalance etc., or improve the quality of the supply voltage. These devices are either connected in shunt or in series or a combination of both. The compensating group includes distribution static compensator (DSTATCOM) to compensate for load reactive power and current harmonics, dynamic voltage restorer (DVR) for voltage support, and unified power quality conditioner (UPQC) for both current and voltage compensation. The present work focuses on the last custom power device UPQC, which is a combination of a shunt and series device and can combine the functions of these two devices together.

Keywords: power quality, DVR, DSTATCOM, UPQC, PI controller, hysteresis controller.

1. INTRODUCTION

Unified power quality conditioner (UPQC) is a custom power device, which mitigates voltage and current-related PQ issues in the power distribution systems. The widespread use of Power Electronics based equipment has produced a significant impact on quality of electric power supply. One modern and very promising solution that deals with both load current and supply voltage imperfections is the Unified Power Quality Conditioner (UPQC) .In this paper, UPQC topology for applications with non-stiff source is proposed. The proposed topology enables UPQC to have a reduced dc-link voltage without compromising its compensation capability. The average switching frequency of the switches in the VSI also reduces; consequently the switching losses in the inverters reduce.

The compensating group includes distribution static compensator (DSTATCOM) to compensate for load reactive power and current harmonics, dynamic voltage restorer (DVR) for voltage support, and unified power quality conditioner (UPQC) for both current and voltage compensation.

Chatterjee, S.A.; Joshi, K.D. 2010, [3] Described Conventional and Advanced methods for the control of D-STATCOM. The mathematical model of conventional double loop control, Direct-Output-Voltage (DOV) control, Decoupled DOV, Fuzzy-PI and Decoupled Fuzzy-PI based control is studied. The control scheme for the above approaches is implemented using Mat lab Simulink platform. The dynamic response of the models are presented and compared.

Sano, K.; Takasaki, M. 2011, [4] deals with a Cascaded Multilevel Converter which has multiple dc voltage values (multi-voltage cascade converter) for a 6.6-kV transformer less distribution static synchronous compensator (D-STATCOM). A control method is proposed to realize dc voltage regulation of series-connected three cells in the STATCOM operation, making it possible to remove dc sources from all H-bridge cells. The simplified configuration without the dc sources makes the STATCOM small and lightweight.

Tang Ping; Yin Xianggen; Zhang Zhe. 2011, [5] analyzed that D-STATCOM (Distributed Static Compensator) is an important member in D-FACTS (Distributed Flexible AC Transmission Systems), and the output filter is one of the key links in the design of it, which has a great influence on its output performance. First, the resonance phenomenon in traditional LC output filter is pointed out. Then, two modified topologies (LCR and LCCR topologies) are proposed to solve this problem.
Kumar, G.S.; Kumar, B.K.; Mishra, M.K. 2011, [8] Mitigates Voltage Sags with Phase Jumps by UPQC with PSO-Based ANFIS. Particle swarm optimization (PSO) has been used to find the solution of the objective function derived for minimizing real power injection of UPQC along with the constraints. Adaptive neuro-fuzzy inference systems have been used to make the proposed methodology online for minimum real power injection with UPQC by using the PSO-based data for different voltage sag conditions. The proposed method has been validated through detailed simulation and experimental studies.

Khadkikar, V., Chandra, A. 2011, [9] 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.

Khadkikar. V 2012, [10] presents a comprehensive review on the Unified Power Quality

VOL. 10, NO. 8, MAY 2015 ISSN 1819-6608
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Conditioner (UPQC) to enhance the electric power quality at distribution levels. This is intended to present a broad overview on the different possible UPQC system configurations for single-phase (two-wire) and three-phase (three-wire and four-wire) networks, different compensation approaches, and recent developments in the field.

Karanki, K.; Geddada, G.; Mishra, M.K.; Kumar, B.K. 2013, [11] Unified Power Quality Conditioner (UPQC) is a custom power device, which mitigates voltage and current-related PQ issues in the power distribution systems. In this paper, a UPQC topology for applications with non-stiff source is proposed. The proposed topology enables UPQC to have a reduced dc-link voltage without compromising its compensation capability. This proposed topology also helps to match the dc-link voltage requirement of the shunt and series active filters of the UPQC.

Ota, J.; Shibano, Y. Akagi, H. 2014, [7] Provides an experimental discussion on Zero-voltage-ride-though (ZVRT) capability of a phase-shifted- PWM D(distribution)-STATCOM using the modular multilevel cascade converter based on single-star bridge cells (MMCCSSBC). The cluster-balancing control producing a significant effect on the ZVRT capability is modeled and analyzed with focus on either low-pass filter (LPF) or moving average filter (MAF) to attenuate the 100-Hz (double the line frequency) component inherent in each dc capacitor voltage

Ambati, B.B.; Khadkikar, V. 2014, [12] Introduces an optimum method to design a unified power-quality conditioner (UPQC) system with the minimum possible VA rating based on the compensation requirements. The variation in series and shunt inverters VA loadings of UPQC for the given compensation requirements is analyzed for all existing control approaches. A novel design method and the corresponding algorithm are proposed to size the major components in an UPQC, such as the series inverter, shunt inverter, and series transformer corresponding to the minimum possible overall VA rating.

2. PROPOSED SYSTEM

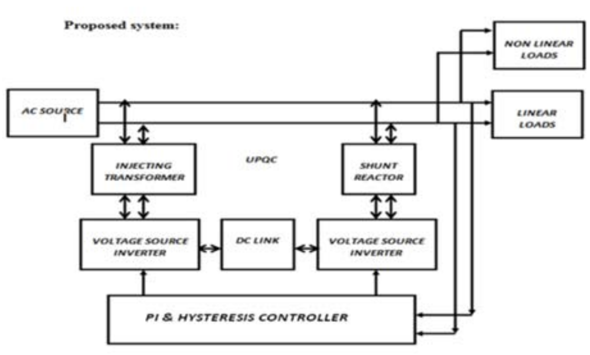

Figure-1. Block diagram of proposed system.

The block diagram of proposed system is shown in Figure-1. It consists of DSTATCOM, DVR, linear and non-linear loads, and PI and Hysteresis Controller.

It is the combination of both DVR and DSTATCOM to improve the power quality issues such as sag, swell and harmonics, reactive power compensation.

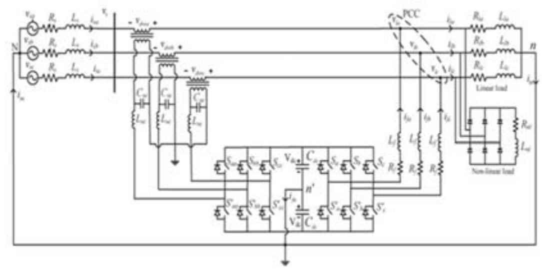

Figure-2. Circuit diagram of proposed system.

3. SIMULATION MODEL OF DVR

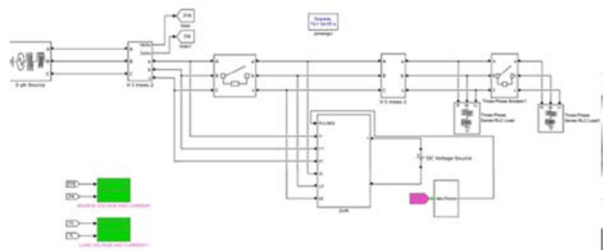

Figure-3. Simulation model of DVR.

Simulation results of DVR

When the DVR is in operation the voltage sag is mitigated almost completely and the RMS voltage of the sensitive load is maintained at 98%. The sag mitigation is performed with a smooth, stable and rapid DVR response, two transient undershoots are observed when the DVR comes in and out of operation. The compensation capability of DVR depends on the capacity of the energy storage device. DVR can also add other features; those are line voltage harmonics compensation, reduction of transients in voltage and fault current limitations and then analyze the dynamic and steady-state performance of DVR.

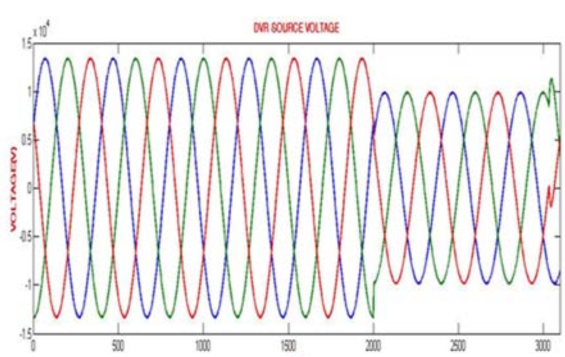

Figure-4. DVR source voltages.

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The source voltage is shown in the Figure-4.

Load-1 always connected to the source. At 0.1 transition time another load-2 is added and there is voltage sag. Correspondingly current increases with decrease in voltage.

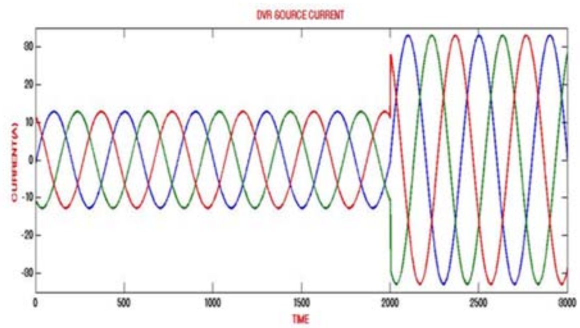

Figure-5. DVR source current.

The source current shown in the Figure-5. During 0.1 transition time breaker closed and DVR comes to picture and compensates voltage due to sag and reaches source voltage, then breaker gets turned off. The load current increases when there is a voltage sag.

DVR is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling.

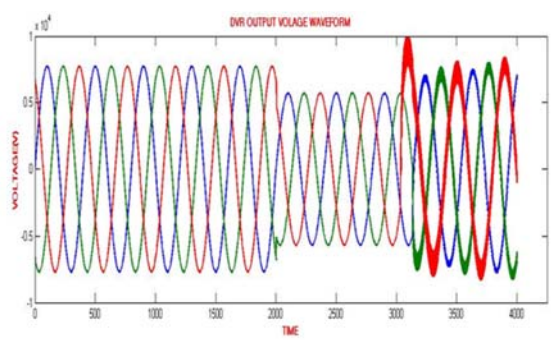

Figure-6. DVR load voltage.

During t=0.1s load-2 gets connected, there is a voltage drop. At t=0.16s DVR turned on and compensates voltage equal to source voltage as shown in Figure-6.

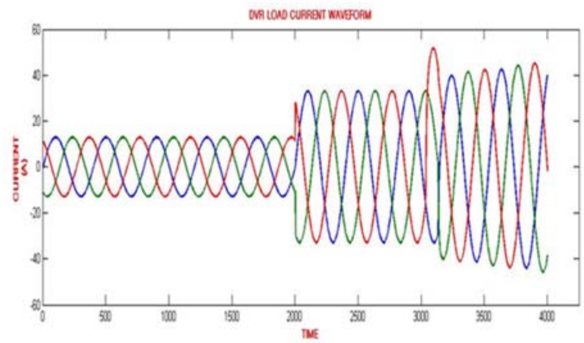

Figure-7. DVR load current.

At t=0.16s DVR comes to a state and injects voltage due to sag and reaches the source voltage and corresponding load current as shown in Figure-7.

4. SIMULATION MODEL OF DSTATCOM

DSTATCOM is a complex power electronics device and the analysis of its behavior, which leads to improved understanding, would be very difficult without computer simulations (if possible at all). The overall design process can be shortened through the use of computer simulations, since it is usually easier to study the influence of a parameter on the system behavior in simulation.

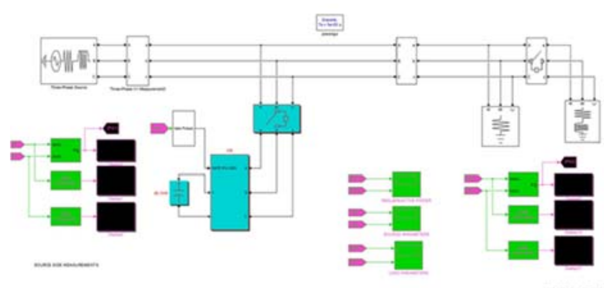

Figure-8. Simulation model of DSTATCOM.

Simulation results of DSTATCOM

Figure-9 shows the three phase load voltage of distribution system with shunt active filter. It can be seen that wave shapes are non-sinusoidal (the harmonic is affected in the source currents).

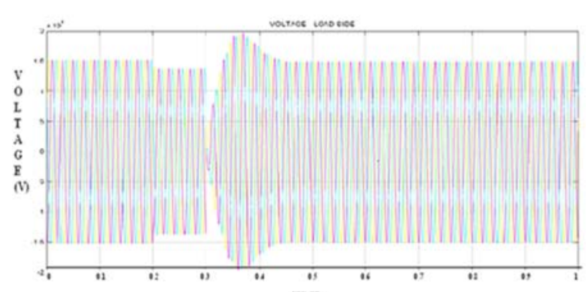

Figure-9. Wave form of DSTATCOM voltage parameter.

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Here the total simulation time is 1sec. Load-1 is always on entire range and at t=0.2s load- 2 is on and there is a voltage sag. At t=0.3s DSTATCOM compensates voltage due to sag and reaches source voltage, then breaker gets turned off.

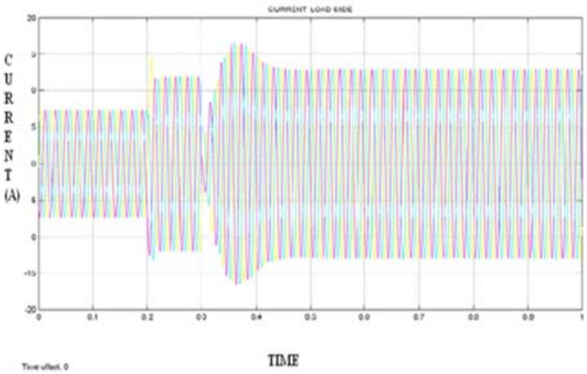

Figure-10. Wave form of DSTATCOM current parameter.

In Figure-10 total simulation time is 1sec.

Load-1 is always on entire range and at t=0.2s load-2 is on and there is a voltage sag and correspondingly load current increases. At t=0.3s DSTATCOM compensates voltage due to sag and reaches source voltage, then breaker gets turned off. The load current maintain with the source voltage.

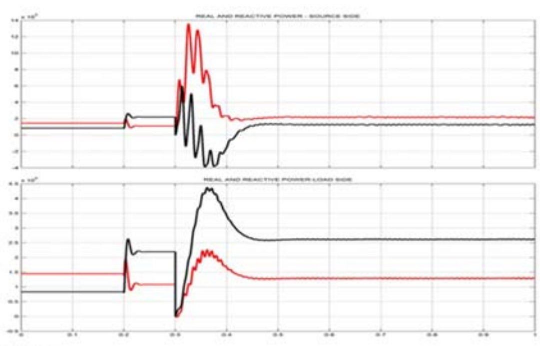

Figure-11. Real and reactive power source.

Figure-11 shows the real and reactive power source. It can be seen that wave shapes are almost nearly sinusoidal (the harmonic is suppressed in the source currents).

Here Load-1 always on for entire time range. When t=0.2 the high inductive load will be turned on. So the reactive power consumption will be high at t=0.2sec. So the real power consumption from source would be reduced.

At t=0.3 the DSTATCOM will enable and provide reactive power compensation. At t=0.3 reactive power consumption will be reduced from source side and real power consumption will be improved.

The three phase load voltage without any harmonic distortion is shown in a Figure-12. But the source current gets affected with non-linear load. Simulated results were show good dc bus voltage regulation, reduced source harmonic currents, and improved power factor and stable operation.

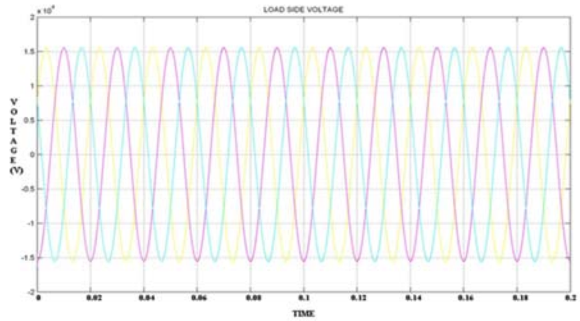

Figure-12. Wave form of DSTATCOM load voltage.

The source current with harmonic distortion due to non-linear load is shown in Figure-13. Simulation results show that the phase difference between voltage and current is cleared by shunt inverter operation. Actually, by operating UPQC, required reactive power is provided.

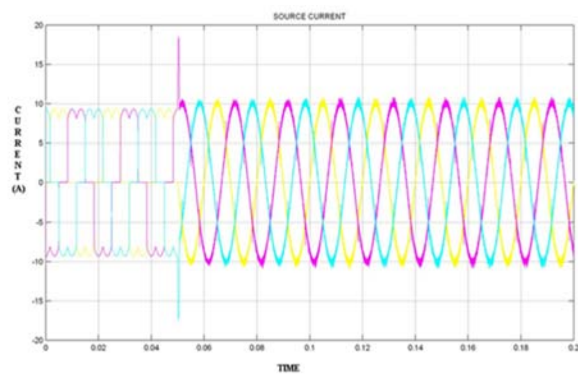

Figure-13. Wave form of DSTATCOM source current with harmonics.

At t=0-0.04s harmonics introduced in source current. This can be reduced by shunt active filter with reduced source harmonic currents, improved power factor and stable operation.

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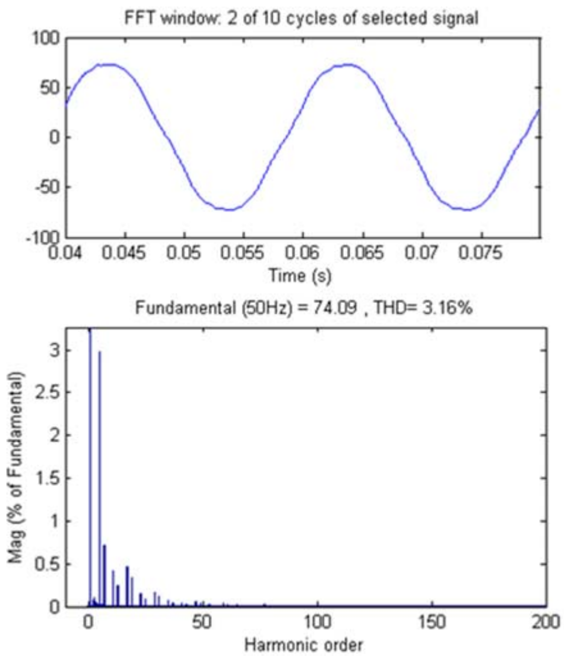

Figure-14. Harmonic spectrum of phase -A source current.

Figure-14 shows the harmonic spectrum of phase-A source current. It can be seen that the Total Harmonic Distortion of source current of phase-A is 3.16 %. In this case the investigation with a DSTATCOM for installation on a power distribution system with mainly focus on harmonic reduction and voltage regulation performance has been successfully demonstrated in Mat lab/Simulink.

Harmonics generated in the distribution system through nonlinear diode rectifier load, which is significantly reduced by Shunt Active Filter. Simulated results shows good dc bus voltage regulation, reduced source harmonic currents, and improved power factor and stable operation.

5. SIMULATION MODEL OF UPQC

A UPQC simulation models have been created in Matlab/Simulink is shown in Figure-15.

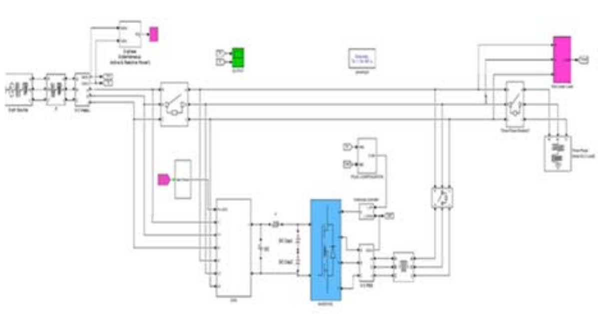

Figure-15. Simulation model of UPQC.

Simulation result of UPQC

Figure-16 shows Three-phase load voltages before and after compensation. The series APF starts compensating for the voltage harmonics immediately by injecting out of the phase harmonic voltage, making the load voltage distortion free. The voltage injected by the series and three-phase load voltage after compensation is shown. The THD of the distorted three-phase load voltages are 47.5%.

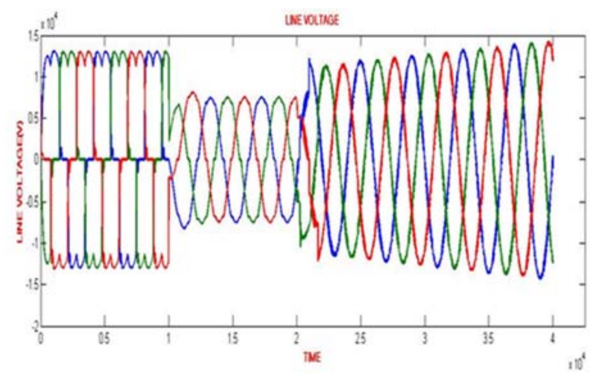

Figure-16. Line voltages before and after compensation.

Harmonic distortion is caused by nonlinear devices in the power system. A nonlinear device is one in which the current is not proportional to the applied voltage. While the applied voltage is perfectly sinusoidal, the resulting current is distorted. Increasing the voltage by a few percent may cause the current to double and take on a different wave shape. This is the source of most harmonic distortion in a power system.

The source current with harmonic distortion due to nonlinear load is shown in the Figure-17.

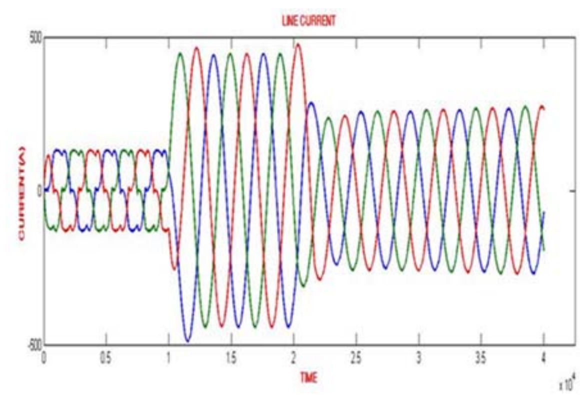

Figure-17. Line current before and after compensation.

UPQC used to compensate sag, harmonics and reactive power. Distortion produced in a line voltage and line current can be reduced with UPQC in which voltage and current injected in series and in parallel. Efficiency improved with the help of UPQC.THD=26.28% before compensation, THD=2.07% after compensation.

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CONCLUSIONS

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 equipments, abnormal operations of facilities and tremendous economic losses. UPQC consisting of two voltage source inverters with a common DC link is a custom power device and can simultaneously perform the tasks of APF and DVR. We have analyzed the operation of a UPQC that combines the operations of a DSTATCOM and DVR. The series component of the UPQC inserts voltage so as to maintain the voltage at the PCC balanced and free of distortion. Simultaneously, the shunt component of the UPQC injects current in the a.c. system such that the currents entering the bus to which the UPQC is connected are balanced sinusoids. Both these objectives must be met irrespective of unbalance or distortion in either source or load sides.

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