Research Inventy: International Journal Of Engineering And Science
Vol.3, Issue 8 (September 2013), PP 19-26
Issn(e): 2278-4721, Issn(p):2319-6483, Www.Researchinventy.Com

Unified Power Quality Conditioner (UPQC) With Storage Device for Power Quality Problems

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ABSTRACT: *The quality of the Electrical power is effected by many factors like harmonic contamination, due to non-linear loads, such as large thyristor power converters, rectifiers, voltage and current flickering due to arc in arc furnaces, sag and swell due to the switching of the loads etc. One of the many solutions is the use of a combined system of shunt and active series filters like unified power quality conditioner (UPQC) This device combines a shunt active filter together with a series active filter in a back to back configuration, to simultaneously compensate the supply voltage and the load current or to mitigate any type of voltage and current fluctuations and power factor correction in a power distribution network.In this paper a novel design of UPQS is proposed which is composed of the DC/DC converter and the storage device connected to the DC link of UPQS for balancing the voltage interruption. Computer simulation by MATLAB/ SIMULINK has been used to support the developed concept.*

KEY WORD: *Universal Power Quality Conditioning System (UPQS), voltage interruption, DC/DC converter, super-capacitor.*

I. INTRODUCTION

The power electronic devices due to their inherent non-linearitydraw harmonic and reactive power from the supply. In threephase systems, they could also cause unbalance and drawexcessive neutral currents. The injected harmonics, reactivepower burden, unbalance, and excessive neutral currents causelow system efficiency and poor power factor. In addition to this,the power system is subjected to various transients like voltagesags, swells, flickers etc.[1]-[2] These transients would affect thevoltage at distribution levels. Excessive reactive power of loadswould increase the generating capacity of generating stations andincrease the transmission losses in lines. Hence supply ofreactive power at the load ends becomes essential.[3-5].PowerQuality (PQ) mainly deals with issues like maintaining a fixedvoltage at the Point of Common Coupling (PCC) for variousdistribution voltage levels irrespective of voltage fluctuations,maintaining near unity power factor power drawn from thesupply, blocking of voltage and current unbalance from passingupwards from various distribution levels, reduction of voltageand current harmonics in the system.[6-7].

One of the most interesting structures of energy conditioner is two back-to-back connected dc/ac fullycontrolled converters. In this case, depending on the control scheme, the converters may have differentcompensation functions. For example, they can function as active series and shunt filters to compensatesimultaneously load current harmonics and supply voltage fluctuations. In this case, the equipment is calledUniversal Power Quality Conditioning System (UPQS) or Unified Power Quality Conditioner (UPQC) (Akagiet al., 2007), (Aredes and Watanabe, 1995), (Han et al, 2006).Custom Power devices is a better solution for these Power Quality related issues in distribution system. Out of these available power quality enhancement devices, the UPQC has better sag/swell compensation capability. Controlling methods has the most significant role in any power electronics based system. It is the control strategy which decides the efficiency of a particular system. The efficiency of a good UPQC system solely depends upon its various used controlling algorithm. The UPQC control strategy determines the current and voltage reference signals and thus, decides the switching times of inverter switches, so that the expected performance can be achieved.This paper proposes a new configuration of UPQC that consists of the DC/DC converter and the supercapacitorsfor compensating the voltage interruption. The operation of proposed system was verified throughsimulations with MATLAB\SIMULINK software.

II. POWER QUALITY PROBLEMS

Any problem manifested in voltage, current orfrequency deviation that results in failure of customerequipment is known as power quality problem.Low power quality affects electricity consumer inmany

ways. The lack of quality can cause loss ofproduction, damage to equipment and human health.Therefore it is obvious to maintain high standards ofpower quality.
The major types of power quality problems are,

- Voltage Sag
- Voltage swell
- Interruption
- Distortion and
- Harmonics.

A. Voltage Sags:

A sag is decrease in voltage between 0.1 and0.9 pu at the power frequency for duration from 0.5cycle to 1min. Voltage sags are usually associated withsystem faults but can also caused by energisation ofheavy loads at starting of large motors.

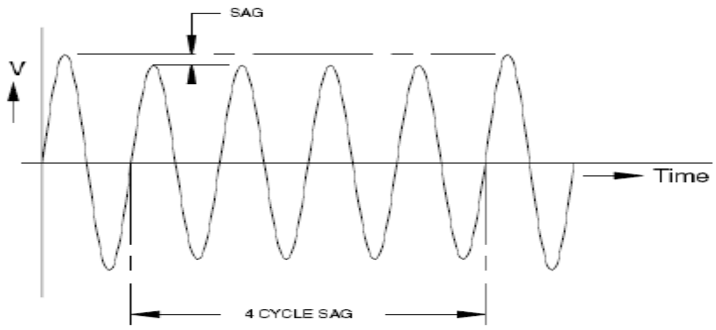


Figure 1 Voltage Sag

B. Voltage Swells:

A swell is increase in voltage between 1.1 and 1.8pu at power frequency for duration from 0.5cycle to 1min. Theseverity of voltage swell during a faultcondition is a function of fault location, systemimpedance and grounding.

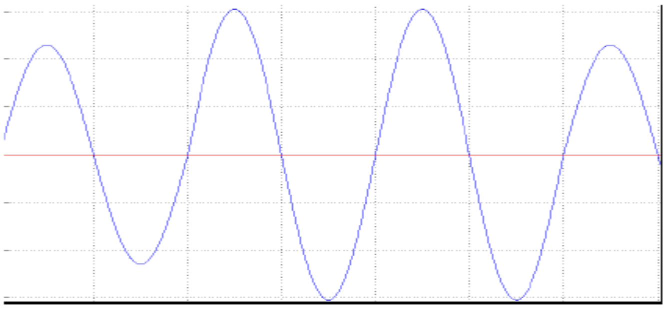


Figure 2 Voltage Swell

C. Interruption:

An Interruption occurs when the supply voltage orload current decreases to less than 0.1 pu for a period oftime that is not exceeding 1 min. Interruptions can bethe result of power system faults, equipment failuresand control malfunction. Instantaneous re-closinggenerally will limit the temporary fault to less than 30cycles.

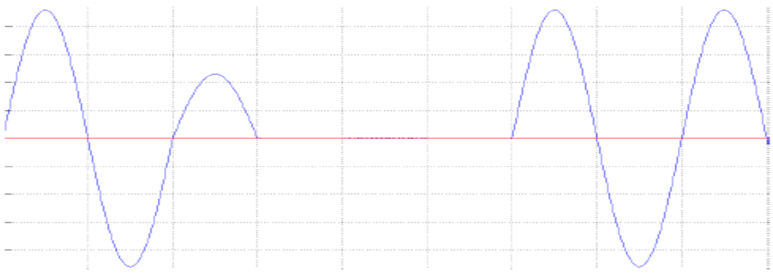


Figure 3 Interruption

D. Distortion:

It is defined as the steady state deviation froman ideal sine wave of power frequency principallycharacterized by the spectral content of the deviation.

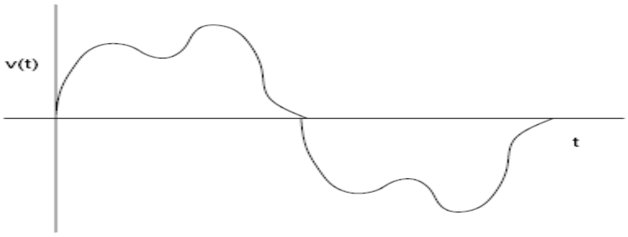


Figure 4 Distorted Waveform

E. Harmonics

Harmonics are sinusoidal voltages or currenthaving frequency that are integer multiples of thefundamental frequency.

III. BASIC CONFIGURATION OF UPQC

UPQC is the integration of series (APFse) and shunt (APFsh) active power filters,connected back-to-back on the dc ide, sharing a common DC capacitor [8],shown in Figure 5. The series component of the UPQC is responsible formitigation of the supply side disturbances: voltage sags/swells, flicker, voltageunbalance and harmonics. It inserts voltages so as to maintain the load voltages ata desired level; balanced and distortion free. The shunt component is responsiblefor mitigating the current quality problems caused by the consumer: poor powerfactor, load harmonic currents, load unbalance etc. It injects currents in the acsystem such that the source currents become balanced sinusoids and in phase withthe source voltages. The overall function of UPQC mainly depends on the seriesand shunt APF controller. A basic functional block diagram of a UPQC controlleris shown in Figure 4. Here, the shunt APF injects the compensating reactive andharmonic current using hysteresis current controller and where as the series APFuses PWM voltage controller to minimize the voltage disturbances.

Mainly 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; and 3) a minimum VA loading approach in which a series voltage is injected at a certain angle, which is known as VAmin. The VA loading in UPQC-VAmin is determined on the basis of voltage sag, may not be at optimal value. The voltage sag/swell on the system is one of the most important power quality problems in distribution. In the paper [9], 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.

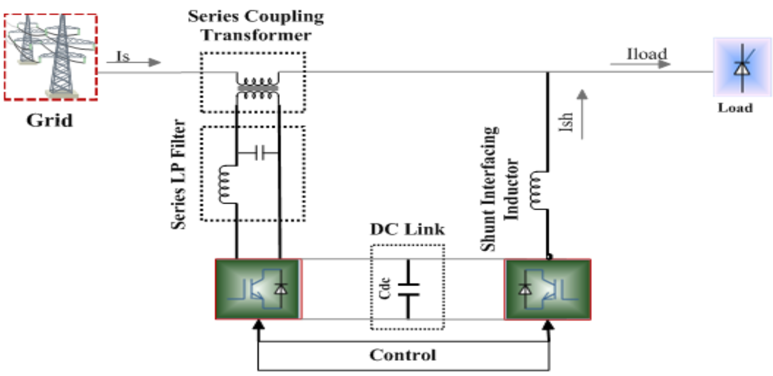


Figure 5 Basic System Configuration of UPQC

IV. PROPOSED CONFIGURATION OF UPQC

Figure 6 shows the configuration of proposed UPQC, which additionally has a DC/DC converter andsuper-capacitors for compensating the voltage interruption. The energy in the DC link charges the supercapacitorsthrough the bi-directional DC/DC converter when the system is in normal operation.The energy in the super-capacitors is released to the DC link through the bi-directional DC/DC converterwhen the voltage interruption occurs.

The control system has three major elements which are shunt inverter control, series inverter control, andDC/DC converter control.When the level of source voltage is maintained as 1.0 p.u., the system works in normal mode.When thelevel is between 0.5 and 1.0 p.u. or higher than 1.0 p.u., the system works in voltage sag or swell mode. Whenthe level is lower than 0.5 p.u., the system works in interruption mode.In normal mode, the series inverter injects the zero voltage and the shunt inverter absorbs the currentharmonics generated by the load. The DC/DC converter works in charge mode or standby mode depending onthe voltage level of the super-capacitors. In voltage sag or swell mode, the series inverter injects thecompensating voltage to maintain the load voltage constant. The shunt inverter absorbs the current harmonicsgenerated by the load and the DC/DC converter works in standby mode. In voltage interruption mode, the seriesinverter is disconnected from the line and the circuit breaker is opened to isolate the source side. The shuntinverter starts to work as an AC voltage source. The DC/DC converter works in discharge mode to supply theenergy stored in the super-capacitors to the load.

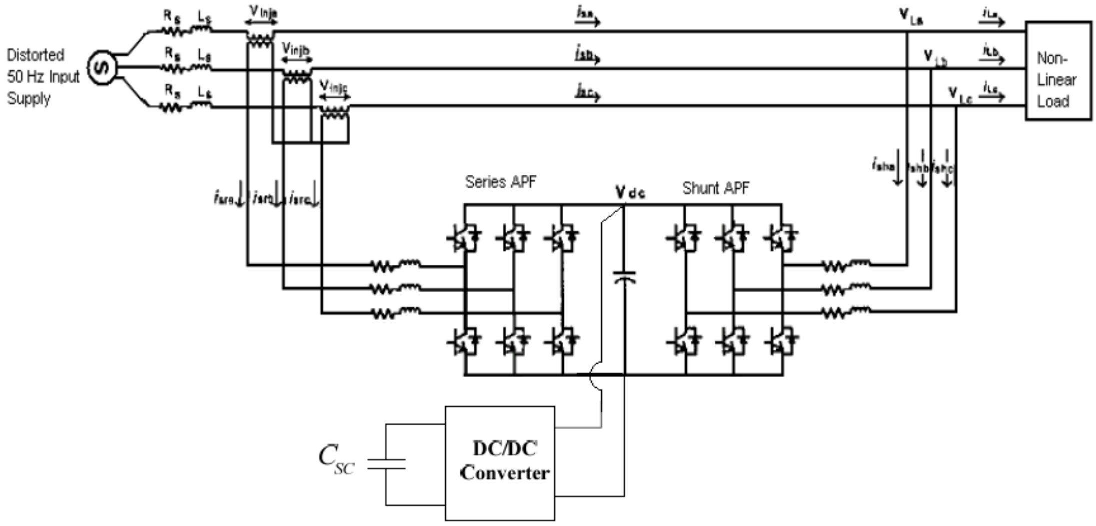


Figure 6 Configuration of proposed UPQC with energy storage

The control strategy for the series and shunt inverters of the proposed UPQC has been derived based onthe Synchronous reference frame method (Hu and Chen, 2000). The series inverter control compensates thevoltage disturbance in the source side due to the fault in the distribution line.

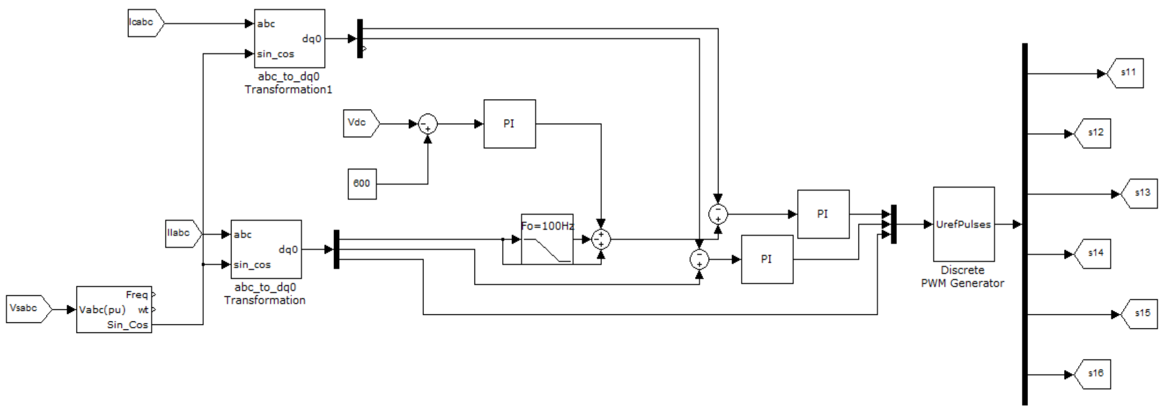


Figure 7 Control block diagram of the shunt converter of the UPQC

The series inverter control determines the reference voltage to be injected by the series inverter as shownin fig. 7, using the algorithm described in reference (Hu and Chen, 2000). The shunt inverter control has twofunctions to compensate the current harmonics and the reactive power in normal operation, and to supply theactive power to the load during the voltage interruption.The DC/DC converter control works in charge mode or discharge mode selectively, depending on thedirection from the system manager. In charge mode, the system manager monitors whether the voltage level ofthe super-capacitors exceeds the maximum operation voltage or not. If the voltage level reaches the maximumvalue, the DC/DC converter works in standby mode. In discharge mode, the system manager monitors whetherthe voltage level of the super-capacitors drops lower than the minimum operation voltage or not. If the voltagelevel reaches the minimum value, the DC/DC converter shuts down to stop supplying power to the load.

DC/DC Converter Design:

The operation voltage of the super-capacitor bank is in the range between 60-75V,while the dc link voltage is about 700V. The ground point in dc link should be isolated from the ground point inthe super-capacitor bank. The converter should have high current rating in bank side and high voltage rating inDC link side. Considering these requirements, a DC/DC converter with two full-bridges was selected as shown in Figure 8.

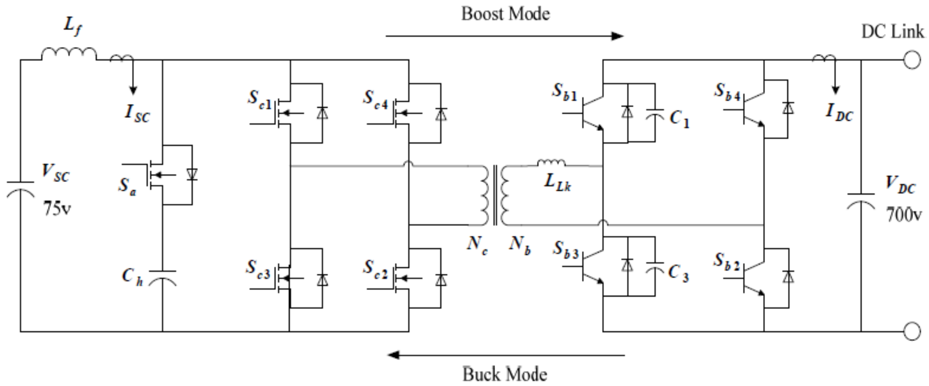


Figure 7 DC/DC converter structure

A filter reactor is inserted between the bank and the full-bridge to reduce the ripple of charging anddischarging current, which can reduce the lifetime of super-capacitors due to unwanted heat generation. Thefull-bridge in bank side works as a current-fed type, while the full-bridge in DC link side works as voltage-fedtype. The DC/DC converter boosts the super-capacitor voltage up to the nominal DC link voltage in dischargemode. The super-capacitor voltage is controlled between 60-75V, while the DC link voltage increases up to 700V. The switches SC1 and SC2 operate with a duty ratio of higher than 0.5. The current through the inductor *Lf*increases as all the switches are on conduction-state. The voltage overshoot can be suppressed by turning onauxiliary switch Sa when two switches in face with diagonal opposition are on conduction state. The currentthrough transformer rises linearly and its peak value becomes larger than the current through the boost inductor.When the auxiliary switch turns off, the magnetic energy stored in the leakage inductance of transformer flowsthrough the back-connection diode of the switch in off state. So, the zero-voltage turn-on condition is provided.The DC/DC converter decreases the nominal DC-link voltage down to the level of super-capacitor voltagein charge mode. When switch Sb1 and Sb2 turns on, the input voltage applied to the leakage inductance oftransformer *LLk*increases the input current. The power in the primary side is transferred to the secondary side.

The secondary voltage charges the capacitor *Ch* through the reverse-connected diode of auxiliary switch Sa. Ifthe charging voltage is high enough to make the charging current zero, switch Sb1 turns off. Switch Sb3 turns onwith zero-voltage scheme while the capacitor *C1* is charged and the capacitor *C3* is discharged. When auxiliarySa turns on, the voltage across the auxiliary capacitor affects the primary voltage of the coupling transformer.This voltage is applied to the leakage inductance *LLk*with reverse polarity. This makes the primary current zeroand switch Sb2 turns off with zero-current scheme.

Energy Storage Design:

The size of super-capacitors is determined depending on the duration of voltage interruption and the sizeof load connected. It is assumed that the maximum voltage interruption has duration of three seconds and theload has a power rating of 10kW. Therefore, total energy to be released during the voltage interruption is 30 kJ.The bank of super-capacitors is designed considering three criteria, the expandability of storage capacity,the unbalance of unit voltage, and the current rating of each unit. HP1700P-0027A manufactured by NessCompany was selected as a basic unit for the energy storage bank. Table 1 shows the specification of selectedsuper-capacitor unit. The bank is designed so as to utilize the upper 25% of maximum storage capacity, considering the expandability of operation capacity by adding more super-capacitors. The maximum current flows through the super-capacitor bank, when it discharges the maximum power. The minimum voltage across the super-capacitor bank can be determined with the maximum discharge power and the current rating as the following.

Table 1: Specification of super-capacitor unit.

Capacitance	1700 F
Continuous operation voltage	2.7V
Peak operation voltage	2.85V
Current rating	360A

$$U_{bank\_min} = 20kw/360A = 55.5\ V$$

It is assumed that the super-capacitor is charged by 2.43V, which is 90% to the maximum charging voltageof 2.7V, for consideration of 10% margin. The lowest discharged voltage is determined to be 2.1V using thefollowing.

$$U_{unit\_min} = \sqrt{\frac{3}{4}}\, U_{unit\_max} = 2.1V$$

Therefore, the lowest discharge voltage and the minimum unit voltage determine the number of units to beconnected in series as the following.

$$N = \frac{U_{bank\_min}}{U_{unit\_min}} = 55.1/2.1 = 26.5$$

However, the bank can be designed using total 28 units of super-capacitors for the purpose of safety margin.

V. SIMULINK RESULTS AND DISCUSSION

The proposed system has been tested in simulation, using the SimPowerSystemsBlockSet from MatLab,according to figure 6 and figure 8 represents the Simulink block diagram of proposed UPQC with energy storage system

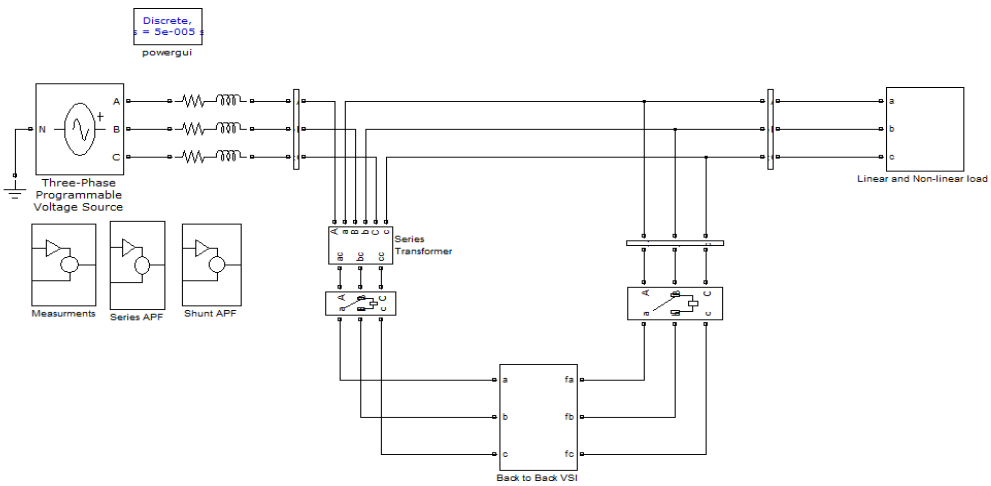


Figure 8 Simulink block diagram of proposed UPQC with energy storage system

The power circuit is modeled as a 3-phase 3-wire system with a non-linear load that is composed of 3-phase diode-bridge with RC load in the DC side.The dc voltage reference of theUPQC has been established at 400Vdc, the output filterof the voltage compensator consists of a low-pass filterwith L1=3 mH, R1=1.0 Ω and C1=230 µF while thecurrent link of the current compensator has been modeledby applying L2=10 mH and R2=0.8 Ω. The nominalpower of the voltage injection transformer is 12 kVAwith a primary and magnetization impedances ofLp=0.17mH, Rp=35mΩ, Lm=252mH and Rm=80Ω. Thesource voltage contains a 50Hz 325 V signal and a 5^{th}harmonic of 5%. A diode rectifier with a RC load(CL=1000µF, RL=300Ω) has been used as local load.In this section, voltage sag is applied and the results are studied. A voltage sag with peak amplitude of100v is applied from t=1sec to t=1.3sec. The source and load voltage are shown in fig. 10. It is seen in this figurethat the UPQC series inverter has modified load voltage correctly. The load current is shown in fig. 9

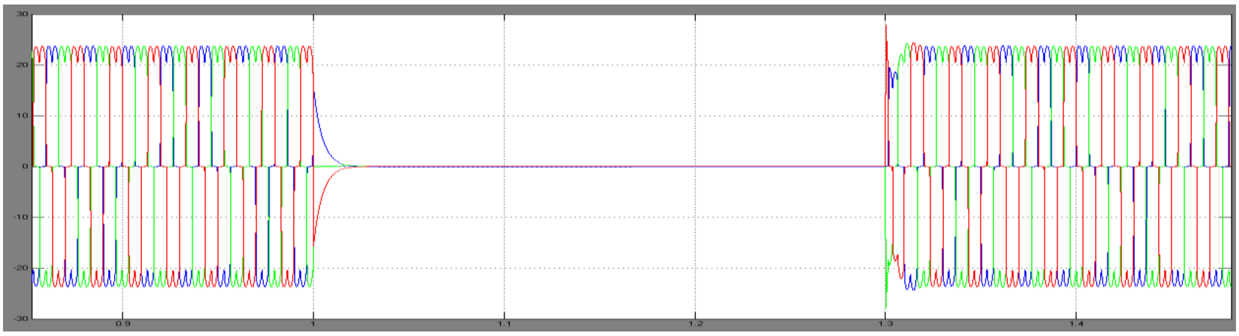
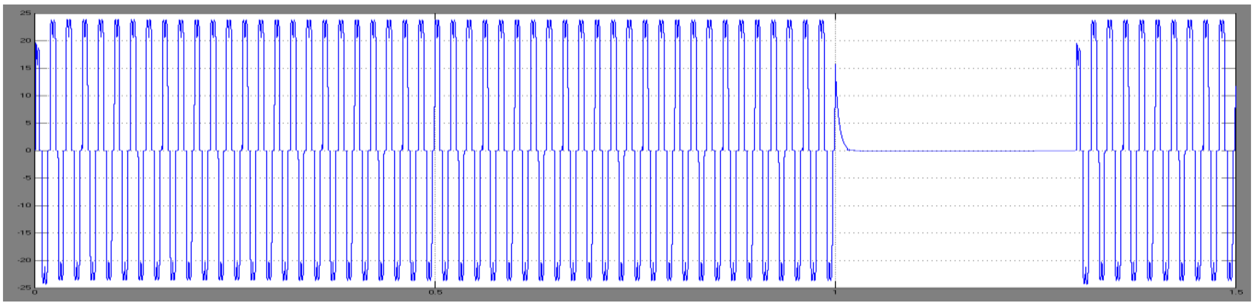
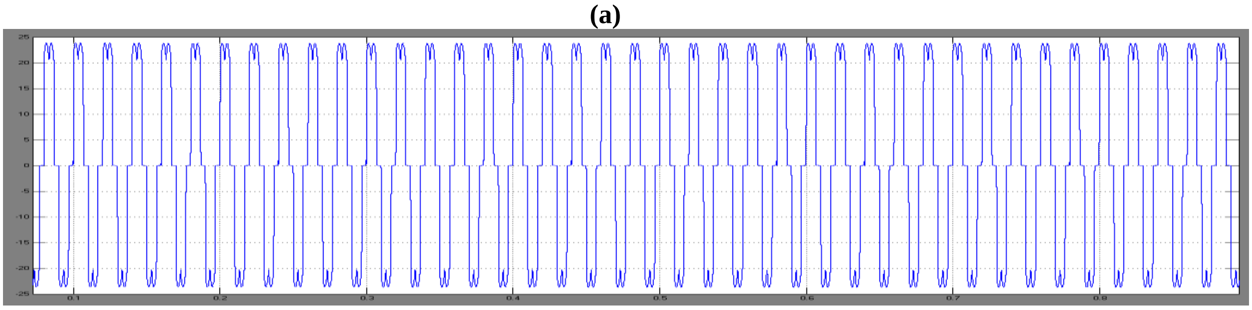


Figure 9 Nonlinear load current



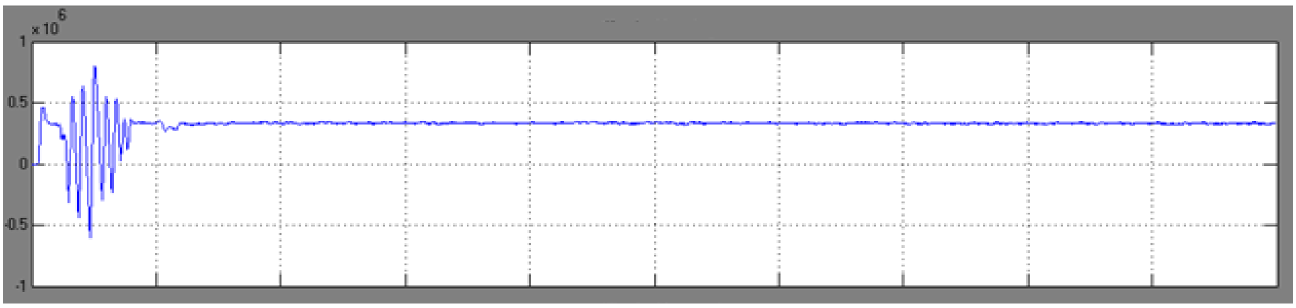
(a)



(b)

Figure 10.Voltage sag compensation. (a) Source voltage. (b) Load voltage.

In this section, voltage interruption occurs from t=1sec to t=1.3sec. Fig. 8 shows the source and loadvoltage and the output current supplied by the DC/DC converter respectively. It is seen that after voltageinterruption, load voltage is remained at its desired value due to shunt inverter operation.



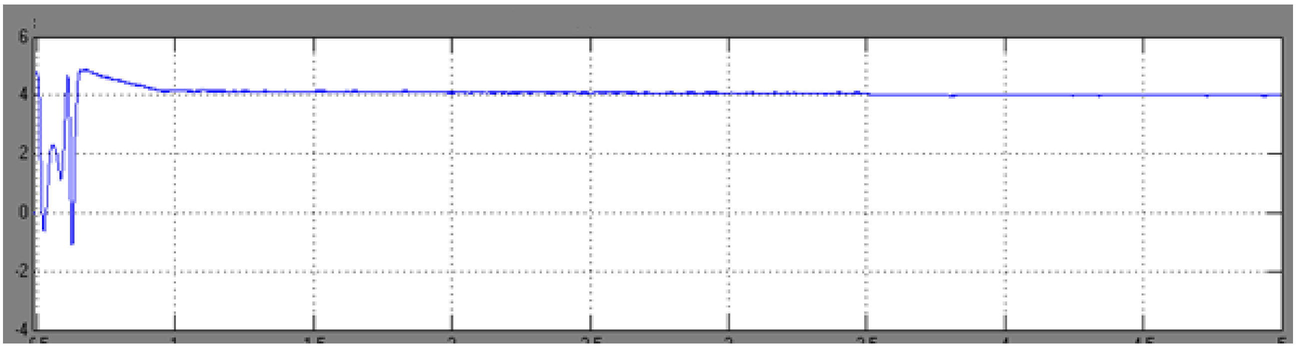


Figure 11 Active and reactive power consumed by load.

VI. CONCLUSION

In distribution system power Quality problem is a major issue. Out of the custom power devices UPQC is the most effective device for mitigating these issues. In this paper a new concept for the optimal utilization of UPQC is introduced. Using the UPQC device the voltage sag and swell can be mitigated successfully. The complex power (simultaneous active and reactive powers) controlling through series inverter of UPQC is proposed and named as UPQC-S. Here the controlling of series inverter of UPQC is done using theDC-DC link capacitor storage device. The operation ofproposed system was verified through simulations with MATLAB/SIMULINK software. The proposed UPQChas the ultimate capability of improving the power quality at the installation point in the distribution system.The proposed system can replace the UPS, which is effective for the long duration of voltage interruption,because the long duration of voltage interruption is very rare in the present power system.

REFERENCES:

[1] L.H.Tey,P.L.So and Y.C.Chu,Unified power QualityConditionar for improveing power Quality Using ANN withHysterisis Control, IEEE Tran. Power Electronics, vol. 9,no.3, May 1994, pp. 1441-1446.

[2] Hirofumi Akagi, Trends in Active Power Line Conditioners,IEEE Tran. Power Electronics, vol. 9, no.3, May 1994, pp.263-268.

[3] Janko Nastran, Rafael Cajhen, MatijaSeliger, and PeterJereb, Active Power Filter for Nonlinear AC Loads, IEEETrans. Power Electronics, vol.9, no.1, Jan. 1994, pp. 92-96.

[4] E. Destobbeleer and L.Protin, On the Detection of LoadActive Currents for Active Filter Control, IEEE Trans.Power Electronics, vol. 11, no.6, Nov. 1996, pp. 768-775.

[5] Mauricio Aredes, Jorgen Hafner, and Klemens Hermann,Three-Phase Four-Wire Shunt Active Filter ControlStrategies, IEEE Trans. Power Electronics, vol.12, no.2,Mar. 1997, pp. 311-318.

[6] Hideaki Fujita and Hirofumi Akagi, the Unified PowerQuality Conditioner: The Integration of Series- andShunt- Active Filters, IEEE Tran. Power Electronics,vol. 13, no.2, Mar. 1998, pp.315-322.

[7] Fang ZhengPeng, George W. Ott Jr., and Donald J.Adams,"Harmonic and Reactive Power Compensation Basedon the Generalized Instantaneous Reactive PowerTheory for Three-Phase Four-Wire Systems, IEEETrans,Power Electronics, vol.13, no.6, Nov. 1998,pp. 1174-1181.

[8] M Hosseinpour, A Yazdian, M Hohamadian, J Kazempour, "Desing andSimulation of UPQC to Improve Power Quality and Transfer Wind Energy toGrid", Jour of Applied Sciences, 2008, vol. 8(21), pp. 3770 – 3782.

[9]. I. Axente, J. N. Ganesh, M. Basu, M. F. Conlon, and K. Gaughan, "A 12-kVA DSP-controlled laboratory prototype UPQC capable of mitigating unbalance in source voltage and load current," *IEEE Trans. Power Electron.*, vol. 25, no. 6, pp. 1471–1479, Jun. 2010.

[10]. M. Yun, W. Lee, I. Suh, and D. Hyun, "A new control scheme of unified power quality compensator-Q with minimum power injection," in *Proc. IEEE Ind. Electron. Soc. (IECON)*, Nov. 2–6,, 2004, pp. 51–56.

[11]. Nabae and T. Tanaka, "A new definition of instantaneous active reactive current and power based on instantaneous space vectors on polar coordinates in three-phase circuits," presented at the IEEE/PES Winter Meeting, Paper 96 WM 227-9 PWRD, 1996.