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Research Article

Different Controllers of UPQC for Power Quality Evolution

P.Ramya[Á*] and J.Bhavani[Á]

[Á]Department of EEE, V R Siddhardha Engineering College, JNT University, Kakinada, A.P, India

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Abstract

This paper presents the Power system consists of electrical, electronical and power electronic equipment used in industries. .Hence they behave as a nonlinear load and inject harmonics in distribution system. one of the solution is the activepower filter. The combination of series and shunt activepowerfilter is UPQC .It not only eliminates harmonics ,and also alleviates any type of voltage and current fluctuations and compensates reactive power in distribution system. In these paper, the compensation code and different control plan (PI,FUZZY, ANN) are proposed and compared by using SIMULATION/MATLAB .The thyristor rectifier feeding an RL load acts as a source of harmonics. The performance is observed under utility disturbances such as sag , swell, flicker and spikes. Different control strategies are compared and the simulation results are listed.

Keywords: *Power quality, harmonics, voltagesag,voltageswell, pi controller,fuzzy,neural networks*

1. Introduction

In electric power supply system use of electronic controllers has become more common. These behave as a nonlinear load and and root severe distortion in distribution system and bring in unwanted harmonics in the supply system.LC passive filters may not solve the problem but Active filters can determine this problem .The APF acts as a power conditioning device such as load balancing ,harmonic filtering ,and reactive power control for power factor correction. The modern explore focuses on use of unified power quality conditioner to reimburse for power quality problems .voltage sag is the factor undergo huge loss in industries .Loads which are nonlinear in nature of fast acting switches and they influence the distribution utility in some tremendously objectionable ways . The solution is the custom power devices for power Quality related issues in distribution system to mitigate sag, swell, at the point of coupling. Out of these available power quality enhancement devices, the UPQC has better sag/swell compensation capability.

It consists of two back to back igbt voltage source bidirectional converters with a common dc link .source side inverter called series inverter is connected through a transformer and load side inverter called the shunt inverter with the nonlinear load. Shunt coupling inductor *L*Sh is used to border the shunt inverter to the network. It helps in smoothing the current wave shape. A dc link can be shaped by using a capacitor aninductor.The dc link is realized by means of a capacitor which interconnects the two inverters and also maintains a steady self-supporting dc bus voltage across it. *LC* filter serves as a passive low-pass filter (LPF) and to eradicate high-frequency switching ripples on generated inverter output voltage. Series injection transformer is used to unite the series inverter in the network. An appropriate turn ratio is often measured to condense the current or voltage rating of the series inverter. The fig is shown below

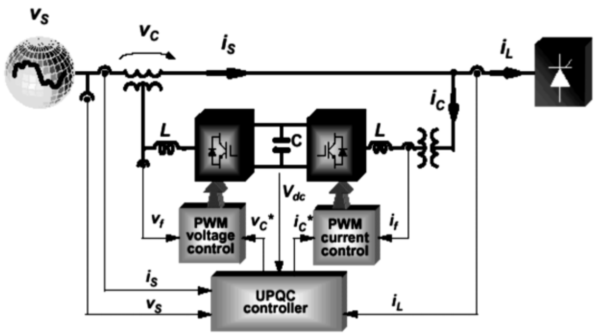


Fig. 1. General configuration of the Unified Power Quality Conditioner — UPQC.

Fig. 1 Block diagram of UPQC

2. Control strategy of UPQC

2.1 PI Control

A PI controller calculates an error value as the difference between a measured process variable and desired set point. The controller attempts to minimize the error by adjusting the process control inputs. Vdc is sensed and compared with its referencev_{dc}*. Error signal is processed in a PI controller. The output of the PI controller is denoted as

*Corresponding author **P.Ramya**is a M.Tech. Scholar and **J.Bhavani** is working as Asst. Prof

$i_{sp(n)}$. The output of controller has a limit ensures that the source provisions active power of the load and dc bus of the UPQC .A self supported dc link of the UPQC is supplied by the activepower. Thus, the dc voltage of the UPQC has a proper current.

2.2 Fuzzy Logic

The word Fuzzy means vagueness. Fuzzy set theory is for solving the uncertainty in the problem . It is an extension of set theory where elements have varying degrees of membership. It uses interval between 0 and 1 for human reasoning. **Fuzzy sets** are sets whose elements have degrees of membership. , fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership functions valued in the real unit interval [0, 1] The process of converting the crisp input to a fuzzy value is called as "fuzzificaton." The output of the Fuzzy is interfaced with the rules. The basic operation of FLC is constructed from fuzzy control rules utilizing the values of fuzzy sets in general for the error and the change of error and control action. The results are combined to give a crisp output controlling the output variable and this process is called as "DEFUZZIFICATION." The sign of the error signals and the output from linguistic codes given in the table

E1	**NVL**	**NL**	**NM**	**NS**	**Z**	**PS**	**PM**	**PL**	**PVL**
NVL	Z	NS	NM	NL	NVL	NVL	NVL	NVL	NVL
NL	PS	Z	NS	NM	NL	NL	NVL	NVL	NVL
NM	PM	PS	Z	NS	NM	NL	NL		NVL
NS	PL	PM	PS	Z	NS	NM	NL	NL	NVL
Z	PVL	PL	PM	PS	Z	NS	NM	NM	NL
PS	PVL	PL	PL	PM	PS	Z	NS	NM	NM

3. Artificial Neural Networks

The quick detection of the signal and fast response of signal are the requirements of desired compensation in upqc .The ANN based controllers give fast dynamic response maintaining stability of the converter .It is the interconnecting of artificial neurons. Neurons are used to store knowledge..ANN is a powerful technique which uses to solve many real world problems. ANNs are being used to explain AI problems without essentially creating a model of a real dynamic system. Artificial neural nets are a type of non-linear processing system that is ideally suited for a wide range of tasks, especially tasks where there is no existing algorithm for task completion. ANN can be trained to solve certain problems using a teaching method and sample data. In this way, identically constructed ANN can be used to perform different tasks depending on the training received. With proper training, ANN are capable of generalization, the ability to recognize similarities among different input patterns, especially patterns that have been corrupted by noise.

4. Generating compensating current

4.1 Shunt control

Isp is the output of three phase reference currents. The unit vectors are ($u_{sa} u_{sb} u_{sc}$) in phase with the three phase supply voltages. ($v_{sa} v_{sb} v_{sc}$) .The magnitude Isp with phases ($u_{sa} u_{sb} u_{sc}$)are multiplied results in reference supply current($i^*_{sa} i^*_{sb} i^*_{sc}$). Load currents($i_{la} i_{lb} i_{lc}$) are subtracted from reference currents($i^*_{sa} i^*_{sb} i^*_{sc}$)results in three phase reference supply currents($i^*_{sha} i^*_{shb} i^*_{shc}$)for shunt inverter .By comparing the reference currents with Iact and error signals are converted into switching signals by using pwm technique .The shunt inverter provisions the current for the load and also the reactive power. The inductor which is connected parallel to the load gives the reactive current to compensate harmonic current and also provides the reactive power to the load and improves power factor.

4.2 Series control

The load is isolated from the supply in series inverter voltagesource in between. The sag, swell and flicker are compensated by the voltage source. The voltage($v_{la} v_{lb} v_{lc}$)are subtracted from the three phase supply voltages($v_{sa} v_{sb} v_{sc}$)and compared with the reference supply voltage results in three phase reference voltages($v^*_{la} v^*_{lb} v^*_{lc}$.).The three phase reference currents are obtained from the reference voltages. The($i^*_{sea} i^*_{seb} i^*_{sec}$)reference currents are fed to thepwm currentcontroller, along with counterparts($i_{sea} i_{seb} i_{sec}$)so the series inverter meets the demand of sag ,swell and flicker. It give the sinusoidal voltage to supply .The consistency of supply voltage is improved at the load by injecting voltage with the supply when sag occurs .The energy of dc link is fatigued when sagoccurs.

5. Model equations of UPQC

The supply voltage from three phase values are

$$v_{sm} = [2/3(v_{sa}^2 + v_{sb}^2 + v_{sc}^2)]^{1/2}$$

Three phase unit vectors are

$$u_{sa} = v_{sa}/v_{sm}; u_{sb} = v_{sb}/v_{sm}; u_{sc} = v_{sc}/v_{sm}$$

Unit vectors are multiplied by amplitude Isp gives reference currents as

$$i^*_{sa} = i_{sp} u_{sa}; i^*_{sb} = i_{sp} u_{sb}; i^*_{sc} = i_{sp} u_{sc}$$

Load currents are subtracted from three phase reference Supply currents gives reference currents

$$i^*_{sha} = i^*_{sa} - i_{la}; i^*_{shb} = i^*_{sb} - i_{lb}; i^*_{shc} = i^*_{sc} - i_{la};$$

Iref and iact are compared to obtain signals for the inverter.

Equations of Series Inverter:

The injected voltage of supply voltage and load voltage is as follows:

$$vinj = vs - vl$$

Magnitude of injected voltage is

$$vinj = |vinj|$$

Injected voltage of the phase is

$$\delta inj = \tan(\mathrm{Re}[vpq]/\mathrm{Im}[vpq])$$

Following inequalities are followed or reducing harmonics:

$vinj \langle vinj \max$ magnitude ;
$O \langle \delta inj \langle 360^{\circ}$ phase control;

The injected voltages of three phase reference are

$$v_{la}^{*} = \sqrt{2}\, vinj \sin(wt + \delta inj)$$
$$v_{lb}^{*} = \sqrt{2}\, vinj \sin(wt + 2\pi/3 + \delta inj)$$
$$v_{lc}^{*} = \sqrt{2}\, vinj \sin(wt - 2\pi/3 + \delta_{inj})$$

Series inverter of the here phase reference currents iref as

$$i_{sea}^{*} = v_{la}^{*}/zse;$$
$$i_{seb}^{*} = v_{lb}^{*}/zse;$$
$$i_{sec}^{*} = v_{lc}^{*}/zse;s$$

The iref and iact are compared to obtain signals for series inverter.

Case Study:

A three phase supply of 230v ,60hz is considered feeding a thyristorrectfiierRl load with rating of 2KVA.Rs and Rl values are 0.1ohm and 0.1mh.

Shunt values

Rsh=1ohm,Lsh=30Mh Csh=700

Series values:

Rsh=0.1ohm, Lse=12Mh

Passive filter values:

Rpsh=3ohm Lpsh=15Mh

Basic Circuit of UPQC Using PI Controller

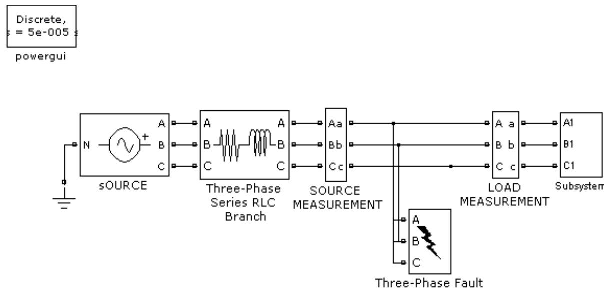


Fig.2 Transmission line without UPQC

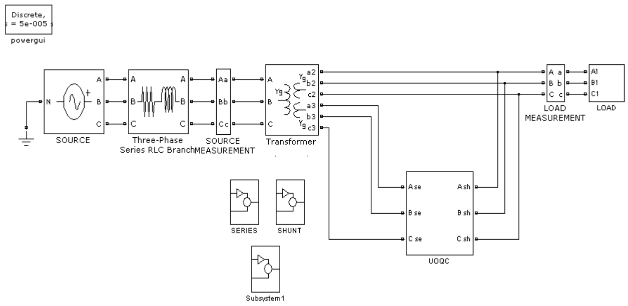


Fig. 3 Transmission line using UPQC

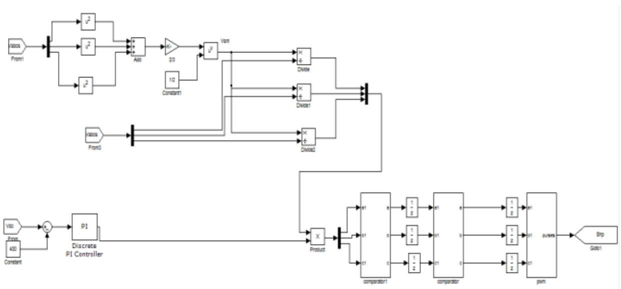


Fig.4 UPQC with PI Controller

Load current compensation:

Case 1: Ideal three phase sinusoidal supply voltage of 230v,60hz is applied to the nonlinear load injecting harmonics in the system supply voltage without upqc is shown in 1(a). The load current 1(b) in THD is establish to be27% before compensation condensed to 10.53% in 1(c).The shunt current1(d) hold harmonics of load but with opposite polarity, such that the harmonic content of supply current is reduced. At the reference voltage capacitor is charged, the charging current is drawn by VDC from supply 1(e) using pi controller it is charged to a required value and held constant .load current harmonics are compensated by the shunt inverter .the dc side after compensation of the load current is shown in fig1(f).

Case2:A voltage sag and voltage swell of 20%is applied to nonlinear load. The immediate existence of flicker 10% and spike of 15% are forced to study the sensible condition of one or more of them . To reimburse the dip and swell upqc used to organize detects and calculates the necessary value by injected in series .The swell and sag of 40%in fig 2(a) is compensated by the supply voltage supplied by the load. In fig 2(b) Dc link voltage more or less reflects in the supply voltage. After compensation of Vdc the voltage tries to come back to the reference voltage. In case of sag compensation the supply voltage in fig 2(c) is 180 out of phase shows the series compensating current required to generate compensating voltage, in case of swell it is in phase with supply voltage. The dc side acts as a nonlinearload on the load before compensation is current.

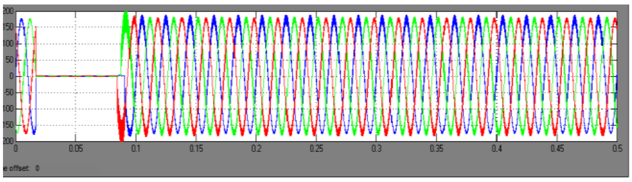


Fig1(a)Supply voltage without UPQC

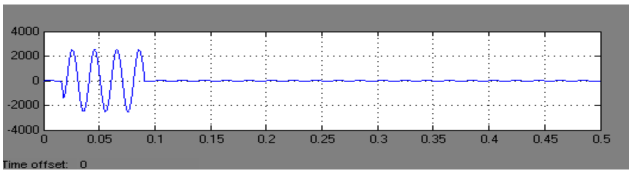


Fig1(b)Line current without UPQC

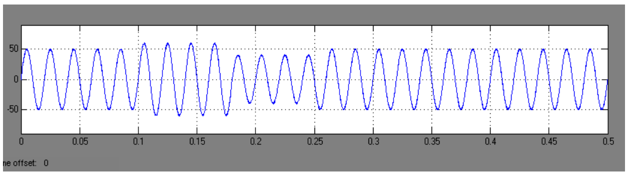


Fig1(C) Line current with UPQC(using PI)

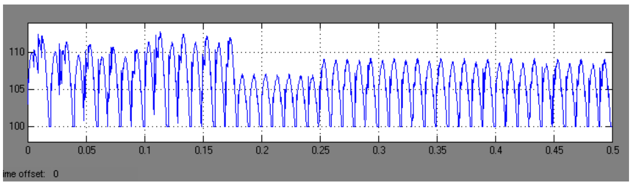


Fig1(d)Compensating current by Shunt Inverter

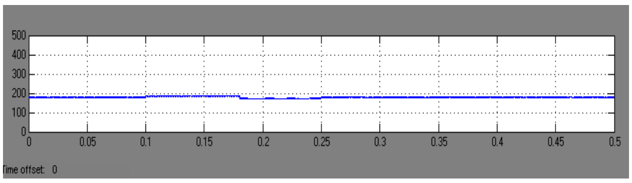


Fig 1(e)VDC Shunt maintained by Inverter

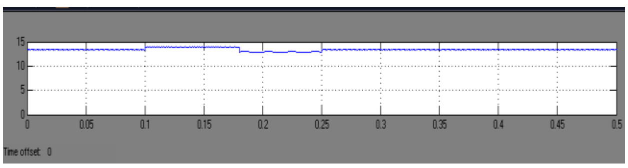


Fig1(f) UPQC using Load Current

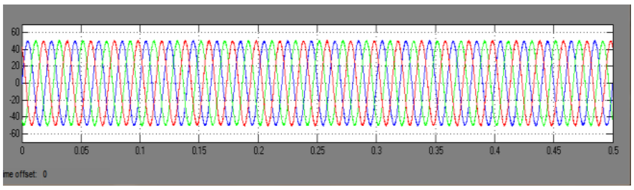


Fig 2(a) Supply voltage using PI Controller

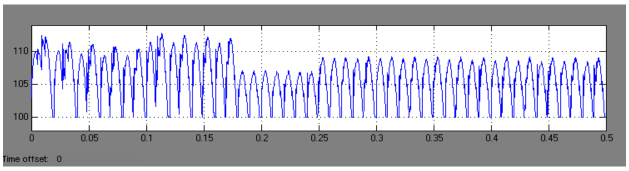


Fig 2(b)Load terminals with UPQC

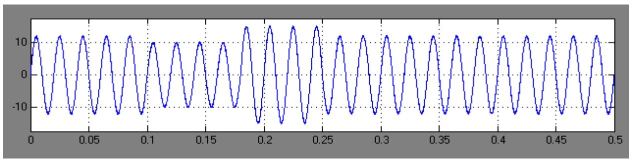


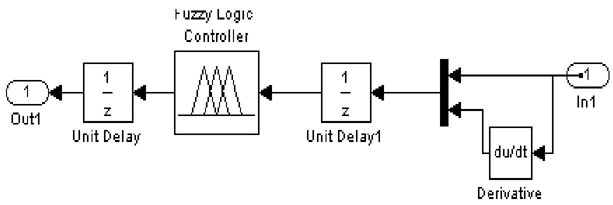
Fig 2(c)Series inverter compensating Current

UPQC using Fuzzycontroller

Load Current Harmonics

Case 1:
Ideal three phase sinusoidal supply voltage of 230v,60hz is applied to the nonlinear load injecting harmonics in the system. The load current 3(a) in THD is establish to be27% before compensation condensed to 10.84% in 3(b).The shunt current1(d) hold harmonics of loadcurrent but with opposite polarity , such that the harmonic content of supply current is reduced. At the reference voltage capacitor is charged, the charging current is drawn by vdc from supply3(c). Using fuzzy controller it is charged to a required value and held constant .load current harmonics are compensated by the shunt inverter .the dc side of the inverter before compensation is fig.13(d) and after compensation of the load current is shown in fig3(e) .

Case 2: A voltage sag and voltage swell of 20%is applied to nonlinear load. the immediate existence of flicker 10% and spike of 15% are forced to study the sensible condition of one or more of them . To reimburse the dip and swell upqc used to organize detects and calculates the necessary value by injected in series. The swell and sag of 40%in fig 4(a) is compensated by the supply voltage supplied by the load. In fig 4(b) Dc link voltage more or less reflects in the supply voltage. After compensation of Vdc the voltage tries to come back to the reference voltage. In case of sag compensation the supply voltage in fig 4(c) is180 out of phase shows the series compensating current required to generate compensating voltage in case of swell it is in phase with supply voltage. The dc side acts as a nonlinear load on the load before compensation is current.



Fig(5) Fuzzy Controller using UPQC

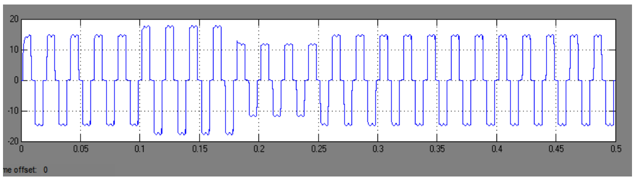


Fig3(a)Line Current without UPQC

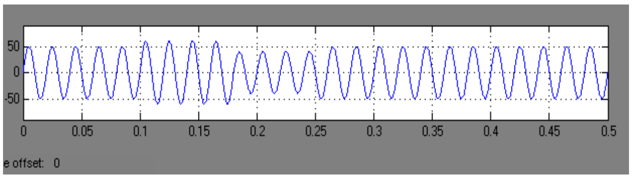


Fig3(b)Line Current with UPQC (Using Fuzzy)

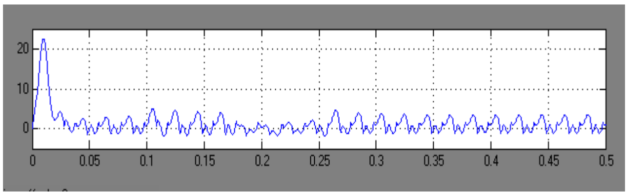


Fig3 (c)Compensating Current by Shunt Inverter

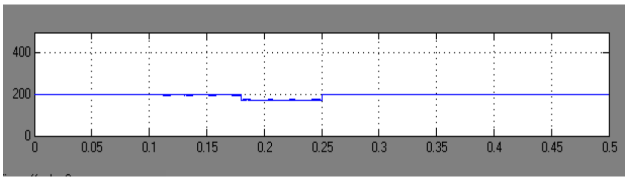


Fig 3(d)Shunt Inverter maintained by Vdc

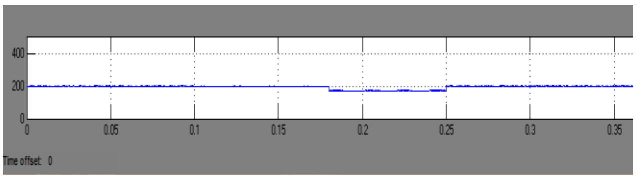


Fig 3(e) Load Current after Compensation

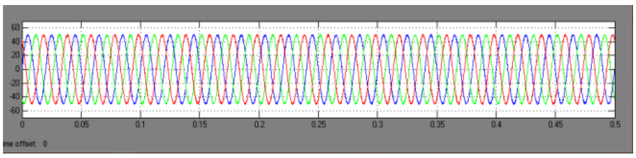


Fig4(a)SupplyVoltage with UPQC(USING FUZZY)

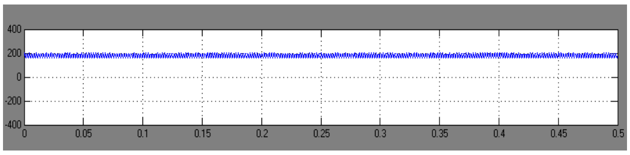


Fig4(b)Load VoltageTerminals with UPQC

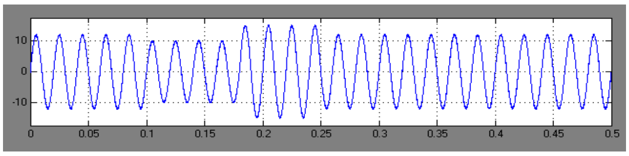
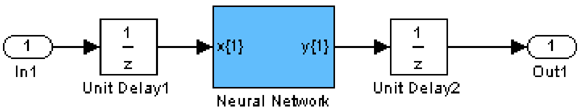


Fig4 (c)Series Inverter by Compensating Current

UPQC using Artificial Neural Networks

Case 1:
Ideal three phase sinusoidal supply voltage of 230v ,60hz is applied to the nonlinear load injecting harmonics in the system. The load current in THD is establish to be27% before compensation condensed to 9.04% in 5(a).The shunt current5(b) hold harmonics of load current but with opposite polarity, such that the harmonic content of supply current is reduced. At the referencevoltage capacitor is charged5(c), the charging current is drawn by Vdc from supply5(c). Using fuzzy controller it is charged to a required value and held constant .load current harmonics are compensated by the shunt inverter .The dc side of the inverter compensation in fig.15(d) After compensation of the load current is shown fig3(d))
Case2:A voltage sag and voltage swell of 20%is applied to nonlinear load. The immediate existence of flicker 10% and spike of 15% are forced to study the sensible condition of one ormore of them . To reimburse the dip and swell upqc used to organize detects and calculates the necessary value by injected in series. The swell and sag of 40%in fig 6(a) is compensated by the supply voltage supplied by the load. In fig 6(b) Dc link voltagemore or less reflects in the supply voltage. After compensation of vdc the voltage tries to come back to the reference voltage. In In case of sag compensation the supply voltage in fig 6(c) is180 out of phase shows the series compensating currentrequired to generate compensating voltage ,in case of swell it is in phase with supply voltage. Line to line compensating voltage of series Inverter in fig 6(d).



Fig(6) Neural Network using UPQC

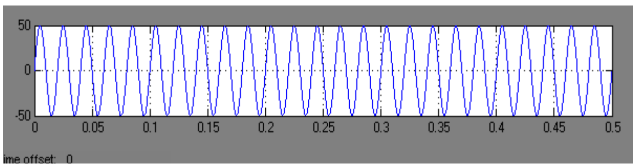


Fig5(a)Line Current with UPQC(Using ANN)

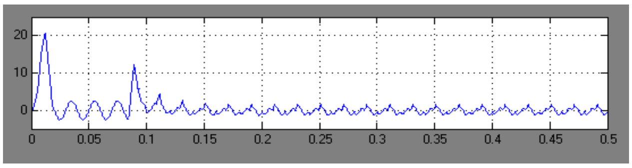


Fig5(b)Compensating Current by Shunt Inverter

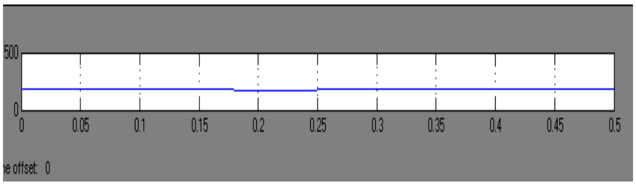


Fig5 (c)Shunt Inverter maintained by VDC

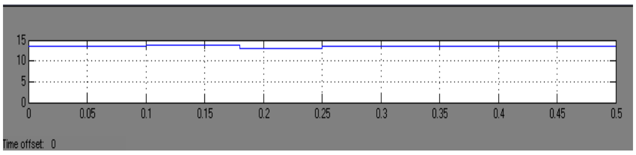


Fig 5(d)Load Current After Compensation

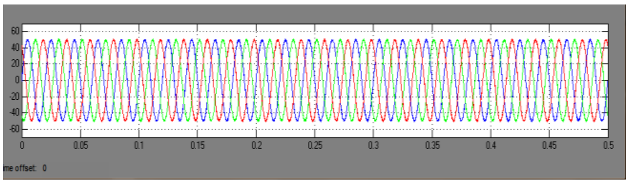


Fig6(a)Supply Voltage using ANN

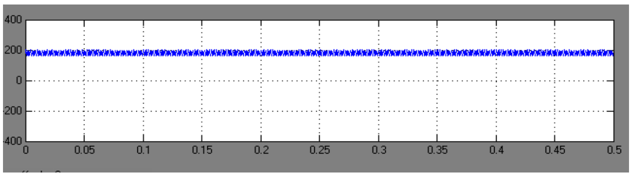


Fig6(b)Load Voltage terminals with UPQC

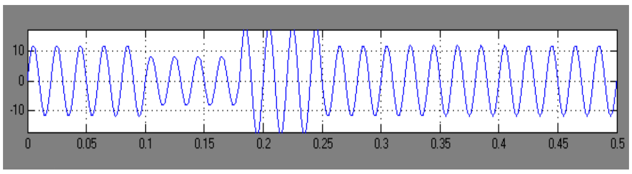


Fig 6 (c)Series Inverter by Compensating current

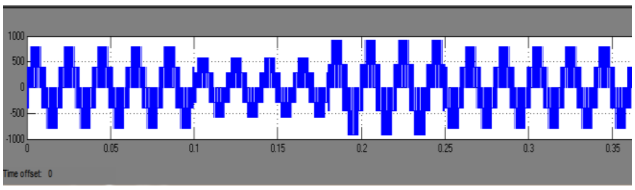


Fig 6(d)Line to Line Compensating current

Comparison of three different Controllers of UPQC

	FACTOR	PI	FUZZY	ANN
1.	Utility side THD	6.78%	3.69%	0.00%
2.	Line current THD with UPQC	10.30%	10.17%	6.79%
3.	Charging of DC link	Slower	Faster	Faster
4.	Time taken for capacitor reach overshoot	0.04s	0.0195s	0.0145s
5.	Sag,swell,flickerin supply voltage	Eliminated	Eliminate d	Eliminated
6.	Powerfactor	0.85	0.9	1

Conclusion

A simple control technique based on unit vector templates, generation is proposed for UPQC. Proposed model has been simulated in MATLAB. The result after simulation compensates the input voltage harmonics and current harmonics caused by non-linear load effectively by the control strategy. The closed loop control schemes of direct current control, for the proposed UPQC have been described. A suitable model of the UPQC has been developed with different shunt controllers (PI FUZZY and ANN) and simulated results are compared. The load current in these cases is found to be content of all odd harmonic minus triplen ,providing a total harmonic distortion (THD) of 27.82%. It is observed from the figure. After compensating the THD is reduced to 6.79% in ANN. Thus by seeing the result obtained through the simulation of UPQC with the controllers PI ,FUZZY and ANN it can be conclude that for the ANN same load the THD obtained is less as compared to the FUZZY and PI controller. Hence the ANN controller is better option than the fuzzy and pi Controller.

References

Hirofumi Akagi. 1996. New trends in active filters for power conditioning. *IEEE Transactions on Industrial Applications*. Vol. 32(6)

Math H.J. Bollen. Understanding power quality problems- Voltage sags and interruptions. *IEEE Press series on power engineering.*

Luis F.C. Monteiro, Mauricio Aredes, Joao A. Moor Neto. 2003. A control strategy for unified power quality conditioner. *IEEE Transactions.*

A. Jayalaxmi, G.Tulasi Ram Das, K.UmaRao. 2004. Design and compensation strategies for unified power quality conditioner. *International Conference on Control, Automation and Communication Systems*, held at Kalinga Institute of Industrial Technology (KIIT), Bhubaneshwar. 22-24 December.

B.N. Singh, Ambrish Chandra, Kamal Al-Haddad and Bhim Singh.Fuzzy Control Algorithm for Universal Active Filter.

Dixon J., Contardo J. and Moran. 1997. DC link fuzzy control design for an active filter, sensing the line current only. *IEEE- PESC*. pp. 1109-1114.

Hwang G.C. and Lin S.C. 1992.A stability approach to fuzzy control design for non-linear systems. *Fuzzy Set and System*. Vol. 48. pp. 279-286.

Ayse Ergun Amac, MeralAltinay and Faruk Aras. 2003. Three kinds of single phase active filters for suppressing harmonics. *IJCI Proceeding of International Conference on Signal Processing*. Vol . 1(2),September.

MalabikaBasu, S.P.Das and GopalK.Dubey. 2001. Requirement of UPQC and its rating issues for non-linear and voltage sensitive loads. *International Conference on Power Quality- Assesment of Impact.* New Delhi. 6-7 November.

Hideaki Fujita and Hirofumi Akagi. 1998. The unified power quality conditioner: The integration of series and shunt active fFilters. *IEEE Transaction on Power Electronics.Vol .13(2).*

Ambra Sannino and Jan Svensson. Static series compensator for voltage sag mitigation supplying non-linear loads.