International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.1, Jan-Feb 2012 pp-359-365 ISSN: 2249-6645

NEURAL NETWORK BASED UNIFIED POWER QUALITY CONDITIONER

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ABSTRACT

The application of artificial intelligence is growing fast in the area of power sectors. The artificial neural network (ANN) is considered as a new tool to design control circuitry for power-quality (PQ) devices. In this paper, the ANN-based controller is designed and trained offline using data from the conventional proportional-integral controller. The performances of ANN and PI controller are studied and compared for Unified Power Quality Conditioner using MATLAB Simulations.

Key Words: **Artificial intelligence (AI), Artificial neural network (ANN), Current Source Inverter (CSI), proportional integral (PI), unified power-quality conditioner (UPQC), Voltage Source Inverter (VSI)**

I.INTRODUCTION

The use of electronic controllers in the electric power-supply system has become very common. These electronic controllers behave as nonlinear load and cause serious distortion in the distribution system and introduce unwanted harmonics in the supply system, leading to decreased efficiency of the power system network and equipment connected in the network [1]. To meet the requirements of harmonic regulation, passive and active power filters are being used in combination with the conventional converters [2]. Presently, active power filters (APFs) are becoming more affordable due to cost reductions in power semiconductor devices, their auxiliary parts, and integrated digital control circuits. In addition, the APF also acts as a power-conditioning device which provides a cluster of multiple functions, such as harmonic filtering, damping, isolation and termination, load balancing, reactive-power control for power-factor correction and voltage regulation, voltage-flicker reduction, and/or their combinations. Resent research focuses on use of the universal power quality conditioner (UPQC) to compensate for power-quality problems [3], [4]. The performance of UPQC mainly depends upon how accurately and quickly reference signals are derived. After efficient extraction of the distorted signal, a suitable dc-link current regulator is used to derive the actual reference signals. Various controlling devices like PI, PID, fuzzy logic, and sliding-mode are in use. The basic disadvantage of PI and PID controllers are these need precise linear mathematical models. These fail to operate when non linear conditions are applied. In the recent years Artificial-intelligence (AI) techniques, particularly the NNs, are having a significant impact on power-electronics applications. Neural-network-based controllers provide fast dynamic response while maintaining the stability of the converter system over a wide operating range and are considered as a new tool to design control circuits for PQ devices [5]–[8]. A lot of research works are going on UPQC combined with neural network. In this paper design of ANN based controller is designed for current control and voltage control of shunt active filter instead of PI controller. Two cases are considered where current source inverters and voltage source inverters are taken ANN controller and PI controller performances at the DC link are compared using MATLAB/SIMULINK.

II.UNIFIED POWER QUALITY CONDITIONER

A conventional UPQC topology consists of the integration of two active power filters are connected back to back to a common dc-link bus [9]. A simple block diagram of a typical UPQC is shown in Fig. 1.

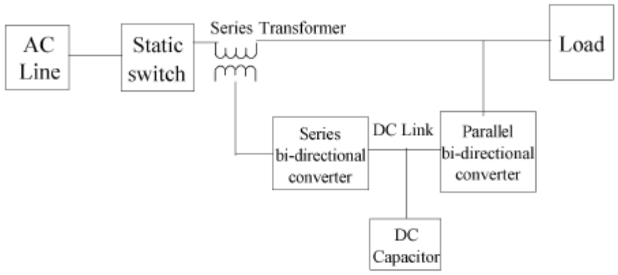


Fig 1: Block diagram of UPQC

UPQC with current source inverters and voltage source inverters are shown in fig 2 and fig 3 respectively

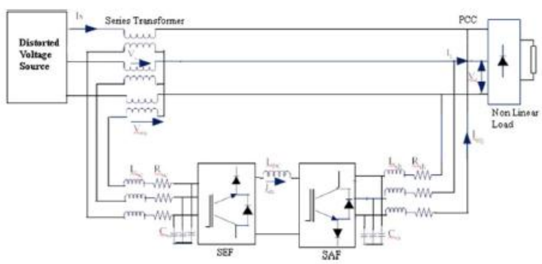


Fig 2: UPQC topology with current source inverters

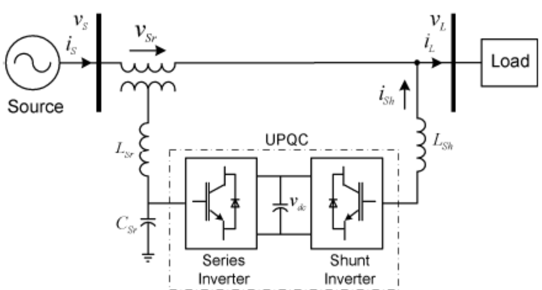


Fig 3: UPQC topology with voltage source inverters

It can be configured either with voltage-source converters or current source converters in single phase, three-phase three wire, or three-phase four-wire configurations. The UPQC with the voltage-source converter (VSC) is most common because of its smaller size and low cost. The current source inverters are used because of their excellent current control capability, easy protection, and high reliability. The performance of the UPQC mainly depends on how accurately and quickly the reference signals are derived [11]. The DC link will derive the reference signals. The difference between actual and reference signals are given to controller whether it may be PI or any other controller. The output of controller is given to the generation of pulses.

III.DESIGN OF THE PI CONTROLLER

The design of PI controller for current source inverter is done by the following assumptions

1) The voltage at PCC is sinusoidal and balanced.

2) Since the harmonic component does not affect the average power balance expressions, only the fundamental component of currents is considered.

3) Losses of the system are lumped and represented by an equivalent resistance connected in series with the filter inductor.

4) Ripples in the dc-link current are neglected.

The average rate at which energy being absorbed by the inductor is

$$Pind = \frac{d}{dt}\left(\frac{1}{2}\,LdcIdc^2\right) = LdcIdc\,\frac{dIdc}{dt} \qquad (1)$$

The power input to the PWM converter

$$Pconv = 3VshIinj \qquad (2)$$

The average rate of change of energy associated with the capacitor filter

$$Pcap = \frac{d}{dt}\left(\frac{1}{2}CshVsh^2\right) \qquad (3)$$

Power loss in the resistor Rsh

$$Ploss = 3Iinj^2Rsh \qquad (4)$$

Equating them

$$Pind = Pconv - Ploss - Pcap \qquad (5)$$

Substituting the values

$$LdcIdc\,\frac{dIdc}{dt} = 3\left(VshIinj - Iinj^2Rsh - CshVsh\,\frac{dVsh}{dt}\right) \qquad (6)$$

In order to linearize the power equation, a small perturbation ΔIinj is applied in the input current Iinj of converter about a steady-state operating point Iinjo, the average dc-link current will also get perturbed by a small amount ΔIdc around its steady-state operating point Idco

$Iinj = Iinjo + \Delta Iinj$ and $Idc = Idco + \Delta Idc$

In (6) neglecting higher order terms

$$LdcIdco\frac{d\Delta Idc}{dt} = 3(VshIinjo + Vsh\Delta Iinj - Iinjo^2Rsh - 2Iinj\Delta IinjoRsh - CshVsh\frac{dVsh}{dt}) \quad (7)$$

Subtracting (7) from (6)

$$LdcIdc\frac{d\Delta Idc}{dt} = 3(Vsh\Delta Iinj - 2Iinj\Delta IinjoRsh - CshVsh\frac{dVsh}{dt}) \quad (8)$$

The transfer function of the PWM converter for a particular operating point

$$Kc = \frac{\Delta Idc}{\Delta Iinj} = 3(\frac{Vsh - CshVshS - 2IinjoRsh}{LdcIdcoS}) \quad (9)$$

The characteristic equation of Pi controller is

$$1 + \left(Kp + \frac{Ki}{S}\right)3\left(\frac{Vsh - CshVshS - 2IinjoRsh}{LdcIdcoS}\right) = 0$$

Some of the parameters are taken from [11] as

Vsh=230V, Iinjo=5 amp, Rsh=0.4Ω, Csh=24μF, Ldc=160mH, Idco=5 amp

Hence the characteristic equation on substitution of the values is

$$0.8S^2 + kp(678 - 0.0165S^2) + Ki(678 - 0.0165S) \quad (10)$$

Using Routh Harwitz criteria the values of Kp=0.5 and Ki=10 are chosen for the PI controller that is used in UPQC.

IV.DESIGN OF ANN CONTROLLER

The rapid detection of the disturbance signal with high accuracy, fast processing of the reference signal, and high dynamic response of the controller are the prime requirements for desired compensation in case of UPQC. The conventional controller fails to perform satisfactorily under parameter variations nonlinearity load disturbance, etc. A recent study shows that NN-based controllers provide fast dynamic response while maintaining stability of the converter system over wide operating range.

The ANN is made up of interconnecting artificial neurons. It is essentially a cluster of suitably interconnected nonlinear elements of very simple form that possess the ability to learn and adapt. It resembles the brain in two aspects: 1) the knowledge is acquired by the network through the learning process and 2) interneuron connection strengths are used to store the knowledge [10]-[11]. These networks are characterized by their topology, the way in which they communicate with their environment, the manner in which they are trained, and their ability to process information. ANNs are being used to solve AI problems without necessarily creating a model of a real dynamic system. For improving the performance of a UPQC, a multilayer feed forward-type ANN-based controller is designed. This network is designed with three layers, the input layer with 2, the hidden layer with 21, and the output layer with 1 neuron, respectively.

The training algorithm used is Levenberg–Marquardt back propagation (LMBP). The MATLAB programming of ANN training is given as follows:

```
net=newff(minmax(P),[2,21,1],{'tansig','tansig','purelin'},'trainlm');
net.trainParam.show=50;
net.trainParam.lr=0.05;
net.trainParam.mc=0.95;
net.trainParam.lr_inc=1.9;
net.trainParam.lr_dec=0.15;
net.trainParam.epochs=5000;
net.trainParam.goal=1e-6;
[net,tr]=train (net,P,T);
a=sim (net,P);
gensim (net,-1);
```

V.SIMULATION RESULTS

1) UPQC with current source inverters

The system considered is 3-phase system and load is taken as non linear load. UPQC consists of series inverter and shunt inverter which are current source inverters. An inductor is taken as taken as a dc link between the inverters.

The parameters of transmission line are taken same values which are mentioned design of PI controller. The simulation diagram is shown in figure 4.

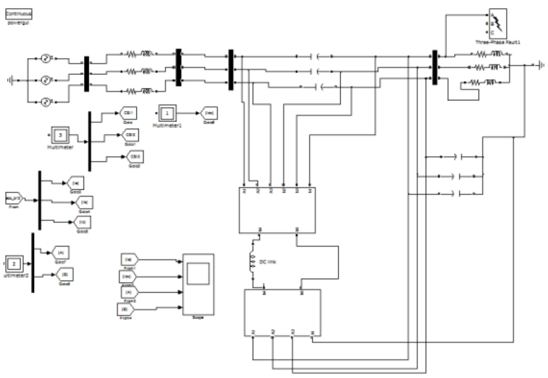
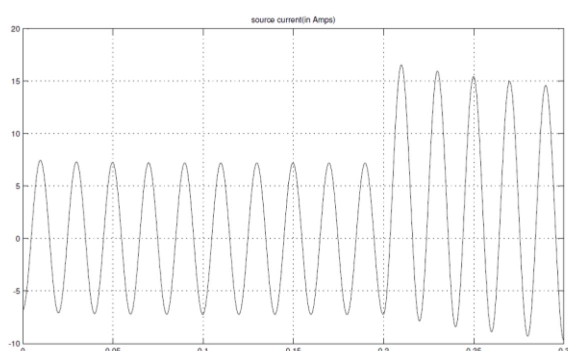


Fig 4: Simulation diagram UPQC with Current Source Inverters

The simulation is performed for 0.3sec and a disturbance at load is applied for a certain period of time and the performance of PI and ANN controller are compared.



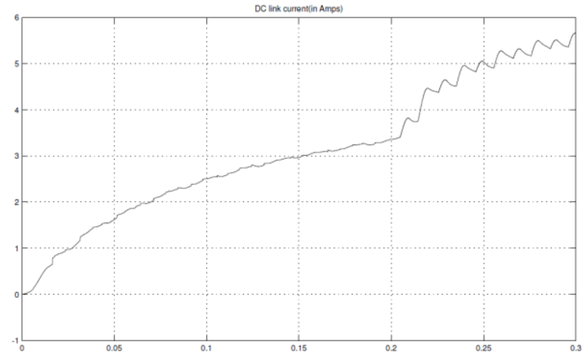
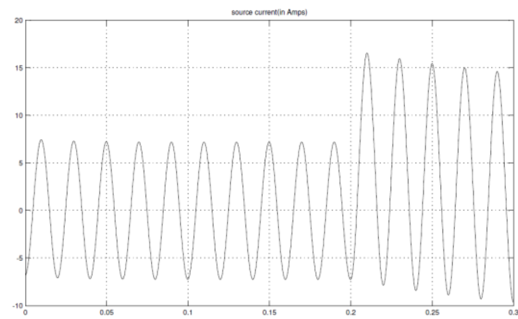


Fig 5: Performance of UPQC with PI controller at load perturbations



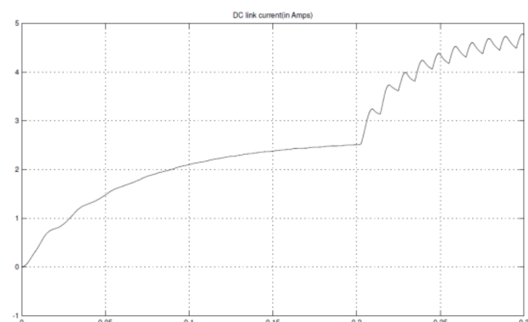


Fig 6: Performance of UPQC with ANN controller at load perturbations

Total harmonic distortion is also taken (0.15sec and 0.25sec). PI and ANN controller performance is compared

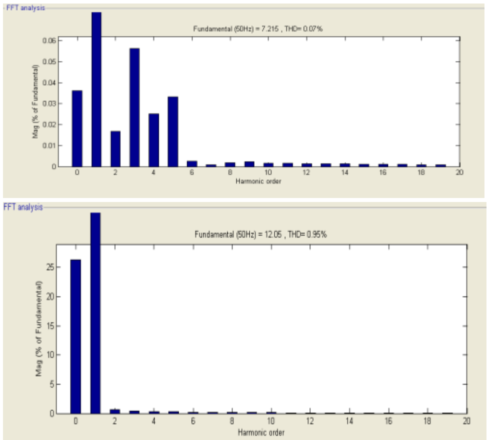


Fig 7: Frequency spectrum of the source current at different loading conditions with the PI controller.

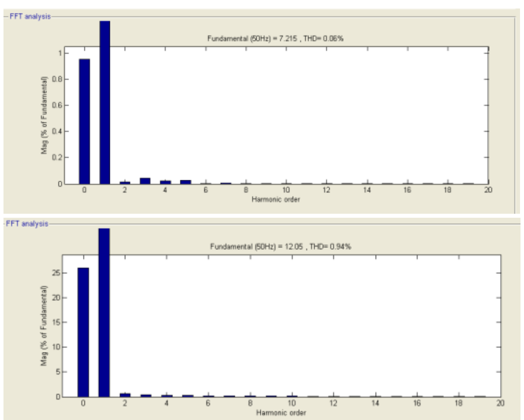


Fig 8: Frequency spectrum of the source current at different loading conditions with the ANN controller.

From figures 5 and 6 the dc link current is taking more to stabilize at initial conditions and load perturbations in the case of PI controller and in the other case of ANN controller dc link current is stabilizing fast in both conditions compared to PI controller.

The performance of harmonic current filtration is shown. The load current in both 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 that the THD of the source current at 0.15 s is 0.07% in the case of the PI controller while it is 0.06% in the case of the ANN controller scheme. Similarly, the THD of the source current at 0.25 s is 0.95% in case of the PI controller while it is 0.94% in case of the ANN controller scheme. At both cases ANN controller performance is proving better than PI controller.

2) UPQC with voltage source inverters

The system considered is 3-phase system and load is taken as non linear load. UPQC consists of series inverter and shunt inverter which are voltage source inverters. A capacitor is taken as taken as a dc link between the inverters.
The parameters of transmission line are taken same values which are mentioned design of PI controller. The simulation diagram is shown in figure 9.

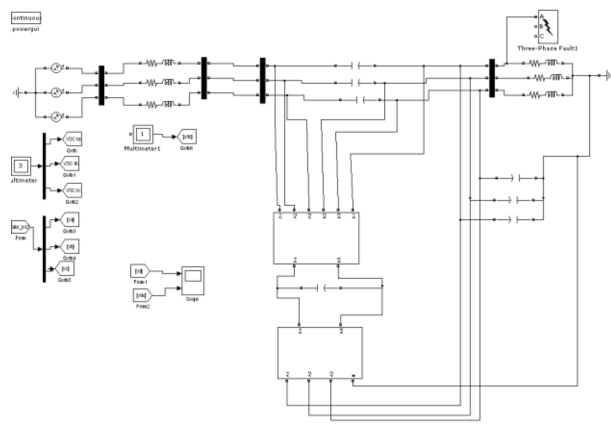
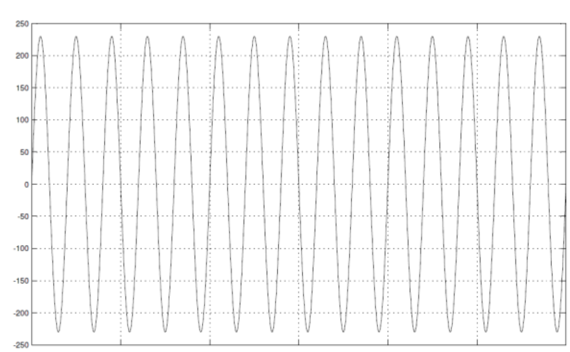


Fig 9: Simulation diagram UPQC with Voltage Source Inverters

The simulation is performed for 0.3sec and a disturbance at load is applied for a certain period of time and the performance of PI and ANN controller are compared



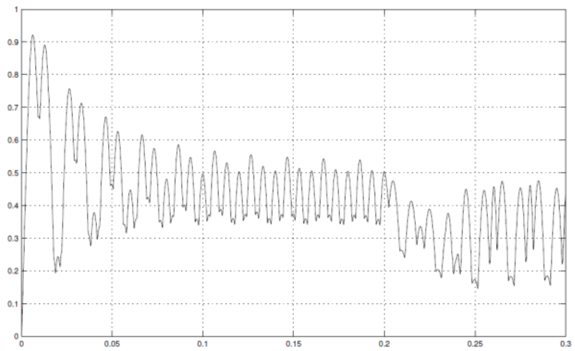


Fig 10: Performance of UPQC with PI controller at load perturbations

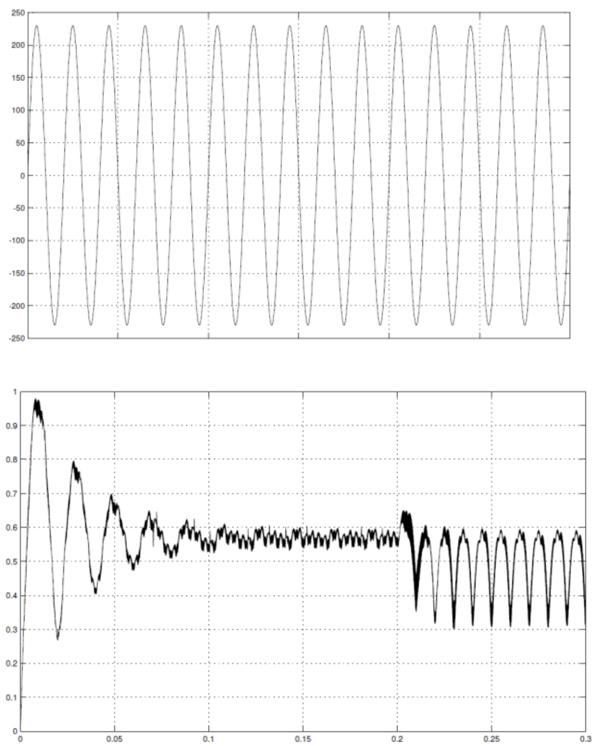


Fig 11: Performance of UPQC with ANN controller at load perturbations

From figures 10 and 11 the dc link is stabilizing fast at initial conditions with ANN controller compared to PI controller. Even at load perturbations there are fewer oscillations occurring with ANN controller compared to PI controller. Hence ANN controller is showing a better performance in the two cases against PI controller.

VI.CONCLUSION

The performance of the UPQC mainly depends upon how accurately and quickly reference signals are derived. There were several conditions that are tested. However, the performance of conventional PI controller is not proving better against proposed ANN controller in both cases of UPQC (considering CSI and VSI inverters). This is proved through simulation results. Finally, with ANN controller there was considerable improvement in the response time of the control of the dc-link current which is the main issue in the case of the power system network.

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