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DESIGN OF CONTROLLER FOR POWER QUALITY IMPROVEMENT BY UPQC

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ABSTRACT

Active Power Filters can be classified, based on converter type, topology and the number of phases. An artificial neural network (ANN), often just called a "neural network" (NN), is a mathematical model or computational model based on biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase.

In this paper, various extraction algorithms for generating reference signals and various modulation techniques for generating pulses already developed and published are discussed. Criterion for selection of dc link capacitor and interfacing filter design are also discussed. The Objective of this paper, one such APLC known as Unified Power Quality Conditioner (UPQC), which can be used at the PCC for improving power quality, is designed, simulated using proposed control strategy and the performance is evaluated for various nonlinear loads (steel plant loads)

KEYWORDS: Power Quality, UPQC, ANN, PCC.

1. INTRODUCTION

Power electronic based power processing offers higher efficiency, compact size and better controllability. But on the flip side, due to switching actions, these systems behave as non-linear loads [1-3]. Therefore, whenever, these systems are connected to the utility, they draw non-sinusoidal and/or lagging current from the source. As a result these systems pose themselves as loads having poor displacement as well as distortion factors. Hence they draw considerable reactive volt-amperes from the utility and inject harmonics in the power networks. Loads, such as, diode bridge rectifier or a thyristorbridge feeding a highly inductive load, presenting themselves as current source at point of common coupling (PCC), can be effectively compensated by connecting an APF in shunt with the load [4-6]. On the other hand, there are loads, such as Diode Bridge having a high dc link capacitive filter. These types of loads are gaining more and more importance mainly in forms of AC to DC power supplies and front end AC to DC converters for AC motor drives. For these types of loads APF has to be connected in series with the load [4, 7].

The voltage injected in series with the load by series APF is made to follow a control law such that the sum of this injected voltage and the input voltage is sinusoidal. Thus, if utility voltages are non-sinusoidal or unbalanced, due to the presence of other clients on the same grid, proper selection of magnitude and phase for the injected voltages will make the voltages at load end to be balanced and sinusoidal.

The shunt APF acts as a current source and inject a compensating harmonic current in order to have sinusoidal, in-phase input current and the series APF acts as a voltage source and inject a compensating voltage in order to have sinusoidal load voltage. The developments in the digital electronics, communications and in process control system have increased the number of sensitive loads that require ideal sinusoidal supply voltage for their proper operation. In order to meet limits proposed by standards it is necessary to include some sort of compensation. In the last few years, solutions based on combination of series active and shunt active filter have appeared [8-9]. Its main purpose is to compensate for supply voltage and load current imperfections, such as

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sags, swells, interruptions, imbalance, flicker, voltage imbalance, harmonics, reactive currents, and current unbalance [10-16]. This combination of series and shunt APF is called as Unified Power Quality Conditioner (UPQC). In most of the articles control techniques suggested are complex requiring different kinds of transformations. The control technique presented here is very simple and does not require any transformation.

2. OPERATION OF THREE PHASE ACTIVE POWER FILTERS

In recent years, the power quality of the AC main system has become a great concern due to the rapidly increased number of electronic equipment. In order to reduce the harmonic contamination in power lines and improve the transmission efficiency Active power filters become essential. A current source is connected in parallel with nonlinear load and controlled to generate the harmonic currents needed for the load. The basic configuration of a three-phase three-wire active power filter is shown in Fig 1. The diode bridge rectifier is used as an ideal harmonic generator to study the performance of the Active filter. The current-controlled voltage-source inverter (VSI) is shown connected at the load end. This PWM inverter consists of six switches with antiparallels diode across each switch. The capacitor is designed in order to provide DC voltage with acceptable ripples. In order to assure the filter current at any instant, the DC voltage V_{dc} must be at least equal to 3/2 of the peak value of the line AC mains voltage.

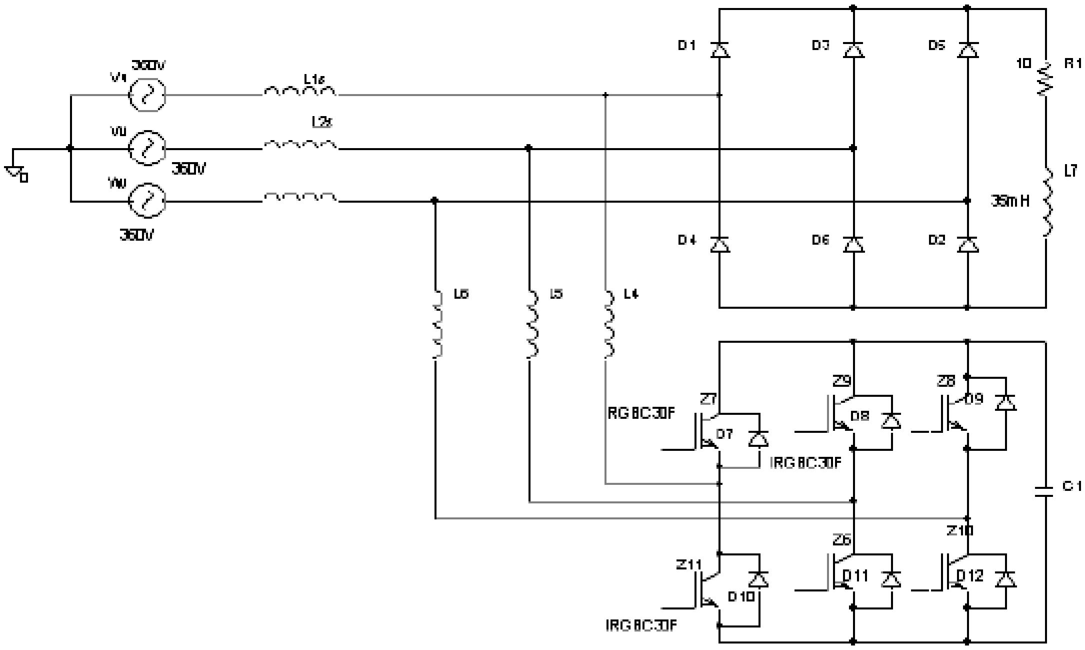

Fig.1 Configuration of the three phase, three wire Active filtering system.

The PWM inverter used in APF makes the harmonic control possible. This inverter uses DC capacitors/inductors as the supply and can switch at high frequency to generate a signal that will cancel the harmonics from the nonlinear load. The active filter does not need to provide any real power to cancel harmonic currents from the load. The harmonic currents to be cancelled show up as reactive power. Therefore, the DC capacitors/inductors and the filter components must be rated based on the reactive power associated with the harmonics to be cancelled and on the actual current waveform (rms and peak current magnitude) that must be generated to achieve the cancellation.

If the inverter is loss free one, the active power flow from the inverter will get translated as an even increasing voltage in the DC side capacitor. Similarly, an active power flow out of the inverter will eventually take the DC side to zero voltage condition. It is necessary that the DC side capacitor voltage be maintained at fixed value (at least within a band around the nominal value) in order to synthesize rated amplitude sinusoidal output at the inverter for all load conditions.

3. CONTROL STRATEGY OF ANN WITH PI:

Uncontrolled system is subject to steady state errors and so control strategy is required. The control specifications are

- Control loop must be characterized by a sufficient degree of stability
- Following a step load change, the harmonics error should return to zero. This is referred to as asynchronous control. Magnitude of transient harmonics must be minimized.
- Integral of the voltage sag,swell and harmonics error should be minimized.
- The individual transmission of the UPQC controller should divide the total non-linear load for improve the power quality.
- Let ΔP_c be the negative feed-back signal drawn from frequency deviation. Suppose, if it was not an integral feedback, i.e. if ΔP_c=-$K_1\Delta F(s)$ where $k_1 \rightarrow$gain for proportion control
- $U(t)=K_P\, e(t) + K_i\, d/dt(E(t))$ the PD controller increases the damping of the system which results in reducing the peack overshoot
- $U(t)=K_P e(t) + K_i \int_0 E(t)$ PI controller reduces the steady state error. The PI controller increases the order and type number of the system by one.

4. DESIGNING & TRAINING OF ANN CONTROLLER ALGORITHM

An ANN is essentially a cluster of suitably interconnected non-linear elements of very simple form that possess the ability of learning and adaptation. These networks are characterised 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. Their ease of use, inherent reliability and fault tolerance has made ANNs a viable medium for control. An alternative to fuzzy controllers in many cases, neural controllers share the need to replace hard controllers with intelligent controllers in order to increase control quality. A feed forward neural network works as compensation signal generator. This network is designed with three layers. The input layer with seven neurons, the hidden layer with 21 and the output layer with 3 neurons. Activation functions chosen are tan sigmoidal and pure linear in the hidden and output layers respectively.

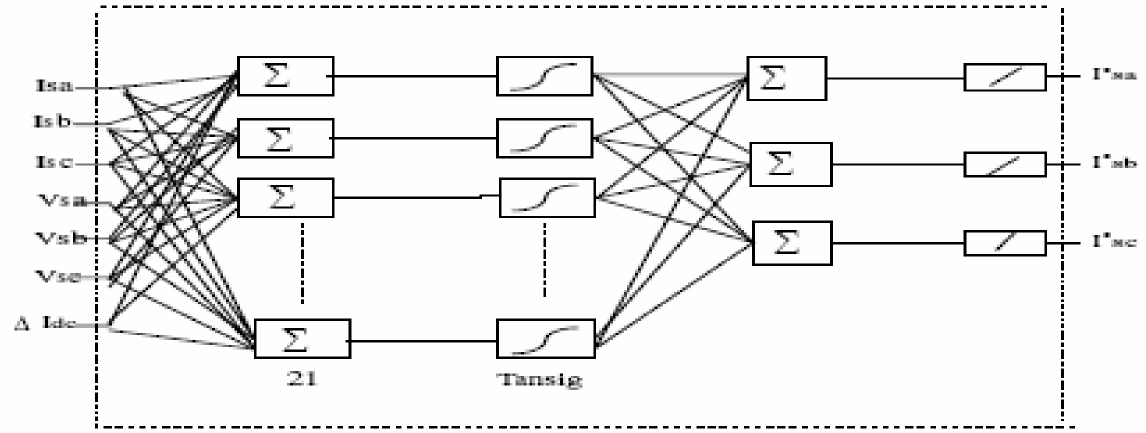

Figure.6 Network Topology of ANN

The training algorithm used is Levenberg Marquardt back propagation (LMBP).

The Matlab programming of ANN training is as given below:

```
net=newff(minmax(P),[7,21,3],
 {„tansig‟,‟tansig‟,‟purelin‟},‟trainlm‟);
net.trainParam.show =50;
net.trainParam.lr = .05;
net.trainParam.mc = 0.95;
net.trainParam.lr_inc = 1.9;
net.trainParam.lr_dec = 0.15;
net.trainParam.epochs = 1000;
net.trainParam.goal = 1e-6;
```

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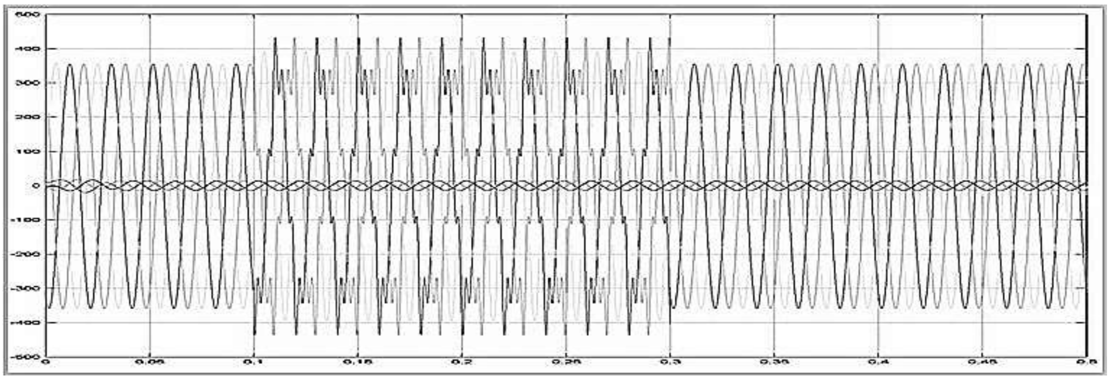
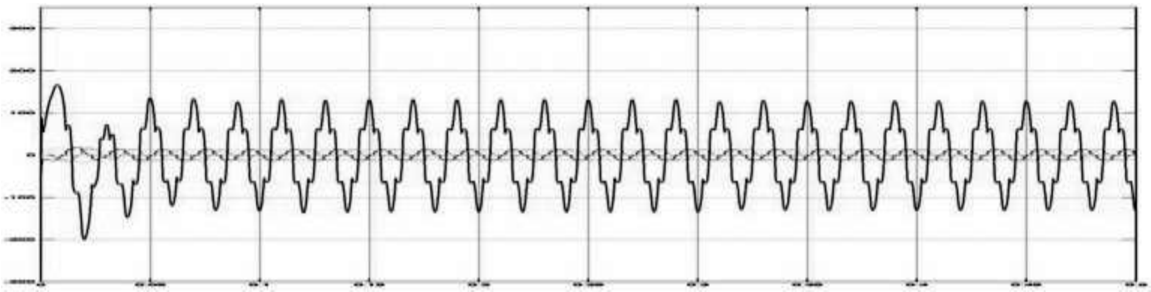
```
[net,tr]=train(net,P,T);
a=sim(net,P);
gensim(net,-1);
```

The compensator output depends on input and its evolution. The chosen configuration has seven inputs three each for reference load voltage and source current respectively, and one for output of error (PI) controller. The neural network trained for outputting fundamental reference currents. The signals thus obtained are compared in a hysteresis band current controller to give switching signals.

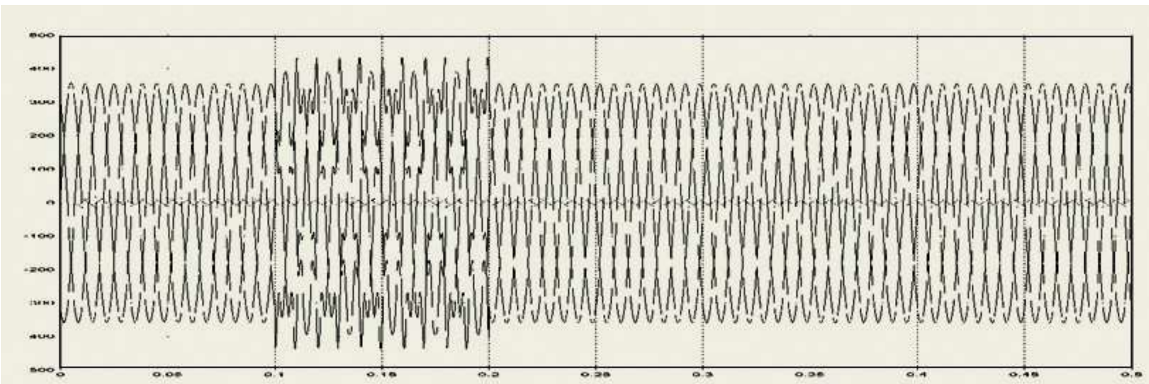
5. RESULTS AND DISCUSSION



6.8(a) input voltage and current using upqc with PI controller



6.8(b) load voltage and current upqc with PI controller
6.8 upqc with PI controller



6.9(a) input voltage and current upqc with ANN contoller

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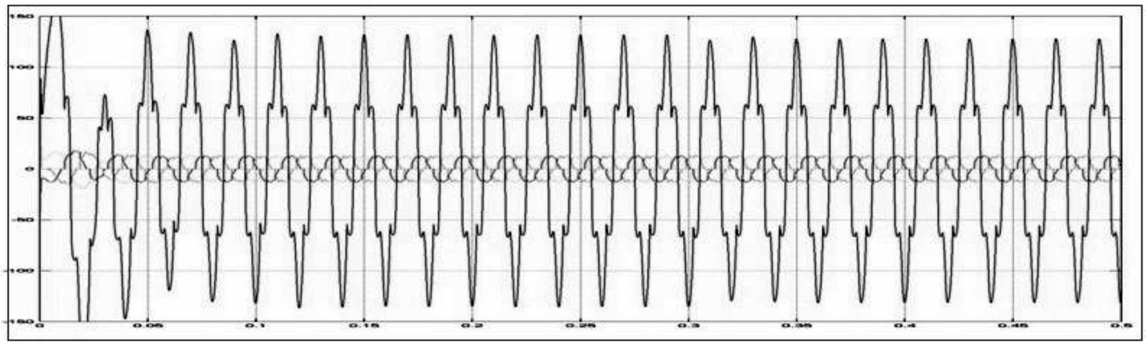
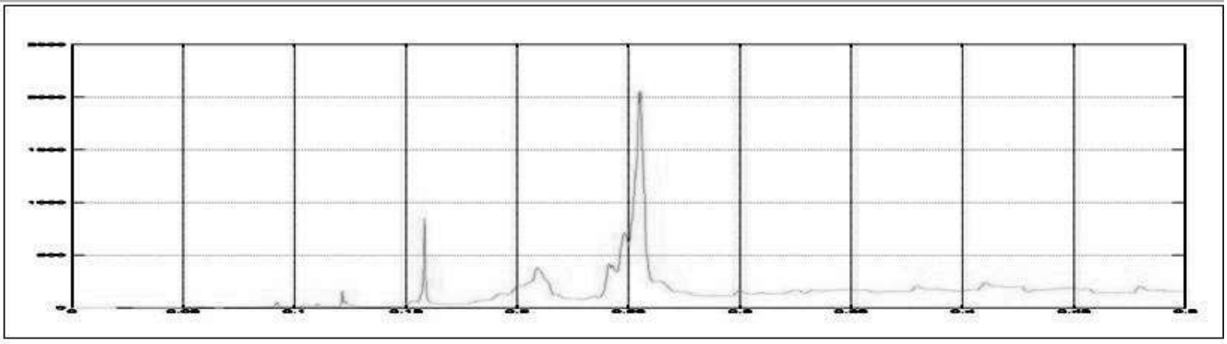
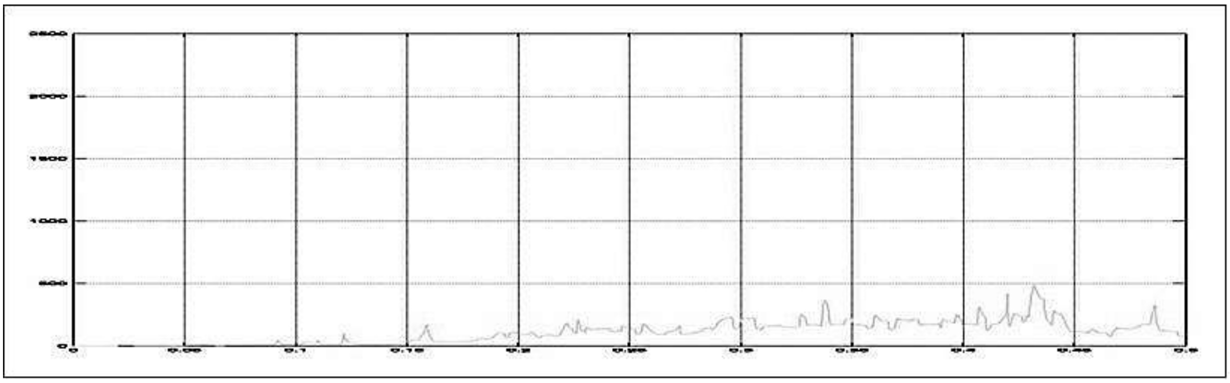


6.9(b) output voltage and current upqc with ANN controller
6.9 upqc with ANN controller



6.10(a) PI THD load voltage(VL)



6.10(b) ANN THD load voltage(VL)
6.10 Total harmonics distortion

Table 6.1 Voltage and current harmonics (THD's) of UPQC

Order of harmonics	WITHOUT UPQC utility side voltage	WITHOUT UPQC utility side current	UPQC with pi controller utility side voltage	UPQC with pi controller utility side current	UPQC with ANN controller utility side voltage	UPQC with ANN controller Utility

3rd&5th	**4.2**	**24.2**	**2.99**	**2.99**	**1.2**	1.2
5th& 7th	**4.2**	**24.6**	**3.42**	**3.42**	**1.19**	1.19
7th&9th	**4.2**	**24.6**	**2.18**	**2.18**	**1.3**	1.3

6. CONCLUSION

Custom power devices like DVR, D-STATCOM, and UPQC can enhance power quality in the distribution system. Based on the power quality problem at the load or at the distribution system, there is a choice to choose particular custom power device with specific compensation. Unified Power Quality Conditioner (UPQC) is the combination of series and shunt APF, which compensates supply voltage and load current imperfections in the distribution system.

The UPQC considered in this project is a multifunction power conditioner which can be used to compensate for various voltage disturbance of the power supply, to correct any voltage fluctuation and to prevent the harmonic load current from entering the power system.

A simple control technique based on unit vector templates generation is proposed for UPQC. Proposed model has been simulated in MATLAB. The simulation results show that the input voltage harmonics and current harmonics caused by non-linear load can be compensated effectively by the proposed control strategy. The closed loop control schemes of direct current control, for the proposed UPQC have been described. A suitable mathematical model of the UPQC has been developed with different shunt controllers (PI and ANN) and simulated results have been described which establishes the fact that in both the cases the compensation is done but the response of ANN controller is faster and the THD is minimum for the both the voltage and current which is evident from the plots and comparison.

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