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Power Quality Improvment by UPQC Using ANN Controller

Shahab Uddin Baqar
Mtech Electrical Engineering
National Institute Of Technology Patna
Patna, India

Mrs Jayanti choudhary
Assistant Professor Electrical Engineering
National Instate Of Technology Patna
Patna, India

***Abstract*—One of the major concerns in electricity industry today is power quality. It becomes especially important with the introduction of advanced and complicated devices, whose performance is very sensitive to the quality of power supply. The electronic devices are very sensitive to disturbances and thus industrial loads become less tolerant to power quality problems such as voltage dips, voltage sags, voltage flickers, harmonics and load unbalance etc. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications. Among these, the distribution static compensator, dynamic voltage restorer and unified power quality conditioner which is based on the VSC principle are used for power quality improvement. In this project, Neural Network controller with reference signal generation method is designed for UPQC and compared its performance with proportional integral based controller. This is used to compensate current and voltage quality problems of sensitive loads. The results are analyzed and presented using matlab/simulink software.**

Keywords—UPQC, Shunt APF, Series APF, PCC, Harmonics, ANN,

I. INTRODUCTION (*Heading 1*)

Unified power quality control was widely studied by many researchers as an eventual method to improve power quality of electrical distribution system [1-3]. The function of unified power quality conditioner is to compensate supply voltage flicker/imbalance, reactive power, negative-sequence current, and harmonics. In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. Therefore, the UPQC is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage flicker/imbalance [2]. The UPQC consisting of the combination of a series active power filter (APF) and shunt APF can also compensate the voltage interruption if it has some energy storage or battery in the dc link [3].

The shunt APF is usually connected across the loads to compensate for all current-related problems such as the reactive power compensation, power factor improvement, current harmonic compensation, and load unbalance compensation [1-2], whereas the series APF is connected in a series with the line through series transformers. It acts as controlled voltage source and can compensate all voltage related problems, such as voltage harmonics, voltage sag, voltage swell, flicker, etc.follow.

II. UPQC CONTROL ALGORITHM

The UPQC consists of two voltage source inverters connected back to back with each other sharing a common dc link. One inverter is controlled as a variable voltage source in the series APF, and the other as a variable current source in the shunt APF. Fig. 1 shows a basic system configuration of a general UPQC consisting of the combination of a series APF and shunt APF. The main aim of the series APF is harmonic isolation between load and supply; it has the capability of voltage flicker/ imbalance compensation as well as voltage regulation and harmonic compensation at the utility-consumer PCC. The shunt APF is used to absorb current harmonics, compensate for reactive power and negative-sequence current, and regulate the dclink voltage between both APFs.

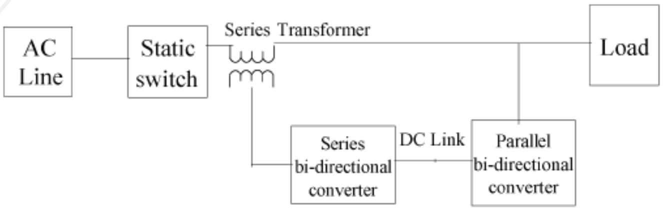

Fig 1:-Unified Power Quality Conditioner

A. *Reference Voltage Signal Generation for Series APF*

The function of the series APF is to compensate the voltage disturbance in the source side, which is due to the fault in the distribution line at the PCC. The series APF control algorithm calculates the reference value to be injected by the series APF transformers, comparing the positive-sequence component with the load side line voltages. The proposed series APF reference voltage signal generation algorithm is shown in Fig. 3. In equation (1), supply voltages v_{Sabc} are transformed to d-q-0 coordinates.

The function of the series APF is to compensate the voltage disturbance in the source side, which is due to fault in the distribution line al the point of coupling. The series APF control algorithm calculates the reference value to be injected by the series APF transformers, comparing the positive-sequence component with the load side line voltages. In equation (3.1), supply voltages V_{Sabc} are transformed to d-q-O coordinate.

$$\begin{bmatrix} Vs0 \\ Vsd \\ Vsq \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \sin(wt) & \sin\left(wt - 2\frac{\pi}{3}\right) & \sin\left(wt + 2\frac{\pi}{3}\right) \\ \cos(wt) & \cos\left(wt - 2\frac{\pi}{3}\right) & \cos\left(wt + 2\frac{\pi}{3}\right) \end{bmatrix}\begin{bmatrix} Vsa \\ Vsb \\ Vsc \end{bmatrix} \quad ......1$$

The voltage in d axes (V_{sd}) given in (2) consists of average and oscillating components of source voltages ($\bar{V}_{sd}$ and $\tilde{V}_{Sd}$). The average voltage V_{Sd} is calculated by using second order LPF (low pass filter).

$$Vsd = \overline{Vsd} + \widetilde{Vsd} \quad ....2$$

The load side reference voltages v^*_{Labc} are calculated as given in equation (3). The switching signals are assessed by comparing reference voltages (v^*_{Labc}) and the load voltages (v_{Labc}) and via sinusoidal PWM controller.

$$\begin{bmatrix} v^*_{La} \\ v^*_{Lb} \\ v^*_{Lc} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \sin(wt) & \cos(wt) & 1 \\ \sin(wt - 2\frac{\pi}{3}) & \cos(wt + 2\frac{\pi}{3}) & 1 \\ \sin(wt + 2\frac{\pi}{3}) & \cos(wt + 2\frac{\pi}{3}) & 1 \end{bmatrix}\begin{bmatrix} \bar{v}_{Sd} \\ 0 \\ 0 \end{bmatrix} \quad ....3$$

These produced three-phase load reference voltages are compared with load line voltages and errors are then processed by sinusoidal PWM controller to generate the required switching signals for series APF IGBT switches.

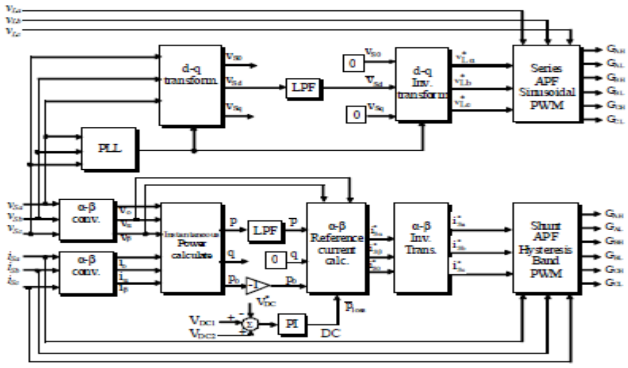

Fig:- series APF voltage generation and shunt APF current signal generation

B. Reference Current Signal Generation for Shunt APF

. The above figure shows the control diagram of shunt active filter. The shunt active filter compensates the current harmonics and reactive power generated by the nonlinear load. The instantaneous active power (p-q) theory is used to control of shunt APF in real time. In this theory, the instantaneous three-phase currents and voltages are transformed to a-p-O coordinates. The instantaneous three phase current and voltages are transformed to α-β-0 coordinates as shown in the equation (4) and (5).

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} v_{Sa} \\ v_{Sb} \\ v_{Sc} \end{bmatrix} \quad ....4$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} i_{Sa} \\ i_{Sb} \\ i_{Sc} \end{bmatrix} \quad .....5$$

The source side instantaneous real and imaginary power components are calculated by using source currents and phase-neutral voltages as given in (6). The instantaneous real and imaginary powers include both oscillating and average components as shown in (7). Average components of p and q consist of positive sequence components (p and q) of source current. The oscillating components ($\tilde{p}$ and $\tilde{q}$) of p and q include harmonic and negative sequence components of source currents. In order to reduce neutral current, p_0 is calculated by using average and oscillating components of imaginary power and oscillating component of the real power; as given in (8) if both harmonic and reactive power compensation is required. $i_{s\alpha}*$, $i_{s\beta}*$ and $i_{s0}*$ are the reference currents of shunt APF in α-β-0 coordinates. These currents are transformed to three-phase system as shown in (9).

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad ....6$$

$$p_0 = v_0 * i_0 \quad ; \quad p = \bar{p} + \tilde{p} \quad ....7$$

$$\begin{bmatrix} i^*_{S\alpha} \\ i^*_{S\beta} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2}\begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix}\begin{bmatrix} \bar{p} + p_0 + \bar{p}_{loss} \\ 0 \end{bmatrix} \quad ...8$$

$$\begin{bmatrix} i^*_{Sa} \\ i^*_{Sb} \\ i^*_{Sc} \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1/\sqrt{2} & 1 & 0 \\ 1/\sqrt{2} & -1/2 & \sqrt{3}/2 \\ 1/\sqrt{2} & -1/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} i^*_{S0} \\ i^*_{S\alpha} \\ i^*_{S\beta} \end{bmatrix} \quad ......9$$

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The reference currents are calculated in order to compensate neutral, harmonic and reactive currents in the load. These reference source current signals are then compared with sensed three-phase source currents, and the errors are processed by hysteresis band PWM controller to generate the required switching signals for the shunt APF switches.

III. TRAINING OF ANN

An ANN is essentially a cluster of suitably interconnected nonlinear 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 [19]. 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.

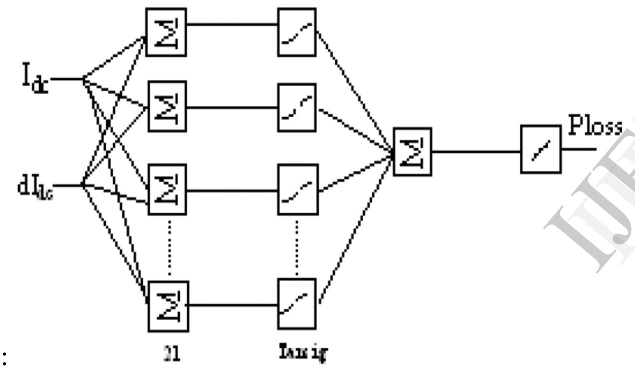

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Fig:- Network topology of ANN

The training algorithm used is Levenberg–Marquardt Backpropagation (LMBP).

Training is given as follows:-

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;

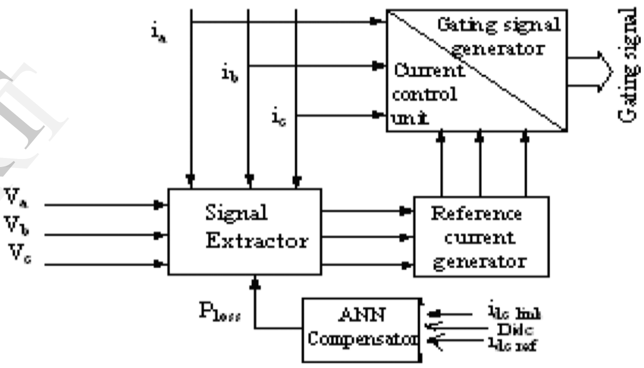
net.trainParam.goal = 1e-6;

[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 [20]. The signals thus obtained are compared in a hysteresis band current controller to give switching signals. The block diagram of ANN compensator is as shown in the figure



IV. AIMMULATION AND RESULTS

The circuit is simulated using Matlab/Simulink .The matlab diagram of series and shunt APF with pi controller and ANN controller is as follow

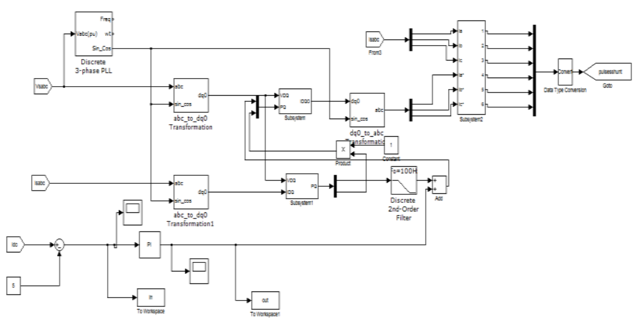


Fig:- the shunt APF with pi controller

The above matlab diagram is of the shunt active power filter. Here the dq0 transform is used to convert the three phase voltage and three phase current into two phase voltage and current. The three phase PLL is used to generate the sine cosine term. The sine and cosine term is used in abc to dq0 transform and then again dq0 to three phase transform. The transformed dq0 is feed into the pq generation. The p term is feed into the low pass second order filter to filter out the harmonics. The q term is left out. Now this filter out P term is feed into the pq to dq0 transform. Now again this signal is feed into the dq0 to three phase transform. This transformed three phase signal is treated as reference signal. Now this reference signal and three phase current signal is feed into the hysteresis current controller. The generated signal is given into the inverter.

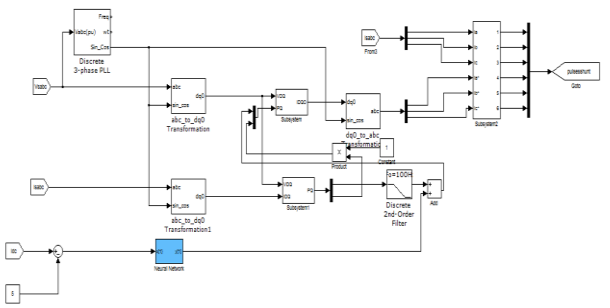


Fig:-shunt APF with ANN control

The waveforms obtained from both of the controller is as

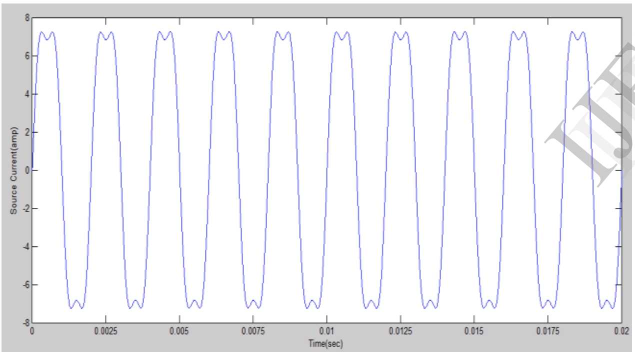


Fig:- the uncompensated current waveforms

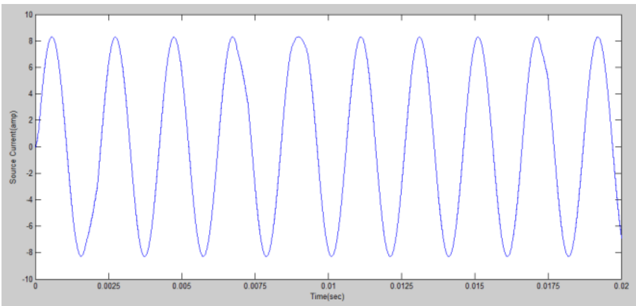


Fig:-the current waveform odtained through pi controller

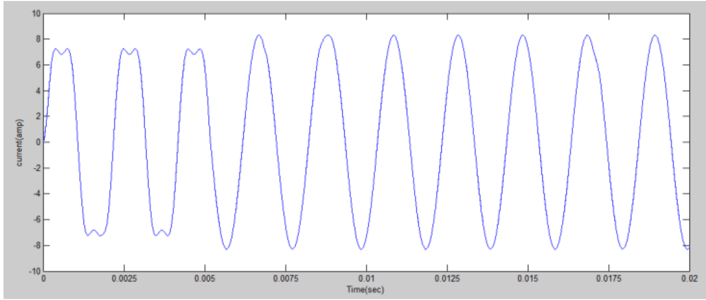


Fig:-the current waveform obtained through the ANN controller

The THD of the unconpensated current obtained without the UPQC in operation is 27.63% which is quit high. The IEEE standerd is that it should be below 5%. The current obtained the UPQC is in the operation with the proportional integral controller is 1.76% which is quit low and satisfy trhe IEE standerd. And when the UPQC is in operation with the Artificial Neural Network controller the THD is 0.67% which much more less than the pi contrioller.

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 compensate 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 and ANN) and simulated results are compared.

The performance of harmonic current filtration is shown in Figs. 5.15 and 5.16. 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 0.69% in the case of the PI controller while it is 0.63% in the case of the ANN controller scheme. Similarly, the THD of the source current at .25 s is 0.7% in case of the PI controller while it is 0.59% in case of the ANN controller scheme. Thus by seeing the result obtained through the simulation of UPQC with both the controller PI and ANN it can be conclude that for the same load the THD obtained is less as compared to the conventional PI controller. Hence the ANN controller is better option than the conventional controller

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