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Active Power Filter for Power Compensation Under Non-Ideal Mains Voltages

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ABSTRACT
In this paper, a new Active Power Filter (APF) control scheme has been proposed to improve the performance of the APF. This paper presents a new technique with instantaneous power theory (p-q theory) in order to control of APF under nonideal mains voltage conditions. Performance of the proposed scheme has been found feasible and excellent to that of the instantaneous reactive power algorithms under various non-idealmains test scenarios. MATLAB/SIMULINK power system toolbox is used to simulate the proposed system. The proposed method's performance is compared with conventional instantaneous power (p-q) theory. The simulation results are presented and discussed showing the effectiveness of the control algorithm.

INTRODUCTION
In a modern power system, increasing of loads and non-linear equipment's have been demanding the compensation of the disturbances caused for them. These nonlinear loads may cause poor power factor and high degree of harmonics.

Active Power Filter (APF) can solve problems of harmonic and reactive power simultaneously. APF's consisting of voltage-source inverters and a DC capacitor have been researched and developed for improving the power factor and stability of transmission systems. APF have the ability to adjust the amplitude of the synthesized ac voltage of the inverters by means of pulse width modulation or by control of the dc-link voltage, thus drawing either leading or lagging reactive power from the supply. APF's are an up-to-date solution to power quality problems. Shunt APF's allow the compensation of current harmonics and unbalance, together with power factor correction, and can be a much better solution than conventional approach (capacitors and passive filters). The simplest method of eliminating line current harmonics and improving the system power factor is to use passive LC filters. However, bulk passive components, series and parallel resonance and a fixed compensation characteristic are the main drawbacks of passive LC filters.

In APF design and control, instantaneous reactive power theory was often served as the basis for the calculation of compensation current. In this theory, the mains voltage was assumed to be an ideal source in the calculation process. However, in most of time and most of industry power systems, mains voltage may be unbalanced and/or distorted. In this theory, non-ideal mains voltages affect all line currents, under such scenario.

The *pq*theory, since its proposal, has been applied in the control of three-phase active power filters. However, power system voltages being often non-ideal, in distorted voltage systems the control using the *pq*theory does not provide good performance. The proposed control algorithm gives adequate compensating current reference even for non-ideal voltage system. Consequently, this paper is primarily concerned with the development of APF performance under non-ideal or distorted mains voltage. This paper

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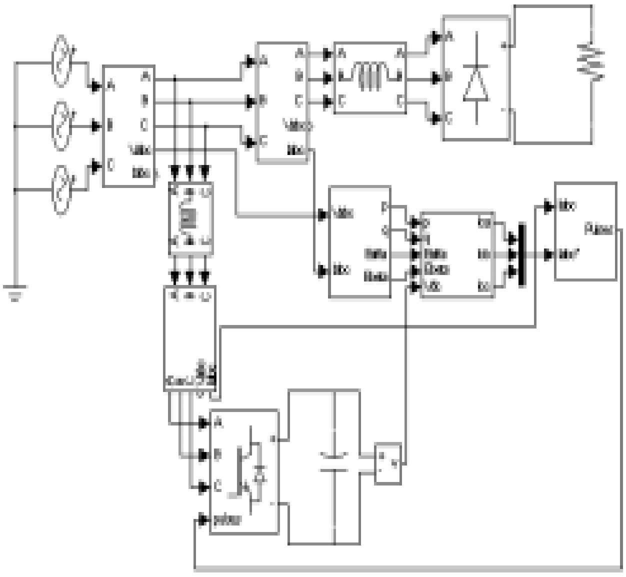
presents a new technique with instantaneous power theory (p-q theory) as a suitable method to the analysis of nonlinear three-phase systems and for the control of APF. Performance of the proposed scheme has been found feasible and excellent to that of the instantaneous reactive power algorithms under various non-ideal mains test scenarios.

As mentioned in other section of the paper, in Turkish electrical energy distribution system harmonic problems caused by power electronic devices are very important. Inherently, mains voltages usually have non-ideal waveforms, and have different levels of harmonics. As shown in Fig. mains voltages have 3., 5., 7. and 11. harmonics.



ACTIVE POWER FILTER

Fig.1 shows basic APF block diagram including non-linear load on three-phase supply condition. In this study, three phase uncontrolled diode bridge rectifier with resistive loading are considered as a non-linear load on three phase ac mains. This load draws non-sinusoidal currents from ac mains.

APF overcome the drawbacks of passive filters by using the switching mode power converter to perform the harmonic current elimination. Shunt active power filters are developed to suppress the harmonic currents and compensate reactive power simultaneously. The shunt active power filters are operated as a current source parallel with the nonlinear load. The power converter of active power filter is controlled to generate a compensation current, which is equal but opposite the harmonic and reactive currents generated from the nonlinear load. In this situation, the mains current is sinusoidal and in phase with mains voltage.

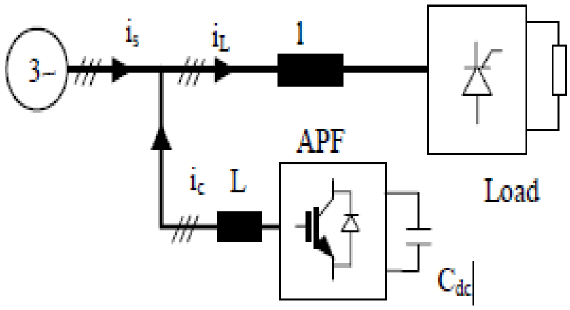


Fig. 1. Block diagram of APF.

A voltage source inverter having IGBT switches and an energy storage capacitor on DC bus is implemented as a shunt APF. The main aim of the APF is to compensate harmonics, reactive power and to eliminate the unwanted effects of no ideal ac mains supplies only unity power factor sinusoidal balanced three-phase currents.

INSTANTANEOUS POWER THEORY

In three-phase circuits, instantaneous currents and voltages are converted to instantaneous space vectors. In instantaneous power theory, three-phase currents and voltages are calculated as following equations. These space vectors are easily converted to α-β coordinates .

$$\begin{bmatrix} e_\alpha \\ e_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (2)$$

In equation (1) and (2), α and β are orthogonal coordinates.eα and iα are on α axis, eβ and iβ are on β axis. In three-phase conventional instantaneous power is calculated as follows:

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$$p = e_\alpha i_\alpha + e_\beta i_\beta \quad (3)$$

In fact, active power (p) is equal to following equation:

$$p = e_a i_a + e_b i_b + e_c i_c \quad (4)$$

Instantaneous real and imaginer powers are calculated as equation (5).

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} e_\alpha & e_\beta \\ -e_\beta & e_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (5)$$

In equation (5), eα.iα and eβ.iβ are instantaneous powers. Since these equations are products of instantaneous currents and voltages in the same axis. In three-phase circuits, real instantaneous active power is p and its unit is watt (VA). In contrast eα.iβ and eβ.iα are not instantaneous powers. Since these are products of instantaneous current and voltages in two orthogonal axis. q is not conventional electric unit like W orVar. q is instantaneous imaginary power.
Equation (5) can be written as equation (6).

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} e_\alpha & e_\beta \\ -e_\beta & e_\alpha \end{bmatrix}^{-1} \begin{bmatrix} p \\ q \end{bmatrix} \quad (6)$$

From equation (6), instantaneous compensating currents onα and β coordinates, are given by,

$$\begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \end{bmatrix} = \begin{bmatrix} e_\alpha & e_\beta \\ -e_\beta & e_\alpha \end{bmatrix}^{-1} \begin{bmatrix} \tilde{p} \\ -q \end{bmatrix} \quad (7)$$

SIMULATION RESULTS

The presented simulation results were obtained by using Matlab Simulink Power System Toolbox software, for a three phase power system with a shunt APF. The proposed method has been simulated under three scenarios, including ideal mains voltage, unbalanced three-phase mains voltage and distorted mains voltage condition. The simulation results are discussed below.

A. Ideal Mains Voltage

Fig. 4 and Fig. 5 show the simulation results of this algorithm under ideal mains voltages when ohmic loaded three-phase rectifier load is connected. The three-phase mains currents after compensation are balanced sinusoidal and in phase with three-phase mains voltages. The instantaneous reactive power theory and proposed method are feasible. After compensation the THD of source current is reduced to 3.7%from 27.6%.

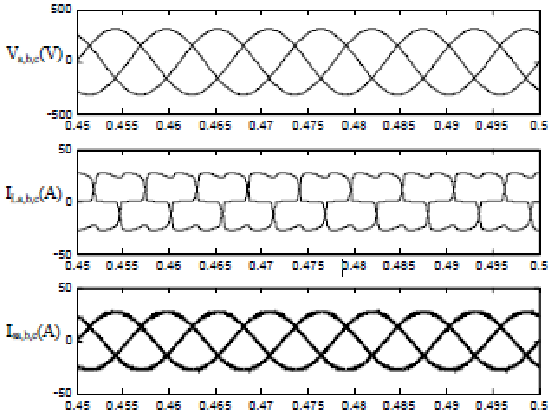

Fig. 2. Ideal mains voltage simulation results with proposed method.

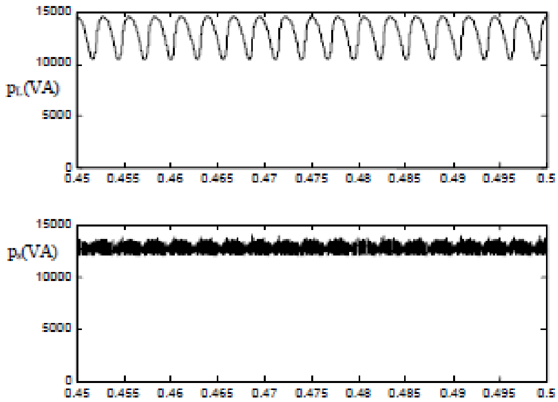

Fig. 3.Load and supply active power variations with ideal mains voltage with proposed method.

B. Unbalanced three-phase voltages

When the three-phase mains voltages are unbalanced, the mains voltage can be expressed as positive and negative sequence components. For this case, the unbalanced three phase mains voltages are:

$$e_{ua} = 311\sin(\omega t) + 31\sin(\omega t)$$
$$e_{ub} = 311\sin(\omega t - 120^o) + 31\sin(\omega t + 120^o)$$
$$e_{uc} = 311\sin(\omega t + 120^o) + 31\sin(\omega t - 120^o)$$

Fig. 6 and 7 show simulation results of 10% unbalanced mains voltages scenario with proposed method and pq theory respectively. The three-phase compensated mains currents are non-sinusoidal and unbalanced in instantaneous power theory the compensated mains currents are sinusoidal in proposed method in unbalanced mains voltages case. Total Harmonic

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Distortion (THD) of source current after compensation is10.5% and 3.7% with conventional and the proposed methods respectively. Proposed method has very good harmonic limit imposed by the IEEE-519 standard. Fig. 6 and Fig. 7 show load and source instantaneous active and reactive power waveforms with p-q theory respectively. The total instantaneous active power supplied has high ripple content.Fig. 8 and Fig. 9 show load and source instantaneous active and reactive power waveforms with proposed method respectively. The total instantaneous active power supplied is not made constant, but it presents only a small ripple. The total instantaneous reactive power is almost zero and has only a small ripple.

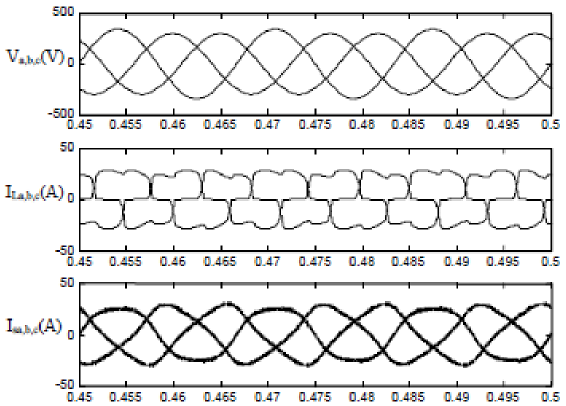

Fig. 4. Unbalanced mains voltage simulation result with pq theory.

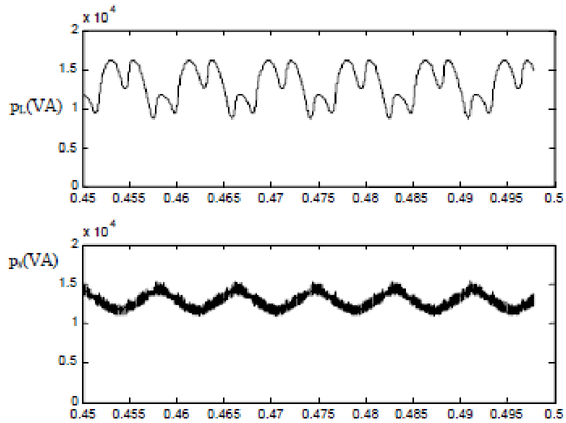

Fig. 5. Load and source instantaneous active power waveforms with pqtheory.

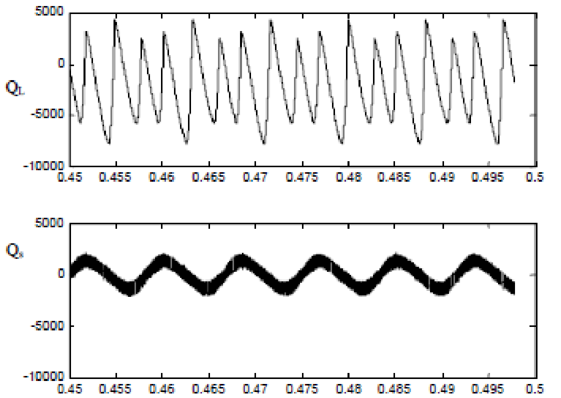

Fig. 6.Load and source instantaneous reactive power waveforms with proposed method.

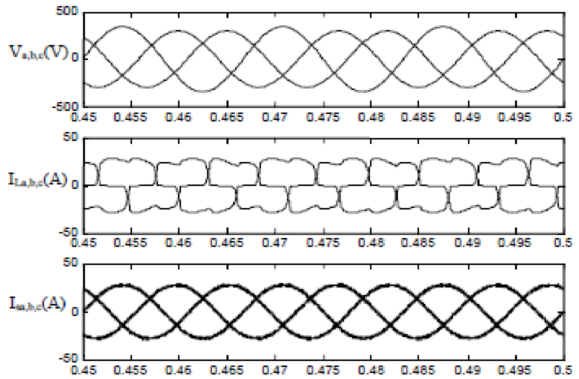

Fig. 7. Unbalanced mains voltage simulation result with proposed method.

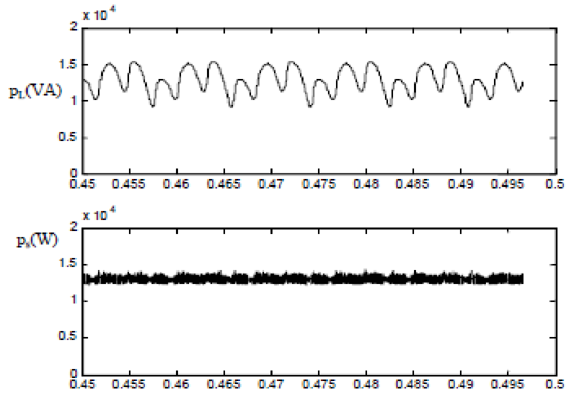

Fig. 8.Load and source instantaneous active power waveforms with proposed method.

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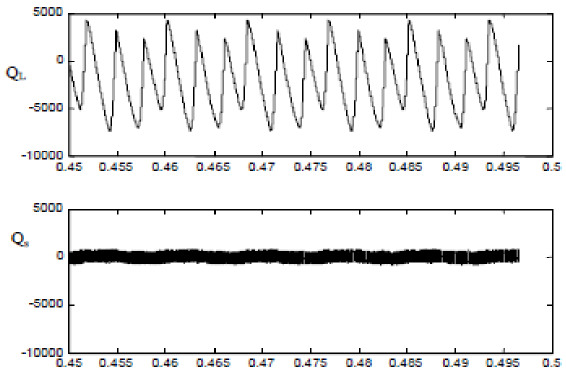

Fig. 9.Load and source instantaneous reactive power waveforms with proposed method.

CONCLUSION

In this paper, a new APF control scheme has been proposed to improve the performance of APF under non-ideal mains voltage scenarios. The computer simulation has verified the effectiveness of the proposed control scheme. Experimental results in a scaled-down laboratory prototype will be done and reported in future paper. From the simulation results, the proposed approach was very successful and easily implemented. Active power filters, based on the proposed theory, give satisfactory operation even when the system phase voltages are unsymmetrical and distorted, because no distortion appears in the line currents. The APF is found effective to meet IEEE 519 standard recommendations onharmonics levels in all of the non-ideal voltage conditions. The switching frequency and also switching losses are reduced%23 in proposed method. The total instantaneous active power supplied is not made constant, but it presents only a small ripple. The total instantaneous reactive power is almost zero and has only a small ripple.

REFERENCES

[1] Akagi,H., Kanazawa,Y., and Nabae,A., "Instantaneous reactive powercompensators comprising switching devices without energy storagecomponents. *IEEE Transactions on Industrial Applications*, Vol.20, pp.625- 630, 1984.

[2] Singh, B., Haddad K., Chandra, A., "A New Control Approach to Three-Phase Active Filter for Harmonics and Reactive Power Compensation,*IEEE Trans. on Power Systems*, Vol.13, No.1, pp. 133-138, 1998.

[3] Komatsu, Y., and T., Kawabata, "A control method for the active powerfilter in unsymmetrical voltage systems" *Int. J. Electronics*, Vol. 86, No.10, pp. 1249-1260, 1999.

[4] Afonso, J., and et.al, "Active Filters with Control Based on the p-qTheory" *IEEE Industrial Electronics Society Newsletter*, Vol.47, No.3,pp. 5-11, 2000.

[5] Hingorani, N. G., Gyugyi L., *Understanding FACTS*. IEEE Press. New York, 2000.

[6] Huang, S. J. and. et. al., "A study of three-phase active power filters undernon-ideal mains voltages" *Electric Power Systems Research* 49, pp. 125-137., 1999.