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UPQC CONTROL BASED ON MO-ADALINE APPROACH

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Abstract- In this paper power quality compensation in sag, swell, unbalance, and harmonized conditions have been done by the use of UPQC (Unified Power Quality Conditioner). It consists of two back to back connected Active Power Filters (APFs) with a common DC link. In the present research voltage problems are compensated by the Series Active Filter (SAF) of the UPQC. On the other hand, No.'s related to the compensation of current problems are done by the Parallel Active Filter (PAF) of UPQC. Related control approach is based on the Multi Output ADAptive LINear (MO-ADALINE) approach. Results are presented to confirm the validity of the proposed approach to achieve a high-quality output voltage and current.

Keywords: UPQC, MO-ADALINE, Power Quality.

I. INTRODUCTION

Nowadays, most of the equipments based on power electronic devices used by the industry, lead to power quality problems. These devices not only need high-quality energy to work properly but also are the major cause for decreasing power quality. In these conditions, both electric utilities and customers are increasingly affected from the quality of electric power. Between the different technical approaches available for the compensation of power quality problems, Active Power Filters (APFs) have an important alternative to compensate the power quality problems [1].

Different configurations of APFs can be found in [2]. One of the most efficient solution systems for power quality problems is Unified Power Quality Conditioner (UPQC). The used configurations consist of two shunt and series inverters as current and voltage compensators with a common dc link. Papers [3-19] use, different control systems to compensate the power quality problems of the grid, like current harmonics, reactive power and the source voltage distortions. The scope of this research is to use UPQC for improvement of power quality and main principle of the proposed control theory is based on MO-ADALINE approach. Simplicity and flexibility in extraction of different reference signals can be one of the proposed algorithm advantages.

Section II generally introduces UPQC. Section III explains proposed control algorithm. Section IV simulates paper. Finally section V concludes the results.

In [20], neutral current in three phase four wire systems is compensated by using a four leg PAF for the UPQC. In [21], UPQC is controlled by H∞ approach which needs high calculation demand. In [22], UPQC can be controlled based on the phase angle control for shared load reactive power between SAF and PAF. In [23] minimum active power injection has been used for SAF in a UPQC-Q, based on its voltage magnitude and phase angle ratings in sag conditions. In [24], a DG has been used as an energy resource for the UPQC. In [25-27] two new combinations of SAF and PAF for two independent distribution feeders power quality compensation have been proposed.

II. UNIFIED POWER QUALITY CONDITIONER

UPQC has composed of two inverters that are connected back to back. One of them is connected to the grid via a parallel transformer and can compensate the current problems. Another one is connected to the grid via a series transformer and can compensate the voltage problems. These inverters are controlled for the compensation of the power quality problems instantaneously.

The shunt APF which acts as a current source inverter is responsible for load current harmonics compensation as well as reactive power. It is connected to the grid via a second order LC filter and parallel star connection transformer. Also, the series PAF which acts as voltage source inverter is responsible for source voltage sag, swell, unbalance and harmonics compensation. It is connected to the grid via a second order low pass LC filter and three series single phase transformer.

Figure 1 shows the general schematic of a UPQC. Second order filters are used to omit the inverter switching frequencies.

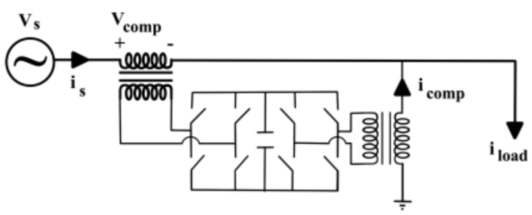

Figure 1. General schematic of a UPQC

A simple circuit model of the UPQC is shown in Figure 2. Series active filter can be modeled as the voltage source and parallel active filter can be modeled as the current source. Related Kirchhoff's current and voltage lows are as Equation (1).

$$i_s = i_L - i_{sh} \qquad v_s = v_L + v_{se} \tag{1}$$

where, i_{sh} is the shunt APF current and v_{se} is the series APF voltage.

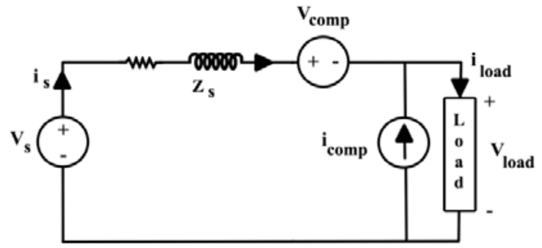

Figure 2. Circuit model of the UPQC

In this paper, the series APF operates as a controlled voltage source arranging the load voltage sinusoidal and at a predetermined constant voltage level. As mentioned earlier in this control approach, series active filter can compensate harmonics as well as voltage sag and swells. Proposed approach can be used for the extraction of direct and indirect first order components of the source side voltage. Thus the magnitude of the reference load side voltage can be setup to the nominal value for generation of desired load voltage. The series APF injects compensator voltage which is a voltage equal to the difference of the desired load voltage and the supply voltage to the grid.

III. PROPOSED CONTROL STRATEGY

Based on MO-ADLINE each $n \times 1$ signal of y can be written as a weighted linear combination of its components. If $S(t)$ be $n \times m$ component matrix of y at time t and $W(t)$ be $m \times 1$ vector of weighted coefficient then, the signal of y can be written as Equation (2). MO-ADALINE can be used for determining weight vector of W which generates a special signal of y from its components [3]. Weighted factors can be updated in each stage of an adaptation approach for extraction of a desired signal. Equation (2) shows adaptation rule that is based on Least Mean Square (LMS) algorithm.

$$y = SW \qquad W(t+dt) = W(t) + kS^T(t)[S(t)S^T(t)]^{-1}e(t) \tag{2}$$

where, $e(t)$ is the error between desired and actual signal of y and k is the convergence factor. It is possible to extract the reference voltage and current from uncompensated source voltage and load current. Fourier coefficients can be determined as vector of y. Reference signal can be determined as W. Matrix of S is constant. After determination of uncompensated signal Fourier coefficients, they can be compared with the desired values. Error signal can be used in adaptation rule for updating the vector of W.

Therefore, reference voltage and current can be determined. For capability of compensation in dynamic condition moving average window Fourier transform has been used for extraction of coefficients. Figure 3 shows block diagram of the proposed MO-ADALINE approach. In the proposed control system there is a data window with the length of the main period of power system which is moved to the right by new data interring for the extraction of the Fourier transforms. This is because of mathematical calculation reduction.

$$y = \begin{bmatrix} a_n \\ b_n \\ a_0 \end{bmatrix} \tag{3}$$

$$S(t) = \frac{2}{m-1}\begin{bmatrix} \cos(n\omega t_0) & \cos(n\omega t_1) & \dots & \cos(n\omega t_{m-1}) \\ \sin(n\omega t_0) & \sin(n\omega t_1) & \dots & \sin(n\omega t_{m-1}) \\ \frac{1}{2} & \frac{1}{2} & \dots & \frac{1}{2} \end{bmatrix} \tag{4}$$

$$W = \begin{bmatrix} w(t_0) \\ w(t_1) \\ \dots \\ w(t_{m-1}) \end{bmatrix} \tag{5}$$

$$\begin{bmatrix} a_n \\ b_n \\ a_0 \end{bmatrix} = \frac{2}{m-1}\begin{bmatrix} \cos(n\omega t_0) & \dots & \cos(n\omega t_{m-1}) \\ \sin(n\omega t_0) & \dots & \sin(n\omega t_{m-1}) \\ \frac{1}{2} & \dots & \frac{1}{2} \end{bmatrix}\begin{bmatrix} w(t_0) \\ w(t_1) \\ \dots \\ w(t_{m-1}) \end{bmatrix} \tag{6}$$

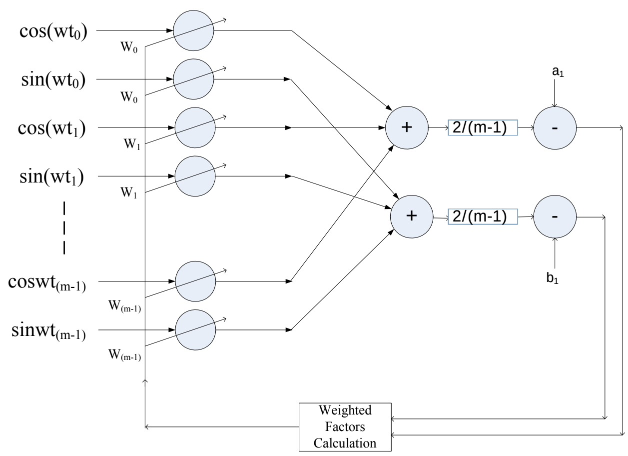

Figure 3. Block diagram of the proposed MO-ADALINE approach

IV. RESULTS

For the investigation of the validity of the mentioned control strategy for power quality compensation of a distribution system, simulation of the test circuit of Figure 1 has been done in MATLAB software. Source current and load voltage have been measured and analyzed in the proposed control system for the determination of the compensator signals of SAF and PAF. Related equations of the controlled system have been compiled in MATLAB software via M-file.

Desired values of a_n and b_n are determined in the proposed algorithm for extraction of the reference signals. Simplicity and flexibility in extraction of different reference signals can be one of the proposed algorithm advantages.

In the mentioned control strategy, voltage problems have been compensated by SAF of the UPQC and current problems have been compensated by PAF of the UPQC. The power system consists of a harmonized and unbalanced three phase 380 V (RMS, L-L), 50 Hz utility, a three phase rectifier as a nonlinear load, a three phase balanced R-L load which is connected to the circuit at 0.04 sec and a one phase load which is connected to the circuit at 0.07 sec.

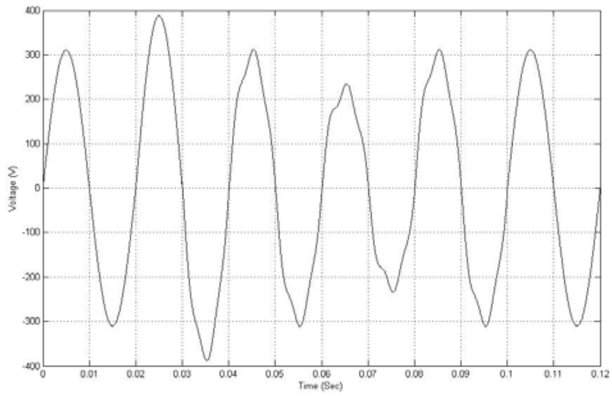

Figure 4. Source side voltage of phase 1

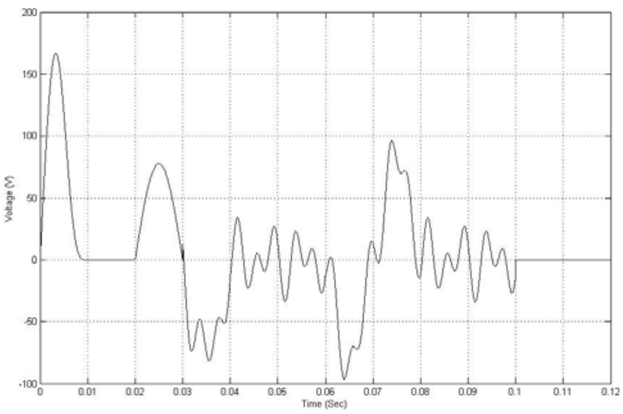

Figure 5. Compensator voltage of phase 1

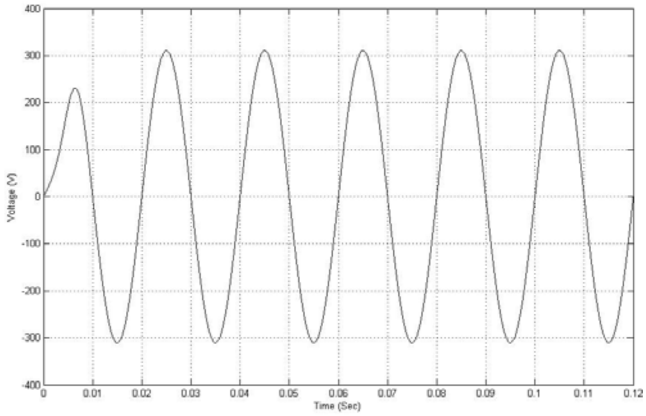

Figure 6. Load side voltage of phase 1

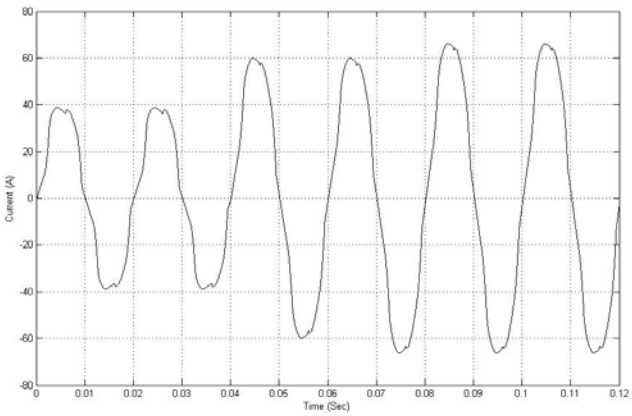

Figure 7. Load side current of phase 1

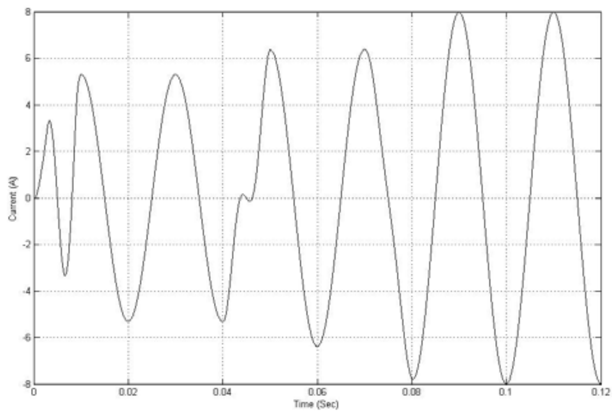

Figure 8. Reactive current of phase 1

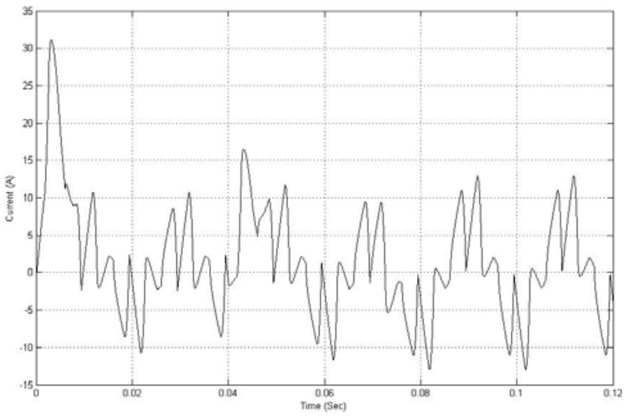

Figure 9. Harmonic current of phase 1

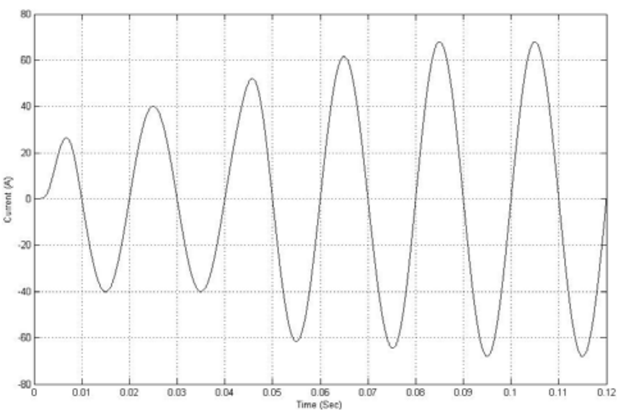

Figure 10. Source side current of phase 1

For the investigation of the voltage harmonic condition, utility voltages have harmonic and negative sequence components between 0.03 sec and 0.1 sec. Also, for the investigation of the proposed control strategy in unbalance condition, magnitude of the first phase voltage is increased to the 1.25 pu between 0.02 sec and 0.04 sec and decreased to the 0.75 pu between 0.06 and 0.08 sec.

A number of selected results will be showed further. Figure 4 shows the source side voltage of phase 1. Figure 5 shows the compensator voltage of phase 1. Figure 6 shows load side voltage of phase 1. Figure 7 shows the load side current of phase 1. Figure 8 shows the reactive current of phase 1. Figure 9 shows the harmonic current of phase 1. Finally, Figure 10 shows the source side current of phase 1. Table 1 shows THDs of source and load voltages and currents. Load voltage and source current harmonics have been compensated satisfactory.

Table 1. Total Harmonic Distortion (THD)

Source Voltage THD	Load Current THD	Load Voltage THD	Source Current THD
0.17	0.12	Almost zero	Almost zero

V. CONCLUSIONS

It is known that active filters are generally used for compensation of voltage and current problems in distribution systems. In this paper power quality compensation has been done by the use of UPQC. The related proposed control algorithm based on MO-ADALINE approach has been compiled in MATLAB software via M-File. Voltage harmonics have been compensated by SAF of the UPQC and current harmonics have been compensated by PAF of the UPQC. Based on the results proposed strategy not only can generate pure sinusoidal source current and load voltage but also can compensate source reactive power satisfactory. Total harmonic distortion of load voltage before compensation was 0.17 which was reduced to almost zero after the compensation. Also, total harmonic distortion of the source current before compensation was 0.12 which was reduced to almost zero after the compensation.

NOMENCLATURES

i_L : The load current

v_s : The source current

$S(t)$: $n \times m$ component matrix at time t

$W(t)$: $m \times 1$ vector of weighted coefficient

$e(t)$: The error between desired and actual signal

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