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CONTROL OF ACTIVE POWER FILTERS BY USING DSPACE 1103 CONTROL BOARD

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Abstract: The paper presents some results obtained with the dSPACE 1103-based control system of a parallel Active Filter (AF) compensating current harmonics of a non-linear load. The main aim of the study was to evaluate the possibilities of the system dSPACE 1103 to control fast dynamics of the AF.

Keywords: Parallel active filters, digital control algorithms.

1 Introduction

The control system DS1103 is determined especially for rapid prototyping of digital controllers working with sophisticated algorithms. The whole system is located on one standard PC/AT board. With host PC it can communicate via ISA-bus or Ethernet.

The reference values of compensation currents of the Active Filter (AF) are calculated from the measured load currents by using proper signal filters that remove the fundamental harmonics of the phase load currents, Fig. 1. By using these reference currents, actual AF currents, and a model of the output high frequency filters at ac terminals of the AF, the reference voltages of the AF are calculated in the synchronously rotating reference frame of two *d*, *q* axes.

2 Control algorithm

The currents in two phases of the load and the AF are measured as well as the mains voltages and voltage on the dc capacitor of the AF. Between the Point

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of Common Coupling (PCC) and ac terminals of the AF the high frequency filter is located, which reduces current component with switching frequencies.

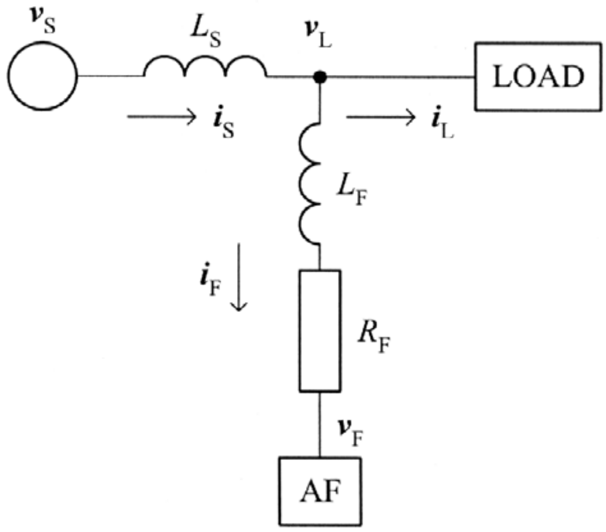

Fig. 1. Block diagram of the implementation of the parallel AF

The equation of the branch with the parallel AF, expressed in the static reference frame, reads

$$\mathbf{v}_L = \left(R_F + L_F \frac{\mathrm{d}}{\mathrm{d}t} \right) \mathbf{i}_F + \mathbf{v}_F$$

After the transformation into the reference frame rotating with the angular velocity ω_1 and the decomposition into real and imaginary parts we obtain

$$v_{Fd} = v_{Ld} - R_F i_{Fd} - L_F \frac{\mathrm{d}i_{Fd}}{\mathrm{d}t} + \omega_1 L_F i_{Fq}$$

$$v_{Fq} = v_{Lq} - R_F i_{Fq} - L_F \frac{\mathrm{d}i_{Fq}}{\mathrm{d}t} - \omega_1 L_F i_{Fd}$$

The reference values of the AF output voltages v^*_{Fd}, v^*_{Fq} can be calculated as follows

$$v^*_{Fd} = v_{Ld} - R_F i^*_{Fd} + \omega_1 L_F i^*_{Fq} + K_P \Delta i_{Fd} + K_I \int \Delta i_{Fd}\, \mathrm{d}t$$

$$v^*_{Fq} = v_{Lq} - R_F i^*_{Fq} - \omega_1 L_F i^*_{Fd} + K_P \Delta i_{Fq} + K_I \int \Delta i_{Fq}\, \mathrm{d}t$$

where

$$\Delta i_{Fd} = i^*_{Fd} - i_{Fd}$$

$$\Delta i_{Fq} = i^*_{Fq} - i_{Fq}$$

and

$$i^*_{Fd} = -\tilde{i}_{Ld} + i^*_C = -\left(i_{Ld} - \bar{i}_{Ld} \right) + i^*_C$$

$$i^*_{Fq} = -i_{Lq}$$

if the load voltage $\mathbf{v}_L = v_{Ld}$ $(v_{Lq} = 0)$ is chosen to lie in coincidence with the axe d of the system and we need to compensate for a full reactive power of the load.

The dc component $\bar{i}_{Ld}$ in the synchronous reference frame of the axis d,q is determined by passing the current i_{Ld} through a low pass filter. This component represents the fundamental harmonics of the load current, thus the fluctuating component $\tilde{i}_{Ld}$ of this current involves all other current harmonics that should be compensated for. The current i_C^* is the output signal of the voltage controller of a dc link voltage v_C of a voltage-type inverter of the AF.

If the AF current $\mathbf{i}_F$ is fully decoupled, the open loop transfer function in both the axes d, q may be written in the form

$$F_0(p) = \frac{K_P}{R_F} \frac{T_I p + 1}{T_I p} \frac{1}{T_F p + 1}$$

where

$$T_F = L_F / R_F, \quad T_I = K_P / K_I .$$

Choosing $T_I = T_F$, the close loop transfer function reads

$$F_W(p) = \frac{1}{\frac{L_F}{K_P} p + 1} = \frac{1}{T_W p + 1} .$$

The time constant T_W should be chosen with respect to the switching frequency of the PWM applied and the sampling period of a DSP. By such a way, the constant $K_P = L_F / T_W$ is determined and the second parameter K_I can be calculated as $K_I = K_P / T_F$.

Fig. 2 shows the main control blocks of the parallel AF. On the basis of the measured phase currents of the load and the AF, their components in the synchronous reference frame are calculated. In the block of the controller the reference currents of the AF are determined by removing the fundamental components from the load currents, the current errors of the AF enter the current PI controllers, the outputs of which are detuned by applying a two axes model of the switching frequency filter.

The reference values of the AF output voltages are then transformed into phase variables that enter the PWM block.

3 Experimental results

The time responses of real AF currents are influenced by many factors, among which the most important are:

1) In case of an unsymmetrical voltage system the quality of current harmonics mitigation depends strongly on the way of synchronization of control algorithm to the voltage system at the PCC.

2) The measured load currents are usually disturbed by the function of switching

elements of the inverter. Appropriate high frequency filters as well as synchronization of the measurement of these load currents with the function of the PWM algorithm may improve the quality of the AF current responses significantly.

3) A good compensation of dead times of switching elements (e.g. IGBT) is also a necessary condition for obtaining desirable AF current responses.

4) In case of a full digital control of the AF a definite sampling frequency results in some time delays that are not negligible, especially in fast current control loops. Proper prediction current control algorithms may improve the quality of current control substantially.

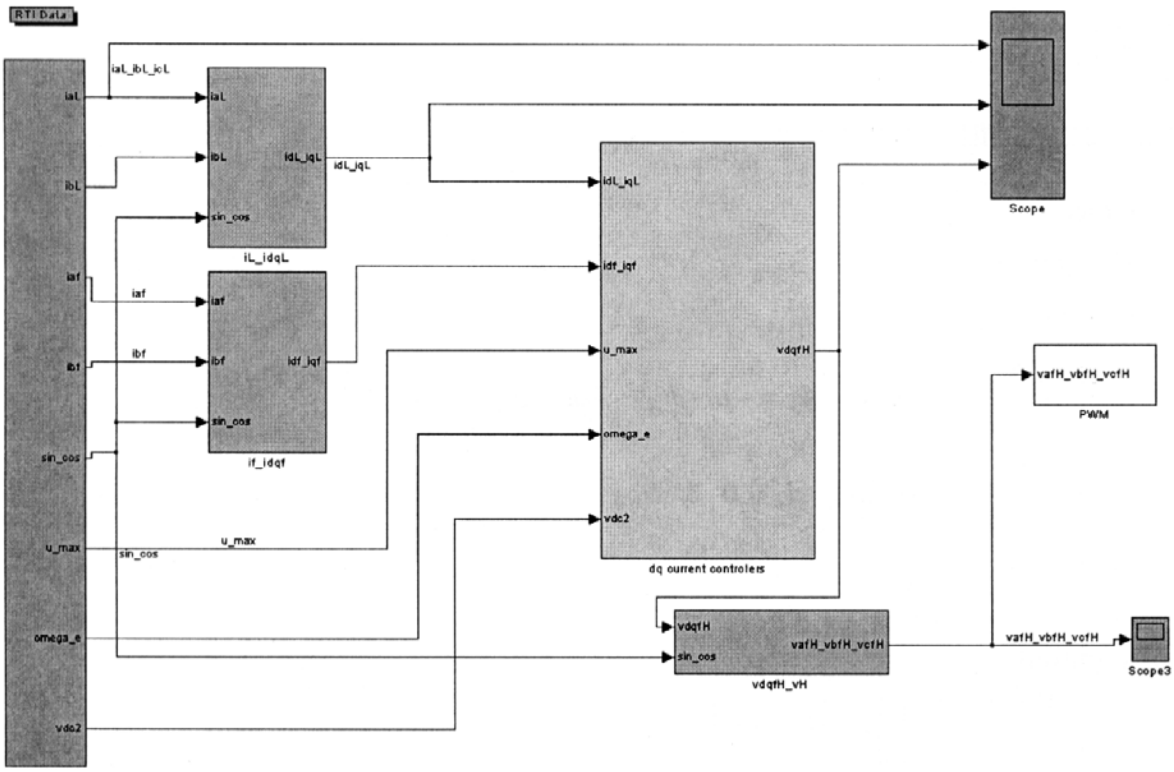

Fig. 2. Basic control blocks of the parallel AF

Fig. 3 presents the control panel of dSPACE 1103-based controller with the AF reference and measured current in *d* axis. The first three items mentioned above have been respected, but none predictive algorithm has been used. It is evident that the real current is not able to follow its reference path ideally, which leads to limited frequency range of load current harmonics that may be compensated for. The sampling period of the controller is 50 μs with a sufficient reserve, so we plan to implement some type of predictive algorithm to enlarge the band wide of the controller.

Fig. 4 shows measured phase current in the mains when AF is in function and Fig. 5 compares harmonic spectra of the load current and compensated current in the mains.

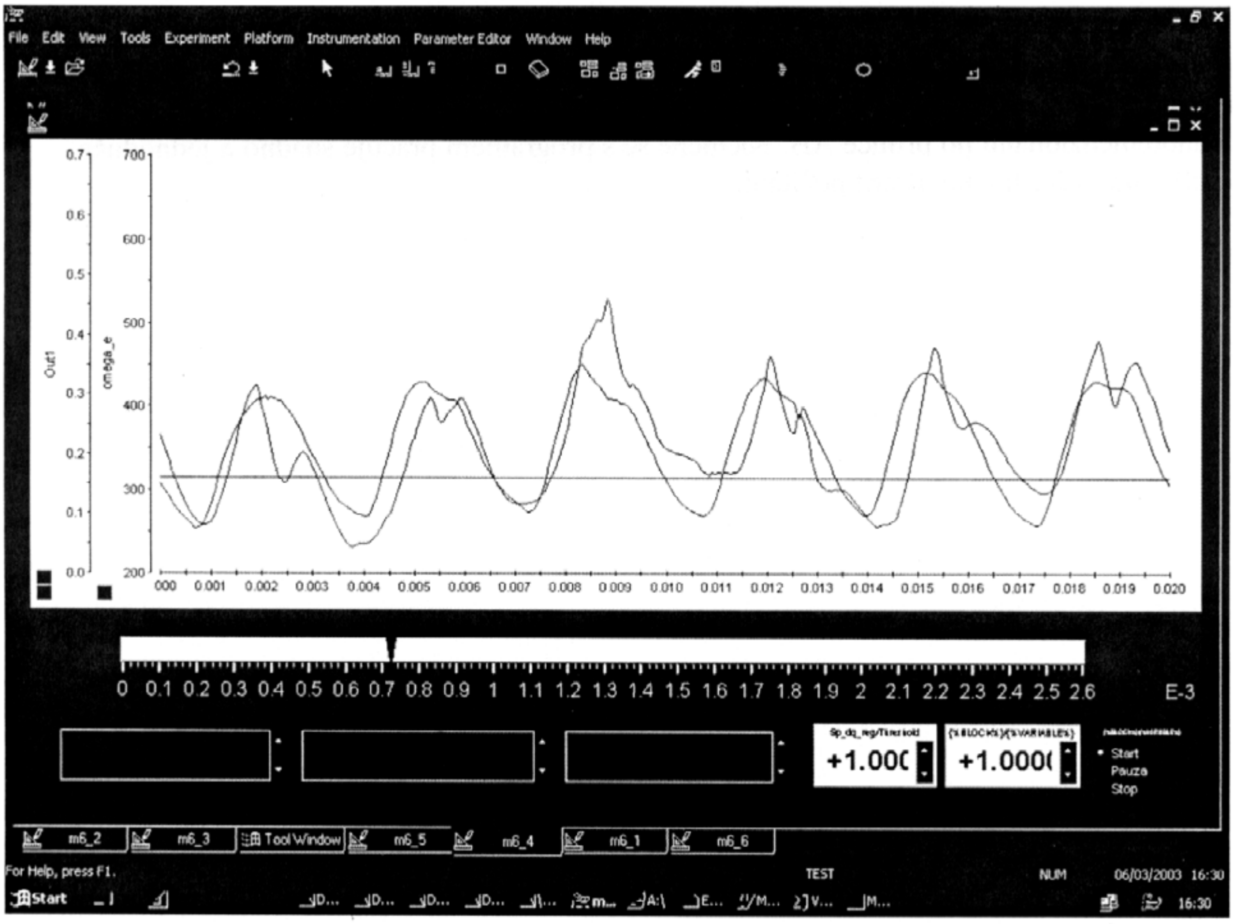

Fig. 3. Control panel of dSPACE 1103-based controller
with the AF reference and measured current in *d* axis

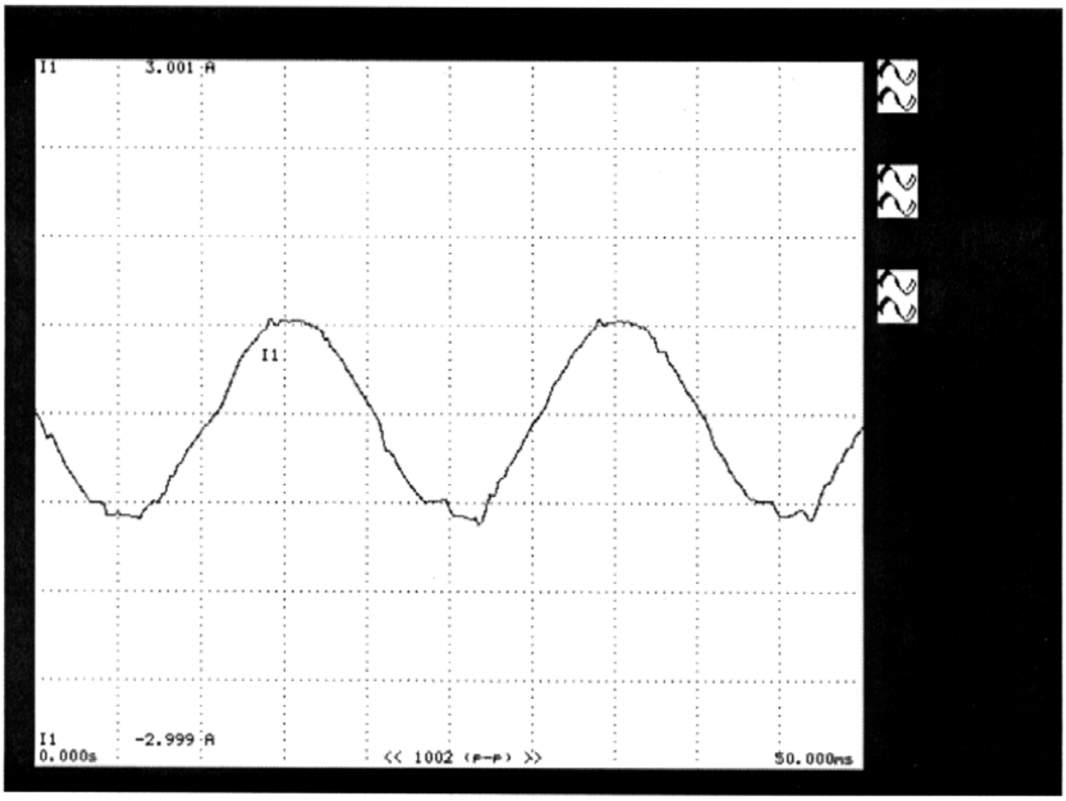

Fig. 4. Measured phase current in the mains when AF is in function

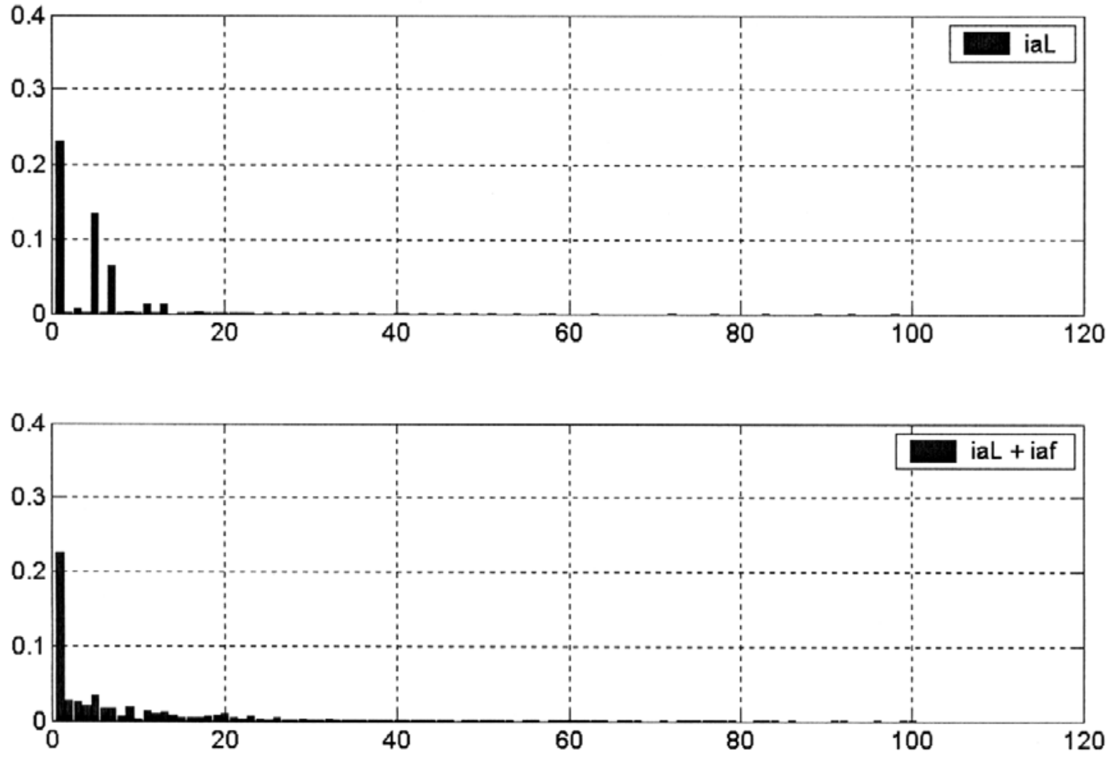

Fig. 5. Harmonic spectra of the load current and compensated current in the mains

4 Conclusion

The control system of the parallel AF realized by using dSPACE 1103 system makes it possible an effective fully digital control of the AF with an appropriate short sampling interval. Thus such an AF could compensate even harmonic load currents of high orders. The system is suitable for the effective research and rapid prototyping of different control strategies.

5 Acknowledgement

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