A wide-band power electronics current source in reference current generator

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The paper considers wide-band voltage controlled power electronics current source. The current source has been designed as a part of 1-channel reference current generator designed for current meters testing. The control module of the generator utilizes a specialized Analog Devices Inc. DSPs based microcomputer module for power electronics applications. Used solutions have allowed obtain high quality referencing of the output current within reference signal. The paper presents the structure and selected aspects of the control algorithm of the current source. Also selected investigations results of the laboratory prototype of generator are presented.

KEYWORDS: control algorithm, DSP, inverter, PWM, stability of an electrical system

1. Introduction

Fast changes of parameters of electrical energy receivers as well as non-linearity of power inverters are reasons that decrease exactitude of inverters output signals within reference ones. To improve this more advanced solutions of power electronics systems have been considered. One of these is wide-band voltage controlled current source [3]. This special inverter may found many applications, for example as execution block of compensators of: currents deformation in power grid [2, 9], systems with Unified Power Flow Controllers (UPFC) [1], power electronics reference generators, modern electrical drives [4] and also equipment for medicine [5, 7].

The paper presents the structure and selected aspects of the control algorithm of the current source. Also selected investigations results of the laboratory prototype of generator with utilization of controlled current source are presented.

2. Structure of the generator

Proposed structure of controlled current sources basis on work of these systems in closed loop of negative feedback, controlled in PWM mode with constant value of carrier frequency. The classical regulators of output current are replaced there by wide-band digital IIR and FIR filters. These solutions essentially increase both, static and dynamics parameters of such current sources [3] as well as reliability.

The passive (LC) low-pass filter at output of inverter limits undesirable products of pulse modulation (within output current) and radiation of electromagnetic noises as well.

The simplified diagram of the power electronics reference current generator is shown in Fig. 1. The generator consists of two main blocks:

- the reference signal generator (RSG),
- the power electronics voltage controlled current source (VCCS).

The RSG is able to generate reference signal u_{REF} with desired shapes, being the sum of selected harmonics (reference signal is synthesized one). VCCS is the execution block of generator system.

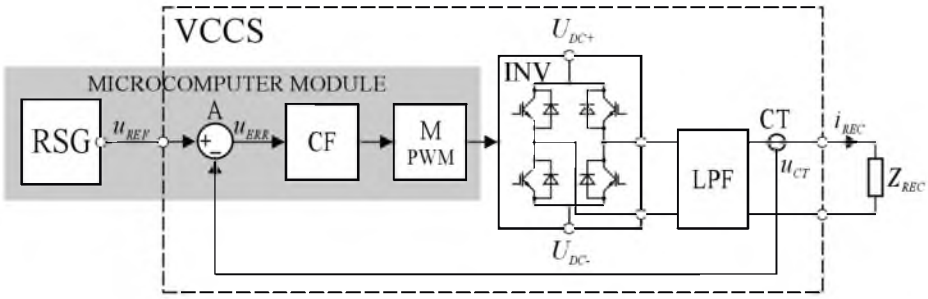

Fig. 1. The block diagram of the reference current generator

Within the VCCS following blocks can be found: the adder (A) producing the error signal: $u_{ERR} = u_{REF} - u_{CT}$, the correction filter (CF), the pulse width modulator (M), the H-bridge power electronics inverter (INV), the passive low pass filter (LPF) and the current transducer (CT). The VCCS works in negative, voltage type, feedback loop. The feedback voltage u_{CT}, being proportional to the output current i_{REC}, is generated by the current transducer (CT).

3. Issue of the system stability

The basic problem of developing discrete-time systems, working in closed feedback loop depends on, that un-stable work of such systems occurs if total gain of system is equal 1 or more. Necessity of using at output of inverter a passive low-pass filter seriously increases possibility of unstable work of a system. Thus utilization of special methods for correction of system transfer function is necessary. In flexibility of control process respect, the most relevant part of system is just the correction filter (CF), that transfer function is given by a general equation:

$$K_{CF}(s) = K_{\Delta}(s)\frac{1}{F_O(s)} \tag{1}$$

where: $F_O(s)$ – transfer function of output filter including the receiver, $F_\Delta(s)$ – transfer function of a control signal parameters correction block (this block is a part of the CF).

The general task of the CF depends on minimization the signal phase shift (delay) in the system signal path caused (mainly) by:
- the output filter,
- the control signal (u_{ERR}) delay, being characteristic for discrete-time systems,
- the output signal (i_{REC}) delay caused by pulse modulator.

The first task of the CF is realized by a $\frac{1}{F_O(s)}$ component of the CF transfer function, while the second and third ones by a $F_\Delta(s)$.

In other words, the CF should suitable shape the transfer function of the system in aid of obtaining its wide pass-band and maximal value of open loop gain – under condition of the system stability preserving. These demanding have fundamental influence at exactitude of referencing the output signal i_{REC} within the reference one. The VCCS control module uses over-sampling technique also, what lets minimize affect of aliasing phenomena at control algorithm [6]. In some cases utilization of specific signal processing solutions in a control algorithm is necessary [8].

4. Laboratory prototype of the reference current generator

In order to check correctness of theoretical assumptions, laboratory model of generator with power electronics current source has been investigated. That model has utilized, for control tasks, multi-DSP microcomputer module in form of PCI card type ALS-G3-2368 [10] (Fig. 2) with ADSP-21368 SHARC™ DSPs and ALS-G3-ACA1812-1 Analog-Front-End Extension Card [11]. In the execution block of the system the IPM/IGBT based H-bridge inverter has been utilized with the Γ-type passive low-pass filter at its output.

Basic features of laboratory prototype of the reference current generator have been as follows:
- the nominal value of amplitude of output current (i_{REC}): 25 A,
- the power supply of DC link of inverter: 2-pulse rectifier with approx. 100 V of the output voltage; the rectifier has been connected to 230V/50 Hz power network across a power transformer,
- the system sampling frequency: 100 kHz,
- the PWM modulation: two sided and unipolar, carrier frequency: 12.5 kHz,
- the receiver impedance: Z_{REC} =0.001÷0.1 Ω.

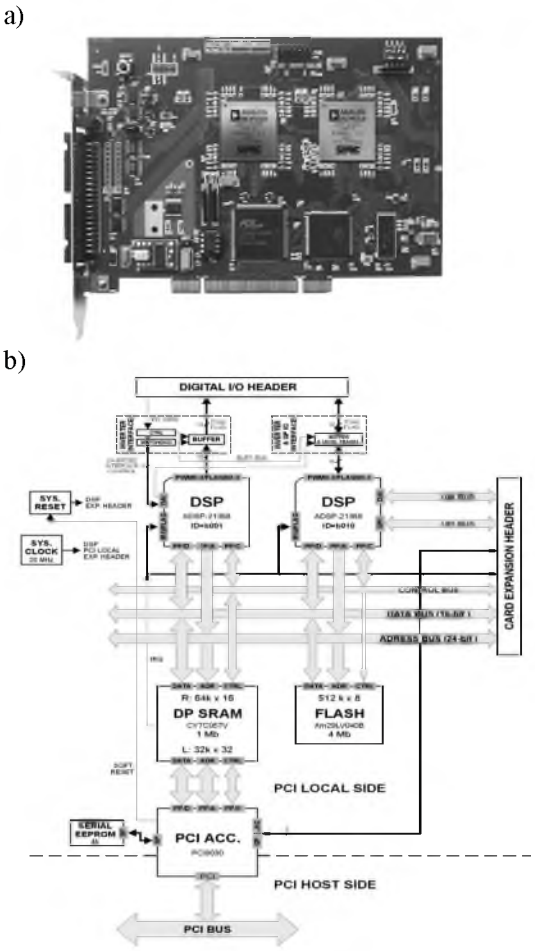

Fig. 2. General view (fig. a) and block diagram (fig. b) of the multi-DSP PCI card type ALS-G3-2368 (ALFINE-TIM) for power electronics control purposes with Analog Devices Inc. ADSP-21368 SHARC DSPs

In Fig. 3 selected reference voltage u_{REF} and receiver (output) current i_{REC} waveforms are shown for three different cases of reference signal shape.

The laboratory investigations of the generator prototype have let evaluate of its both, static and dynamic parameters. All tested cases of reference voltage have shown good mapping of output current within reference voltage – with such limitation that fundamental harmonic of the reference signal have not exceeded 500 Hz. The pass-band of VCCS has been approximately 2.6 kHz.

The THD of output current (for 50 Hz of fundamental frequency and its nominal amplitude value) has not exceeded 0.25 %.

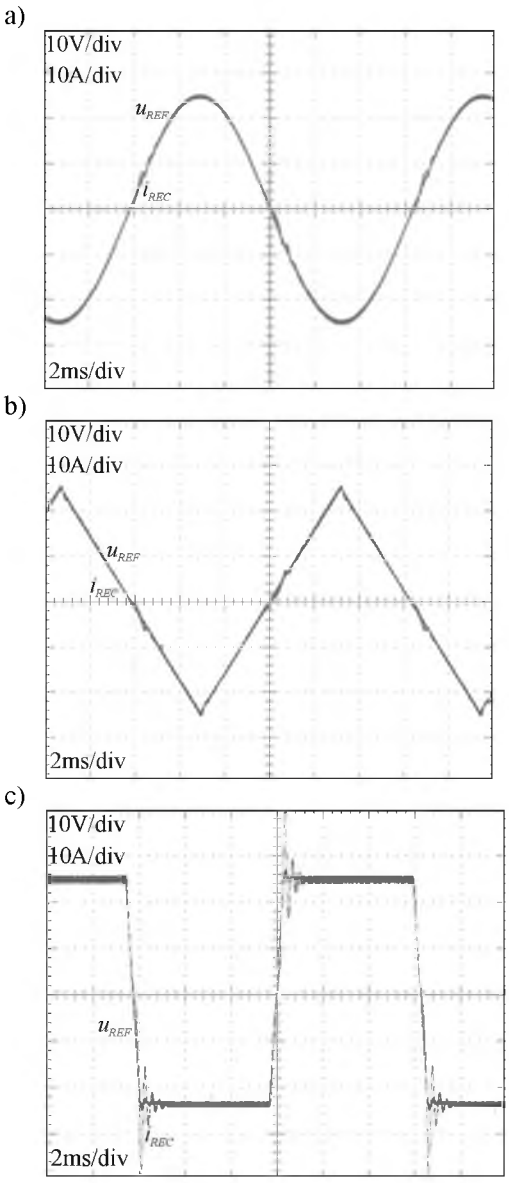

Fig. 3. Investigation results of the laboratory prototype of generator – waveforms of the reference signal and receiver (output) current for following cases of the reference signal: a) sinusoidal, b) triangular and c) trapezoidal. Amplitude of reference signal is 100% of the nominal value while its fundamental frequency is 80 Hz

Thanks utilization of the low-pass filter at the output of inverter an amplitude of PWM carrier component in the output current has been essentially lowered.

5. Summary

Investigation results show that established aim of the work depending on designing the precision current generator for reference purposes has been achieved. Effective control algorithms give possibility of stable work of the essential part of this system, i.e. the voltage controlled current source. The passive low-pass filter at the output of the inverter has essentially increased suppression of both, undesirable PWM products within output current and radiation of electromagnetic noises.

It seems necessary to continue investigations of such type of an advanced power electronics converters. The reason is their unique advantages and possibilities of direct utilization in modern power electronics equipment.

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