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THE POWER ELECTRONICS CONTROLLED CURRENT SOURCE UTILIZED IN THE REFERENCE CURRENT GENERATOR

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 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 laboratory prototype of generator with utilization of controlled current source are presented.

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 laboratory prototype of generator with utilization of controlled current source are presented.

2. THE 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

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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 on 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.

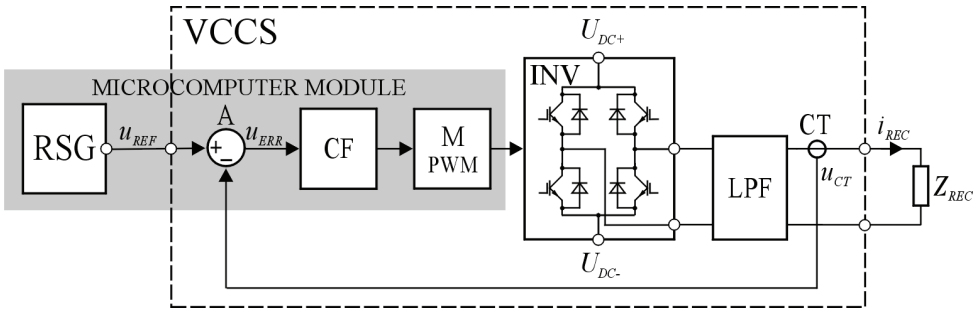

Fig. 1. Block diagram of the reference current generator

Within VCCS following blocks can be found: adder (A), producing the error signal $u_{ERR} = u_{REF} - u_{CT}$, correction filter (CF), pulse width modulator (M), H-bridge power electronics inverter (INV), passive low pass filter (LPF) and 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. THE 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 correction filter (CF), that transfer function is given by 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 control signal parameters correction block, being the part of the CF.

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

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

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 input 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 special solutions of signal processing in a control algorithm is necessary [8].

4. THE LABORATORY PROTOTYPE OF THE REFERENCE CURRENT GENERTOR

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 the output current (i_{REC}): 25 A,
- the power supply of DC link of inverter: 2-pulse rectifier with approx. 100 V of output voltage connected to 230V/50 Hz power network; isolated from the network,
- the system sampling frequency: 100 kHz,

– the PWM modulation: two sided, unipolar, the carrier frequency: 12.5 kHz,
– the receiver impedance: Z_{REC} =0.001÷0.1 Ω.

a) b)

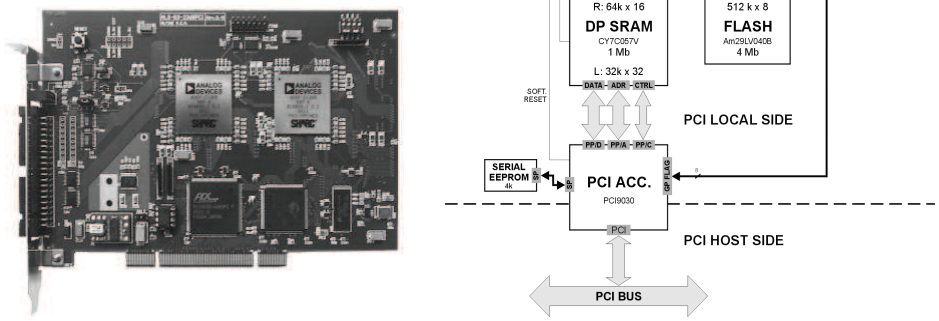

Fig. 2. General view – fig. a), and block diagram – fig b), of multi-DSP PCI card type ALFINE-TIM ALS-G3-2368 for power electronics control purposes with Analog Devices Inc. ADSP-21368 SHARC™ DSPs

At Fig. 3 selected reference voltage u_{REF} and receiver (output) current i_{REC} waveforms are shown – for the case of sinusoidal shape of the reference signal.

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 %.

Thanks utilization of the low-pass filter at the output of inverter PWM carrier components within the output current have been essentially suppressed.

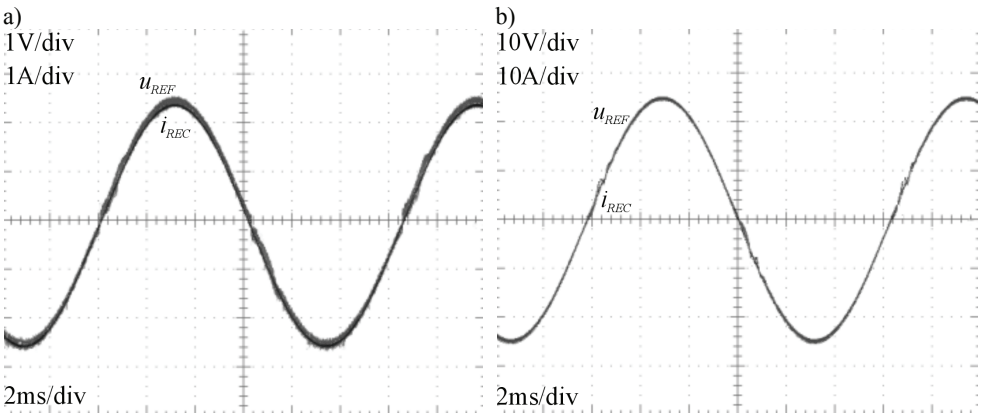

Fig. 3. Laboratory prototype of generator – waveforms of reference voltage (blue curve) and receiver (output) current (red curve) for case of sinusoidal shape of reference signal. Amplitude of reference signal: a) 10% of nominal, b) 100% of nominal value. The fundamental frequency of the reference signal: 80 Hz

5. SUMMARY

Investigation results show that established aim of work depending on designing the precision current generator for reference purposes has been achieved. Effective control algorithms give possibility of stable work of essential the part of this system – 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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