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THE REAL-TIME SIMULATOR OF AN ELECTRIC DRIVE WITH A SQUIRREL-CAGE INDUCTION MOTOR

Introduction. A development of complex electromechanical systems with electrical drives requires testing before applying in real conditions. Nowadays, real-time digital simulators of electromechanical and electric power systems are used in tests. It is subject of a scientific research. One of other interesting ideas is real-time emulator of induction motor, which is implemented in FPGA using floating point representation [1]. Such approach allows simulating induction motor with different parameters and in different conditions without losing precision. The main purpose of real-time simulation presented in [2] is to provide an efficient, cost-effective and secure way of testing the control system of an electric drive. Therefore, the electric motor and converter are simulated using a time-step of about 50 μs. In [3,4] is presented the RT-LAB simulation software enables the parallel simulation of electrical circuit on PC-clusters running QNX or RT-Linux operating systems at sample time below 10 μs. The paper presents a real-time simulator of an electric drive with a squirrel-cage induction motor, based on PC with two-core processor, running Microsoft Windows XP Professional operating system at sample time equal 0,25 ms.

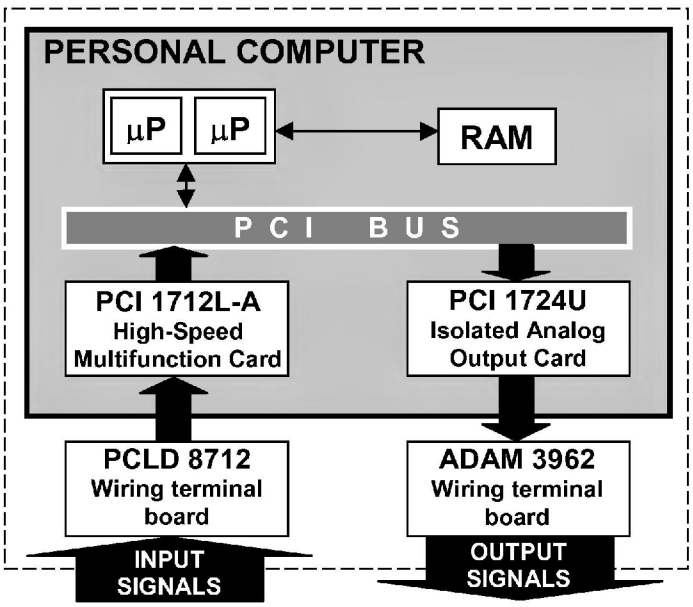

Fig. 1. Structural scheme of the simulator

Hardware Technology. The hardware technology for real-time simulators of power systems was presented in [5]. The structural scheme of the simulator is showed in Fig. 1. At the heart of presented simulator is a personal computer. This computer is based on the motherboard, with a 2,8 GHz two-core Intel Pentium processor. The PCI 1712L is a powerful high-speed multifunction card for PCI bus. It features a 1 MHz 12-bit A/D converter, an on-board FIFO buffer (storing up to 1K samples for A/D, and up to 32K samples for D/A conversion). The PCI 1712L provides a total of up to 16 single-ended or 8 differential A/D input channels or a mixed combination. PCI 1724U is an isolated high-density multiple channel analog output card for the PCI bus, where each analog output channel is equipped with a 14-bit D/A converter. The input and output is connected with the card by a wiring terminal board – PCLD 8712 and ADAM 3962 respectively.

Software. The simulator running Windows XP Professional uses Rapid Driver version 2.1.4.11. to direct communication with interface cards registers. The simulated electric drive consists of a squirrel-cage induction motor supplied by three-phase voltage source and loaded by mechanical device with a load torque. The load torque is an input signal for the simulator. The mathematical model of the electric drive was implemented in Borland Builder C++.

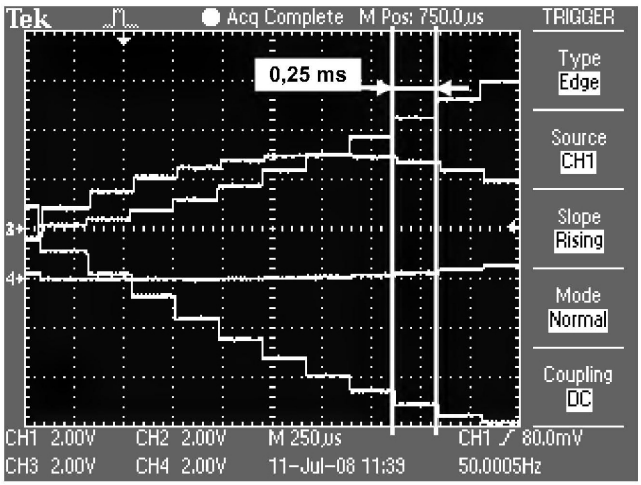

Fig. 2. The simulation time-step

The mathematical model of an induction machine it was assumed that the magnetic core is of a classic construction, where three phase windings are displaced on the stator and rotor (and in case of a squirrel-cage motor – compact winding on the rotor). Machine windings approximated are with symmetric windings of continuous sinusoid distribution. Power loss in magnetic core and the phenomenon of current displacement in rotor windings were not taken into account of. Magnetic field was considered as three independent parts: main field (taking account of nonlinearity caused by core

saturation), leakage field of stator windings, and leakage field of rotor windings [6].

For calculations are used following numerical recipes: linear differential equations solved using the Gear method, nonlinear algebraic equations solved using the Newton method and algebraic equations solved using the Gauss elimination with complete pivoting.

Case study. The simulator was tested for a squirrel-cage induction motor Sg 189 160L-6 (INDUKTA product). Rated parameters of this machine are: 11 kW; 220/380 V; 39,8/23 A; 960 rpm; $\cos\phi = 0{,}82$. The parameters for mathematical model of this machine are: resistance of phase stator and rotor winding is 0,36 Ω; leakage inductance of phase stator and rotor winding is 3,2 mH; and the magnetization characteristic of main magnetic circuits is expressed by following formulae: $\Psi_\mu(i_\mu) = -0{,}0223132 \cdot i_\mu + 1{,}7956254 \cdot \arctan(0{,}0554401 \cdot i_\mu)$, for $i_\mu <= 31{,}112698$ A; and $\Psi_\mu(i_\mu) = 0{,}0006953 \cdot i_\mu + 0{,}7797644 \cdot \arctan(0{,}3934468 \cdot i_\mu)$, for $i_\mu > 31{,}112698$ A.

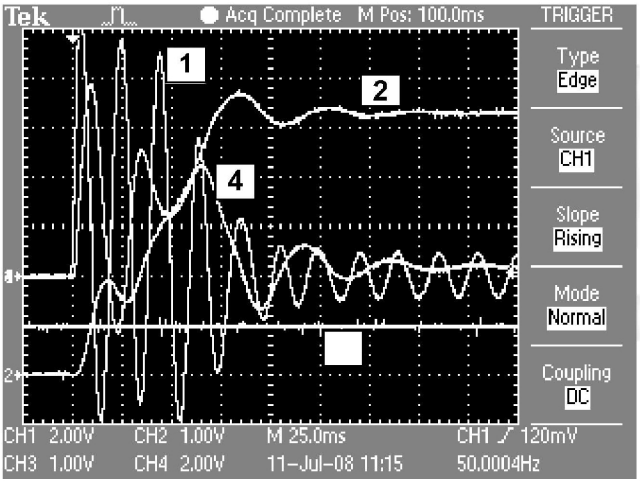

Fig. 3. Start-up of induction motor

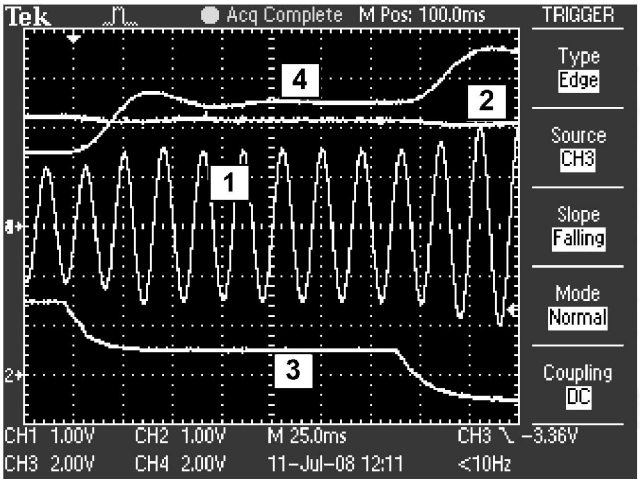

Fig. 4. Change of load torque

where: 1 – current (phase A) [×20 A/V]; 2 – angular rotor speed [×20 rad/(V·s)]; 3 – load torque [×20 N·m/V]; 4 – electromagnetic torque [×50 N·m/V for Fig. 3. and ×20 N·m/V for Fig. 4].

Fig. 2. shows that the time-step occur when the simulator operates. Simulation time step is equal 0,25 ms. It is time for calculations of differential equations in mathematical model and time for signal converting. Fig. 3. shows the real-time simulation results of electric drive start-up with 20 Nm load torque. The second case is load torque step. The results of this case is showed in Fig. 4. In Fig. 3. and Fig. 4. are showed following variables: current of phase winding (1), rotor speed (2), load torque (3) and electromagnetic torque of machine (4).

Conclusions. This paper presents the real-time simulator of an electric drive with squirrel-cage induction motor, which operates with 0,25 ms time-step. Examples and simulation results demonstrate its speed, precision and robustness. Proposed simulator may be used for testing real control systems of electric drives.

This paper includes part results of scientific research of real-time simulators in Electrical Engineering Institute of University of Technology and Life Sciences in Bydgoszcz.

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