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ESTIMATED AND ACTUAL SPEED OF INDUCTION MOTOR FED FROM DTC INVERTER

INTRODUCTION

Up-to-date frequency converters, which include DTC (Direct Torque Control) inverters [2, 3, 6, 7, 9], do not require an additional tachometer feedback in their control systems. Their performance does not differ from that of d.c. drives. Reconstruction of an electromagnetic torque in a drive with a DTC converter, under condition of wide regulation of the angular speed, is possible because an induction motor model is implemented in the converter microprocessor control system [1, 3, 7, 9]. In the control system architecture, a speed estimator plays a principal role. On the basis of the voltage-current state of the motor, it carries out real-time reconstruction of its speed [8, 9]. Estimation of the speed reconstruction error on the basis of the motor model enables correct control of the drive without measurement of the actual speed, especially in dynamic states. This advantage plays role in design of complex drive systems, because makes it possible to abandon the speed measurement. Determination of relations between the actual and estimated speed is an important problem and can be analyzed with reference to both modeled and real systems. Works [3, 5] present comparison of these speeds obtained from computer simulation carried out for the assumed mathematical model of the drive and estimators of the torque and speed. Another method of analysis of the speed reconstruction accuracy is presented by authors of paper [8], who compare speed from the real system with that calculated from a dynamic model of the motor fed from a DTC converter.

The subject of this paper is evaluation of consistence of the speed estimated numerically by a DTC converter and the actual speed recorded by a computer. To obtain complete information about the electromagnetic state of the drive, we simultaneously recorded the electromagnetic torque generated by the drive loaded by torque containing a component resulting from eccentricity of the mechanical subsystem. Analysis of electromechanical systems of this type is important when DTC converters are installed in metallurgical roller table drives, in which eccentric movements of the rollers occur.

INVESTIGATION OF DRIVE SYSTEM WITH ECCENTRIC LOAD

A real roller table drive was replaced in the laboratory with an electro-mechanical unit consisting of a 4 kW asynchronous cage motor coupled eccentrically with a d.c. generator. A diagram of the supply and control system is shown in Fig.1.

Induction motor M is fed from the DTC converter type ACS600, controlled by an autonomous computer with DriveWin program. In the experiment, we carried out a start-up and reverse for command speed n=±500 rpm at the load with stationary torque component of $0.3M_N$. Communication between the converter and the computer was realized with the use of a fiber-optic link, which ensured elimination of electromagnetic disturbances during signal transmission.

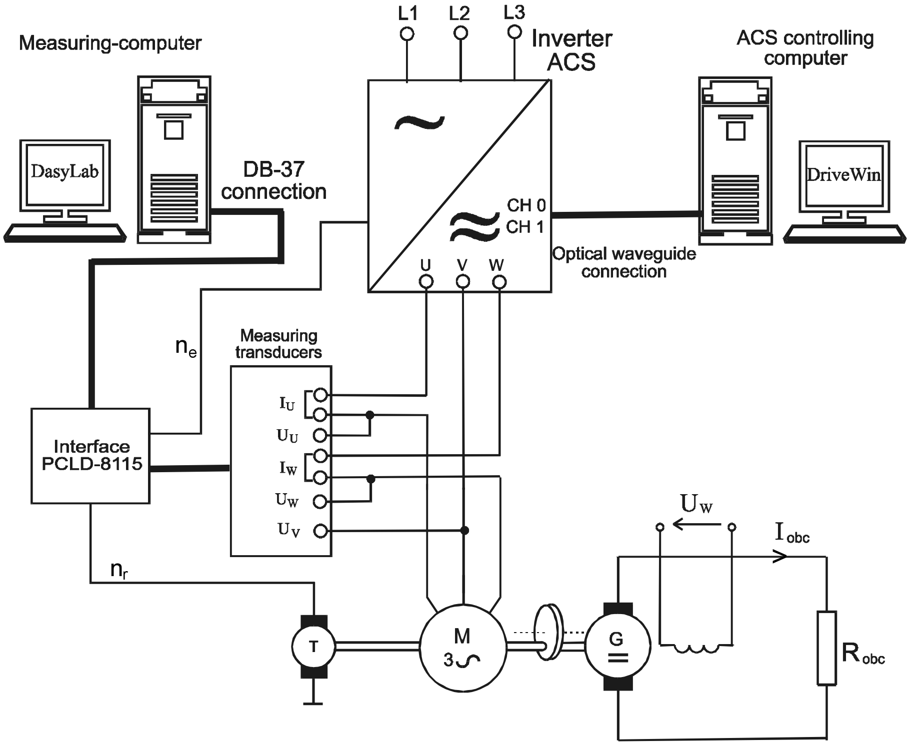

Fig.1. Diagram of measurement and control system of an asynchronous drive with DTC inverter/

Measurements of the electro-mechanical quantities (I_U , I_W, U_{UV}, n_e, n_r) were carried out with the use of the PCL-818HD data acquisition card at sampling frequency up to 100 kHz. The card was controlled by DasyLab software [10]. Galvanically separated current and voltage signals were obtained from measuring transducers type LEM [11].

Two characteristic dynamic states of the drive operation, i.e. start-up and reverse, are illustrated in Fig.2 and 3. Changes of the actual speed and electromagnetic torque generated by the motor fed from the DTC converter are representative electro-mechanical waveforms for the case of eccentric load of the drive. For comparison, we recorded – with the aid of DasyLab software – changes of voltage signal corresponding to the estimated speed calculated from the motor model implemented in the DTC converter control algorithm.

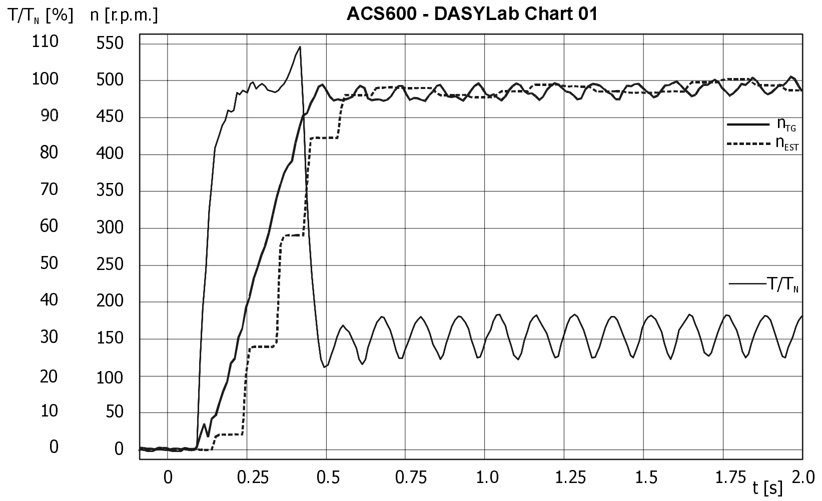

Fig.2. Waveforms of the actual speed n_{TG}, estimated speed n_{EST} and relative torque T/T_N at the drive start-up for the set speed n = 500 rpm.

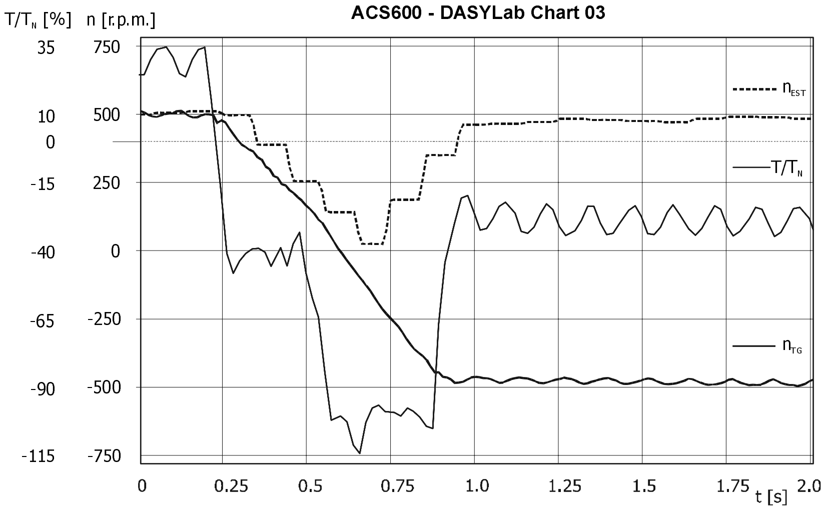

Fig.3. Waveforms of the actual speed n_{TG}, estimated speed n_{EST} and relative torque T/T_N at the drive reverse for the set speed n = 500 rpm.

Analysis of the electro-mechanical waveforms in the drive with an eccentric component of the load shows that:

1. Torque fluctuations occur in the steady state at frequency corresponding to the command speed. The frequency satisfies equality:

$$f_n = n_z/60\ [\text{Hz}] = 1/\tau_{Mel}\ [\text{Hz}] = 8.33\ \text{Hz} \tag{1}$$

Amplitude of the torque component resulting from the load character is $0.06T_N$.

2. Periodic component of frequency f=8.33 Hz and initial phase shifted by $\pi/2$ with respect to the torque variable component also occurs in the actual speed waveform in the obtained by integration according to relation:

$$\omega = k\int_0^T (M_{el} - (M_{st} + M_{eks}(\omega)))dt \tag{2}$$

3. During the start-up, which takes about 0.5s, the electromagnetic torque attains its nominal value, which is calculated by the microprocessor system on the basis of the initial drive identification and pre-entered nominal parameters of the motor.

4. The estimated speed of rotation is obtained from the motor model and the speed estimator. In the drive system under examination, the value of the speed is reconstructed every 100 ms from the motor model, whose inputs are measured values of current and voltage. The actual waveform of the estimated speed is a discrete function quantized in accordance with time parameters defined in the algorithm of the DTC converter microprocessor control system. In the quasi-steady state one can observe coincidence of the estimated speed with the average value of the actual speed. Essential differences occur in intermediate states, i.e. during start-up and reverse.

5. In the case of reverse, the estimated speed is calculated as an absolute value, while the appropriate speed sign is introduced by a logic unit included in the model of the motor and DTC frequency converter.

CONCLUSIONS

On the basis of electro-mechanical waveforms measured in dynamical states of the examined drive we can state that:

1. In dynamical states during the drive start-up or reverse, the average difference between the actual and estimated speed is about 15 %, which results from time delay of the discrete speed reconstruction in the control algorithm.

2. The speed estimator implemented in the motor model does not reconstruct fluctuations of the actual speed resulting from the eccentric component of the load torque.

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