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IMPULSE-CONTROLLED SYSTEM FOR MATCHED ROTATION OF INDUCTION MOTORS

Abstract. *The circuit of impulse-controlled converter for matched rotation of two wound-rotor induction motors with limited standpoint on predetermined starting current is supposed in this paper. The simulation findings for speed mismatch of two wound-rotor induction motors in the speed up process as function of moment of inertia under conditions of direct starting and with limited standpoint on predetermined starting current at different acting torque frequencies of the motor rotors are derived.*

Keywords: *converter, regulation, motor, recuperation, speed, frequency, toque, impulse, model, crane*

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СИСТЕМА ИМПУЛЬСНОГО РЕГУЛИРОВАНИЯ СОГЛАСОВАННОГО ВРАЩЕНИЯ АСИНХРОННЫХ ДВИГАТЕЛЕЙ

Аннотация: *В работе предложена схема импульсного преобразователя для согласованного вращения двух асинхронных двигателей с фазным ротором с ограничением по заданному пусковому току. Получены результаты моделирования в виде зависимостей рассогласования скоростей от момента инерции в момент разгона двух асинхронных двигателей с фазным ротором в режимах прямого пуска и с ограничением по заданному пусковому току при разных значениях частоты воздействующих моментов роторов двигателей.*

Ключевые слова: *преобразователь, регулирование, двигатель, рекуперация, скорость, частота, момент, импульс, модель, кран*

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СИСТЕМА ІМПУЛЬСНОГО РЕГУЛЮВАННЯ УЗГОДЖЕНОГО ОБЕРТАННЯ АСИНХРОННИХ ДВИГУНІВ

Анотація: *В роботі запропоновано схему імпульсного перетворювача для узгодженого обертання двох асинхронних двигунів з фазним ротором з обмеженням заданого пускового струму. Отримані результати моделювання у вигляді залежності неузгодженості швидкостей від моменту інерції в момент розгону двох асинхронних двигунів з фазним ротором у режимах прямого пуску та з обмеженням по заданому пусковому струму при різних значеннях частоти діючих моментів роторів двигунів.*

Ключові слова: *перетворювач, регулювання, двигун, рекуперація, швидкість, частота, момент, імпульс, модель, кран*

Introduction. The majority of operating cranes are equipped with electric drives controlled by relay-contactor-based systems, which have a series of well-known shortcomings, such as, low power factor, impossible to realize smooth running the crane. The former causes to significant wear of positioning mechanism constituents caused by the tendency to curving the wheel pairs and the crane rails. The result is occurrence of improper performances for matched rotation of wound-rotor induction motors [1 – 3].

The present-day tendency of clearing denoted shortcomings is aimed to application of variable-frequency electric drive [4 – 6]. However, such solution leads to significant complication as well as rise of the electric drive cost.

There are a series of technical solutions aimed to refinement of crane mechanisms based on application of parametric current sources [7]. Mentioned solutions are simple enough, but offer a number of shortcomings that are associated with the increase of design power of inductive-capacitive converter.

The aim of the work is the development and investigation of energy-effective converter providing reasonable static and dynamic characteristic of the drive with matched rotation of induction motors (IM).

The main findings. The principle of rising voltage impulse converter (RVIC) construction is based on formation of starting and regulating characteristics based on impulse-current regulation (ICR) in IM rotor circuit. Such technique allows to use modern achievements in power electronics, in particular, to unite advantage of IM ICR with possibility to regenerate energy in same manner as in those circuits of hypo synchronous cascade [8 – 10].

Power circuit of RVIC is represented in Fig. 1.

The main advantages of the circuit are the following:

– grid-controlled inverter (GCI) operates with constant angle of lead β=30°;

– the voltage across capacitor *C* is maintained with the help of RVIC;

– the rotors of two IM are paralleled with the help of uncontrollable rectifies *R1* and *R2*.

Operation of GCI with constant β=30° provides slip energy recuperation with power factor equal to

$$\cos\phi = \cos\left(\beta - \frac{\gamma}{2}\right), \qquad (1)$$

where γ is commutation angle.

Depending on the accepted inverting angle $\beta = \text{const}$, the magnitude of cos φ is in the range of 0,86÷0,94 that corresponds to the power factor range of the IM for the most crane applications. Therefore, it may be considered that power factor will be determined by the power factor of the IM under slip energy recuperation in the process of their starting and reversing.

When the IM has attained its natural characteristic, the rotor is short-circuited by the switch of the RVIC and energetic characteristics of the drive are defined by operating duty of the IM.

In the process of the IM speeding up the RVIC is in impulse operation with predetermined starting current of two IM. The frequency of RVIC switch operation is determined by the time constant of the rotor circuit and the swing value Δ*I*, which is determined as the difference between maximal and minimal rectified current values of rectifiers *R1* and *R2*.

To realize dominant IM speeds, feedback for ICR is introduced. The feedback type depends on flatness requirements of the mechanical characteristics. The highest flatness is ensured when speed and slip sensors are available; the least flatness takes place under indirect changing the rotor voltage.

The RVIC provides discharge of slip energy to capacitor *C* followed by its regeneration into power network (power recuperation) via GCI (Fig. 1).

To perform investigation of two induction motors matched rotation in MatLAB medium with the help of Simulink structural means, the simulating model of RVIC system with parameters $C = 400\ \mu\text{F}$, $L_1 = 15\ \text{mH}$, $L_2 = 35\ \text{mH}$ is developed. As investigate object two IM of the type MTF-111-6, $P_\text{n} = 3.5\ \text{kWt}$ (relative duty is 0,4), and $M_\text{n} = 45\ \text{N}\cdot\text{m}$ are used. For the purpose to research synchronizing properties of the system, the resisting force mismatch of two crane arms is represented as dynamic resisting torques sine-varying in opposite phase of one motor in relation to another for achievement of maximal torque spread:

$$M_{\text{IM1}} = M_\text{n} \cdot \frac{1}{3} \cdot \left[1 + \sin(2 \cdot \pi \cdot f \cdot t)\right], \qquad (2)$$

$$M_{\text{IM2}} = M_\text{n} \cdot \frac{1}{3} \cdot \left[1 + \sin(2 \cdot \pi \cdot f \cdot t + \pi)\right], \qquad (3)$$

where f is the oscillation frequency of elastic joints of the first and second crane arms, respectively.

Fig. 2 shows dependences of speed mismatch ($\Delta\omega$) from the moments of inertia ($J_\text{n} = 0.195\ \text{kg}\cdot\text{m}^2$) in speeding up process of two IM in the conditions of direct starting and with limited standpoint on predetermined starting current for different frequency values of IM rotors disturbing torques. Analysis of the dependences shows that application of this technique to match the rotation of two IM provides decrease in mismatch of the IM rotors. The most decrease in mismatch is evident under increasing relationship between flywheel masses of IM and mechanism as well as under increasing frequency of effecting torques. Fig. 2, a represents dependences typical for the crane positioning mechanism ($f = 3\ \text{Hz}$). In this case, decrease of mismatch compared with direct starting more than by 2,4 times takes place. With increase in frequency of affecting torques not only acting value of mismatch, but its absolute value reduce as well. As the frequency of disturbance torques reduces in the range $f = 3 \div 144\ \text{Hz}$, the value of mismatch reduces by 20 times. Little speed mismatching for direct starting IM and with limited standpoint on the predetermined starting current is observed only at significantly high values of the disturbance torques frequency, above 100 Hz in the range of moments of inertia $J = 6 \div 10$ r.u. When going into natural characteristic, equable value of two IM speed mismatch in the conditions of direct starting and with limited standpoint on predetermined starting current takes place.

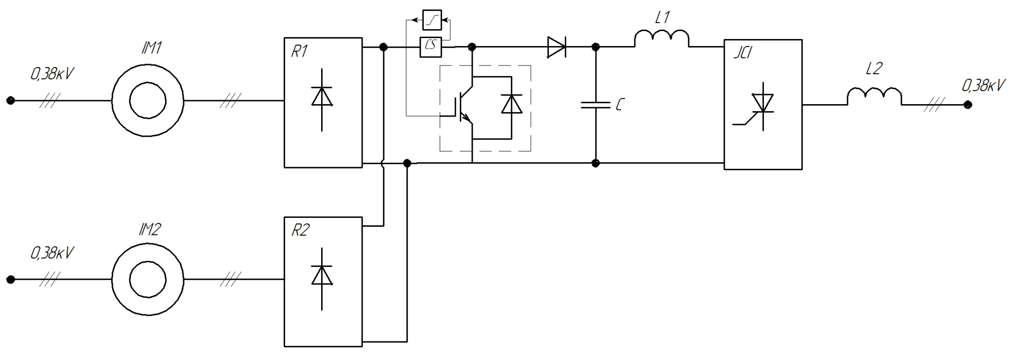

Fig. 1. Power circuit of RVIC for IM

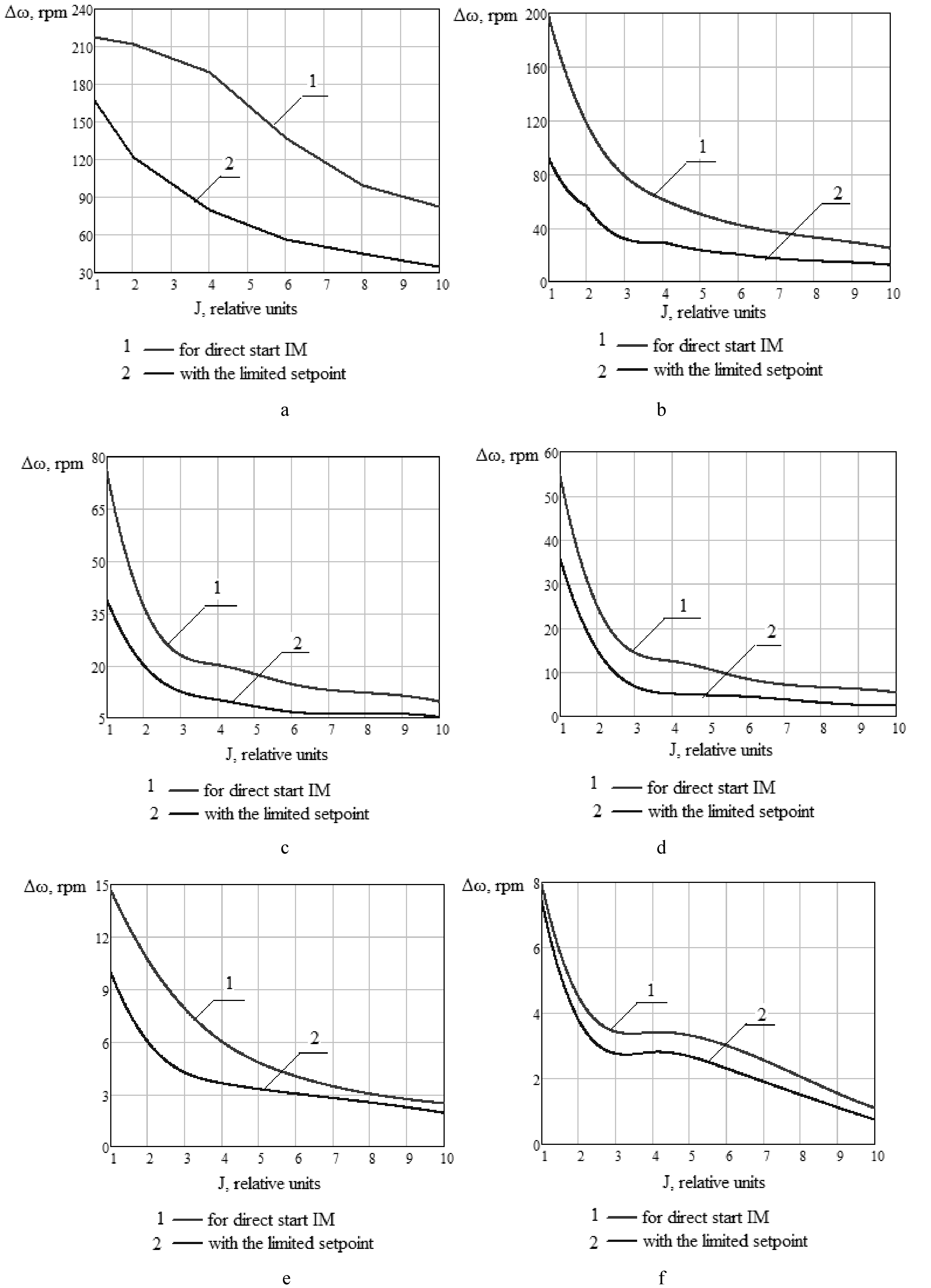

Fig. 2. Speed mismatching of two motors in direct starting (1) and with limited standpoint on predetermined starting current (2):
a – at f = 3 Hz ; b – at f = 9 Hz ; c – at f = 27 Hz ; d – at f = 54 Hz ; e – at f = 109 Hz ; f – at f = 144 Hz

Deductions. The energy-effective circuit for matched rotation of two rotation of two IM with limited standpoint on predetermined starting current is proposed. It offers high synchronizing properties under action of torques $\pm 0.3M_n$, with changing frequency $f = 3 \div 144$ Hz.

The circuit can be recommended for the drives with IM of the crane positioning mechanisms as well as pumped and fanned devices to obtain equable productivity.

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