PROSPECTS FOR THE USE OF MULTIPHASE PHASE-POLE-CONTROLLED AC INVERTER DRIVES IN TRACTION SYSTEMS

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The use of the multiphase (i.e. having a number of phases more than four) systems «inverter – induction motor», in which the frequency control principle and phase-pole control method are used together, allows to improve considerably a number of technical-and-economic characteristics of the traction systems of transportation facilities: in this case the drive system can have decreased mass-and-overall dimensions and manufacturing cost as well as improved reliability in comparison with DC and 3-phase AC drives.

Keywords: multiphase, induction motor, 3-phase AC drives

The results of the investigation made by the authors of this paper allow making a conclusion about the following: the use of the multiphase (i.e. having the number of phases more than four) systems «inverter – induction motor» in the traction drives of transportation facilities allows to improve considerably a number of the technical-and-economic characteristics of these traction systems. The use of these multiphase drives is most effective if the classical frequency control principle and phase-pole control method (PPM) [l-4] are used together in them.

Expansion of AC drive control field

The phase-pole method of a multiphase inverter control bases upon the following principle: if the electrical angles between the voltages (or currents) of the nearest phases of an inverter are increased by a factor of some whole number (without any change in the inverter voltage frequency), a set of the induction motor mechanical characteristics can be obtained (Fig. 1). These characteristics differ in the synchronous speed and maximal torque values. Such effect can be obtained only if the phase number «*m*» (i.e. the number of phases) equals certain values that are more than four [2, 3].

The use of this mode together with the frequency control principle in the multiphase systems produces the effect that could not be obtained in the analogous 3-phase systems: that allows a few times increase of the motor maximal torque over all range of the rotation speed regulation without any change in the saturation extent of the motor magnetic circuit. The control fields (i.e. the fields completed by motor mechanical characteristics that can be obtained in a drive system without any change in the motor magnetic circuit saturation extent) of the 30 kW power system «inverter – induction motor», in which the classical frequency control principle is used (field 1), and of the 12-phase similar system, in which the frequency control method and PPM are used together (field 2), are shown in Fig. 2.

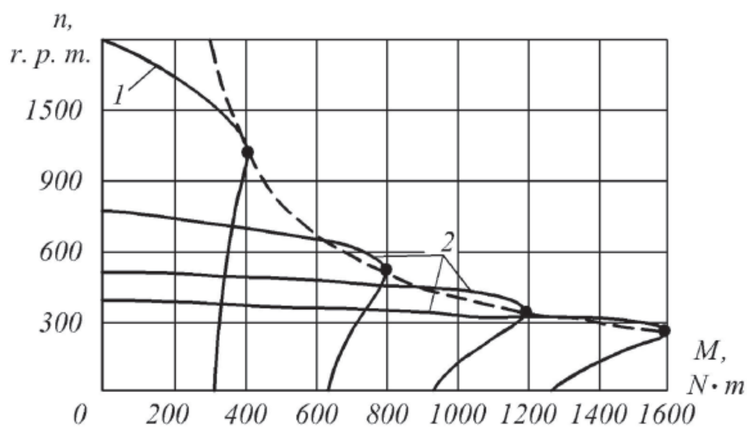

Fig. 1. Mechanical characteristics of a 30 kW power 12-phase induction motor, where the line 1 is natural characteristic, line 2 is the characteristic when PPM is only used (without frequency control), *n* is speed of rotation, and M is motor torque

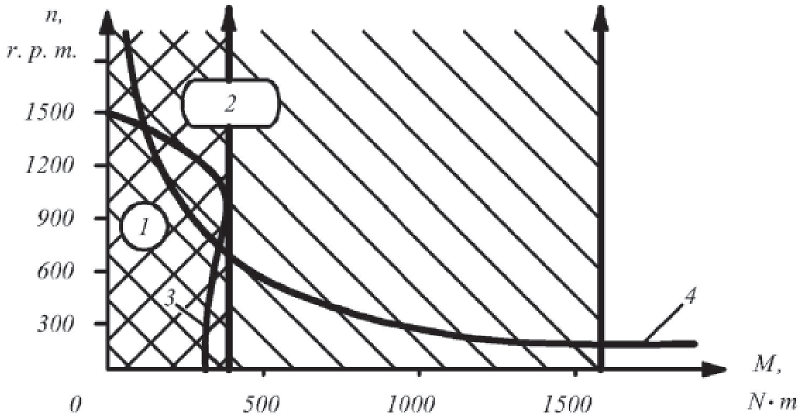

Fig. 2. Control fields of the system «inverter – induction motor», where the field 1is for the classical frequency control, field 2 is for the combined use of PPM and frequency control, line 3 is the natural mechanical characteristic of the induction motor, and line 4 is nonlinear-falling mechanical characteristic of the drive system load mechanism

Improvement of technical-and-economic characteristics

From this it follows, among other things, that forming nonlinear-falling mechanical characteristics of a drive system (line 4 in Fig. 2), that is necessary in the traction drives, the use of the multiphase PPM-and-frequency-controlled systems allows (in comparison with the case when the analogous 3-phase system is used):

1) without any change in the saturation extent of the motor magnetic circuit:

– to use the motors having less mass-and-overall dimensions (for example, less by about 40 % if $m = 12$) and less manufacturing cost for the obtaining of the same torque value; or

– to achieve considerable increase (for example, the 3,5–3,8 times rise if $m = 12$) of the maximal torque of the motor having the same mass-and-overall dimensions;

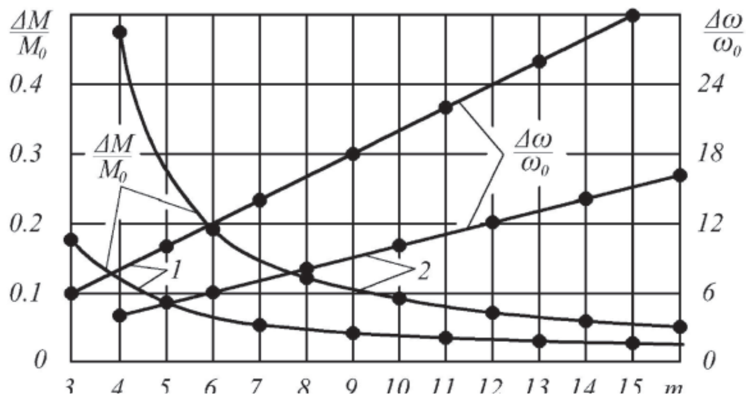

Fig. 3. m-dependences of torque swing (ΔM) and frequency ($\Delta\omega$) of torque and inverter input current oscillations for the case when the classical 180-degree algorithm of inverter control is used, where the line 1 is for odd m, line 2 is for even m, M_0 is the torque constant component, and ω_0 is the inverter output voltage frequency

2) to improve the drive reliability parameters as the time of trouble-free (non-stop) operation of the system can be prolonged if the system operation condition changes into some abnormal one (for example, if a motor phase winding was broken). This can be obtained owing to the combined use of PPM and some other special algorithms of multiphase inverters control.

Besides, the results of the investigations [1, 2] show that even if the classical 180-degree algorithm of inverter control is used, the increase of the induction motor drive phase number leads to the following:

– decrease of the amplitude and increase of the frequency of the oscillations of the motor torque and inverter input circuit current (Fig. 3 and Fig. 4). That allows to expand the rotor speed regulation range down from the nominal speed value (for example, by about 100 % if the phase number rises from 3 to 9) and to decrease the mass-and-overall dimensions of the filter in the inverter input circuit (for example, about 2,5–3,0 times decrease if the phase number rises from 3 to 9);

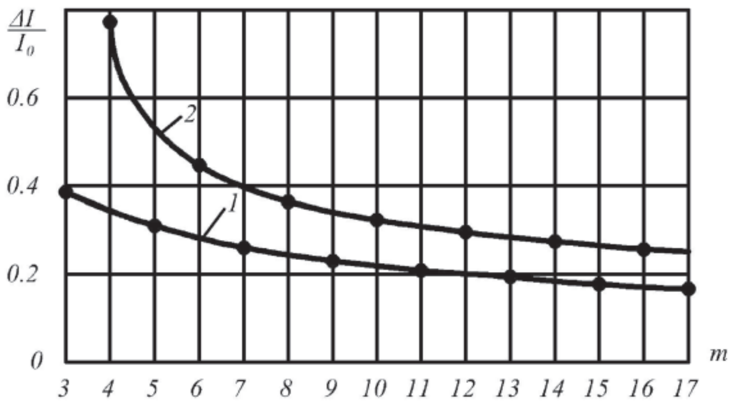

Fig. 4. *m*-dependences of inverter input current swing (ΔI) for the case when the classical 180-degree algorithm of inverter control is used, where the line 1 is for odd *m*, line 2 is for even *m*, and I_0 is the inverter input current constant component

– decrease of the electrical losses in the rotor circuit (for example, by 30–40 % if the phase number rises from 3 to 9).

Conclusion

The use of the multiphase «inverter – induction motor», in which the classical frequency control principle and phase-pole control method are used together, will allow improving considerably a number of technical-and-economic characteristics of the traction systems of transportation facilities.

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