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COMPARATIVE ANALYSIS OF ROTOR CONTOURS CIRCUITS OF ASYNCHRONOUS MOTOR FOR CALCULATION OF ELECTROMAGNETIC AND ELECTROMECHANICAL TRANSIENTS

On the base of the carried out calculations of transients in asynchronous motor, using single and multiple – loop circuits the conclusion is made regarding the spheres their application.

Key words: *asynchronous motor, multiple – loop circuit, transient process, short – circuit current, electromagnetic moment.*

Introduction

Nowadays two different approaches are used to compose circuits for modeling transient processes in energy supply systems with asynchronous motors (AM); these approaches differentially take into account parameters change of rotor loops of deep bar machines or machines with double – squirrel cage. In the first case, AM is represented by the scheme with one circuit on the rotor. To take into account the saturation on the ways of scattering and current displacement phenomenon functional dependence of (R, X) parameters of this circuit on slip is introduced [1-3].

The second case – parameters change is taken into account by means of application of multiple loop equivalent circuits [4 – 8]. Unfortunately, in literature the comparative analysis of these approaches is not given.

The aim of the paper is determination of application sphere of single and multiple loop circuits of AM on the base of calculation results comparison of electromagnetic and electromechanical transients.

Results of the research

For comparison of the above- mentioned approaches two models of one and the same motor of A 114-4 type, having the following parameters are considered P_{nom} = 320 кW; U_{nom} = 6 кV; $cos\varphi$ = 0.89; efficiency = 0.928; n_{nom} = 2970 rpm; I_{n} = 6,6 p.u.; M_{n} = 1,6 p.u.; M_{p} = 2,8 p.u.; T_j = 13 sec.

According to the technique, suggested in [1] parameters of single-loop circuits (Fig. 1) are determined: $X_s = 0.0714$; $X_m = 3.2028$; $X_{r0} = 0.1547$; $X_{r1} = 0.0731$; $R_s = 0.0192$; $R_{r0} = 0.0085$; $R_{r1} = 0.03173$. Values $X_r(s)$ and $R_r(s)$ are determined by the expression:

$$R_r = R_{r0} + \left(R_{r1} - R_{r0}\right)\sqrt{s}, \tag{1}$$

$$X_r = \frac{X_{r0}X_{r1}}{X_{r1} + \left(X_{r0} - X_{r1}\right)\sqrt{s}}. \tag{2}$$

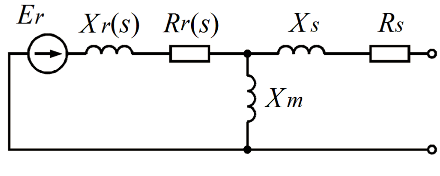

Fig. 1. Single-loop circuit of AM

For calculation of the parameters of the equivalent multiple loop circuit (Fig. 2) by the expressions (1), (2), at various slides the resistances of rotor contours (Table 1) were determined.

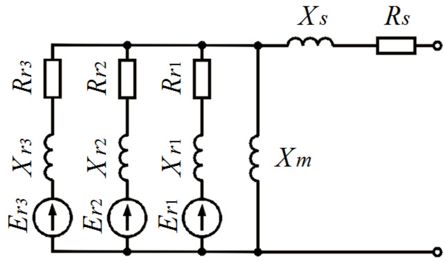

Fig. 2. Multiple loop circuit of AM

Table 1

Resistances of rotor circuits at various values of the slip

s	R_r	X_r
0,9	0,030545187	0,075107336
0,4	0,023183133	0,090659567
0,09	0,015443282	0,115887414

Further the system of equations (3) is composed, the parameters of the equivalent three loop circuit are found (Table 2)

$$\frac{1}{\frac{R_{r(i)}}{s_{(i)}}+jX_{r(i)}}=\frac{1}{\frac{R_{r1}}{s_{(i)}}+jX_{r1}}+\frac{1}{\frac{R_{r2}}{s_{(i)}}+jX_{r2}}+\frac{1}{\frac{R_{r3}}{s_{(i)}}+jX_{r3}}, \quad (3)$$

where i = 1, 2, 3.

Table 2

Resistances of rotor loops of multiloop circuit

№ of circuit	Rr	Xr
1	0,111355149	0,124238125
2	0,021299808	0,156805059
3	0,045201967	1,279714058

Three loops are used, because less number of loops does not provide satisfactory coincidence of characteristics of these models and in case of greater number the roots with negative sign appear that causes problems in the process of solution of differential equations of such model by numeral methods.

Starting characteristics of the models are shown in Fig. 3 and 4.

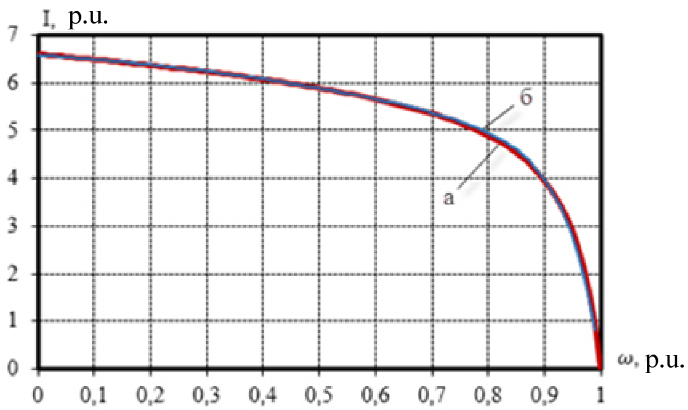

Fig. 3. Starting characteristics of the models $I = f(s)$ of single - (a) and multi loop model (b)

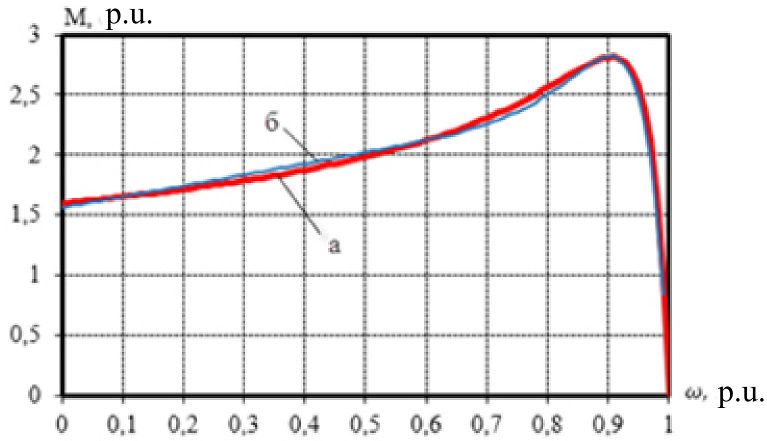

Fig. 4. Starting characteristics of the models $M = f(s)$ of singe - (a) and multiloop models(b)

To confirm models equivalence by calculation parameters of rotor circuits calculation of AM start was performed and the curves of acting values change of phase “A” current of the stator (Fig. 5) and curves of rotor rotation speed change (Fig. 6) in this mode are constructed.

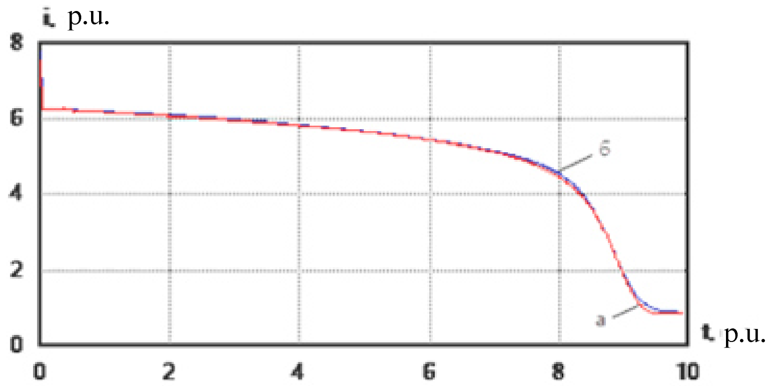

Fig. 5.Curves of acting values change of phase «A» current of the stator during the start of AM of single (a) and multiloop model (b)

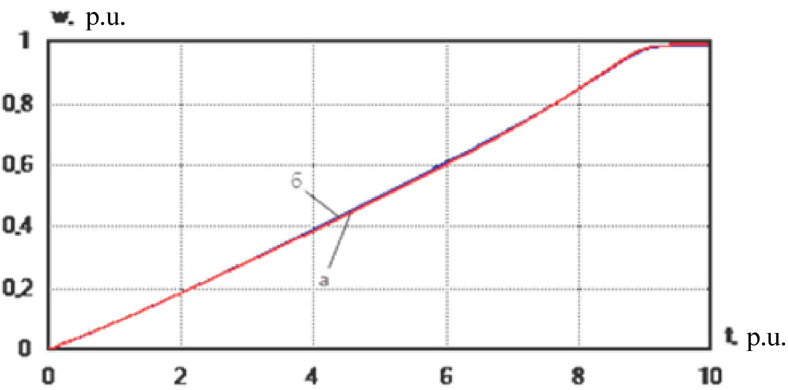

Fig. 6. Curves of rotor rotation speed change during the start of single - (a) and multiloop model (b)

In spite of coincidence of the curves at the start, calculation of three –phase short—circuit at the terminals of stator winding showed the discrepancy in mode parameters change for these models (Fig.7, Fig. 8). The discrepancy in maximum values of current was 16 %, electromagnetic moment – 30%. Speed of transient process attenuation also differs.

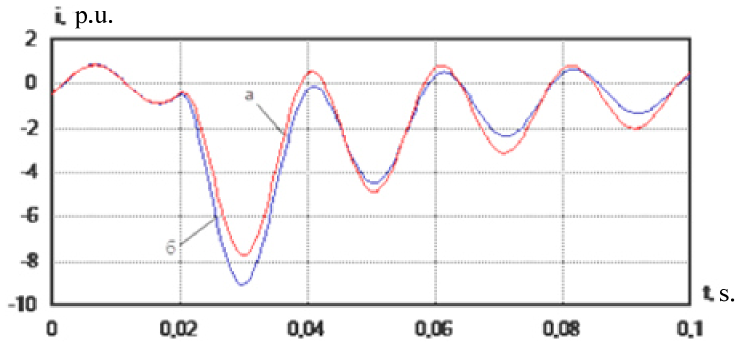

Fig. 7. Curves of instantaneous value change of stator phase «A» current during three-phase short-circuit AM terminals of single (a) and multiloop model (b) (start of short – circuit from 0,02 sec)

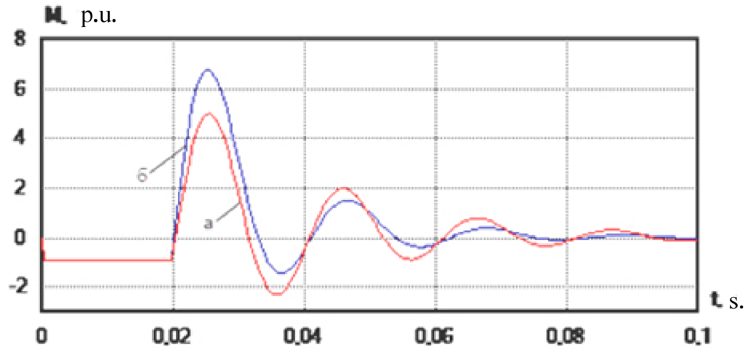

Fig. 8. Curves of electromagnetic moment change during three-phase short-circuit at AM terminals of single (a) and multiloop model (b) (start of short-circuit from КЗ з 0,02 sec)

The reason of such considerable discrepancy in the obtained results is in the assumption, taken for single loop model, that current frequency in the rotor is connected with the slide. In the process of the start the frequency of current in the rotor changes proportionally to the slide, that is why, the models behave similarly. If we look at Fig. 9, we can see, that due to availability of aperiodic component in stator current in case of short – circuit at AM terminals the component emerges in rotor current, that changes with the frequency of about 50 Hz, where as the slide (Fig. 10) during this time did not practically change and parameters of rotor circuit also remained unchanged. The above-mentioned assumption does not extent to multiloop circuit, that is why in this case the latter behaves more adequately.

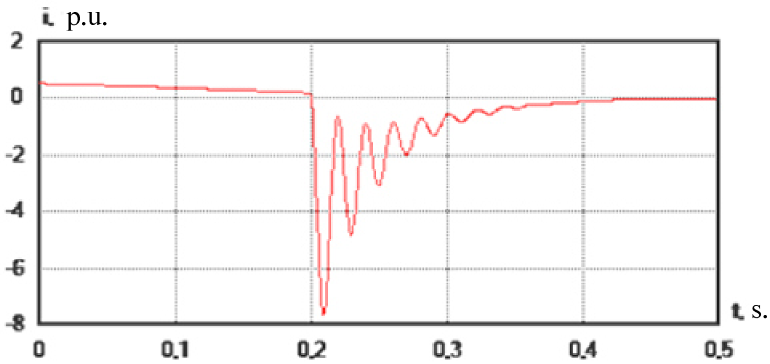

Fig. 9. Curve of instantaneous value of equivalent contour current of the rotor change during three-phase short-circuit at AM terminals (start of SC form 0,2 sec)

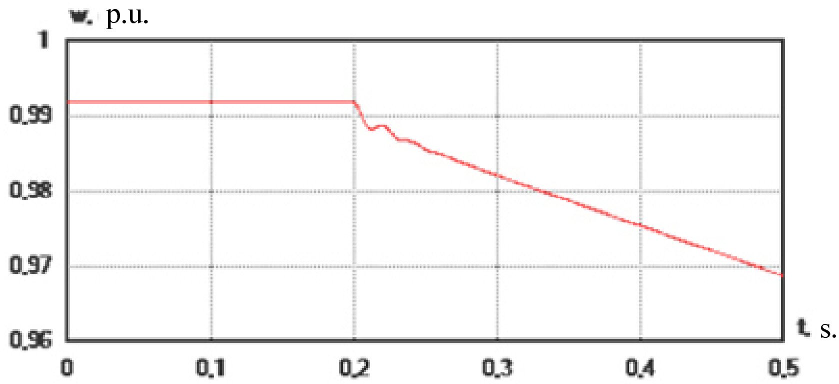

Fig. 10. Curves of rotation speed change during three-phase short-circuit of AM terminals (start of SC form 0,2 sec)

Conclusions

Single-loop model of AM is considered; the saturation of dissipation routes and current displacement in the rotor is taken into consideration by means of introduction of functional dependences between the parameters of rotor contour and slide. It is shown that single-loop model of AM is expedient to use in cases when current frequency in the rotor is proportional to slide, namely, in the modes of start and self-start. In the process of modeling of electromagnetic transient processes during short-circuits, short-term energy supply disturbances the above- mentioned condition is violated and in this case it is expedient to use multicontour models. It is obvious, that three recommendation can be extended to synchronous machines.

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