Considerations Regarding Influences of Reluctance Synchronous Motors Parameters on the Asynchronous Starting

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Abstract—**This paper analyzes the reluctance synchronous motors behavior for a particular regime – the asynchronous starting. There are presented the mathematical model in the two axes d-q theory and an original simulation program, conceived in Matlab-Simulink. The simulations results are confronted with experimental results, obtained with the help of a data acquisition system. The conclusions which are finally presented emphasize the way in which the motor parameters influence the mentioned dynamic regime.**

Index Terms—**Reluctance synchronous motor, dynamic regime, mathematical model, Matlab-Simulink simulations, test.**

I. INTRODUCTION

The analysis of the dynamic processes from the synchronous machine is quiet difficult because of the magnetic and electric asymmetry of the rotor; this one has symmetry only on two axes, d and q, which are electrically orthogonal. When the stable operation regime is disturbed there occur both alternating components and practically non-periodic components of the machine windings currents, which tend to keep unchanged the windings fluxes (at the moment t=0 the machine windings have a behavior of superconductor circuits). Owing to the transient currents established through windings, the magnetic field configuration into machine in the subsequent moments is modified and the machine parameters are also modified.

In order to avoid the computation complications, the transient processes study is made in the general case by means of the two axes theory, with enough precision for practice.

II. MATHEMATICAL MODEL OF THE MOTOR

The equations detailed in [1] are the starting point, but the fact that the RSM has not excitation winding is taken into account. The mathematical model written in the reference frame which is fixed relatively to the rotor is such obtained:

$$\begin{aligned} u_d - R_s i_d &= \frac{d\psi_d}{dt} - \omega\psi_q \\ u_q - R_s i_q &= \omega\psi_d + \frac{d}{dt}\psi_q \\ -R_D i_D &= \frac{d\psi_D}{dt} \\ -R_Q i_Q &= \frac{d\psi_Q}{dt} \end{aligned} \tag{1}$$

where

$$\begin{aligned} \psi_d &= L_d i_d + L_{dh} i_D \\ \psi_q &= L_q i_q + L_{qh} i_Q \\ \psi_D &= L_{dh} i_d + L_D i_D \\ \psi_Q &= L_{qh} i_q + L_Q i_Q \end{aligned} \tag{2}$$

The following equations are obtained by replacing (2) in (1):

$$\begin{aligned} u_d - R_s i_d + \omega L_q i_q + \omega L_{qh} i_Q &= L_d \frac{di_d}{dt} + L_{dh}\frac{di_D}{dt} \\ u_q - R_s i_q - \omega L_d i_d - \omega L_{dh} i_D &= L_q \frac{di_q}{dt} + L_{qh}\frac{di_Q}{dt} \\ -R_D i_D &= L_{dh}\frac{di_d}{dt} + L_D\frac{di_D}{dt} \\ -R_Q i_Q &= L_{qh}\frac{di_q}{dt} + L_Q\frac{di_Q}{dt} \end{aligned} \tag{3}$$

The motion equation is attached to these relations:

$$\frac{3}{2}p(\psi_d i_q - \psi_q i_d) - m_r = \frac{J}{p}\frac{d\omega}{dt} \tag{4}$$

respectively

$$\frac{3}{2}p(L_d i_d i_q + L_{dh} i_D i_q - L_q i_q i_d - L_{qh} i_Q i_d) - m_r = \frac{J}{p}\frac{d\omega}{dt} \tag{5}$$

The relations (3) and (5) can also be written in matrix form:

$$\begin{bmatrix} L_d & 0 & L_{dh} & 0 & 0 \\ 0 & L_q & 0 & L_{qh} & 0 \\ L_{dh} & 0 & L_D & 0 & 0 \\ 0 & L_{qh} & 0 & L_Q & 0 \\ 0 & 0 & 0 & 0 & \frac{J}{p} \end{bmatrix} \cdot \frac{d}{dt}\begin{bmatrix} i_d \\ i_q \\ i_D \\ i_Q \\ \omega \end{bmatrix} =$$

$$= \begin{bmatrix} u_d - R_s i_d + \omega L_q i_Q + \omega L_{qh} i_Q \\ u_q - R_s i_q - \omega L_d i_d - \omega L_{dh} i_D \\ -R_D i_D \\ -R_Q i_Q \\ \frac{3}{2} p(L_d i_d i_q + L_{dh} i_D i_q - L_q i_q i_d - L_{qh} i_Q i_d) - m_r \end{bmatrix} \quad (6)$$

III. MATLAB-SIMULINK PROGRAM

The following program „parmsrv” has been obtained in Matlab-Simulink.

```
clear
pack
% PN = 1,5 kW
Rs=3.77;
RD=1.7;
RQ=1.7;
Ld=0.281;
Lq=0.081;
Lsigma=0.0081;
Ldh=Ld-Lsigma;
Lqh=Lq-Lsigma;
LD=Ld;
LQ=Lq;
p=2;
j=4e-03;
msrv
```

This Matlab program runs the Simulink program „msrv” of which mask is depicted further on.

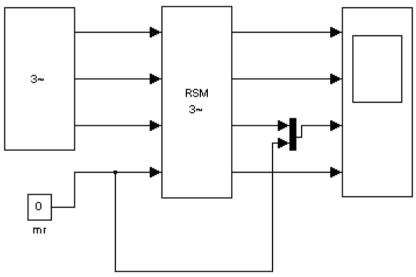


Fig. 1 Mask of the simulation program

The structure of the block RSM is the following one.

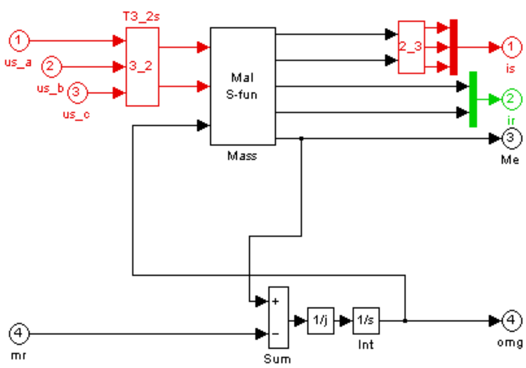


Fig. 2 Block „RSM”

At its turn, the block „Mass” has the following structure.

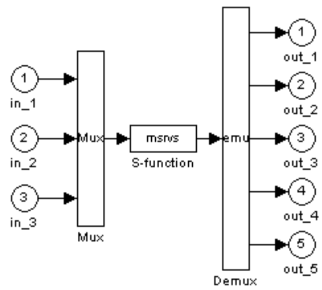
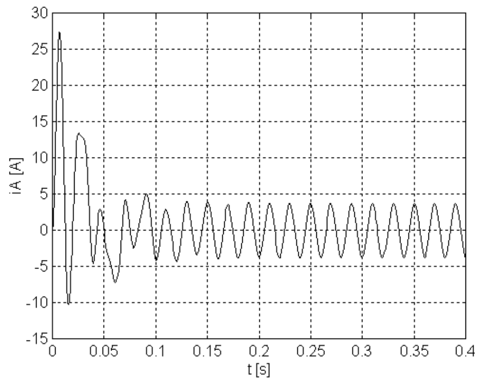


Fig. 3 Block „Mass”

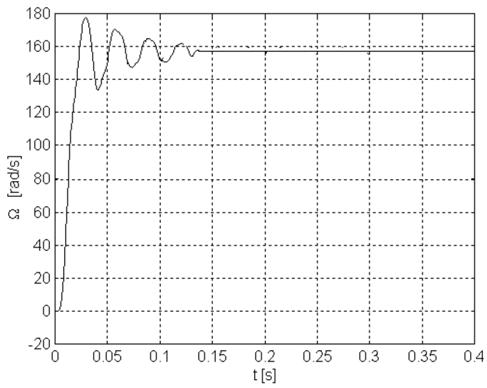
The previous program uses a s-function „msrvs”.

IV. SIMULATIONS

A series of graphic representations have been obtained by running the program, but only a few of them, corresponding to the dynamic regime of the asynchronous starting, are depicted further on.

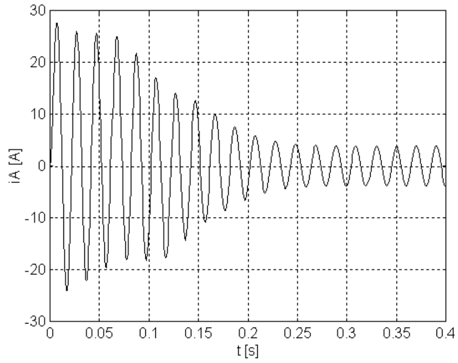


a) Characteristic i_A=f(t)

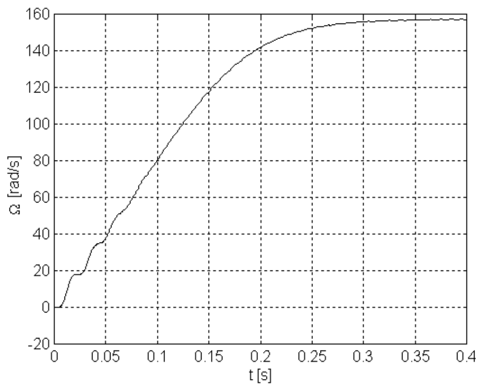


b) Speed characteristic Ω=f(t)

Fig. 4 Starting characteristics obtained for the case of the simulation with real parameters

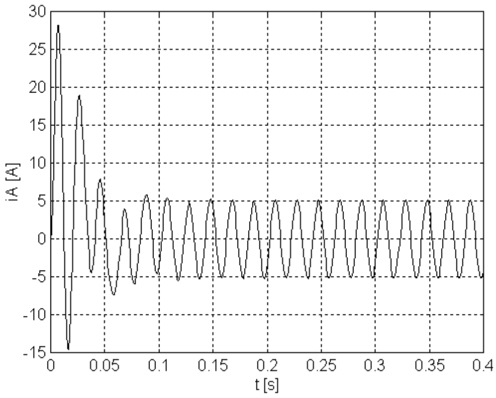


a) Characteristic i_A=f(t).

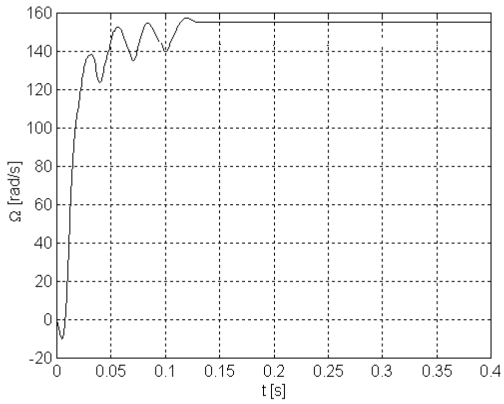


b) Speed characteristic Ω=f(t).

Fig. 5 Starting characteristics obtained for the case J=10 Jm

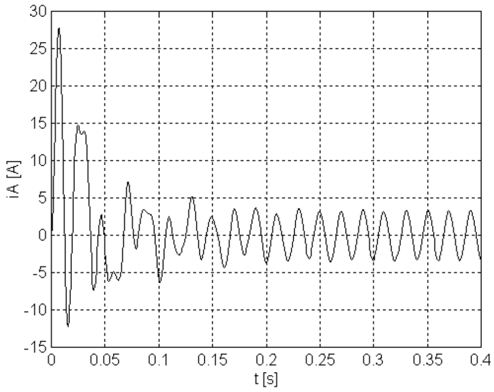


a) Characteristic i_A=f(t).

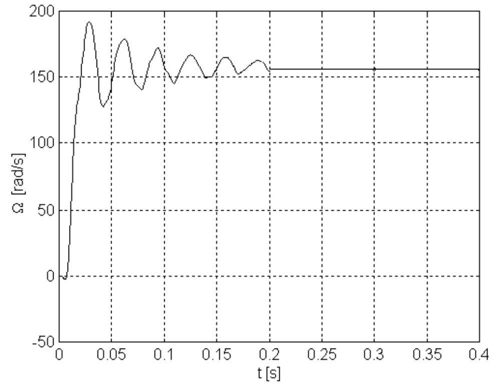


b) Speed characteristic Ω=f(t).

Fig. 6 Starting characteristics obtained for the case Mr=10 Nm

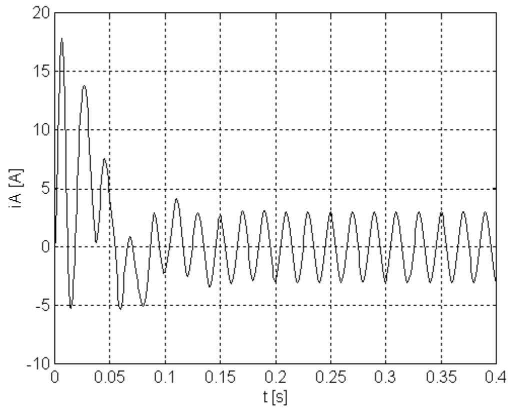


a) Characteristic i_A=f(t).

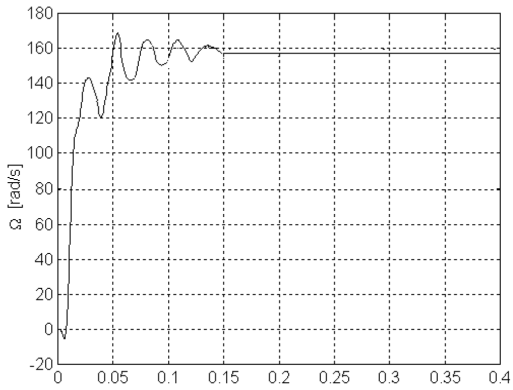


b) Speed characteristic Ω=f(t).

Fig. 7 Starting characteristics obtained for the case R_Q=0,5 R_{Qm}



a) Characteristic i_A=f(t).



b) Speed characteristic Ω=f(t).

Fig. 8 Starting characteristics obtained for the case R_D=2,5 R_{Dm}

V. CONCLUSION

The following conclusions result from the analysis of these graphics:

- a similar phenomenon also occurs in the case of the starting with a great resistant torque (when the resistant torque increases very much it is possible for the motor not to synchronize anymore);

-the increase of the inertia moment value determines the increase of the analyzed transient process duration, the synchronization being made after a great number of oscillations;

- the increase of the resistance R_D value has a non-stabilizing effect;

- a small value of the resistance R_Q, even at null resistant torque, and a small inertia moment, can lead to an unstable operation.

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