MOTOR PARAMETERS INFLUENCE ON STABILITY OF DRIVE FOR INDUSTRIAL ROBOT

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Abstract: This paper analyzes a driving system for an industrial robot from the stability point of view. For doing this, an original analysis method has been conceived. The method has as starting point the two axes mathematical model with equations written in per unit values. A Matlab program has been conceived with their help; this program has led to results and conclusions detailed in this paper. Finally a series of experimental results confirming the conclusions deduced with the new method are presented.

1 INTRODUCTION

The induction motors have been recognized for a long time as being the most reliable electrical machines, allowing an easy maintenance and utilization in dangerous medium, being at the same time cheap, easily to be built and having a high power/weight ratio. Yet, the speed adjustment of the squirrel cage induction motors is made with the help of some relatively complicated static equipments, of the voltage and frequency static converters.

The high cost of these ones is in a permanent decrease owing to the achievements from the field of power electronic components. Concomitantly with the progresses of the power electronics, we watch the introduction of the microelectronics in the command and adjustment part of the power converters.

Owing to the flexibility provided by the microcomputers programming, it is possible to achieve solutions of high complexity and reliability. Owing to these progresses there have been implemented some new multi-variable adjustment techniques, field orientation, field accelerating etc.

All these aspects made the induction motor to conquer new positions in variable speed drives.

This way, the power electronics has practically reduced the problem of the use extension of the induction motor supplied from a voltage and frequency static converter, to a problem of investment cost and economic efficiency.

The ever greater utilization of the induction motor as an execution element in the automatic systems has imposed an ever larger approach, in the speciality papers, of the problems concerning the dynamic regime of it.

This paper joins to this context, analyzing a few aspects regarding the dynamic processes when operating with variable frequency. So, first of all it is necessary to use an adequate mathematical model for performing a study in this field. The two axes theory models are discussed in the analyzed case.

Starting from the conclusion that the stability is a qualitative feature of the systems associated to their dynamic behaviour, it also results that it is necessary to analyze the stability of the converter-motor-robot assembly and the motor parameters influence on it.

2 MATHEMATICAL MODEL

The equations system that is used has the following form (Enache, 2005):

$$
\begin{aligned}
\omega_s^* &= s_{ks}\left(\underline{\Psi}_s^* - k\underline{\Psi}_r^{/*}\right) + \frac{d\underline{\Psi}_s^*}{dt^*} + j\omega_s^*\underline{\Psi}_s^* \\
0 &= s_{kr}\left(\underline{\Psi}_r^{/*} - k\underline{\Psi}_s^*\right) + \frac{d\underline{\Psi}_r^{/*}}{dt^*} + j\left(\omega_s^* - \omega^*\right)\underline{\Psi}_r^{/*} \\
h \cdot \frac{d\omega^*}{dt^*} &= -\frac{k}{x_{rt}^{/*}}\operatorname{Im}\left[\left(\underline{\Psi}_s^*\right)^* \underline{\Psi}_r^{/*}\right] - m_r^*
\end{aligned}
\qquad (1)
$$

where m_r is the resistant torque corresponding to the industrial robot.

3 SIMULATIONS: QUANTITATIVE RESULTS

A Matlab program for the stability analysis has been conceived.

The representations from Figs. 1, 2 and 3 have been obtained by running this program, for the concrete case of a motor rated at 1,1 kW.

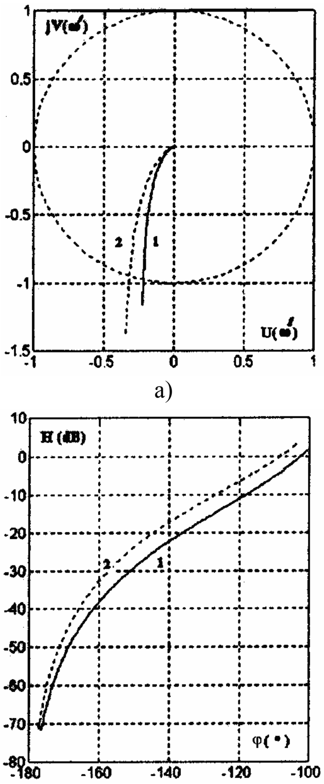


Figure 1: Transfer locus (a) and amplitude-phase characteristics (b) obtained in the case of the inductances modification: $L_S = 0{,}529$ H (1) and $L_S = 0{,}549$ H (2).

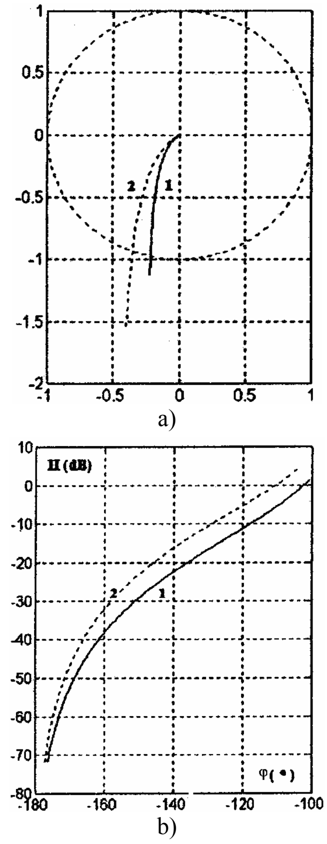
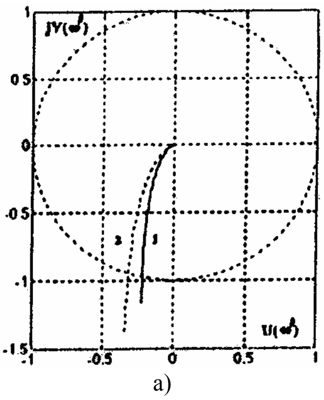
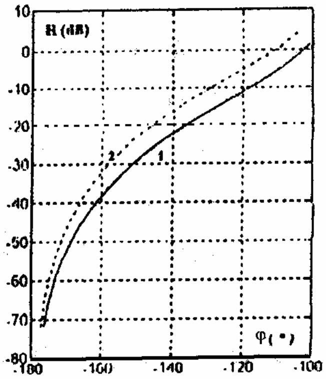


Figure 2: Transfer locus (a) and amplitude-phase characteristics (b) obtained in the case of the inductances modification: $L_r^/ = 0{,}528$ H (1) and $L_r^/ = 0{,}548$ H (2).

There must be also mentioned the importance of the introduced method resulting from the possibility to emphasize the machine parameters influence and especially the inertia moment influence, on stability when operating at variable frequency, fact that provides originality to this method.





b)

Figure 3: Transfer locus (a) and amplitude-phase characteristics (b) obtained in the case of the inductances modification: $L_{sh} = 0{,}498$ H (1) and $L_{sh} = 0{,}558$ H (2).

In order to catch quantitatively these interdependences the following table has been filled.

Table 1: Absolute values and phase margins.

Param.	Absolute value	Per unit param.	Per unit value	Phase margin [^{0}]
L_s	0,549	x_s^*	2,2735	69,13
$L_r^{/}$	0,548	$x_r^{/*}$	2,2694	75,31
L_{sh}	0,558	x_{1m}^*	2,3104	71,32

These results help us to emphasize a few important conclusions regarding the resistances influence on the studied system stability:

- the increase of the inductance L_s leads to the stability decrease;
- at the same time with the rotor inductance increase the system stability decreases;
- the increase of the main inductance has a stabilizing effect.

4 EXPERIMENTAL CIRCUIT

In order to confirm the previous conclusions, a series of experimental tests have been performed; a few of them are detailed further on.

Thus, the experimental circuit has the structure depicted in the following figure.

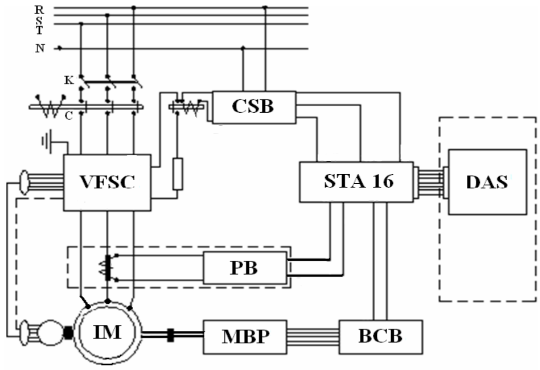


Figure 4: Scheme of the experimental circuit.

The notations have the following meaning:

IM – induction motor;
VFSC – voltage and frequency static converter;
DAS – data acquisition board;
CSB – command and synchronization block;
PB – protection block;
MPB – magnetic powder break;
BCB – brake command block;
STA 16 – connection block.

A picture of this circuit is depicted for conformity.

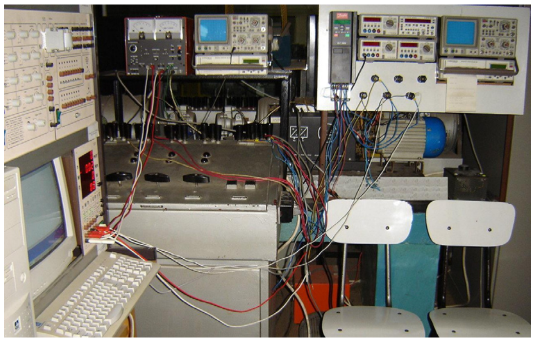


Figure 5: Picture of experimental circuit.

In order to obtain the determinations in dynamic regime the experimental circuit depicted before has been carried out, having a data acquisition board DAS as a central element (Enache, 2007). This high speed analogical and digital interface has been assembled inside a computer. Both the acquisition and the adequate data processing are controlled with the help of a program conceived in Matlab.

5 EXPERIMENTAL RESULTS

A series of graphic results have been obtained with the help of the acquisition program; the following figures are depicted further on.

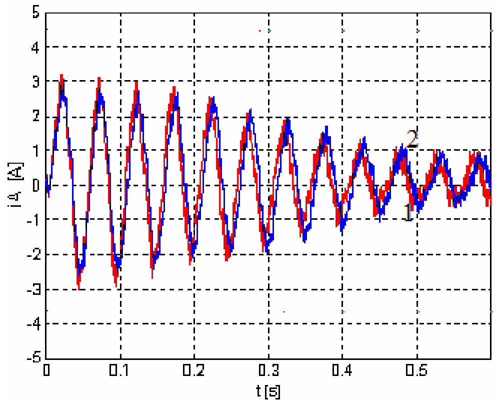


Figure 6: Graphic dependences corresponding to the cases L_s=0,529 H (1) and L_s=0,549 H (2).

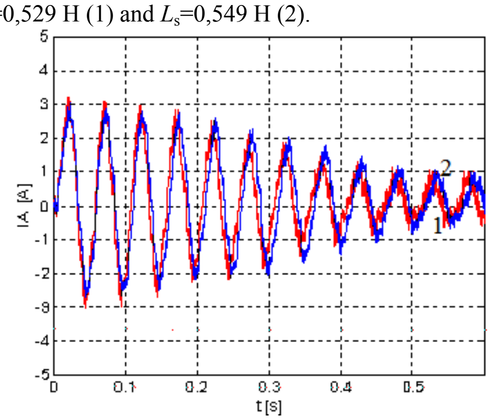


Figure 7: Graphic dependences corresponding to the cases L'_r =0,528 H (1) and L'_r =0,548 H (2).

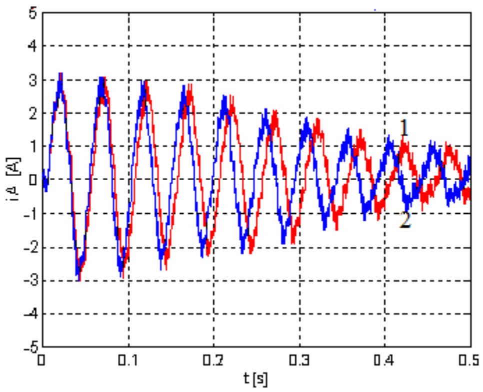


Figure 8: Graphic dependences corresponding to the cases L_{sh}=0,498 H (1) and L_{sh}=0,438 H (2).

These graphics lead to the following conclusions:

- when the value of the stator inductance increases the transient process duration increases (the stability decrease);
- the increase of the rotor inductance also involves the increase of the transient process duration (the stability decreases);
- the decrease of the main inductance value determines a faster stabilization of the process (stability increase).

These conclusions confirm the theoretical analysis performed before.

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