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A STUDY OF THE PARAMETER ESTIMATION OF THE SINGLE/TWO-PHASE INDUCTION MACHINES

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ABSTRACT: A key point in simulation and control of the electrical drives is the accuracy of the available dynamic model. Especially for the squirrel-cage induction machines, the exact determination of the rotor's parameters i.e. resistances and inductances is not a straightforward task because these parameters cannot be determined through direct measurements during the drive's operation. Several techniques are used to obtain estimates for the machine's parameters as well as to obtain estimates for the process parameters such as flux-linkages components. Among these techniques, the observer-based methods are widely used in control engineering. The finite elements methods (FEM) are commonly used in design. In this work, the authors implemented both methods to determine the process parameters for a given single/two-phase induction machine. To validate the estimations, the results were compared with the measurements.
KEYWORDS: electrical drives, simulation and control, finite elements methods, measurements

❖ INTRODUCTION

The on-line estimation of the process parameters is essential in the adaptive control of the variable- parameters systems but also for the constant-parameters systems in the presence of stochastic disturbances, such are the electrical drives destinated to the control of speed and position.

In particular, the sensor-less estimation of the rotor's position is of major interest due to (1) the low cost implementation and (2) the increased maintenance issued from the elimination of the speed or position transducers. In addition, the on-line estimation of the process parameters allow the direct torque control and the implementation of advanced control algorithms such as the slider-mode control.

In this approach, the deterministic Luenberger's observer may be used to the angular speed reconstruction of the induction machine's rotor based on the measurements or estimated values of the torque and rotor's position. The Bocker's observer allows the reconstruction of the electromagnetic field's components based on the phase-voltages and currents, and the angular speed at the machine's shaft. In the same context, there are two applications of the extended Kalman filter that allow estimating the time constant of the rotor in presence of disturbances [1].

The typical applications of these algorithms are the control laws for the command of the three-phase inverters into the speed and position control of the induction machines electrical drives. Despite that from the theoretical point of view, the state observers are asymptotical stable, the convergence – and the estimate accuracy – depend on the accuracy of the parameters of the motor and finally on the electrical and mechanical parameters of the machine.

Because not all parameters of the machine may be determinate through direct measurements, numerical methods, based on the machine's geometry are often used, [2]. The commonly used approach is the use of the finite differences method, the finite elements method, integrals methods the frontier's elements methods. The field analysis allows determining the process parameters in the same manner as the observer-based methods and in addition the model's parameters or the physical parameters may also be determined.

Based on this idea, the paper presents an implementation of a state observer with the separation of the fast variables, the Pietrzak-David algorithm,[1], in comparison with the implementation of the FEM method to estimate the stator flux-linkages components within an single/two-phase induction machine.

❖ METHODOLOGY

The Implementation of the FEM method to compute the inductances and the magnetic fluxes within the single/two-phase induction machine

The basis of the FEM method, [3] is the transformation of the solution of the electromagnetic potential, ψ into a linear combination of coordinate functions $\psi=\sum_{k=1}^{n}\alpha_k\cdot\varphi_k$. The unknown coefficients, $\alpha_k, k=\overline{1,n}$ result from a minimisation of the energetic functional associated to the field $F(\psi)$. There are various software applications that allow the FEM implementation to analyse the electromagnetic field both at low and high frequencies. In this paper, the Ansoft-Maxwell SV environment was used for the 2D analysis of the electrical machine, [4].

The Implementation of the Pietrzak-David State Estimator, [1]

The dynamic model of the induction machine is represented into a coordinate reference system related to the magnetic motion field as shown in the expressions below.

$$\frac{d}{dt}\begin{bmatrix}\Psi_{1d}\\ \Psi_{1q}\\ i_{1d}\\ i_{1q}\end{bmatrix}=\begin{bmatrix}0 & \omega_e & -R_1 & 0\\ -\omega_1 & 0 & 0 & -R_1\\ \frac{R_2^{'}}{\sigma\cdot L_2^{'}\cdot L_1} & \frac{\omega}{\sigma\cdot L_1} & -\frac{1}{\sigma}\cdot\left(\frac{R_1}{L_1}+\frac{R_2^{'}}{L_2^{'}}\right) & \omega_1-\omega_2\\ -\frac{\omega}{\sigma\cdot L_1} & \frac{R_2^{'}}{\sigma\cdot L_2^{'}\cdot L_1} & -\omega_1+\omega_2 & -\frac{1}{\sigma}\cdot\left(\frac{R_1}{L_1}+\frac{R_2^{'}}{L_2^{'}}\right)\end{bmatrix}\cdot\begin{bmatrix}\Psi_{1d}\\ \Psi_{1q}\\ i_{1d}\\ i_{1q}\end{bmatrix}++\begin{bmatrix}1 & 0\\ 0 & 1\\ \frac{1}{\sigma\cdot L_1} & 0\\ 0 & \frac{1}{\sigma\cdot L_1}\end{bmatrix}\cdot\begin{bmatrix}v_{1d}\\ v_{1q}\end{bmatrix} \quad (1)$$

The time constants of the drive may be grouped into three categories as follows.

1	very slow time constants:	mechanical
2	slow time constants:	magnetic
3	fast time constants:	electrical

After eliminating the variations of the variables associated to the very slow and slow time constants, the dynamic model of the induction machine may be reduced to a second-order linear system as shown in the expressions below.

$$\left|\begin{array}{l}\frac{d\mathbf{Y}_1}{dt}=\mathbf{A}\cdot\mathbf{Y}_1+\mathbf{B}\cdot\mathbf{U}_1\\ \mathbf{X}_1=\mathbf{C}\cdot\mathbf{Y}_1+\mathbf{D}\cdot\mathbf{U}_1\end{array}\right. \quad (2)$$

where the significance of the matrices is given in expressions (3) to (6).

$$\mathbf{A}=\begin{bmatrix}-\frac{1}{T_1+T_2} & \omega_1-\omega\cdot\frac{T_2}{T_1+T_2}\\ -\left(\omega_1-\omega\cdot\frac{T_2}{T_1+T_2}\right) & -\frac{1}{T_1+T_2}\end{bmatrix}\quad T_1=\frac{L_1}{R_1}, T_2=\frac{L_2^{'}}{R_2^{'}} \quad (3)$$

$$\mathbf{B}=\frac{T_1}{T_1+T_2}\cdot\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix} \quad (4)$$

$$\mathbf{C}=\frac{T_1}{T_1+T_2}\cdot\begin{bmatrix}1 & \omega\cdot T_2\\ -\omega\cdot T_2 & 1\end{bmatrix} \quad (5)$$

$$\mathbf{D}=\frac{T_1}{T_1+T_2}\cdot\begin{bmatrix}T_2 & 0\\ 0 & T_2\end{bmatrix} \quad (6)$$

Input variables: $\begin{bmatrix}v_{1d} & v_{1q}\end{bmatrix}^T$

Output variables: $\begin{bmatrix}i_{1d} & i_{1q}\end{bmatrix}^T$

State variables: $\begin{bmatrix}\Psi_{1d} & \Psi_{1q}\end{bmatrix}^T$

The Luenberger observer reconstructs the flux-linkage components based on the measurements of the input and output variables. Then the estimations are corrected in closed-loop with a term $K\cdot\left(i_{1d}-\hat{i}_{1d}\right)$ where the gain is determined with a Kalman filter

❖ DISSCUSIONS/RESULTS/ANALYSES

The motor under the investigation was a MSP311 type. The nominal parameters of the motor are given in Table 1.

Table 1: The Nominal Parameters of the MSP311 Motor

Denomination	Rated supply voltage	Rated frequency	Rated angular speed	Number of pair poles	Capacitor
Units	[V]	[Hz]	[rpm]	[-]	[μF]
Value	220	50	2820/420	1/6	14

The determination of the flux-linkage components with the FEM method

In Figure 1 the spectra of the magnetic field components are presented, [4]. The spectra have been determinate within the MAXWELL SV software environment and a geometrical representation of the cross-section of the machine.

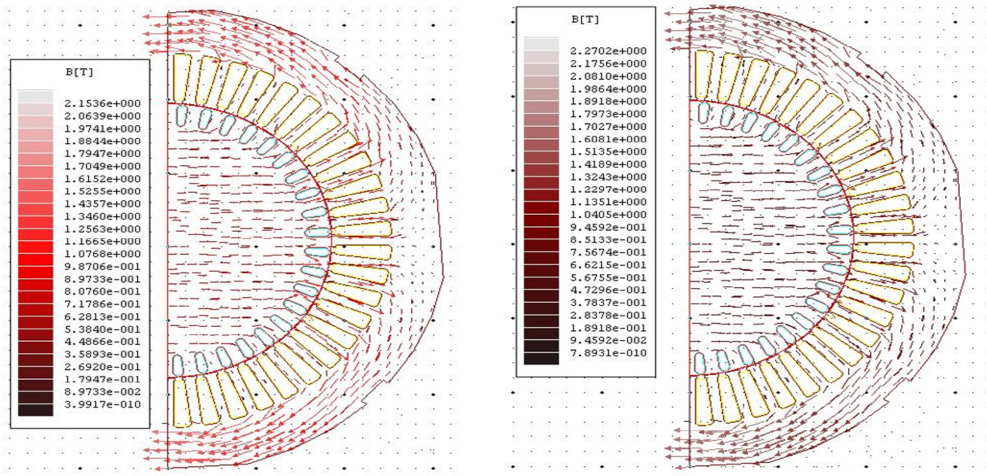

Figure 1: The spectra of the magnetic field determined with the FEM method; to the left - the (Od) axis component, to the right – the (Oq) axis

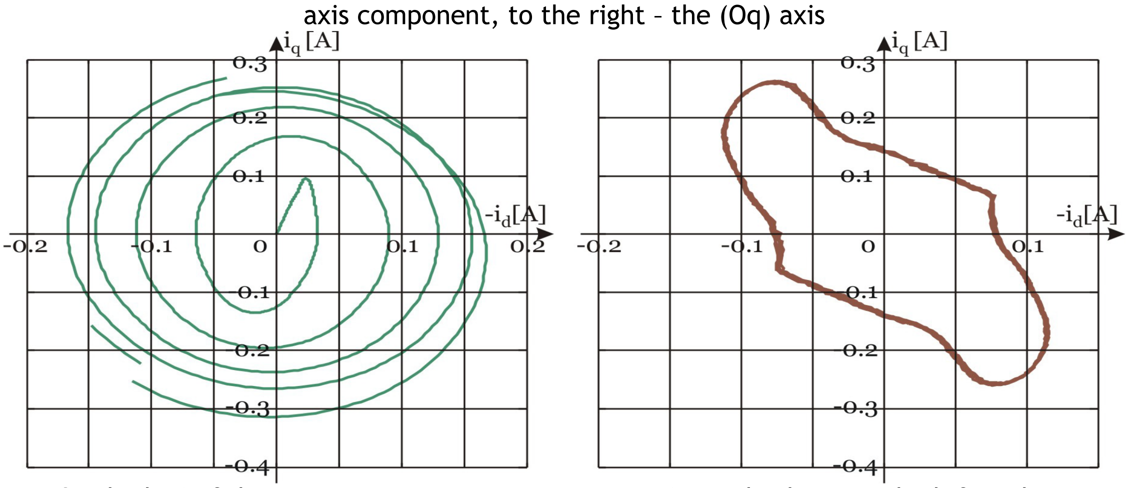

Figure 2: The loci of the stator currents space-vector, estimated values- to the left and measured values – to the right.

The computations performed with the field calculator give the following values for the self inductances of the stator: $L_{1d} = 0{,}665\ H$ and $L_{1q} = 0{,}358\ H$. A remark issued at the implementation of the method is that the estimate is dependent on the values of the magnetic permeability of the on the magnetization curve. If an experimental determination of the magnetization curve is not available the estimation will be performed carefully and several data sets shell be used to increase the accuracy of the estimate.

The determination of the magnetic flux with state observers

The measurements used within the observer's implementation are presented in [4]. The implementation of the state observer is associated to the model in notation (2). The loci of the stator currents space-vector, estimated values and measured values are depicted in Figure 2.

From the analysis follows that the estimator cannot describe the non-linearity effects into the model but the information about the magnitude of the variables is conserved. The time-dependencies of the estimated flux components are presented in Figure 3.

❖ CONCLUSIONS/FURTHER PROPOSALS

In this paper, the implementation of two different methods - the FEM method and an observer-based method - for the magnetic field components estimation is presented. The model under investigation was a single/two-phase capacitor-run induction machine.

The FEM method is widely used at the design level; the state observer is implemented in the adaptive control. From the analysis above, both methods provide.

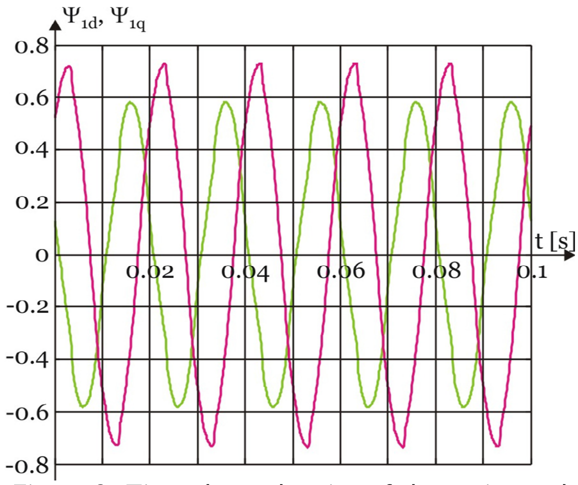

Figure 3: Time-dependencies of the estimated flux components

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