CONTRIBUTION TO PARAMETER IDENTIFICATION OF AN INDUCTION MOTOR BY GENETIC ALGORITHMS

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SUMMARY

The paper presents contribution to parameter identification of an induction motor by genetic algorithms (GA) programme. Its correctness was verified by identification of the model assembled by five rated parameters. Then phase current and speed of the 1.5 kW motor were measured during start by direct connection to mains. Unknown parameters of the mathematical model were identified by GA. Because of varying motor parameters some differences appear among model time responses and real curves. However, certain constant parameters distinct from rated values but ensuring satisfactory matching with measurement may be found. Deviations of time responses were evaluated at measurement of speed, current or both magnitudes. Particular solutions are illustrated by corresponding graphs.

***Keywords**: induction motor, mathematical model, parameter identification, genetic algorithms*

1. INTRODUCTION

Knowledge of the induction motor analytical model is necessary for design of controllers. The required accuracy depends on the applied control method. Whilst approximate values are satisfactory for robust and scalar control, more precise determination of real motor parameters is necessary for field-oriented control, direct torque control and speed sensorless control. Many methods of parameter measurement and calculation were published, some of them using genetic algorithms [1], [3], [5]. They were based on different initial data, measured magnitudes, simplifications of the motor model and chosen selection methods. Rated parameter values may be obtained if conditions similar to the nominal operating point are realized [1]. However, assumption of constant and rated model parameters does not correspond to the real motor behaviour during start by direct connection to mains and some deviations of time responses are observed. Detailed analysis [2] based on comparison of measured and calculated values has shown that model with certain constant parameters may offer satisfactory description of real situation. The aim of this contribution was to find a simple procedure for identification of induction motor model parameters corresponding to measured time responses during start. Application of genetic algorithms (GA) may be regarded as suitable for this aim.

2. THE MOTOR MODEL

The mathematical model of an induction motor is described in the stator coordinate system under usual assumptions [4]:

$$\frac{di_{1\alpha}}{dt} = -\frac{R}{\sigma L_1} i_{1\alpha} + \frac{L_m}{\sigma L_1 L_2 T_2}\psi_{2\alpha} + \frac{L_m}{\sigma L_1 L_2}\omega\psi_{2\beta} \qquad (1)$$

$$\frac{di_{1\beta}}{dt} = -\frac{R}{\sigma L_1} i_{1\beta} - \frac{L_m}{\sigma L_1 L_2}\omega\psi_{2\alpha} + \frac{L_m}{\sigma L_1 L_2 T_2}\psi_{2\beta} \qquad (2)$$

$$\frac{d\psi_{2\alpha}}{dt} = \frac{L_h}{T_2} i_{1\alpha} - \frac{1}{T_2}\psi_{2\alpha} - \omega\psi_{2\beta} \qquad (3)$$

$$\frac{d\psi_{2\beta}}{dt} = \frac{Lm}{T_2} i_{1\beta} + \omega\psi_{2\alpha} - \frac{1}{T_2}\psi_{2\beta} \qquad (4)$$

$$\frac{d\omega}{dt} = \frac{3p^2}{2J}\frac{L_m}{L_2}\psi_{2\beta} i_{1y} - \frac{p}{J} m_z , \qquad (5)$$

where $\sigma = 1 - \frac{L_m}{L_1 L_2}$ and $R = R_1 + R'_2 \left(\frac{L_m}{L_2}\right)^2$.

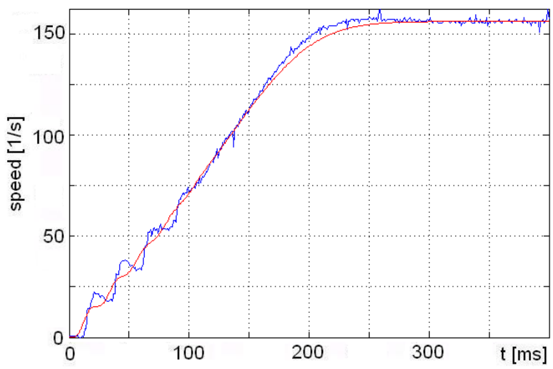

Fig. 1 Measured and modelled speed responses with rated parameters

Nameplate data of the examined motor were: P= 1.5 kW, U=220 V, I=3.9 A, n=1410 rpm. and J=0.034 kgm^2. The last value was increased by coupled mechanism. Further parameters were obtained by no-load and locked rotor test: R_1=5.47 Ω, R'_2=4.3 Ω, L_m=0.27 H, L_s=0.0139 H, J=0.034 kgm^2. Comparison of modelled and measured time responses is shown in Fig. 1 and Fig. 2. Varying parameters and voltage distortion by the 5-th harmonics caused deviations of both curves.

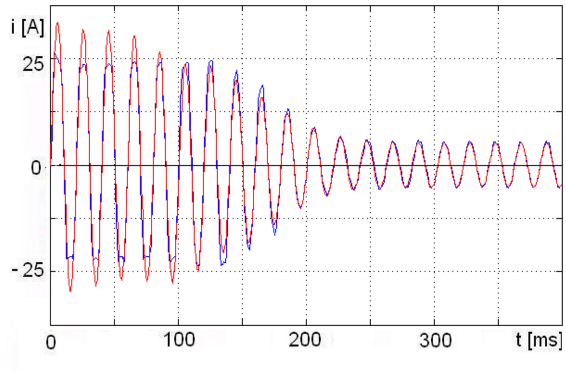

Fig. 2 Measured and modelled current responses with rated parameters

3. GENETIC ALGORITHM

Genetic algorithm programme was written in JAVA language. The induction motor model has simulated direct connection to mains. Small load torque corresponding to friction was supposed. Time responses of stator phase current and rotor speed were recorded every millisecond and stored in computer. The weighted fitness functions of speed and current were evaluated by squared differences between measured time responses and curves calculated by analytical model with estimated parameters. Solution was stopped if fitness has not improved at least by 5 % during specified number of generations. Because phase voltage shift was uncertain, GA has also searched its value. Since transients and higher harmonics of mains voltage have distorted mainly the first part of responses, evaluation of the fitness function has begun after chosen time delay. Initial population was defined for motor parameters found from catalogues as mean values. These approximate values of resistance R_1, leakage reactance X_{1s}, main inductance L_m and moment of inertia J as functions of motor power are depicted in Fig. 3 and Fig. 4. Real parameters are expected to lie within intervals given by ± 50 % of the listed catalogue values: $R_1=R'_2=3.6\ \Omega$, $L_m=0.293$ H, $L_{1\sigma}=L_{2\sigma}=0.012$ H, $J=0.008$ kgm^2.

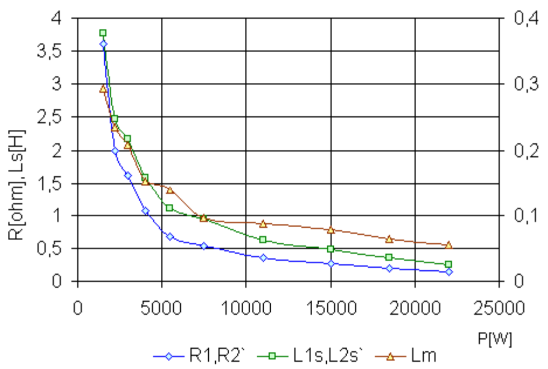

Fig. 3 Catalogue values of motor parameters

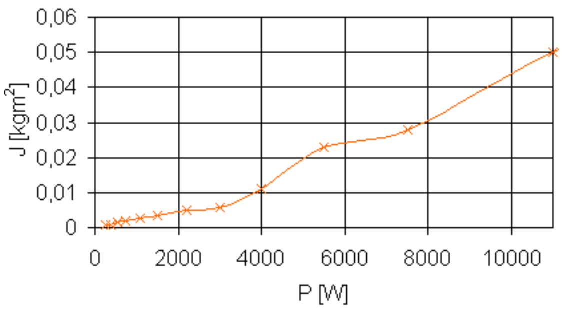

Fig. 4 Catalogue values of motor moment of inertia

Correctness of the GA programme was verified by identification of the motor model assembled by rated parameters. Thirty individuals were applied in every generation. As may be seen in Fig. 5 deviations converge to zero.

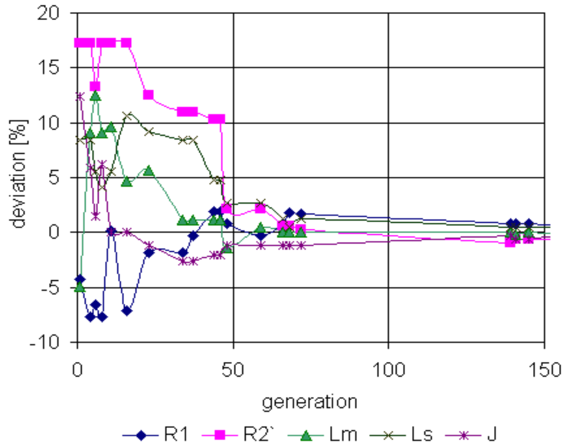

Fig. 5 Deviations of rated parameters identified by GA

4. IDENTIFICATION AT MOTOR START

The simplest identification procedure could have been based on speed as only measured magnitude. In this case few generations of GA were satisfactory for determination of parameters (Fig. 6).

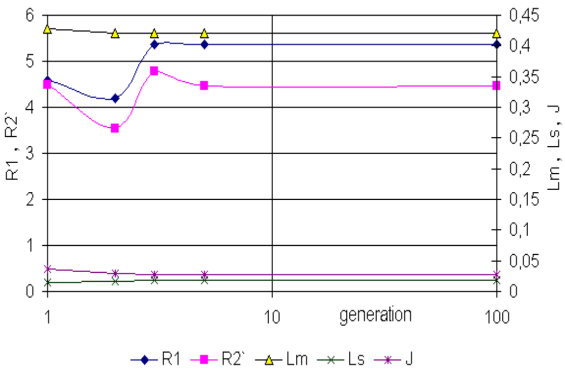

Fig. 6 Identification by speed measurement

Coincidence with the real speed curve was very good (in Fig. 7 full line measured, dashed line modelled). However, the found parameters cause not negligible current differences (Fig. 7a).

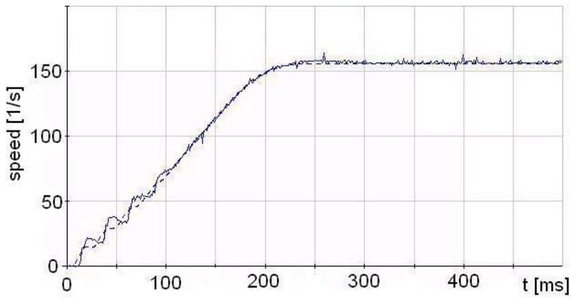

Fig. 7 Speed responses at speed measurement

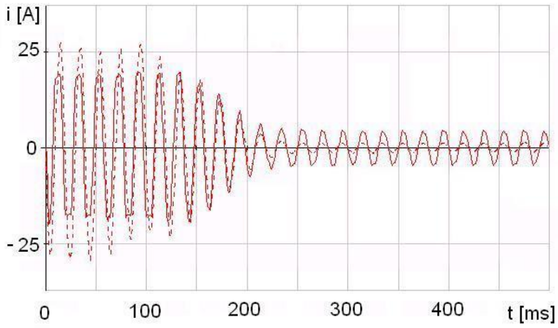

Fig. 7a Currents at speed measurement

Another approach assumes measurement of one phase current. Deviation of current time response is smaller than in the previous case but speed response is a little worse, especially in the first part of transients. Identification by measured current only cannot reliably determine moment of inertia.

From the previous tests follows that measurement of both magnitudes may improve parameter identification. Therefore fitness components (speed: current) were balanced by 50:50 %. Two-point crossover 75 % and 10 % mutation were chosen. Population size consisted of 100 individuals. Fig. 8 and Fig. 9 present values of the identified parameters during particular generations.

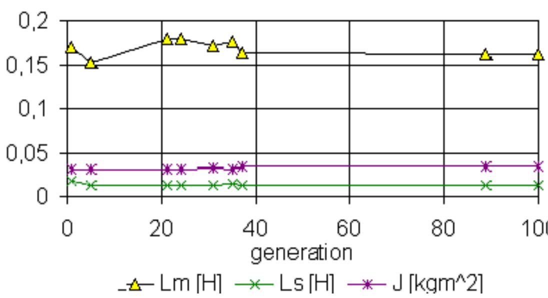

Fig. 8 Motor parameters identified by GA

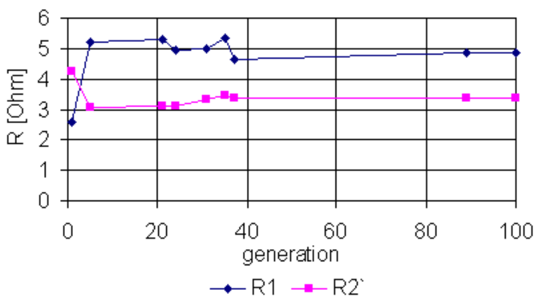

Fig. 9 Motor parameters identified by GA

The listed motor parameters are: R_1=4.88 Ω, R'_2=3.38 Ω, L_m=0.162 H, L_s=0.0128 H, J=0.0342 kgm^2. Model speed response obtained by these parameters and measured curve are introduced in Fig. 10. Comparison to Fig. 1 shows better coincidence.

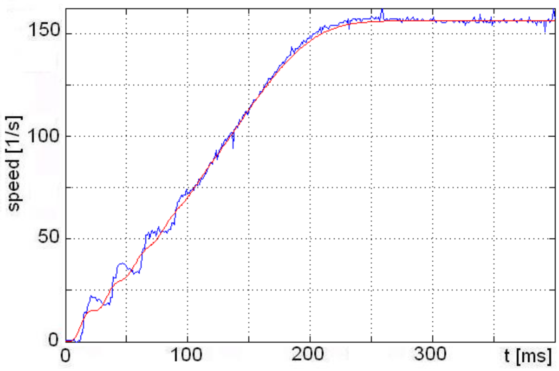

Fig. 10 Measured and modelled speed time responses for 50/50 fitness ratio

At last the relation of obtained to rated parameters is to evaluate (Fig. 11). As expected, the main inductance has changed because of saturation. Further parameters differ depending on chosen fitness ratio. Compromising 50/50 % ratio may be regarded as most acceptable.

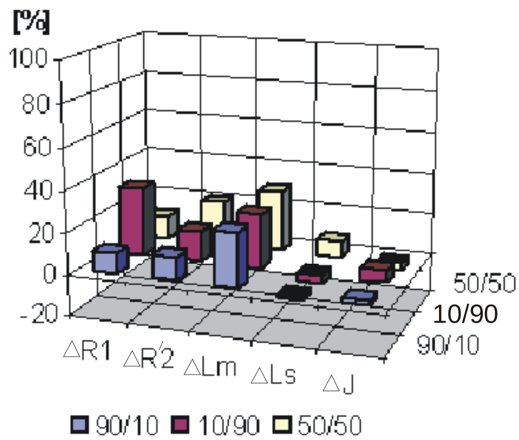

Fig. 11 Differences to rated parameters at various speed/current fitness ratios

5. CONCLUSION

Identification of induction motor parameters assumes their constant values during measurement and due structure of the mathematical model. These conditions are only partly fulfilled, because some parameters vary at motor start and simplified model cannot reflect all physical phenomena. However, certain constant model parameters are sufficient for simulation of speed and current time responses. Application of genetic algorithms programme needs only few measured magnitudes; therefore it may be regarded as satisfactorily simple. Because induction motor start by direct connection to mains is often used in industry, such dynamical model may be useful for evaluation of starting conditions.

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BIOGRAPHY

Želmíra Ferková (Ing. PhD.) graduated in electrical engineering from the Technical University Košice in 1982 and received her PhD in 1994. At present she is a senior lecturer of electric machines at the Department of Electrical Drives and Mechatronics TU Košice. Her professional area is design of electrical machines, mainly of switched reluctance motors.

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