Wiktor HUDY, Kazimierz JARACZ

Institute of Technology, Pedagogical University of Cracow, ul. Podchorążych 2, 30 – 084 Kraków, Poland,

Identification of mathematical model induction motor's parameters with using evolutionary algorithm and multiple criteria of quality

***Abstract**. In this paper identification's method of mathematical model induction motor's parameters was shown. This identification is based on evolutionary algorithm. The criterion, which is the functional of four quality indexes, was applied. Mathematical model parameters of induction motor were values of individuals' parameters. On the basis of calculated parameters' values characteristics generated were compared with experimental characteristics. The identification was made with using Tamel Sg90L-6 induction motor.*

Streszczenie.** W artykule zaprezentowano metodę identyfikacji parametrów modelu matematycznego silnika indukcyjnego wykorzystującą wielokryterialny algorytm ewolucyjny. Zastosowano kryterium będące funkcjonałem 4-ch wskaźników jakości. Wartości parametrów osobników stanowiły parametry modelu matematycznego silnika indukcyjnego. Wygenerowane charakterystyki na podstawie obliczonych wartości parametrów porównano z charakterystykami doświadczalnymi. Identyfikację przeprowadzono przy wykorzystaniu do tego celu silnika indukcyjnego firmy Tamel Sg90L-6.* (Identyfikacja parametrów modelu matematycznego silnika indukcyjnego przy zastosowaniu algorytmu ewolucyjnego i multiplikatywnego wskaźnika jakości***)

Keywords: induction motor, evolutionary algorithm.
Słowa kluczowe: silnik indukcyjny, algorytm ewolucyjny.

1. Prefatory

At present stage of development induction motors find application in electric driving systems.

In research of dynamic of these systems the basic task is describing mathematical model of induction motor. The next step is identification of parameters of this model. The work of mathematical model of induction motor reflects transitory process, which occurs in motor with some approximation. This model shouldn't be too complicated, but should reflect these processes precisely enough. In this paper the commonly used simplifications are assumed [1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 13].

To identify mathematical model' parameters of induction motor were used the evolutionary algorithm (AE), which has the basic attitudes [11]:

- manipulates many potential solutions at the same time – individuals,
- imitates natural evolution,
- is easy in implementation,
- it cannot be assumed the received result is optimal, but it can use techniques, which allow a decrease in final mistake ex. by using progressive mutation and two kinds of selection.

Table 1. Evolutionary algorithm's parameters

Generation amount	100 000
Individual amount in population	200
Cross amount	80
Mutation amount	80
Progressive mutation amount	from 30 to 100. Every 1000 generations it was increased amount mutations about 1 to border 100.
Amount of points, in which there are calculated criterion (P)	150

For selection there was used a method, which takes advantage of two ways of natural selection: tournament method and deterministic method [5].

Measurements of Sg90L-6 induction motor's characteristics were made on Department of Electrical Machines with using DAMOT program. Measurements of starting characteristics were made for five values of power voltages (among it for the power U_n, which was used in identification process) and steady state's characteristics (the mechanical characteristic and the function of phase current in the slip function).

In this paper a method of identification of mathematical model induction motor's parameters with use of multi-criteria evolutionary algorithm. Four quality indexes were used (K_1, K_2, K_3, K_4) and they were calculated as following:

- K_1 – as the sum of squares of errors in discrete moments of time between measured values of registered during starting rotational speed and values, which were calculated on the basis of individual;
- K_2 – as the sum of squares of errors in discrete moments of time between measured root mean square values of phase current registered during starting and values, which were calculated on the basis of individual;
- K_3 – as the sum of squares of errors between measured values of electromagnetically moment and values which was calculated on the basis of individual in measurement points;
- K_4 – as the sum of squares of errors between measured values of phase current and values, which were calculated on the basis of the individual in selected measurement points.

In [3, 4, 5, 6, 9, 12, 13, 14, 15] paper the same assumptions were assumed, with regarding to mathematic model, evolutionary algorithm's parameters and partial index of quality similar as in this paper. Distinctively to this paper final index of quality was assumed, which was the sum of partial indexes of quality.

The final index is the product fitness function (1) with assuming real-valued representation of task. After taken simplified assumption the individual is seven-dimensional vector at coordinates {R_1, R_2, L_1, L_2, L_{12}, J, D}, where R_1 – stator resistance, R_2 – rotor resistance, L_{12} – magnetizing inductance, L_1 – stator leakage inductance, L_2 – rotor leakage inductance, J – moment of inertia, D – coefficient of friction. In this situation final index has a form:

$$F = \prod_{i=1}^{k} \frac{1}{N_r^2} \sum_{j=1}^{P} \left(w_{zi,j} - w_{oi,j} \right)^2 \qquad (1)$$

where: k – number of criteria (k=4), N_r – maximum value received for i-th measure characteristics, $w_{zi,j}$ – measure value of i-th criterion in j-th time's moment, $w_{oi,j}$ – the value of i-th criterion calculated in j-th time's moment.

2. Identification of mathematical model induction motor's parameters

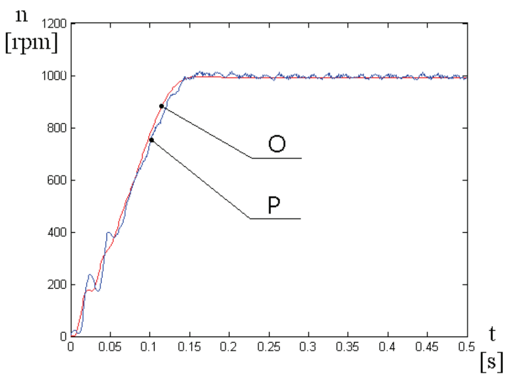
There were many processes of simulation made based on evolutionary algorithm. Evolution results chosen for made assumptions are in table 2. Values of fitness function (F) are unitless quantities.

Table 2. Results of evolution for Sg90L-6 induction motor

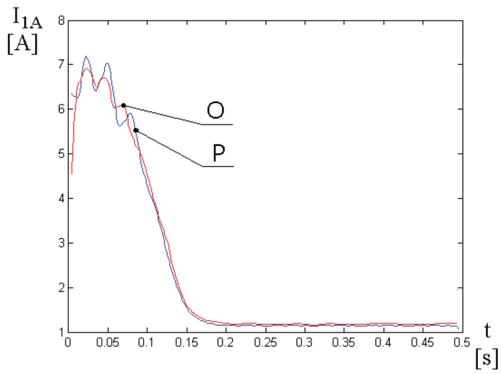
Lp.	R_1 [Ω]	R_2 [Ω]	L_1 [H]	L_2 [H]	L_{12} [H]	D [Nms/rad]	J [kg m²]	F
1.	5,03858	3,42817	0,20297	0,10028	0,08056	0,00609	0,01360	0,01200
2.	5,02335	3,43469	0,19985	0,10191	0,08080	0,00603	0,01384	0,00075
3.	5,02197	3,43951	0,20150	0,10083	0,08085	0,00597	0,01384	0,00150
4.	5,02710	3,43345	0,19812	0,10311	0,08083	0,00602	0,01404	0,00056
5.	5,02107	3,43550	0,20057	0,10149	0,08076	0,00599	0,01378	0,00101
6.	5,01527	3,43361	0,20122	0,10128	0,08078	0,00603	0,01375	0,00152
7.	5,01479	3,42843	0,20446	0,10045	0,08092	0,00608	0,01342	0,00022
8.	5,02177	3,43749	0,19826	0,10291	0,08077	0,00597	0,01370	0,00065
9.	5,01471	3,42506	0,20085	0,10124	0,08077	0,00596	0,01372	0,00099
10.	5,01988	3,43788	0,20117	0,10120	0,08083	0,00601	0,01351	0,00143

The best individual (it is the solution of identification problems) is '7' individual from table 2. This individual represents identified mathematical model's parameters of induction motor. On drawings 1 a, b, c, d there is measurable data and characteristics calculated base on optimal individual number '7' from table 2.

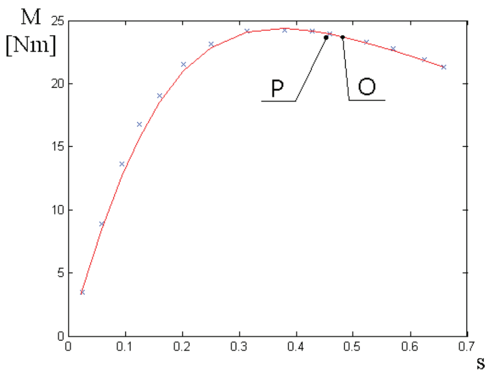
a)



b)



c)



d)

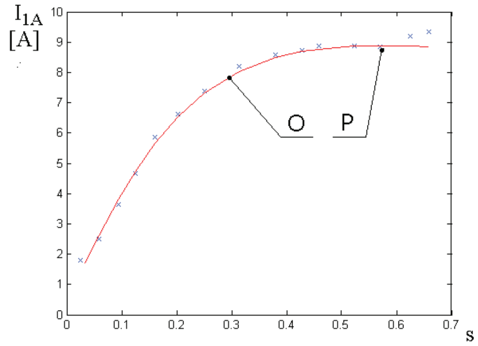
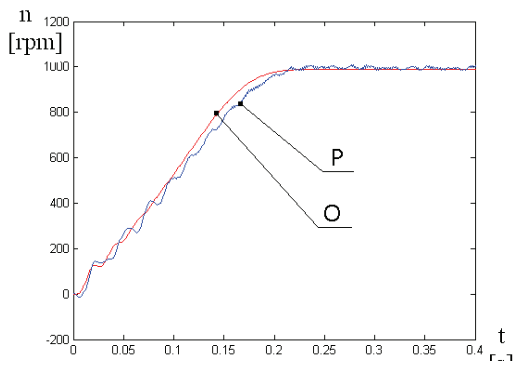


Fig. 1. Rotational speed characteristic (a) and current first phase stator (b), mechanical characteristic (c) and first phase current in the slip function (d) for measuring data and individual '7' from table 2

3. Verification of calculated parameters

Measurable characteristics for various values of power voltage were using to verification of counted parameters of mathematical model induction motor. Fig. 2a,b, 3a,b, 4a,b show measurable characteristics (P) and counted characteristics (O) based on individual '7'.

a)



b)

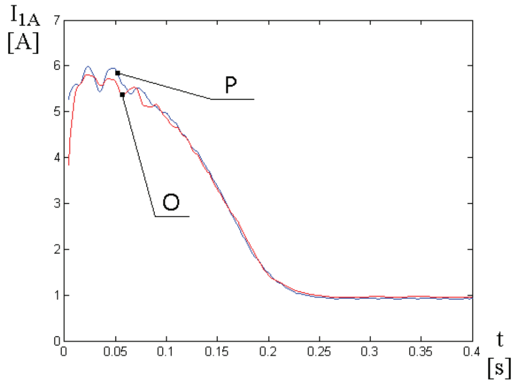
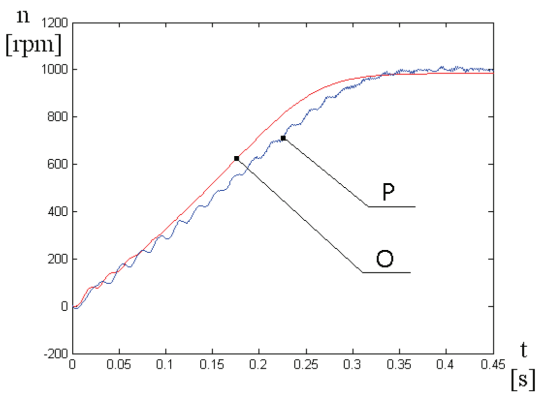


Fig. 2. Rotational speed characteristic – (a) and first phase current – (b) start motor Sg90L-6 for $U_{z,sk}$ = 252 V

a)



b)

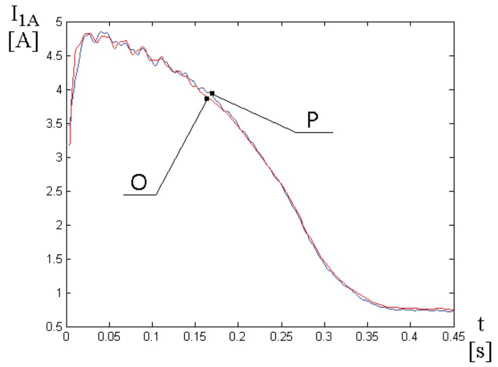


Fig. 3. Rotational speed characteristic – (a) and first phase current – (b) start motor Sg90L-6 for $U_{z,sk}$ = 203.7 V

a)

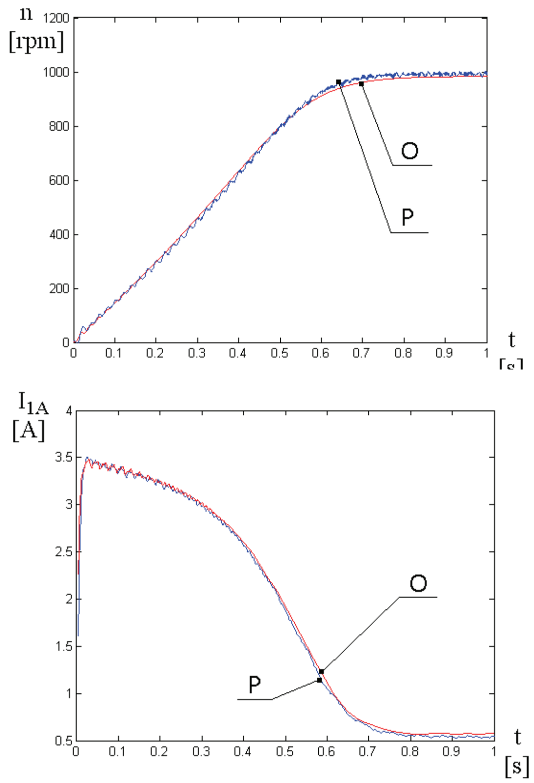


Fig. 4. Rotational speed characteristic – (a) and first phase current – (b) start motor Sg90L-6 for $U_{z,sk}$ = 150 V

4. Resume

As follows from table 2 received results are recurring. On the basis of drawings 2, 3, 4 it can be affirmed that assumed model and received results of mathematical model's parameters imitate processes occurred into induction motor in a good way. The result from '7' position from table 2 is the best one. On the basis of received results it is possible to affirm that using the evolutionary algorithm, which uses 4-th quality indexes and a product quality index, gave good results. These results differ insignificantly from results received in paper [3]. Using the final criterion, which is product of partly criterions, insignificantly shorten time of calculations. Received results are usable as a input degree to other optimization methods.

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***Authors**: dr hab. inż. Kazimierz Jaracz,* Institute of Technology, Pedagogical University of Cracow, ul. Podchorążych 2, 30 – 084 Kraków, Poland, E-mail: jaracz@ap.krakow.pl*; dr inż. Wiktor Hudy,* Institute of Technology, Pedagogical University of Cracow, ul. Podchorążych 2, 30 – 084 Kraków, Poland, E-mail: *whudy@up.krakow.pl*