DESIGN PARAMETERS OPTIMIZATION OF ASYNCHRONOUS MOTOR BY USING ARTIFICIAL BEE COLONY ALGORITHM AND INVESTIGATING EFFECTS OF USING DIFFERENT FITNESS FUNCTIONS ON EFFICIENT

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Abstract - In this study, design parameter optimization of three-phase asynchronous motor is performed by using Artificial Bee Colony Algorithm. In the optimization process three different fitness function have been used. Fitness functions aims to maximize the efficiency of the motor. In the study, firstly initial parameters of the motor have been determined and then these parameters have been compared with optimized values. Also, motor performances according to these parameters have been obtained and compared with tables and graphics. Results show that all of fitness functions give better results than initial condition and improve the motor efficiency.

Index Terms - Asynchronous Motor, Design Parameter Optimization, Artificial Bee Colony Algorithm

I. INTRODUCTION

Nowadays, Asynchronous Motors (AMs) are widely used in industrial applications due to their advantages on high power capacity and efficiency. The design procedure of these motors is very difficult and requires expertise. [1, 2] In the design phase, required power should be ensured while aiming to keep the efficiency high. Moreover, each parameter that affects the performance of the motor and hence the efficiency must be included in the optimization process [3]. When all these factors are taken into consideration, the design process becomes more complicated. Today, there are some package programs used for design purposes. However, in these programs, the design process can be realized in a limited way.

In order to increase the efficiency of the electric machines, several studies have been carried out by using different methods to optimize the design parameters. Especially, meta-heuristic methods such as Simulated Annealing Algorithm (SA), Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) have been used to solve the optimization problem and it can be said that they have succeeded [4-8].

In this study, designing of an asynchronous motor has been carried out as an optimization problem and results obtained have been presented. Stator outer diameter (SOD) , stator inner diameter (SID), core length, stator and rotor slot geometry, conductor per slot (CPS) have been chosen as designing parameters which will be optimized. Initial geometric values of the AM have been determined firstly and the performance results of the motor have been examined with these values. Then, the objective functions, which aim to maximize the motor efficient, have been designed in three different ways and optimized by using Artificial Bee Colony (ABC) algorithm. In this optimization process, ANSYS Maxwell software has been used as motor design and analysis, and MATLAB Mathworks software has been used to solve the optimization problem. These two programs have been run simultaneously during optimization process. While the connection between these two programs has been provided by means of scripts, the performance values of optimized AM for each epoch have been recorded. After the optimization process has been completed, FEM analyzes have been performed according to the parameters obtained from the initial parameters and from the three different objective functions, and the results have been presented comparatively by carrying out the design validation. The obtained results show that a higher efficiency design has been achieved than initial conditions by optimizing via Artificial Bee Colony algorithm.

II. ARTIFICIAL BEE COLONY ALGORITHM

The Artificial Bee Colony Algorithm (ABC) was produced by Karaboğa in 2005 and it simulates the behavior of honeybees in the food search process [9, 10]. This algorithm, which has a simple structure and few control variables such as colony size and maximum cycle number, provides a powerful searching strategy when comparing other methods such as PSO and Differential Evolution (DE). In the ABC, artificial bees modify the food positions by the time search the food sources having high nectar amount. The food source with the highest nectar amount finding at the end of searching process corresponds to best solution (global optimum) for the problem to be optimized. In the figure3 1, the general flow diagram of the searching process of ABC algorithm [10] is given.

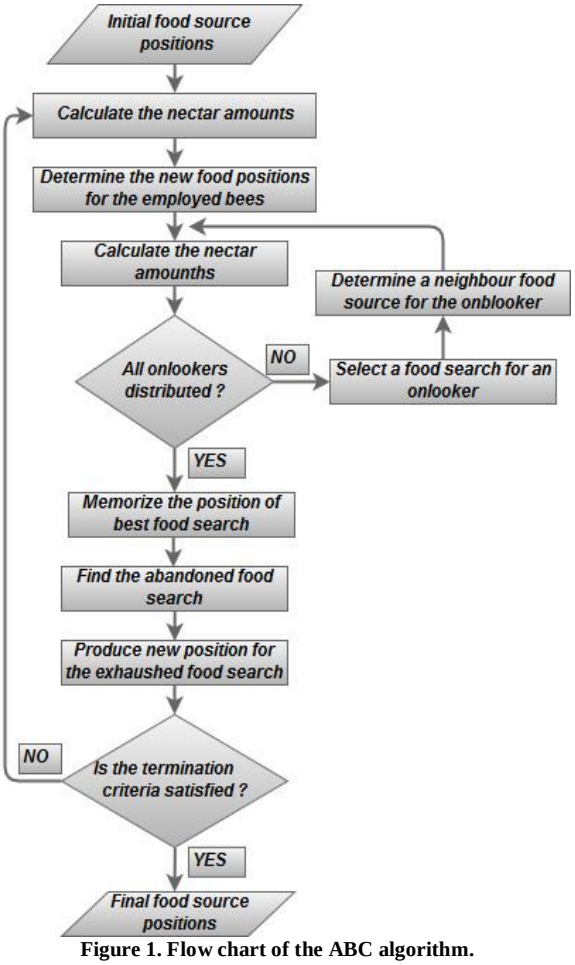


Figure 1. Flow chart of the ABC algorithm.

In the ABC algorithm, there are three types of bee that are employed, onlooker and scout. Employed and onlooker bees fly around in the search space and find food sources having higher nectar amount. The duty of scout bees is choosing food sources randomly according to nectar amount chosen source. According to the searching strategy, if the nectar amount of a source chosen is better than old one, it memorizes and the old one is eliminated.

III. INITIAL MOTOR PARAMETERS AND PERFORMANCE

General parameters of the three-phase asynchronous motor used in the operation and the optimization process are given in the Table 1 below.

Initial Parameters	Value
Number of Poles	4
Rated Output Power	18.5 kW
Rated Frequency	50 Hz
Rated Voltage	380 Volt
Stator Outer Diameter	260mm
Stator Inner Diameter	170 mm
Rotor Inner Diameter	65 mm
Core Length	150 mm
Air Gap Length	1 mm
Number of Stator Slots	36
Number of Rotor Slots	28
Specific Electric Loading (A/m)	37583
Stator Ohmic Loss (W)	984.25
Rotor Ohmic Loss (W)	527.44
Core Loss (W)	375.12
Efficiency	%88.9
Power Factor	0,811
Rated Speed (Rpm)	1458

Table 1. Main dimensions and performance values of initial design

When the analysis results of the initial model are analyzed, it is seen that the Specific Electric Loading and slip (s) value is high and the efficiency and power factor is low. While the objective of the fitness function used in ABC is to maximize efficiency, when examining the results, these parameters are also considered to avoid the local maximum.

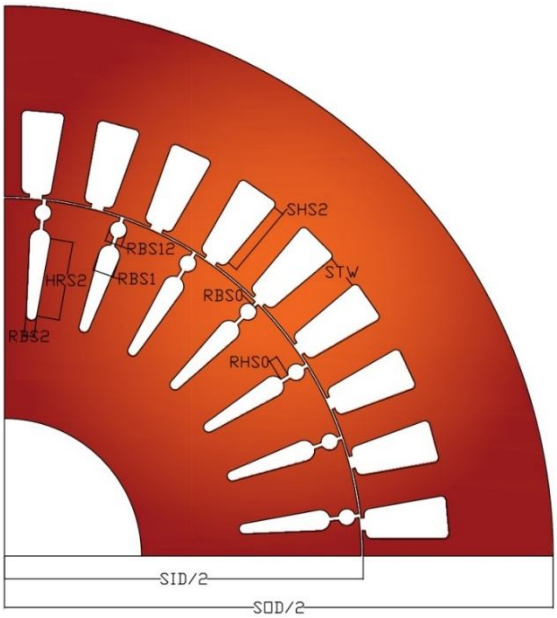


Figure 2. Parameters to be used in the optimization

Figure 2 shows the parameters to be used in the optimization and In Table 2, the starting, minimum and maximum values of these variable parameters used in optimization process. Here, the total cross section is automatically adjusted by Ansys Maxwell as the stator slot fill factor does not exceed %65 since CPS value and stator slot area are variable during optimization.

Parameter	Initial Value	Minimum Value	Maximum Value
CPS			
SOD (mm)	260	240	300
SID (mm)	170	150	190
L (mm)	150	100	220
STW (mm)	8	6	11
SHS2 (mm)	17	15	22

RBS12 (mm)	4	2	7
RBS0 (mm)	1	0.5	2
RHS2 (mm)	18	14	22
RBS1 (mm)	5	2	8
RBS2 (mm)	2.5	1	4
RHS0 (mm)	2	1	4

Table 2. Initial Geometric Parameters

IV. EXPERIMENTAL STUDY AND RESULTS

In this study, the optimization of an asynchronous motor parameters, which are the stator outer diameter (SOD), stator inner diameter (SID), core length, stator and rotor slot geometry, and conductor per slot (CPS), was performed using the Artificial Bee Colony (ABC). The results obtained from different fitness functions are presented comparatively. Objective functions used to maximize efficiency are given below.

$F_1 = 100 - \text{Efficiency}$(1)
$F_2 = 1/\text{Efficiency}$(2)
$F_3 = 1/(100 - \text{Efficiency})$(3)
(3)

In the optimization process, while the above objective functions were run in the MATLAB Mathworks environment with the ABC algorithm, performance analysis of the engine in the Ansys Maxwell environment was performed instantaneously with each iteration-generated parameter. Performance exits from Maxwell are presented as input to the ABC algorithm in the Matlab platform. The connection between these two programs is provided by the scripts written and concurrent operation of the two software platforms is provided until the end of the optimization process. A comparison of 2000 iterations for each function is given in Figure 3.

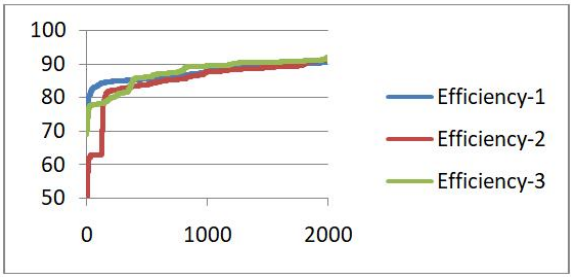


Figure 3. Compare of efficiency results obtained from three different fitness functions

Table 3 shows parameters values for initial and obtained from three different objective functions, and motor performance values according to these parameters.

Parameters	Initial	F_1	F_2	F_3
CPS	100	76	76	78
SOD (mm)	270	297.4	294.6	294.8
SID (mm)	170	182.8	188.3	188.3
L (mm)	150	210.1	205.4	205.4
STW (mm)	8	7.98	8.17	8.17
SHS2 (mm)	17	17.88	20.05	21.54
RBS12 (mm)	4	4.43	5.27	5.27
RBS0 (mm)	1	1.21	0.56	0.56
RHS2 (mm)	18	20.49	21.6	21.6
RBS1 (mm)	5	5.31	6.77	6.77
RBS2 (mm)	2.5	2.42	3.13	3.13
RHS0 (mm)	2	1.51	1.48	2.55
Air Gap Length (mm)	1	1	1	1
Specific Electric Loading (A/m)	37583	24406	24152	24572
Stator Ohmic Loss (W)	984.25	519.84	412.63	442.78
Rotor Ohmic Loss (W)	527.44	299.98	257.03	267.68
Core Loss (W)	375.12	406.40	547.95	492.69
Efficiency	%88.9	%91.79	%91.85	%91.9
Power Factor	0,811	0.855	0.834	0.846
Rated Speed (Rpm)	1458	1476	1479	1478

Table 3. Parameters and Performance Values

According to the table, the Specific Electric Loading (A / m) value decreased by 35% while the efficiency value increased by 3.25% and the power factor value by 5.42% with F1 function. With F2, the output value increased by 3.31% and the power factor value increased by 2.83%, while the Specific Electric Loading value (A / m) decreased by 35.7%. With F3, the output value increased by 3.37% and the power factor value increased by 4.31%, while the Specific Electric Loading (A / m) value decreased by 34.6%. As can be seen here, the efficiency values for all three fitness functions are close to each other and higher for the initial condition. but the highest efficiency value was obtained with F3 function.

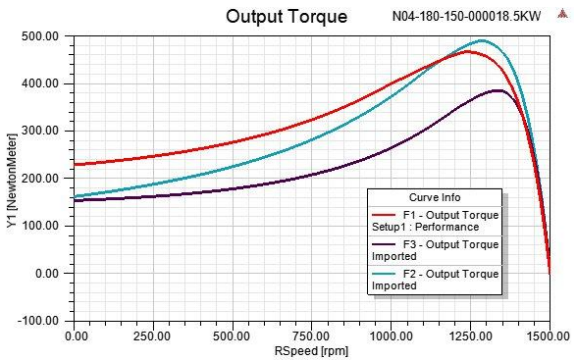


Figure 4. Compare of Torque-Speed Curve

The optimum design of classical asynchronous motors has to meet two requirements that are contradictory in terms of electro-magnetic torque. These are high starting torque and high tipping torque. The rotor slot geometry, rotor resistance and inductance values directly affect these torque values. When the comparative torque-speed graphs in Figure 4 are examined, it is seen that the model obtained by the F1 objective function has higher starting torque and the model obtained by F2 has higher tipping moment.

CONCLUSION

In this study, parameter optimization of three-phase squirrel-cage asynchronous motor was performed by using ABC with three different objective functions and the results are presented comparatively. While the results are compared, efficiency, power factor values and torque-velocity graphs are examined. When the results obtained with F2 and F3 are examined, it is seen that the values obtained are very close to each other. The best efficiency value is obtained with F1. It is also seen that the optimization of the electric machines and electromagnetic problems can be done by using this method with the different algorithms.

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