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A MATLAB Graphical User Interface Dedicated to the Optimal Design of the High Power Induction Motor with Heavy Starting Conditions

In this paper, a Matlab graphical user interface dedicated to the optimal design of the high power induction motor with heavy starting conditions is presented. This graphical user interface allows to input the rated parameters, the selection of the induction motor type and the optimization criterion of the induction motor design also. For the squirrel cage induction motor the graphical user interface allows the selection of the rotor bar geometry, the material of the rotor bar as well as the fastening technology of the shorting ring on the rotor bar. The Matlab graphical user interface is developed and applied to the general optimal design program of the induction motor described in [1], [2].

Keywords: induction motor, optimization, Matlab GUI

1. Introduction

Due to the constructive and operation advantages of the induction motor over the other motor types, the continuously optimization of the motor construction in order to be adapted to the specific operation regimes is an imperious requirement. Order to adapt the constructive solutions of the motor to the peculiarities of the driven system it is a prerequisite to obtain the optimal motor constructions having the high efficiency, minimal losses, reduced costs or reduced dimensions. The optimization of the motor can be adapted to the customers requirements, like: minimal operating costs or high efficiency or must be adapted to the producers requirements, such as: minimal manufacturing costs (concerning the energy or materials) or minimal weights of the motor. Regarding the optimal design, whatever the optimization criterion is, the Matlab can be used as the automatic design tool, allowing a matriceal approach [3] or can be used for the study of the dynamic regime of the induction motor. In this paper a Matlab graphical user interface dedicated to the optimal design of the induction motor is described. The optimal design

program developed in Matlab is detailed presented in [1]. This Matlab program is developed for the squirrel cage induction motor which can have four distinct geometries of the rotor bar section: rectangular/deep bar, trapezoidal bar, T inverse bar or special geometry, in order to efficiently use the skin effect, as they can been seen in the figure 1. The design procedure is based on the design algorithm which is described in the reference [4].

2. The description of the optimization design program

The optimization design program comprises the packages of programs which are developed as interconnected: stator computation, rotor computation, magnetic circuit computation, parameters computation, optimization program. Each of these design programs can independently runs or can be connected through the instrumentality of the graphical user interface. The output data of one of these programs are input data to other software packages. The CAD program allows the computation of the squirrel cage induction motor and consists in a selection process of the decision variables namely: overall sizes or electromagnetic stresses: stator winding current density j_1 [A/mm^2], linear stator current density A [A/cm] and air gap flux density Bδ [T]. The electromagnetic stresses are defined as vectors with variable lengths. Several design data are interactively provided by the program user (e.g.: stator connection type, rotor bar shape, rotor bar material, insulation class etc. Another design data which are involved in the design process can be displayed in a matrix form, matrix families or in a graphical representations. The optimal design program uses 93 data files as input which corresponds to the graphs, experimental curves from the references in the field and standards in forces. The general program of the optimal design, described in this paper, allows to the user to select one of the four optimization criteria or objective functions under constraints. The constraints focus mainly on the starting characteristics: the relative starting current, the relative starting torque or the motor efficiency, the cost or the motor weight.

$$F_1 = \max(m_p(X)), \ i_p <= i_{pmax}, \eta > \eta_{max} , \tag{1}$$

$$F_2 = \max(i_p(X)), \ m_p >= m_{pmax}, \eta > \eta_{max} , \tag{2}$$

$$F_3 = \max(\text{Cost}(X)), \ m_p >= m_{pmax}, i_p <= i_{pmax} , \tag{3}$$

$$F_4 = \max(\text{Weigth}(X)), \ m_p >= m_{pmax}, i_p <= i_{pmax} , \tag{4}$$

where X=X(j_1 [A/mm^2], A [A/cm] , Bδ [T]). The limited values of the constraints are regulated by the motor users. Accordingly to the optimal design method, a variable number V of the constructive variants of the motor are computed:

$$V = \max(\text{length}(j_1)) * \max(\text{length}(A) * \max(\text{length}(B_\delta) , \tag{5}$$

The optimal construction of the motor is selected from the V variants number corresponding to the selected optimization optimization criterion F_1, F_2, F_3 or F_4 subject to the constraints conditions. The selection is made by searching method

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after the admissible directions defined by the $X=X(j_1$ [A/mm^2], A [A/cm] , Bδ [T]). In this paper an application of the CAD program using the Matlab graphic user interface for the optimal design of the induction motor with the rated: 250W, 6kV, 1500 rpm is presented. Running the developed Matlab graphical user interface, a number of 123 output data of the optimized motor solution are displayed in the text data files. The program allows to compare four types of the induction motor with four rotor bar geometry, corresponding to the same optimal criteria or to compare four types of the induction motor with the same rotor bar geometry but selected after the four optimization criteria.
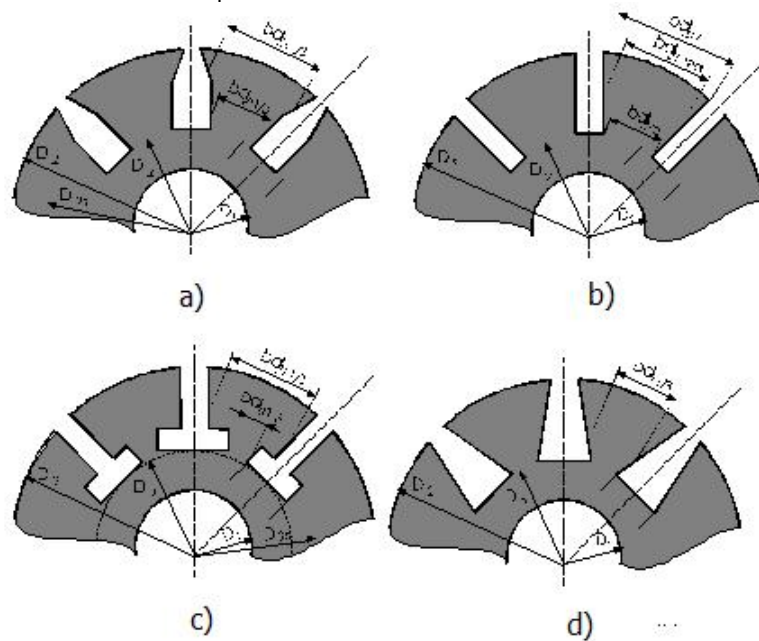
Figure 1. The different geometries of the rotor bar – a) special geometry, b) deep bar, c) T inverse bar, d) trapezoidal bar

3. The Matlab guide user interface presentation

The optimal design program of the squirrel cage induction motor has been upgraded with a Matlab graphical user interface to provide friendly communications and it can be used much more conveniently [5], [6], [7], [8]. Building a Matlab application based on the graphical user interface environment for the optimal design of the squirrel cage induction motor allows input rated data, design data, data processing and data visualization.
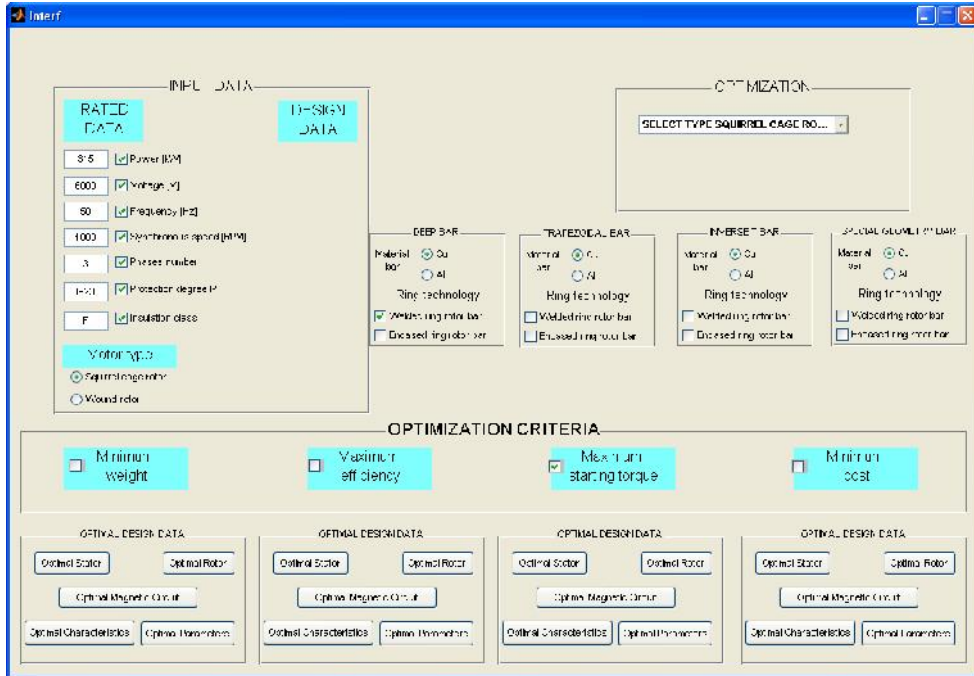
Figure 2. The main configuration of the Matlab GUI.

To build the Matlab GUI are used Radio Button, labeled with their own names, which allows to the user to chose the motor type subject to the optimization process (there are two basic types of induction motor – squirrel cage induction motor or wound rotor induction motor) or to chose the optimization criterion accordingly to the point of view of producer or the customer. These are minimum cost, maximum efficiency, maximum starting torque, minimum weight. The Check Box to select the optimization criterion is used. The main configuration of the GUI comprises ten frames to input the rated data and design data, to select the motor type, the rotor bar geometry, material and the ring technology and the optimization criterion. The interface was conceived in such way to be intuitive and easy to use. In the same time, more inter-blockings were inserted, in order to avoid the transmission of wrong commands, keeping always the high versatility of the module's programming [6]. In the figure 2 the main GUI components can be observed.

Concerning the design data these can be visualized in the graphical form or vectorial form as it can be noticed from the data interface, which is shown in the figure 3.
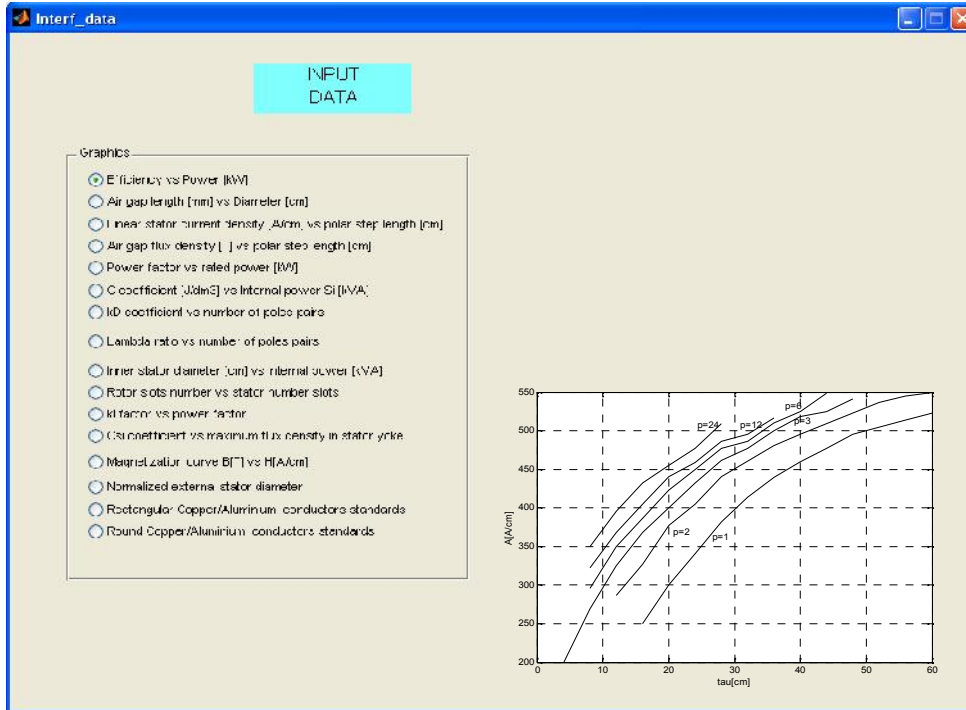
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Figure 3. The data design interface window.

Accordingly to the design algorithm, a large number of data must be used in the design motor process. In the data interface presented in figure 3, only the main 16 design data are shown. The graphical dependencies such as the efficiency variation depending on the rated power and the linear stator current density depending on the polar step length are visualized in order to explain how the interface runs.

The main configuration of the GUI for the optimal design of the squirrel cage induction motor with deep bar made from cooper and the welded ring technology, having the rated: 250W, 6kV, 1500 rpm, three-phase, 50Hz frequency, F insulation class and IP 23 protection degree is presented in the Figure 4.

Choosing the minimum cost as the optimization criterion, the basic optimal motor parameters concerning the optimized stator, optimized rotor and the optimized characteristics are shown in the interface window from figure 5.
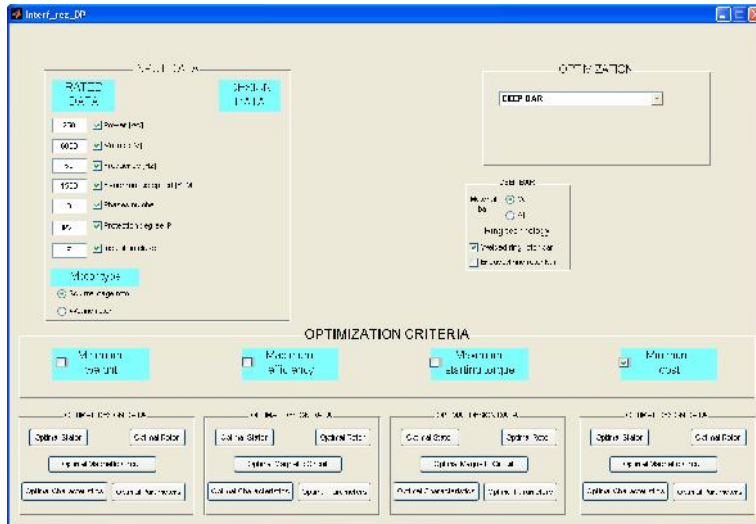
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Figure 4. The GUI configuration for the squirrel cage induction motor optimization.
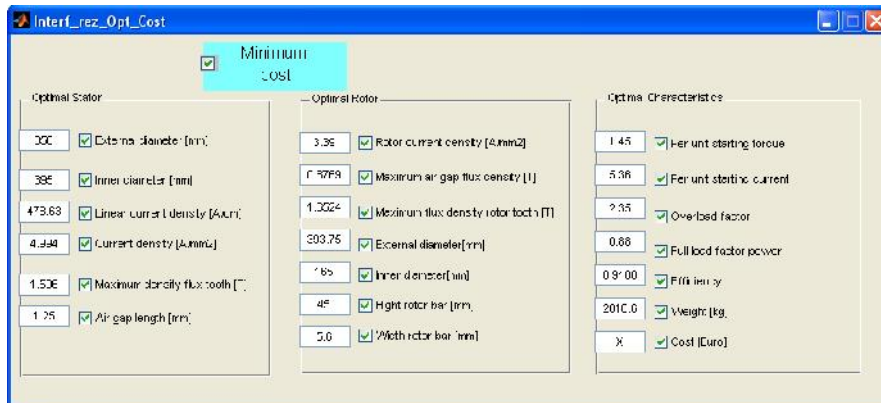

Figure 5. The optimal design parameters-the optimization criterion: minimum cost

If the maximum efficiency is selected as the optimization criterion, the optimal design parameters of the motor are shown in the figure 6.

The optimal design parameters in case of the the maximum starting torque as the optimization criterion, for the same rated motor, are presented in the figure 7.
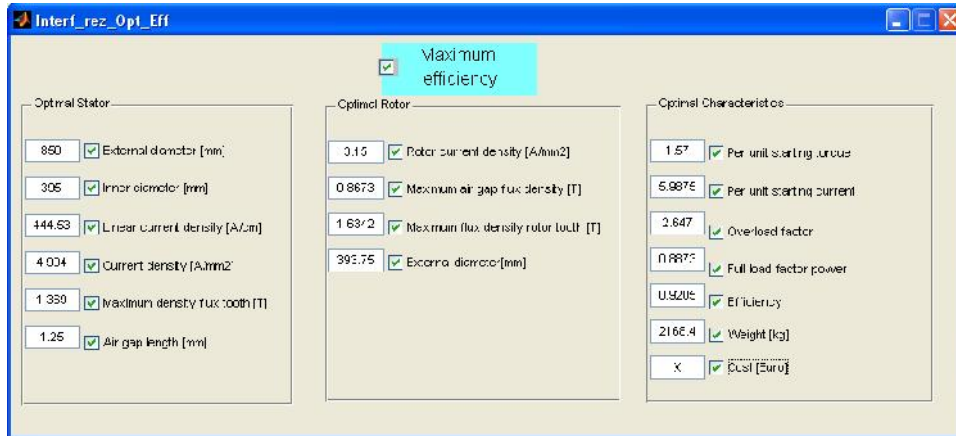
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Figure 6. The optimal design parameters - the optimization criterion: maximum efficiency.

Figure 7. The optimal design parameters - the optimization criterion: maximum starting torque.

4. Conclusion

A Matlab graphical user interface which has the purpose to upgrade the optimization design program of the induction motor with heavy starting conditions is presented. Through the combination of the general design program with the facilities of the developed graphical user interface it is provided to the user one friendly and more conveniently designing environment. The optimized parameters corres-

ponding to the selected optimizing criterion can be obtained and the basic ones are visualized. The validity of the optimal design results can be pointed out by the comparison with the manufactured motor parameters from the companies in the field.

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