Computational Methods for sizing Switched Reluctance Motors

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***Abstract* – This paper presents a Switched Reluctance Motor CAD software developed using Delphi language. The purpose of this software is to aid the electrical engineer to calculate the electrical and mechanical parameters involved with the switched reluctance machine design and sizing. This software contributes with a reduction of time expended during the project and a number of experimental activities with prototyping, contributing also with a development cost reduction of this kind of electrical machine.**

KEYWORDS
Switch reluctance motor, design, software, CAD, Modeling.

I. INTRODUCTION

Nowadays the Switched Reluctance Motors – SRM - are object of study in some Universities and research centers, because this type of electrical machine is more efficient, with physical dimensions smaller than the traditional ones and offer many possibilities of use for several applications.

The switched reluctance machine is basically a doubly salient structure in which concentric coils are assembled around the stator poles and the rotors have neither windings nor permanent magnets. The stator and the rotor are assembled with ferromagnetic laminations. The coils of opposite stator poles are connected in series or in parallel according to the rated voltage and current values of the power source. The cross-section of the 6/4 SRM, which has 3 phases, 6 stator poles and 4 rotor poles is shown in Fig. 1.

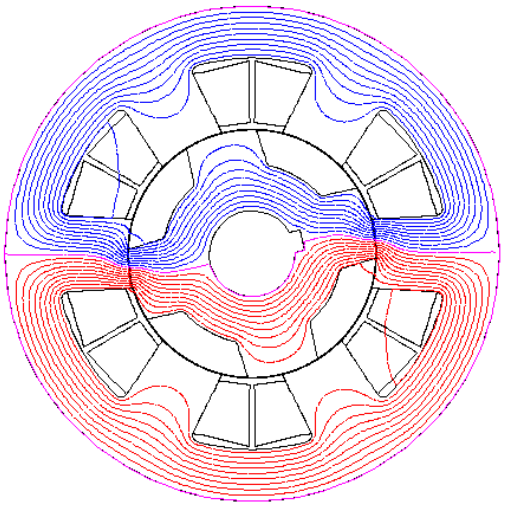

Fig. 1 – 6/4 SR Machine cross-section and flux plot

The studies generally are focused on the sizing or in the drive techniques although this type of electrical machine due to its characteristic needs an external controller through its discrete circuits, microcontroller or even microcomputers, presenting the following advantages:

The rotor pole are smooth and they don't use permanent magnet , which reduces prototyping costs significantly;
The stator is simple and its windings have few turns which never cross;
Almost all the losses occur in the stator, which facilitate its refrigeration;
When correctly projected, the controller has high efficiency in a wide range of torque and speed;
It does not have brushes, mechanical commutators or rings;
It presents high output power in relation to its weight and volume;
Its converter does not have chain peaks and its operation in open circuit or short circuit does not present danger;
It has high initial torque and fast dynamic response.
On the other hand, it presents the following drawbacks:
It must be fed through a switched converter, it cannot be directly fed by an alternate current source or a battery;
The ripple torque and the noise can be high if the machine project is not adequately calculated;
A position sensor is necessary, but nowadays there are many applications which use rotor position indirect sensing techniques;
The switched reluctance motors needs a high number of feeding cables and controls than the controller of induction machines,

Like any engineering project, the advantages and disadvantages must be analyzed according to its application to achieve the best project performance.

To contribute with the research development of these motors, it was developed a computational tool that has the objective of accomplishing of all calculations involved in the physical sizing of the machine and integration with software for CAD, analysis through the finite elements method and simulation of

the machine's performance.

II. Objectives

As well as any another type of electrical machine, the physical specifications (dimensions and number of rotor and stator pole, number of turns of the winding, etc.), electric (DC link voltage, winding currents, etc.), and dynamic (torque and speed) of the switched reluctance motors need a detailed study due to its application [1,2,3,4].

Even though these calculations are complex and involve a good theoretical and practical knowledge of the designing engineer, in the case of switched reluctance motors this knowledge is relatively recent and is in formation. The objective of this software is to facilitate the project of this type of machine, trough a tool that facilitates the determination of the physical specifications, electric and dynamic of the machine, based in the characteristics of its use.

This tool is a computational program, which has friendly and objective interfaces, to retract from the designing engineer the necessary information, and through these, calculate and present the possible physical configurations of the machine specified. This process will facilitate the project and the choice of the best machine to be manufactured; with its calculations it will be possible to create a file compatible with the existing software of CAD; this facility reduces the time and the costs of prototyping project.

III. Methodology

The program that physically sizes the electrical machine is being developed in Delphi [5], language that makes possible the development of fast and modular programs for the MS-Windows® environment. The modularity described in the previous paragraph allows the addition of new features in the main program, either in phases or accordingly to the development of the new modules which will be added in the main module. The original scope considers the creation of three added modules that will be responsible for the integration with:

- CAD softwares (already developed),
- Software's for analysis through the method of the finite elements (in study),
- Software's for performance of machines simulation (in study).

In the end of the development of these modules, the activities will be directed for the product evolution, based on the experience acquired during the development period and also with the results obtained in the experiences performed with the sizing program aid.

Main module

The program responsible for the physical project of the switched reluctance motor is operating and its main interfaces with the user are presented in figures 2 and 3. The original language used for the program was in Portuguese, and a translation to English will be done after finished all software performance evaluation tests. The equations and considerations adopted for the SRM design are in according to the calculation methods presented by Miller [4]. Several arrangements of stator and rotor poles and other characteristics can be accomplished using this software, and the simulation parameters results of the motor design can be fast obtained and visualized.

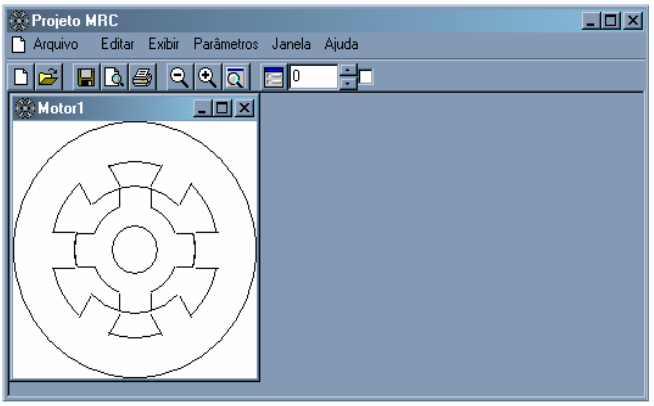

Figure 2 - Main interface of the program

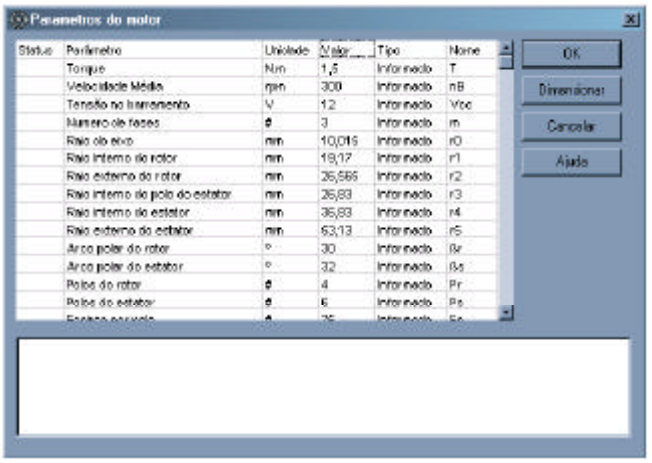

Figure 3 - Screen for parameters configurations of the machine

This interface makes possible the access to all facilities of the program and its graphical presentation is well known by the users of the MS-Windows® operational system, using resources as menus, icons, dialogue boxes, etc. This characteristic allow an easily use of the program, focusing the user's attention to the machine project, not in the learning on how to use the program, as can be seen below the menus are extremely simple, and are presented as follow:

Arquivo

Novo: It creates a new machine template;

Abrir: It loads an file with the data of previously recorded engine;

Salvar: It records the data of the active engine in record;

Salvar Como: It allows saving the active data changing the name of the file;

Exportar como DXF: It creates an file in format ".DXF" with the data of the active machine and it can be opened in any program of CAD;

Configurar página: It allows to specify the printer and size of the paper where the drawing of the machine will be printed;

Imprimir: It prints the drawing of the active machine and its main parameters,

Sair: It abandons the program asking to the user if the modified file will have to be recorded;

Editar

Copiar para Meta File: It copies the drawing of the active machine in Windows Meta File format , thus allowing the exportation of the drawing for many other programs that accept this format;

Copiar para Bitmap: It executes the same function that to "Copiar para MetaFile", however using the format Windows Bitmap;

Copiar Parâmetros: Copy all the parameters of the engine in text format, allowing pasting to any text edition;

Exibir

Ampliar: It extends the visualization of the machine drawing;

Reduzir: It reduces the visualization of the engine;

Ajustar à tela: It adjusts the visualization in a way it can occupy the biggest space possible in the screen at the same time where as can be seen the drawing of the engine in its totality;

Parâmetros

Editar parâmetros: It presents to the user the edition screen of parameters;

Janela

Organizar janelas: It organizes all the windows of drawings of the engine in the screen, allowing a bigger space organization of work to the user;

Organizar Ícones: It organizes all the windows of drawings that are minimized;

Icons

Below of the menu the icons of the functions used in the program are presented:

 Novo : It creates a new machine template;

 Abrir : It loads an file with the data of previously recorded engine;

 Salvar : It records the data of the active engine in record;

 Imprimir : It prints the drawing of the active machine and its main parameters,

 Reduzir : It reduces the visualization of the engine;

 Ampliar : It extends the visualization of the machine drawing;

 Ajustar à tela : It adjusts the visualization in a way it can occupy the biggest space possible in the screen at the same time where as can be seen the drawing of the engine in its totality;

 Editar parâmetros : It presents to the user the edition screen of parameters;

Posição do rotor: It allows to inform and to visualize the position angular of the active machine;

Ativar rotação : A set in motion time makes all the machines of the screen to simulate its rotation;

CAD Module

This module has access through the menu Arquivo – Exportar como DXF – in the main module. It's responsible for the generation of the archive in DXF format compatible with the majority of the existing programs of CAD in the market.
The main objective of this module is to create a file based on calculated values with the quoted drawing of the projected machine. Reducing the time and the cost of the project, and also, the file can be easily converted to CAD-CAM coordinates for manufacturing.

IV. Results

In figure 4, are presented the drawings of the stator, the rotor and the set (stator + rotor) generated by the program.

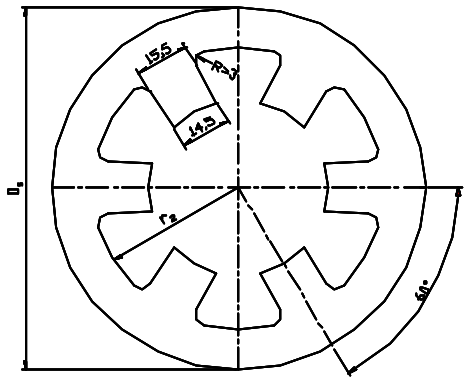

Fig. 4 Output CAD drawings from SRM software design

A machine prototype with 3 phases, 6 stator poles and 4 rotor poles and its respective converter are depicted at Fig. 5. The machine was designed with the software aid to develop 3.8 Nm until 3000 rpm and to operate under constant power of 1200 W from 3000 rpm to 10000 rpm. The converter power is about 10 kW and the nominal DC link voltage is 250 V.

III. CONCLUSION

The use of computational methods and software to aid the SR machine design presented in this paper, become a necessary CAD tool and can contribute for a time reduction expended with the project and a number of experimental activities with prototyping, contributing also with a development cost reduction of this kind of electrical machine.

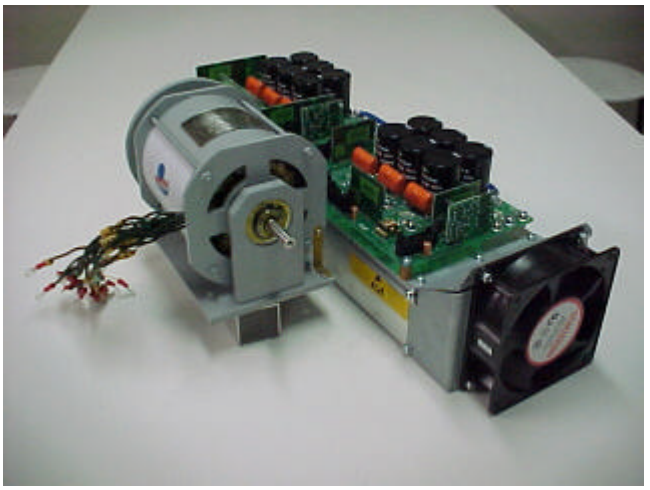

Fig. 5 – Machine and power converter

The parameters of the machine are:

Stator diameter: 144 mm

Rotor diameter: 72 mm

Stator pole arc: 32 degrees

Rotor pole arc: 34 degrees

Air gap: 0.25mm

Number of turns in one phase (=two poles in series): 180

Resistance of one phase: 0.637

Iron stack: 72 mm

Weight (rotor and stator stack, shaft): 7.16 kg

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