

Graphical User Interface to Extrapolate the Ideal Covering Factor of the Polar Step

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Abstract - This paper treats some aspects of the geometrical design of salient synchronous generator, used in railway traction. It focus on the transformation of given experimental data curves into polynomial based regression model which could be use easier in a Computer Aided Design. The final aim of this work is to summarize many detailed by literature recommendations regarding the fabrication experience and to use these to design a Graphical User Interface with which, the user perform a specific task in area of designing a salient synchronous generator. For this paper, the proposed task is to interpolate and to plot the dependence between ideal covering factor of the polar step and the real one, based on the curves offered by the literature. Using this representation, the user/the designer could choose the appropriate value of the ideal covering factor of the polar step for its case study in a short time and, also, could send this data to the main program. The added value of this work is to create a tool which could be used easier, in different situations. This tool is completely original and is a part of a collection of graphical user interfaces created by the authors to be used in a computer aided design of a salient pole synchronous generator calculation.

Cuvinte cheie: Interfata grafica utilizator, factor de acoperire ideala a pasului polar, factor de acoperire reala a pasului polar, generator sincron cu poli aparenti.

Keywords: Graphical User Interface, ideal covering factor of the polar step, real covering factor of the polar step, salient synchronous generator.

I. INTRODUCTION

The design of a salient synchronous generator is a complex process aimed to establish all the dimensions and data required for the fabrication of the salient synchronous generator. Short reviews of the steps of electromagnetically calculus (Fig.1) underline the following notes: 1. For the electromagnetic calculation of the synchronous generator, it is necessary to define the internal electromagnetic power S_i , obtained as the results of the energy conversion. 2. This conversion is possible because of the interaction between the two active means: total magnetic flux between generator's windings and total currents of the windings. 3. The internal electromagnetic power is directly proportional with total magnetic flux between generator's windings and total currents of the windings, the proportionality factor being the speed of the generator (n , [rpm]). 4. The distribution of magnetic flux density in the air gap of the salient synchronous generator has a major influence on harmonics of the induced voltage in the stator winding. 5. The distribution of the magnetic flux density along the air gap circumference and the magnetic

flux density depend by the shape of the stator and rotor magnetic surfaces: decreases at the stator and rotor slots opening and increases when the length of air gap decreases.

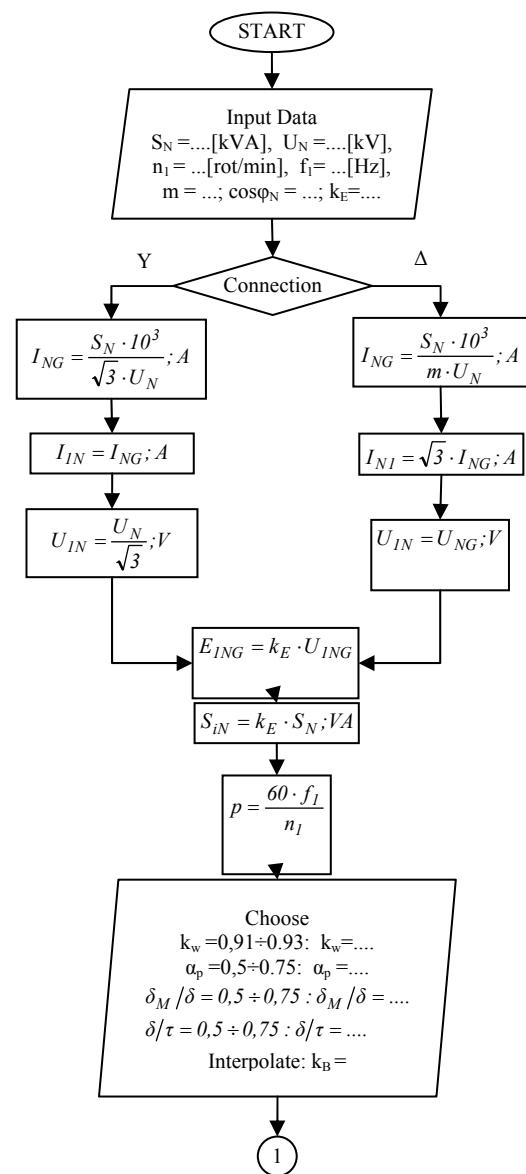


Fig. 1 Logical diagram of synchronous generator calculus

Most of times, in practice, some of these data are known from fabrication process, being necessary to determine the others. This is the assumption of this paper: to

use given experimental data map (Fig.2), to create a tool which could be used in the calculus of the other required data.

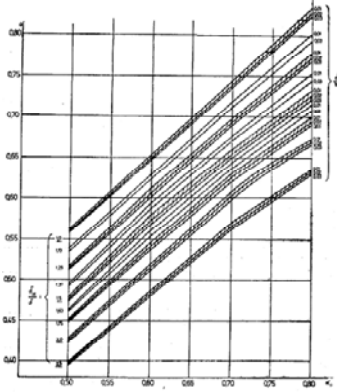


Fig. 2 Given data map with ideal covering factor of the polar step (source [1])

The tool created in this paper is a Graphical User Interface in Matlab which convert the given experimental data curves into a polynomial based regression model. Using this interface the designer could use easier any curve from that families shown in Fig.1 to obtain a value for the ideal covering factor of the polar step. This interface could be applied with efficiency in any optimal designing of a salient synchronous generator.

II. THEORETICAL BACKGROUND

Ideal or calculus dimensions of a salient synchronous generator are the dimensions of an equivalent machine, in terms of stresses and phenomena that occur in the real machine, but in which, the magnetic field is uniform, so that, it is possible to apply the known basic laws of electro technical science. For the equivalent machine, which has the same useful magnetic flux in the pole, the ideal dimensions are described in table I. Ideal dimensions of the generator are different from the geometrical.

TABLE I.
IDEAL DIMENSIONS OF SALIENT SYNCHRONOUS GENERATOR

Name	Features		
	Definition	Symbol	Unit
Diameter	inner diameter of the stator ferromagnetic core	D	m
Polar step/Slot step	arc length of circle with D, diameter, related to a pole: $\tau = \frac{\pi \cdot D}{2 \cdot p}$	τ	m
Ideal length	axial length of the ferromagnetic core when the magnetic induction in the air gap is constant and equal with the amplitude.	l_i	m
Ideal length of polar arc	Ideal length of polar arc, when the magnetic induction in the air gap is constant and equal to the maximum value B_{dm} from the pole axis.	b_i	m
Equivalent air gap	Width of air gap in the equivalent machine having two smooth frames and the same maximum inductance value	δ'	m

Name	Features		
	Definition	Symbol	Unit
	B_{dm} , as in the actual machine.		

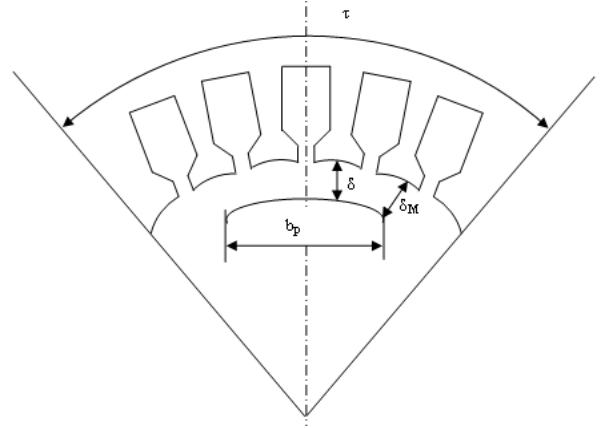


Fig. 3 Air gap width variation across a pole shoe

The expressions geometrical dimensions are functions of the ideal dimensions. In Fig.3, b_p is real length of the pole shoe.

Related to the real width of the pole shoe, b_p , and the ideal length of the pole shoe, b_i , could be defined the real covering factor of polar step α_p (1):

$$\alpha_p = \frac{b_p}{\tau} \quad (1)$$

and the ideal covering factor of polar step α_i (2):

$$\alpha_i = \frac{b_i}{\tau} \quad (2)$$

For the salient synchronous generator, the distribution of magnetic induction in the air gap is sinusoidal 3:

$$B_{\delta x} = B_{\delta m} \sin\left(\frac{\pi}{\tau} \cdot x\right) \quad (3)$$

This impose a width variation of the air gap describe with 4:

$$\delta_x = \frac{\delta}{\sin\left(\frac{\pi}{\tau} x\right)} \quad (4)$$

and an ideal length of the polar arc defined by 5.

$$b_i = \frac{l}{B_{\delta m}} \int_0^{\tau} B_{\delta m} \cdot \sin\left(\frac{\pi}{\tau} \cdot x\right) dx = \frac{l}{B_{\delta m}} \cdot B_{\delta m} \left[-\frac{\tau}{\pi} \cdot \cos\left(\frac{\pi}{\tau} x\right) \right]_0^{\tau} = \frac{2}{\pi} \tau \quad (5)$$

Because the ideal length of the pole shoe, b_i , depends on the real width of the pole shoe, b_p , and on the air gap variation law, δ_x , results the dependence between ideal covering factor of polar step α_i and the real covering factor of polar step α_p and the air gap variation law, δ_x .

For the salient synchronous generator, α_i is taken from data map as those given in Fig. 2, and is a function defined with 6. Normally, real covering factor of polar step α_p is varying in the limits of (7), but usually, the limits are (8).

$$\alpha_i = f\left(\alpha_p, \frac{\delta_M}{\delta}, \frac{\delta}{\tau}\right) \quad (6)$$

$$\alpha_p = 0.6 \div 0.75 \quad (7)$$

$$\alpha_p = 0.65 \div 0.7. \quad (8)$$

III. DESIGNING A GRAPHICAL USER INTERFACE IN MATLAB

Matlab is a used matrix based equation solving program which has a built in Graphical User Interface Development Environment (GUIDE), with which the designer can layout a GUI graphically and generate automatically a Matlab code. GUI is a hierarchical oriented programming with graphical objects as children of parents. For examples, in [5], [6], [7], and [8] the 'parents' were a figure and the 'children' were text boxes, edit text box and push buttons. To generate a GUI, the code could be introduced in command mode or run as a program.

According with this theoretical background, the aim of this paper is to create a GUI, used as a tool to extract the value of the ideal covering factor of polar step, α_i , for a given situation. The specifics objectives of this tool are: to plot the family of curves from Fig.2, to choose points from these figures and to imagine a mode to transfer these points in the main program of designing the synchronous generator.

To plot the family of curves from Fig. 2 is important to write an m file code (named F) which transforms the data map in graphics. The dependency between data maps [1] is described with 9 (table II) and a model of graphic representation is given in figure 4.

$$\alpha_i = f\left(\alpha_p, \left(\frac{\delta_M}{\tau}\right) = \begin{pmatrix} 1; 1.13; 1.25; 1.37; 1.5; \\ 1.63; 1.75; 2; 2.5 \end{pmatrix}, \left(\frac{\delta}{\tau}\right) = (0.01; 0.02; 0.03)\right) \quad (9)$$

TABLE II.
IDEAL DIMENSIONS OF SALIENT SYNCHRONOUS GENERATOR

		Features $\delta_M/\tau = 1$						
α_p		0.5	0.55	0.6	0.65	0.7	0.75	0.8
α_i	δ/τ							
	0.01	0.568	0.612	0.658	0.7	0.748	0.789	0.845
	0.02	0.565	0.607	0.653	0.695	0.745	0.784	0.84
	0.03	0.56	0.6	0.648	0.69	0.74	0.779	0.835

The results of running F1.mfile was shown in Fig.4. With red line was plotted the curve $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1$ and $\delta/\tau = 0.01$, with blue $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1$, and $\delta/\tau = 0.02$ and with green $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1$ and $\delta/\tau = 0.03$.

Running the F2.m file will be obtained the Fig. 5 where with red line was plotted the curve $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau =$

1.13 and $\delta/\tau = 0.01$ and with blue $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1$ and $\delta/\tau = 0.03$. Using F3.m file, as in figure 6, could be obtain with red line the curve $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.25$ and $\delta/\tau = 0.01$, with blue $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.25$ and $\delta/\tau = 0.02$ and with green $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.25$ and $\delta/\tau = 0.03$.

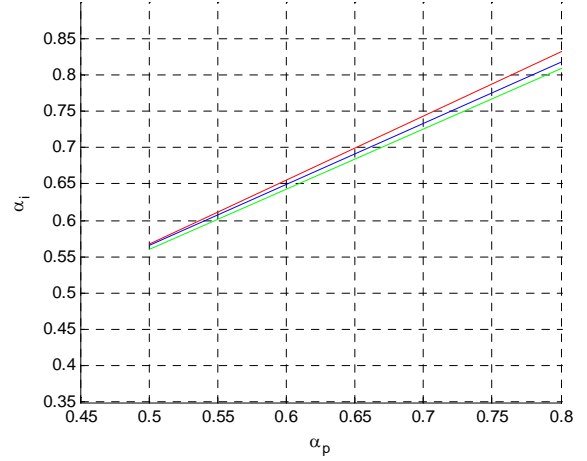


Fig. 4. $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1$ and $\delta/\tau = (0.01; 0.02; 0.03)$

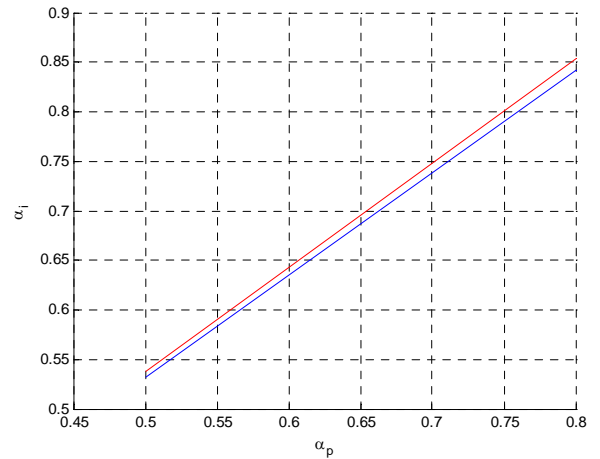


Fig. 5 $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.13$ and $\delta/\tau = (0.01; 0.03)$

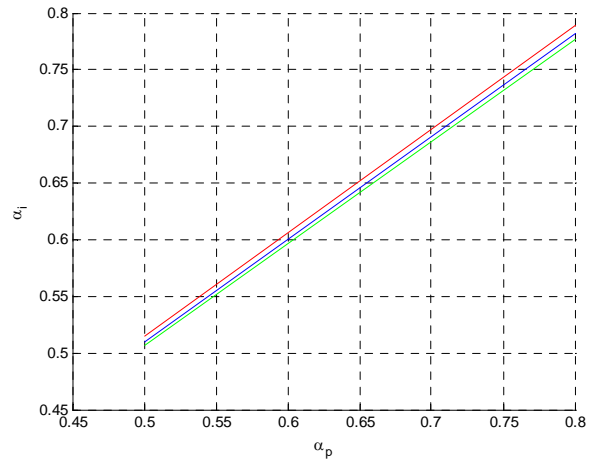


Fig. 6 $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.25$ and $\delta/\tau = (0.01; 0.02; 0.03)$

Running the F4.m file will be obtained the Fig. 7 where with red line was plotted the curve $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.37$ and $\delta/\tau = 0.01$ and with blue $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1$ and $\delta/\tau = 0.03$. Using F5.m file, in Fig. 8, with red line was plotted the curve $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.5$ and $\delta/\tau = 0.01$, with blue $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.5$ and $\delta/\tau = 0.02$ and with green $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.5$ and $\delta/\tau = 0.03$.

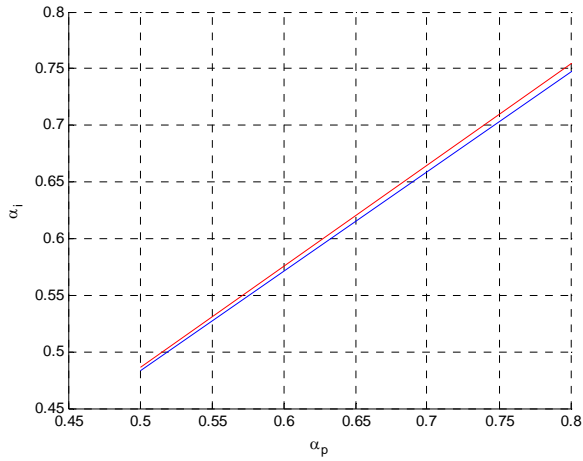


Fig. 7 $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.37$ and $\delta/\tau = (0.01; 0.03)$

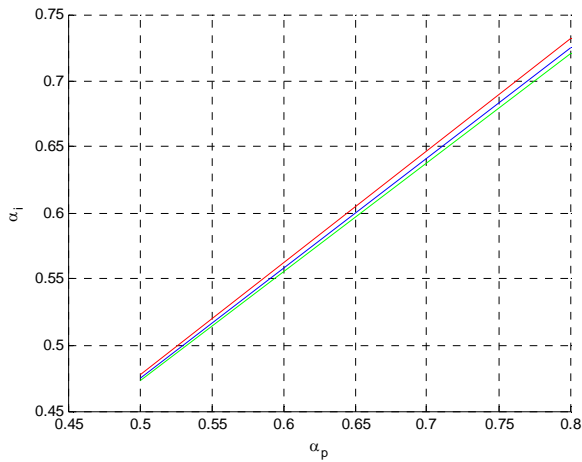


Fig. 8 $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.5$ and $\delta/\tau = (0.01; 0.02; 0.03)$

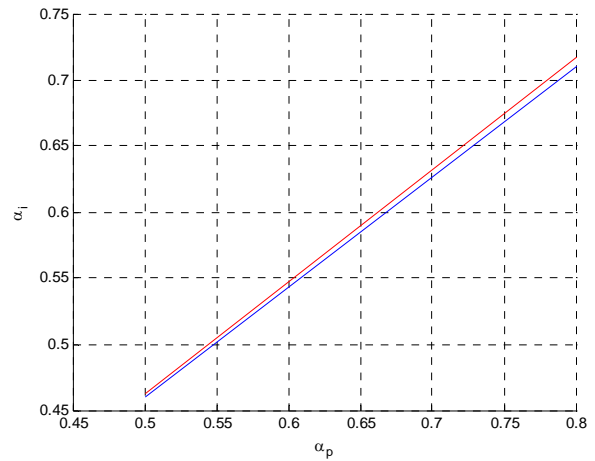


Fig. 9 $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.63$ and $\delta/\tau = (0.01; 0.03)$

Running the F6.m file was obtained the Fig. 9 where: with red line was plotted the curve $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.63$ and $\delta/\tau = 0.01$ and with blue $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.63$ and $\delta/\tau = 0.03$. Using F7.m file, in figure 10, with red line was plotted the curve $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.75$ and $\delta/\tau = 0.01$, with blue $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.75$ and $\delta/\tau = 0.02$ and with green $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.75$ and $\delta/\tau = 0.03$.

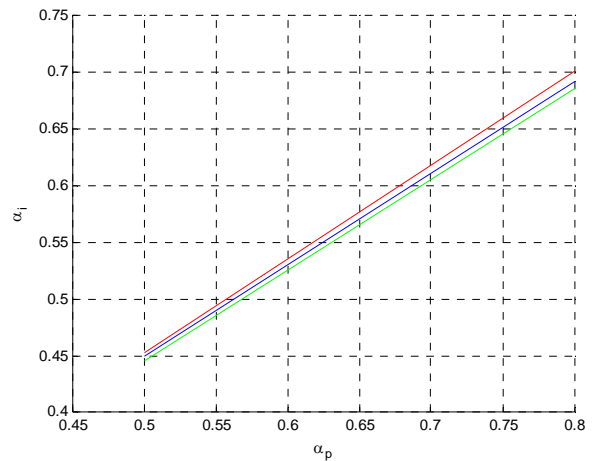


Fig. 10 $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 1.75$ and $\delta/\tau = (0.01; 0.02; 0.03)$

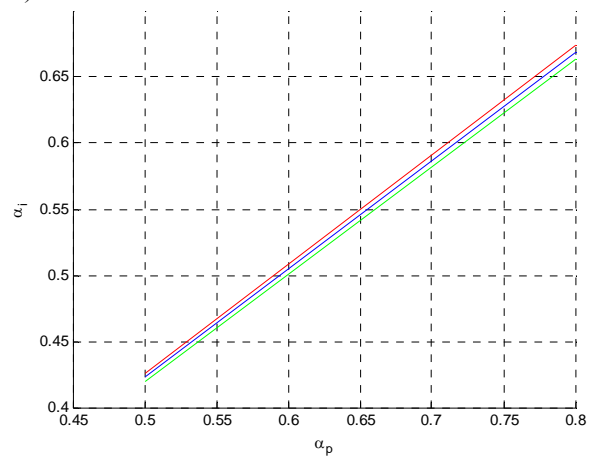


Fig. 11 $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 2$ and $\delta/\tau = (0.01; 0.02; 0.03)$

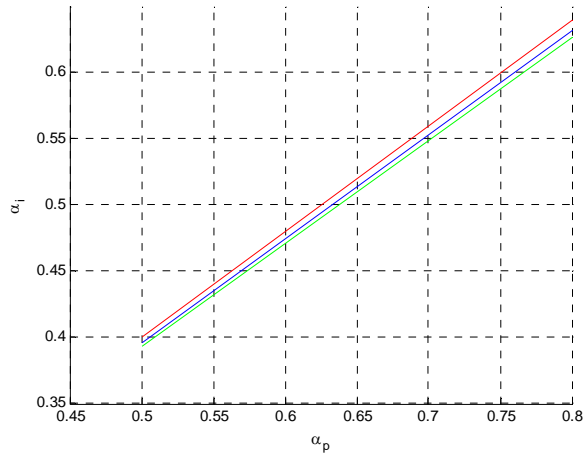


Fig. 12 $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 2.5$ and $\delta/\tau= (0.01; 0.02; 0.03)$

Running the F8.m file was obtained the Fig. 11 where: with red line was plotted the curve $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 2$ and $\delta/\tau = 0.01$ with blue $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 2$ and $\delta/\tau = 0.02$ and with green $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 2$ and $\delta/\tau = 0.03$. Running the F9.m file was obtained the Fig.12 where: with red line was plotted the curve $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 2.5$ and $\delta/\tau = 0.01$, with blue $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 2.5$ and $\delta/\tau = 0.02$, and with green $\alpha_i=f(\alpha_p)$ when $\delta_M/\tau = 2.5$ and $\delta/\tau = 0.03$. Figure 13 shows the entire family of curves used to establish the ideal covering factor of the polar step.

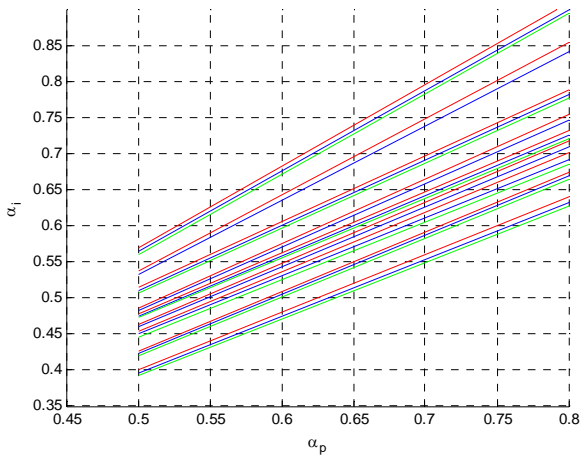


Fig. 13 Ideal covering factor of the polar step – families curves

Next objective is to obtain the points required by the designing program of the synchronous generator. There are many possibilities to get the required values from this graph: could be used the 'data cursor' tools or could be used the interpolation functions. In any case, to accomplish this target, must be created a script in Matlab which could be called with uicontrol.

IV. SIMULATIONS AND RESULTS

The design of the graphical interface starts with a clear definition of tasks: plot curves, interpolate points and saved these points in a .txt file which could be used in the main program of designing synchronous generator. In Fig.13 is shown the design of the GUI.

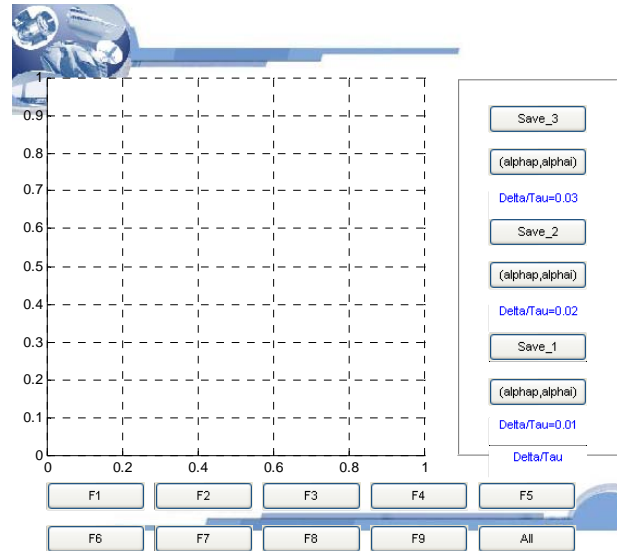


Fig. 14 GUI to plot the ideal covering factor of the polar step – families curves

Nine push button F1, F2,..., F9 allow to users to plot each family curves obtained above. By pushing button All the user could obtain all the curves in figure zone: the interface will became as in Fig.14.

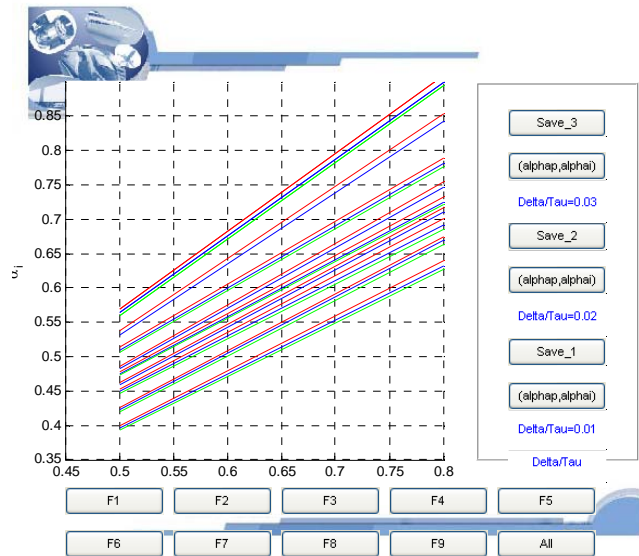


Fig. 15 Plotting all curves family $\alpha_i=f(\alpha_p)$

The interface offers the possibility to choose the required points for the main program. By pushing (alfap, alfai) push button the user can select the points by using 'data cursor' (Fig. 15). By pushing Save_1 push button these points could be saved in a txt file (Fig. 16).

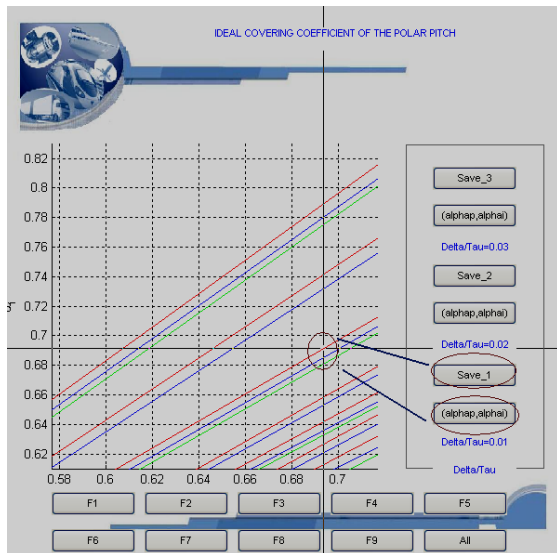


Fig. 16 Points selection

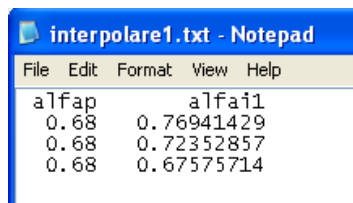


Fig. 17 Saved value of selected points

V. CONCLUSIONS

The paper presents the details of implementation and designing of a Graphical User Interface. This interface could be used in area of designing a salient synchronous generator.

With this interface, the user selects easier the ideal covering factor of the polar step and save it in a format which could be used by others subroutines of a Computer Aided Design of the synchronous generator.

The main advantage of this graphical interface is the easier interaction between designer and software. This interface is a part of an original research developed by the authors to put together a CAD of a synchronous generator used in diesel electric traction.

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First coauthor – 30%

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