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Rapid Calculation Program of Certain Sizes used in design of Synchronous Generators

This paper presents a program of rapid determination of certain sizes required in the design of synchronous machines using Mathcad software. During the design of electrical machines are phases in which certain sizes are extracted from different tables depending on certain variables. This operation is difficult and sometimes hard to do. To eliminate this problem and greatly shorten the time of determination of sizes and to ensure accurate values we have designed a program allowing even interpolation between two known values. The program developed applied, in this paper, to quickly determine the value of the voltage form factor k_B and the value of the ideal polar coverage coefficient α_i of polar step τ.

Keywords: *voltage form factor, the ideal polar coverage coefficient, interpolation*

1. Introduction

The designer of a synchronous electric machines needs to predetermine certain values [3]. In this paper we show how to predetermine the value of voltage form factor and the ideal polar coverage coefficient α_i , based on polar step τ, the parameters are reports [1]:

- maximum air gap / air gap of the d axis, $(\dfrac{\delta_M}{\delta})$, which takes values in the range 1,5 ÷ 2,5, and

- air gap from the d axis / polar step τ, $(\dfrac{\delta}{\tau})$, which takes values in the range 0,01 ÷ 0,03.

Independent variable factor is the ratio α_p polar coverage:

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

In this relation b_p is the width of the sole polar.

Typically, the independent variable α_p [2] has values in the range $0,5 \div 0,75$ but the graphics in the literature have values up to $\alpha_p = 0,8$.

The values choose of the two sizes k_B and α_i [2] for a given value of independent variable and different values of the reports mentioned, is a difficult operation that requires special attention especially if the independent variable has values in the interval between two consecutive specified sizes.

To eliminate this disadvantage and any error in interpreting the graphs, we have designed a program that determines alone and precisely the wanted values.

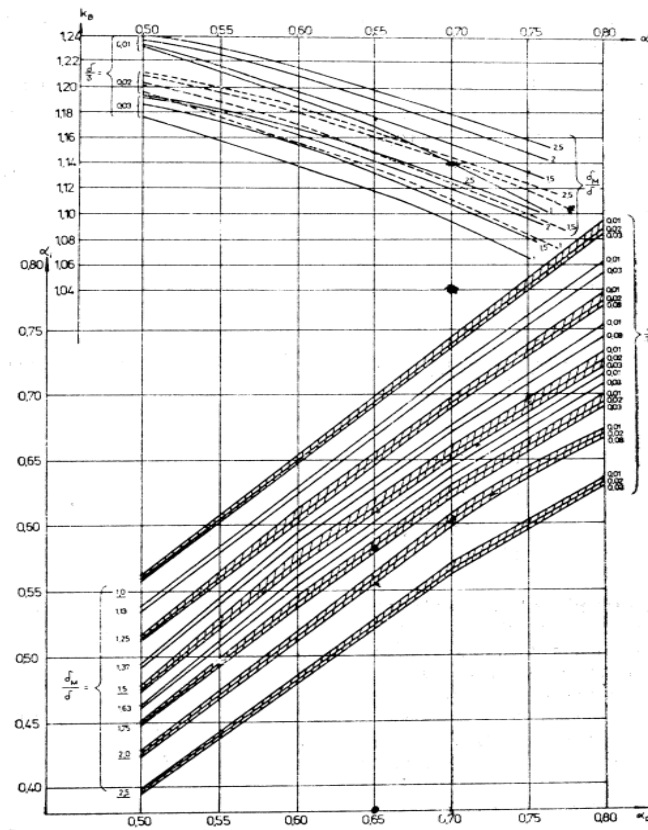### 2. Presentation of current situation

Figure 1. Graphs in which k_B and α_i are determined

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In the current design calculations, for a given value of independent variable α_p, the designer must read from the graphic (Figure 1) factors values k_B and α_i for the chosen values of parameters defined in § 1.

3. Presentation of the program for rapid calculation of form factor k_B

We used vector calculation possibilities offered by MathCad software. We represented the graphics for several values of the mentioned parameters and then using the opportunity offered by the same software interpolation, resulting in accurate and fast values form factor k_B. We define vectors below.

$$\text{ORIGIN} \equiv 0 \qquad i := 1..7$$

$$v\alpha_{p_i} := \qquad vK_{f1/0.03/1_i} := \qquad vK_{f2/0.03/1.5_i} := \qquad vK_{f3/0.03/2_i} := \qquad vK_{f4/0.03/2.5_i} :=$$

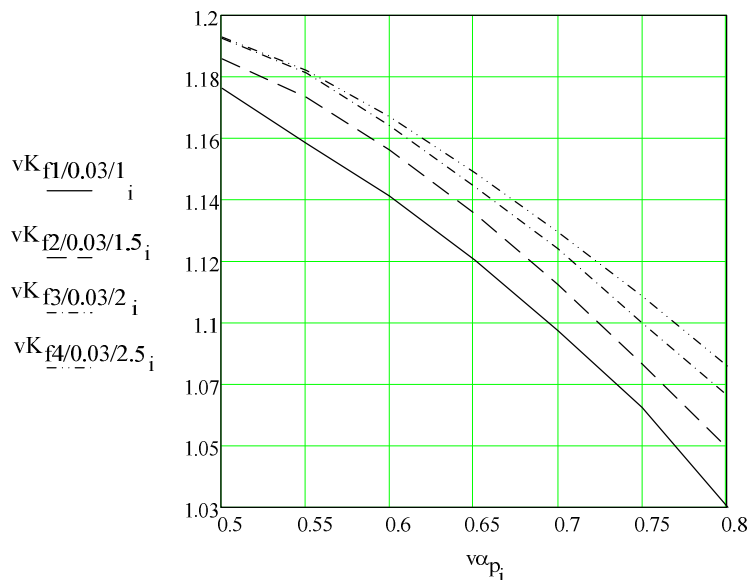| $v\alpha_{p_i}$	$vK_{f1/0.03/1_i}$	$vK_{f2/0.03/1.5_i}$	$vK_{f3/0.03/2_i}$	$vK_{f4/0.03/2.5_i}$
0.5	1.175	1.185	1.192	1.1925
0.55	1.156	1.172	1.18	1.181
0.6	1.138	1.154	1.162	1.165
0.65	1.116	1.132	1.141	1.146
0.7	1.092	1.108	1.12	1.126
0.75	1.066	1.081	1.095	1.104
0.8	1.032	1.052	1.07	1.08

Figure 2. Graphs in which k_B is determined for $\delta / \tau = 0,03$ and δ_M / δ with values 1; 1,5; 2 and 2,5

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Thus, in Figure 2 are the curves of variation of voltage form factor k_B for different values of the ratio δ_M / δ and $\delta / \tau = 0{,}03$.

We defined four variables corresponding to the four values of the report noted: $k_{B1/0,03/1}$; $k_{B1/0,03/1,5}$; $k_{B1/0,03/2}$; $k_{B1/0,03/2,5}$.

We have introduced their numerical values, sizes corresponding to the seven default polar coverage coefficient α_p: 0,5; 0,55; 0,6; 0,65; 0,7; 0,75; 0,8 , using graphs in Figure 1.

Using the interpolation calculation presented by relations 2 and 3, we can determine quickly and accurately the value of the form factor k_B for any value factor α_p in the definition.

$$\text{vsk}_{B1/0,03/1} := \text{cspline}(v\alpha_p,\ vk_{B1/0,03/1})$$
$$\text{vsk}_{B1/0,03/1,5} := \text{cspline}(v\alpha_p,\ vk_{B1/0,03/1,5})\ , \qquad (2)$$
$$\text{vsk}_{B1/0,03/2} := \text{cspline}(v\alpha_p,\ vk_{B1/0,03/2})$$
$$\text{vsk}_{B1/0,03/2,5} := \text{cspline}(v\alpha_p,\ vk_{B1/0,03/2,5})$$

$$k_{B1/0,03/1}(\alpha_p) := \text{interp}(\text{vsk}_{B1/0,03/1},\ v\alpha_p,\ vk_{B1/0,03/1},\ \alpha_p)$$
$$k_{B1/0,03/1,5}(\alpha_p) := \text{interp}(\text{vsk}_{B1/0,03/1,5},\ v\alpha_p,\ vk_{B1/0,03/1,5},\ \alpha_p), \qquad (3)$$
$$k_{B1/0,03/2}(\alpha_p) := \text{interp}(\text{vsk}_{B1/0,03/2},\ v\alpha_p,\ vk_{B1/0,03/2},\ \alpha_p)$$
$$k_{B1/0,03/2,5}(\alpha_p) := \text{interp}(\text{vsk}_{B1/0,03/2,5},\ v\alpha_p,\ vk_{B1/0,03/2,5},\ \alpha_p)$$

For example, introducing $\alpha_p = 0{,}72$, the resulting values are :

$$k_{B1,/0,03/1}(\alpha_p) = 1{,}082$$
$$k_{B1/0,03/1}(\alpha_p) = 1{,}098 \qquad (4)$$
$$k_{B1/0,03/1}(\alpha_p) = 1{,}11$$
$$k_{B1/0,03/1}(\alpha_p) = 1{,}117$$

Now the designer can proceed with the calculation with one of values resulting in the ratio δ_M / δ.

We proceded similarly to the case with the graphs presented in Figures 3 and 4.

For each value of the form factor and $\delta / \tau = 0{,}02$, four variables are defined for the four reports δ_M / δ (1; 1,5; 2 and 2,5). The results for the same $\alpha_p = 0{,}72$ values are:

$$k_{B1/0,02/1}(\alpha_p) = 1{,}099$$
$$k_{B1/0,02/1}(\alpha_p) = 1{,}115 \qquad (5)$$
$$k_{B1/0,02/1}(\alpha_p) = 1{,}13$$
$$k_{B1/0,02/1}(\alpha_p) = 1{,}136$$

Considering the ratio $\delta / \tau = 0.01$, the resulted values for the same $\alpha_p = 0{,}72$ are:

$$k_{B1/0,01/1}(\alpha_p) = 1{,}128$$
$$k_{B1/0,01/1}(\alpha_p) = 1{,}145 \qquad (6)$$
$$k_{B1/0,01/1}(\alpha_p) = 1{,}16$$
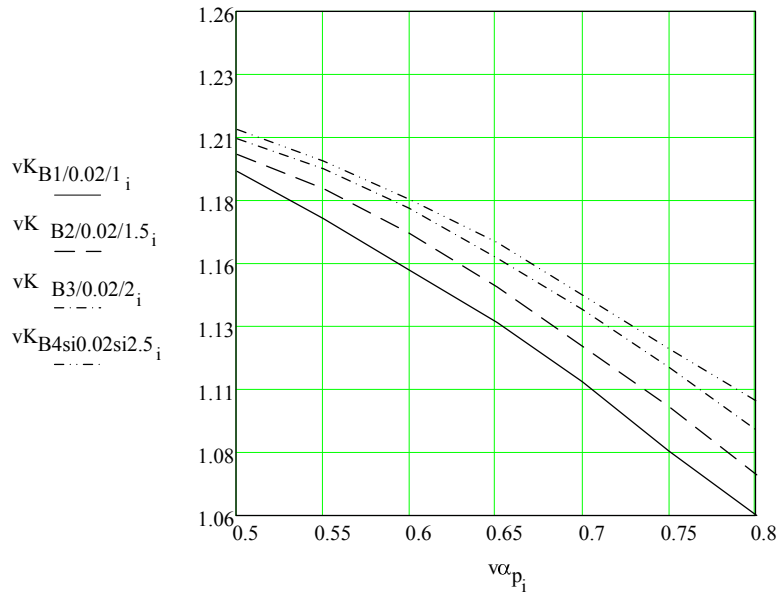$$k_{B1/0,01/1}(\alpha_p) = 1{,}17$$

Figure 3. Graphs in which k_B is determined for $\delta / \tau = 0{,}02$ and δ_M / δ with values 1; 1,5; 2 and 2,5
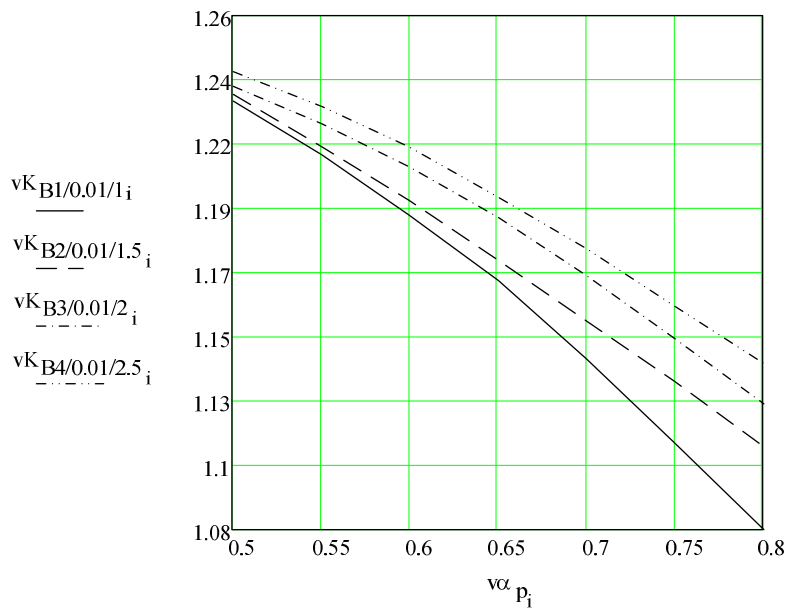
Figure 4. Graphs in which k_B is determined for $\delta / \tau = 0{,}01$ and δ_M / δ with values 1; 1,5; 2 and 2,5

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3. Presentation of the program for fast calculation of the ideal polar coverage coefficient α_i of the polar step

We used the same facilities offered by the Mathcad software, for vector calculation. We represented graphics for each mentioned parameter values and then using the same software offered by interpolation, we determined the ideal polar coverage coefficient α_i of the polar step.

Thus, in Figure 5 are the curves of variation of the ideal polar coverage coefficient α_i of polar step, for different values of the report δ_M / δ and $\delta / \tau = 0,03$.

We define the corresponding variables of the four values of the noted report:
$\alpha_{i1/0,03/1}$; $\alpha_{i1/0,03/1,5}$; $\alpha_{i1/0,03/2}$; $\alpha_{i1/0,03/2,5}$.

We have introduced their numerical values corresponding to the seven sizes default polar coverage coefficient α_p: 0,5; 0,55; 0,6; 0,65; 0,7; 0,75; 0,8 , using graphs in Figure 1.

Using the same calculation as in the interpolation relations 2 and 3, we can quickly and accurately determine the ideal polar coverage coefficient α_i of the polar step, for any value of the field definition α_p factor, as shown in Figures 5, 6, 7 and relations 7, 8, 9.
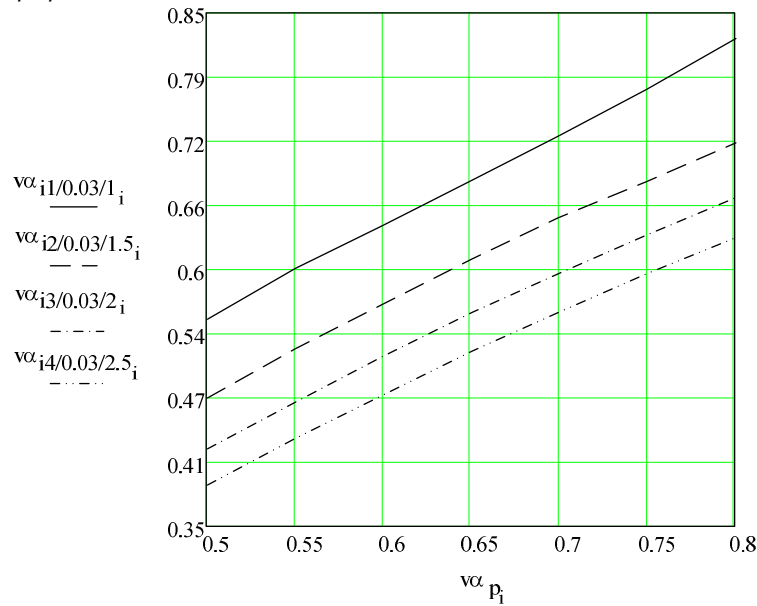

Figure 5. Graphs of which is determined α_i for $\delta / \tau = 0,03$ and δ_M / δ with values 1; 1,5; 2 and 2,5

For the same amount of polar coverage factor α_p = 0,72, results are:

$$\alpha_{i1/0,03/1}(\alpha_p)=0,748 \qquad \alpha_{i1/0,03/2}(\alpha_p)=0,609 \qquad (7)$$
$$\alpha_{i1/0,03/1,5}(\alpha_p)=0,664 \qquad \alpha_{i1/0,03/2,5}(\alpha_p)=0,575$$

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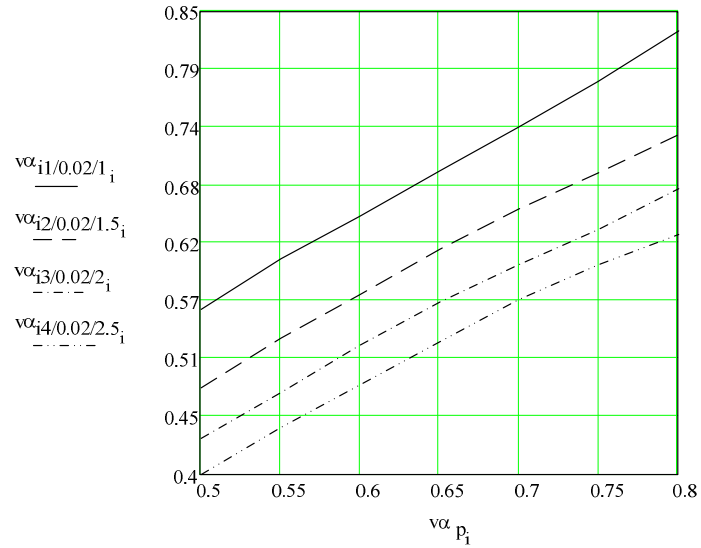
Figure 6. Graphs of which is determined α_i for $\delta/\tau = 0,02$ and δ_M/δ with values 1; 1,5; 2 and 2,5

$$\alpha_{i1/0,02/1}(\alpha_p)=0,754 \qquad \alpha_{i1/0,02/2}(\alpha_p)=0,615 \qquad (8)$$
$$\alpha_{i1/0,02/1,5}(\alpha_p)=0,67 \qquad \alpha_{i1/0,02/2,5}(\alpha_p)=0,582$$
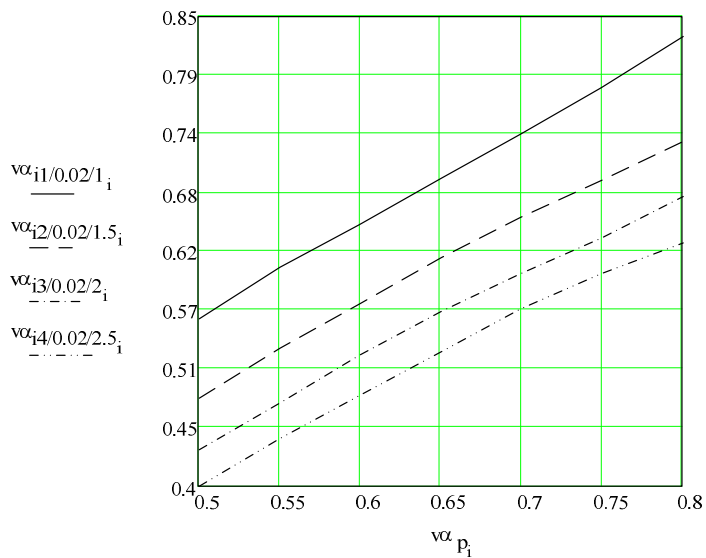
Figure 7. Graphs of which is determined α_i for $\delta/\tau = 0,01$ and δ_M/δ with values 1; 1,5; 2 and 2,5

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$$\alpha_{i1/0,01/1}(\alpha_p)=0,797 \qquad \alpha_{i1/0,01/2}(\alpha_p)=0,65 \qquad\qquad (9)$$
$$\alpha_{i1/0,01/1,5}(\alpha_p)=0,705 \qquad \alpha_{i1/0,01/2,5}(\alpha_p)=0,614$$

4. Conclusion

The paper presented brings an important contribution to the substantial time and effort reduction in the synchronous machine design phase, increasing the accuracy of the results and contributing to optimal design of a synchronous machine [4].

It can be used both in design calculation teaching tool and as a real design in various design institutes, if you have the source program or executable program.

The sizes of voltage form factor k_B, namely the that's ideal coverage coefficient α_i of polar step, involved in determining the main machine synchronous requests (induction in air gap, polar flow) and its overall dimensions.

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