THE NOTCH WIDTH EFFECT UPON THE PERFORMANCE OF THE SYNCHRONOUS GENERATOR

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REZUMAT. Proiectarea generatoarelor sincrone are la bază îndeplinirea unei anumite funcţii obiectiv, care de cele mai multe ori este definită de costul sau de performanţele acestuia. În realizarea acestui desiderat este esenţial alegerea de către proiectant a unei valori optime pentru diverşi coeficienţi şi parametrii. În acestă lucrare ne-am propus să determinăm efectul modificării lăţimii crestăturii statorice a generatorului sincron, asupra costului şi a randamentului acestuia.

Cuvinte cheie: crestătură statorică, generator sincron, cost, randament

ABSTRACT. The design of the synchronous generators is based on the fulfillment of certain objective functions, which often is defined by the cost or performance. In achieving this desiderat it is essential the designer's choice of the optimal value for different coefficients and parameters. In this paper we proposed to determine the effect of changes in the width of the notch stator of the synchronous generator, upon the cost and its efficiency.

Keywords: stator notch, synchronous generator, cost, efficiency

1. INTRODUCTION

According to current requirements, it is imposed a more efficient use of the materials used in the manufacture of the synchronous generators, and this is possible through their optimal designing.

In the classic designing, the choice of the values for different coefficients or parameters leads to a performant or less performant generator. To achieve an efficient generator, the optimal designing is required, aimed at choosing optimal values for the main variables, so that they lead to the achievement of the required objective function.

In this paper we aimed to analyze the influence of notch width on the cost of generator and its performance. This analysis was possible from the classical designing, followed by an optimal designing of a three-phase synchronous generator with an power 300 kVA, the voltage 400 V, speed 1000 rev. / Min, the power factor cos φ - 0,9.

I did the optimal designing conceiving a program using MathCad software, and after multiple iterations, it returns the optimal value of the variable chosen and lead to the fulfillment of the objective function [4].

In this paper, the main variable chosen is the width of notch stator, which in the program takes into account the coefficient β, defined by relation [1], [3]:

$$\beta = \frac{b_c}{t_1} \qquad (1)$$

where b_c is the width of notch stator and t_1 is the step teeth as determined by the relation [2]:

$$t_1 = \frac{\pi \cdot D}{N_c} \qquad (2)$$

In the relation (2) D is the inner diameter of the the stator and N_c is the number of stator notches. Because in the designing stage, to calculate the inner diameter stator, D, we start from apparent power of the generator and the number of pole pairs. The inner diameter stator once calculated and fixed its value, t_1, the dental step also depends on the number of stator notches. This, in its turn, depends on the number of phases, number of pole pairs and the number of notches per pole and phase. When these quantities were fixed, the tooth step can not be changed or even rounded. It follows that changing notch width, b_c, is expressed by the size of the coefficient β. This is the reason why we refer to this factor as a significant size of the generator.

The literature stipulates that the coefficient β values must be in the interval (0,4 ÷ 0,5), so a very small interval which determines the notch width and influences the performances of the analysed generator [1], [3].

The value of the coefficient β, noted in graphic with β_{c1}, resulted in the classical designing is β_{c1c} = 0,446 and from optimal design, the value obtained is β_{c1opt} = 0,422.

We analyze the influence of this change in the coefficient β_{c1}, through the graphics results from the optimal designing. The sizes values presented in the graphs below are reported in units (u.rap.) to the classic designing.

2. THE STATOR NOTCH WIDTH EFFECT UPON THE GEOMETRIC DIMENSIONS OF THE SYNCHRONOUS GENERATOR

The choice of a specific value for the coefficient β_{c1}, influences outside length, L_e and the external diameter, D_e, of the synchronous generator, as shown in Figure 1.

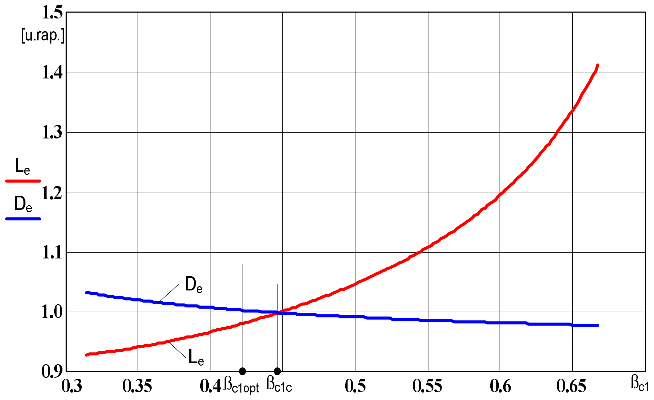

Fig. 1. The effect of the coefficient value changes β_{c1} upon the geometric dimensions of the synchronous generator

The value of the coefficient β_{c1opt} = 0,422, resulted in the optimal designing, leads to an increase in the external diameter of the stator, D_e, with 1% and a decrease in its length, *Le*, with 3, 6%.

It was found the maximum value of the coefficient β_{c1} that leads to an increase in the iron length with 5% of the value resulting from the classical designing and the 8,6% of the value resulting from optimal designing.

3. THE STATOR NOTCH WIDTH EFFECT UPON THE WEIGHT OF THE SYNCHRONOUS GENERATOR

To determine the costs of the synchronous generators is necessary to know the active materials weight (iron and copper), the total weight of the generator, weights that occur in manufacturing cost and the material losses in the active and the total losses, losses that occur in the operating cost, throughout the normat life of the generator.

The effect of changes of the coefficient β_{c1}, upon the weights of the generator is shown in Figure 3.

From this graph we found that the optimal value of the coefficient β_{c1opt} led to an increase in weight of iron, m_{Fe}, with 1,1%. This increase is determined mainly by the increase of the stator external diameter, D_e, and the increase of the teeth width with 5,4%.

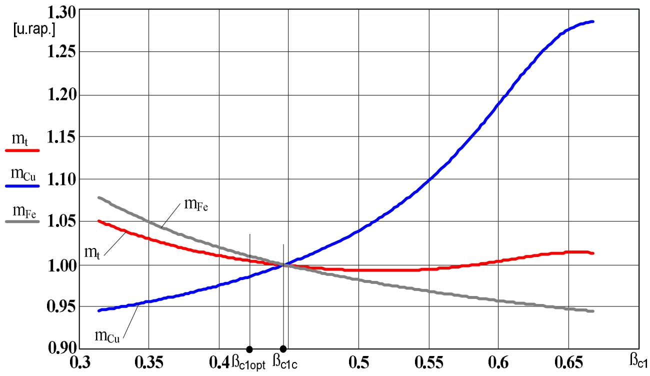

Fig. 2. The effect of the coefficient value changes β_{c1} upon the weight of the synchronous generator

From the same graph was found that the weight of copper, m_{Cu}, decreased with 2,02% and the total weight, m_t, increased 0,5%, so an insignificant increase. More pronounced decrease of the weight of copper is determined bz a lower coefficient β_{c1} causing a smaller notch width and therefore the weight of copper of notch is lower, too.

The maximum value of the coefficient β_{c1} = 0,5 leads to a decrease in the total weight of the generator, with 1,5%, compared to the weight resulted in classical designing, but the weight of copper increases, by about 4%.

4. THE STATOR NOTCH WIDTH EFFECT UPON LOSSES OF THE SYNCHRONOUS GENERATOR

The coefficient β_{c1} variation effect upon the losses of the synchronous generator is shown in Figure 3 graph.

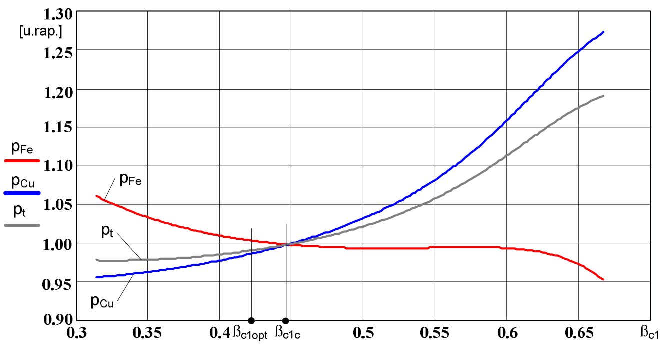

Fig. 3. The effect of the coefficient value changes β_{c1} upon the losses of the synchronous generator

From this graph we found that the optimal value of the coefficient β_{c1opt} has led to increased iron loss, p_{Fe}, with 0,43%, to the decrease of the copper losses, p_{Cu}, with 1,24% and the total losses, p_t, with 0,83%, compared to the values obtained fron the classical designing.

For the maximum value of the coefficient β_{c1}, the iron losses decrease with 0,57%, the copper losses increase with 3,42%, and the total losses increase with 2,2%, compared to the values from classical designing.

For the maximum value of the coefficient β_{c1}, compared to the values resulted in optimal design, the iron losses decrease with 1%, the copper losses increased with 4,66% and the total losses increase 3,03%.

5. THE STATOR NOTCH WIDTH EFFECT UPON THE COSTS OF THE SYNCHRONOUS GENERATOR

The losses values determine the operating cost, C_e, and the weight values determine the manufacturing cost C_f. The sum of the two costs determine the total cost of synchronous generator. The normated lifetime of the operating costs were determined for 20 years non-stop daily operation.

The influence of the coefficient β_{c1opt} change upon the cost is presented in Figure 4.

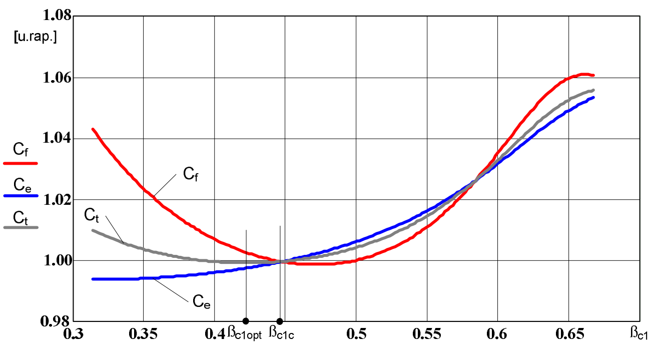

Fig. 4. The effect of the coefficient value changes β_{c1} upon the costs of the synchronous generator

In this graphic we found that compared to the values resulted from the classical designing, the manufacturing cost, C_f, increases with 0,256%. This increase is determined by the iron weight increasing and the total weight of the generator.

For the same reference, the operating cost, C_e, deacreases with 0,242%, due to the total losses decrease of the synchronous generator.

For the optimal value of the coefficient analyzed β_{c1opt} = 0,422, the total cost, C_t, decreases with 0,067%.

The maximum values of the coefficient β_{c1}, lead to keeping constant the cost of manufacturing and operating cost increases with 0,62% and the total cost increases with 0,42%.

The minimum value of coefficient β_{c1}, leads to keeping the total cost to the same value as that resulting from classical designing.

From the same graphical analysis we found that the required objective function, that is a minimum cost of the generator designed β_{c1}, is achieved for a coefficient in the range (0, 4039 ÷ 0, 4425).

6. THE STATOR NOTCH WIDTH EFFECT UPON THE EFFICIENCY OF THE SYNCHRONOUS GENERATOR

The losses values of the synchronous generator determine the efficiency, η, which is an indicator of its performance. The influence of variation coefficient β_{c1} upon the performance of the designed synchronous generator is shown in Figure 5.

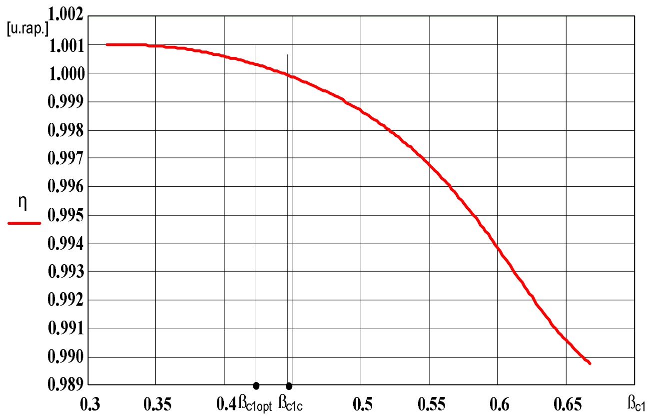

Fig. 5. The effect of the coefficient value changes β_{c1} upon the efficiency of the synchronous generator

From the graphical analysis we found that the optimum value β_{c1opt} = 0,422, contributes to an efficiency increase of the synchronous generator with 0,03%.

The maximum value of the coefficient β_{c1} determines a decrease in efficiency with 0,12% to the value resulting from the classical designing and a decrease with 0,15% in the optimal design.

Although the efficiency increase, corresponding to the optimal value of the coefficient β_{c1}, is low, however, it is not to be neglected, it contributes to the proper appreciation of the generator.

5. CONCLUSIONS

By the optimal designing we managed to obtain a generator at lower costs and a higher efficiency than a generator designed by the classical method.

It should be noted that to have a generator whose cost is minimal, in the designing stage, the coefficient β_{c1}

values must be chosen as close as possibile to the minimum value (0.4), therefore notch width will be minimal.

From the graphics presented and analyzed results that all parameters analyzed were inadequate values to maximum value of the coefficient β_{c1}. So, technical literature should limit the range of this coefficient.

Through this work we contribute to the restriction of the variability coefficient β_{c1}, called coefficient β_{c1}, in literature the coefficient β_{c1}, is know as coefficient β, the interval (0,4 ÷ 0,45).

This limitation of the coefficient β, gives designers the guarantee that, even using the classical design they can achieve adequate performance of the designed synchronous generator.

BIBLIOGRAPHY

[1] Cioc, I., ş.a., *Maşini electrice - Indrumar de proiectare.* Vol. III, Editura Scrisul Românesc, Craiova 1985

[2] Dordea, T., *Proiectarea şi construcţia maşinilor electrice*, Institutul Politehnic „Traian Vuia” Timişoara, 1979

[3] **Spunei, E., Piroi, I.,** Maşini electrice – Proiectarea generatorului sincron, Editura Eftimie Murgu, Reşița 2011

[4] **Vlad, I., ş.a.,** *Proiectarea asistată a maşinilor asincrone – Probleme de optimizare,* Editura Universitaria Craiova 2011

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