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ANALYSIS OF THE TYPE OF APPROXIMATION OF THE MAGNETIZATION CURVE FOR ELECTROMAGNETIC CONVERTERS OF HIGH CURRENTS

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Abstract - *In the article discuss analyzes the type of approximation of the magnetization curve of a direct current, alternating current, direct current and alternating current magnetic circuit in order to calculate the magnetic circuits of high-current electromagnetic transducers.*

Keywords: *current transducer, magnetic circuit, magnetization curve, direct current, alternating current, types of approximation, accuracy.*

INTRODUCTION

At present, a number of works by domestic and foreign scientists are known, devoted to the development of a method for calculating magnetic circuits, taking into account the nonlinearity of magnetic characteristics. However, most of these works were carried out according to a technique based on the linearization of magnetic characteristics, where nonlinearities are partially taken into account, which leads to inaccurate calculations, as a result of which it is impossible to correctly choose the optimal ratios between the parameters to obtain the most effective values of the main characteristics of the magnetic circuits of electromagnetic high-current converters (EMPBT). Therefore, it is necessary to create a method for calculating the magnetic circuits of EMPBT, taking into account the nonlinearity of the magnetic characteristics, which makes it possible to solve the problem in a general form, which is an advantage over the graphic and graphical analytical methods of calculation. To obtain such a method of magnetic circuits of EMFBT, it is necessary to describe the magnetic characteristics by analytical expressions. At present, about a hundred analytical expressions are known, determined by the methods of approximation of the magnetization curve and the dependence of the specific magnetic resistance ρμ on the magnetic induction, obtained by domestic and foreign authors [6–10]. From these expressions, it is necessary to choose the simplest ones that make it possible to solve the problem to the end, while obtaining a not cumbersome result of sufficient accuracy. The quality of the developed calculation methodology depends on the correct choice of the approximation formula.

The formula for approximating the magnetization curve of a DC magnetic circuit in general form is given in 1

$$B = K_1 H + \left(K_2 + K_3 e^{K^1}\right)^g$$

$$K^1 = \frac{cH^B}{d + BH^B} \qquad (1)$$

One of the particular solutions of formula (1) is Kopsel's formula, which has the form:

$$B = e^{\frac{H}{d+BH}} \qquad (2)$$

Approximation coefficients of formula (5) can be determined with sufficient accuracy by the methods of selected points. In this case, it is necessary that the magnitude of the magnetic flux at the selected point to the knee is equal to half the magnitude of the magnetic flux at the point selected after the knee of the magnetization curve, which limits the area of its application.

Robinson's formulas

$$B = \frac{H}{\alpha + \beta H} \quad (3)$$

The approximation formulas given in this group, due to the above-mentioned shortcomings, cannot be widely used for the analytical calculation of the magnetic circuits of the EMPBT.

Approximation of the magnetization curve of AC and DC magnetic circuits.

In this group, universal formulas for the approximation of the magnetization curve are considered, suitable for the analytical calculation of the magnetic circuits of EMPBT both on direct current - with one value of constant coefficients, and on alternating current - with another value of constant coefficients.

One of the first recommended formulas 4 for this group is as follows:

$$B = Aarctg(aH) \quad (4)$$

Formula (9) describes well the actual magnetization curve of transformer steels, moreover, at low H, the calculated curve goes slightly higher, and at large H, slightly below the actual magnetization curve.

The approximation by a polynomial in powers of B in the general case can be written in the following form

$$H = a_0 B + a_1 B^3 + a_2 B^5 + a_3 B^7 + \ldots; \quad (5)$$

The more the number of terms on the right side, the better the calculated curve will coincide with the actual curve. If we restrict ourselves to three members of the series, then it turns out that the second term is negative and the formula takes the form:

$$H = a_0 B - a_1 B^3 + a_2 B^5 \quad (6)$$

This formula, with the addition of a linear term, will be written as:

In order to select a suitable approximation expression for obtaining a more perfect method for calculating the magnetic circuits of the EMFBT, taking into account the nonlinearity of the magnetic characteristics, the author analyzes the existing analytical expressions for the magnetic characteristics and recommends new formulas for the approximation of the magnetization curve for magnetomodulation magnetic circuits of the EMFBT. EMPBT magnetic circuits can be with constant, variable, or simultaneously operating constant and variable sources of MDS. Therefore, the calculation of EMPBT magnetic circuits can be divided into direct current magnetic circuits, alternating current magnetic circuits and magnetic circuits with simultaneously acting direct and alternating currents, that is, into magnetomodulating magnetic circuits. To calculate these groups of magnetic circuits, it is required to divide the existing formulas for the approximation of the magnetization curve into three groups:

a) approximation of the magnetization curve of the DC magnetic circuit;

b) approximation of the magnetization curve of DC and AC magnetic circuits;

c) approximation of the magnetization curve of magnetomodulation magnetic circuits.

Let's consider each group, presenting the approximation formulas found in the literature over the past 30-40 years.

Approximation of the magnetization curve of the DC magnetic circuit.

In this group, we will consider the analytical expressions for the magnetization curve obtained only for calculating direct current magnetic circuits.

A piecewise linear approximation is also used , the advantage of which is the reduction of a nonlinear problem to a linear one. However, the application of this method is possible only on a limited portion of the curve, or for materials with a low degree of nonlinearity of the magnetization curve.

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The coefficients of the above approximation formulas can be determined by the methods of selected points or the least squares methods, and the coefficients of the formula when approximating by a power polynomial, in addition, can be determined by interpolation methods. Of these methods, the least squares method is the most accurate, but it is cumbersome; therefore, this method is used when high accuracy is required in approximating the magnetization curve.

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