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Approximation of the main magnetization curve of sensor magnetic circuits

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ABSTRACT: The paper shows a linear dynamic model magnitomodulyatsionnye DC converter. In this article we make a revised calculation of the transition process in the model magnitomodulyatsionnye DC converter, without producing replacement of pulse-width modulation (PWM) on the analysis method of space (ILA).

KEYWORD: DC converter, a mathematical model, the static characteristics, dynamic, active zone, filter, battery, pulse width modulation, the analysis method of space, nonlinear discrete-time systems, impulse.

I. INTRODUCTION

The magnetomodulation DC converters (MDCC) are a nonlinear element of the control and control systems, since it contains a ferromagnetic core having a nonlinear characteristic with a hysteresis loop magnetization. In addition, the principle of operation considered in the article of MDCC is based on the pulse width modulation (PWM) of the duration of the generated pulses by the converted current. This type of modulation is nonlinear [1].

As is well known [1], with an infinitesimal bandwidth of the continuous part of the signal in a discrete system, the influence of the discreteness of the system on the magnitude of the output signal is minimal, i.e, in this case the discrete system is equivalent in its properties to a continuous system.

When analyzing the MDCC conversion function in the static mode, the bandwidth of the continuous part of the converter is assumed to be zero, which for an infinite time t does not affect the value of the output signal. Therefore, the discreteness of the work of MDCC in the analysis of its function transformation in this case will not be taken into account, which will not lead to any errors in the calculation of the transformation function.

Since the discreteness of the operation of the MDCC does not practically affect its transformation functions, the nonlinearity caused by the PWM also does not affect the transformation functions of the MDCC.

II. STATEMENTOFAPROBLEM

Thus, when analyzing the static characteristics of MDCC with PWM, it can be considered that MDCC is a continuous link of control and control systems with a nonlinear conversion function. It is due to the nonlinearity of the hysteresis loop of the ferromagnetic core. Analyzes like elements-links, as a rule, are carried out by the compilation and solution of non-linear differential equations describing the work of MDCC.

One of the main tasks in the study of the characteristics of MDCC is the correct choice of the approximating analytic function for the hysteresis loop of magnetization of a ferromagnetic core. There is the concept of static and dynamic hysteresis loop of magnetic materials [2]. The static hysteresis loop is the dependence of the steady-state values of the magnetic induction in a magnetic material on the strength of the magnetic field. At high frequencies of the change in the magnetizing current, the shape of the hysteresis loop changes, it becomes wider. This is due to an increase in losses in the magnetization reversal of the ferromagnetic core. At high frequencies, the magnetic viscosity of the substance

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and the eddy currents also affect the shape of the hysteresis loop. In the developed MDCC, ferrite rings are chosen as the cores, which have high magnetic permeability and low losses. Energy at working frequencies, i.e. frequencies of the order of several kilohertz.The dynamic properties of ferrites are significantly affected by the magnetic viscosity of the substance, while the effect of eddy currents on their dynamic properties is negligible compared to the influence of the magnetic viscosity of the substance [1]. The effect of magnetic viscosity is felt only for magnetization times of the order of tenths of microseconds [1]. In connection with this, the influence of the magnetic viscosity of the magnetic material on the shape of the hysteresis loop can be neglected and the expression for the static hysteresis loop can be used to calculate the characteristics of the MDCC.

A large number of papers are known in which various functions are proposed for the analytical description of the hysteresis loop of ferromagnetic materials [3].

In most cases, to analyze the electromagnetic elements and devices of the monitoring and control systems, a middle magnetization curve is used at the hysteresis loop point, drawn through the middle of the horizontal segments connecting the ascending and descending branches of the hysteresis loop. In these MDCCs, a core of ferrite is used, in which the losses due to hysteresis phenomena are small. In this connection, in the future, we will use the average magnetization curve to analyze the characteristics of the MDCC.

III. THE CONCEPT OF THE PROBLEM DECISION

The investigations carried out by many authors show that the hyperbolic sine and trigonometric functions provide a satisfactory accuracy when approximating the average magnetization curve of MDCC cores from electrotechnical steel and ferrites with a nonrectangular hysteresis loop [4]:

$$H = a_1 sh(a_2 B), \qquad (2.1)$$

$$H = a_1 tg(a_2 B), \qquad (2.2)$$

where a_1, a_2 - are the approximation coefficients.

In order to obtain analytic expressions that are convenient for studying the characteristics of MDCC, we use the expression (2.2) for differentiating and integrating the approximating function.

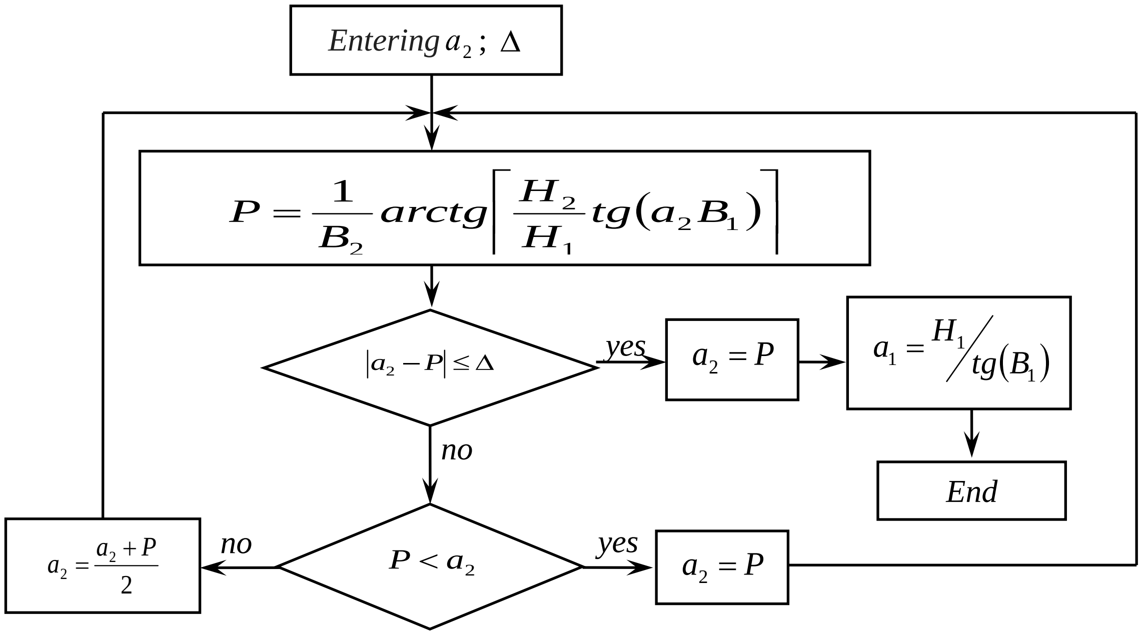

Fig.2.1. Algorithm for finding the approximation coefficients

We find the approximation coefficients a_1 and a_2 solve the system of two equations obtained as a result of substituting in (2.2) the values of the magnetic induction B and in the magnetic field H strength for the two most characteristic points of the experimentally-removed magnetization curve. The characteristic points for the average

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magnetization curve of the steel are the experimentally taken points $B_1 = B_r$ and $B_2 = B_m$ for the values of the tension, respectively, H_1 and H_2 , here, B_r residual induction; B_m is the maximum value of induction.
Substituting these values B and H in (2.2), we obtain the following system of two equations:

$$\left.\begin{array}{l} H_1 = a_1 tg(a_2 B_2) \\ H_2 = a_1 tg(a_2 B_2) \end{array}\right\}, \quad (2.3)$$

IV. REALIZATION OF THE CONCEPT

The algorithm for solving the system of equations (2.3) with respect to the coefficients a_1 and a_2 the method of successive approximations with a given accuracy Δ is shown in Fig. 2.1.
The calculated average magnetization curve for a ferrite toroidalcore $M2000HMI\ K20x12x6$, calculated by the formula $B = \frac{1}{a_2} arctg\left(\frac{H}{a_1}\right)$, is shown in Fig. 2.2.

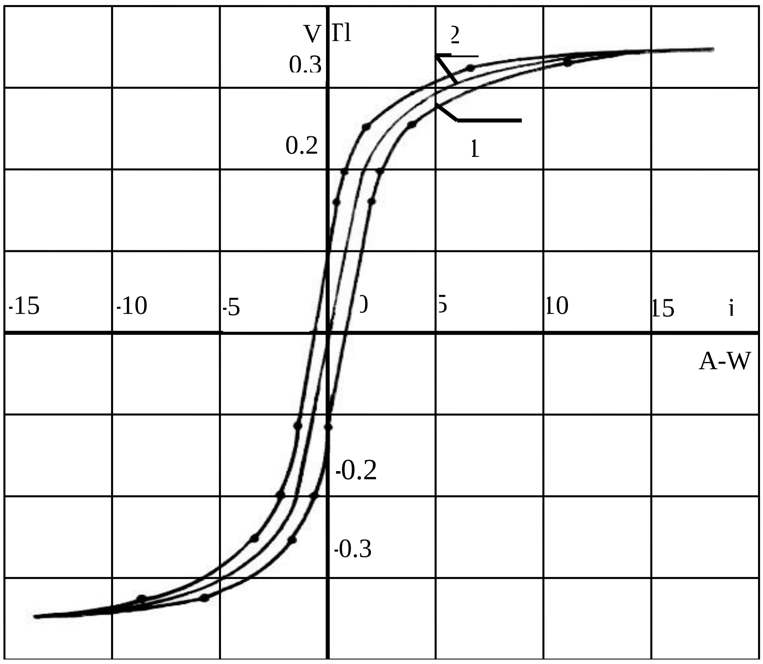

Fig.2.2. Static hysteresis loop (1) and calculated average magnetization curve (2) for the brand ferrite

For comparison, the same figure shows a static hysteresis loop constructed on the basis of data given in the manuals on magnetic materials [2].

V. CONCLUSION

Thus, the study of the main characteristics of the developed MDCC is carried out using differential equations, and as an analytical function approximating the average magnetization curve of a ferromagnetic core, we select the trigonometric tangent.

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