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Static Mathematical Model of Magnetic Modulation Converters for Solar Panel Control Systems

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ABSTRACT: The study of magneto-modulation converters for the control and management of electricity during transmission to the network coming from solar panels. Managing the operating mode of solar panels with magnetic modulation converters and monitoring the system, increasing the sensitivity, accuracy and reliability of the differential, monitoring its static characteristics in the form of a linear graph. Pulse-width modulation converter is used to create a chain of linear and dynamic links with pulse-amplitude modulation and to more accurately study the dynamic characteristics - (β-pulse generation switch) the formation of positive pulses.

KEYWORDS: MC, ferromagnet, solar panel, core, impulse, sinusoidality, magnetic induction, dynamic connection, converter**.**

I. INTRODUCTION

In autonomous power supply systems, renewable sources based on solar batteries (SB) are often used, which is explained by their environmentally friendly and long service life, however, the problem of switching SB to the power system requires high-precision synchronization parameters. In most cases, direct converters are used for this purpose, which have a minimum number of power elements, however, the dynamic characteristics when switching to the power system significantly increase the risk of accidents. In such cases, it will be necessary to obtain accurate electrical parameters of the power system and SB. This will require measuring instruments.

Currently, a large number of converters are known and this creates certain difficulties in choosing the required type, the specific design of these converters for monitoring and control systems for switching power supply to the SB in the main power system. In this regard, it is advisable to classify current converters, which will reveal their fundamental and design features.

II. MAIN PART

To measure the voltage in the SB, the most acceptable are magneto-modulation converters (MC), in which the magnetic permeability of a core made of a ferromagnetic material is modulated. They have the highest sensitivity and are the easiest to implement.

Magnetomodulation converters are devices containing a magnetic system and an element that is sensitive to changes in the magnetic field (magnetometer). With the mutual movement of these elements or individual control ferromagnetic parts, the intensity of the magnetic field penetrating the magnetometer changes, and, accordingly, the magnitude of the output signal. The advantage is the absence of friction, simplicity of design and the possibility in some cases to separate the moving element from the magnetometer by a hermetic baffle.

The magnetic resistance to the alternating current increases, the inductance of the winding falls, the current and the voltage drop across the resistor increase. The input is the movement of the magnet, the output is the voltage drop. U = f (X) is the conversion function of the magneto-modulation converter.

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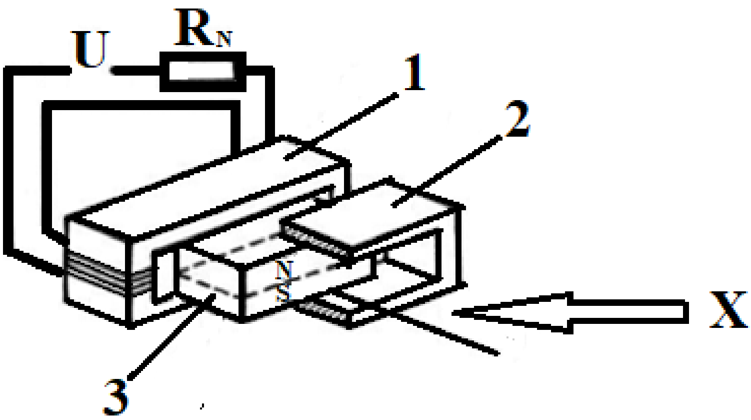

Fig. 1.1. Magnetic modulation displacement transducer

III.RESULTS AND DISCUSSIONS

Let us determine the dependencies $U_{out} = f(I_x)$ for the considered magnetomodulation converter (MC) using the approximation of the dependence $B = f(H)$ by the expression. In this case, we assume that the measured current I_x passes through one turn in the window of the MP core.

We write the system of equations according to the second Kirchhoff law for each half-cycle:

$$E - U_{k1} = I_{k1} + S_\mu W_k \frac{dB_1}{dt}$$

$$E - U_{k2} = I_{k2} + S_\mu W_k \frac{dB_2}{dt} \qquad (1.1)$$

where I_{k1}, I_{k2} – collector currents of transistors $VT1$ and $VT2$; S_μ - core cross section; W_k- number of turns in the collector winding of the transformer; $\frac{dB_1}{dt}, \frac{dB_2}{dt}$ - derivatives of magnetic induction in T_1 and T_2; U_{k1}, U_{k2} – voltage drop across saturated transistors $VT1$ and $VT2$.

The expression taking into account $H = \frac{I}{2\pi r_c} = \frac{I}{l_c}$ for a toroidal core takes the following form:

$$B = k_1 arctg(k_2' I), \qquad (1.2)$$

where $k_2' = \frac{k_2}{l_c}$.

as an expression of the magnetic field strength is taken.

Denote $I_1 = I_{k1} + I_x'$, $I_2 = I_{k2} + I_x'$, (1,3)

here $I_x' = \frac{I_x}{W_k}$ – is the value of the measured current reduced to the number of turns in the collector winding.

Substituting in (1.2) instead of I the values I_1 and I_2 from (1.3) and differentiating, we obtain:

$$\begin{cases} \frac{dB_1}{dt} = \frac{k_1 k_2'}{(1 + k_2'^2 I_1^2)} \frac{dI_1}{dt}, \\ \frac{dB_2}{dt} = \frac{k_1 k_2'}{(1 + k_2'^2 I_2^2)} \frac{dI_2}{dt}. \end{cases} \qquad (1.4)$$

In expression (1.2) we denote $E_1 = E - U_{k1} = E - U_{k2}$, since with identical transistors $U_{k1} \approx U_{k2}$.

Taking (1.4) into account, equations (1.2) take the following form:

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$$\begin{cases} E_1 = I_1R - I'_xR + S_\mu W_k \dfrac{k_1k'_2}{(1 + k'^2_2 I^2_1)} \dfrac{dI_1}{dt}, \\ E_1 = I_2R - I'_xR + S_\mu W_k \dfrac{k_1k'_2}{(1 + k'^2_2 I^2_2)} \dfrac{dI_2}{dt}. \end{cases} \quad (1.5)$$

In expressions (1.5), the currents I_1 and I_2 vary within

$$-(I_{km} - I'_x) = -I'_1 \le I_1 \le I'_2 = I_{km} + I'_x,$$
$$-(I_{km} + I'_x) = -I'_2 \le I_2 \le I'_1 = I_{km} - I'_x \quad (1.6)$$

where I_{km} is the maximum value of the collector current of transistors VT1 and VT2.

To calculate the values of T_1 and T_2, it is necessary to find the value of the current I_{km}. To do this, we write the following equations:

$$I_{km} = I_b\beta_a, \quad (1,7)$$
$$I_d = \left(S_\mu W_k \frac{dB}{dt} - 2U_d\right)\frac{1}{R_b}, \quad (1,8)$$

where W_b - number of turns of the base winding; R_b - base resistor value; U_d- voltage drop across diodes $VD1$, $VD2$ and at the base-emitter junction of transistors $VT1$, $VT2$; β_a – coefficient of transistor amplification.

At the moment of switching, the collector current of the transistors is equal to the current I_{km}. Therefore, the voltage on the base winding at this moment is equal to:

$$S_\mu W_k \frac{dB}{dt} = (E_1 - I_{km}R)\frac{W_b}{W_k}. \quad (1,9)$$

Solving together (1.7), (1.8) and (1.9) with respect to the current I_{km} we get:

$$I_{km} = \frac{E_1 \dfrac{W_b}{W_k} - 2U_d}{\dfrac{R_b}{\beta_a} + R\dfrac{W_b}{W_k}}. \quad (1,10)$$

The formulas for the durations of the half-cycles T_1 and T_2 are obtained after integrating (1.5) within the limits of the maximum changes in the currents I_1 and I_2 in accordance with (1.6). Here we confine ourselves to bringing their final expressions:

$$T_1 = k_1k'_2S_\mu W_k \left\{\frac{k'_2U_{2x}}{R^2 + k'^2_2U^2_{2x}} arctg\left[\frac{2k'_2I_{km}}{1 - k'_2I'_1}\right] - \right.$$
$$\left. - \frac{R}{2[R^2 + k'^2_2U^2_{1x}]} ln \frac{U^2_{1k}[1 + k'^2_2 {I'_1}^2]}{U^2_{2k}[1 + k'^2_2 I'^2_2]}\right\}, \quad (1,11)$$

$$T_2 = k_1k'_2S_\mu W_k \left\{\frac{k'_2U_{1x}}{R^2 + k'^2_2U^2_{1x}} arctg\left[\frac{2k'_2I_{km}}{1 - k'_2I'_1}\right] - \right.$$
$$\left. - \frac{R}{2[R^2 + k'^2_2U^2_{1x}]} ln \frac{U^2_{1k}[1 + k'^2_2 I'^2_2]}{U^2_{2k}[1 + k'^2_2 {I'_1}^2]}\right\}, \quad (1,12)$$

Where $I'_1 = I_{km} - I'_x$; $I'_2 = I'_x + I_{km}$; $U_{1k} = E_1 - I_{km}R$; $U_{2k} = E_1 + I_{km}R$; $U_{1x} = E_1 - I'_xR$; $U_{2x} = E_1 + I'_xR$.

Equations (1.11) and (1.12) express the dependence of the pulse duration T_1 and T_2 on the measured current I'_x and are static mathematical models of the pulse formation process.

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Analysis of expressions (1.11) and (1.12) shows that the duration of the generated pulses, in addition to the measured current, also depends on the voltage of the power source, the resistance of the ballast resistor, the current of the collector winding and the magnetic properties of the core.

IV. CONCLUSION

Using magnetic modulation sensors when connecting solar panels to the network, we can control the electrical energy coming from them, have accuracy in the direction of current, high differential sensitivity, linearity of the conversion characteristic, reliability and at the same time low power consumption when measuring high currents. A comparative analysis of the technical characteristics of these sensors showed that the combined use of pulse-width modulation (PWM) and magnetic modulation sensors allows you to fully meet the requirements of solar panel control systems. We learned that ongoing research should be aimed at increasing the differential sensitivity, simplifying the design, increasing the reliability and linearity of the conversion characteristics of magnetically modulated PWM sensors.

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