ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 11 , November 2020

Research of dynamic characteristics of magnetic modulation current converter with negative feedback

Ataullayev N.O., Muxammadov B.Q., Idieva A.A.,

Ph.D, associate professor, of NSMI Energy-Mechanical Faculty, Doctor of philosophy
NSMI candidate for a master degree of «Electrical power engineering» Department
NSMI candidate for a master degree of «Electrical power engineering» Department

ABSTRACT: It is shown that the developed current Converter with pulse-width modulation for small deviations of the pulse width can be represented as a series of connected chains of linear dynamic links with amplitude-pulse modulation, and for more accurate studies of dynamic properties - as a key that forms δ-pulses and a nonlinear shaper that forms positive rectangular pulses.

KEYWORDS: Operating modes of the battery, autonomous power sources, pulse-width regulator, overcharge, control circuit, linear characteristic, negative feedback.

I. INTRODUCTION

Magnetic modulation current converters (MMCC) are used to automatically control the processes of recharging batteries in autonomous power supplies, electrolysis and other monitoring and control systems for various technological processes.

II.ENERGY EFFICIENCY

In these automatic control systems (ACS), various schemes of MMCC are used [1]. Figure 1 shows a diagram of the developed MMCC with negative feedback (NFB). A distinctive feature of this MMCC in comparison with the known ones is that it excludes an additional power source for a magnetic transistor multivibrator (MTM). Here MTM is powered from the power supply circuit of the operational amplifiers. To assess the dynamic characteristics of the ACS, it is necessary to know which link or set of dynamic links is used by the MMCC in the general structural diagram of the ACS.

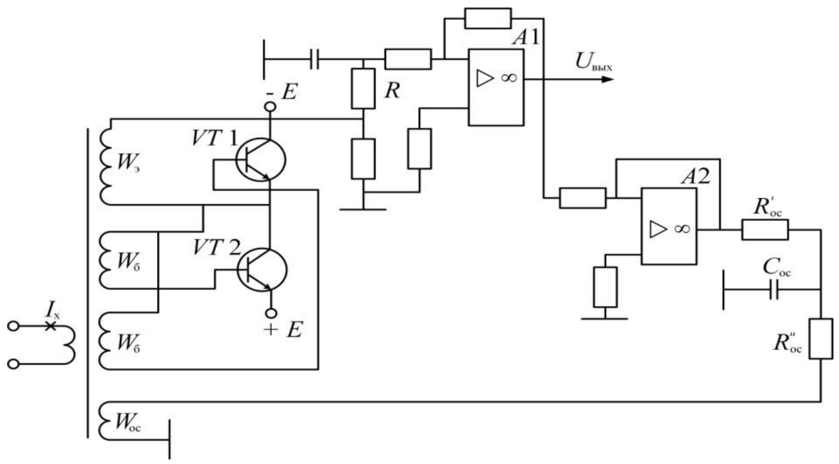

Fig.1. MMCC scheme with NFB.

Consider the dynamics of this MMCC, the structural diagram of which is shown in Fig.2. When analyzing the dynamics of MMPT with NFB, we neglect the value of the time constant formed by the winding and the resistor (see Fig. 1), since experience shows that with the real parameters of the NFB circuit, the values of this time constant are units of microseconds, which is at least two orders of magnitude less than the time constants of other circuits.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 11 , November 2020

III.RESULTS AND DISCUSSIONS

The transfer function of MMCC with NFB has the following form [2]:

$$W(p)=\frac{W_1(p)}{1+W_1(p)W_2(p)}=K_1\frac{p-e^{\frac{T}{\tau_{oc}}}}{p^2+вp+c},$$

when $W_1(p)=K\frac{e^{-\frac{T}{\tau_\Phi}(1-\lambda)}-e^{-\frac{T}{\tau_\Phi}}}{p-e^{-\frac{T}{\tau_\Phi}(1-\lambda)}}$

–transfer function of MMCC without NFB;

$$W_2(p)=\frac{W_{oc}}{R_{oc}}\cdot\frac{p}{p-e^{\frac{T}{\tau_\Phi}}}-$$

transfer function of the NFB circuit;

$\tau_\Phi=R_\Phi C_\Phi$, $\tau_{oc}=R_{oc}C_{oc}$ – time constants of the low-pass filter (LPF) and the feedback circuit, respectively

$$K_1=K\left(e^{-\frac{T}{\tau_\Phi}(1-\lambda)}-e^{-\frac{T}{\tau_\Phi}}\right);\ в=-\left[K\frac{W_{oc}}{R_{oc}}\left(e^{-\frac{T}{\tau_\Phi}(1-\lambda)}-e^{-\frac{T}{\tau_\Phi}}\right)-e^{-\frac{T}{\tau_{oc}}}-e^{-\frac{T}{\tau_\Phi}}\right];$$

$$C=e^{-\frac{T}{\tau_\Phi}(1-\lambda)--\frac{T}{\tau_{oc}}};$$

$\tau_u,\lambda=\frac{\tau_u}{T}$ - respectively, the relative duration of the formed pulse. Since the MMCC with NFB is a closed system, it is of great importance to determine the conditions for its stability. To determine the stability of the investigated transducer, we will use the Schur - Cohn algebraic criterion [2], which is reduced to the wiring of the absence of sign changes in the sequence of determinants composed of the coefficients of the characteristic equation.

In our case, the characteristic equation is of the second order and the determinants are found as:

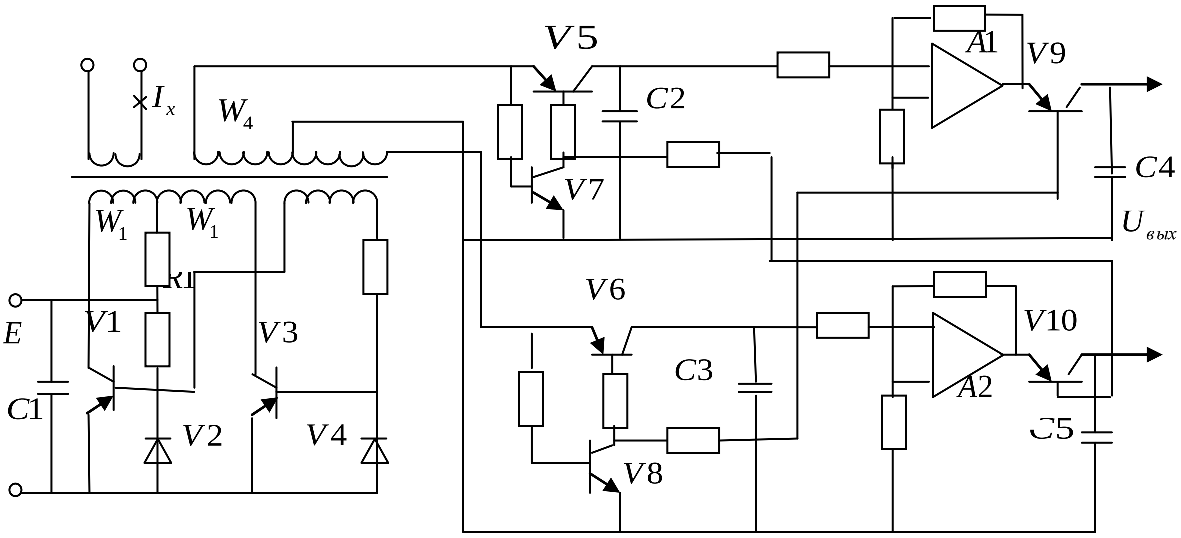

Fig. 3. MMCC circuit with discrete filter.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 11 , November 2020

$$\Delta_1 = \begin{vmatrix} 1 & C \\ C & 1 \end{vmatrix} = 1 - C^2,$$

$$\Delta_2 = \begin{vmatrix} 1 & 0 & C & b \\ b & 1 & 0 & C \\ C & 0 & 1 & b \\ b & C & 0 & 1 \end{vmatrix} = (1 - C^2)(1 + b + c)(1 - b + c).$$

The stability conditions are as follows:

$$\Delta_1 > 0;\ \Delta_2 > 0.$$

From here
$$\begin{cases} 1 - c > 0, \\ 1 + b + c > 0, \\ 1 - b + c > 0. \end{cases}$$

Substitute b (1) for b and c;
$$\begin{cases} \{1 - e^{-T\left(\frac{1}{\tau_\Phi} + \frac{1}{\tau_{oc}}\right)} > 0 \\ 1 - K\frac{W_{oc}}{R_{oc}}\left(e^{-\frac{T}{\tau_\Phi}(1-\lambda)} - e^{-\frac{T}{\tau_\Phi}}\right) + e^{-\frac{T}{\tau_{oc}}} + e^{-\frac{T}{\tau_\Phi}}(1 + e^{-\frac{T}{\tau_{oc}}}) > 0 \\ 1 + K\frac{W_{oc}}{R_{oc}}\left(e^{-\frac{T}{\tau_\Phi}(1-\lambda)} - e^{-\frac{T}{\tau_\Phi}}\right) - e^{-\frac{T}{\tau_{oc}}} - e^{-\frac{T}{\tau_\Phi}}(1 - e^{-\frac{T}{\tau_{oc}}}) > 0 \end{cases} \quad (2)$$

The first condition b (2) is always satisfied. The second and third conditions give restrictions on the MMCC gain. Let's rewrite them as follows:

$$K\frac{W_{oc}}{R_{oc}} < \frac{1 + e^{-\frac{T}{\tau_{oc}}} + e^{-\frac{T}{\tau_\Phi}}(1 + e^{-\frac{T}{\tau_{oc}}})}{e^{-\frac{T}{\tau_\Phi}(1-\lambda)} - e^{-\frac{T}{\tau_\Phi}}}, \qquad K\frac{W_{oc}}{R_{oc}} < \frac{e^{-\frac{T}{\tau_{oc}}} + e^{-\frac{T}{\tau_\Phi}}\left(1 + e^{-\frac{T}{\tau_{oc}}}\right) - 1}{e^{-\frac{T}{\tau_\Phi}(1-\lambda)} - e^{-\frac{T}{\tau_\Phi}}}$$

For MMCC with the following parameters:

$$W_э = 150;\ W_б = 75;\ W_{oc} = 400;$$

$E = \pm 12В;\ R = 180\ Ом;\ R_б = 300\ Ом;\ R_{oc} = 7{,}5\ Ом;\ \tau_ф = 0{,}5\ мс;\ \tau_{oc} = 0{,}35\ мс;$ these conditions are as follows:

$$K\frac{W_{oc}}{R_{oc}} < 21{,}5;\quad K\frac{W_{oc}}{R_{oc}} < 6{,}2.$$

In this case, the value $K\frac{W_{oc}}{R_{oc}} = 0{,}13$. Consequently, MMCC with NFB has a significant stability margin.

To exceed the speed of operation, the MMCC in [3] is used as. Discrete filter consisting of two identical channels with sampling and storage devices. One of the variants of such a MMCC is shown in Fig. 3. On the capacitors C2-C5, the values of the pulse amplitudes are memorized, depending on the measured current, therefore, along with the PWM, in this case there is an AIM.

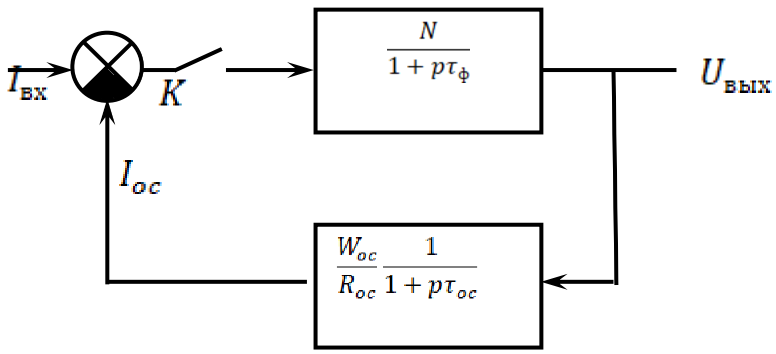

Fig. 4. Block diagram of an MMCC with a discrete low-pass filter.

In order to compare the capabilities of this MMCC with other current converters, we will analyze its operation in a dynamic mode. In this case, we will accept the following assumptions: - transistors VT3, VT5, VT7, VT8 work as ideal keys; the input resistance of the repeaters A1 and A2 is equal to infinity, and the output resistance is zero; - we neglect the inertia of the repeaters, since their bandwidth is much larger than $1/T$; - we neglect the values of the charge and discharge time constants of the capacitors C2-C5, considering them to be much less than the period T of the MTM self-oscillations; - the duration of the leading edges of the pulses that control the keys VT3, VT5, VT7, VT8 are assumed to be zero.
Taking into account the above assumptions, we will present this MMPT with the structural diagram shown in Fig. 4 [4]. In this case, the sampling and storage devices are presented in the form of shapers that form rectangular pulses with amplitudes depending on the current magnetizing the core of the MTM transformer. Coefficients M1 and M2 are proportional to the current, equal:

$$M_1 = \frac{U_1}{I_{\text{вх}}} = \frac{2(E - i_s R_2)T_2}{I_{\text{вх}}(T_1 + T_2)} \cdot \frac{W_4}{W_1},$$

$$M_2 = \frac{U_2}{I_{\text{вх}}} = \frac{2(E - i_s R_2)T_1}{I_{\text{вх}}(T_1 + T_2)} \cdot \frac{W_4}{W_1},$$

Where E is the supply voltage; Is the current corresponding to the saturation induction; - resistance of the ballast resistor; - duration of half periods of generated pulses; - respectively, the number of turns of the collector and output windings.
It can be seen from the block diagram that the sampling and storage devices introduce the total delay of the output signal relative to the input signal by the value $T_1, T_2/2$, since for transmitting a signal from the first storage capacitors C_2, C_3 on capacitors C_4, C_5 it takes time approximately equal to $T_1, T_2/2$.
From the analysis of the structural diagram of the studied MMCC follows, that its dynamic characteristics are determined mainly by the value of the time constant of the input circuit $\tau_{\text{вх}}$ and period (T_1, T_2), determining the delay time of the output voltage relative to the current $I_{\text{вх}}$.

IV. CONCLUSION

Thus, the article shows that it is advisable to represent the latter in the form of a second-order linear impulse link with amplitude-impulse modulation when analyzing the dynamic operating mode of ACS containing MMCCs. The transient time of an MMCC with a discrete filter is mainly determined by the value of the time constant of the input circuit.

REFERENCES

[1]. Atamalyan E.G. Instruments and methods for measuring electrical quantities: Textbook. - Moscow: Bustard, 2005 .-- 415 p.
[2]. Besedin V.M., Yagodkina T.V. Analysis of linear pulse automatic control systems. Moscow, 2000 – 50p.
[3]. Amirov S. F., Ataullaev N.O. Performance of Magnitemodulying Carrent Sensor// International Jornal of Advanced Research in Science, Engineering and Technology. ISSN(Online): 2350 – 0328. Vol. 3, Issue 7, July 2016. – 2337 – 2346.
[4]. Svyatochevsky A.A. DC control devices on magnetic - transistor multivibrators with pulse - width modulation. Tomsk, 1987
[5]. Amirof S.F., Ataullaev N.O., Rustamov D.Sh. Linear dynamic model of magnetomodulation current sensor // Chemical technology. Control and management. Toshkent, 2011, No. 5-C. 36-41.
[6]. G.V. Dzhikaev Measuring transducers of large alternating currents in the electric power industry: Author's abstract. dis .... cand. tech. sciences. - Ulyanovsk, 2004 .-- 18 p.
[7]. Kochemasov Yu.N., Kolegaev Yu.B. Comparative analysis of the characteristics of magnetic field sensors // Sensors and systems. - Moscow, 2001. - No. 4. - S. 33-34p
[8]. Liberzon K.Sh. Magnetic transistor converters in automation // Moscow, "Energia", 1975, - 120 p.
[9]. Mazmanyan R.O. and others. SPICE-models of Hall measuring transducers // Tekhn. Electrodynamics, 2006 .-- 224 p.