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Applications of Nonlinear Electrical Circuits for Control and Energy Efficiency Improvement Electromagnetic Vibration Exciters

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ABSTRACT: In order to ensure sustainable energy-efficient modes of operation of a frequency-controlled electromagnetic vibration exciter, it is necessary to conduct theoretical and experimental studies of the nonlinear characteristics of the elements of the electrical and magnetic circuits of an electromagnetic vibration exciter powered by a single-phase frequency converter. The study of the nonlinear characteristics of elements, oscillatory circuits and modes, non-reversible and reversible pulse-width DC converter makes it possible to develop a simplified, energy-efficient converter circuit for powering a frequency-controlled electromagnetic vibration exciter.

KEY WORDS: electric drive, magnetic flux, capacitor, thyristor, pulse-width converter, magnetic gap, resonant machines, pulse duty cycles, semiconductor technology

I.INTRODUCTION

However, despite the fact that consumers with single-phase electrical equipment or power supplies occupy an impressive share in industry and the domestic sector, the above successes in science and production cannot be attributed to the development and implementation of single-phase frequency converters [1-3].

Just as in multi-phase electrical equipment systems, when solving issues of energy-efficient single-phase electric drives, in particular Electro Magnetic Vibration Exciter (EMVE), it is necessary to apply an integrated approach. At the beginning, effective (from the point of view of ensuring the optimal technological process) operating modes of the production mechanism with EMVE, with minimal power consumption, are determined, then systems for providing an energy-efficient production mechanism are developed, taking into account the processes of mutual influence of their parameters and nonlinearities [4-7].

II. RESEARCH PROBLEM AND METHOD

So, in particular, in vibration machines with EMVE, belonging to the group of resonant machines, the input-output characteristics are of an extreme nature. In the resonant zone, the amplitude of vibration (displacement, speed and acceleration) of the working body, useful mechanical power and productivity increase many times, the specific power losses are significantly reduced, while the energy efficiency of the EMVE is increased. According to the conditions of the technological process, frequent changes in the mass of the vibrated product are observed in them, r.o. and stiffness of the elastic elements of the VM. This leads to a continuous change in the frequencies of free oscillations 0 in a fairly wide range, in connection with which a spontaneous shift in the amplitude-frequency characteristic is observed [1].

This causes an urgent need to tune into the resonant mode by changing the frequency of forced oscillations, using the laws of frequency control, which are facilitated by the proposed sufficiently effective methods for frequency control of

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Vol. 9, Issue 3 , March 2022

the EMVE performance, which make it possible to maintain the amplitude of oscillations r.o. necessary for the production process vibrators [2-3]. One of such methods for controlling the resonant mode of the EMVE is the use of a pulse-width DC converter circuit, previously used to control the magnitude of the direct current in the excitation circuits of DC machines, changing the duty cycle of the pulses. One of these schemes is shown in Fig. 1, a.

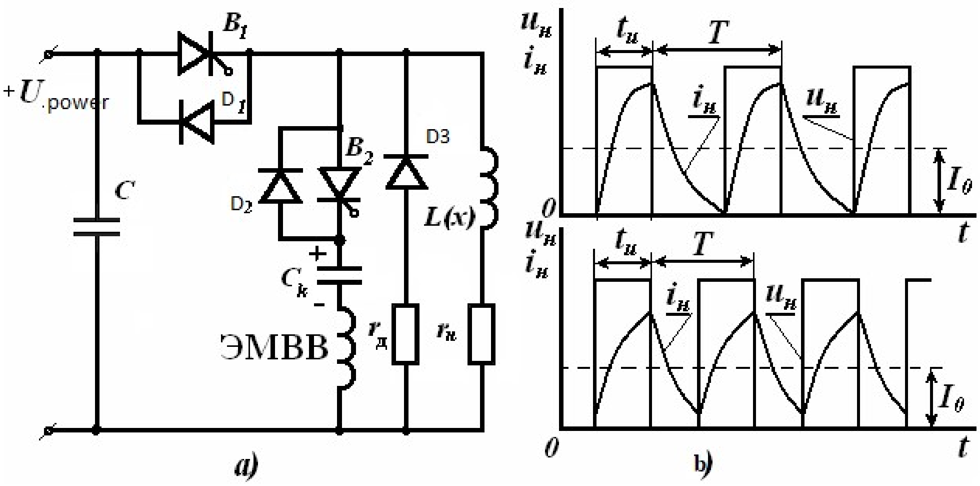

Fig. 1 a) DC breaker circuit, b) current and voltage diagrams

The circuit works in the following sequence. When at some point in time t0 a control signal is applied to the thyristor B1 and it is unlocked, a voltage u_H appears in the EMVE winding (Fig. 2), the value of which is equal to the voltage of the power source. The load current i_H begins to flow through the winding of the EMVE and it will increase. After some time, at time t1, a control signal is supplied to thyristor B2 and the switching capacitor begins to charge in the oscillatory circuit, the voltage of which will be greater than the voltage of the power source, because. this circuit is tuned to resonant mode; therefore, it will be recharged, this recharge current will be directed against and more than the current of valve B1, which turns off the thyristor B1. The load is provided with a rectangular voltage with a controlled frequency and duration ti.

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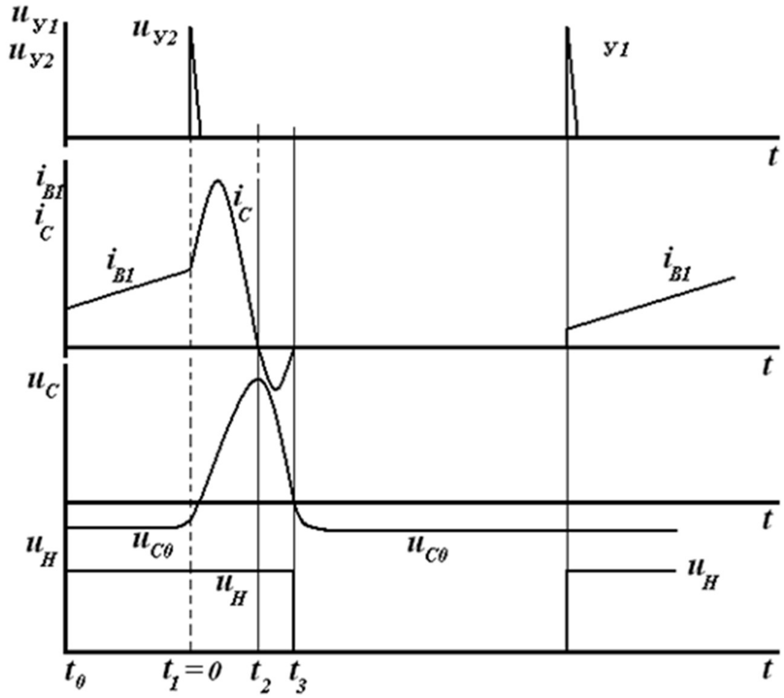

Fig.2 Diagrams of currents and voltages of circuit elements

When valves V1 and V2 are periodically opened, load currents i_H and charge current of the switching capacitor of the oscillatory circuit flow through them.
On fig. 2, the time interval from t1 to t3 is shown on a larger scale for clarity. In fact, when calculating the circuit, the parameters Lk - Ck are chosen so that the time required to turn off the thyristors is 5-8 microseconds.
It can be seen from Fig. 2 that in the time interval after the thyristor B2 is unlocked and before the thyristor B1 is locked, the current in the last i_{B1}, equal to the load current of the EMVE i_H, will be maximum. In the same time interval, the charging current of the switching capacitor i_{Ck} flows through this thyristor, the value of which is several times greater than the value of the load current.

Thus, during the duration time, the current flowing through the thyristor B1 in the forward direction will be 2-3 times the value of the load current. This leads to the need to select thyristors with a sufficiently large power margin and overestimation of the cost of this circuit and is one of the main disadvantages of this circuit.

Another, no less significant, disadvantage of this circuit is that it uses ordinary, non-locking thyristors, which require a switching circuit. As a result of modern advances in semiconductor technology, the appearance of gated thyristors in operation makes it possible to create circuits without switching circuits.

Another - the most effective way to control the resonant mode of the EMVE can be obtained using the reverse pulse-width converter (PWC) circuit used in the winding circuits of the armature. At the same time, the use of a circuit for controlling the EMVE allows you to simultaneously tune into the resonant mode and control the amplitude of the armature oscillations, changing the frequency and duty cycle of the voltage pulse (Fig. 3).

III. PULSE-WIDTH CONVERTER CONTROL

In them, the alternate unlocking and locking of two pairs of thyristors B1-B3 and B2-B4 with different time shifts make it possible to change the duty cycle of the generated pulses, thereby controlling the magnitude of the direct current in the inductance winding. When analyzing the operation of the frequency converter, we will assume that the resistances of diodes and thyristors (in the open state) in the forward and reverse directions of currents are equal to zero and

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infinity, respectively; the resistance of the thyristor in the forward direction of the current (when it is locked) is also equal to infinity. Leakage currents will be neglected.

When a pair of thyristors B1-B3 (Fig. 3) is turned on, the load current i_H flows through the main winding $r_{H\text{ -}L}$ (x) EMVI in the direction "left - right", the switching capacitor Ck is simultaneously charged
current i_{Ck} (Fig. 4) is sign, as shown in Fig. 3 without brackets.

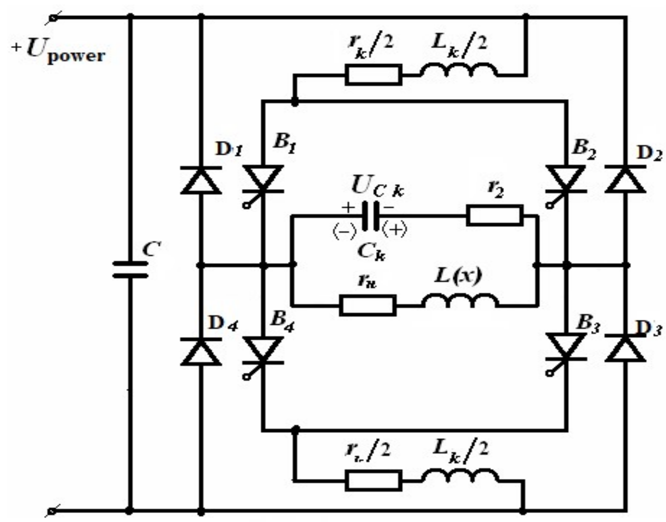

Fig.3. Pulse Width DC Converter Circuit

If we take the moment of time t0 (Fig. 4) as the reference point, the oscillatory current i_{Ck} of the charge of the switching capacitor C_k will change according to the law $i_{Ck} = I_{Ckm} \sin \omega t$, when $0 \le t \le \pi/\omega$.
The switching inductances Lk, resistors rk and capacitance Ck are selected so that so that the voltage on the switching capacitor Uck is greater than the voltage of the power source.

After the time has elapsed after turning on the thyristor B1, the capacitor will charge and its current becomes zero, and the voltage across it will be (2Upower+ u) twice the source voltage.

When a pair of thyristors B2-B4 is turned on, the voltage of the switching capacitor UC k is applied to a pair of thyristors B1-B3 in the opposite direction. Since UC k > UIST currents will flow through the reverse diodes D1-D3, the value is greater than the currents in the thyristors V1-V3 in the forward direction, as a result of this, the currents in these thyristors will be equal to zero during the discharge time of the capacitor Ck to the capacitor CF. This time will be enough to lock the thyristors B1-B3. Through a pair of thyristors B2-B4 and the main winding rH -L (x) current flows in the direction "from right to left". At the same time, the switching capacitor Ck is recharged with the sign, as shown in brackets in Fig. 3; this will continue periodically - when the first pair of thyristors is unlocked, the other pair will be locked, and so on.

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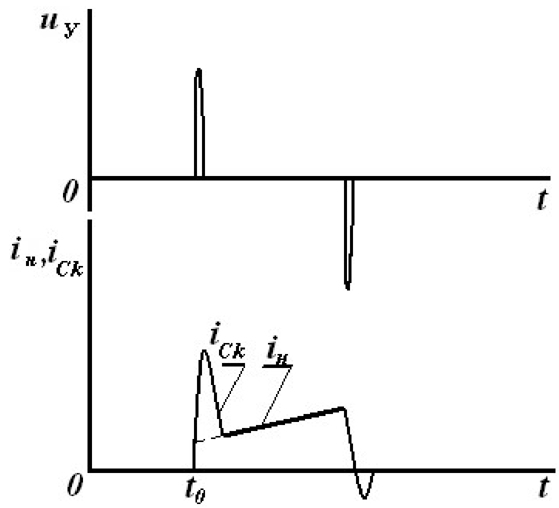

Fig.4. Curves of control voltage signals, valve currents and switching capacitor

Thus, a periodic alternating voltage is provided at the terminals of the EMVE winding (Fig. 6). By controlling the thyristor triggering time, in particular, by changing the thyristor pair triggering period T, it is possible to change the frequency of the voltage EMVE, and tune it to the resonant mode. At the same time, by changing the firing duration of one pair of thyristors with respect to another pair of thyristors, without changing the period T, it is possible to change the duty cycle of the voltage - the constant component of the current I_0 (Fig. 5,b), i.e. to control the value of the bias current of EMVE, therefore, to control the amplitudes of vibration, speed and acceleration of the working body.

When one pair of thyristors is unlocked, electrical energy from a constant voltage source with a filter capacitor SF enters parallel-connected reactive elements Ck - L(x) with active resistance r_H. Part of the energy is converted into useful mechanical power and transferred to the working body of the VM. Another part of the energy is spent in the form of heat in the core of the electromagnet (losses in steel), in the active resistance of the winding r_H and the switching active resistance rk. The rest of the energy is returned (energy recovery) to the filtering SF capacitor through the reverse diodes D1-D3 and D2-D4. When another pair of thyristors is unlocked, the processes of energy consumption and exchange will proceed similarly.

IV. RESULTS

By combining the flow of alternating and direct currents in one winding, it leads to a reduction in the number of bias windings. The main disadvantage of such a scheme is the fact that a substantially non-sinusoidal current flows in the EMVE winding and the presence of significant energy recovery, commensurate with the main energy consumption. They cause energy losses in the EMVE winding, circuit elements and conductors.

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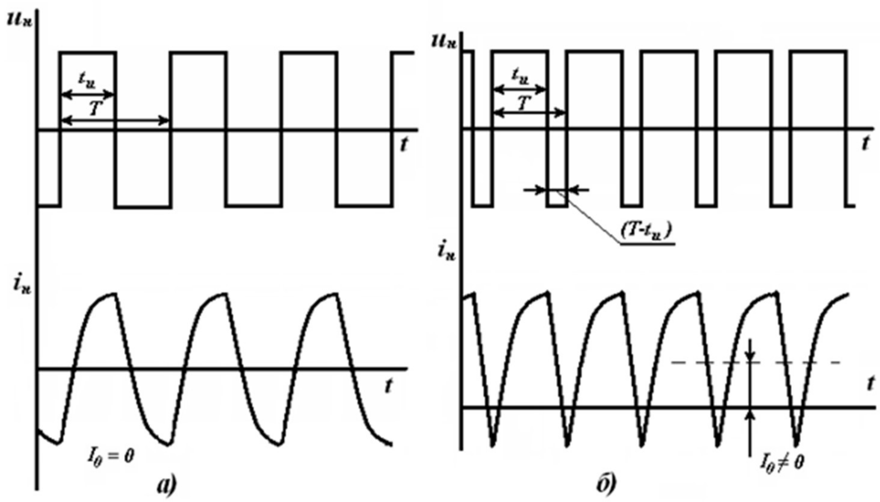

Fig..5 Formation of alternating voltage EMVE

V. CONCLUSION

The use of such a circuit for powering the EMVE with biasing allows you to simultaneously tune the EMVE in the resonant mode and control the maximum vibration amplitude of the working body. This leads to an improvement in the energy efficiency of the vibrator, the establishment of efficient operating modes, a decrease in energy losses, a significant improvement in the weight and size indicators of the EMVE.

REFERENCES

[1] Toirov O.Z., Khalikova M.O. Development of a mathematical model of a frequency-controlled electromagnetic vibration motor taking into account the nonlinear dependencies of the characteristics of the elements, Problems of Informatics and Energy. Tashkent, No. 3. P. 77-84. 2021.
[2] Hantila F., Vasilin M., Ifrim C., Leuce T. Bounts for the difference between the computed and the exact solutions of nonliner field problems. Electrotech. energ. 48, no. 2-3, p.157-165. 2003.
[3] Timofeev A.V. Reversible dynamics of mechatronic systems and methods for the synthesis of modal and invariant controllers. Scientific, technical and industrial journal "Mechatronics". Moscow: Mashinostroenie Publishing House. N 4, P. 2-6. 2000.
[4] Sharyakov V.A., Shestakov V.M., Epishkin A.E. Starting modes of vibration electromechanical stands for testing products operating in extreme conditions. Materials of the XI scientific and technical conference. St. Petersburg: Publishing House of St. Petersburg. GTU. 2001. 141-142 p.
[5] Olimjon Toirov, Kamoliddin Alimkhodjaev, Akhror Pardaboev Analysis and ways of reducing electricity losses in the electric power systems of industrial enterprises, SUSE-2021, E3S Web of Conferences 288, 01085 (2021) https://doi.org/10.1051/e3sconf/202128801085
[6] Olimjon Toirov, Utkir Mirkhonov Principles for Controlling the Excitation of Synchronous Motors of the Compressor Installation, International Journal of Advanced Research in Science Engineering and Technology, Vol. 7, Issue 5 , P. 13876-13881, 2020.
[7] Olimjon Toirov, Utkir Mirkhonov Overview of Compressor Installations and Issues of Their Energy saving, International Journal of Advanced Research in Science Engineering and Technology, Vol. 6, Issue 10, P. 11446-11452, October 2019.