Electric converters of electromagnetic strike machine with battery power

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Abstract. At present, the application of pulse linear electromagnetic engines to drive strike machines for immersion of rod elements into the soil, strike drilling of shallow wells, dynamic probing of soils is recognized as quite effective. The pulse linear electromagnetic engine performs discrete consumption and conversion of electrical energy into mechanical work. Pulse dosing of a stream transmitted by the battery source to the pulse linear electromagnetic engine of the energy is provided by the electrical converter. The electric converters with the control of an electromagnetic strike machine as functions of time and armature movement, which form the unipolar supply pulses of voltage and current necessary for the normal operation of a pulse linear electromagnetic engine, are proposed. Electric converters are stable in operation, implement the necessary range of output parameters control determined by the technological process conditions, have noise immunity and automatic disconnection of power supply in emergency modes.

1. Introduction

At present, the application of pulse linear electromagnetic engines to drive strike machines for immersion of rod elements into the soil, strike drilling of shallow wells, dynamic probing of soils is recognized as quite effective. [1, 2, 4,]. A distinctive feature of LEME and systems with their use is the cyclic nature of the electromechanical energy conversion, in which the pulses of electrical power that are regularly fed into the engine winding, are converted into mechanical work for moving the armature and articulated working part [1, 3, 4]. The discrete nature of the energy conversion makes it impossible to connect the LEME winding directly to the source, as, for example, in a conventional asynchronous engine, and it makes it necessary to include a special electric converter (EC) between the source and LEME clamps, which generates the supply pulses of voltage and current in each energy conversion cycle of LEME [5, 6, 7, 13].

The power of the strike machine with pulse LEME in the absence of AC general-purpose electrical networks is provided by a battery power supply [1].

2. Subject of research

The paper proposes electric converters with control in the time and displacement function of the LEME armature.

The control of electromagnetic drives as a function of time has the advantage that it does not require the use of special sensors that fix the positions of the working body of the machine. To
implement this, the method of controlling the movement of the working body of the shock machine in the electrical converter requires a generator of control pulses.

In the practice of pulsed thyristor control, due to the known benefits, devices on unijunction transistors are widely used. Generators built on another element base are used. The scheme of such generator, which is based on a dynistor multivibrator, developed and tested together with the pulse converter in the control system of an electromagnetic strike machine [1, 11, 12] is shown in Fig. 1.

![Diagram of a pulse converter with LEME control as a function of time](image_url)

**Figure 1.** A pulse converter with LEME control as a function of time

The scheme contains dinistors VS1, VS2, to which switching capacitor C3 is connected, time-setting resistors R2, R3, R6, R7, thyristor optocouplers V1, V2, forming the control pulses for high-power thyristors VS3, VS4 of the DC breaker. To stabilize the frequency of switching dinistors, when the voltage of source G decreases during power consumption, chain R1, VD2, VD1, C2 serves as a load. Diode VD6 prevents the effect of locking dinistors VS1, VS2 of the voltage pulses from capacitor C3 to turn on and off the LEDs V1, V2, ensuring a clear circuit operation. Trimmer resistors R2, R3 change the duration of the conductive condition of the dinistors, set the required frequency of the control pulses, and, consequently, the movements of the armature of the LEME.

The control current pulses are submitted to the control electrodes of the VS3, VS4 power valves via photothyristors V1, V2 at the moments of switching on the corresponding LEDs. Switching off the photothyristors after unlocking VS3, VS4 occurs due to the action of stabistors VD3, VD4.

The analysis of published data, the results of laboratory studies, production tests show that the highest frequency of the moves of the working member of electromagnetic machines, their maximum power and efficiency are provided in a self-oscillatory, close to a resonant mode of operation with control as a function of the position of the working body [1, 8, 9, 11]. Unlike open control systems as a function of time, such system is closed and has feedback on the position of the striker, which is provided by sensors located on the engine. The advantage of this method of control is the automatic self-tuning of the LEME of the strike machine into the optimum operating mode when the conditions of the armature and tool collision, the discharge of the source, and the environmental conditions change.

Analysis of the results of the research shows that in this case, a dynamic cycle of pulse LEME with a higher efficiency is provided; this allows one to increase the duration of continuous operation of the machine with the same capacity of the source batteries. It should be noted that with this method of
control, the electrical converter circuit can be simplified as much as possible and only contain sensors for the limit positions of the striker, for example, of the contact type.

A circuit diagram of the rechargeable electric converter with control in the position function of the pulse LEME armature of the strike machine is shown in Fig. 2.

**Figure 2.** The pulse converter with control in the position function of the armature LEME

The circuit contains a protection unit \((A1)\) and a pulse interrupter with a control unit \((A2)\). The power circuits of the electric converter are shown in the diagram with thick lines.

The power circuit of the \(A1\) unit contains the main contacts of contactor \(KM\) and measuring resistance (bridge) \(R2\). Switching on is made by short-term pressing of "Start" button \(SB2\), deactivation at the end of the device operation - by briefly pressing "Stop" button \(SB1\). The LEME is switched on and off by the \(SA\) toggle switch installed on the machine. Resistor \(R1\) limits the current in the coil circuit of a small contactor after closing its main \(KM\) contacts and releasing the \(SB2\) button.

To disconnect the electric converter from the G source, in the event of emergency regimes, current protection is provided, the sensitive element of which is the \(R2\) bridge. The current setting is controlled by resistor \(R3\). Due to the action of this resistor, the temperature stabilization of the cascade is also carried out.

An increase in the current in the power circuit in excess of the permissible voltage is opened by transistor \(VT\), and a current opens up in the control circuit of the \(VS4\) thyristor. There is radiation from the LEDs of optocoupler pairs \(VI, V2\), which opens the photothyristors included in the control circuit of the \(VS2, VS3\) valves. As a result, the \(VS2\) power thyristor (and the interruption of the current from the source) sequentially occurs due to the unlocking of \(VI\) and the mechanical opening of the power circuit by the \(KM\) contactor - due to the integrating of \(VS3\). Diode \(VD2\) and resistor \(R10\) increase the speed of the contactor. In the circuits of the \(A2\) electric converter block, the elements of LEME - winding \(M\), the sensors of the upper \(SQ1\) and the lower \(SQ2\) of the armature position are shown included. The power circuits of this unit contain power \(VS1\) and \(VS2\) blocking thyristors, autotransformer \(T\), diode \(VD1\), commutating capacity \(C1\), and also elements \(VD4, C2, R15\), which form the circuit for damping the energy of the magnetic field of the engine.
After pressing the SB2 button and closing the KM contacts with the SA toggle switched on on the thyristor VS1 control electrode, gate trigger voltage appears, as the contact sensor SQ1 top position is closed. Thyristor VS1 is opened and a current flows through winding M. At the same time, switching capacitor C1 is charged through the secondary winding of autotransformer T. The current in the winding creates a magnetic field that accelerates the LEME armature. Before hitting the armature on the tool, the contact of the low position sensor of armature SQ2 closes, the control signal of thyristor VS2 is formed, which is unlocked and, due to the discharge of switching capacitor C1, secures the closing of VS1. The residual energy of the magnetic field of the engine is converted into an electrical one, partially recovered into a source, and partially dissipated in circuit VD4, C2, R15. The armature is returned to its original position by the spring sensor contact SQ1 is closed and the cycle is repeated.

Structurally the electrical converter is designed in the form of a portable container, the body of which is welded from a sheet aluminum alloy. On the front side of the container two handles for its carrying, power terminals for connecting the source and the strike machine, the control cable from the LEME armature position sensors are fixed. On the body of the electrical converter, the "Start", "Stop" buttons for turning the device on and off are placed. One of the side walls of the body, on which thyristors VS1, VS2 are fastened, has external fins to improve the heat dissipation conditions.

3. Conclusion

The electric converters with control of an electromagnetic strike machine are proposed as functions of time and armature movement, forming unipolar supply pulses of voltage and current necessary for the normal operation of the LEME.

Electric converters are stable in operation, implement the necessary range of output parameters control determined by the technological process conditions, have noise immunity and automatic disconnection of power supply in emergency modes.

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