Magnetic Thyristor Generator for Electrodischarge Technologies

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The generator is aimed to operate in the area of electrodischarge technologies. Depending on the electric strength of a load the generator forms a voltage pulse up to 50 kV. The distributed energy in pulse is up to 200 J, the pulse frequency rate is up to 100 Hz. In the generator a direct discharge of pulsed capacitors to the discharge gap through a coaxial cable 200 m in length without additional commutated elements is used. The technical solutions applied in the generator circuit allow it to operate stable as in the mode of short circuit in the load so in the idling mode. To stabilize energy distributed at a load the circuit of pulse energy stabilization was used due to unused energy recuperation to the power source filter capacitor. The generator has a micro processing control system of operation modes. It allows performing a control of power in the load by the change of pulse frequency rate and input power supply. Constructively, the generator is performed in the form of movable construction on wheels with 420 kg weight. The power of the generator is carried out from industrial three-phase net of alternate current 380/220 V – 50 Hz.

1. Introduction

Magnetic thyristor generators (MTG) using primary commutation basing on semi-conductive equipment - thryristors with further energy compression in saturation throttles are capable of working with high pulse frequency rate. They have practically unlimited service life [1-4] what is quite important while using them in variable electrodischarge technologies: surface cleaning from insoluble sediments, fragmentation of insoluble particles in solutions and so on. At that, because of a significant nonlinear load representing spark gap in a water media MTG must reliably stand the modes of both short-circuit and idling.

2. Magnetic thyristor generator (MTG)

Figure 1 shows the principal electric circuit of the generator. From three-phase net of alternate current through the rectifier R made according to Larionov's scheme and filter inductance L_1 the capacitor of filter C_F is charged. When the launching pulses arrive from the generator controller the thyristors VS_1 and VS_2 switch on and an oscillating charge of capacitors C_1 and C_2 begins.

The initial voltage at the capacitors C_1, C_2 depends on the conditions of previous pulse formation and can vary. In the modes close to short-circuit the capacitors C_1, C_2 can recharge to a significant voltage and at an oscillating charging the voltage at them increases from pulse to pulse. In order to exclude this mode the charging throttle L_2 is supplied by an additional winding shunted by the diode VD_1.

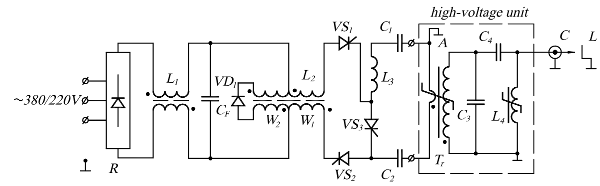

Fig. 1. Principal electric circuit of magnetic thyristor generator of pulses: R is rectifier, L_1 is filter inductance (0,3 H), C_F is filter condenser (1300 μF), L_2 is throttle (10^{-2} H), L_3 is inductance in discharge chain ($7\cdot10^{-6}$ H), C_1 and C_2 is capacitors (total capacity 400 μF), C_3 and C_4 is capacitors (total capacity 0,564 μF), L_4 is saturation throttle, VD_1 is diode D 133-200, VS_3 is thyristor TB 453-1000, VS_1 and VS_2 is thyristors TB 132-250, C is matching cable, L is load

Figure 2 shows the current and voltage diagrams in the circuit of voltage stabilization.

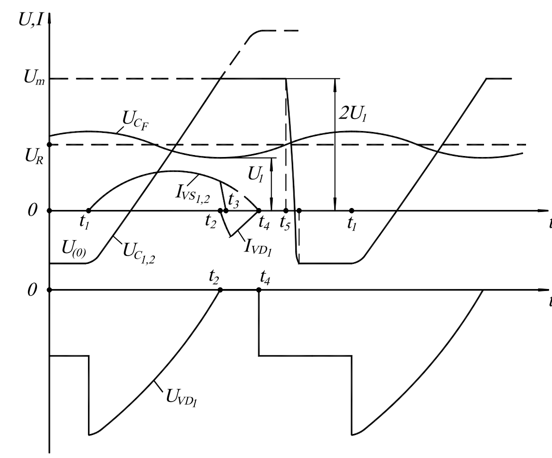

Fig. 2. Diagrams of Currents and Voltages in the stabilization chain of voltage. U_R is rectifier voltage; Uc_F is filter capacitor voltage; $U_{(0)}$, U_m – initial and final voltage at capacitors C_1 and C_2, U_{VD1} is voltage at a diode VD_1, $I_{VS1,2}$ is current of thyristors VS_1, VS_2, i_{VD1} is diode VD_1 current

When the voltage at C_1, C_2 reaches its double value, remained at the filter capacitor and under the condition of equality of coil number W_1 and W_2 of the charging throttle the diode VD_1 opens. During the time t_2-t_3 the current from windings W_1 commutates to the windings W_2. The thyristors VS_1, VS_2 switch off and the energy remained in the throttle L_2 recuperates to the filter capacitor. At the charge of capacitors C_1, C_2 the core of pulsed transformer T_r demagnetizes. Partially due to the transfer process the saturation throttle L_4 demagnetizes.

The controller in some definite period of time of delay which depends on the parameters of charging throttle L_2 forms a launching pulse for a thyristor VS_3 with the frequency rate controllable from 0.1 to 100 Hz. At the thyristor VS_3 switching on the capacitors C_1, C_2 discharge at the capacitors C_3, C_4.

In the discharge chain of capacitors C_1 and C_2 the inductance L_3 is included. The value of L_3 is equal to the value of pulsed transformer T_r distribution inductance. It performs two functions: limits discharge current of capacitors through thyristor VS_3 at ~5kA level and provides equal conditions at the charge of capacitors C_1 and C_2 relative to the earthed point A, Fig.1.

Figure 3 shows the voltage and current diagrams in a high-voltage unit. At the charge of capacitor C_4 the saturation throttle L_4 demagnetizes completely. The period of time t_6-t_5 and capacitors C_3 and C_4 charge in parallel. The value of capacitors C_1, C_2 and C_3, C_4 and transformation coefficient are related by the following condition:

$$C_1/2 = C_2/2 = K^2 \cdot (C_3 + C_4). \qquad (1)$$

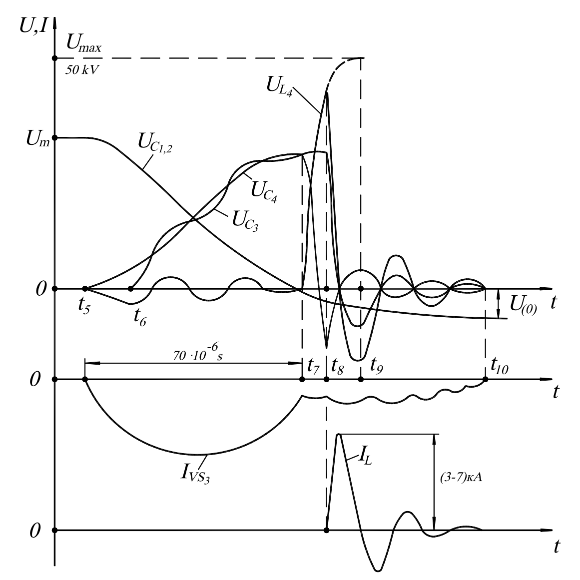

Fig. 3. Diagrams of current and voltages in high voltage unit. U_{C1} and U_{C2} are discharge voltages of capacitors C_1, C_2; U_{C3} and U_{C4} are discharge voltages of capacitors C_3 and C_4; U_{L4} is a voltage on the saturation throttle L_4, output generator voltage; I_{VS3} is thyristor VS_3 current, I_L is load L current

In this case almost all energy from C_1 and C_2 goes to the capacitors C_3 and C_4. In the moment of time t_7 the saturation of pulsed transformer takes place and the capacitor C_3 begins to recharge through the inductance of the secondary winding. A high-voltage pulse of positive polarity forms at the throttle L_4.

The core of the saturated throttle is aimed for the magnetization within t_9-t_7=$7\cdot10^{-6}$ s period of time which is a little bit more than the discharge time of capacitor C_3 and it allows forming a voltage pulse at a load up to 50 kV. At that the voltage at the secondary winding of the transformer does not exceed 27 kV. In order to exclude the overvoltage appearance at the thyristor VS_3 it is limited by the control pulse in the open state during time ~$150\cdot10^{-6}$ s. If the breakdown in the load takes place at the voltage 30 kV and higher the amplitude of recharge current of capacitors C_1 and C_2 is not significant and the energy distributes in the load. The time interval is t_7-t_{10}. At low breakdown voltage or at idling mode the amplitude of post-pulse oscillations increases.

The amplitude of the current pulse formed in the load depends on the length of the matching cable. At the cable length of 5 m the current in the load at the output voltage of 50 kV reaches 7 kA, at the cable length of ~200 m it decreases down to 3 kA but due to the increase of oscillations period of discharge current the energy distributed in the load does not change.

Figure 4 shows the assembling of elements of high-voltage unit.

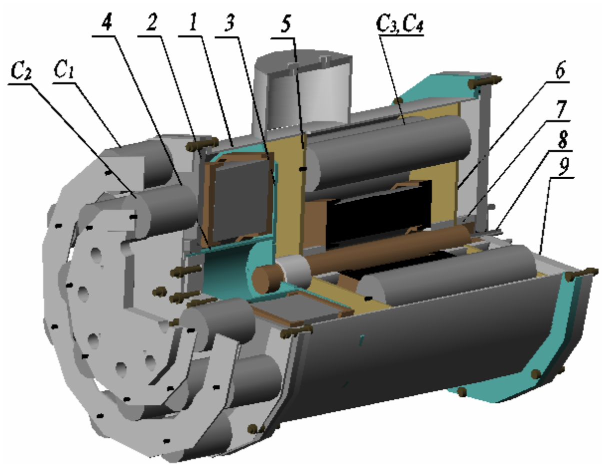

Fig. 4. Assembling of Elements of High-voltage Unit

The primary winding of the pulsed transformer T_r is formed by the body 1, flange 2 and inner wall 3 with centering tube 4. The capacitors C_1, C_2 are fixed at a flange 2 and tube 4 uniformly around the circle. The high-voltage capacitors C_3, C_4 are fixed at dielectric disks 5, 6. The saturation throttle L_4 is placed at a centering rod 7. The high-voltage output is screened by the screen 8 placed in the center of the disk isolator 9. The core of pulsed transformer is made of four rings K360×150×25, 0.03 mm, 50 NP. The high-voltage winding is toroidal and is sectioned into two parts. The same construction has the saturation throttle L_4 which consists of seven rings K180×70×25, 0.03 mm, 50 NP. The considered construction has a minimal assembling inductance and occupied capacity of used element base.

The controller of the generator is done on the base of microcontroller Atmega 8535 by Atmel company and contains the following principal units: controller board, board of control buttons and indication, 2 the former of launching pulses with optical isolator on the base of optical receivers and transmitters produced by Infineon company for generator thyristors, the power source and filter board for pulse noises suppression. The use of microcontroller for the generator monitoring allows flexibility in change of the accelerator operation modes, it allows realizing the functions of current defense of generator elements. The possibility of operative control from the remote control is considered.

References

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