

EMIR-M INSTALLATION IN THE MODE OF OPERATION WITH PLASMA OPENING SWITCH

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Abstract

The EMIR-M generator is modified to perform a series of experiments to explore the Plasma Opening Switch (POS). Results of the first experiments with POS are described. EMIR-M operates in two different modes: first one, with Marx generator voltage of 0.95 MV and current of 300 kA; second one, 1.42 MV and 460 kA, correspondently. Vacuum diode and inductance (short-circuit diode) was used as a load. PIN-diodes and TLD detectors are used for radiation parameters measurements. The results have been obtained:

- voltage gain of 2.6;
- maximum conduction time of 2.3 μs ;

Current rise rate up to $3 \cdot 10^{13}$ A/s with front duration of $10 \div 13$ ns has been measured.

I. INTRODUCTION

During the past 10 years nano- and microseconds POS has been investigated at VNIITPh. The investigations are the logical continuation of the works with inductive pulsed power accelerators based on fuse used as an opening switch. Using POS has a significant advantage over fuse because of the productivity increasing, size reduction, and ecological cleanliness.

POS investigations at VNIITPh showed real possibility of POS using in existing and developing installations.

The paper presents the first stage of POS investigations for power pulse forming on EMIR-M.

Figure 1 shows the geometry of experiments.

POS is located in the gap of the EMIR-M diode container. Experiments were conducted using central electrode (cathode) diameter of 40 and 60 mm. The cathode-anode flange of container distance D was taken in two cases: first one: short-circuit regime, and second one, in the range of 10-30 mm. In the first case the experiments with inductance load were conducted with the parameters: 0.26 μH and correspondent cathode diameter of 60 mm; and 0.32 μH and correspondent cathode diameter of 40 mm. Second case is suitable for vacuum diode regime. Plasma injection unit and plasma guns unit (PGU) is located on the steel ring (Figure 1). Up to 40 guns could be located at the ring. Ring design permits the radial shift of the guns and their hermetically sealed location. POS consists from PGU and cathode central electrode. From 10 to 15 plasma guns charged form individual high-voltage generator are the sources of plasma in the experiments. Usual coaxial cable-type guns are used.

Electrical circuit of the experiment is shown in Figure 2.

Plasma formed by plasma guns is injected from anode to the POS region. After fixed time of delay the Marx generator starts

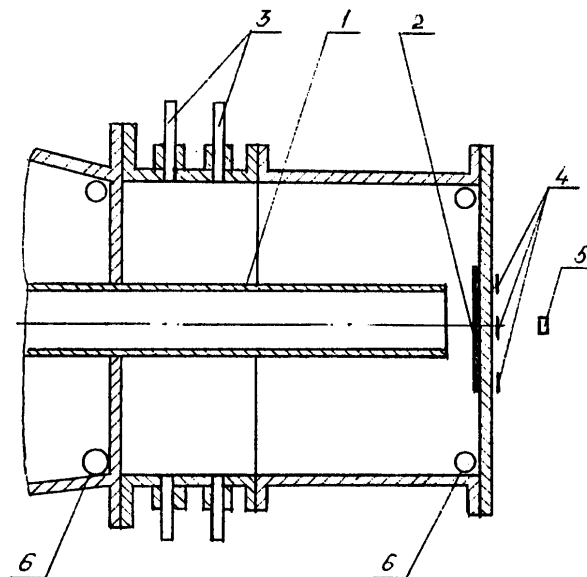


Figure 1. EMIR-M POS configuration in the switch region: 1 - cathode, 2 - anode, 3 - cable plasma guns, 4 - TLD dosimeters, 5 - PIN-diode, 6 - Rogovsky coil.

to discharge. Current flows through the plasma in anode-cathode gap.

The voltage and current has been diagnosed using standard techniques: capacity voltage divider and Rogovsky coils (see Figure 2). Rogovsky coils have shielding design and are located in the gaps of anode container. PIN-diodes are used for bremsstrahlung radiation measurement in diode regime. TLDs are used for radiation dose measurement. Seven dosimeters are located at 1 cm distance from the anode surface (Figure 1).

II. EXPERIMENTAL RESULTS

Experiments were performed in two different regimes of installation's work. First one, Marx voltage of 0.95 MV and current amplitude of 300 kA. Total impedance of circuit is 2.85 Ohm. Plasma is created by 10 guns with correspondent currents of $4 \div 11$ kA and period of 3.5 μs in individual gun. Marx generator operates with delay of $3.5 \div 10 \mu\text{s}$. Second one, Marx voltage of 1.42 MV and current amplitude of 460 kA; total impedance of circuit is 2.4 Ohm. Plasma guns are the same as using in the first regime.

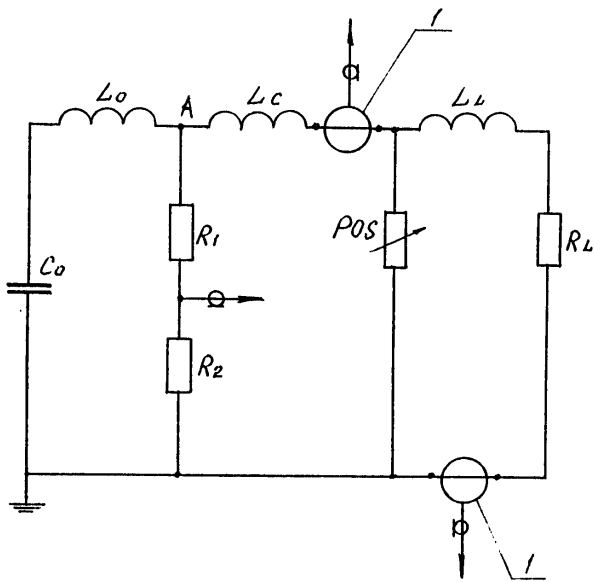


Figure 2. Discharge circuit: L_0 - Marx generator inductance, C_0 - Marx generator capacitance, L_c - cathode inductance, (R_1 - R_2) - voltage divider, L_1 - load inductance, R_1 - load resistance, 1 - Rogowski coil.

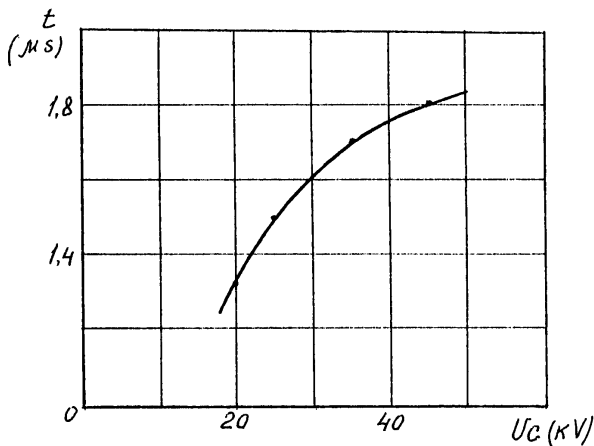


Figure 3. POS conduction time as function of plasma gun voltage.

The next problems were solved in the investigation:

- method search for conduction time increasing t_c ;
- maximum current rise rate obtaining;
- maximum voltage gain using POS obtaining.

Conduction time increasing allow to transmit the Marx generator energy into the load with increasing period of the generator discharge. Experimental results show the dependence t_c versus charged voltage of plasma guns generator. It could be shown that this allows to increase t_c up to $1.8\mu s$ (Figure 3). The dependence t_c versus delay t_d between the time of the guns generator operation and the time of Marx generator operation has been obtained. The unstable regime of work with the increasing of t_d has been observed. This unstable regime could be connected with the unstable processes in plasma (ion-acoustic instability development).

In regime 1 the maximum current rise rate in inductance load

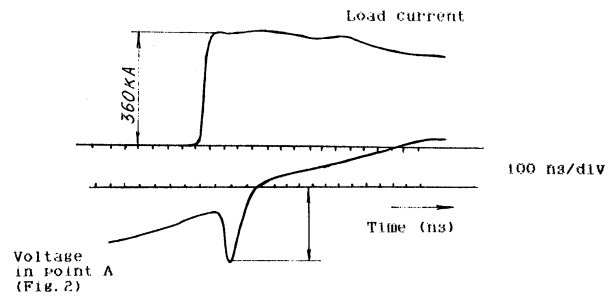


Figure 4. Load current and voltage waveforms measured at EMIR-M (Inductance Load).

of $\dot{I}_l \approx 10^{13}$ A/s was obtained for POS conduction time of $2\mu s$, guns generator voltage of 40 kV and $\tau_d = 3.5\mu s$. Current rise time in load (t_f) reaches 25 ns and current amplitude 270 kA (about 90% of maximum current amplitude). In the case of anode-cathode (A-C) distance of 30 mm the $\dot{I}_l \approx 7 \cdot 10^{12}$ A/s and $t_f = 25$ ns has been obtained. POS gap increasing up to 130 mm allows to obtain $t_f \approx 10$ ns for A-C distance of 30 mm and diode voltage of 3 MV.

In regime 2 the maximum current rise rate in inductance load of $\dot{I}_l \approx 2.8 \cdot 10^{13}$ A/s with $t_f \approx 13$ ns was obtained for POS gap of 50 mm and cathode diameter of 60 mm (Figure 4).

$\dot{I}_l \approx 1.8 \cdot 10^{13}$ A/s with $t_f \approx 13$ ns has been obtained in experiments with A-C distance of 30 mm. Cathode with diameter of 40 mm and 60 mm is used in the experiments. Greater voltage on POS $U_{POS} = 2.5$ MV has been obtained with cathode diameter $d_c = 40$ mm than with $d_c = 60$ mm (other parameters are identical). It is interesting to note that cathode was fused lengthwise of 70 cm on the distance of 55 cm from the plate of plasma guns location to the diode direction and 15 cm to the opposite direction. For the cathode diameter of 40 mm "fusing" was located on the distance of 65 cm from the guns plate to the load and during 25 cm in opposite direction. These differences could be explained by electrodynamic force action to the load. Average value of axial velocity reaches $30 \div 40$ cm/ μs . Radiational parameters are diagnosed by PIN-diodes and TLD detectors. Radiational dose achieved $8 \div 25$ kRads with the pulse width of $100 \div 150$ ns.

III. CONCLUSION

A considerable volume of research has been carried out that showed the principal possibility of EMIR-M operation using POS:

- voltage gain of 2.6 was reached;
- maximum conduction time $t_f = 2.3\mu s$ in regime 1 was obtained;
- current rise rate up to $3 \cdot 10^{13}$ A/s with front duration $10 \div 13$ ns was obtained.

With the goal of further improving of EMIR-M stable operation some experiments using POS are planned.

References

- [1] Diyankov, V.S., et al., "Device EMIR-M – generator of impulse electron beams, bremsstrahlung and electromagnetic fields," Proceedings of the 10th International Conference on High Power Particle Beams, San Diego, CA, 1994, p.371.