Pulse Generator with Inductive Storage and Explosive Wire Opening Switch

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Abstract - This report is devoted to the design study of the voltage generator with an inductive storage and a wire opening switch which provides 20 GW and 60 GW pulses in vacuum e-beam 50 Ohm and 12 Ohm diodes with FWHM ~300 ns.

1. Introduction

The present paper is a continuation of work [1] on creation of high-voltage generators for generation of high-frequency radiation pulses.

2. Generator electrical scheme

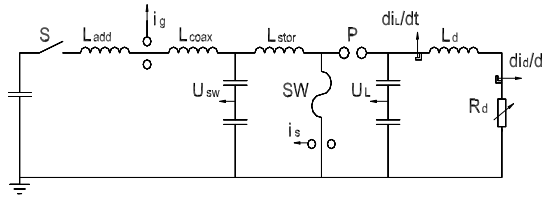

Fig. 1. Generator electrical scheme.

Electric circuit of the generator is shown in Fig. 1. The primary Marx energy storage discharges into series storage inductance and wire opening switch SW. When the switch SW opens the high voltage pulse appears on the sharpening switch P. After it breaks down the voltage applies to the diode R_d . The cutoff switch is connected in parallel to the load and allows to control the pulse length on the load.

3. Design of the generator

Fig. 2 shows the generator design. The primary energy store discharges through the coaxial transmission line with a conical insulator (1) at the end into series 10 μH inductance (2) and the wire opening switch (3). The inductance (2) is molten into the polyethylene block (4). The wire opening switch consists of 71 μm diameter copper wires that are wounded on square frameworks located inside the polyethylene block (4). When the current reaches the threshold value and the wires explode, the induced high voltage pulse is applied to the sharpening switch which is formed by the electrodes (5) and (6). The switch breakdown voltage is adjusted by the gap length between these electrodes. After it breaks down the voltage is applied through the high voltage insulator consisting of polyethylene (7) and metal rings to the diode with cathode (9) and anode (10) locating in the vacuum chamber (11). A set of current and voltage probes (12-15) is used to control the system performance. The generator discharge

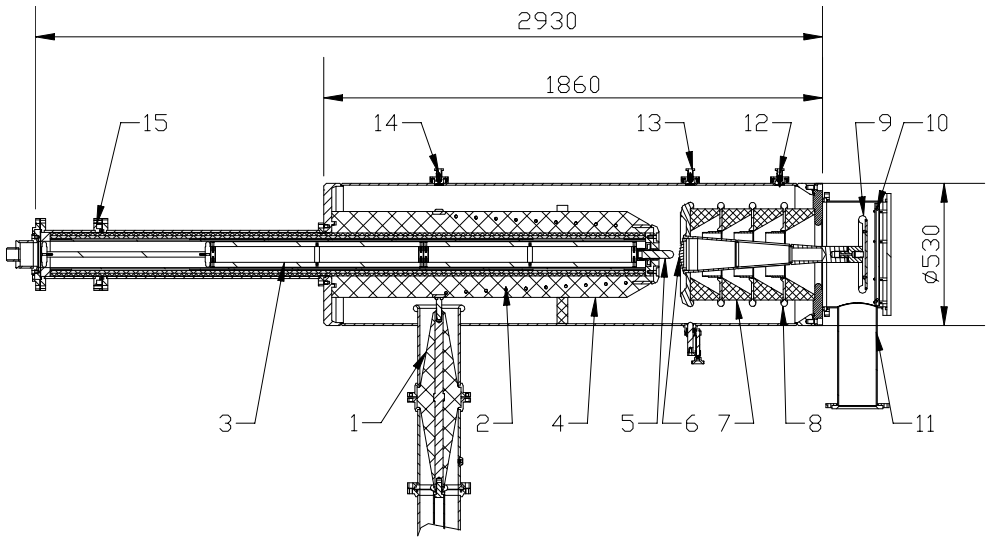

Fig. 2. Generator design.

current and the current in the wire opening switch are measured by Rogovsky coils, the diode voltage is measured by E-dot probe, the generator output current is measured by the B-dot probe.

4. Tests results

4.1. 50 Ohm diode

In these experiments the primary storage is a one-section Marx with 0.53 μF erected capacitance. At 50 kV charging voltage the Marx open circuit voltage is 300 kV and the stored energy is 24 kJ.

The vacuum diode is installed inside the chamber with 390 mm inner diameter and the length of 240 mm (Fig. 2). The cathode is made in the form of conical electrode with the 82 mm length and the 80 mm/60 mm diameter ratio. The emitting cathode surface is made of velvet. The anode is a 380 mm diameter metal disc with the 2 mm thickness. The anode-cathode gap in the diode is 60 mm.

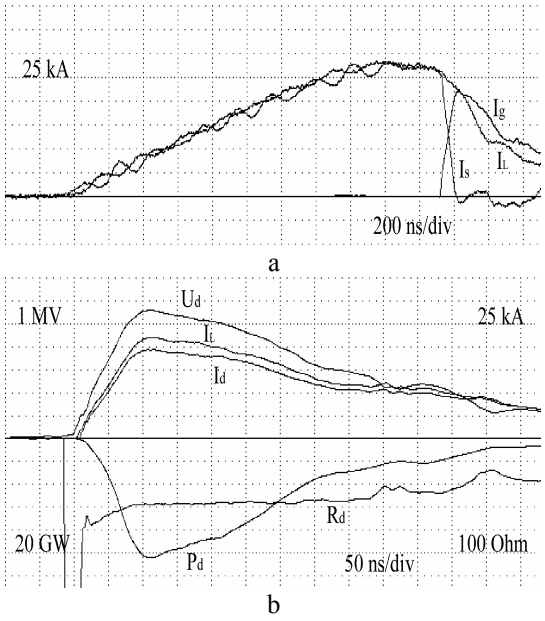

Fig. 3. Waveforms for the 50 Ohms diode.

The wire opening switch consists of 2 rectangular frames that are 792 mm long each. By increasing the number of wires N from 10 up to 20 the switch current is increased from 22 kA up to 33 kA, the conduction time is increased from 1.7 μs to 2.8 μs, and the load voltage is increased from ~0.9 MV up to ~1.2 MV. The generator discharge current, Ig, the switch current, Is, and the load current, Il, are shown in Fig. 3a. At N=14 the conduction time is ~2.1 μs and the switch current is 28 kA. The opening switch operates in the regime with current pause. The diode voltage, Ud, and the downstream current in gas, Il, and in vacuum, Id, volumes are presented in Fig. 3b. The currents Il and Id are rather similar indicating small current losses. The peak diode voltage is ~1.1 MV, the beam current is ~20 kA, the output pulse FWHM is ~370 ns. To get such pulse length the volume around the wires in the switch was filled with nitrogen at 2 atm pressure. The e-beam power is ~21 GW, the diode impedance ~56 Ohm.

4.2. 12 Ohm diode

In these tests two more sections were added to the Marx increasing it's capacitance from 0.53 μF to 1.6 μF. The generator was charged to 60 kV resulting in Marx open circuit voltage of 360 kV and stored energy of 104 kJ.

The diode cathode was a 290 mm diameter metal disk with 260 mm diameter emitting surface made of velvet. The anode-cathode gap was 44 mm.

To get the switch current of ~80 kA the number of wires was increased to 82 (wire mass is 6.5 g). However the switch doesn't operate in regime with current pause: after opening the switch current appears immediately. This limits the e-beam power at ~50 GW and the voltage pulse FWHM doesn't exceed ~200 ns. To

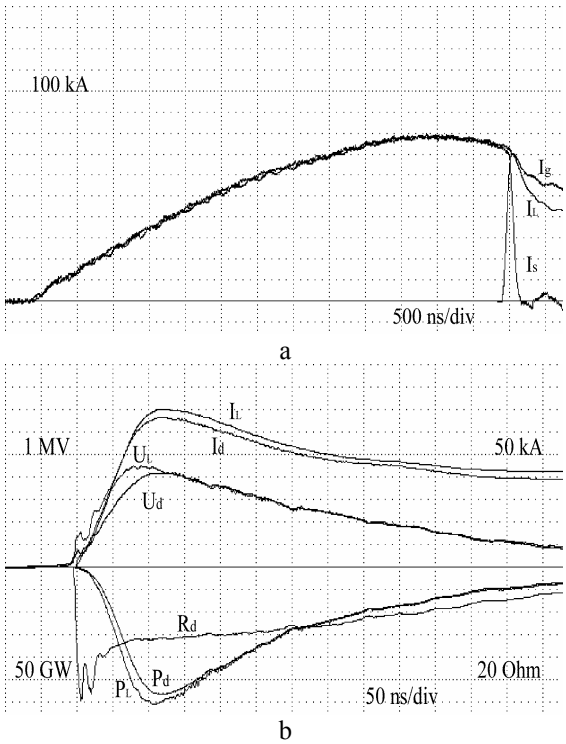

Fig. 4. Waveforms for the 12 Ohms diode.

avoid these restrictions the switch length was increased in two ways. The first, the length of the external bore with the switch inside was increased from 200 mm to 630 mm, the switch was made of 3 frameworks each being 738 mm long. The second, the switch was made of 5 frameworks each being 316 mm long. On the ends of the frameworks square polyethylene plates were installed with dimensions of 100×100 mm^2, 5 mm thick. These plates allowed to

increase the length of the wire winded up on framework up to ~1900 mm. Both designs provide the possibility to operate in regime with current pause at the 28 kJ energy loss in the switch (Fig. 4). The bore with the switch inside was filled with nitrogen at the 4 atm pressure. The conduction time is ~6.3 μs, the switch peak current is ~80 kA. The diode and the load currents are similar again, the diode voltage is 0.85 MV, the e-beam current is ~70 kA. The diode voltage FWHM is ~310 ns, the beam power reaches 60 GW, the diode impedance at peak power is ~12 Ohm.

5. Conclusion

The presented generator is characterized by high reproducibility of the pulse applied to the diode. The current and the voltage amplitude spread is less than ~5-10%. It was used for generation of gigawatt high-frequency radiation pulses in the vircator with ~50 Ohm diode impedance [2].

The work has been executed under the contract ITHPP/HCEI/00-11.

References

[1]. Efremov A. M., Kovalchuk B. M., Loginov S. V., Zherlitsin A. A., *in Proc. of 12th Intern. Symp.on High Current Electronics*, Tomsk, 2000, p. 363-365.

[2]. Korovin S. D., Kurkan I. K., Pegel I. V., Polevin S. D., *in Proc. of Intern. Power Modulator Conf*, Hollywood, 2002, p. 244-247.