Compact Pulsed Power Generator

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Abstract – The paper describes the design of a compact pulse generator with a load current of amplitude no less than 650 kA and a risetime no greater than 200 ns. The capacitor bank of the pulse generator features a 1 μF capacity and a 3.5 nH inductance and is capable of storing an energy of 5 kJ. The inductance of the transmission line is 1.5 nH. The internal resistance of the generator is 0.018 Ω. The basic element of the pulse generator is an assembly consisting of a low-inductance pulse capacitor and a high-current pulsed switch. The total inductance of the assembly is 35 nH, the capacitor capacity is 100 nF, the voltage is 100 kV, the energy stored by the capacitor is 500 J, and the current through the switch is 150 kA.

1. Introduction

Recently, an increasing interest has been shown in simulating the behavior of matter under extreme conditions (high specific energies, strong magnetic fields, high density and temperature). This is due to the growing demand for radiation materials research in different branches of science and technology and to the advances made in the field of controlled thermonuclear fusion. Extreme states of matter are normally investigated using stationary facilities such as ANGARA-5 [1], MIG [2], or GIT-12 [3] terawatt pulse generators in which the matter is magnetically imploded by current pulses of several megaamperes, giving rise to short-lived (10–20 ns) plasma bunches. Considerable progress in the design of fast multimegaampere generators gives grounds to expect threshold thermonuclear experiments on generators with a current of 30–40 MA. Attaining this goal requires new approaches to the design of pulse generators and new techniques for diagnostics of fast processes.

At the Institute of High Current Electronics (SB RAS), a compact pulse generator with a load current of amplitude not less than 650 kA and a risetime not greater than 200 ns was designed. Up to this point, only bulky stationary generators weighing as much as a few tons could provide the above parameters. It is expected that the generator design will make possible pulsed radiation sources with different load types: soft x-ray sources based on plasma shells and X-pinches, and hard x-ray and neutron sources based on “plasma focuses”.

2. Design of the pulse generator

The pulse generator consists of a high-voltage power supply, a high-voltage synchronization system, a capacitor bank in which each capacitor is equipped with its own high-current switch, and a transmission line. The generator operates as follows. The high-voltage power supply charges the pulse capacitors to a voltage of 100 kV and, on the synchronous operation of the pulsed switches started by the synchronization system, the current pulse is transmitted through the transmission line to the load.

The basic element of the pulse generator is a capacitor-switch assembly (CSA) consisting of a low-inductance pulse capacitor and a high-current pulsed switch. A photo of the capacitor-switch assembly is shown in Fig. 1. The prototype of the CSA is an assembly with lower parameters described in [4].

Fig. 1. Capacitor-switch assembly

The pulse capacitor was designed with special emphasis on minimizing the resistance and decreasing the current load on the contacts. The capacitor is a hollow cylinder with a high-current pulsed switch located in its inside. The switch is connected to the capacitor in series and is used to extract the energy from the capacitor. Minimizing the inductance and the resistance allows a required rate of energy extraction.

The parameters of the capacitor-switch assembly are the following:

Total inductance of the assembly	35 nH
Capacitor capacity	100 nF
Voltage	100 kV
Energy stored by the capacitor	500 J
Load current	150 kA

The pulse generator consists of 10 capacitor-switch assemblies connected in parallel. A photo of the pulse generator is shown in Fig. 2.

Fig. 2. Photo of the pulse generator

The assemblies are placed in a cylindrical tank of inner diameter ~ 110 cm filled with transformer oil and are connected to a common bus. The bus is a metal plate used as the transmission line. The parameters of the pulse generator are the following:

Capacity of the capacitor bank	1 μF
Charged voltage	100 kV
Energy stored by the capacitor bank	5 kJ
Inductance of the capacitor bank	3.5 nH
Inductance of the transmission line	1.5 nH
Total inductance of the generator	5 nH
Internal resistance of the generator	0.018 Ω
Pulsed power of the generator	70 GW

The operation of the generator with the assembled capacitor bank was adjusted through synchronous charging of the bank using the high-voltage power supply incorporated in the generator set.

In a high-voltage test of the generator, all capacitor-switch assemblies were charged to 62 kV and were triggered in synchrony. Oscillogram of the generator current taken in the test is shown in Fig. 3.

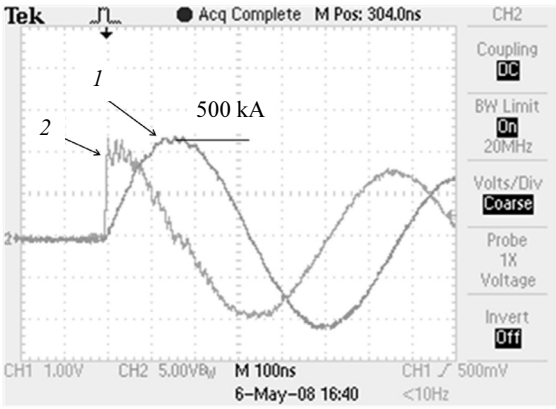

Fig. 3. Oscillogram of the generator current (*1*) and its derivative (*2*) in the high-voltage test

Considering the resistance losses, determined mainly by the losses in a switch, the generator produces a current of amplitude up to 1.2 MA at a risetime of 120 ns in the short-circuit mode and current pulses up to 650 kA at a risetime less than 200 ns during the operation into an equivalent load (12–17 nH).

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