# High Voltage Pulse Capacitors for High Current Pulse Generators

A.V. Saushkin, N.A. Ratakhin, V.F. Feduschak, N.V. Zharova

*Institute of High Current Electronics SB RAS, Tomsk, Russia*

**Abstract – At the Department of High Energy Densities (IHCE SB RAS) works are conducted on the development and manufacture of capacitors for high-current pulsed devices. The technological methods and engineering techniques necessary for manufacturing and testing the capacitors are now available and used. This paper presents preliminary results of tests of capacitors of two quite different types and considers their main characteristics.**

## 1. Introduction

At the Department of High Energy Densities (IHCE SD RAS) works on the development and manufacture of capacitors has been carried out since 2000. The necessity of conducting this work is determined by several factors. First, Tomsk is located far from the main designers of capacitors ("DDB Hydraulics", Nikolaev, "LPI", St-Petersburg), which are entirely absent beyond the Ural. Second, high-current pulsed generators, in which the key element is a capacitor with a switch specially designed for it, are simultaneously test benches for the devices. They should be supplied to capacitor plants, but the latter are at a breaking economical point in Russia. At these plants no one wants to get down to the design of these devices and to the development of their production, because you should have too much money. Finally, designers of high-current generators have a freedom in choosing whether they will develop a generator and lay down demands on capacitors or they will develop the generator based on the available devices.

## 2. Technology and Engineering Techniques

At the first stage, technological and engineering equipment has been developed for assembling, preparing preservative fluids, vacuum dehydration, and tests of capacitors.

The equipment for assembling makes it possible to manufacture flat and roll capacitor sections. The length of the flat capacitor sections may range to 2.5 m.

The preservative fluids (castor and capacitor oils) are subjected to additional cleaning to achieve the required electric strength and acid number.

Vacuum dehydration and oiling is realized in chambers with an ultimate vacuum of $10^{-3}$ Torr. The modes of dehydration and oiling (temperature, time, and degree of vacuum) are traditional [1, 2]. To improve the process of oiling, ultrasound with a gradually varying frequency of up to 20 kHz is added.

## 3. Capacitor HCEIcap 2μF-100kV

The idea of designing the capacitor HCEIcap 2μF-100kV resulted from long-term operation with capacitors IK50-3, IK40-5. Most of the inductance of these capacitors (75%) falls on bus bars and high-voltage outlet. Estimates have shown that should one minimize the inductance, the discharge current may reach more than 500 kA. A 20-nH modified version of the capacitor IK50-3 has been developed. The circuit with a total inductance of 40 nH consisted of a capacitor IK50-3 and a multigap switch [3]. At a charge voltage of 50 kV, the circuit current was 360 kA with a risetime of 525 ns. The resistance of the circuit was 25 mΩ and the resistance of the switch was several mΩ. Thus, the twofold increase in charge voltage and the simultaneous decrease in resistance to 10 mΩ allow realization of a capacitor with a ~ 1-MA current and with a risetime of less than 500 ns.

A prototype of the capacitor HCEIcap 2μF-100kV [4] was developed for a transformer-type multimegajoule generator within the framework of the program "Studies of the characteristics of matter at pressures of 10÷100 Mbar produced by nanosecond megaampere generators". This explains the unusual dimensions of the capacitor (2500 × 150 × 300 mm). At 100 kV, the stored energy is 10 kJ. The general view of the capacitor is shown in Fig. 1.

Fig. 1. Illustration of metal-cased energy discharge HCEIcap 2μf-100kVcapacitors

In the sections, combined paper-foil insulation with castor oiling and operating electric field strength of 100 kV/mm was employed. The flat-pressed sections were 2.5 m long. The self-inductance of the capacitor was 20 nH with a test output insulator. There was a possibility of decreasing the inductance at least two times.

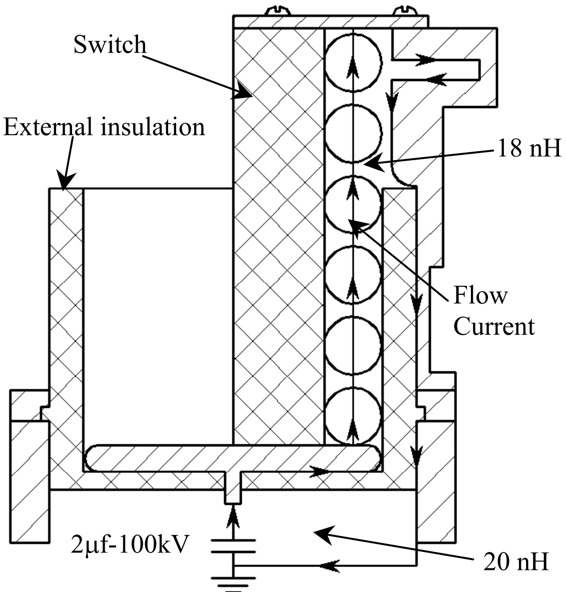


Fig. 2. Scheme of the discharge circuit with the multigap switch

The capacitor was tested with a circuit of self-inductance of 38 nH, the same multigap switch (Fig. 2) and without absorbing load (the mode of short-circuiting) at a voltage of 50 kV. In this mode, about 100 pulses were produced. A waveform for this mode is shown in Fig. 3. The circuit current was 330 kA with a risetime of 450 ns.

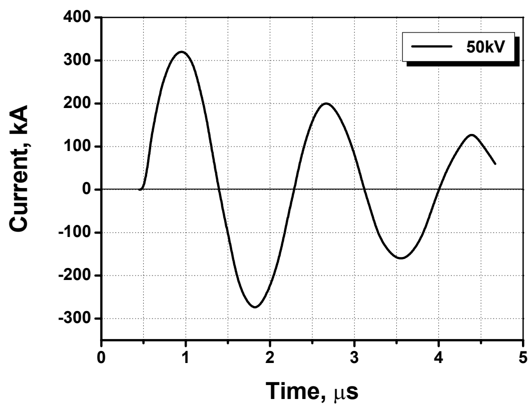


Fig. 3. Waveform of the short-circuit current of the capacitor HCEIcap 2-100.

It can be seen that the circuit resistance is decreased somewhat and is 20 mΩ that is likely due to the capacitor design (a larger number of parallel sections). The current load per unit capacitance is 160 kA/μF that is higher than in the case with IK50-3 (130 кA/μF), but no special measure have been used to decrease the resistance of the capacitor (to increase the foil thickness to the skin-layer thickness). We have managed to perform static tests with a voltage of up to 60 kV because of the insufficient strength of the output insulator. At present, manufacturing of a bench for tests with an active load at a voltage of 100 kV and at a circuit inductance of 25 nH.

In the future we plane to design a low-inductance switch for this capacitor (100 kV) to perform a full-scale experiment. It is also planned to introduce some changes in the capacitor design to decrease the resistance and inductance of the capacitor itself.

## 4. Capacitor PC 200-1.5

One of the tasks of the contract between ITHPP/HCEI/03-C06 and Sandia National Labs was to develop a pulse transformer for the LTDR stages of a pulsed voltage generator [5]. This generator was made in the form of a line pulse transformer, which consisted of seven series-connected LTDR stages. The objective was to obtain voltage pulses of amplitude 1MV and duration no greater than 60 ns at 80% of the maximum amplitude.

In tests of the LTDR stage, a voltage maximum of 125 kV and duration of 75 ns at 80% from $U_{max}$ has been obtained at the load (Fig. 4).

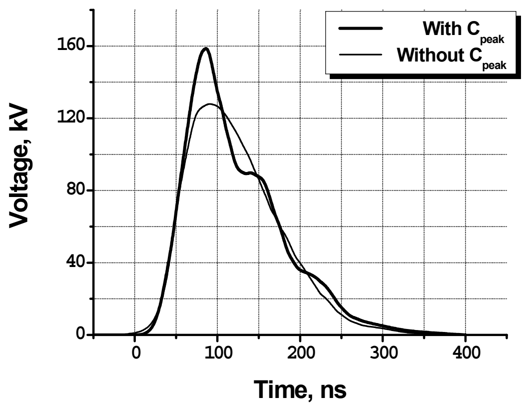


Fig. 4. Voltage across the load of the LTDR stage with and without peaking capacitors

This result for seven stages $U_{load} = 875$ kV and $\Delta T_{80\%} = 75$ ns. Therefore, to obtain the required characteristics of the generator the task was set to attain the required parameters without modifying the generator design and also without replacing the capacitors of the main discharge circuit. This problem was solved by using peaking (forming) capacitors connected in parallel by the pulse capacitor of the main discharge circuit. This capacitor should not use water, have a capacitance of 1.5 nF and hold off a charge voltage of ±100 kV within a risetime of 50 ns. It should also have dimensions for arrangement in the stage without changing the seats for their location. Such a capacitor has been designed and manufactured at our lab. It was made with two different cases for operation in oil and air. The view of the capacitors is shown in Fig. 5. The capacitor at the left is with a caprolon case and that at the right with a polyethylene one. The dimensions of the capacitor are Ø96×125 mm and Ø74×125 mm for caprolon and polyethylene, respectively.

Fig. 5. External view of the peaking capacitors

The capacitor has been bench tested. In these tests, the mode of the operation of the stage was reproduced in full measure. The tests were performed at a pulse repetition rate of 5 pulses/min. By the customer request, the capacitor lifetime should be more than $10^3$ pulses. In the capacitor combined paper-film insulation with an operating strength of 150 kV/mm is employed. The results of tests are presented in Fig. 4. It can be seen that the use of peaking capacitors in the LTDR stage has made it possible to obtain a voltage of 160 kV and duration 40 ns at 80% from $U_{max}$ that is $U_{load}$ = 1.12 MV and 40-ns duration at 80% from $U_{max}$ for the whole generator.

Preliminary tests for the lifetime have been conducted. In the aperiodic operating mode (Fig.4) with a pulse repetition rate of 5 pulses/min the lifetime was higher than 2 000 pulses.

**Conclusion**

Capacitors are the key elements of any high-current pulsed device. Together with a switch, the capacitor dictates the efficiency of the whole device. The state of high-current electronics is such that there is a need for small lots of capacitors of different high-current devices. Thus, our team demonstrates the possibility of meeting the current requirements and working for the future high-current electronics.

**References**

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