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ELECTRIC STRENGTH OF ARRESTER FOR LIGHTING SHIELDING OF 6-35 KV TRANSMMCSION LINE WITH LIGHTNING OVERVOLTAGE

Rodion A. BELSKII[1], **Vladimir Ya. FROLOV**[1], **Georgii V. PODPORKIN**[2]
[1] *St. Petersburg Polytechnic University of Peter the Great, Saint-Petersburg, Russia*
[2] *JSC «NPO Streamer», Saint-Petersburg, Russia*

The most common device for protection against overvoltages is a valve-type arrester. Due to obsolescence it is proposed to replace valve-type arresters with nonlinear overvoltage limiters or multi-chamber arresters. Modern recommendations for the selection of means for protection against overvoltage take into account not all factors when placing protection devices. For example, when replacing valve arrester with non-linear overvoltage arresters (arrester), accidents often occur. Often, due to the replacement of protective devices, there are violations of the operating conditions of new devices, since in the design of the arresters, they are placed in place of the vale-type arresters. Nonlinear surge arresters have a number of reliability problems, for example, due to frequent single-phase ground faults, thermal instability problems occur. Therefore, as an alternative to arresters in urban distribution networks, it is proposed to use multi-chamber arresters – devices that are a series of discharge chambers in silicone rubber. The purpose of this work is to calculate the electric field strength and conductivity at the exit from the discharge chamber of the multichambe arrestor, study the effect of multichamber dischargers on distribution networks, build up the dependence on the voltage and conductivity of the plasma exhaust gases, depending on the distance to the multichambe arrester.

***Key words*:** multicameric arrester; overvoltage protection; electrical breakdown; expansion of plasma; city distribution networksи

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Introduction. Reliability of high-voltage equipment is one of the factors of normal work of city distribution networks 6-35 kV receivers. Due to the density of the building and the large number of companies involved in network design, the power grids that are nearby can have individual projects – with different materials in the conductors of cables, different cross-section, with their insulation, as well as with protective apparatuses that differ not only nominal characteristics, but also the type of arc suppression performance [5, 8].

Currently, surge arresters are used to protect against overvoltages in urban distribution networks, which must be abandoned for the following reasons [4]:

• The industry suspends the discharge of dischargers according to GOST 16357-83;

• a large metal consumption leads to a rise in the cost of protective devices, as well as an increase in the mass and dimensions of the protective device;

• Low life expectancy in comparison with modern means within 25 years, while for nonlinear overvoltage limiters (OVL) the service life is 30 years;

• Valve-type arresters do not always provide the necessary technical and economic indicators;

• the current-voltage characteristic for valve-type arresters is increased by 10-15 % for 20 years of operation.

Valve-type arresters are still used in many distribution networks, so their ubiquitous replacement with non-linear overvoltage limiters can cause serious design and construction costs. It is necessary to revise the regulatory documentation relating to devices for protection against overvoltage. To replace valve-type arresters, the use of OVL is assumed, but in the operation of OVL in urban distribution networks there are a number of problems.

Problem formulation. As an alternative to arresters in urban distribution networks, the use of multi-chamber arresters (MCA) is proposed [3, 10, 13]. These devices are multi-chamber arresters with rod or tubular electrodes placed in silicone rubber. The principle of their work: when the surge wave passes, each of the chambers breaks, the arc heats the cell, hot air moves the arc out of the cell, the arc increases the length and eventually breaks. The multi-camera system and its device are shown in Fig.1.

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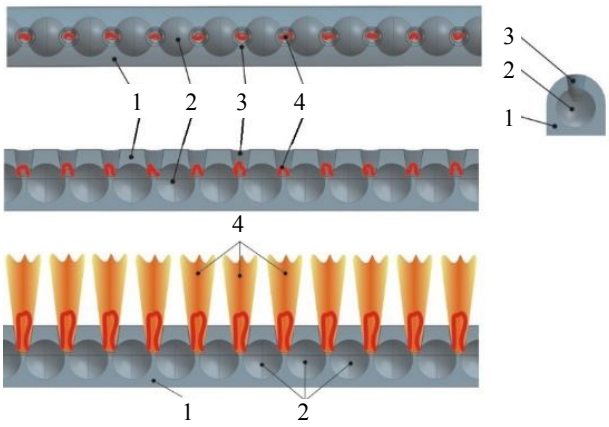


Fig.1. Multi-camera system
1 – silicone rubber; 2 – electrode; 3 – air gap;
4 – discharge channel



Fig.2. Experimental setup

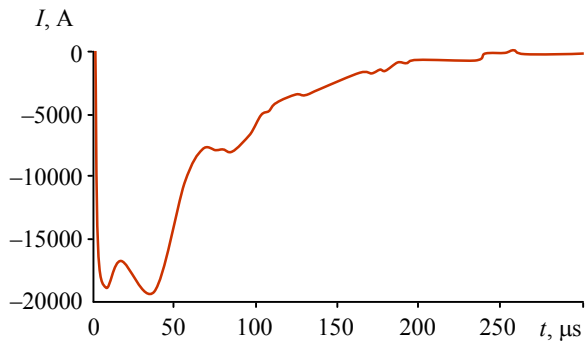


Fig.3. Current pulse 20 kA

• No need for air Multicamera arresters have several advantages:

pressure relief devices; high pressure can form due to the arc of the closure when the current passes during overvoltage; Most of all, the pressure increase is manifested with single-phase earth faults;

• Explosion-proof; one of the problems of OVL operation is the flying fragments during explosion during overvoltage [14];

• high cost for installation and operation;

• varistors are subject to oxidation processes, which causes the device to degrade;

• External contamination does not affect the performance of the protective device.

Multicameric surge arresters have proved effective in protecting against lightning overvoltages in high voltage distribution networks in Indonesia and China [11, 15].

One of the problems in the operation of multi-discharge devices is the open flame that arises when the arc is extinguished, which can create problems in their use inside the premises, as well as the inability to operate in explosive environments. Another problem is the accompanying current – it is the current from the network that passes through the spark gap during the passage of the overvoltage pulse.

Methodology. The purpose of the experiments was to measure the intensity of the electric field and the conductivity of the exhaust plasma at the outlet of the discharge chamber of the multi-chamber system (MCS), and also in plotting the tension and conductivity of the plasma exhaust from the distance to the multi-chamber system. For the experiment, a sample was used, which was a section of the multicameral system to which the electrodes responsible for the electrical phase and ground were connected. The values of the strength and conductivity were measured with a sensor, which is a capacitor connected to the electrodes and placed in front of the exhaust chamber of one of the MCS cells. A current pulse of 20 kA, simulating the shock of lightning overvoltage, was created with the help of a pulse voltage generator (PVG). The MCS together with the sensor are shown in Fig 2. The oscillogram of the lightning pulse is shown in Fig.3.

The experiment was carried out according to the following algorithm:

1) the discharge gap between the electrodes is established, the limit of the gap is from 1 to 60 mm;

2) the capacitor is charged, the capacitor must be charged from 250 to 500 V for the purposes of experiments;

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3) the capacitor with a discharge gap connected to it is set to a specified distance; the discharge gap should be perpendicular to the MCS cell; it is necessary to arrange the electrodes in front of the MCS cell so that the arc from the MCS cell passes between the electrodes of the discharge gap;

4) the PVG is started;

5) the residual voltage on the capacitor is measured;

6) a new discharge gap or a new distance to the MCS is established.

The work of the PVG during the passage of the pulse is shown in Fig.4.

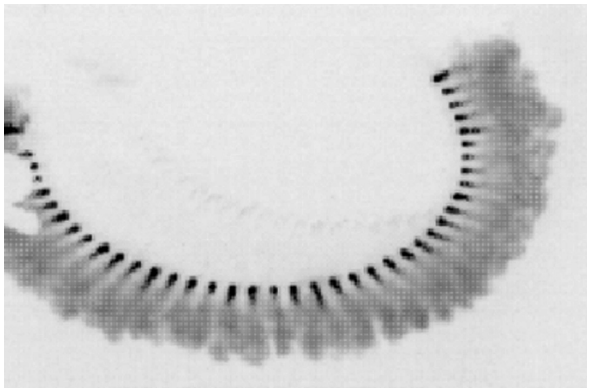


Fig.4. Plasma flow on the outer side of the MCS

The results of measurements of electrical strength and electrical conductivity as a function of the distance to the MCS are shown in Fig. 5, 6.

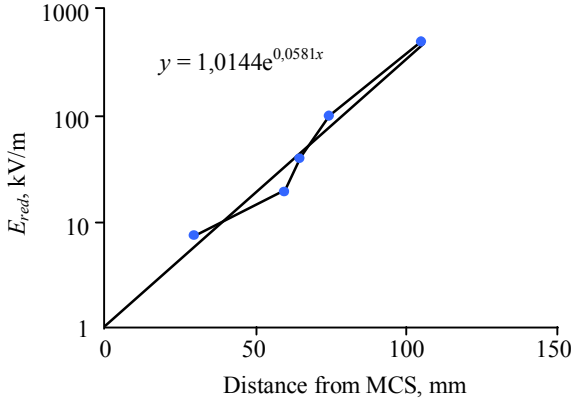


Fig.5. The dependence of the electrical strength of the plasma on the distance to the MSS at a pulsed current of 20 kA

All measurements were made according to the following formulas [1].

Breakdown voltage stress

$$E_{red} = \frac{U_{red}}{d},$$

where U_{red} is the initial voltage, V; d is the distance between the electrodes, m.

Electric residue

$$Q = \Delta UC,$$

where ΔU is the difference between the initial and final voltage, V; C is the capacitance of the condenser, F.

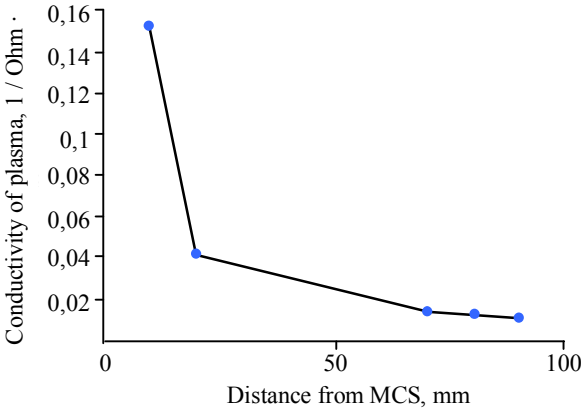


Fig.6. The dependence of the electrical conductivity of the plasma to the distance to the MCS; current 3 kA, current duration 50 μs

Current in the air gap

$$I = \frac{0.7Q}{t_{0.5}},$$

where Q is the electric charge, C; $t_{0.5}$ – time of current flow to half-decay, s.

Electrical resistance of the gap

$$R_x = \frac{U}{I},$$

where U is the charge voltage value, V; I is the electric current in the gap, A.

Airgap conductivity

$$\rho_{sp} = \frac{R_x S}{d},$$

where R_x is the air gap resistance, Ohm; S is the area of the electrode, m^2; d is the distance between the electrodes, m.

Conductivity

$$\sigma_{sp} = \frac{1}{\rho_{sp}}.$$

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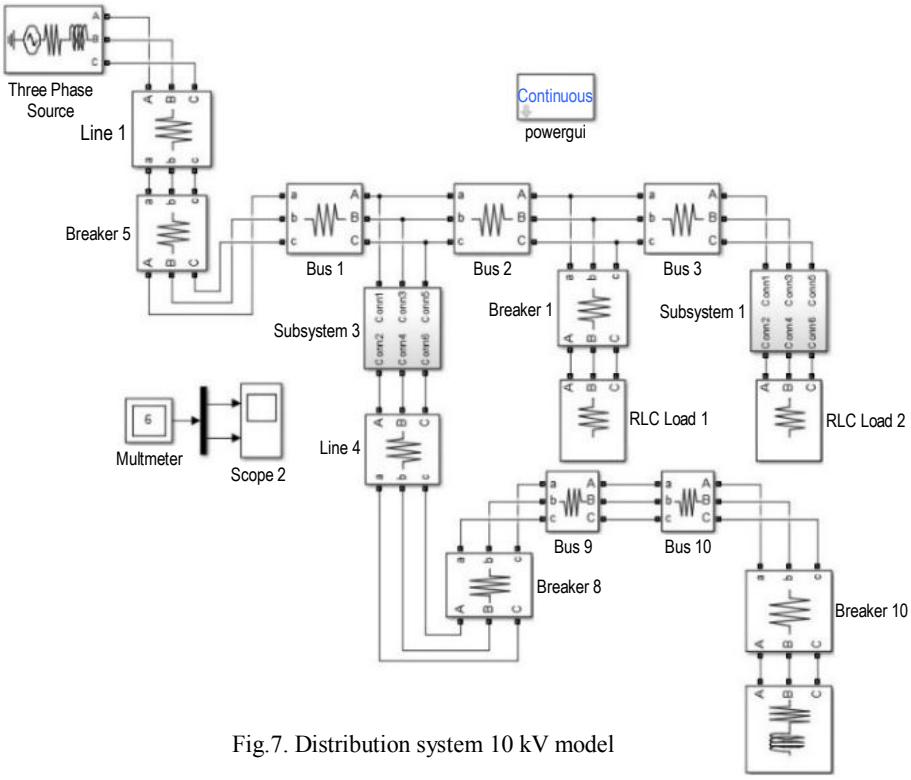


Fig.7. Distribution system 10 kV model

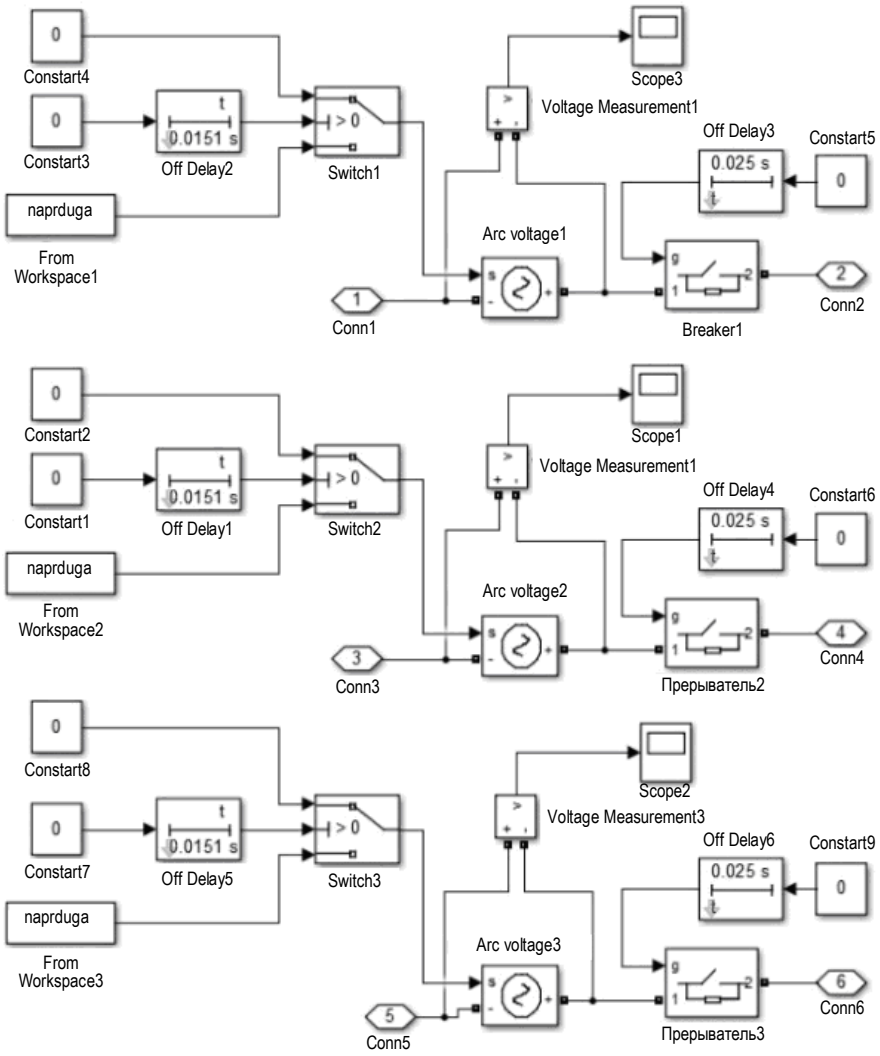


Fig.8. Three-phase vacuum circuit breaker model

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Results. Based on the results of the experiment, the following was obtained:

• developed and experimentally tested the procedure for measuring the electrical strength and electrical conductivity of the plasma at the output of the exhaust chamber of the MCS;

• The range of variation in the electrical strength of the exhaust plasma near the MCS is determined from 1 to 500 kV/m, which is many times less than the electric strength of air;

• The range of the electrical conductivity of the exhaust plasma near the MCS is determined from 0.0001 to 0.3 1/Ohm·m, which is many times greater than the electrical conductivity of the air;

• The values of E_{red} depend strongly on the amplitude of the pulsed current.

The obtained experimental data will be useful for the analysis of physical processes taking place in the MCS, in estimating the dimensions of the exhaust zone, as well as in the design of individual elements of the arrester. The absence of an arc closure in the outer plasma will allow us to design in the future more compact multi-ampere arresters.

The next stage of the work will be checking the influence of the MCS on the city distribution network in the event of a switching overvoltage. For this, it is necessary to create its mathematical model. As a modeling environment, the simulation environment of SIMULINK simulation is used (Fig.7). A 10 kV distribution network from a distribution point to a high-voltage side of a transformer substation was modeled. The modeling was carried out taking into account the positions of [2, 6, 7, 9, 12]. For the sake of simplicity of calculation, only active resistances of cables, buses at the substation, contacts of switches and intercontact connections were taken into account. As a source of overvoltage, a vacuum switch was selected for 10 kV, the model of which is shown in Fig.8. Overvoltage on the switch was based on the Cassie model, Fig.9 shows the implementation of the model in the SIMULINK environment. The results of switching the vacuum circuit breaker are shown in Fig.10.

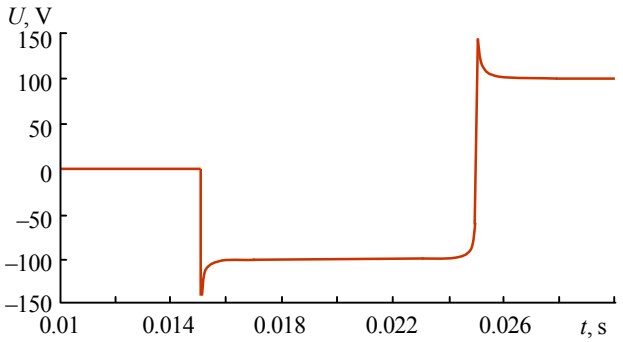


Fig.9. Circuit breaker arc voltage according to Cassie model

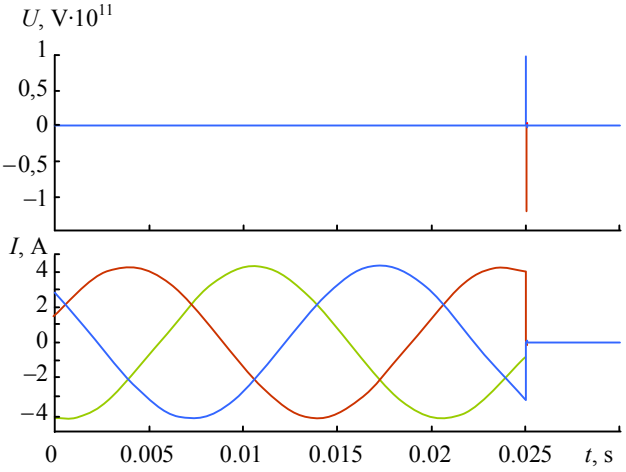


Fig.10. Oscillogram of voltage and current on the consumer when switching the circuit breaker

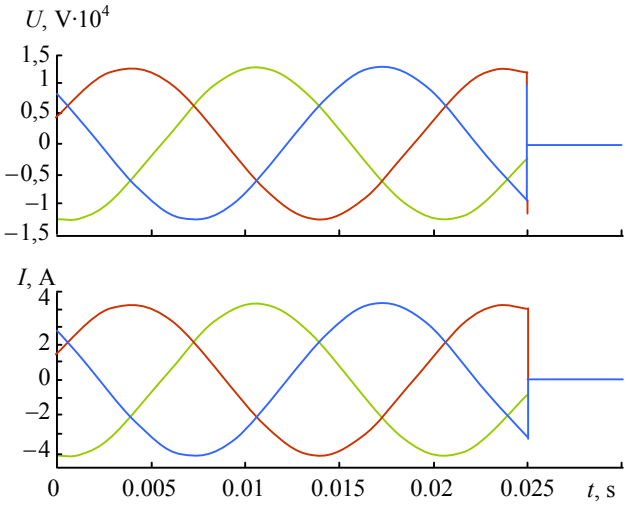


Fig.11. Oscillogram of voltage and current on the consumer when using a multi-chamber arrester

When operating the network with the MCS, you can see a significant decrease in the surge voltage. MCS was installed in the entrance to the transformer substation, the oscillogram of this process is shown in Fig.11.

The resulting calculations for the MCS will be used in the presented model of the distribution network, and recommendations for the placement of multi-chamber spreaders will also be developed.

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Authors: **Rodion A. Belskii**, *Assistant Lecturer*, *zero19@mail.ru* (*St. Petersburg Polytechnic University of Peter the Great*, *Saint-Petersburg*, *Russia*), **Vladimir Ya. Frolov,** *Doctor of Engineering Sciences*, *Professor*, *frolov.eed@gmail.com* (*St. Petersburg Polytechnic University of Peter the Great*, *Saint-Petersburg*, *Russia*), **Georgiy V.Podporkin,** *Doctor of Engineering Sciences*, *Senior Researcher* (*JSC «NPO Streamer»*, *Saint-Petersburg*, *Russia*).

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