DESIGN AND APPLICATION OF EXPULSION FUSES IN 123 kV NETWORKS

S. Grudziecki, A. Wiśniewski, B. Kacprzak

INTRODUCTION In gas-expulsion-type apparatus used for protection against overvoltages and short-circuit currents, a special insulating material produces gases under the influence of an electrical arc, which cause its extinction. Apparatus based on this principle have been used in different countries for a long time, but they have not been developed to such extent as other types of apparatus.

In Poland this problem has been investigated for more than 20 years. On the basis of long-term field and laboratory research, the usefulness of their application as apparatus of universal use, with moderate technical parameters has been confirmed. Their investment and exploitation costs are low and they are fire proof.

GENERAL CONSTRUCTION PRINCIPLES OF EXPULSION-TYPE APPARATUS

In expulsion-type apparatus we have to deal with a long electrical arc. Its extinction is achieved by volume cooling with gases produced by the arc. In the solutions studied a stream of gases accumulated in special containers during the arc burning period, as well as the expansion effect of gases produced from gas evolving material at the instance of the current passing through zero were used. There, the rate of decrease of pressure plays an important part.

The condition of arc extinction is

$$a\left(\frac{dp}{dt}\right)_{i=o} + bp_{i=o} > c\left(\frac{du}{dt}\right)_{i=o}$$

S. Grudziecki, A. Wiśniewski, B. Kacprzak are with the Institute of High Voltages and Electrical Apparatus, Gdańsk Polytechnic.

where p - gas pressure in the extinction chamber, u - recovery voltage, a,b,c - constants.

Depending upon the type of apparatus, the share of the components on the left side is different. An important factor is the life of the apparatus which results in exploitation costs. Extinction devices of small inside dimensions soon lose their extinction properties. For this reason greater values of these dimensions have been used, i.e. relatively large section surfaces of the chambers.

The variation in the pressure depends on the construction parameters of the extinguishing system. This pressure is inversely proportional to the section surface of the extinction chamber. Its increase has an adverse influence on the extinguishing capacity. It was thus necessary to increase the length of the arc, which results in an increase of the power and consequently in an increase of the pressure and a decrease of the recovery-voltage gradient. Owing to the increase of the arc length the voltage drop on it increases which results in some limitation of the current.

The effect of a narrow gap has been utilised to extinguish small currents. In this case surface cooling plays an important part. Construction parameters corresponding to the above relation were chosen experimentally. The same pertains to the volume and surface insulation.

<u>INSULATING GAS-EVOLVING MATERIAL</u> The insulating gas-evolving material is essentially important in all gas-expulsion apparatus. First, fibre was employed, afterwards boric acid and then different compounds together with binding substances. Pure plastics have also been used.

The nature of the gases produced by an arc has a strong influence on its extinction. The extinguishing capacity depends on such factors as the thermal conductivity at high temperatures, diffusion and recombination coefficients, ability to bind electrons. Most gases have similar extinguishing capacities. Hydrogen is specially good owing to a high thermal conductivity at arc temperatures and large diffusion coefficient. An essential problem is the state of the surface of the gas-

evolving material after the arc extinction. The conducting deposits may lead to arc reignitions.
A new gas-evolving material has been applied. It comprises an inorganic component $Al_2O_3 \cdot 3\ H_2O$ and an organic one as a binding agent. Under the action of an arc a quick water vapour evolution occurs. The organic component is also decomposed, giving hydrogen and carbon. As the average temperature of the gases exceeds 1300 K, a reaction takes place :

$$C + 2\ H_2O \rightarrow CO + H_2 - 31{,}4\ \text{Cal}$$

Then the formation of the C deposit becomes difficult. The reaction is endothermic, which assists in the extinction of an arc. Indeed, this reaction also takes place near the passage of the current through zero, and some part of the thermal energy accumulated in the arc column may be absorbed. The hydrogen produced in this reaction, together with that from the decomposition of the organic component, plays an important part in the extinction process. The organic component besides the binding and the production of gases, plays an additional role. It renders impossible the creation of a high temperature resistant layer of Al_2O_3 .

The investigations have shown that superficial insulating properties of this material do not change under the influence of the electric arc. The ability to expand gases is less than in the case of other materials. This is why apparatus using such a material have suitable gas containers in order to give an adequate gas stream during the zero-value of the current. Research has shown that the consumption of this material is lower than that of others.

THE 123 kV FUSE SHORT-CIRCUITING SWITCH On the basis of the above principles of the arc extinction and gas evolving material, different types of apparatus for the protection against atmospheric overvoltages and against short-circuit current, as well as apparatus for switching purposes have been built. One of them will be described as follows.

Design 123 kV lines are now distribution lines. For economic reasons simplified stations with short-circuiting switches are being used more and more instead of circuit-breakers /Fig.1/. In these stations relatively small short-circuit currents occur. A disadvantage of the short-circuiting switches is the overloading of the circuit-breakers in principal stations. This and some other exploitation disadvantages lead to limiting the number of the simplified stations. In order to eliminate these disadvantages and to apply the simplified stations more extensively, a new type of apparatus has been studied, this comprising a short-circuiting switch and expulsion fuses. It is presented schematically in Fig.2. In Fig.3 a cross-section of the expulsion-type fuse is shown. A fuse-link of silver foil is placed on a gas-evolving rod of such diameter, that there is no corona. The arc is produced in a gap between the rod and the gas-evolving tube. A gas-container facilitates the arc extinction. The gas-evolving tube is strengthened mechanically with epoxy-glass tube.

Application The scheme of a simplified station is shown in Fig.4. The 123 kV fuse-short-circuiting switch is realised in a three-phase scheme. Each phase comprises two series-connected fuse elements and one short-circuiting switch. The short-circuiting switches of each phase are combined together and driven by a common spring mechanism. The cooperation of the fuses with the short-circuiting switches consists in the fact that the short-circuiting switches released by the overcurrent protection always cause three-phase ground short-circuits, eliminated afterwards by the fuses. Reversed functioning is also possible. The melting of a fuse may occur in one phase following a fault in the network. One fuse element of each phase is mounted rotationally and rotates after melting under the influence of gravitational force, releasing the short-circuiting switch mechanism in the last phase of the motion, which causes three-phase short-circuit. This short-circuit is afterwards eliminated by other fuses.

The switching off and on of the station is realised with an isolating switch with a switch closer. The switch closer has an automatic block system which makes the switching on and off of the load-current impossible. The fuse-short-circuiting switch, as opposed to the existing simplified solutions, switches off the faulty station at once, without the action of the automatic reclosing in principal stations. Then a fault in one station is not felt by other stations connected to the same transmision line. The ground short-circuit current during the functioning of the fuse-short-circuiting switch is very small, resulting from the asymetry and can be neglected. This is important because of ground voltage drops /security reasons/. Besides, the short-circuit duration is small, resulting from the functioning of fuses. It is also possible to apply 123 kV fuses in important stations, as a reserve protection.

Tests These fuse elements are constructed in such a manner that they do not melt under overload currents. They act only under short-circuit currents. For example in Fig.5 the pre-arcing time/current characteristic of the fuses for 63 A rated current is shown. Proper coordination between the time/current characteristics of the 123 kV fuses and those of the 123 kV and 17,5 kV overcurrent protection devices is ensured.

The short-circuit current breaking tests were made in the - laboratory /oscillograph records in Fig.7/ and in 123 kV net-works with the grounded neutral /osc.rec.in Fig.8/. In Fig.6 the arcing times are shown. They are always lower than one cycle. There are no dangerous overvoltages.

CONCLUSION The above described fuse-short-circuiting switch is a useful apparatus for the protection of the simplified stations in the distribution 123 kV networks from both technical and economic reasons.

REFERENCES 1. Grudziecki S.: Nowy materiał izolacyjno-gazujący, Piorun i Ochrona odgromowa, Acta Technica Gedanensia nr 2, GTN, 1963.

2. Grudziecki S.: Zespół odłącznika i bezpieczników wysokiego napięcia typu napowietrznego, Opis pat.PRL nr 45690, 1961.

3. Grudziecki S., Wiśniewski A., Kacprzak B.: Bezpiecznikozwiernik wysokiego napięcia, Opis pat. PRL nr 62422, 1968.

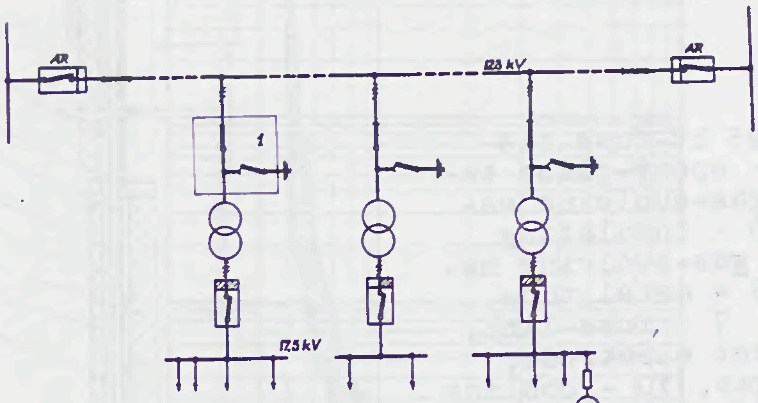

Fig.1. Scheme of the 123/17,5 kV network with simplified stations. 1 - short-circuiting switch with coupled isolating switch. AR - automatic reclosing.

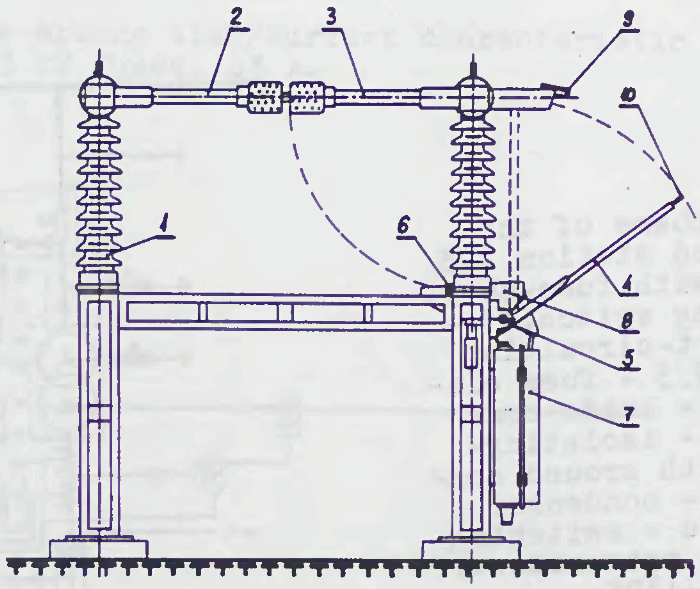

Fig.2. 123 fuse short circuiting switch. 1 - stand-insulator, 2 - immovable fuse element, 3 - rotationally mounted fuse element, 4 - short-circuiting switch knife-contact, 5 - drive-shaft, 6 - lock release device, 7,8 - casings, 9 - immovable contact, 10 - arcing contact.

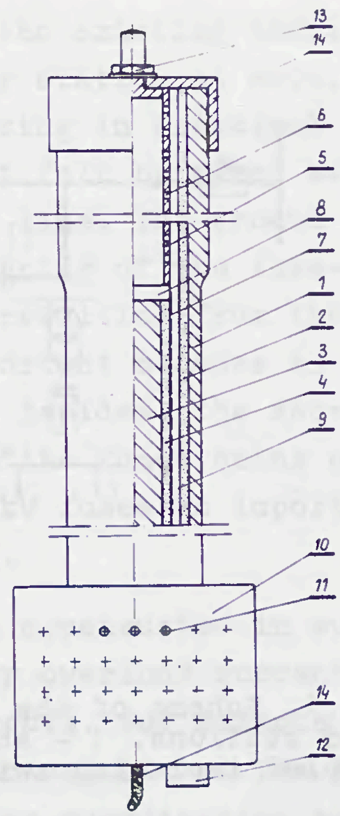

Fig.3. 123 kV-fuse element. 1 - epoxy-glass tube, 2 - gas-evolving material, 3 - insulating rod, 4 - gas-evolving material, 5 - metal tube, 6 - hole, 7 - fuse-link, 8 - contact electrode, 9 - air-gap, 10 - cooling device, 11 - hole, 12 - contact, 13 - nut, 14 - flexible cable.

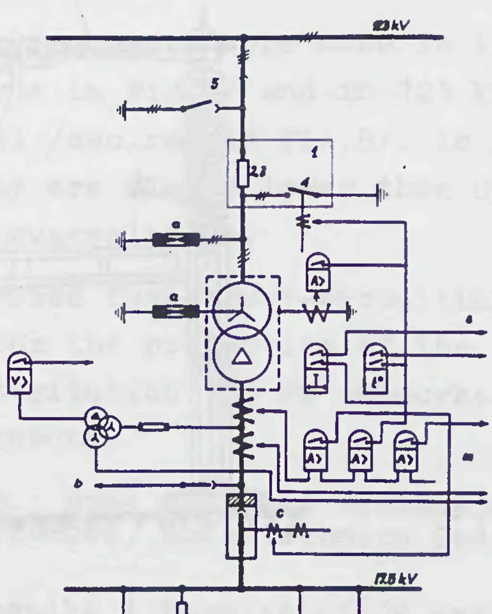

Fig.4. Scheme of the simplified station 123/17,5 kV with fuse-short-circuiting switch. 1 - fuse short-circuiting switch, 2,3 - fuse elements, 4 - knife-contacts, 5 - isolating-switch with ground contacts, b - condenser battery, c - switching coil, m - measurement, s - sygnalling.

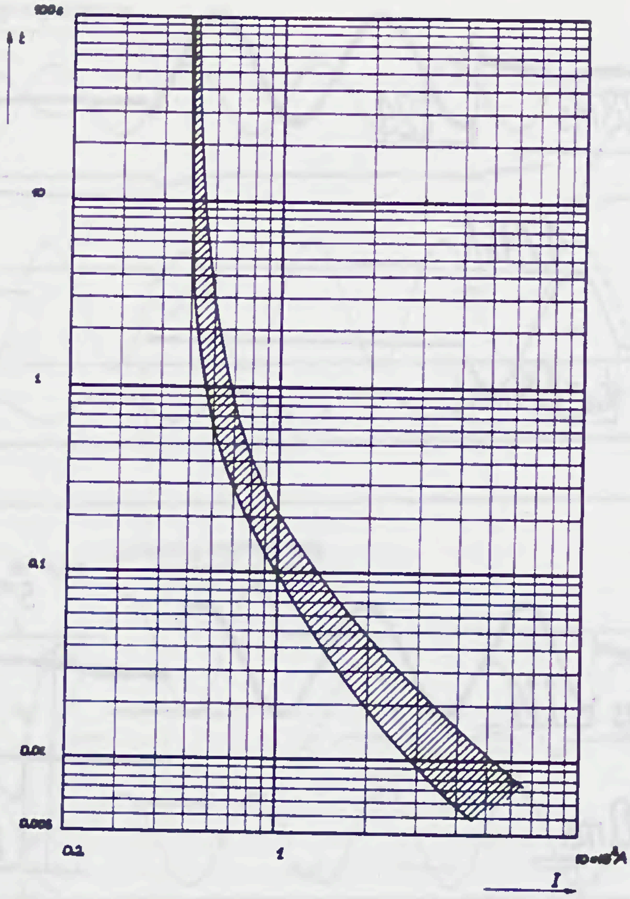

Fig.5. Pre-arcing time/current characteristic of the 123 kV fuses, 63 A.

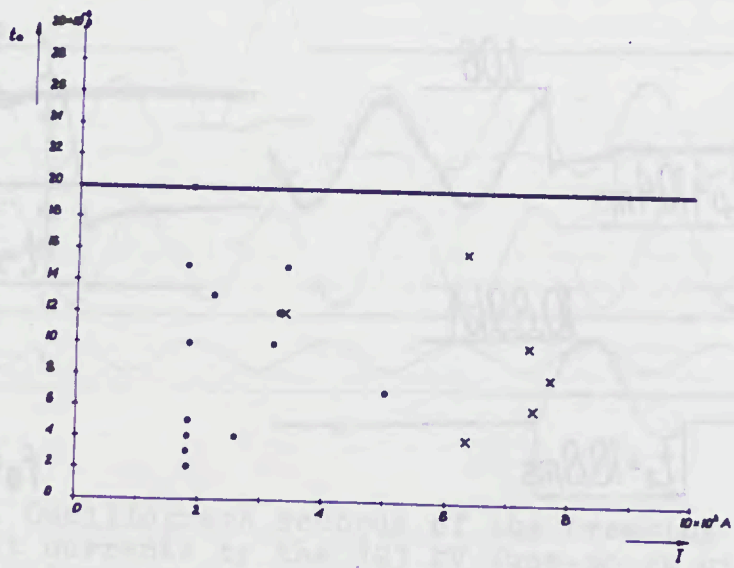

Fig.6. Arcing time versus current of the 123 kV fuses. Different rated currents ; x - laboratory tests ; • - field tests.

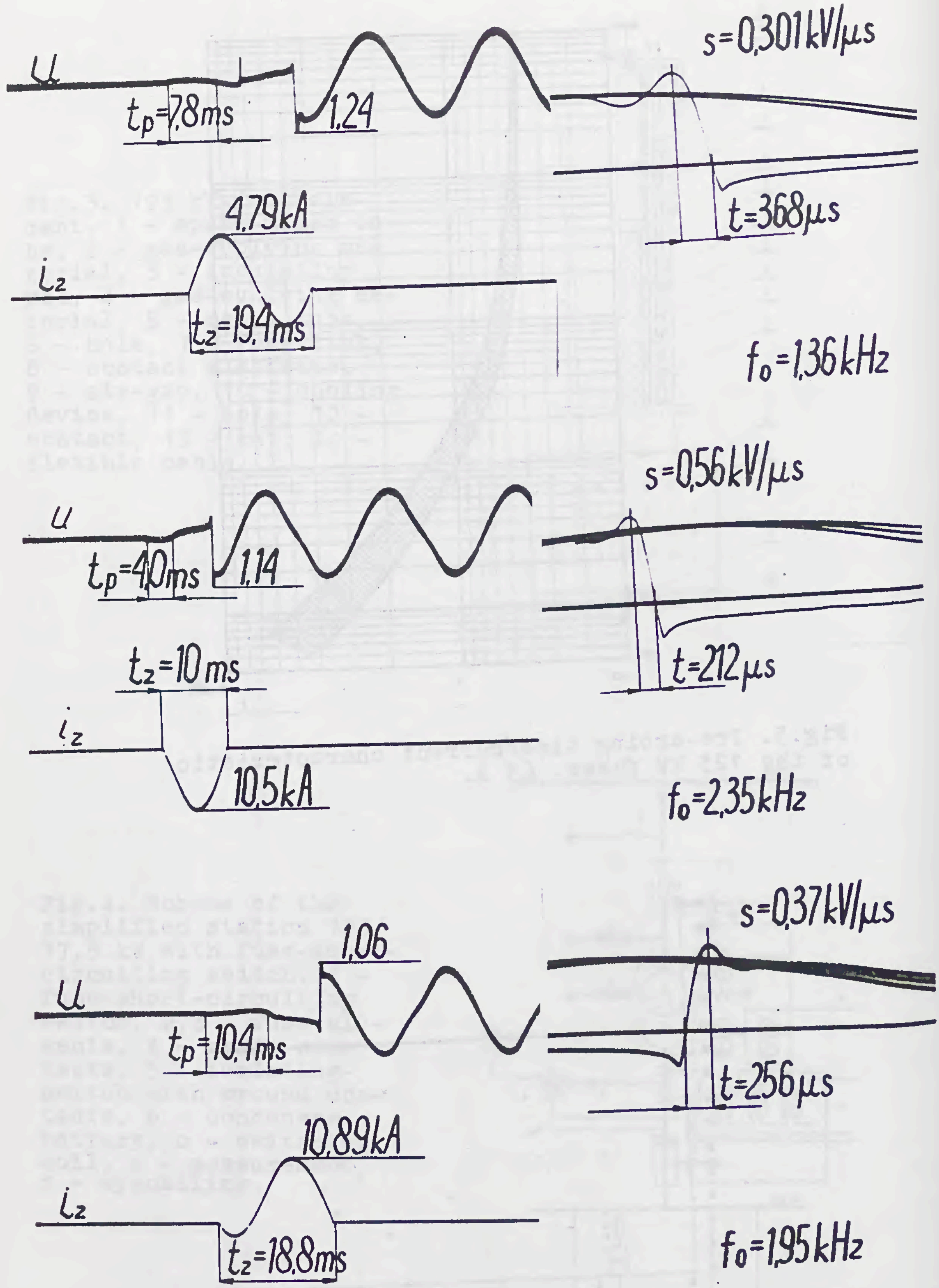

Fig.7. Oscillograph records of the breaking of short-circuit currents by the 123 kV fuse-short-circuiting switch. Phase to ground recovery-voltage. Laboratory tests.

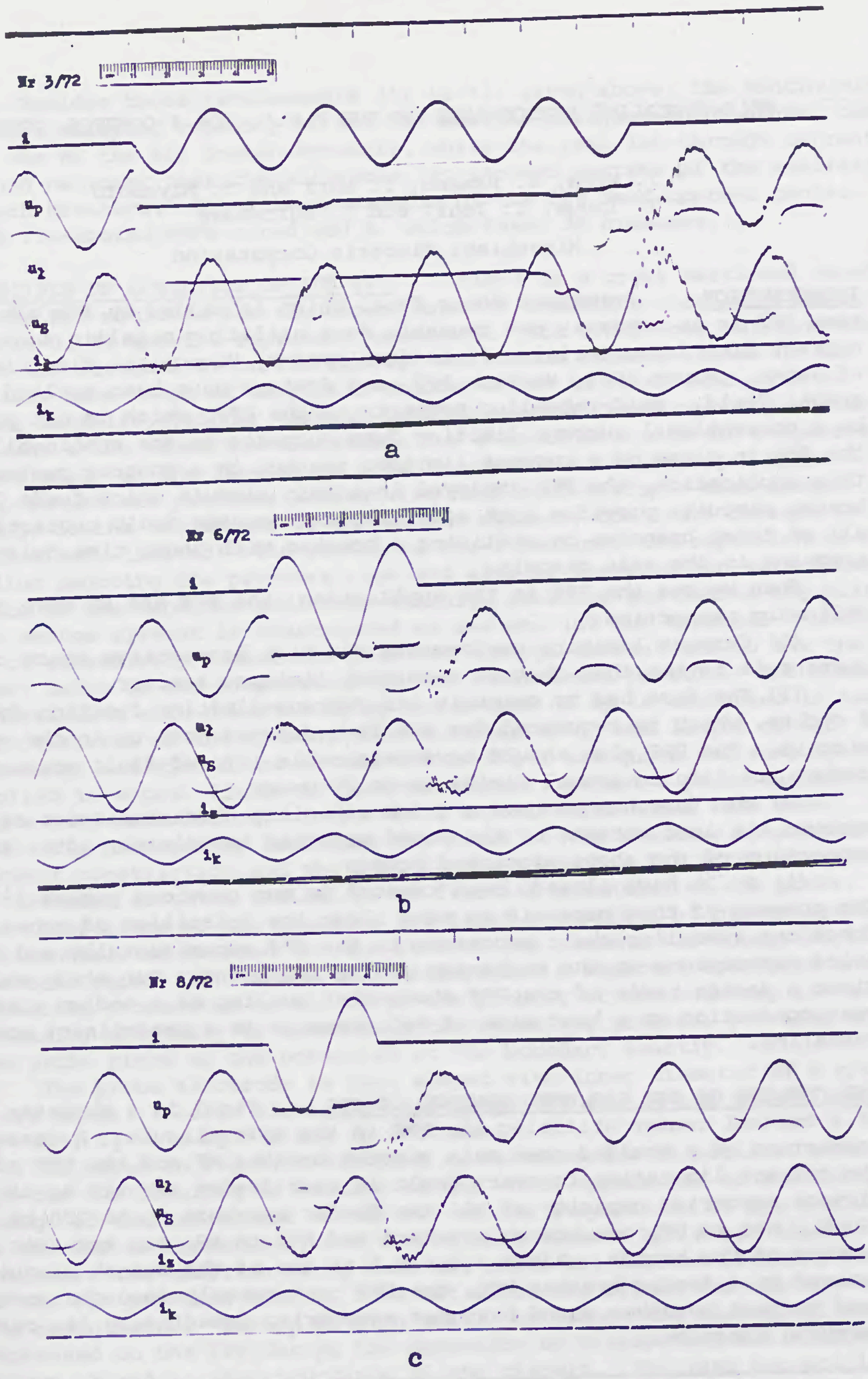

Fig.8. Oscillograph records of the breaking of short-circuit currents by the 123 kV fuse-short circuiting switch. Phase to ground recovery-voltage. Tests in 123 kV networks with the grounded neutral; a - 1800 A, b - 3200 A, c - 3400 A.