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EXPERIMENTAL STAND FOR INVESTIGATIONS OF INSULATOR DEGRADATION AND ELECTRODE EROSION IN HIGH-CURRENT BREAKER

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Abstract. An experimental stand for studies of electric arc, electrode erosion and insulator degradation processes in high-current circuit breakers and some preliminary experimental data is described. The setup includes a discharge chamber, a capacitive energy storage with capacitance of 0.11 F, voltage up to 10 kV, and all necessary diagnostic techniques. The stand is designed for modeling current pulse with amplitude of 3–150 kA and duration of the first half period of 1.0–3.0 ms during the process of disconnecting the ring and the pin contacts. The arc is cooled by transverse gas blowing at pressure in the chamber of 0.5–3 MPa. Acquired experimental data can be used for verification of the modelling results of the heat transfer processes in the discharge chamber. At the stand, advanced composite materials based on carbon and iron-copper pseudoalloy are studied.

Keywords: high-current high-pressure gas discharge, electrode erosion, insulator degradation, high-voltage test techniques, high-current circuit breaker, high-voltage engineering.

1. Introduction

Design and development of high-voltage high-current gas circuit breakers and new technologies for manufacturing their contact systems is rather uneasy and expensive problem. Now instead of traditional technologies there come new ones, including the creation of new composite materials, such as laser weld deposition [1, 2], and plasma technologies [3, 4].

In the present work, the description of the experimental stand with a modelling discharge chamber intended for research of arc processes, electrode erosion and degradations of insulation materials is presented. The stand has been created in addition to the available one [5] for research and test of lightning protection devices in air power lines [6] and for continuation the research of erosive characteristics of new perspective composite materials [7, 8].

2. Discharge chamber

The experimental setup is intended for studies on blown arcs with current amplitude up to 300 kA and pulse pressure up to 1 MPa. In the design of the discharge chamber flexible change of the configuration is incorporated. So, for example, an puffer-type electrode unit or an transverse gas blowing through an arc are stipulated.

Figure 1 shows the variant of the discharge chamber with a transverse gas blowing.

The housing of the chamber (1) is a thick-walled vessel made of the stainless steel, inside it there is a mobile acetal resin piston (2). The anode holder (3) is mounted on the piston. The studied material sample is fixed on anode end (4). The opposite end of the anode holder is connected with the ground conductor line by means of flexible copper wires laid inside of polycarbonate tube (5). The orificed cathode (6) is fasten on the current input (7), isolated from the chamber case and connected with the high voltage conductor line.

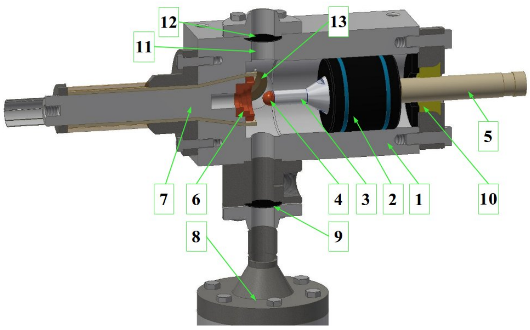

Figure 1. Discharge chamber (all designations in the text of article).

Movement of the piston occurs by means of compressed gas which is pumped into a cylindrical volume (8) and enters the chamber volume after the break of the diaphragm (9). The cavity behind the piston also plays the role of a shock-absorber since air is squeezed out from it through a narrow slit between the tube (5) and the fluoroplastic cartridge (10).

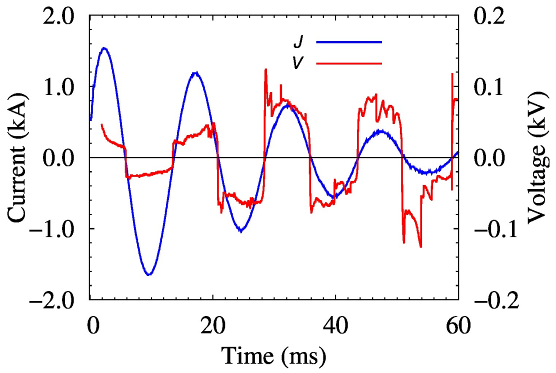

Figure 2. Current (J) and voltage across arc gap (V) at frequency of 75 Hz.

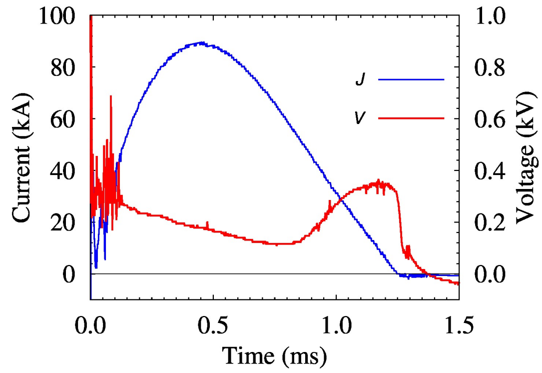

Figure 3. Current (J) and voltage across arc gap (V) for high current amplitudes.

Coaxially with an inlet aperture for gas puffing, the exhaust outlet (11) also closed by a diaphragm (12) is placed, which is allowed to limit the maximum pressure in the chamber volume and to model an arc blowout at transverse gas blowing through an arc.

Perpendicularly to the chamber axes, two coaxial diagnostic windows (13) are located, through which optical diagnostics is performed. The construction of the windows allows for mounting of various materials for test of thermal and radiative arc action. Specially constructed channel in the chamber housing is used for pulse pressure measurements in the discharge volume.

The energy source is the modular capacitive system with maximal storage energy of 6 MJ, maximal charging voltage of 10 kV and capacity of 0.11 F. The storage system is divided into six identical independent modules which can be switched on a load both simultaneously, and independently with delays. The commutation of each module is carried out by a triggered air switch (trigatron). The current is measured by Rogovskiy coil. For the measurement of the voltage drop on an arc a high-ohmic resistive divider with a transformer decoupling is used, which high-voltage end is connected to the current input (7 in figure 1), and the low-voltage end − to a junction of flexible copper wires going from the anode with the ground conductor line.

The study of arc quenching is feasible in several current modes.

At current amplitude up to 10 kA, it is possible to pass up to 20 half-cycles of a current with frequency of 75 Hz through electrode system (figure 2). Higher current amplitudes (up to 300 kA) correspond to a current mode in one or two half-cycles of the discharge (figure 3) with a half-cycle duration of 1–3 ms. The duration depends mainly on number of used modules and connected inductive reactor. During the first current half-cycle of the current (1–3 ms), the contacts move away on the distance of 3–4 cm.

The chamber construction is described in more details in [9].

3. Available diagnostics

At the stand, various high-speed diagnostic methods are presented, which are now used for detailed studies of arc processes. The scheme of the diagnostic equipment arrangement is shown in figure 4. Additional details about the diagnostic methods and equipment can be found in [10, 11].

For a pulse pressure measurements in the discharge volume the membrane piezoelectric gauge T-500 is used. It allows to register a pressure magnitude during all discharge process with a time resolution of ∼ 5 µs.

To study temperature conditions of electrodes, two identical high-speed monochromatic pyrometers with calibrated semiconductor sensors and a time resolution of ∼ 1 µs are used. In figure 5, the brightness temperature of the cathode vs time is presented for current amplitude of 40 kA and electrodes made of copper-chromium 50/50 alloy.

For a high-speed dual angle photographing of the arc burning and the piston movement, a 9-frame ICCD camera K011 (BIFO Moscow, frame exposition up to 100 ns) and a 16-frame rotatory mirror CCD camera CORDIN-530 (USA, frame exposition up to 0.2 µs) are used. These cameras allow to carry out high-speed imaging of the processes by a duration up to several milliseconds with a high temporal and spatial resolution. In figure 6, the frames of a high-speed imaging of an arc with current amplitude of 90 kA between the disconnecting copper electrodes are shown.

The direct shadow method is realized with a probing of the discharge volume by a continuous laser expanded beam. The shadow images is registered by a camera CORDIN-530. A schlieren technique configuration is also possible.

Spectral measurements are carried out with the imaging spectrograph LOT-Oriel MS257 and CCD-camera with a mask DU-420-UV-FK (UK, Andor Tech.). On the CCD-matrix the metal mask [12] is put, that allows to register several consecutive spectra with a time resolution up to several microseconds.

In figure 7, the spectra of the arc radiation in three consecutive periods of the current with amplitude of

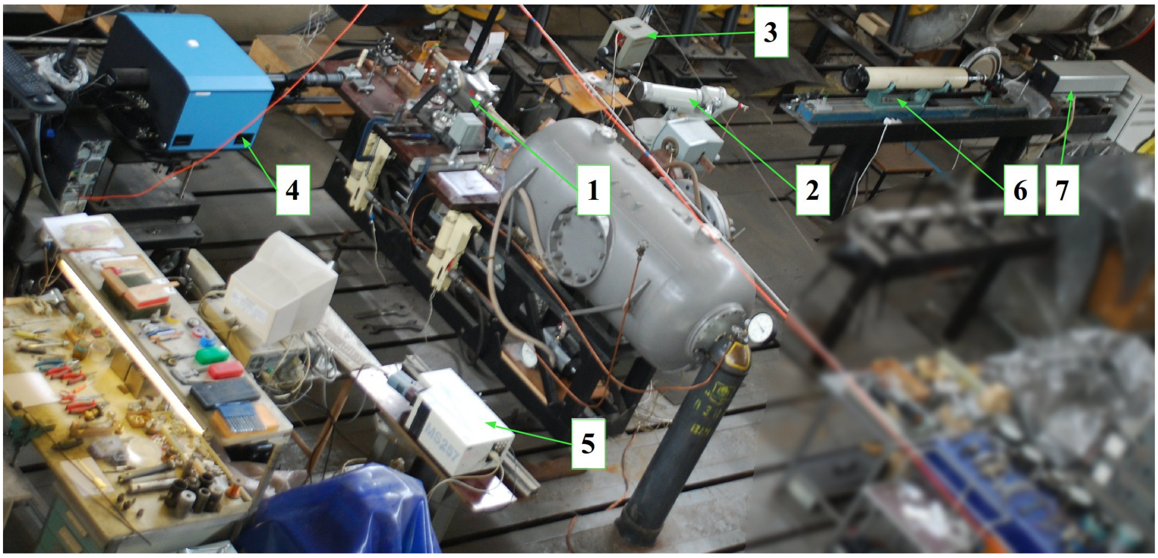

Figure 4. The scheme of the diagnostic arrangement on the experimental stand: 1 – discharge chamber; 2 – high-speed pirometer; 3 – high-speed ICCD camera Bifo K-11; 4 – high-speed rotatory mirror CCD camera Cordin-530; 5 – imaging spectrograph LOT-Oriel MS257i with masked CCD Andor DU-420-UV-FK; 6 – collimating optics and 7 – laser for shadow and schlieren techniques.

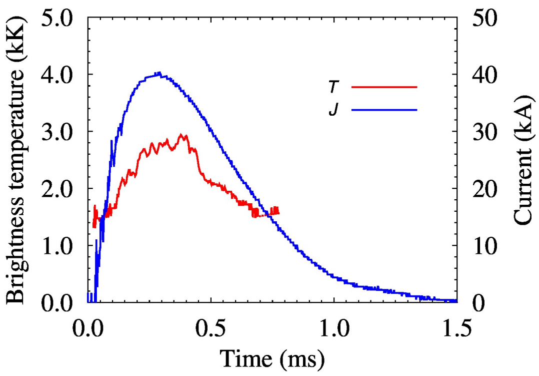

Figure 5. Brightness temperature of the cathode (T) and current (T).

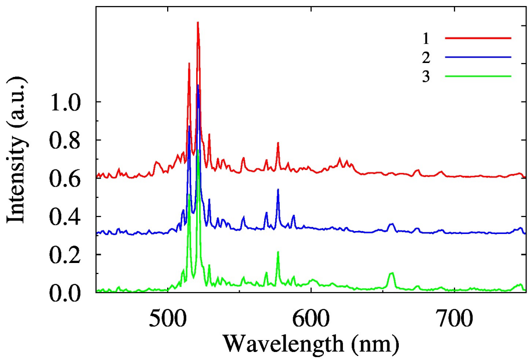

Figure 7. Arc spectrum for current amplitude of 2 kA and frequency of 75 Hz: 1 – first half-cycle of the current, 2 – second, 3 – third.

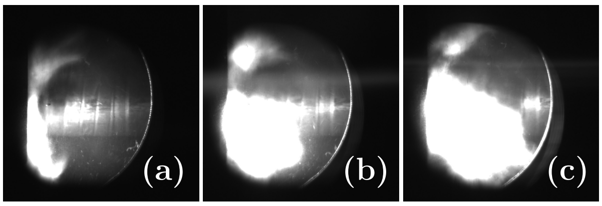

Figure 6. High-speed frames of arc with current amplitude of 90 kA between divergent copper electrodes in time moments of 500 *(a),* 550 *(b) and* 600 μs *(c) after discharge ignition.*

2 kA between electrodes with copper-graphite covering deposited by means of plasma sputtering [3] and fluoroplastic sample installed in the field of discharge action are shown. A change in the spectrum corresponds to a change of the structure and parameters of the arc plasma during the discharge development.

4. Conclusions

The experimental installation for a physical modelling and study of processes in high-voltage high-current gas breaker is created. At the stand, the complex of various methods of high-speed diagnostics for detailed investigations of discharge processes is realized.

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