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MONITORING GAS INSULATION OF A 2 MV ELECTROSTATIC ACCELERATOR

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Methods for monitoring gas insulation of high- and ultra-high-voltage installations are discussed using a 2 MV electrostatic accelerator (ESA) as an example. The dependents of the operating voltage on gas pressure, gas mass spectra, and the voltage-current characteristic (VAC) of the gas-insulated measuring gap were obtained for the "Sokol" ESA at the IAP NASU. The proposed VAC method was verified.

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INTRODUCTION

The most important factor determining the dielectric strength of high-voltage and ultra-high-voltage (HV, UV) structures is the dielectric strength of the gas structure (GS) [1]. During operation, the GS ages due to breakdowns, partial discharges, chemical influences, radiation, temperature, etc. Therefore, to ensure the reliable operation of the installation, monitoring (control) of the gas system is necessary. Several types of GS monitoring are known:

- measurement of temperature, humidity (water vapor content), dust, and the chemical composition of mixtures [2];
- testing the method for measuring the breakdown voltage of the installation [3]. We will consider only the assessment of the dielectric strength of the gas, since the breakdown voltage is affected not only by the resistance but also by the state of the solid load (e.g., arresters, high-voltage equipment). But above all, this method is dangerous for the high-voltage structure of the power supply system;
- mass spectrometric analysis of the gas mixture [2]. This requires expensive precision instruments, the development of complex technology, and various labor costs.

Therefore, there is currently no simple, direct, and equipment-safe method. In this paper, the concept and practical justification for a gas load monitoring method are based on changes in the VAC of a system of live electrodes implemented in the high-voltage circuit of a high-voltage (HV) installation.

Monitoring using the example of the "Sokol" of the Institute of Applied Physics of the National Academy of Sciences of Ukraine [4]. In a high-pressure vessel (tank) with a volume of 1.9 m^3, the elements of the high-voltage system are placed under voltage up to 2000 kV. The insulating gas is nitrogen at a pressure of up to 5 atm. Gas is supplied from linear cylinders, the gas is repeatedly fed to a dryer, and dust is removed using the method described in [2]. Gas quality criterion: number of N time T at a given operating voltage U_o. For the "Sokol", based on almost 30 years of operation, N = 1, T = 1 h, and U_o = 1.4 MV were adopted.

1. BREAKDOWN VOLTAGE METHOD

During operation for one year, the gas was purified monthly through silica gel and dust filters. The experiment was conducted according to the methodology described in [2, 3]. Fig. 1 shows the results of the ESA electrical strength tests. Without gas purification, it was not possible to achieve an operating voltage of the ESA above 0.9 MV, with an electrical breakdown rate of 10…30 per hour. After gas purification, the operating voltage of the ESA was U_o = 1.4 MV, and the electrical breakdown rate did not exceed the permissible value (1 per hour).

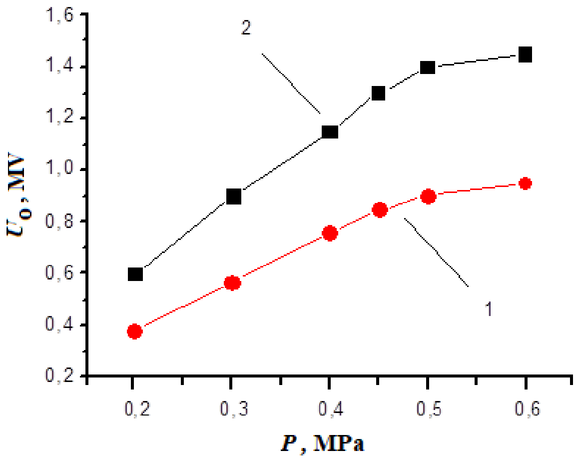

Fig. 1. Accelerator operating voltage versus gas mixture pressure: 1 – before gas cleaning and ESA conditioning; 2 – after gas cleaning and ESA conditioning

2. MASS SPECTROMETRIC METHOD

Let's consider the mass spectrometric analysis of GI. Measurements were performed using a compact magnetic mass spectrometer MS-U of the Institute of Applied Physics of the National Academy of Sciences of Ukraine, which can record a range from 7 to 200 u [5]. Fig. 2 shows the mass spectrum of unpurified gas from the cylinder manifold. The spectra contain: water group (H_2O, OH, O; 15-18 u), nitrogen group (N_2, N_2H, NO, 27-30 u), and argon (Ar; 40 u). Fig. 3 shows the spectrum of purified gas from the tank.

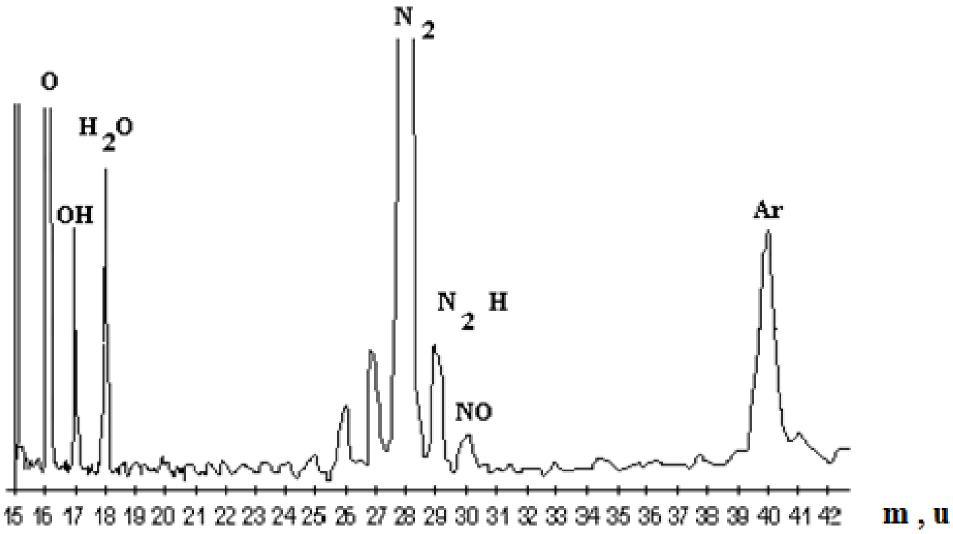

Fig. 2. Mass spectrum of unpurified (not conditioned) gas, U_o=0.9 MV

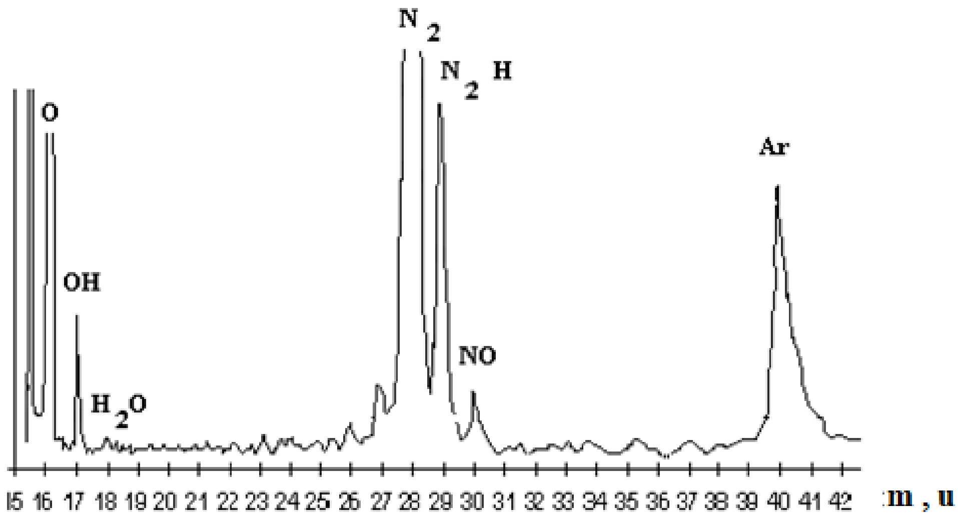

Fig. 3. Mass spectrum of purified (conditioned) gas, U_o=1.4 MV

The water vapor content in the mixture is within the device's sensitivity (spectral noise) of μ<10 ppm. For stable operation of this class of ESA, achieving μ<100 ppm is sufficient. Moreover, the electrical breakdown rate at an ESA voltage of 1.4 MV does not exceed the permissible value (1-2 per hour). Therefore, this spectrum corresponds to a gas that ensures reliable operation of the device and can be adopted as a reference for the “Sokol” ESA.

3. VAC (DARK CURRENT) METHOD

The experimental setup is shown in Fig. 4. Electrodes 1 and 2 of an E3 automobile spark plug were used as measuring electrodes. The electrodes are located inside the accelerator's tank (high-pressure vessel) 3 and are connected to a high-voltage source 4. The power source was a high-voltage power supply NCN 35-35000 manufactured by Fug (Hamburg, Germany).

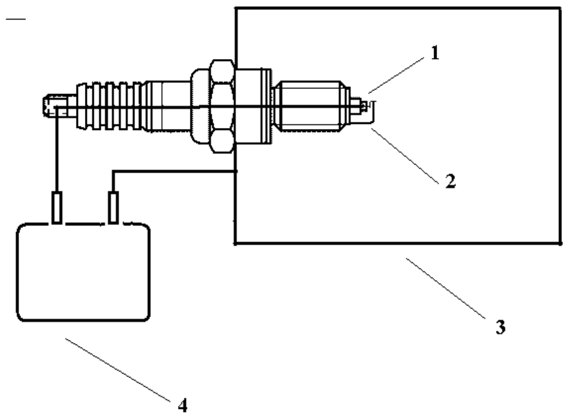

Fig. 4. Experimental diagram for determining the current-voltage characteristics of the sensor: 1, 2 – electrodes; 3 – ESA tank; 4 – high voltage source

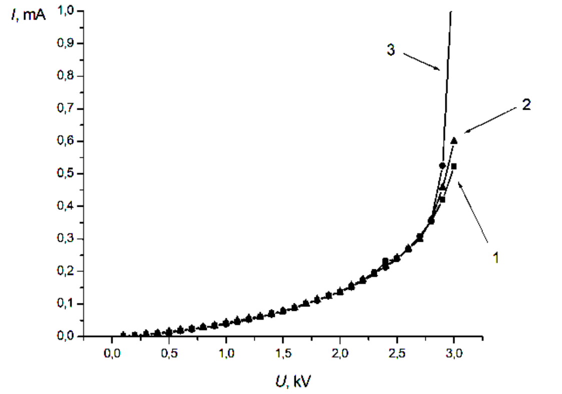

Fig. 5. VAC characteristic of unpurified gas (from a cylinder). The gap between the electrodes is 0.8 mm, t = 20 °C; 1 – P = 1.3 MPa; 2 – P = 2.8 MPa; 3 – P = 3 MPa

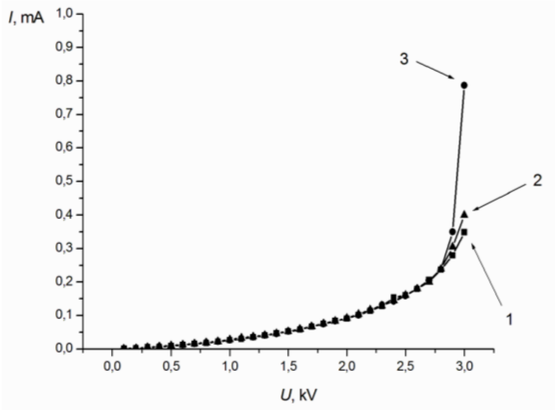

Fig. 6. VAC of purified gas (reference). The gap between the electrodes is 0.8 mm, t = 20 °C; 1 – P = 1.3 MPa; 2 – P = 2.8 MPa; 3 – P = 3 MPa

Figs. 5, 6 shows the VAC of the unpurified (see corresponds to Fig. 2) and purified gas (see corresponds to Fig. 3).

4. DISCUSSION OF RESALTS

Correlations (based on the “bad-good” gas principle) of the voltage-current characteristic (see Figs. 5, 6) with the electrical strength tests of the ESA (see Fig. 1) and mass spectra (see Figs. 2, 3) suggest the feasibility of using the dark current measurement method to assess the electrical strength of the gas insulation of the HV, UV gas supply system. To determine the quality monitoring of the UV gas, it is necessary to:

• find reference VAC and a mass spectrum corresponding to the operating voltage;

• measure the VAC and mass spectrum during operation and compare them with the reference characteristics.

CONCLUSIONS

Using the proposed methods allows:

• to measure the dielectric strength of gas insulation with sufficient accuracy (due to the fact that the measurements are direct and eliminate the influence of extraneous factors);

• to ensure low cost and ease of operation (measurements are performed with the accelerator turned off);

• to ensure equipment safety (during possible breakdowns of the measuring gap, negligible energy is released).

ACKNOWLEDGEMENTS

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МОНІТОРИНГ ГАЗОВОЇ ІЗОЛЯЦІЇ ЕЛЕКТРОСТАТИЧНОГО ПРИСКОРЮВАЧА НА 2 МВ

І.Г. Ігнатьєв, С.В. Колінько, О.Г. Пономарьов

Методи контролю газової ізоляції високо- та надвисоковольтних установок обговорюються на прикладі електростатичного прискорювача (ЕСП) потужністю 2 МВ. Для ЕСП «Сокіл» в ІПФ НАН України отримано залежність робочої напруги від тиску газу, мас-спектри газу та вольт-амперну характеристику (ВАХ) вимірювального проміжку з газовою ізоляцією. Запропонований метод ВАХ був верифікований.