Breakdown with solid insulation flashover in naturally occurring gases, SF6, and its alternatives

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Electrical engineering utilizes power components such as gas/solid insulated switchgear, switches, substations, or busbars for power distribution. The SF_6 gas with high global warming potential should be replaced with alternatives like C_4F_7N and its mixtures or with naturally occurring gases (air, N_2, CO_2) at higher pressures. Understanding the breakdown behavior in these gases with solid insulation flashover [1 - 4] is therefore important. Two different test cells were designed and built to study these phenomena[i]. The cells enable evacuation to high vacuum and gas filling up to 300 kPa, monitored by a pressure sensor. Both cells enable modification of the geometry (electrode distance, solid insulator position) without breaking the atmosphere. This work focuses on the measurement of the tested gas mixtures in both cells and statistical data evaluation of results.

The experiments were focused on the measurement of the process of streamer formation and propagation in time, the measurement of the electric strength/breakdown voltage of the gas dielectric with user-adjustable parameters: different distribution of the electric field and gas pressure, and on further analyzing the discharge activity near the surface of inserted solid dielectric materials. Areas of research on discharges in gases include experiments with streamers at the submillimeter levels and measurements of discharges at equivalent voltage levels with the power distribution industry, i.e., at dimensions in the order of millimeters and centimeters.

The first smaller test cell located at the workplace at Masaryk University is used for impulse measurement of streamer formation, barrier partial discharges, and advanced EFISH methods of non-invasive electric field distribution measurement. The maximum peak value of the input voltage is 15 kV - limited by input electrical bushing. The cell is equipped with a stainless-steel electrode system and the possibility of setting the flashover gap in the order of millimeters in the axial direction. The solid dielectric barrier can be placed and manipulated in two directions using an external manipulator in a perpendicular radial axis.

The larger test cell is located in the high voltage laboratory CVVOZEPowerLab at BUT. The test cell is designed for testing overvoltage conditions in equipment up to a nominal voltage level of 35 kV. This corresponds to tests with applied alternating effective voltage up to 70 kV and tests with applied impulse voltage (LI – lightning impulse 1.2/50 μs) up to the peak value of both polarities 170 kV. The flashover distance of the electrode system in the axial direction can be adjusted in the range of 0-50 mm. Using a bellows-sealed 3-axis manipulator, the inserted solid dielectric barrier can be manipulated in the direction perpendicular to the electrode`s axis in the range of 0-50 mm and the position of both other axes can be corrected in the range of ±10 mm.

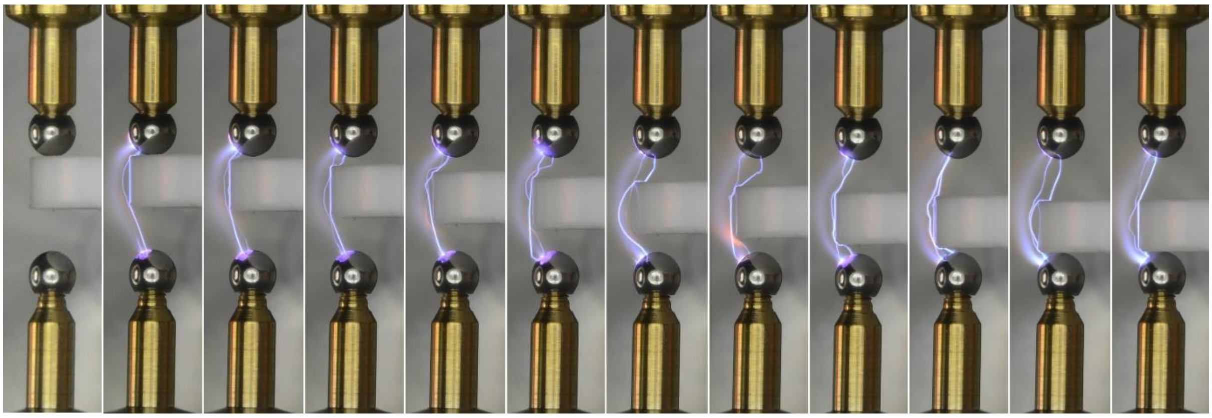

Figure 1: Sphere-sphere flashover in dry air with a PTFE solid dielectric barrier in different vertical positions.

Measurements of electric strength/breakdown voltage under different conditions of pressure, distribution/homogeneity of the electric field, and flashover distances are presented. The comparison of SF_6 results with other naturally occurring gases and C_4F_7N gas in various mixtures with CO_2, O_2, and N_2 is given. The analysis and measurement of the discharge activity are carried out not just by measurement of applied voltage and current time course, but also by recording a static photograph of the discharge track and by using advanced tools such as a high-speed camera and a high-speed spectrum analyzer. Examples of flashover in the air with a PTFE solid dielectric barrier in different positions are shown in Figure 1.

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