SC XXI 2018 PARIS SESSION

STUDY OF PARTIAL DISCHARGE IN FREE GAS BUBBLES IN TRANSFORMER OIL

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SC A2 Power Transformers and Reactors

FAILURE OF TRANSFORMERS WITH PAPER-OIL INSULATION

Fig. 1 – Transformer failure resulted in a fire

Diagnostics of high-voltage equipment is important to prevent accidents and identify defects at the early stages of development. Partial discharge monitoring in power transformers is one of the most effective diagnostic methods. Bubbles due to their low electrical strength can cause partial discharges. Therefore, a study of the starting mechanism and development of partial discharges in bubbles is an actual task

SCHEME OF THE CELL AND THE EXPERIMENTAL SETUP

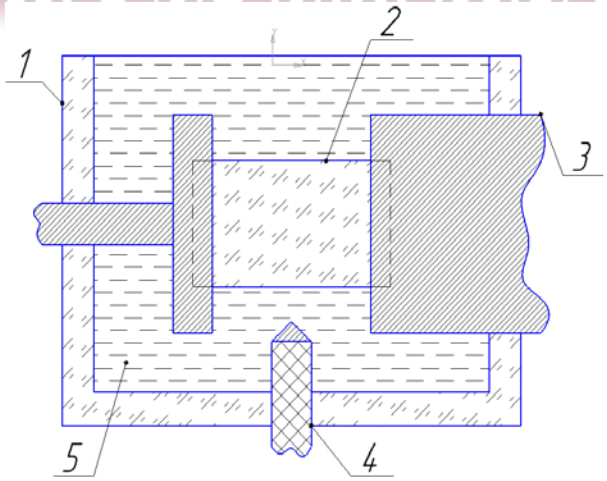

Fig. 2 – Experimental cell 1– cell body; 2- optical window; 3- electrodes; ***4- needle for bubble injection****; 5- transformer oil*

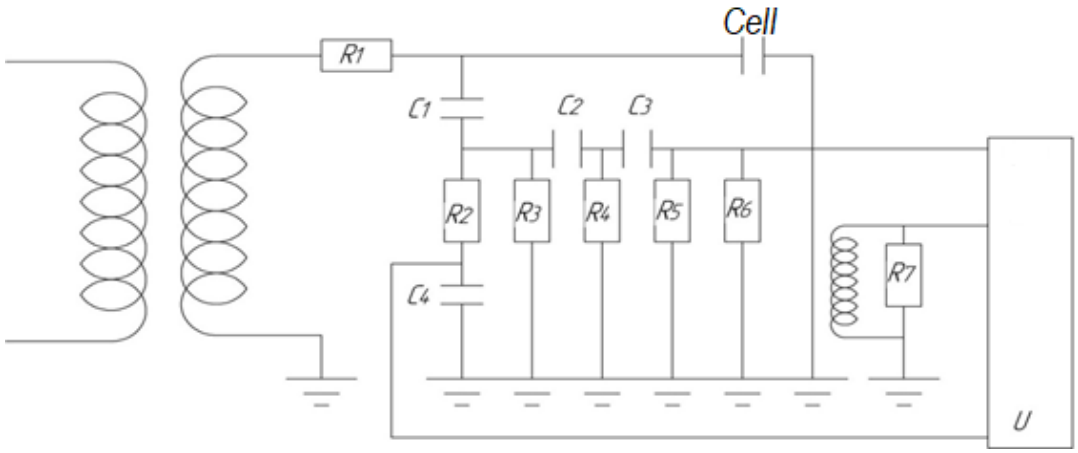

Fig. 3 – High voltage setup

What was registered:

- voltage on the cell;
- 2 electrical PD signals in moving bubbles or 1 electric and 1 light (Photomultiplier);
- Optical recording of moving bubbles (video 1200 fps)

DEFORMATION OF BUBBLES UNDER AC VOLTAGE ACTION

- On the left picture there are simultaneously registration of three bubbles at the moment of near zero voltage value
- On the right picture they are also at the amplitude value of the voltage

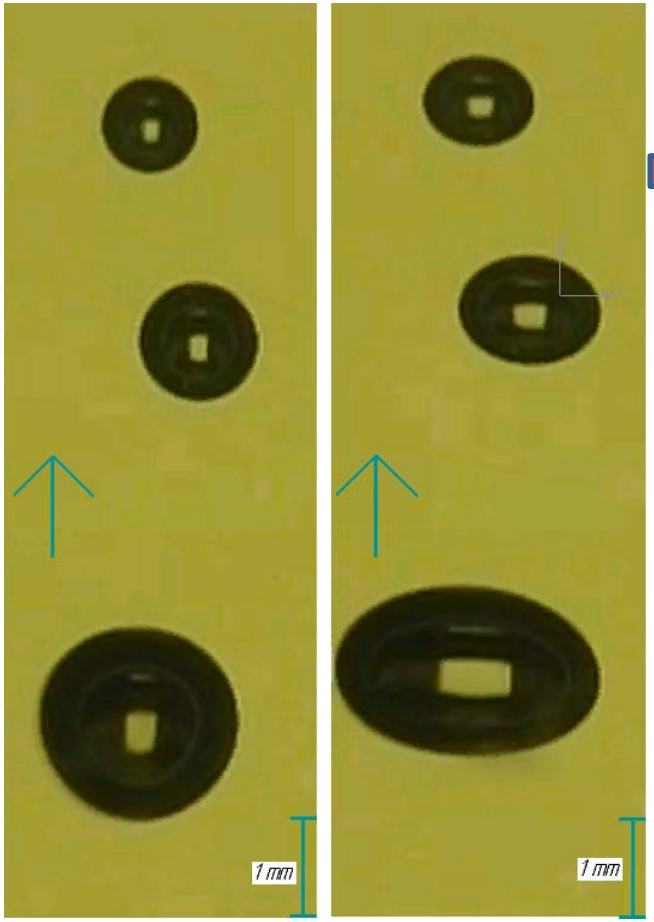

Fig. 4 - Deformation of bubbles

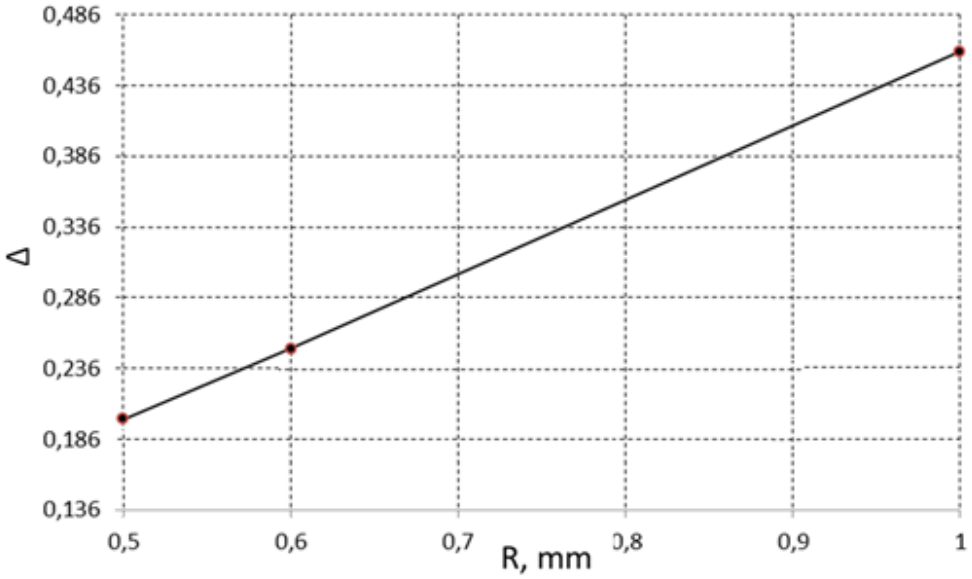

Fig. 5 - Dependence of deformation on the bubble radius

PARTIAL DISCHARGES IN FREE BUBBLES

- Partial discharges **wasn't observed** in air bubbles 1.5 mm in diameter at the voltage magnitude Uexp up to 42 kV. According to Pashen's law PD inception voltage Ui is 26 kV
- In the case of helium bubbles **Ui = 6 kV**, but **Uexp =15 kV**
- Nevertheless the partial discharges in free bubbles is **very rare** (time duration - hours)
- Partial discharges occur near the voltage amplitude only

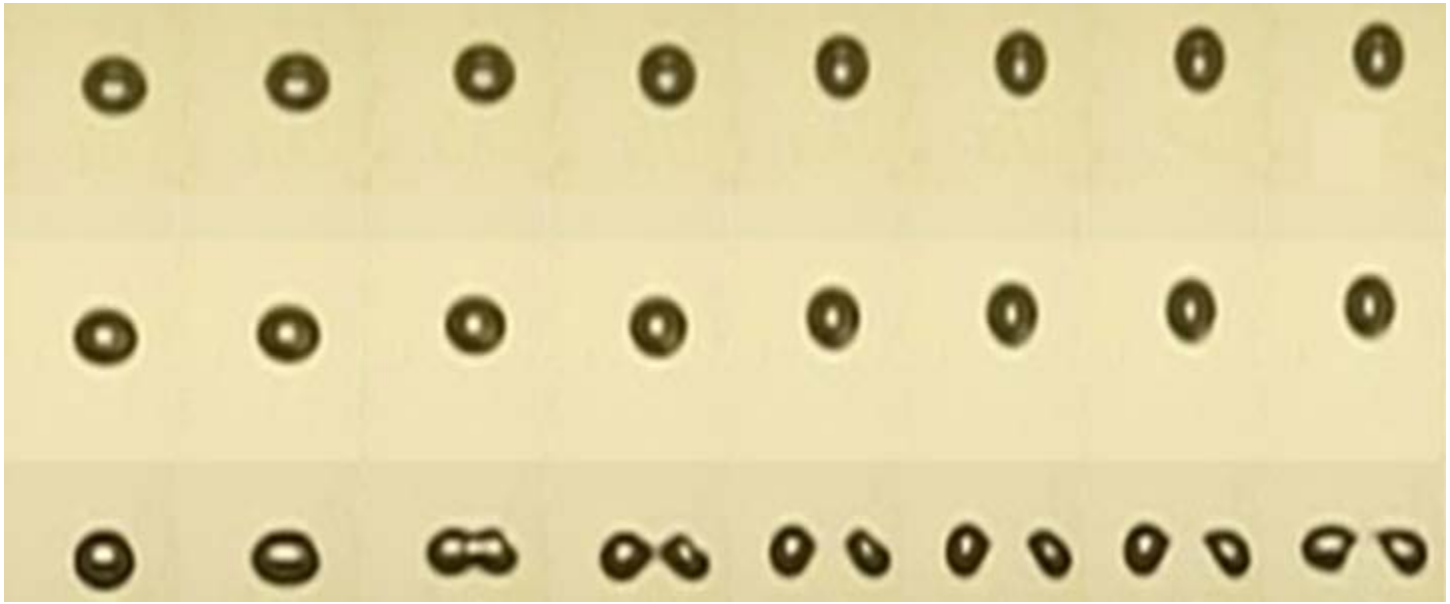

Fig. 6 – PD development in the bottom bubble. PD occurs on the second frame.

Time interval between frames is 1/1200 sec

SIMULTANEOUS RECORDING OF CURRENT AND GLOW DURING PARTIAL DISCHARGE IN A BUBBLE

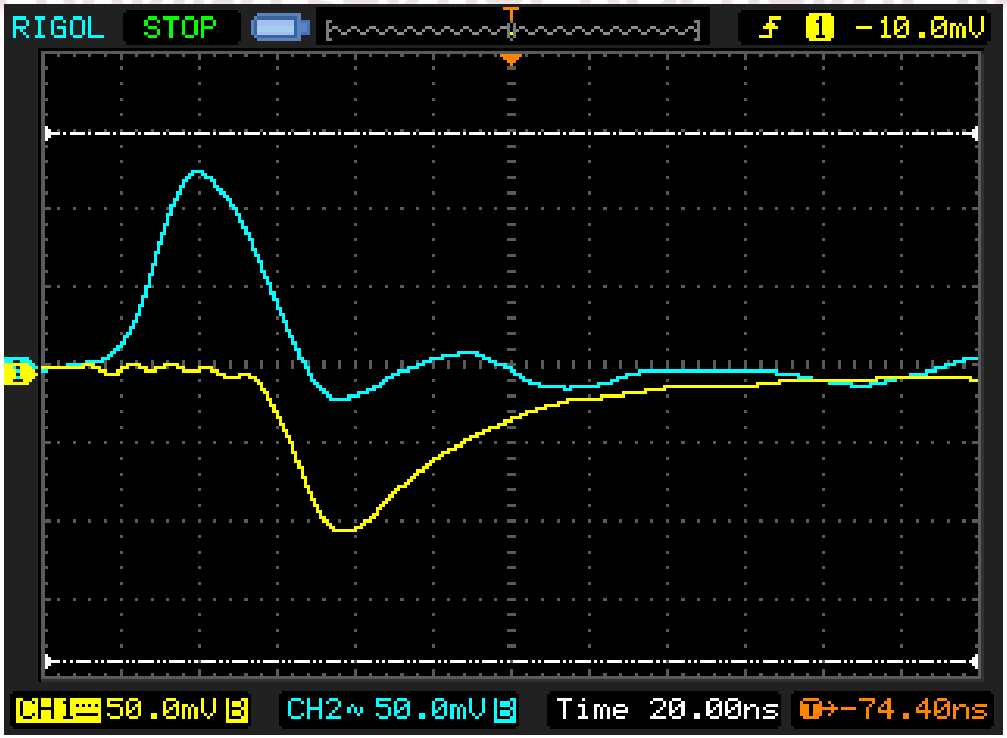

Fig. 7 – Partial discharges oscillograms

Current pulse (blue) and emission (yellow) from partial discharges in a helium bubble D = 1.6 mm;

- Apparent charge = 80 pC.
- Time rise duration is 20 ns approximately
- The shift between the curves is related to the flight time in the photomultiplier

REPETITIVE PARTIAL DISCHARGE

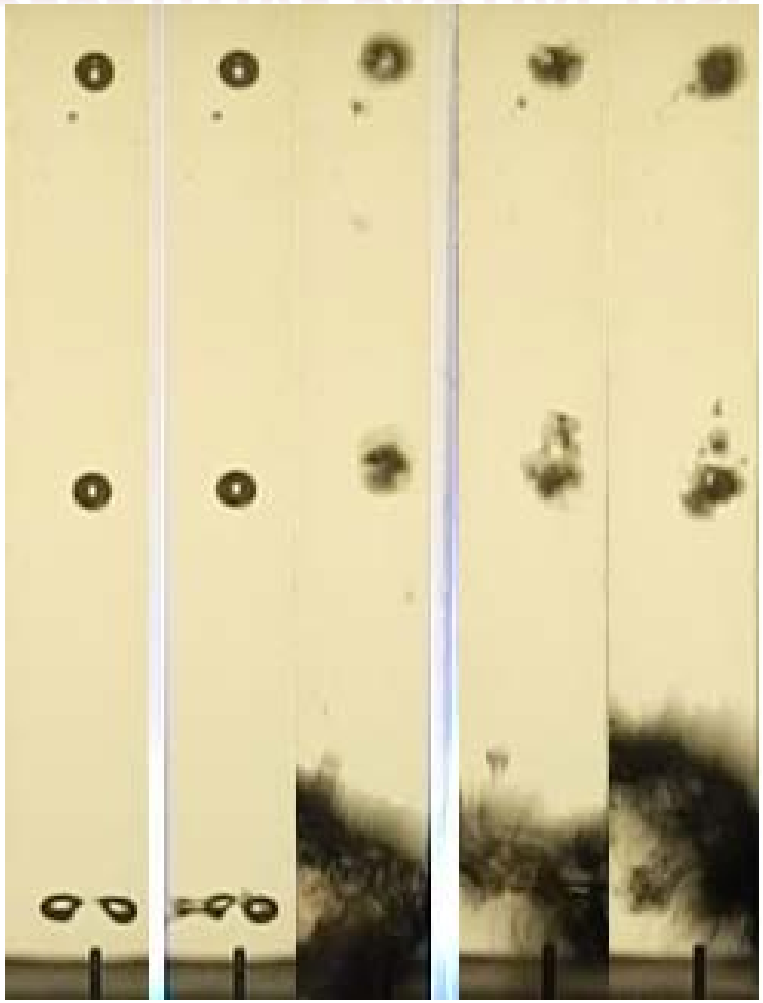

Fig. 8 – Discharge between electrode and one of the charged bubble

Time interval between frames is 1/1200 sec

The development of partial discharge in the bubble leads to its drammatic elongation, with the subsequent division into two bubbles. Both parts of the bubble have opposite charges and oscillate under the action of alternating electric field in opposite directions. Sometimes the partial discharge with apparent charge up to 1nCl was recorded. It was a discharge between electrode and one of the charged bubbles. Repeated partial discharges with a higher apparent charge result from the presence of a residual charge in some of the bubbles, which distorts the electric field in the system

PARTIAL DISCHARGES IN FREE BUBBLES UNDER THE INFLUENCE OF X-RAYS

Fig. 9 – PD development in all bubbles simultaneously. PD occurs on the second frame

Time interval between frames is 1/1200 sec

- According to Pashen's law PD inception voltage **Ui is 6 kV** in helium bubbles and **Uexp =6 kV**!!!
- As a result of X-rays influence, a PD develops in all bubbles **simultaneously**

CONCLUSION

- Deformation of bubbles is proportional to their size
- PD in free bubbles is rare event without X-rays, besides it takes place at the moment of the voltage amplitude.
- X-ray radiation causes partial discharges in all bubbles at lower voltages
- For the diagnostics of high-voltage equipment this effect is very important. Using X-rays one can artificially initiate PD in ALL gas defects. It performs a better evaluation of the state of electrical equipment

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