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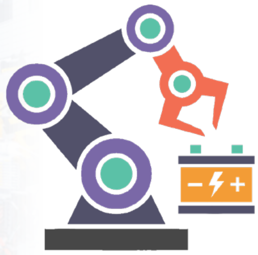

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Partial Discharge Gas Dynamics Study

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Abstract. *The aim of the work is to study partial discharge at DC voltage below 1000 V in the presence of an aqueous solution of sodium chloride on a vehicle plug. By analogy with high-voltage partial discharge, such partial discharge stages as incomplete and completed partial discharge are distinguished. To develop discharge, such elements of low-voltage equipment have been used as a contactor, a rectification circuit with voltage multiplication, and a ballast resistance. It has been found that in the presence of an electrolyte, a complete partial discharge is ignited at a low voltage with a high current and a short delay time. When the current value has been controlled by the ballast resistance, the completed partial discharge has the form of a damped ball, in the absence of ballast resistance, the form of an exploding ball. This is due to the appearance or absence of a shock wave in the completed discharge.*

Keywords: *partial discharge, low voltage, pulse RC generator, switch, salt solution, incomplete discharge, completed discharge, discharge initiation, luminous ball formations, ballast resistance, voltage-multiplying rectification schemes.*

Introduction

Partial (sliding) discharge (PD) plays an important role in the electric power industry when operating high-voltage power lines. It is a breakdown of a gas in the presence of a dielectric. Numerous experiments were performed at high voltages and high rates of current change [1,2]. It was found that a partial discharge is a source of intense ionizing radiation and has a wide range of practical applications in high-voltage engineering. In particular, it allows switching currents of several mega amps at a voltage of up to 100 kV. On the other hand, it presents a problem for high-voltage insulation of power lines.

Partial discharges that occur in electrical equipment at a much lower voltage (200-300 V) described in [3] are a negative factor that reduces the service life of the equipment, and require the cost of their detection and neutralization are. The fight against the negative impact of partial discharges on the insulation state naturally raised the question of the useful use of partial discharges at low voltages. Therefore, the aim of this study was to study the characteristics of a partial discharge over the surface of a solid dielectric at a low voltage (up to 1000 V). The subject of the study was a partial discharge on a rectified pulse current of one direction. We took into account the fact that in the presence of an electrolyte, the intensity of the PD glow sharply increases in the visible region due to the fact that arcs appear on the electrolyte surface, and not a glow discharge, as on a dry surface [4]. At the same time, the ignition voltage and the timing belt of the PD are reduced.

Research results

Experimental setup

A schematic diagram of the installation is shown in Figure 1.

An automobile spark plug Sv/Ca was used as a spark gap, in which the upper electrode was cut down. The value of the air gap 5 between the central electrode 1 and the grounded electrode 2 (see Figure 1) was 2 mm. Such a gap at a voltage of 1000 V did not break through. Therefore, to reduce the breakdown voltage, an electrolyte was poured into the candle - a 1.5% solution of table salt (NaCl) in water. The electrolyte level reached the upper level of the dielectric 3.

Current and discharge voltage pulses were recorded on an ADS-2031 oscilloscope. In particular, when applying a pulse to a candle placed in tap water, a voltage pulse with an amplitude of 700 V with a front of 1.6 microseconds and a duration of 20 microseconds was recorded. For the electrolyte, 550 V, 0.4 μs, and 2 μs, respectively. The ignition was photographed and partial discharge burns at 30 and 150 frames per second. Switching of the capacitor to the spark gap was performed using a controlled switchboard K/S, which is a small-sized contactor KMI-10910.

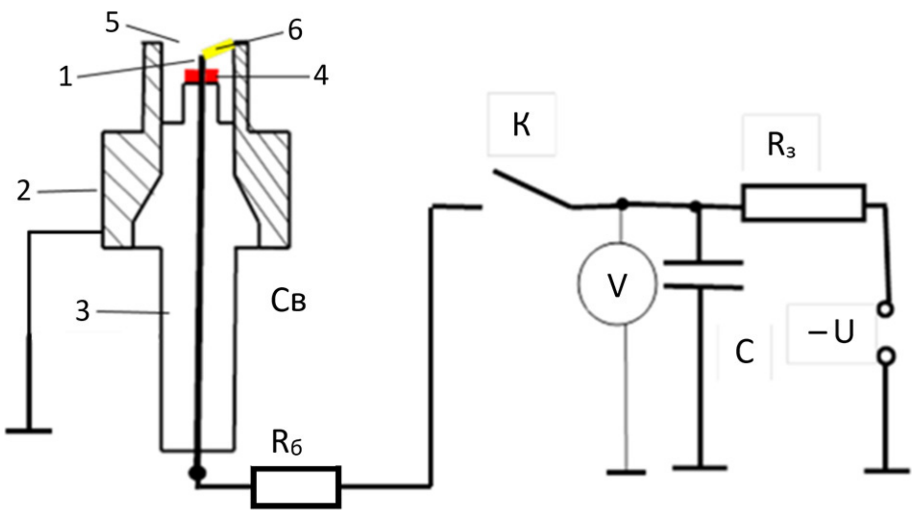
An experiment

Incomplete partial discharge occurred when a negative potential was applied with a voltage of 450 V on the central electrode of the candle. In this case, a round glowing region was lit at the end of the insulator surrounding the central electrode (Figures 1,2). This area existed until the capacitor was discharged. The lifetime of the incomplete PD was 0.1...0.15 s and coincided well with the time of discharge of the capacitor C to the electrolyte resistance (Re). The latter increased due to the evaporation of the electrolyte from 300 to 10,000 ohm (see figure 2).

Oscillograms of the voltage of an incomplete discharge had a duration of about 10 ... 20 ns, a current value from 2 to 0.05 A. The occurrence of an incomplete discharge was associated with the presence of an electrolyte dissociating into positive Na+ and negative Cl- ions. Unlike the high-voltage discharge, this discharge was not independent.

A completed partial discharge (Rb=0) occurred when a negative potential was applied with a voltage of more than 450 V on the central electrode of the candle. At the same time, a large dazzling white spark was generated in the air between the candle electrodes, accompanied by a loud sound (figure-3).

The current reached several thousand amperes,



-U – DC voltage 0–1000V Rz – charging resistance Rb – ballast resistance, V – digital voltmeter, S – low voltage switchboard, Ca – candle, 1 – central electrode, 2 – earthed electrode, 3 – dielectric, 4 – the ignition place of incomplete partial discharge (I stage), 5 – digit span, 6 – the ignition place of completed partial discharge (II stage)

Figure 1 – Scheme of partial discharge generation on a car candle

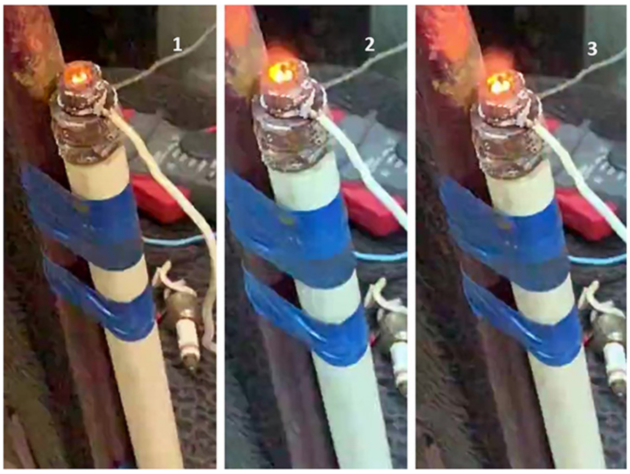


Figure 2 – Incomplete partial discharge with an electrolyte. Rb = 0, U = 450 V, t = 1/150 s (1); t = 2/150 s (2); t = 3/150 s (3)

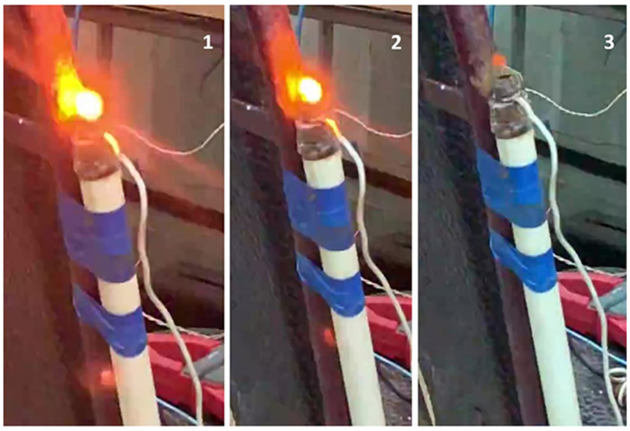


Figure 4 – Completed partial discharge with electrolyte in the presence of ballast resistance (Rb = 68 Ohm). U = 950 V t = 1/150 s (1), t = 2/150 s (2), t = 3/150 s (3)

Figure 3 – Completed partial discharge with electrolyte. Rb = 0, U = 950 V, t = 1/150 s (1); t = 2/150 s (2)

and the discharge lifetime was less than 1/150 s. A shock wave was generated, which gave the discharge area an extended shape (figure 3.1). The velocity of discharge products spreading is 15 m/s. In figure 3.2 cooling products are fixed.

The completed partial discharge (Rb=68 ohm) had a slightly different ball shape. At the same time, the discharge current passed during 1.5·10-2 s (figures 4.1, 4.2) and the discharge cooled down during 1.5·10-2 s (figures 4.2, 4.3).

Apparently, this was due to the limitation of the discharge current value by the ballast resistance and the absence of a shock wave.

The complete discharge was initiated by an incomplete discharge at the corresponding voltage: 600 V for a discharge gap of 3 mm, 450 V for a discharge gap of 2 mm. The discharge delay time was about 0.1 microseconds. The discharge zone reached the surface at a rate of 0.2 m/s.

The stage of the completed discharge generally corresponded to the description of a spark discharge in air from [5] with approximately the same parameters.

When using an industrial-frequency AC rectification circuit with voltage quadrupling without ballast resistance as a power source, complete partial discharges with a shock wave break were obtained [6].

When using a rectification circuit of alternating industrial frequency with voltage doubling with a ballast resistance of 60 ohm, completed partial discharges in the form of balls were obtained [7].

Conclusions

1. When studying partial discharge at low voltages (in the range of 500-1000 V) in the presence of an electrolyte, the following stages of PD were studied:

- incomplete discharge U = 450-600 V, which lasts while the capacitor is charged, for a long period (0.1...0.15 s);
- a completed discharge U > 450-600 V, > Rb = 0 that lasts less than 7 * 10-3 s and is accompanied by a bright white spark and a loud sound;
- a completed discharge U > 450-600 V, > Rb = 68 ohms, which lasts more than 1.5 * 10-2 s and is accompanied by a reddish spark and a weak sound.

2. When powered by pulsed installations without ballast resistance in the completed discharge mode, luminous formations are formed, which are torn apart by the shock wave that occurred in the gas during the completed discharge. When powered from pulsed installations with a ballast resistance Rb=68 ohm, spherical formations appear, which gradually fade as they cool down.

3. An incomplete discharge at a certain voltage value initiates a completed discharge with a certain delay time (0.1 microseconds).

4. When using industrial frequency current rectification circuits as a power source, discharges are obtained, both with a shock wave and in the form of balls, depending on the value of the ballast resistance.

5. An incomplete discharge is a non-independent discharge in air along the surface of a dielectric. The source of charges is the electrolyte. A completed discharge is a non-independent discharge in the air. The source of charges is an incomplete discharge.

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Жартылай разрядты газодинамикасын зерттеу

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Аңдатпа. *Жұмыстың мақсаты автомобиль шамындағы ас тұзының сулы ерітіндісінің қатысуымен тұрақты тоқ кернеуі 1000 В төмен болған кезде ішінара разрядты зерттеу болды. Жоғары вольтты жартылай разрядқа ұқсас, жартылай разрядтың аяқталмаған және аяқталған жартылай разрядтар сияқты кезеңдері бөлінеді. Разрядты құру үшін контактор, кернеуді көбейтетін түзету схемасы, балласт кедергісі сияқты төмен вольтты жабдықтың элементтері қолданылды. Электролиттің қатысуымен аяқталған жартылай разряд жоғары тоқпен төмен кернеуде және кідіріс уақыты аз болған кезде жанатыны анықталды. Тоқ шамасын балласт кедергісімен реттеу кезінде аяқталған жартылай разряд сөнетін шар түрінде болады, балласт кедергісі болмаған кезде – жарылатын шардың пішіні. Бұл аяқталған разрядта соққы толқынының пайда болуымен немесе болмауымен байланысты.*

Кілт сөздер: *жартылай разряд, төмен кернеу, импульстік RC генераторы, коммутатор, ас тұзы ерітіндісі, аяқталмаған разряд, аяқталған разряд, разрядты бастау, жарқыраған глобулярлы түзілімдер, балласт кедергісі, кернеуді көбейту арқылы түзету схемалары.*

Исследование газодинамики частичного разряда

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***Аннотация.** Целью работы являлось проведение исследования частичного разряда при напряжении постоянного тока ниже 1000 В в присутствии водного раствора поваренной соли на автомобильной свече. По аналогии с высоковольтным частичным разрядом выделены такие стадии частичного разряда, как незавершенный и завершенный частичный разряды. Для создания разряда использовались такие элементы низковольтной аппаратуры, как контактор, схема выпрямления с умножением напряжения, балластное сопротивление. Установлено, что в присутствии электролита завершённый частичный разряд зажигается при низком напряжении с большим током и с малым временем запаздывания. При регулировании величины тока балластным сопротивлением завершенный частичный разряд имел форму затухающего шара, при отсутствии балластного сопротивления – форму взрывающегося шара. Это связано с возникновением либо отсутствием ударной волны в завершенном разряде.*

***Ключевые слова:** частичный разряд, низкое напряжение, импульсный RC-генератор, коммутатор, раствор поваренной соли, незавершенный разряд, завершенный разряд, инициирование разряда, светящиеся шаровые образования, балластное сопротивление, схемы выпрямления с умножением напряжения.*

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