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Experimental Studies of Partial Discharge Currents of Suspended Insulators of High-voltage Power Lines

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Abstract. *The purpose of article is to analyze the results of experimental studies of one of the components of the leakage current determined by partial discharges on the surface of suspended insulators of high-voltage power lines. A laboratory stand was made for conducting experimental studies. The oscillograms of current and voltage on the insulator are obtained. The sufficiency of a sample of waveforms for analysis was determined. A relative error was detected for the negative and positive half-wave voltage on the insulator. The density of the distribution of partial discharges relative to one period of voltage on the insulator is determined, recommendations for the development of a combined control and indication leakage current sensor are proposed.*

Keywords: *partial discharges, leakage current, electricity losses, suspended insulator, high-voltage overhead power lines, electric power industry, electric power, experimental research, current and voltage.*

Introduction

Currently, when transmitting electricity by means of overhead high-voltage power transmission lines (HVPTL), one of the most important economic indicators is the amount of active losses. Climatic conditions have a significant impact on the amount of active losses during the transportation of electricity. The most powerful influence on active losses is exerted by: humidity and air temperature, solar radiation, wind speed and direction. Humidification of the insulator surface causes an increase in leakage currents. The leakage current has two components: background current and partial discharge current. The background current has a frequency, the voltage of the live wires. The energy of the background current is mainly spent on heating suspended insulators [1-2].

Partial discharges (PD), having the character of an electric arc on the insulator surface, reduce its insulating properties. In addition, partial discharges ionize the air in the immediate vicinity of the insulator surface. An increase in the concentration of air ions leads to an increase in active electricity losses. Due to the ionization of the air, an electric arc may overlap the insulator or the entire garland of insulators. In turn, the overlap of insulators leads to a power outage on the section of the power line. Thus, the control of partial discharge currents is an urgent task of energy saving and reducing the number of emergencies. In order to reduce the number of emergencies and increase the reliability of the overhead line, it is necessary to constantly monitor the PD [3].

Analysis of the literature on the research topic

To date, various methods have been developed and used to monitor the condition of insulation, account for losses and diagnose overhead lines. The frequency characteristics of the PD pulse sequence have a wide spectrum. In the process of developing PD current sensors, it is very important to determine the technical requirements for its design and circuit solutions.

In [4-7], the results of studies of the mechanism of the appearance of surface PD, taking into account the properties of the insulator material, are presented. A diagram of a laboratory installation for the study of the PD is presented. In the course of experimental studies, the frequency of PD repetition and their voltage were monitored for insulation with various types of defects. A method for diagnosing various types of insulation defects depending on the density of the PD has been developed. The dependence of the frequency and amplitude of the PD with different types of defects is established.

In [8-10], a technique for diagnosing and predicting defects in suspended insulators is presented. The paper substantiates the possibility of using a sequence of partial discharge pulses to predict defects in suspended insulators. The proposed method does not consider the energy characteristics of the partial discharge current. Currently, glass and polymer materials are used in the construction of the suspended insulator. The presence of silicon in glass insulators implies the need to take into account the semiconductor properties of the insulator when analyzing electromagnetic processes. Current monitoring of partial discharges is an important tool for diagnostics and quantitative assessment of defects and insulation properties of insulators of high-voltage equipment of distribution substations and power lines. The most common PD detection system is based on electrical measurements, in which PD signals are recorded in the form of individual electrical pulses or their series [3].

Description of the object of research and the obtained waveforms

The object of the study is a disc-shaped glass suspended insulator of overhead power lines. In this article, an experimental study of the distribution of the pulse sequence and the current distribution density of the PD relative to the harmonic component of the voltage on the insulator is carried out.

In order to conduct experimental studies, a laboratory stand of a suspended insulator was developed, the block diagram of which is shown in Figure 1.

The laboratory stand in Figure 1 consists of an element of a current–carrying wire HVPTL 1, a receiving antenna for recording the dynamic characteristics of an electric discharge 2, a transformer 3, a laboratory autotransformer 4, a resistive voltage divider 5 and an oscilloscope with software 6. The oscilloscope recorded two parameters – the current of the insulator and the voltage drop on the insulator. According to Figure 3, the voltage regulation on the insulator F1 was carried out by means of an autotransformer T1 with a supply voltage of 220 V and a power of 200 watts. The voltage increase to 10 kV on the insulator F1 was carried out using a transformer T2 with a power of 200 W at a voltage

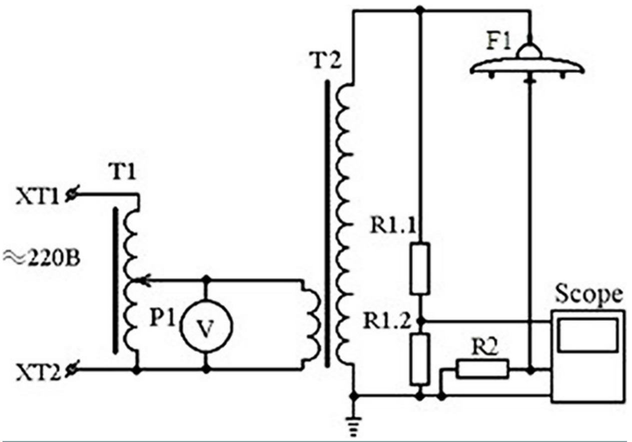


Figure 1 – Diagram of the laboratory stand

of 220 V on the primary winding. The voltage divider consisted of resistors R1.1 and R1.2 with a resistance of 18.6 mOhm and 1 kOhm, respectively. The resistance of the resistive current sensor R2 is 880 ohms. Registration of the voltage of the secondary winding T2 and the current through the insulator F1 is carried out on Scope.

In the course of experimental studies, several waveforms of current and voltage transients were obtained.

Results of laboratory stand research

As a result of experimental studies, oscillograms of current and voltage on the insulator were obtained, which are shown in Figure 2.

Using a graphical editor and a software application to the oscilloscope, the time and amplitude parameters of the PD were determined. By means of the Excel spreadsheet editor, an array was created where the amplitude and time parameters of the PD were taken into account within each interval for the entire waveform. Figure 3 shows a graphical form of the PD distribution relative to one half-wave of the voltage on the insulator.

In the graphical dependence of the PD distribution relative to one half-wave of voltage on the insulator, there is a grouping of current pulses in the first and third quarters of one period of the harmonic component of the voltage.

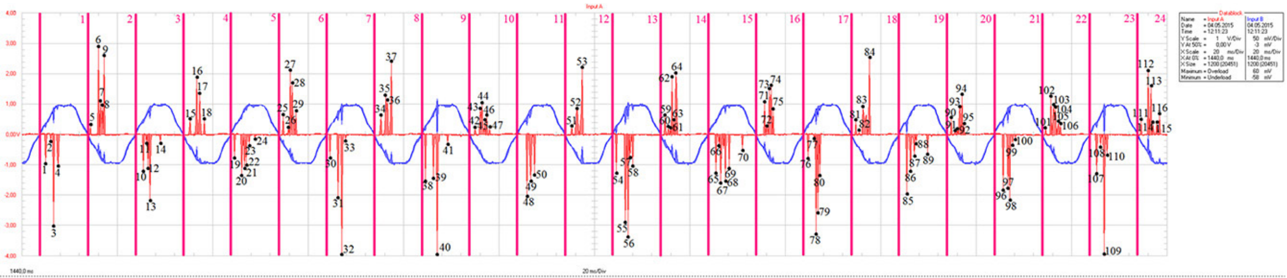
The graphical form of the dependence of the pulse distribution density of the PD is shown in Figure 4.

The maximum value of the pulse distribution density of the PD corresponding to the negative half-wave of the voltage is 10% greater than the maximum value of the pulse distribution density of the PD corresponding to the positive half-wave of the voltage. The dependence of the pulse distribution density of the PD corresponding to the positive half-wave of the voltage has one extremum, and the dependence of the pulse distribution density of the PD corresponding to the negative half-wave of the voltage has two extremes.

In order to perform a comparative assessment of the magnitude of the error δ at time intervals corresponding to the positive and negative half-waves of the voltage diagram applied to the insulator, using an Excel spreadsheet editor, the error dependence for the positive and negative half-waves of the voltage in the function of the sequence number of the sample (n) was constructed. The relative error for the positive (1) and negative (2) half-wave voltage across the insulator is shown in Figure 5.

Discussion and conclusions

According to the results in Figures 3 and 4, the vowel parameter of the samples was implemented to determine the densities of the PD distributions relative to one period of tension on isolators. Formatting, determining the affluence of the coefficients of the processed waveforms and following the religious features of the PD relative diagrams is strained on the



220v

Figure 2 – Oscillograms of the voltage and current of the PD

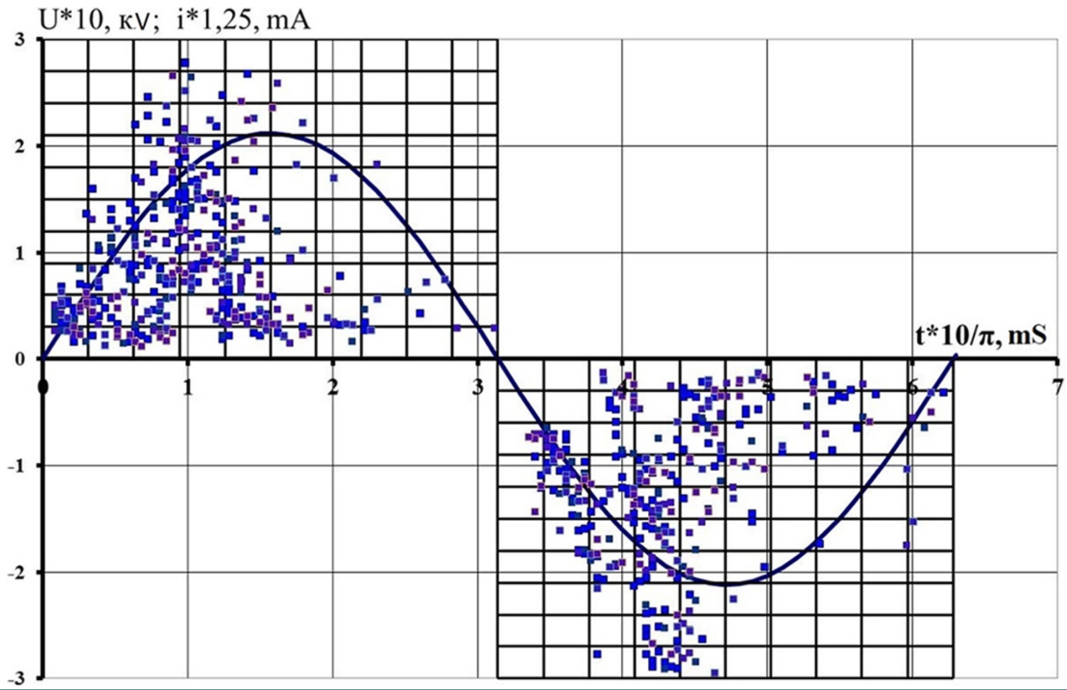


Figure 3 – Distribution of PD pulses relative to the voltage on the insulator

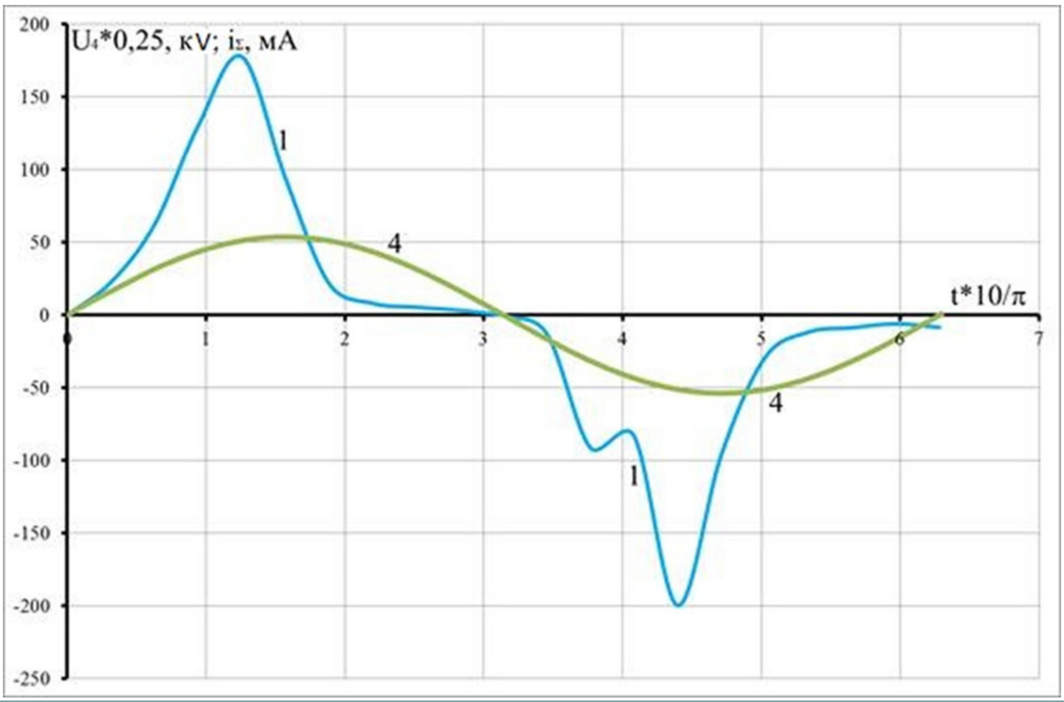


Figure 4 – Dependence of the pulse distribution density of the PD relative to the voltage on the insulator

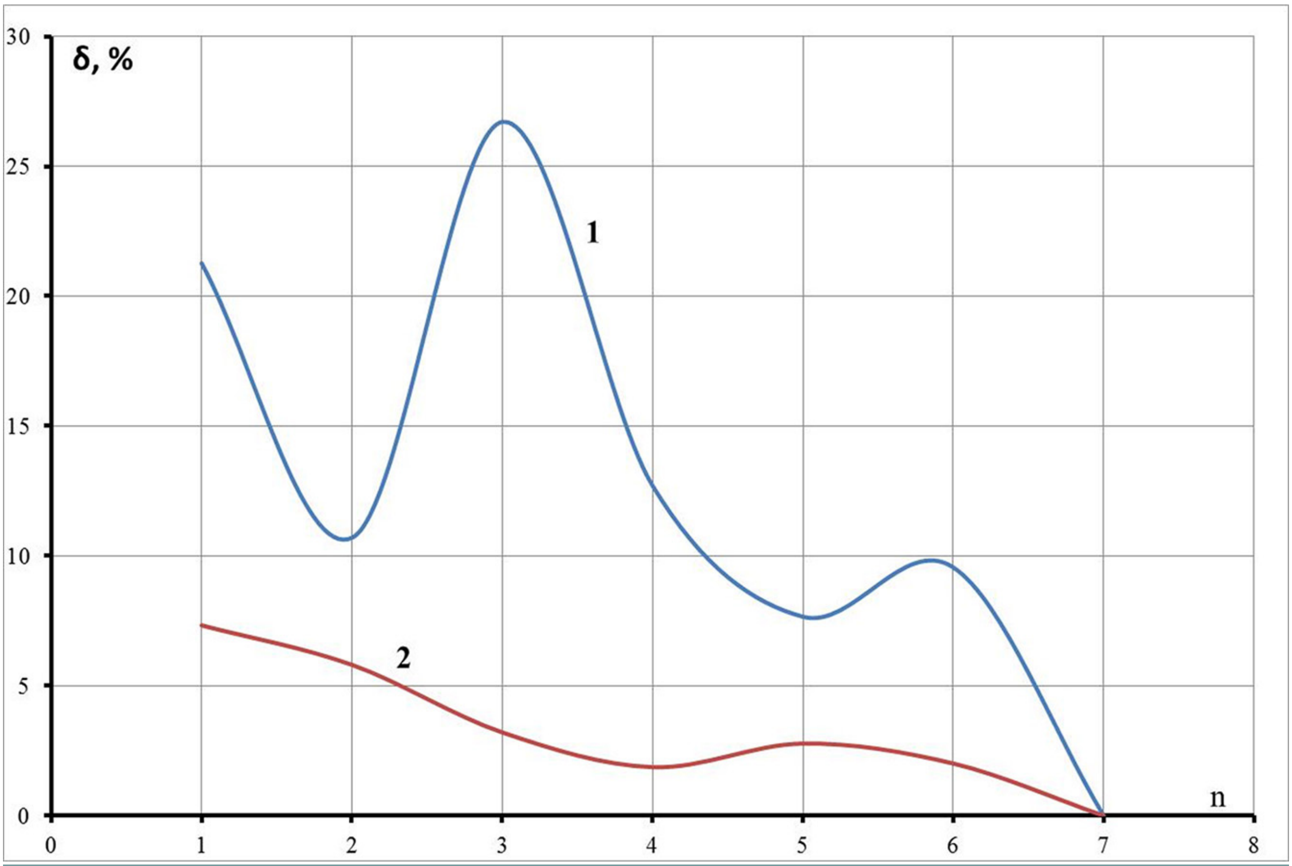


Figure 5 – Relative error for positive (1) and negative (2) half-wave voltage across the insulator

insulators of precipitation based on the algorithm of program experimental studies.

It should be noted that the maximum concentration of partial discharge pulses falls on the first and third half-cycles of the voltage.

According to the results in Figure 6, it is established that in order to develop the design of the leakage current sensor, it should be taken into account that the determination of the integral value of partial discharge currents of suspended insulators should be carried out using information of partial discharge currents from the time domain corresponding to the negative half-wave voltage, which will reduce the error, expand the range of parameter indication and shorten the time to establish the output parameter reading.

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Жоғары вольтты электр беру желілерінің аспалы оқшаулағыштарының ішінара разрядтарының токтарын эксперименттік зерттеу

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Аңдатпа. *Мақаланың мақсаты – жоғары вольтты электр желілерінің аспалы оқшаулағыштарының бетіндегі ішінара разрядтармен анықталатын ағып кету тогының құрамдас бөліктерінің бірінің эксперименттік зерттеулерінің нәтижелерін талдау. Эксперименттік зерттеулер жүргізу үшін зертханалық стенд жасалды. Оқшаулағышта ток пен кернеудің осциллограммалары алынды. Талдау үшін осциллограммаларды іріктеудің жеткіліктілігі анықталды. Оқшаулағыштағы теріс және оң жартылай кернеу толқындары үшін салыстырмалы қатесі анықталды. Оқшаулағыштағы кернеудің бір кезеңіне қатысты ішінара разрядтардың таралу тығыздығы анықталды, бақылау мен индикацияның ағып кету тогының аралас сенсорын жасау бойынша ұсыныстар ұсынылды.*

Кілт сөздер: *жартылай разрядтар, ағып кету тогы, электр энергиясының жоғалуы, аспалы оқшаулағыш, жоғары вольтты электр желілері, электр энергетикасы, электр энергиясы, эксперименттік зерттеулер, ток және кернеу.*

Экспериментальные исследования токов частичных разрядов подвесных изоляторов высоковольтных линий электропередач

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Аннотация. *Целью статьи является анализ результатов экспериментальных исследований одного из компонентов тока утечки, определяемого частичными разрядами на поверхности подвесных изоляторов высоковольтных линий электропередач. Для проведения экспериментальных исследований был изготовлен лабораторный стенд. Получены осциллограммы тока и напряжения на изоляторе. Определена достаточность выборки осциллограмм для проведения анализа. Выявлена относительная ошибка для отрицательной и положительной полуволны напряжения на изоляторе. Определена плотность распределения частичных разрядов относительно одного периода напряжения на изоляторе, предложены рекомендации для разработки комбинированного контрольно-индикационного датчика тока утечки.*

Ключевые слова: *частичные разряды, ток утечки, потери электроэнергии, подвесные изоляторы, высоковольтные линии электропередач, электроэнергетика, электроэнергия, экспериментальные исследования, ток и напряжение.*

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