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PORTABLE COMPLEX FOR REMOTE CONTROL OF HIGH-VOLTAGE INSULATORS USING WIRELESS DATA COLLECTION AND TRANSMISSION MODULE

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ABSTRACT

The identification of defective insulators from a common system of high-voltage insulators under operating voltage and located at certain distances from each other at distribution nodes and substations is a very difficult task. Based on these conditions, we developed a portable complex for the measurement and localization of occurrence of partial discharges (PD) on insulators with the ability to transfer information using a wireless network of process automation (WNPA) module. A complex two-channel method for remote diagnostics of the operating state of high-voltage insulators is developed. It is based on simultaneous recording, transmission and subsequent computer processing of PD signals detected by electromagnetic and acoustic sensors. WNPA modules with the ability to interact with Bluetooth, Wi-Fi, PLC, Ethernet, USB, RS-485, IrDA communication protocols are designed for monitoring the state of objects, automation of corporate and public buildings by collecting and transmitting information from external sensors, automatic retranslation of transmitted data, etc.

Keywords: remote diagnostics, partial discharges, high-voltage insulators, acoustic and electromagnetic sensors, wireless interface module, line of modules, a wireless network, automation system, set of parameters, method of transmitting information.

1. INTRODUCTION

Recently, research of electrical processes and mechanisms of aging and subsequent damage to various high-voltage insulation elements due to prolonged exposure to high voltage is actively developing. This problem occurs because of widespread use of outdated high-voltage insulation components. Their random replacement, without a reasoned identification of residual life, in this context, becomes an actual problem of identification of the residual life of high-voltage insulation components due to prolonged exposure to high voltage, along with missing methodology and tools for that purpose.

The stability of modern high-voltage power equipment is largely determined by the reliability of its insulating elements. The most vulnerable in this regard are high-voltage insulators much exposed to high voltage and adverse operating conditions. So, premature aging of ceramic or polymer insulating materials occurs. As a result, various defects occur, leading ultimately to electrical breakdown and even to complete destruction of high-voltage insulators. As is known [1], complete breakdown, as a rule, is preceded by microbreaks or electrical discharges, which shunt only a part of insulation between the electrodes, called partial discharge (PD). PD is the result of occurrence during the operation of local increases in the intensity of applied electric field in the volume or on the surface of insulation exceeding its electrical strength. The increase in the size of defects caused by various factors is accompanied by an increase in the intensity and number of PD at time intervals, as well as a decrease in the field strength for the occurrence of PD. The latter is equivalent to a change in the phase of the alternating operating voltage. In modern conditions, there is a significant need for remote, non-contact monitoring of the operating status of high-voltage equipment, especially high-voltage insulators.

2. MEASUREMENT PROCEDURE

Registration of electromagnetic pulses PD (Figure. 1) is carried out by an electromagnetic sensor, in this case, by a directional antenna, which makes it possible to detect pulses in the frequency range 0.5-600 MHz. Acoustic pulses are registered with an acoustic sensor, which is an active parabolic antenna operating at a frequency of 40 kHz. The choice of measurement frequency was justified by frequency dependence of wave attenuation, industrial and electromagnetic noise of surrounding electrical equipment. So acoustic noise dominates in the low-frequency region (20 Hz – 20 kHz), the upper frequency is limited by the frequency dependence of the attenuation ($f \geq 100$ kHz). In the 35-45 kHz interval, as experiments have shown, for a signal-to-noise ratio ≈ 2, acoustic pulses from the PD are recorded at a distance of 15-25 m. Taking into account low-frequency industrial electromagnetic interference in the range 50-200 MHz and above 600 MHz, the bands of 20-50 MHz and 400-550 MHz are the most preferred for electromagnetic registration of PDs. The intensity of PD signals is much higher in the second band than in the first.

When using a directional antenna, the complex provides localization of the signal source with an accuracy of 1-2 meters on a distance of 5-10 meters even with a large number of signal sources and reflective surfaces. In the microwave range, the level of interference is much lower and antennas with a high degree of directivity can be used to provide localization of the signal source in good conditions with localization accuracy of about 0.5 meters.

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These sensors are most sensitive to defects in the outer parts of the equipment.

The integrated acoustic sensor allows for a very precise localization of the source of signals within the object of low-frequency PD signals. In this case, the delay of the arrival of the acoustic pulse relative to the electrical signal at several points of the equipment is measured and, based on this; an approximate position of the source is calculated taking into account the design of a particular object. Acoustic sensors are practically not subject to external interference on power equipment of substations.

Schematic location of the measuring cells in the complex with the objects of measurement is shown in Figure-1. Connected to the ADC with a WNPA module, acoustic and electromagnetic sensors are placed next to the monitoring object. The data received from the sensors (MS) are collected and transmitted to the control station (CS) by means of the WNPA module.

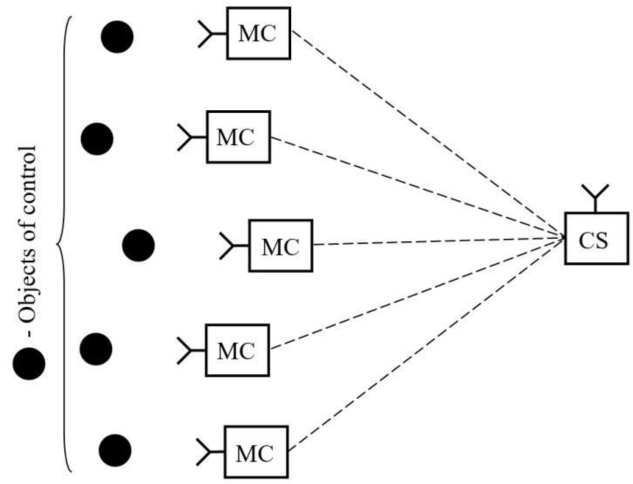

Figure-1. Schematic location of the measuring system: MC - Measuring cell, CS - Control station

The WNPA module is a microcontroller device with a radio transmitter IEEE 802.15.4 compliant operating with own software [2]. Depending on the applied tasks, the WNPA module can be used separately as a radio transmitter or as a data gateway compliant with the desired protocol (USB, RS-485, PLC, etc.) [3, 4].

Considering the process of PD registering in detail, Figure-2 shows a block diagram of the measuring device.

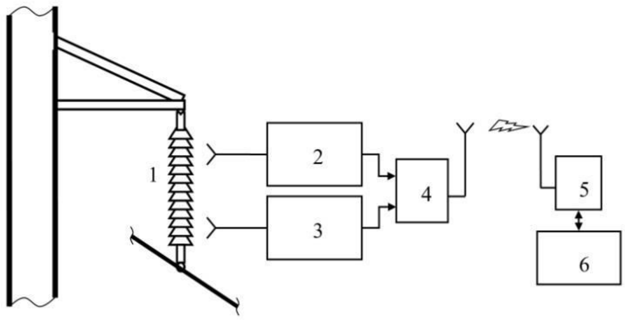

Figure-2. Block diagram of the measuring system: 1-high-voltage insulator; 2 - receiver of electromagnetic signals; 3 - receiver of acoustic signals; 4- A/D converter with WNPA module; 5 - WNPA module with USB interface; 6 - personal computer.

The set of blocks 2, 3 and 4 form a measuring cell, which is installed near the object of investigation - a high-voltage insulator (1 in Figure-2). Block 4 in Figure-2 is an A/D converter for converting data from sensors 1 and 2. The ADC is connected to the WNPA module via interfaces I^2C, SPI or UART/USART. The WNPA module transmits the received data to the dispatch center via 2.4 GHz radio channel. A WNPA module is connected to a personal computer (PC) installed in the control room via USB interface, which receives incoming data via the radio channel from the measuring cell (2, 3 and 4 in Figure-1). Reliable communication between neighboring devices can be carried out at a distance of up to 1,000 meters when adjacent devices are located within line of sight, which can be used in the event of failure of one or more devices because it is possible to transmit information bypassing faulty links.

The PC collects information, records it (6 in Figure-2) then processes the data (information about the amplitude, repetition frequency and phase of the signals) with the developed software [5]. The accumulation of signals over narrow phase intervals (of the order of 20 deg.) occurs within 18 sec. That completely satisfies the stochastic nature of the PD occurrence.

3. RESULTS OF RESEARCH

The PD signals processing ends with the construction of the following characteristics: the amplitudes and number of pulses in each phase interval and the amplitude distribution of the number of pulses. The results of data processing are shown in Figures 3 and 4.

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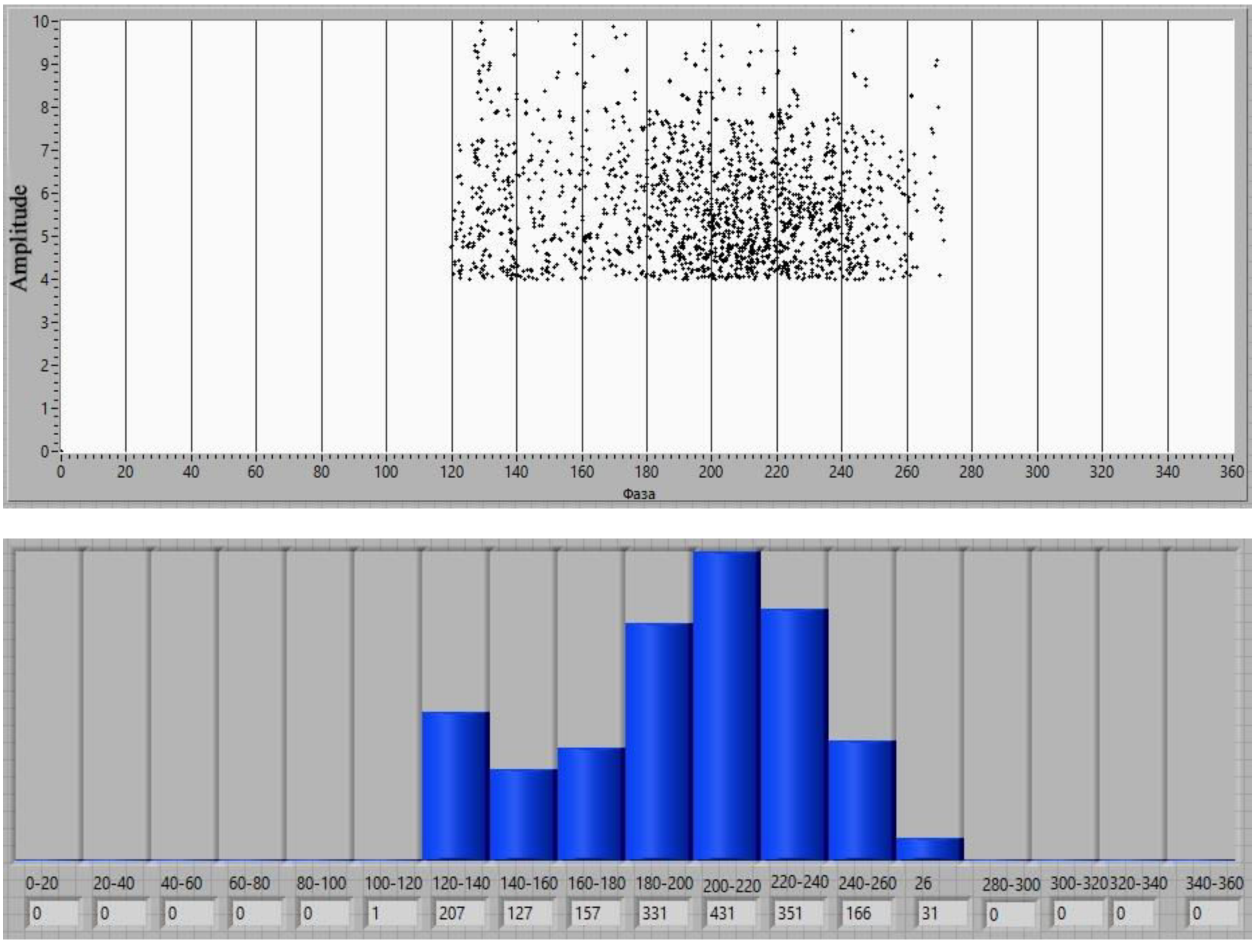

Figure-3. Amplitude-phase and phase characteristics of the PD number from the electromagnetic sensor (defective isolator).

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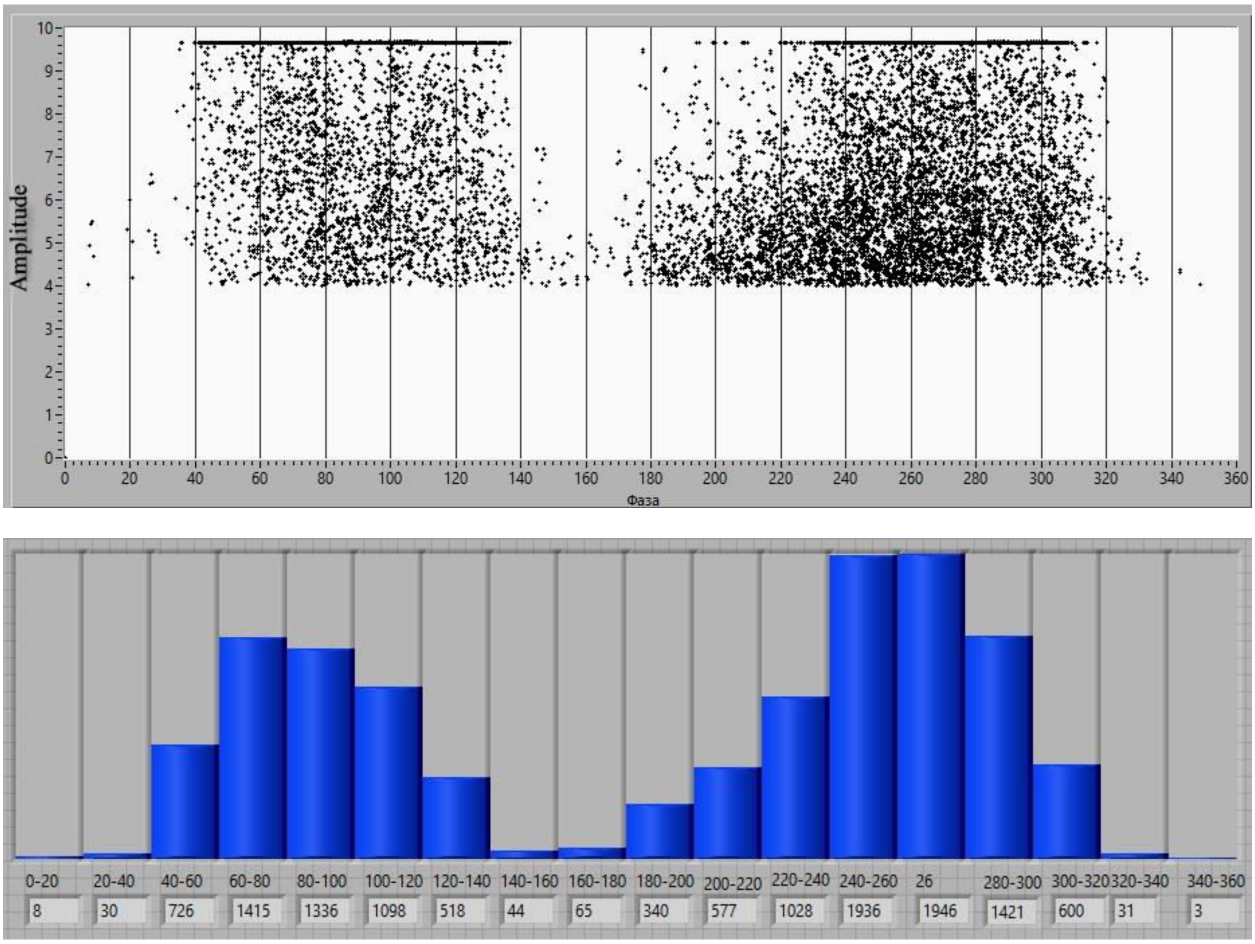

Figure-4. Amplitude-phase and phase characteristics of the PD number from the acoustic sensor (defective isolator).

The obtained phase distribution of the pulse parameters is compared with the previously recorded distribution of the pulse signal parameters for a (defect-free) high-voltage insulator of the same type [6]. Since the propagation velocities of electromagnetic and acoustic pulses differ by several orders of magnitude, a program synchronization block taking into account the distance between the defect and the sensors is used to synchronize them with each specific phase interval.

4. CONCLUSIONS

This paper presents the results of the development of an integrated two-channel method and a device that allows to remotely identify the operating state of high-voltage insulators during their operation. The experimentally established diagnostic features allow for a certain set of amplitude-phase characteristics to distinguish working high-voltage insulators [7-14] from defective ones that require immediate replacement.

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