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Technical Implementation of the Combined Leakage Current Sensor of Suspended Insulators

[1]**GORSHKOV Konstantin,** *Cand. of Tech. Sci., Associate Professor, k.gorshkov@list.ru,*
[2]***ABISHEVA Dinara,** *Doctoral Student, abisheva_dinara_95@mail.ru,*
[2]**KAVERIN Vladimir,** *Cand. of Tech. Sci., Acting Professor, kaverinkz@inbox.ru,*
[2]**KALININ Alexey,** *PhD, Head of Department, leokalinin@mail.ru,*
[2]**EM Gennadiy,** *Master, Senior Lecturer, egaapp@mail.ru,*
[1]*ITMO National Research University, Russia, Saint Petersburg, Kronverksky Avenue, 49,*
[2]*NPJSC «Abylkas Saginov Karaganda Technical University», Kazakhstan, Karaganda, N. Nazarbayev Avenue, 56,*
**corresponding author.*

Abstract. *The development of a combined leakage current sensor of a suspended insulator is presented. Negative factors of the influence of partial discharge currents on suspended insulators are described. The relevance of the development is justified. The requirements for the block diagram of a combined current sensor consisting of a background current sensor and a partial discharge current sensor are formulated. A block diagram of a combined leakage current sensor of a suspended insulator has been developed. A constructive solution for mounting a combined current sensor is proposed. Experimental studies of the upgraded current sensor were carried out. The main components of its layout are presented.*

Keywords: *combined current sensor, partial discharge current, background leakage current, electricity losses, suspended insulator, high-voltage overhead power lines, electric power industry.*

Introduction

Currently, when transmitting electricity from the north to the south of Kazakhstan, aerial high-voltage power transmission lines (AHVPTL) with a voltage of 500 kV are used.

The main elements of the AHVPTL are current-carrying wires, supports, suspended insulators, lightning rods and electric arc air arresters. Supports come in various modifications, but most of them are structurally portal-type supports. The supports consist of reinforced concrete vertical uprights, horizontal traverses, cable ties, anchor bolts for fixing the supports and a ground loop [1].

The failure of one of the elements of the lines leads to large economic losses for the organization operating these power lines [2].

Suspended insulators are designed for mechanical fastening of live wires and isolating them from the grounded horizontal traverse of the support. The main characteristics of insulators are mechanical strength and insulating properties [3]. In the process of reducing the insulation properties of suspended insulators, leakage currents increase, which leads to an increase in active losses of the entire line. Glass or polymer suspended insulators are used on AHVPTL with a voltage of 500 kV in the Republic of Kazakhstan.

Specialists of the Department of APP of Karaganda Technical University named after Abylkas Saginov together with employees of the company operating power lines, JSC «KEGOC», identified the main negative factors that have a significant impact on the reliability of structural elements and active losses of the AHVPTL: leakage current of the suspended insulator, icing of the current-carrying wires of the AHVPTL, as well as electrochemical corrosion of the fastening elements of portal-type supports located underground.

In order to reduce active losses and reduce the search time for failed suspension insulators, it is necessary to implement current monitoring of leakage currents and timely localize the damage sites by means of control and indication sensors. To develop combined leakage current sensors, it is necessary to analyze the physical properties of leakage currents [4].

The leakage current of the suspended insulator has two components: the background current characterizing active losses, as well as the current of partial discharges, when exceeding the maximum permissible value, which causes an electric arc overlap of the suspended insulator, which, in turn, leads to disconnection of the power line from the energy source [2].

One of the most common reasons why insulators lose their insulating abilities are climatic and man-made factors. The value of the background current increases during the operation of insulators due to their contamination. When the insulator is moistened, a surface conductive layer is formed, which is the main reason for the increase in background current. The energy of the background current of the industrial frequency of 50 Hz is spent on heating the suspended insulator.

Partial discharges are electric arc discharges along the insulator surface, the energy of which is spent on ionization of the insulator surface and ambient air, which lead to a decrease in its electrical strength and, as a consequence, to an increase in active electricity losses. Additionally, partial discharges form an ionized conductive channel, which leads to an electric arc overlap of the suspended insulator, followed by an emergency disconnection of the line section from the power source.

A number of negative influences, in addition to the above, should also include thermal heating and mechanical destruction of the glass insulators themselves, as well as the formation of microcracks in the glass due to sudden temperature changes in which dust and dirt accumulate.

Currently, to combat contamination, it is recommended to use periodic washing and wiping of the surfaces of insulators in order to remove them. To strengthen the external insulation, the number of insulators in the garlands is increased. These measures require additional economic costs when installing and operating power transmission lines. Practice shows that in order to increase the insulating properties of suspended insulators, it is required to apply hydrophobic coatings to the insulator surface [5], but in the Republic of Kazakhstan this method is ineffective, since the properties of such coatings decrease due to strong winds, dust storms containing abrasive sand. The most promising means of reducing the negative impact of leakage currents of suspended insulators is their current control. Therefore, the development of means of current control of leakage currents is of great practical importance and is relevant.

Currently, research and development of sensors monitoring leakage currents of suspended insulators is underway in the CIS countries. The value of the background current is controlled using transformer-type sensors or based on Hall elements. Structurally and schematically, the proposed sensor options cannot be used for direct monitoring of leakage currents of suspended insulators. Also, the issue of transmitting information from sensors to the control room has not been resolved. Sensors for partial discharge of leakage currents are under development.

Technical implementation

The combined leakage current sensors of the suspension insulators 3A, 3B and 3C are structurally located in the upper part of the portal-type 2 support and have a magnetic connection with the grounded part 5 of the suspension insulator attachment (Figure 1).

The paper [6] substantiates the relevance of the modular approach in the development of electronic technology. When developing a combined current sensor, the principle of constructive separation of electronic components by functional feature was used.

In order to check the operability of the combined leakage current sensor of the suspended insulator, experimental studies of the sensor layout were carried out. In accordance with the results of experimental studies, the following sensor correction was performed: the issue of choosing the polarity of the information signal has been schematically solved in the current sensor matching unit of the discharge particles; the optimal value of the time constant of the output signal filter has been determined; a bipolar voltage converter with galvanic isolation is installed to power the operational amplifiers of the background current and partial discharge current sensor matching units; a controller is installed that performs the functions of converting analog signals of the terminal cascades of sensors into digital form, as well as testing the information signal and preparing the transmitted information; a radio modem is installed for transmitting a telemetry signal over a radio channel.

The appearance of the layout of the upgraded current sensor is shown in Figure 2.

The main components of the layout of the upgraded current sensor:

1 – partial discharge current sensor matching unit;

2 – primary converter of the partial discharge current sensor;

3 – primary converter of the volumetric (background) current sensor;

4 – volume current sensor matching unit;

5 – power supply voltage converter of electronic equipment of combined current sensor;

6 – controller for primary processing of output signals of volume current and partial discharge current sensors, as well as preparation of the transmitted signal by means of a radio modem;

7 – radio modem.

The primary converter of the background current sensor 3 is made on the basis of a toroidal magnetic core made of electrical strip steel. The use of such a design makes it possible to reduce the negative impact of the high-frequency component of partial discharge currents and increase the amount of flow coupling between the windings of the primary converter. The electronic blocks of converters 1 and 4 are structurally placed in shielded enclosures, which increased their noise immunity. The design of the primary converter of the partial discharge current sensor 2 is based on the Rogovsky Belt scheme [7], which provides the required frequency characteristics.

The block diagram of the combined sensor of the industrial frequency background current and partial discharge current is shown in Figure 3.

The combined leakage current sensor consists of four functionally complete units:

B – volumetric (background) current sensor;

C – power supply unit;

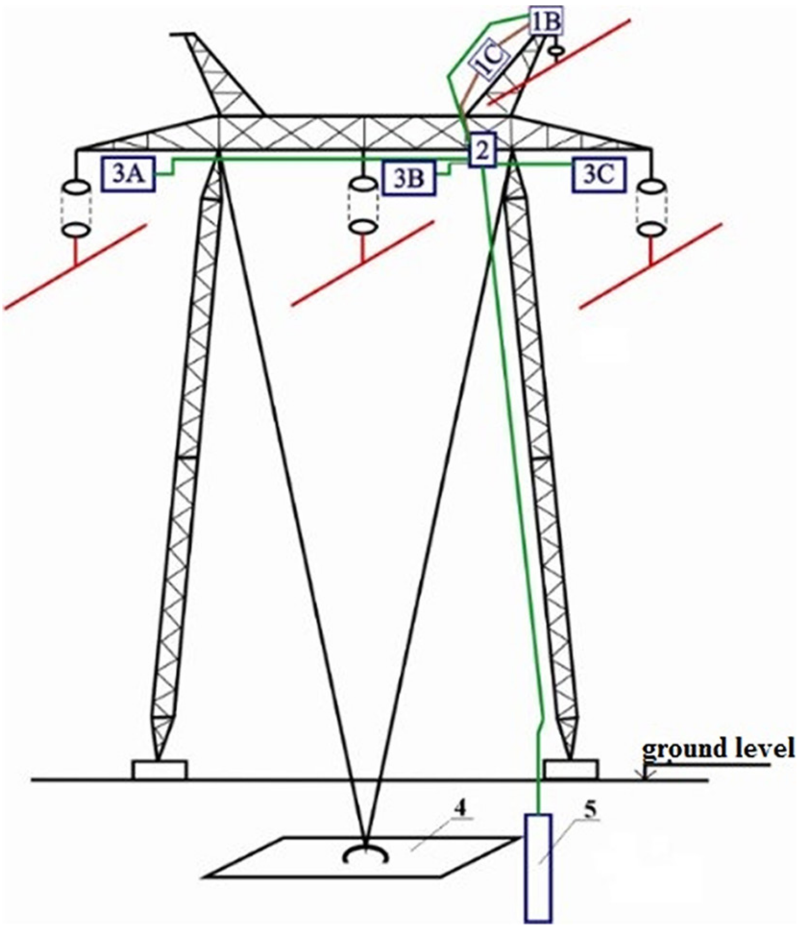

Figure 1 – Layout of the leakage current sensors of suspended insulators on the support

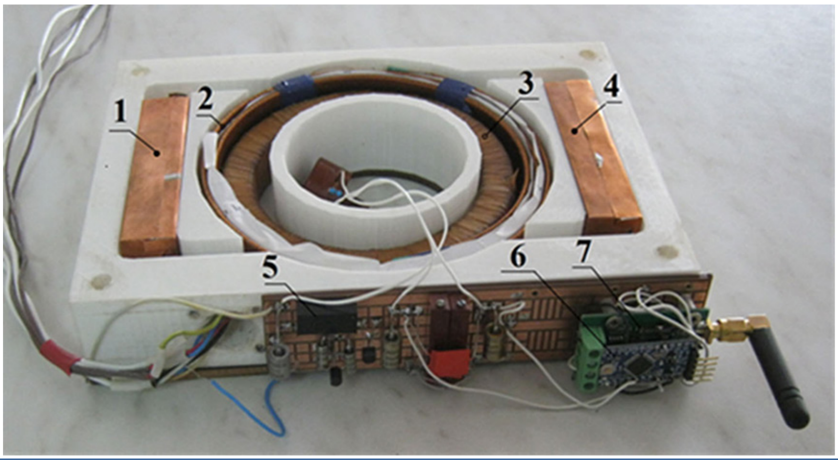

Figure 2 – Design of the layout of the combined leakage current sensor of suspended insulators

D – block for transmitting telemetry information over the radio channel;

E – partial discharge current sensor.

The volumetric leakage current of the suspended insulator Iob through the winding Wp of the transformer T1 enters the input of the amplifier A1 with a differential input. The main harmonic of the industrial frequency from the output of the amplifier A1 enters the input of the low-pass filter A2. The signal from the output of the filter A2 through the compensation winding Woc enters the resistor R1. The presence of negative feedback makes it possible to linearize the nonlinear dependence of the magnetic system of the transformer T1. The harmonic signal from the resistor R1 enters the input of the single-half-period precision rectifier A5. The signal from the output of the precision rectifier A5 enters the input of the sampling – storage device – C1. This ensures the conver-

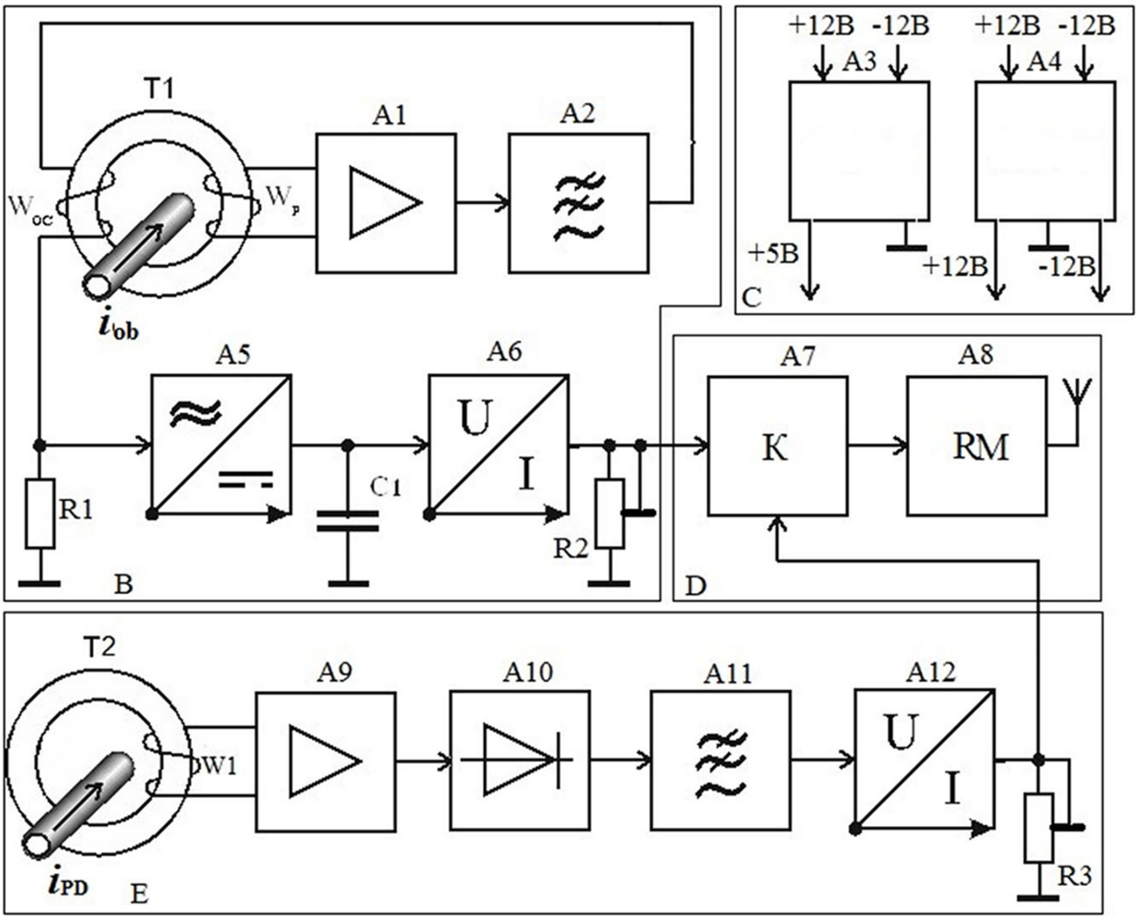

Figure 3 – Block diagram of the combined leakage current sensor of the suspension insulator

sion of the signal from the output of a single-half-period rectifier into an analog signal proportional to the amplitude value of the leakage current. To reduce the influence of electromagnetic interference on the analog output signal, it is converted to A6 in current form. By means of resistor R2, the output signal of the voltage-current converter A6 is consistent with the analog input of the controller A7.

Monitoring of the current of partial discharges in block E is carried out by means of a primary converter T2, made on the basis of a transformer with an air magnetic circuit (Rogovsky belt). The signal from the transformer winding W1 is amplified in the amplifier A9 with a differential input. In the precision rectifier A10, a constant component of the high-frequency signal of positive polarity is allocated. High-frequency signal filtering is implemented by a second-order filter A11. In order to increase the noise immunity of the partial discharge sensor, the voltage to current converter A12 converts the output signal of the filter A11 into a current form. By means of resistor R3, the signal is scaled and matched with the analog input of controller A7.

The collection, averaging, primary processing of information, as well as monitoring the operability of the radio channel is carried out by the A7 controller. The transmission of telemetric information is carried out by the RM radio modem.

In the course of experimental studies of the combined current sensor, a significant negative effect of the induced variable component in the power supply wires of the combined current sensor was found. In order to eliminate this negative influence, galvanic isolation devices combined with power supply voltage stabilizers are installed in the power supply circuit.

Thus, the relevance of the development of a combined leakage current sensor of a suspended insulator on AHVPTL is justified. Taking into account the safety requirements, a constructive solution for mounting a combined current sensor in the grounded part of the suspended insulator is proposed. A block diagram of a combined current sensor providing information transmission over a radio channel has been developed [8-10].

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Аспалы оқшаулағыштарының ағып кету тогының біріктірілген датчигінің техникалық жасауы

[1]***ГОРШКОВ Константин Сергеевич,*** *т.ғ.к., доцент, k.gorshkov@list.ru,*
[2]****АБИШЕВА Динара Каиржановна,*** *докторант, abisheva_dinara_95@mail.ru,*
[2]***КАВЕРИН Владимир Викторович,*** *т.ғ.к., профессор м.а., kaverinkz@inbox.ru,*
[2]***КАЛИНИН Алексей Анатольевич,*** *PhD, кафедра меңгерушісі, leokalinin@mail.ru,*
[2]***ЭМ Геннадий Аркадьевич,*** *магистр, аға оқытушы, egaapp@mail.ru,*
[1]*ДМОИ ұлттық зерттеу университеті, Ресей, Санкт-Петербург, Кронверкский даңғылы, 49,*
[2]*«Әбілқас Сағынов атындағы Қарағанды техникалық университеті» КеАҚ, Қазақстан, Қарағанды, Н. Назарбаев даңғылы, 56,*

**автор-корреспондент.*

Аңдатпа. *Аспалы оқшаулағыштың ағып кету тогының біріктірілген датчигінің дамуы көрсетілген. Ішінара разряд токтарының аспалы оқшаулағыштарға әсер етуінің жағымсыз факторлары сипатталған. Дамудың өзектілігі негізделген. Фондық ток датчигі мен жартылай разрядты ток датчигінен тұратын аралас ток датчигінің құрылымдық схемасына қойылатын талаптар тұжырымдалған. Аспалы оқшаулағыштың ағып кету тогының біріктірілген датчигінің құрылымдық схемасы жасалды. Біріктірілген ток сенсорын бекітудің конструктивті шешімі ұсынылды. Жаңартылған ток сенсорына эксперименттік зерттеулер жүргізілді. Оның орналасуының негізгі компоненттері ұсынылған.*

Кілт сөздер: *біріктірілген ток датчигі, ішінара разряд тогы, фондық ағып кету тоғы, электр энергиясының жоғалуы, аспалы оқшаулағыш, жоғары вольтты электр желілері, электр энергетикасы.*

Техническая реализация комбинированного датчика тока утечки подвесных изоляторов

[1]***ГОРШКОВ Константин Сергеевич,*** *к.т.н., доцент, k.gorshkov@list.ru,*
[2]****АБИШЕВА Динара Каиржановна,*** *докторант, abisheva_dinara_95@mail.ru,*
[2]***КАВЕРИН Владимир Викторович,*** *к.т.н., и.о. профессора, kaverinkz@inbox.ru,*
[2]***КАЛИНИН Алексей Анатольевич,*** *PhD, зав. кафедрой, leokalinin@mail.ru,*
[2]***ЭМ Геннадий Аркадьевич,*** *магистр, старший преподаватель, egaapp@mail.ru,*
[1]*Национальный исследовательский университет ИТМО, Россия, Санкт-Петербург, Кронверкский пр., 49,*
[2]*НАО «Карагандинский технический университет имени Абылкаса Сагинова», Казахстан, Караганда, пр. Н. Назарбаева, 56,*

**автор-корреспондент.*

Аннотация. *Представлена разработка комбинированного датчика тока утечки подвесного изолятора. Описаны негативные факторы влияния токов частичных разрядов на подвесные изоляторы. Обоснована актуальность разработки. Сформулированы требования к структурной схеме комбинированного датчика тока, состоящего из датчика фонового тока и датчика тока частичных разрядов. Разработана структурная схема комбинированного датчика тока утечки подвесного изолятора. Предложено конструктивное решение крепления комбинированного датчика тока. Проведены экспериментальные исследования модернизированного датчика тока. Представлены основные компоненты его макета.*

Ключевые слова: *комбинированный датчик тока, ток частичных разрядов, фоновый ток утечки, потери электроэнергии, подвесной изолятор, высоковольтные воздушные линии электропередач, электроэнергетика.*

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