TESTING OF PROTOTYPE SIGNALING DEVICES FOR INSULATOR CONTROL

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ABSTRACT

The article introduces laboratory studies of RFID tags used for radio frequency identification and control of the dielectric state of linear polymer insulators LK-70, which are used in the overhead power lines, including the contact network. The effect of electrical discharges on RFID technology performance capability, the effect of climatic factors, the angular distance dependence and the speed of registration of RFID tags for signal reception by a terminal for data collection are measured, the breakdown current is determined. The results of tests that confirm the possibility of radio-frequency identification monitoring of the state of insulators are analyzed.

Keywords: *overhead power line, contact network, polymer insulators, RFID technology, tests, prototypes, built-in signaling device, RFID tags.*

Background. *In research works [1–4] various methods for controlling the dielectric state of insulators are classified, methods are proposed, one of which is contactless mobile RF identification using RFID technology. The RFID option is suitable for the whole life cycle of insulators. RFID technology allows for direct monitoring of the location and individual and system analysis of the state of insulators, taking into account the input data. In this case, nothing prevents taking into account any production and technological factors affecting the performance of the product. The information on the equipment may contain data on the manufacturer of the product, the materials used, specifications, the method of attachment, installation, operating conditions, emergency situations in the power supply system.*

For the introduction of contactless identification control of insulators, a technical specification for creating RFID tags for a certain type of insulator and operating conditions was developed and agreed with the manufacturer (Table 1). The main purpose of the insulator with an integrated signaling device is to detect the dynamics of the dielectric properties of the product due to the passage of the leakage current or the breakdown current through the RFID tag. This allows to find the exact location of the site with reduced dielectric properties and provide more reliable protection of power lines by cleaning or replacing poor-quality insulators. The manufactured samples of insulators with an integrated signaling device must comply with GOST [state standard] 55189–2012 [5].

Table 1

Basic requirements for insulators with built-in signaling device LK 70/110 GP

Main technical parameters	
Climatic modification	UHL1
Degree of pollution	III
Reading angle	180 degrees
Simultaneous reading	50 tags
Reading speed	not less than 100 km/h
Reading range	not less than 10 m
Radio standards, electromagnetic compatibility	EN301489
Vibration resistance	EN60068–2–6 10–150 Hz: 0,075 mm/g
Impact resistance	EN60068–2–27 acceleration: 30 g
Building height of an insulator	1270–1370 mm
Length of an insulating part	1030–1130 mm
Length of a leakage path	2780–3100 mm

The choice of the insulator LK 70/110 GP as a prototype for a test sample was not accidental. Firstly, the task was to convince energy-supplying enterprises of the advantage of polymer insulators in comparison with the currently used porcelain and glass insulators. Secondly, insulators should be standard products and easily integrated into the existing power supply system.

Objective. *The objective of the author is to consider results of laboratory testing of RFID prototype signaling devices for insulator control.*

Methods. *The author uses general scientific and engineering methods, comparative analysis, graph construction, particular methods of electrical engineering.*

Results.

I.

The obtained samples of the first series of prototypes of RFID tags for a signal device on the insulator LK 70/110 GP with built-in electrodes (Pic. 1) were studied under laboratory conditions. For the experimental verification, the IzoTag tag samples made with TAL 500 were used.

The effect of electrical discharges on RFID technology operations, the effect of climatic factors, measurements of the angular dependence of the registration distance when the signal is received from the reader, the reading speed, the parameters of the current passing through the tag, and the breakdown current were studied. The work was carried out in the laboratories «High Voltage Engineering», «Material Science» of the department «Electric Machines» and the testing center of technical equipment of railway transport of USURT (Pic. 2). One of the positions was recorded during an inspection in an anechoic chamber using the reader CISC RFID Xplorer 100 and the software CISC RFID Xplorer Tag Tester v. 130320.

The main purpose of the tests was to study samples of RFID tags for monitoring the state of polymer insulators LK70/110. In the experiments, the influence of various factors on reception and transmission of a radio frequency signal between the reader and passive RFID tags was considered. The

Table 2

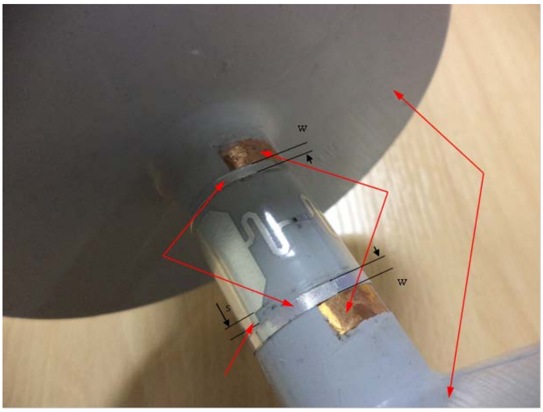
Results of climatic tests at a humidity from 20 to 98 %

Tag	Temperature, °C									
	+70	+55	+25	+10	0	-10	-20	-30	-55	-70
D9407 (LK-70)	+	+	+	+	+	+	+	+	+	+
D8C03 (PS-70)	+	+	+	+	+	+	+	+	+	+
D8C08 (CAP)	+	+	+	+	+	+	+	+	+	+
D8C0A (ShS-20)	+	+	+	+	+	+	+	+	+	+

Table 3

Results of measuring the breakdown current of RFID tags

Tag number	Op3	Op2	Op6	Op7
Breakdown current, A	0,27	0,28	0,28	0,29



Pic. 1. A sample of an insulator with a built-in signaling device.

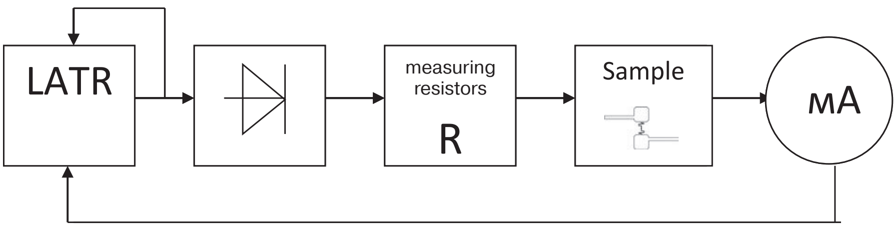
Pic. 2. Experimental tests of RFID-tags in the climate chamber using a portable reader.

RFID tags were read using a portable ATID AT570RF data collection terminal (reader).

For testing, samples of radio frequency tags with numbers D9407, D8C03, D8C08, D8C0A were fixed to insulators: polymer rod LK-70/10, suspension PS-70, pin glass ShS-20, and also to the modeled extended cap of the pin insulator. The location of the samples in the climatic chamber is shown in Pic. 3. The numbers on the reader have 28 characters, the last five characters of the tag code were taken to simplify the recording.

Experiments have shown that the test samples of RFID tags are read within the whole range specified by the temperature test program (from +70 to –70°C). It was noted that at temperatures below zero: from –10 to –30°C the speed and range of reading increased to some extent. Table 2 shows the results of climate studies.

Pic. 3. Location of RFID-tags in the climate chamber:
1 – D9407 on the polymer insulator; 2 – D8C03 on the suspended glass insulator;
3 – D8C08 on the cap of the pin insulator; 4 – D8C0A on the pin glass insulator.



Pic. 4. Block diagram of tests of RFID tags.

Pic. 5. Breakdown of the RFID tag on the test installation.

Thus, the test results confirmed the possibility of using the developed RFID-tag samples for contactless diagnostics of insulators made of various materials (glass, porcelain, polymer).

II.

The second part of the experiments involved the study of the effect of electric current on the reading range and the detection of the breakdown current of the prototype RFID tag. For this purpose, a test setup was assembled including a constant current source, laboratory automatic transformer (LATR), a rectifier, an ammeter, a measuring set of resistors, while RFID tag was connected to the circuit with the help of conductors. The structural scheme of the tests is shown in Pic. 4.

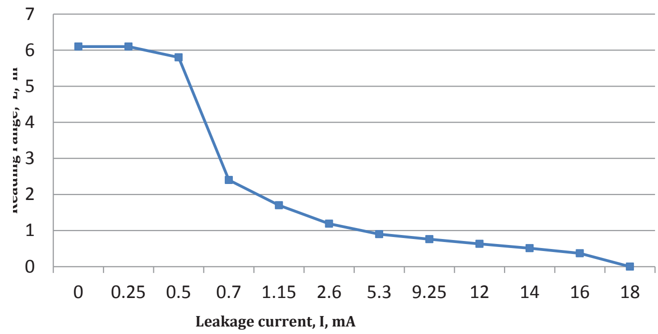
Table 3 shows the test results. The average breakdown current of four samples was 0,28 A. Pic. 5 shows the passage of the breakdown current through the chip of the sample Op3.

A graph of the dependence of the reading range of the RFID device on the current value is plotted (Pic. 6). The tag was connected directly to the test installation, the maximum reading range was 6 meters.

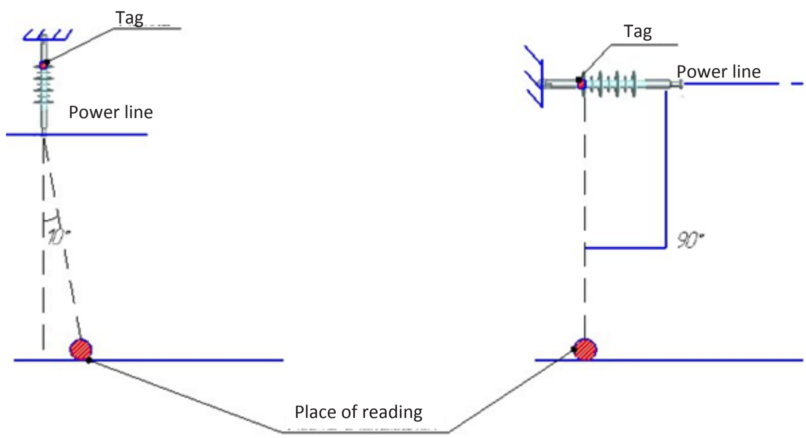
The effect of the flow current on the reading range when receiving the high-frequency signal between the reader and the passive tag is clearly traced: with increasing current, the reading range decreases. With the help of the built-in signaling device of the insulator, it is possible to detect the leakage current passing over 0,5 mA regardless of the cause of its generation (through-conduction current, geometric capacitance, absorption current).

The results of the research determine the passage of a small amount of current in the early stage of defect development and, possibly, allow repeated application of the tag, since its properties are restored in the absence of a current of less than 0,5 mA through it. For example, in case of contamination of the insulator surface, there is no need to replace the passive tag. After cleaning the insulator, the tag will still function.

The angular dependence of the registration distance which is constituted by the range and speed of reading the prototypes of RFID tags, was measured.



Pic. 6. Graph of dependence of the reading range of the RFID device on the current value.

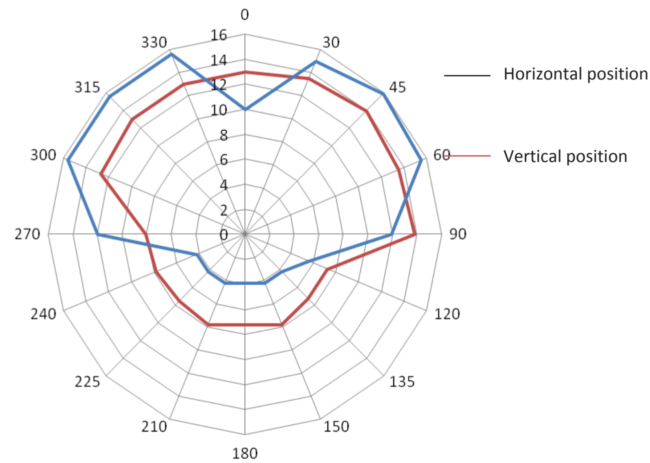


Pic. 7. The model of reading RFID-tags.

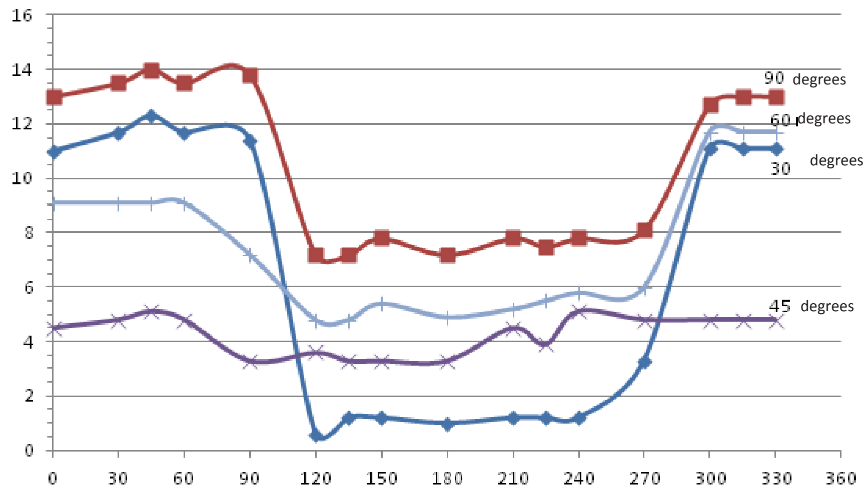
Pic. 8. Conducting experiments to determine range and reading speed regarding samples of RFID-tag on the insulator LK-70–110 with the location of insulators: a) vertical, b) horizontal.

This was done by changing the spatial position of the polymer insulator LK-70–110 with an integrated signaling device (Pic. 7). The measurements included horizontal and vertical positions, a fixed frequency of 870 MHz. The prototype was rotated by means of a pivot device around the vertical axis in the range of angles 0–360˚ in increments of 5˚ and 10˚ with horizontal and vertical placement of the insulator, respectively.

On the basis of the results obtained, diagrams of the angular dependence of the tag registration distance, shown in Pic. 9 and 10, were built. The speed of reading of the data during signal reception was determined using the ATUHF_Net program. The



Pic. 9. Vertical and horizontal location of the insulator in relation to the reader.



Pic. 10. Measurement of the angular dependence of the registration distance.

average speed was 791,75 readings per minute at a constant distance of 10,2 m, regardless of the reading angle. The results of the experiments revealed the effect of the angular dependence of the distance of registration of the RFID tag.

For example, the distance exceeded 10 m at angles from 0 to 90 and from 270 to 360 degrees. This fact should be taken into account when attaching a tag in relation to the location of the reader, and in the second stage it is necessary to envisage an increase in the reading angle to 360 degrees during development.

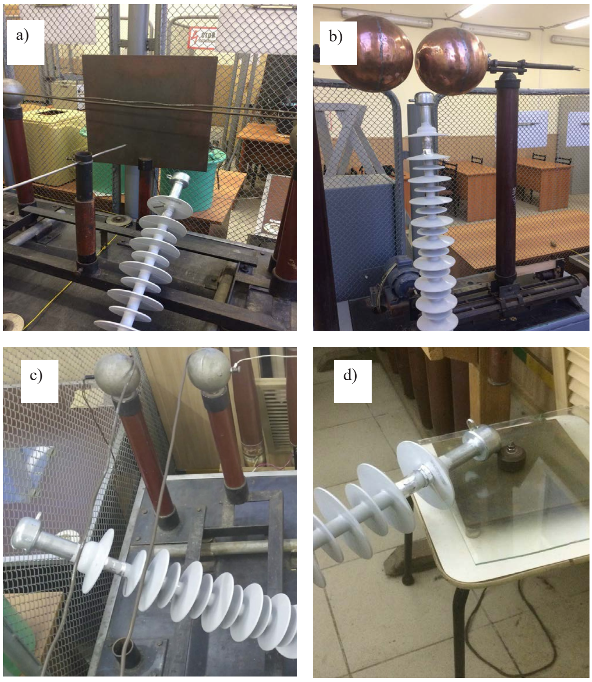
The influence of various types of electrical discharges was studied during the reception and transmission of signals between the reader and samples of passive tags that were attached to the insulator LK 70/110 (Pic. 12).

In the laboratory, the effect of discharges at the boundary of a solid dielectric and air (corona, spark, arc discharges) was checked. To perform the study, electrodes of various shapes were used: needle–plane, needle–needle, wire–wire.

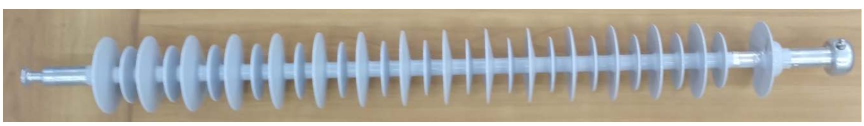
In the course of the experiments, the signal was received and transmitted between the reader and the RFID tag. As a result of the experiments with «wire–wire» electrodes, the tags were read, while the distance of reading was reduced as the distance between the wires was reduced.

It is known that as the distance between the electrodes increases, the breakdown voltage increases. When the distance between the potentials was 30 mm, and the tag was near the parallel wires (at a distance of 50 mm), a breakdown occurred, the RFID tag was no longer read. In the remaining experiments, when the distance between the insulator with the built-in tag and the electrodes was not more than 0,2 m, for electrodes «needle–plane», «needle–needle» and in the form of spark balls of 0,25 m in diameter, the reading was continuous, but with different speed and regardless of the mode of air breakdown, while the influence of external factors (pressure, temperature, humidity) and the distance between the operator and the sample were unchanged.

The obtained results do not contradict the main goal – to reveal the dielectric properties of insulators, since the breakdown of the tag increases with an increase in the breakdown voltage, and consequently this fact allows either to fix the decrease in the dielectric properties of



Pic. 11. Carrying out of researches on the form of electrodes: a) needle–plane; b) spark balls (d = 0,25); c) wire–wire; d) corona discharges.



Pic. 12. Insulator LKi 70/110-4 UHL1 with built-in RFID-tag signal device.

the air gap or the appearance of partial discharges caused by a decrease in dielectric properties of the insulator.

Conclusion. *The results of laboratory tests of the main characteristics of the RFID tag registration for a signal device placed on an insulator with built-in electrodes allow the following conclusions.*

The test samples underwent climatic tests. The influence of the leakage current on the detection distance of the tag and the possibility of repeated application of the tag are revealed when eliminating the cause of the appearance of a current higher than 0,28 A. In this case, it is possible to detect a leakage current exceeding 0,5 mA, that is, in the early stage of decrease in dielectric properties of the insulator. The influence of the angular dependence of the registration distance of prototypes of RFID tags is determined, which must be taken into account when attaching the tag to the insulator and further to increase the reading angle from 180 to 360 degrees.

The consequences of the influence of electrical discharges on the boundary of a solid dielectric and air were studied.

Experimental samples of insulators with an integrated signaling device have successfully passed the required laboratory tests. The obtained results confirm the possibility of using the radio frequency identification method for operational monitoring of the contact network insulators.

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