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N. Yu. Taran[1], V. V. Kaverin[2], E. Zh. Sarsikeyev[3], V. V. Titkov[4]
[1,2]Abylkas Saginov Karaganda Technical University,
Republic of Kazakhstan, Karaganda;
[3]S. Seifullin Kazakh Agrotechnical University, Republic of Kazakhstan, Astana;
[4]Peter the Great Saint-Petersburg Polytechnic University, Russian Federation, Saint-Petersburg
**e-mail: 1814n97@mail.ru*
[1]ORCID: https://orcid.org/0000-0002-7852-714X
[2]ORCID: https://orcid.org/0000-0003-2021-7445
[3]ORCID: https://orcid.org/0000-0002-7209-5024
[4]ORCID: https://orcid.org/0000-0002-6763-8688

SYSTEM OF MONITORING THE DEGREE OF DESTRUCTION FROM ELECTROCHEMICAL CORROSION OF UNDERGROUND METAL ELEMENTS OF OVERHEAD POWER LINE SUPPORTS

In this article, the studies were carried out and the block diagram was developed for a system of monitoring the degree of destruction from electrochemical corrosion of underground metal fastening elements for overhead power line supports. The analysis of the causes of emergency shutdowns of overhead power lines in the CIS and the methods of assessing the consequences used in foreign countries are carried out. The studies were aimed at modernizing the unified power system of Kazakhstan, reducing emergency situations and increasing reliability of power supply to consumers. The article presents a diagram of the design solutions of the proposed monitoring system for the portal-type support mounting unit. One of the aspects was direct controlling the degree of destruction of the support fastening points located underground. The proposed system allows collecting and transmitting to the control center *the information of the degree of destruction from electrochemical corrosion of metal fastening elements of portal-type supports.*

Key words: portal type supports, overhead power lines, power system safety, power system reliability, galvanic corrosion, U-bolt, monitoring system.

Introduction

In the course of overhead power lines (OHPLs) operation, unforeseen emergency situations arise that lead to outages. Each emergency shutdown is accompanied by large economic costs, automatic restrictions on the transmitted power to large consumers and switching overvoltages, which negatively affect the quality of electricity. In the world power history, there were large-scale blackouts with serious consequences. For the further development of the power industry of the Republic of Kazakhstan, it is necessary to take into account the experience and problems faced by power transmission organizations of foreign countries. Thus, scientists K.M. Jawadur Rahman, Maria Moosa Munnee, Shahriar Khan from the People's Republic of Bangladesh, in article [1] carried out the most complete analysis of major emergency shutdowns in the world that occurred from 1965 to 2015. The work used a formula for assessing damage during emergency shutdowns. The formula equally took into account the number of people injured and the time it took to recover from the consequences of the accident. According to this formula, the analysis of the scale of consequences and causes of emergency shutdowns was carried out. Most outages occurred due to natural weather conditions (hurricane, earthquake, snow storms). Weather conditions that have recently reached extreme values render a great impact on reliability of electricity transmission in the Republic of Kazakhstan. In severe weather conditions, the weak points of overhead power lines are susceptible to destruction.

Emergency outages of overhead power lines with voltage of 220 kV and higher, the length of which across the territory of the Republic of Kazakhstan is more than 26 thousand km, were analyzed by E. Bapin in work [3] based on the data from the power system operator.

Technical causes of emergency situations include damage to supports, insulator strings, linear fittings, cables, and wires. The main factor in damage to supports is corrosion of underground fastening elements. The STC FGC UES

JSC carried out and provided the analysis of the damage causes to overhead power lines in the CIS countries from 1997 to 2007. Figure 1 shows the ratio of damage caused by technical reasons [4].

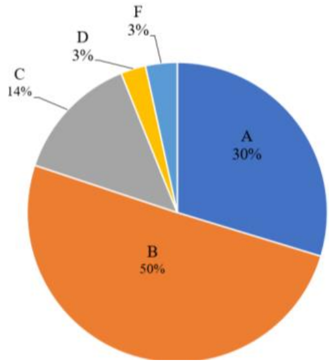

Figure 1 – Causes of emergency shutdowns in the CIS countries:
A – reducing the insulating properties of a string of insulators;
B – wire break; C – break of the lightning protection cable;
D – violation of the integrity of linear reinforcement;
F – destruction of supports

Most emergency shutdowns of overhead power lines in the CIS countries occur due to damage to insulators and wire breaks. In case of such damage, restoration work takes place in a short time. A different situation arises when the supports are damaged. The main causes of damage to portal-type supports are the destruction of metal fastening units. In these assemblies, the most vulnerable elements are the U-bolt and the metal loop. The destruction of these elements under the impact of electrochemical corrosion leads to the fall of the support. Since the overhead transmission line supports are interconnected, the fall of one support leads to the fall of groups of supports, which is accompanied by lengthy and costly restoration work.

At present, in the Republic of Kazakhstan, the main method of reducing emergency situations and assessing the technical condition of supports is, as a rule, the method of visual inspection of metal fastening elements of supports. This method is used in accordance with the regulations, and planned openings of soil are carried out along the entire length of the overhead power line. These measures are carried out with long-term power outages in large industrial zones and as a result, incur large financial costs. During the excavation of the soil, it is revealed that a significant part of the support fastening elements is not subject to electrochemical corrosion.

It is normatively recommended to replace the support fastening unit when the cross-section is lost by 20% of the factory values. However, operating organizations replace the support fastening elements on all the overhead power lines at once.

In this regard, an urgent task is the diagnosis and timely identification of the overhead power lines sections that are most susceptible to electrochemical corrosion.

The degree of electrochemical corrosion of metal elements depends, as a rule, on the properties of the soil. The main ones are as follows: the soil type, the composition and concentration of salts, pH, humidity, differential aeration, the soil structure, the presence of bacteria in the soil, the soil temperature, electrical resistivity.

Previously, methods based on the magnetoplastics effect and ultrasonic flaw detection were used to assess the condition of the metal fastening elements of overhead power transmission line supports located underground. They made it possible to determine the complete structure of the metal and to identify the sections of the element that were most susceptible to corrosion. But to do this, the sensor must be directly applied to the element under study. Such measurements were highly accurate and made it possible to determine internal defects in the metal fastening elements of overhead power transmission poles [5].

The fastening points of overhead power transmission lines located underground are subject to surface and pitting corrosion. Consequently, the use of these methods to diagnose the condition of elements is not advisable, since it is necessary to open the soil, and internal corrosion is very rare.

At present, there are no automated systems of remote monitoring the current state of metal fastening elements for portal-type supports. The proposed system will make it possible to determine timely the unit susceptible to electrochemical corrosion and the degree of its destruction. This will allow replacing it in a timely manner, taking into account planned outages. Developing and studying the system of monitoring the degree of destruction from electrochemical corrosion of metal fastening elements for overhead power line supports located underground is a science-intensive, technically complex and urgent task.

Materials and methods

The system of control and indication equipment in the field of high voltage electrical equipment is designed for continuous monitoring of the degree of the controlled object destruction and the residual life of metal elements subject to electrochemical corrosion when interacting with the ground, as well as taking into account the flow of induced currents through the controlled object.

There is a device for identifying the degree of corrosion damage, in particular, to the loops of anchor plates and U-shaped bolts of the underground anchor assembly of guy wires for overhead power transmission lines. There is a method of determining the corrosion state of metal elements of the anchor assembly of guy wires for supports, in which the loss of cross-sectional area of the elements under study is determined. It is compared with the standard value and based on the resulting difference, the degree of corrosion damage is judged, characterized in that the electrical resistivity of the soil is first measured in two mutually perpendicular directions near the anchor assembly. There are measured the electrode potentials of each U-shaped bolt relative to the copper-sulfate reference electrode, the induced currents in each guy support; there is determined the depth of immersion in the ground of the anchor plate loop and, according to the measurement data and according to the known calculation method, there is determined the loss of cross-sectional area of the metal elements [6].

The disadvantages of the device are include relatively low reliability of the results, the inability to monitor automatically changes in the degree of destruction from electrochemical corrosion over time, and the absence of the data transmission system to the control center.

At the Federal State Educational Institution of Higher Vocational Education "Novosibirsk State Academy of Water Transport", Novosibirsk, studies were carried out and a device was developed for measuring corrosion by the surface electromagnetic wave method. The method uses a microwave signal generator of tunable frequency; generator and indicator communication elements, a microwave power detector characterized in that it additionally contains a power divider connected to the output of the generator; a switch, the control input of which is connected to an electronic computing device, microwave inputs are connected to the output of the divider and an indicator communication element, and the output is connected to the input of the power detector; a digital-to-analog converter, the output of which is connected to control input of the microwave generator, and the input to the electronic computing device; an analog-to-digital converter, the input of which is connected to the output of the power detector, and the output to the electronic computing device; a temperature sensor connected to the input of the electronic computing device; an interface unit connected to an electronic computing device and a control electronic computing device [7].

The disadvantages of the device include technical complexity of diagnosing the degree of damage to metal structural elements; when operating the device, it is necessary to turn off the power in the area under study; the absence of a data transmission system to the control center.

The proposed system of monitoring the degree of destruction from electrochemical corrosion of metal elements located underground allows expanding functionality by constant monitoring their condition, without excavation during measurements and transmitting information to the control center via a wireless network.

Results and discussion

The system of monitoring the degree of destruction from electrochemical corrosion of metal elements located underground consists of a serially connected monitoring object, a primary transducer unit connected to a matching and measurement unit, the output of which is connected to the input of the communication unit, and contains a system power supply unit. It differs in the design of the sensitive element and the presence of a communication unit [8].

Figure 2 shows a block diagram of monitoring the degree of destruction from electrochemical corrosion of metal elements located underground.

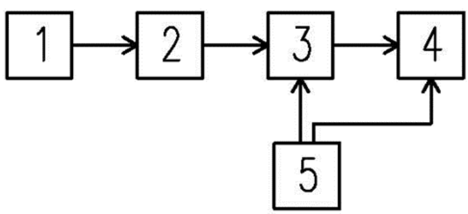

Figure 2 – Block diagram:
1 – object of control; 2 – primary converter block; 3 – coordination and measurement block; 4 – communication unit; 5 – power supply unit

The system consists of control object 1, primary converter unit 2, matching and measurement unit 3, communication unit 4, power supply unit 5.

The system continuously monitors the sequence of the sensitive element destruction.

It is known that significant reducing the regulated service life of metal structural elements is caused by electrochemical corrosion that occurs during interaction with the soil [9, 10].

The system operates as follows: control object 1 is connected to primary transducer block 2 and the signal about the state of the sensitive element from the output of primary transducer block 2 is supplied to the input of matching and measurement block 3. There the signal is converted into a digital code and the signals received from primary converter block with saving the results. The signal about the state of the sensitive elements from the output of matching and measurement unit 3 is supplied to the input of communication unit 4 that transmits this signal to the control center. Based on the data received, the control center makes a decision on either compliance with current operating conditions or non-compliance.

Unit 5 is used to power the system.

The blocks included in the device are implemented on the basis of the known technical solutions: control object 1 is a metal structure made of steel and located underground; primary transducer block 2 consists of sensitive elements and of four metal plates with the thickness of 2, 4 , 8, 12 mm made of steel; matching and measurement unit 3 is in the simplest case a microcontroller with a certain set of software and hardware that converts the number of destroyed sensitive elements into a digital code; communication unit 4 is a wireless transmitting device in the form of GSM or radio modem; power supply unit 5 is a rechargeable battery. Since the process of electrochemical corrosion is slow and data are transmitted once a month within 2-3 minutes, it is sufficient to use a rechargeable battery for power supply. The batteries are replaced during scheduled work on overhead power lines.

Figure 3 shows a block diagram of design solutions for a system of monitoring the degree of destruction from electrochemical corrosion of metal elements located underground, on a portal-type support.

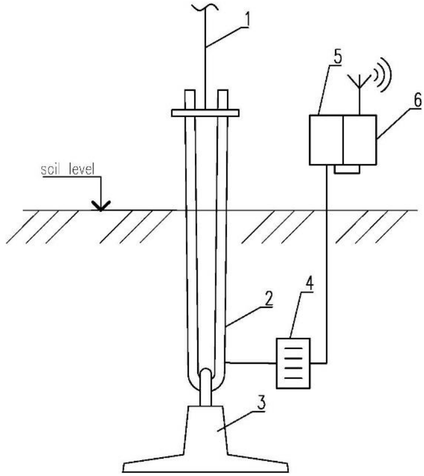

Figure 3 – Diagram of design solutions for the monitoring system:
1 – cable guy 1, 2 – U-shaped bolt; 3 – anchor plate with a loop;
4 – primary converter block; 5 – coordination and measurement block; 6 – communication unit

The proposed design solutions for the monitoring system make it possible to quickly replace the batteries and to transmit data to the control center. The presence of electrical contact between the sensitive element and the object of study allows taking into account the effect of leakage currents on electrochemical corrosion.

Conclusions

Thus, the work substantiates the relevance of developing an automated diagnostic system for support fastening elements, formulates the basic requirements and proposes a technical implementation.

The proposed system allows periodical collecting the information of the degree of destruction from electrochemical corrosion of metal fastening elements of supports located underground, and transmitting it to the control center.

For further research, it is necessary to develop an autonomous power supply unit for the monitoring system. This will eliminate routine work for replacing batteries.

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**Н. Ю. Таран*[1], *В. В. Каверин*[2], *Е. Ж. Сарсикеев*[3], *В. В. Титков*[4]

[1,2] Әбілқас Сағынов атындағы Қарағанды техникалық университеті, Қазақстан Республикасы, Қарағанды қ.;

[3]Қазақ агротехникалық университеті. С. Сейфуллин атындағы, Қазақстан Республикасы, Астана қ.;

[4]Ұлы Петрдің Санкт-Петербург политехникалық университеті, Ресей Федерациясы, Санкт-Петербург қ.

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ЖЕР АСТЫНДА ОРНАЛАСҚАН МЕТАЛЛ ЭЛЕМЕНТТЕРДІҢ, ӘУЕ ЭЛЕКТР ЖЕЛІЛЕРІНІҢ ТІРЕКТЕРІНІҢ ЭЛЕКТРОХИМИЯЛЫҚ КОРРОЗИЯДАН БҰЗЫЛУ ДӘРЕЖЕСІН БАҚЫЛАУ ЖҮЙЕСІ

Бұл мақалада зерттеулер жүргізіліп, жер астында орналасқан электр желілерінің тіректерін бекітетін металл элементтерінің электрохимиялық коррозиядан бұзылу дәрежесін бақылау жүйесінің құрылымдық схемасы жасалды. Авариялық ажыратулардың себептеріне талдау жасалды ТМД аумағындағы әуе электр желілері мен салдарын бағалау әдістері шет елдерде қолданылады. Зерттеулер Қазақстанның бірыңғай энергетикалық жүйесін жаңғыртуға, авариялық жағдайларды азайтуға және тұтынушыларды электрмен жабдықтау сенімділігін арттыруға бағытталған. Бағыттардың бірі-жер астында орналасқан тіректерді бекіту түйіндерінің бұзылу дәрежесін тікелей бақылау. Мақалада портал тірек тірек қондырғысы үшін ұсынылған бақылау жүйесінің құрылымдық шешімдерінің схемасы келтірілген. Ұсынылған жүйе Портал типті тіректерді бекітудің металл элементтерінің электрохимиялық коррозиясынан жойылу дәрежесі туралы ақпаратты жинауға және диспетчерлік пунктке беруге мүмкіндік береді. Ақпаратты өңдеу нәтижелері бойынша әуе электр беру желілерінің тіректерін бекітудің жерасты элементтерін ауыстыру туралы шешім қабылданады.

Кілтті сөздер: портал түріндегі тіректер, әуе электр желілері, электр желісінің қауіпсіздігі, электр желісінің сенімділігі, электрохимиялық коррозия, U-болт, бақылау жүйесі.

**Н. Ю. Таран[1], В. В. Каверин[2], Е. Ж. Сарсикеев[3], В. В. Титков[4]*
[1,2] Карагандинский технический университет имени Абылкаса Сагинова, Республика Казахстан, г. Караганда;
[3]Казахский агротехнический университет имени С. Сейфуллина, Республика Казахстан, г. Астана;
[4] Санкт-Петербургский политехнический университет Петра Великого, Российская Федерация, г. Санкт-Петербург
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СИСТЕМА МОНИТОРИНГА СТЕПЕНИ РАЗРУШЕНИЯ ОТ ЭЛЕКТРОХИМИЧЕСКОЙ КОРРОЗИИ МЕТАЛЛИЧЕСКИХ ЭЛЕМЕНТОВ, РАСПОЛОЖЕННЫХ ПОД ЗЕМЛЕЙ, ОПОР ВОЗДУШНЫХ ЛИНИЙ ЭЛЕКТРОПЕРЕДАЧ

В данной статье проведены исследования и разработана структурная схема системы мониторинга степени разрушения от электрохимической коррозии металлических элементов крепления опор воздушных линий электропередач, расположенных под землей. Выполнен анализ причин аварийных отключений воздушных линий электропередач на территории СНГ и методы оценки последствий применяемый в зарубежных странах. Исследования направлены на модернизацию единой энергетической системы Казахстана, уменьшение аварийных ситуаций и повышение надежности электроснабжения потребителей. Одним из направлений является непосредственный контроль степени разрушения узлов крепления опор, расположенных под землёй. В статье представлена схема конструктивных решений предлагаемой системы мониторинга для узла крепления опоры портального типа. Предлагаемая система позволяет собирать и передавать на диспетчерский пункт информацию о степени разрушения от электрохимической коррозии металлических элементов крепления опор портального типа. По результатам обработки информации принимается

решение о замене подземных элементов крепления опор воздушных линий электропередач.

Ключевые слова: опоры портального типа, воздушные линии электропередач, безопасность энергосистемы, надежность энергосистемы, электрохимическая коррозия, U-образный болт, система мониторинга.

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«Toraighyrov University» баспасынан басылып шығарылған
Торайғыров университеті
140008, Павлодар қ., Ломов к., 64, 137 каб.

«Toraighyrov University» баспасы
Торайғыров университеті
140008, Павлодар қ., Ломов к., 64, 137 каб.
67-36-69
e-mail: kereku@tou.edu.kz
www.vestnik-energy.tou.edu.kz