About the development of a method for remote determination of the underground pipeline insulation coating condition

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Abstract. Corrosion protection of underground steel pipelines is carried out by means of electrochemical protection and insulation coatings. During the operation of pipelines, under the effect of various external factors, the insulation properties of coatings decrease over time, which leads to an increase in the operating modes of electrochemical protection means. Operating organizations need to monitor the condition of the coating of underground pipelines, to predict the protection against corrosion and to plan repair work. Using the remote corrosion monitoring systems made it possible to obtain a mathematical model of the electrochemical protection system against corrosion of the object, which allowed to determine the true impact of cathodic current sources on the protective potential control points, excluding the impact of related and external power sources. Knowing the effect of the source on the protective potentials on the section, accordingly, it can accordingly be assumed that it is possible to identify patterns between the amount of change in this effect and the condition of the insulation coating on the section. A method for determining the integral condition the insulation coating is proposed, with the possibility of remote implementation on the basis of remote corrosion monitoring equipment, for which the pipeline model was tested in the laboratory. Testing of the developed method on a real gas main transport facility showed its practical applicability, as well as sufficient accuracy for engineering tasks, in determining the indicators of the insulation coating condition.

1. Introduction
The insulating coating plays the role of a primary diffusion barrier and prevents the metal of the pipeline from contacting a corrosive environment (water, oxygen, air, etc.) [1].

At each stage of the life cycle, the insulating coating is affected by various factors that worsen its properties and contribute to the formation of insulation defects (figure 1) [2].

As known, the insulating coating condition affects the parameters of the electrochemical protection equipment. In case of an unsatisfactory condition of the insulating coating, as a rule, under-protection zones are formed in the area of the protected object, since the current strength of the cathodic protection stations (CPS) is not enough to ensure the protective potential along the entire length of the object. Corrosion protection specialists must monitor the condition of the insulating coating, to monitor the operation of the electrochemical protection system, as well as to plan the timing and amount of overhaul of the coatings.

The disadvantages of operating methods for determining the coating condition during operation, such as cathodic polarization, contactless assessment of signal attenuation in the pipeline, intensive electrical measurements, etc. the accuracy of the chosen methods. Accordingly, it is necessary to expend human
and material resources, there is no possibility of monitoring changes in the coating condition over time. In addition, the operating methods are not applicable as part of a remote corrosion monitoring system [3, 4].

The fundamental possibility of performing remote measurements of security indicators is associated with the increased functionality of modern cathodic protection stations capable of remotely changing the output parameters of protective cathodic current sources through an automated process control system, as well as measuring the value of protective potentials at control points through a remote corrosion monitoring subsystem, as well as transmitting the specified data on the automated workstation (AWS) of corrosion monitoring.

Accordingly, the development of methods and algorithms on the basis of the subsystem remote corrosion monitoring to calculate the resistance value of the insulation coating on the pipeline, with the output of information for professionals operating pipelines organizations is a necessary task, which in general will improve the reliability of the anti-corrosion protection system and the entire hydrocarbon transport system [1-3].

2. Development of a method for remote determination of the underground pipeline insulating coating condition

The value of the magnitude of the protective potential for each point of the underground steel pipeline depends on the set of values of the affecting resistances.

The effect of the current strengths of cathodic protection stations on the value of the protective potential at each control point of the pipeline can be expressed through the matrix of coefficients. Accordingly, the value of these coefficients is similar to the parameter of the input characteristic resistance of the pipeline, which also takes into account the longitudinal resistance of the pipeline, the resistance to spreading of the pipeline current, which depends on the specific electrical resistance of the soil and the transient resistance of the pipeline.

The data required to find the coefficients of affect today can be obtained and processed remotely, since all cathodic protection stations are telemechanized today, and there is also an active implementation of equipment for the remote corrosion monitoring subsystem, which allows obtaining data on the values of protective potentials at control points. Accordingly, the use of the capabilities of modern equipment makes it possible to obtain a mathematical model of the security of the object, on the basis of which it is possible to develop methods for the remote determination of the insulation coating condition [4-7].

The authors propose a method for assessing the technical condition of the insulation coating of an underground pipeline section, based on a mathematical model of the object's security [8].

The proposed method for finding the insulation coating condition is to determine the current propagation constant in the controlled area between the control point and the selected cathodic protection station, to find which it is necessary to know the value of the change in protective potentials that is caused by the selected cathodic protection station. These potential shifts cannot be measured using direct measurements, since the results always contain additive errors associated with interference from third-party power supply sources, neighboring cathodic protection stations and cathodic protection stations of foreign objects, and power line interference.

The use of a mathematical model of security eliminates the effect of the indicated interference and leveling. To find the coefficients of the mathematical model of the object's security at the drainage point and at the control point, remotely change the operating modes of the selected cathodic protection station, as well as two adjacent cathodic protection stations for it, and remotely, using the remote corrosion monitoring subsystem, measure the values of the protective potentials (figure 1).
Figure 1. Scheme for assessing the insulation coating condition on the section of the operating main gas pipeline.

The effect coefficients are calculated as the ratio of the increment of the protective potential "pipe-ground" to the increment of the current of the cathodic protection station according to the formula [6-8].

$$ A_{im} = \frac{\Delta \phi}{\Delta I_p} \quad (1) $$

To determine the offset value of the protective potential of the “pipe-to-ground" $\phi_{p,g}$ at the control point and at the point of drainage $\phi_{d,p}$ one can by removing from the measured values of the protective potential aggregate impact imposed on this point adjacent cathodic protection stations and stationary potential of the metal $\phi_A$ at a given point by formulas:

$$ \Delta \phi_{p,g} = \phi - A_{1rel} \cdot I_{1rel} - A_{2rel} \cdot I_{2rel} - \phi_A \quad (2) $$

$$ \Delta \phi_{d,p} = \phi_2 - A_{21rel} \cdot I_{1rel} - A_{22rel} \cdot I_{2rel} - \phi_A \quad (3) $$

To calculate the value of the current propagation constant in the control area $\alpha(t)$ 1/m, one can using the formula:

$$ \alpha = \frac{\ln{\frac{\Delta \phi_{d,p}}{k \cdot \Delta \phi_{p,g}}}}{2L_c} \quad (4) $$

where $k$ - coefficient that takes into account the mutual effect of neighboring CPS, equal 2; $L_c$ - distance from the control point to the drainage point of the selected cathodic protection station (CPS).

To determine the transition resistance of the pipeline $R'_{pr}$ Ohm $\cdot$ m, one can using the formula:

$$ R'_{pr} = \frac{R_{pl}}{\alpha^2} \quad (5) $$
where \( R_{pl} \) - longitudinal resistance of the pipeline, Ohm / m, determined by the formula:

\[
R_{pl} = \frac{\rho_{pl}}{\pi(D_{pl} - \delta_{pl})\delta_{pl}} .
\]  

(6)

where \( \rho_{pl} \) - specific electrical resistance of the pipeline metal, Ohm · m;
\( D_{pl} \) - pipeline diameter, m;
\( \delta_{pl} \) - pipeline wall thickness, m.

3. Practical implementation of the developed method

For testing the developed method determining the insulating coating condition, it was tested at a real facility for gas transmission.

A section of the main gas pipeline was selected, where work was carried out to determine the insulation coating condition. The section was selected based on the conditions that the integral condition of the insulation coating was assessed on it.

The object of the research was a section of the gas pipeline “Perm-Gorky 1” (840 km - 849 km) with a length of 9 km. Gas pipeline diameter was 1220 mm, wall thickness was from 10.5 mm to 15.4 mm. The gas pipeline was put into operation in 1974. Insulation type of reinforced type (not less than 4.7 mm) included:

- primer “Transcor-GAZ”;
- mastic “Transcor-GAZ”;
- fiberglass mesh SST-B;
- heat-shrinkable tape DRL 60.450.07 (hot application).

Also, in parallel with the main gas pipeline “Perm-Gorky 1”, the main gas pipeline “Perm-Gorky 2” was laid, with which there are technological bridges, respectively, cathodic protection stations from this main gas pipeline also affect the controlled section. A cathodic protection station at km 847 was installed on this section (figure 1).

The cathodic protection station No. 50 (840 km) and the cathodic protection station No. 51 (849 km) were installed on this section of the main gas pipeline. The CSP at 846.6 km was chosen as the control point (CP). The distance from the control points to the drainage point is 4.6 km and 5.4 km, respectively.

Insulation coating control is carried out on the section between CPS No. 51 and the control point at km 844.6.

Table 1 provides the current strength of the cathodic protection station, before and after the change of modes, as well as the values of the protective potential difference “pipe-ground”, measured at the beginning and end of the controlled section.

| Mode No. | I CPS No. 50, A | I CPS No. 51, A | I CPS No. 847, A | \( \phi \) CP, B | \( \phi \) DP, B |
|----------|----------------|----------------|----------------|--------------|-------------|
| 1        | 1.9            | 6              | 1.7            | -1.83        | -2.04       |
| 2        | 8.5            | 6              | 1.7            | -2.01        | -2.09       |
| 3        | 1.9            | 9.4            | 1.7            | -1.91        | -2.4        |
| 4        | 1.9            | 6              | 0              | -0.83        | -1.4        |

As a result of the calculations according to the developed method, it was found that the transient resistance of the coating at the time of electrometric measurements in the control section was 22015
Ohm \cdot m^2$, which corresponds to the satisfactory condition of the bitumen coating in the controlled section of the pipeline.

4. Conclusion

Thus, it has been established that the use of the capabilities of the remote corrosion system allows obtaining a mathematical model of the electrochemical corrosion protection system, the coefficients of which reflect the true effect of the cathodic current of the cathodic protection station on the value of the protective potentials on the pipeline section. Accordingly, by determining the displacement of these potentials on the section, it is possible to determine the current propagation constant in the pipeline, the value of which is directly related to the resistance of the insulating coating. Approbation of the developed methods was carried out at a real object of the main gas transportation, the result of which was the finding of an integral indicator of the insulation coating condition on the section of the operating main gas pipeline.

Reference

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