Fault location method for unexposed gas trunk line insulation at stray current constant effect area

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Abstract. For the purpose of gas trunk lines safe operation, two types of pipe wall metal anticorrosion protection are generally used - the passive (insulation coating) protection and the active (electrochemical) protection. In the process of a pipeline long-term operation, its insulation is subject to wear and damage. Electrochemical protection means of a certain potential value prevent metal dissolution in the soil. When insulation wear and tear attains a level of insufficiency of the protection potential value, the insulating coating needs repair which is a labor-consuming procedure. To reduce the risk of such situation, it is necessary to make inspection rounds to monitor the condition of pipe insulation. A method for pipeline insulation coating unexposed fault location based on Pearson method is considered, wherein a working cathodic protection station signal of 100 Hz frequency is used, which makes installation of a generator unnecessary, and also a specific generator signal of 1 kHz frequency is used at high noise immunity and sensitivity of the instrument complex. This method enables detection and sizing of unexposed pipeline defects within the zones of earth current permanent action. High noise immunity of selective indicators allows for operation in proximity to 110 kV, 220 kV, and 500 kV power transmission lines in action.

1. Introduction
At present, there is a range of instruments for locating fault points of insulation coating damage without opening trunk pipes. However, they are not devoid of complexity in accurate search for defective insulation segments because of strict requirements for an instrument complex operator's experience and attentiveness, not to mention environmental conditions which due to excessive humidity make trunk line fault location ineffective.

Currently, electrometric gauges are widely used for on-route measurements (such as ANPI, UKI-1M, ANTP, POISK, and others), which help to find out an insulation blanket disruption by gauging potentials on the ground surface. Minimally satisfying results may be obtained by checking with magnetometric instrumentation (e.g. Radiodetection RD 8000 PCM current topographer or Seba vLocDM2 tool, IKN-2M and IKN-3M stress concentration meters, Skif MBS/04 complex, high-fidelity line locators of Onyx, C-Scan, and etc. types). Accuracy of logging controlled parameters (currents) depends on multiple factors: precise positioning above the pipe axis, spatial attitude of magnetic sensitive probes, pipeline laying depth. A sophisticated system of electromagnetic interference is created by wandering currents, currents of electric power cables and communication cables, power transmission lines, and etc., which decrease efficacy and sensibility of measurements. Therefore, the main drawback of the above-mentioned instrumentation is low noise immunity. Thus, the problem arose to develop a highly sensitive and noise-resistant instrument complex capable to efficiently detect and exactly localize without exposure main gasline insulation damages in the area of stray current constant effect.

2. Methods of investigation
The method for gas trunk line anticorrosive insulation fault location is based on Pearson method, wherein the search for insulation coating defects is provided by means of either a working cathodic protection station signal of 100 Hz frequency, or a specific generator signal of 1 kHz frequency.

The proposed instrumentation complex from the point of view of insulation fault location as compared to the existing devices has the following basic advantages:

1. Possibility of operation by Pearson method applying a longitudinal gradient of potentials. This requires a smaller labor input (compared to the transverse gradient or to the intensive measurement technique with the help of MoData2 complex or similar). At that, the method of transverse gradient is also applicable, if necessary.

2. Possibility of operation using a 100 Hz frequency signal from working cathodic protection stations, which makes installation of a generator unnecessary and saves time. Installation of a generator is obligatory in case of absence of a cathodic protection within the inspected portion.

3. Performance by two operators working at a distance of 6 to 7 meters from each other to provide a larger measuring base for obtaining a useful signal. As a result, each local defect of an insulation coating is characterized by two maximums and one minimum of a useful signal, which practically eliminates possibility of an accidental omission of an insulation defect by the operators. The same specificity weakens within reasonable bounds the requirements of fault location operators' expertise and attentiveness.

4. Applicability of the proposed fault location method within the area of constant stray currents effect (as opposed, for example, to the intensive measurement method or trailing electrode method).

5. High noise immunity of selective indicators enables operation in proximity to active power transmission lines under the voltage of 10 kV, 35 kV, 110 kV, 220 kV, and 500 kV.

6. The above-mentioned possibility to range defects by physical size without exposing a pipe line.

For comparative testing, as a comparison base a known insulation checking unit UKI-1M was utilized, which had been priorly verified and adjusted to achieve maximal characteristics of sensitivity and selectivity.

| Table 1. Fault Locators Comparative Testing Results (100 Hz frequency) |
|--------------------------|-------------|-------------|-------------|
| **Item No.** | **Instrument type** | **Signal Level** | **Measuremen t Date** |
| 1 | UKI-1M | 130 x 6 - 170 x 6 | 04.09.2015 |
| | | 6.5 - 8.5 mV | |
| | | 0.8 mV | |
| | | 0.75 mV | |
| 2 | P-1 | 5.9 - 7 mV | 04.09.2015 |
| | | 0.25 - 0.3 mV | |
| | | 0.19 – 0.24 mV | |
| 3 | P-2 | 5 - 6 mV | 04.09.2015 |
| | | 0.19 – 0.23 mV | |
| | | 0.16 – 0.3 mV | |

| Table 2. Fault Locators Comparative Testing Results (1000 Hz frequency) |
|--------------------------|-------------|-------------|
| **Item No.** | **Instrument type** | **Signal Level** | **Measuremen t Date** |
| 1 | UKI-1M | 8 x 7 | 04.09.2015 |
| | | 12 mV | |
| | | 0.06 mV | |
| 2 | P-1 | - | - |
| 3 | P-2 | 40 mV | 04.09.2015 |
| | | 0.2 mV | |
| | | 0.12 mV | |
Table 3. Transverse Gradient

| Points | Points UKI-1M | P-2 Signal 1 | P-2 Signal 2 | P-2 Signal 3 | P-2 Signal 4 | P-2 Signal 5 | P-2 Signal 6 |
|--------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 1      | 7x7          | 14 mV        | 11.5         | 11           | 11           | 9.5          | 9            |
| 2      | 5x7          | 12           | 11.1         | 10.9         | 11           | 9.5          | 9            |
| 3      | 4x7          | 7            | 9.5          | 9.4          | 9            | 8            | 8            |
| 4      | 5x7          | 7            | 8.7          | 8.5          | 8.5          | 5            | 8            |
| 5      | 5x7          | 13           | 9.7          | 10           | 9.5          | 7.5          | 9            |
| 6      | 4x7          | 12           | 9.3          | 9            | 9            | 9            | 7            |
| 7      | 8x7          | 15           | 18           | 17           | 18.5         | 17           | 19           |
| 8      | 12x7         | 26           | 27           | 27.5         | 29.5         | 28           | 30           |
| 9      | 12x8         | 79           | 77           | 78           | 80           | 80           | 90           |
| 10     | 16x9         | 270          | 261          | 268          | 265          | 265          | 290          |
| 11     | 20x11        | 2600         | 2700         | 2800         | 2800         | 2500         | 2700         |
| 12     | 12x9         | 230          | 234          | 228          | 240          | 220          | 260          |
| 13     | 9x8          | 62           | 60           | 62           | 63           | 60           | 66           |
| 14     | 11x7         | 25           | 23           | 23           | 25           | 23           | 24           |
| 15     | 4x7          | 10           | 8.5          | 9            | 9            | 8            | 8.5          |

Therefore the fault location (location and localization) for gas trunk line insulation coating should be based on the electromotive power measurement of an inductive transducer placed in an alternating magnetic field of a direct conductor.

During pipeline insulation fault location, measurements of current spread over a pipe body should be made to estimate the operational condition and detect an affected segment by means of an ampermeter.

Further, electrical resistance of a gas pipe section should be measured to confirm an insulation defect presence with the help of an earth resistance meter (figure 1).

To detect and locate an insulation impairment, marking current is wanted on the pipe section under survey, which current is provided by a temporally grounded connection of a two-frequency generator GA-1 to the main gasline end at a metering control station (KIP-S) outfitted at a distance not less than 10 m from the extended anodic grounding. Resistance to the temporary grounding spread should not exceed 50 Ohm. Then, the trunk pipe disposition under the ground is determined by means of an inductive sensor.

In parallel with tracing the axis of a trunk pipe run under maintenance, insulation fault location is carried out by measuring the potential transverse gradient between the metering electrodes along the pipeline.

A first electrode is placed above the pipe longitudinal axis, while a second electrode is positioned at a distance not less than 7 m perpendicularly to the flow direction from the opposite side of the protected pipeline.

Once a maximal signal is detected, a marker is put.

Subsequently, the generator is switched over to the other end of the surveyed pipe run to fulfill measurements in the opposite direction.

The midpoint between the two measured signal peak values is accepted as an insulation defect spot.
3. Conclusion

Thus, the proposed instrumental complex enables efficient pipeline insulation unexposed fault location and defect sizing over a stray current constant action area (as opposed, e.g. to the methods of intensive measurements or trailing electrode). High noise immunity of selective indicators allows for operation in proximity to effective 110 kV, 220 kV, and 500 kV power transmission lines.

References

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