

**SC D1 Materials and emerging test techniques  
PS 1 Testing, monitoring and diagnostics**

**A new method for evaluating the degree of polymerization of paper insulation of power transformers**

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Today, more than 50% of the transformers of the power grid complex in many countries have fulfilled the established service life, and in some transformers the deterioration can reach up to 60%. Service life of power transformers according to regulatory documents is 25 years.

Many of these transformers can be used for a long time, however, in this case, there must be increased requirements for methods of diagnosing their technical condition. Experience shows that the main reason for the failure of oil-filled electric appliances is the deterioration of liquid and paper (cellulose) insulation. The service life of the insulation system of transformers is determined by the service life of the paper insulation, which is mainly calculated as a result of determining the degree of polymerization.

To assess the state of the paper insulation, it is necessary to study furan compounds dissolved in oil, as well as determine the degree of paper polymerization. The first of these techniques is inefficient, since furan compounds decompose under the action of an acidic medium and are adsorbed by a thermosiphon filter since most of the transformers with a thermosiphon filter are used in the power systems of the CIS countries. Existing chemical methods for determining the degree of polymerization of paper provide for the sampling of the insulation, followed by research in a chemical laboratory. However, the use of these methods are accompanied by the opening of transformers, the sampling of insulation, which requires time-consuming and time-consuming operations that lead to a certain destruction of the coil or barrier insulation. Time to determine the degree of polymerization of paper insulation in the chemical laboratory can be up to 1 day without taking into account the time for selection and transportation. It should also be noted that the cadoxene solution used in determining the degree of polymerization of paper insulation belongs to the first class of chemical hazard, which causes increased requirements for the organization of safe labor.

Also important problem is the lack of reliable tools for online monitoring the condition of the paper insulation of transformers, which leads to excessive costs for inspection and repair of transformers when using the chemical method.

The base of tools for repairing transformers by state has not been implemented, namely, to determine the degree of polymerization.

Today, the methods for determining the degree of polymerization of paper-oil insulation of transformers at wavelengths in the visible spectral range of 650 ÷ 655 nm in laboratory has been developed. This method involves determining the degree of polymerization of paper-oil insulation of transformers by determining the reflection coefficients at wavelengths of 650-665 nm.

We selected ten samples of the electric-grade cardboard and transformer paper-oil insulation with different service life from power transformers with different terms and conditions of operation. For the development of the methods, the reflection coefficients of each sample of paper-oil insulation and the degree of polymerization were determined.

Based on the obtained measurement results, the dependence of the reflection coefficient on the degree of polymerization of the paper-oil insulation of the transformers was obtained.

The developed methods of measurement applies to paper insulation of transformers and establishes requirements to the contents and execution of works, when measuring the degree of polymerization of paper insulation by the optical method. The evaluation is carried out for power transformers of 110 kV and above.

The methods is certified in the Federal State Institution "State regional center of standardization, Metrology and testing in the Republic of Tatarstan", Kazan. The number of the certificate about attestation is 66-01.00267-2014 and The methods is included in the Federal Information Fund for ensuring the uniformity of measurements under the number FR.1.31.2015.20126.

For power companies, a tool has been created which allows in a few minutes to determine the condition of paper insulation of power transformers without spending time and money for this analysis in chemical laboratories. Knowing the degree of polymerization of paper-oil insulation specialists of energy companies will be able to predict the remaining service life of the transformer fleet, because all the installed dependencies calculation of residual life of transformers is calculated on the basis of the polymerization degree of paper-oil insulation at the end of the service life of the transformer.

Today an industrial sample of a device for determining the degree of polymerization of paper insulation has been developed, which makes it possible to determine the degree of polymerization without sampling paper insulation, as well as to exclude the contact of the personnel of chemical services with harmful chemical reagents used to determine the degree of polymerization of paper insulation.