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Methodical Basics for the Experimental Determination of Oil Resource Characteristics and Measures for Their Correction

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Abstract
For the first time, a method has been developed for the experimental determination of the liquid dielectric resource and measures for its restoration. The application of the new method on energy production will increase the efficiency of the oil regeneration units of transformer equipment, and, accordingly, reduce operating costs, increase the durability of the oil-filled equipment, and improve the environmental friendliness of production.

Keywords: Resource, Liquid Dielectric, Quality Indicators, Method

Introduction

In course of long-term exploitation in oil-filled equipment, transformer oil changes its physico-chemical characteristics. The main process that determines the change in the properties of the oil is its oxidation [1,2,3].
Oils have a complex chemical composition, which determines the variety of oxidation products formed, and, accordingly, the complexity in determining the early stages of its aging, i.e. the period when the implementation of preventive exploitational measures is the most effective.
At the same time, procuring chemical stability and chemical resistance of oils during the entire lifespan of the oil-filled equipment is one of the tasks of chemical control over energy production. Therefore, the search for new methods for recognizing the early aging of insulating oils and the experimental selection of measures for their recovery is relevant and aimed both at increasing the efficiency of oil regeneration units (thermosyphon, adsorption filters) and on increasing the work durability of power equipment (preventing the formation of aggressive aging products, causing the destruction of cellulose insulation), as well as improving the environmental friendliness of production (reducing the amount of spent petroleum oil in circulation of energy companies.

1. Influence of a liquid dielectric resource on a resource of transformers isolation

Works [3,4] show the efficiency of power transformer resource management through the management of the resource of transformer oil filled into it. As a result of the oxidation process, an insoluble deposit (sludge) is formed in the oil, acids, water and other aging products incl. aggressive ones appear. The speed of aging in oil is not constant. At the first stage of exploitation, the speed is small – this is the induction period of oxidation. In the future, as the accumulation of aging products, the speed increases, then grows sharply.
Aging mechanisms are implemented for all types of petroleum oils, regardless of the raw materials used for their production, the percentage composition of the components, the methods for cleaning petroleum distillates, and other factors. However, the speed of aging processes depends significantly on a number of factors, including temperature, oxygen, metal (oxidation catalyst), etc.

Stability is the sustainability of the oil against oxidation and sludge formation during exploitation. An indicator of the oil quality, determining its resistance to aging factors, is the "antioxidant stability of the oil." Residual resource of transformer oil is the total operating time of transformer oil from the moment of its quality control to the transition of oil to the limiting state, i.e. a condition in which the oil is unable to perform the specified functions, and the restoration of its operable state is impossible and (or) impractical [3,5]. Accordingly, the method for evaluating the "stability against oxidation" is a method that allows a qualitative assessment of the oil resource. One of the methods widely used in electric power industry for evaluating stability against oxidation is the standardized method of GOST 981-75 [6]. The stability of oils, measured by this method [6], is estimated by a set of indicators – the acid value of the oxidized oil (hereinafter referred to as "AVOO") and the sediment formed after oxidation (hereinafter "Sediment"). By measuring the antioxidant stability of the exploitational transformer oil by accelerated oxidation of the oil sample in the laboratory, it is estimated how much the condition of the studied oil, at a given time, is resistant to the influence of key factors that determine the course of oxidation processes and take place in real conditions. Accordingly, the worse the indicators that determine the stability against oxidation, the greater the proportion of the initial resource oil lost. Comparative analysis of the change in the parameters of antioxidant stability before and after the exploitational impact on the oil makes it possible to evaluate the effectiveness of the selected / conducted measures to restore its resource.

2. Experimental determination of the oil resource and measures for its restoration

Modeling in laboratory conditions of various methods for restoring the properties of transformer oils, followed by a comparative evaluation of their qualitative changes, is laid into the first developed method for the experimental determination of the liquid dielectric resource and measures for its restoration.

The essence of the method is the comparative oxidation of oil (before and after treatment according to the set rules) in the VTI device under the influence of oxygen at an elevated temperature in the presence of a catalyst. The results of the oxidation of the oil are characterized by AVOO and Sediment. The method covers experimental determination of the exploitational transformer oil resource with the subsequent experimental laboratory valuation of the volume of materials, nomenclature and the order of performing the regeneration work.

A qualitative evaluation of the exploitational transformer oil resource is proposed to conduct by measuring the antioxidant stability according to the GOST 981-75 [6] method using an apparatus for determining the stability of oils against oxidation of APSM-1, the oxidation being carried out in a VTI device.

In the course of previous research work [3,4], the following defective values were established: AVOO – not more than 0.1 mgKOH/g; Sediment – not more than 0.01% of the mass. At the same time, it was found that the presence of AVOO exceeding the accepted standardized value, followed by the absence of Sediment, usually indicates a smaller share of the spent resource, in comparison, when the results of oil oxidation in the laboratory conditions, including the presence of Sediment in excess of the allowable value. The result of the single experimental evaluation is the following conclusion: the oil resource is reduced, or the resource is not reduced.

At the same time, consideration of the results of tests for estimating the residual resource of a liquid dielectric is carried out in a complex manner, taking into account the results of measurements of such quality indicators as acid value, the content of water-soluble acids and alkalis, the tangent of the oil dielectric loss angle, the content of the antioxidant additive (agidol-1), general sludge content. These quality indicators are indicative for aging products formed

during oxidation processes in transformer oil [2,3,7]. Based on the results of a comprehensive review of the measured oil resource and the specified quality indicators, an algorithm is determined for performing an experimental laboratory determination of the volume of materials, nomenclature and the procedure for performing oil regeneration work.
Due to the fact that the chemical composition of different brands of transformer oils is complex and specific and in each power transformer there are individual conditions of work, nomenclature of the necessary preventive measures to restore the oil resource is reasonable to define exactly by modeling processes in the laboratory – a special laboratory experiment. It is important that for a certain degree (depth) of oil aging, the efficiency of its recovery will depend on the chosen set of measures, on the order of their conducting, on the duration of the impact, so it is impossible to develop one universal set of measures to restore the resource of the oil. Accordingly, to solve this task, the most common combinations of preventive works used at electric grid enterprises were identified.
It is also important that the cost of carrying out work for various sets of measures to restore the resource of the oil will be different and will grow with an increase in the degree of oil aging [3].
A key criterion for evaluating the effectiveness of the restoration of the oil resource [3,7,8] is the change in the antioxidant stability before and after exposure to oil. Effective measures to change (restore) the resource characteristics of the oil are all the cases of improvement in indicators (AVOO and Sediment) characterizing the antioxidant stability, as well as such parameters of the oil as acid value, the content of water-soluble acids and alkalis, the tangent of the oil dielectric loss angle.

Conclusion

A method has been developed for the experimental determination of the resource of a liquid dielectric and measures for its restoration. The method provides experimental determination of the transformer exploitational oil resource in laboratory conditions with the subsequent experimental laboratory determination of the volume of materials, nomenclature and the order of performance of works for the regeneration of operational transformer oil.

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