Study of optimal temperature during adsorption cleaning of transformer oil under conditions of long-term operation

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Abstract. The article presents the results of an experimental study of the optimal temperature of a transformer under conditions of long-term operation during adsorption cleaning. The study was conducted on five types of samples of used transformer oil with a long service life. Cleaning of each sample of used transformer oil was carried out at temperature ranges of 20 - 80 °C. Silica gel and zeolite were used for adsorption purification. The conducted experimental studies and analysis of the obtained data showed that the optimum temperature for heating the used oil in the process of adsorption purification is 80°C. Regression equations have been obtained that make it possible to determine the dependence of the oil breakdown voltage on the oil temperature after cleaning with adsorbents. These equations will allow you to predict the expected outcomes without having to perform experimental tests.

1 Introduction

Transformer oil is a petroleum product that is used in power transformers. Oil in a transformer performs three main tasks [1-3]:
1. Isolation from electrical breakdown;
2. Cooling of the transformer and its main elements (magnetic circuit, winding, etc.);
3. Washing of the magnetic circuit and windings in order to prevent rusting.

Failure to perform one of the above tasks of the oil will result in failure of the power transformer.

An analysis of literary sources showed that 85% of the failure of power transformers is due to the deterioration of their oil quality [4]. In connection with the above, timely maintenance of power transformers with liquid dielectrics is one of the main tasks of the energy industry.

Purification of used transformer oils for their reuse. There are several ways to clean transformer oil [5]. One of the methods is adsorption method. Silica gel, zeolite and others...
are used as an adsorbent. In the process of adsorption purification of used transformer oil with silica gel and zeolite, the question arises of its heating. Optimum heating of used oil allows deep cleaning of used transformer oil with silica gel and zeolite. During adsorption purification, oil is heated in the range of 50–70 °C [6–7]. In some literature, information is given that it is not necessary to heat during the purification of used oil with zeolite. And in some sources, the optimum temperature for cleaning used oil with silica gel is equal to 60–70 °C [8–9]. After cleaning the used oil with silica gel and zeolite in the temperature range of 50–70 °C, the dielectric strength of the liquid dielectric does not always increase [10, 11]. Therefore, the question arises, especially when it comes to power transformers with a service life of more than 30 years, what is the optimal temperature for heating used oil in the adsorption process.

The purpose of the study is to determine the optimal temperature of used transformer oil under long-term operation conditions during adsorption treatment.

2 Materials and methods

For experimental studies, five samples of used oil were obtained, taken from different power transformers with an operation of more than 30 years. Information about used oil samples taken is given in Table 1.

Table 1. Information on received waste oils.

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Power transformer type</th>
<th>Voltage, kV</th>
<th>Service life, years</th>
<th>Power, kVA</th>
<th>Volume of taken oil, l</th>
</tr>
</thead>
<tbody>
<tr>
<td>№1</td>
<td>TMG-250</td>
<td>10/0.4</td>
<td>32</td>
<td>250</td>
<td>30</td>
</tr>
<tr>
<td>№2</td>
<td>TMG-400</td>
<td>10/0.4</td>
<td>34</td>
<td>400</td>
<td>30</td>
</tr>
<tr>
<td>№3</td>
<td>TMG-250</td>
<td>10/0.4</td>
<td>35</td>
<td>250</td>
<td>30</td>
</tr>
<tr>
<td>№4</td>
<td>TMG-400</td>
<td>10/0.4</td>
<td>40</td>
<td>400</td>
<td>30</td>
</tr>
<tr>
<td>№5</td>
<td>TMG-100</td>
<td>10/0.4</td>
<td>38</td>
<td>100</td>
<td>30</td>
</tr>
</tbody>
</table>

As methods, an experimental study on the adsorption purification of used transformer oils and a regression method for analyzing the data obtained were used.

Each sample of used oil was divided evenly into two parts. The first part of each sample of used oils was passed through an adsorbent - silica gel. The second part of each sample of used oils was passed through the zeolite. The cleaning time for each adsorbent was 4 hours.

The oil was evaluated for electrical strength using an AIM-80 measurement equipment before and after cleaning the old transformer. Purification of each sample of used transformer oil with adsorbents was carried out at temperature ranges of 20 - 80 °C.

3 Results and discussion

Fig. 1 shows the results before and after cleaning the used oil with silica gel. When used oil is heated to 80°C before it is cleaned, the breakdown voltage increases from 8.4 kV to 8.6
kV, i.e. at 0.2 kV. This is explained by the fact that some of the free moisture in the used oil evaporates at 80°C.

The results showed that after heating the oil to 80°C, the breakdown voltage increased from 15.1 kV to 19.7 kV, i.e. at 4.6 kV. This indicates that silica gel at a temperature of 80°C easily impregnates various impurities than at temperatures lower.

Fig. 1. The results of used oil purification with silica gel.

In the course of the study, the dependence of the breakdown voltage of the oil on the temperature of the oil after cleaning with silica gel was also determined and equation (1) was obtained. The coefficient of determination (R²) between the two variables is equal to 0.991.

\[ f(x) = 7.1905e^{0.252x} \]  

where,

- \( x \) - oil temperature;
- \( f(x) \) - is the breakdown voltage of the oil.

Fig. 2. shows the results before and after treatment of used oil with zeolite. The results showed that after heating the oil to 80°C, the breakdown voltage increased from 17.1 kV to 23.8 kV, i.e. at 6.7 kV. This indicates that the zeolite at a temperature of 80°C easily soaks up various impurities than at temperatures lower.
Fig. 2. The results of cleaning used oil with zeolite.

In the course of the study, the dependence of the breakdown voltage of the oil on the temperature of the oil after cleaning with silica gel was also determined and equation (2) was obtained. The coefficient of determination (R²) between the two variables is equal to 0.993.

\[
f(x) = 0.525x^2 + 2.205x + 6.375
\]

where,
- \( x \) - oil temperature;
- \( f(x) \) - is the breakdown voltage of the oil.

Fig. 3 shows the results before and after purification of used oil with silica gel and zeolite. The results showed that after heating the oil to 80°C, the breakdown voltage increased from 17.8 kV to 31.8 kV, i.e. at 14 kV. This indicates that silica gel at a temperature of 80°C easily impregnates various impurities than at temperatures lower.
In the course of the study, the dependence of the oil breakdown voltage on the oil temperature after cleaning with silica gel was also determined, and equation (2) was obtained. The coefficient of determination (R²) between the two variables is equal to 0.993.

\[ f(x) = 0.525x^2 + 2.205x + 6.375 \]  

(2)

where,  
\( x \) - oil temperature;  
\( f(x) \) - is the breakdown voltage of the oil.

### 4 Conclusion

1. The results of the experimental studies have shown that during adsorption purification, the temperature of used transformer oil must be increased to 80°C.

2. The conducted experimental studies and analysis of the obtained data showed that the optimum temperature for heating the used oil in the process of adsorption purification is 80°C.

3. Regression equations have been obtained that make it possible to determine the dependence of the oil breakdown voltage on the oil temperature after cleaning with adsorbents. These equations will make it possible to preliminarily determine the expected results without conducting experimental studies.
References


