The Frequency Impact of Diagnostic Measurements on the Operational Condition of High-Voltage Transformers

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ABSTRACT

This paper presents the substantiation of the phenomenon of the frequency of diagnostic measurements on the operational state of high-voltage transformers. The article gives examples of defects of switching devices of rectifier transformers and methods of their detection. The substantiation of the importance of a defect recognition is given in an early stage of their occurrence.

THE FREQUENCY OF DIAGNOSTIC MEASUREMENTS

The technique of diagnostic measurements of high-voltage transformers and switches in the operating mode has been widely introduced. In this case, diagnostics is carried out under a running voltage and operating load, that is without disconnection of converting transformers and switches from a network. Diagrams of the number of diagnostic asurements and emergency situations are submitted in Figure 1.

The analysis of the presented dependences shows that with the increase of diagnostic measurements [1], the accident rate of electrical equipment and transformers is reduced due to small and medium repairs. This reduces the probability of major accidents and consequently increases the reliability of the power supply system.

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Figure 1. Monthly distribution of transformer and switch failures depending on the number of diagnostic measurements.

CHROMATOGRAPHY

The most famous example of diagnostics is chromatographic analysis of dissolved gases in transformer oil. With the help of measured concentrations of gases in the oil and comparing them with the boundary permissible values, the types of defects in the transformer are determined. The table presents the gas chromatogram of the rectifier transformer TDNL-40000/10.

It follows from Table I that during the planned diagnostic measurements on March 27, 2017, the excess of the boundary concentrations of gases: hydrogen, methane, acetylene, ethylene and ethane was detected. The quickened gases monitoring of the rectifier transformer had been carried out and over the next three days a positive dynamics of gas growth had been observed. It was decided on March 30, 2017 to switch off the rectifier transformer, to conduct medium urgent repairs with drainage of oil and opening of the switching device hatches, during which burnt plug-in contacts of the switching device PHTA-35/1000 were found.
TABLE I. THE CHROMATOGRAM RECTIFIER TRANSFORMER TDNL-40000/10 WITH A SWITCHING DEVICE OF RNTA-35/1000.

<table>
<thead>
<tr>
<th>Date of analysis</th>
<th>Boundary concentrations of the transformer gases, formation rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hydrogen</td>
</tr>
<tr>
<td>14.11.16</td>
<td>0.01</td>
</tr>
<tr>
<td>21.12.16</td>
<td>0</td>
</tr>
<tr>
<td>06.02.17</td>
<td>0.0028</td>
</tr>
<tr>
<td>27.03.17</td>
<td>0.0322</td>
</tr>
<tr>
<td>27.03.17</td>
<td>0.034</td>
</tr>
<tr>
<td>28.03.17</td>
<td>0.0271</td>
</tr>
<tr>
<td>29.03.17</td>
<td>0.0292</td>
</tr>
<tr>
<td>30.03.17</td>
<td>0.0293</td>
</tr>
<tr>
<td>30.03.17</td>
<td>0</td>
</tr>
<tr>
<td>03.04.17</td>
<td>0.0011</td>
</tr>
</tbody>
</table>

REPAIRS BY THE CHROMATOGRAM

After the repair and replacement of the contacts, the rectifier transformer was put into operation and further put on gas control [2]. As can be seen from Table I, on 03/30/2017, after the rectifier transformer was put into operation, there was no growth of gases, and further the rectifier transformer continues to operate normally. The dependence of the results which confirmed the correctness of defect determination on the number of measurements was constructed [3]. Figure 2 shows that the repeatability of the correct result is high and accounts for 90% with the number of diagnostic measurements increase from 50 units [4].
While switching the stages of the switching device, transition processes which cause switching over-voltages [5] proceed. Due to the pulse flowing at switching AC overvoltage, there is a vibration that destroys the paper insulation of the transformer.

The multiplicity of over-voltages leads to the partial destruction of the insulation due to the impact of the intensity of the pulsed electromagnetic field on the bond sites of the cellulose molecule, which leads to their rupture (Figure 3).
**PAPER INSULATION**

The breaking of bonds reduces the dielectric strength of paper insulation, which leads to an increase in leakage currents through the places of insulation damage, accompanied by intense heating of these areas and, subsequently, this area leads to insulation breakdown.

Paper insulation loses its physical properties during the operation. The reasons for the physical deterioration of paper insulation rectifier transformers are mechanical vibration, switching overvoltage, thunderstorm overvoltage, thermal heating of conductors and cooling systems, oxidation.

The main causes of cellulose molecules destruction, as can be seen from Figure 3, are the breaks in the molecules at the sites of oxygen bonds. The acceleration of this process is directly affected by the presence of moisture (H2O), oxidation (O2), and an elevated temperature, which leads to both intense oxidation and the process initiation—pyrolysis. Thus, the presence of influencing factors that are harmful to cellulose has a detrimental and irrevocable effect on the destruction of paper insulation and, in general, on the reliable operation of a transformer.

Therefore, it is very important to carry out rapid diagnostics of rectifier transformers during the overhaul period and under operating voltage and workload, at least 50 times during the controlled period, as mentioned above and illustrated in Figure 2.

**CONCLUSIONS**

As it is stated above, an increase in the frequency of diagnostic measurements leads to effective monitoring of the state of high-voltage transformers and allows the detection of defects at an early stage of their occurrence. In this case, the approximation of the reliability and repeatability of the results, according to Figure 3, is within acceptable limits, exceeding 1% [6]. Since transformers provide power supply to consumers of aluminum electrolysis production, which is characterized by continuity of the technological process, during the repair work associated with the disconnection of the power transformer, its load is redistributed to other transformers. With such a power supply repair scheme, the current in the line increases and the voltage in it decreases. Therefore, the current strength and, accordingly, the active power decrease. During the power system peak times, the consumed active power of the electrolysis plant is calculated. In this case, if the power is lower during the peak times, then the payment of electricity will be less. Therefore, in case of timely detection of defects and maintaining high-level operational readiness of high-voltage transformers, using parallelism of processes and the KANBAN operational control system during repair work, the work is carried out during the peak times of the power system [7]. Thus, there is a
simultaneous reduction of power and payment for it, and repair work is carried out, entering self-sufficiency mode.

REFERENCES


