

The diagnosis of winding deformation is based on comparing frequency characteristics of impedance recorded on the same winding at various time intervals at adjacent phases of the same transformer or on similar units. Changes in winding geometry result in differences in the frequency response characteristic. Energo-Complex is the first company in Poland which started conducting such measurements and boasts a database of over one hundred medium and high power transformers.

Economical effects

The application of modern research methods and analysis of previous operation and parameters of unit simplifies decision-making processes in respect of operation and investment. Diagnostics, if used properly, help in detecting defects, avoiding serious failure in ordinary operation, but also improves economical effects by prolonging transformer operation at acceptable levels of the risk of failure. Assessment of the technical condition can be helpful for identification of units, which can operate for a 60% longer period than their lifetime defined by producers.

The algorithm of the decision-making process and estimated cost of modernization is presented below, for the example of a 30 year old, 110/15 kV, 25 MVA transformer; operated at low load without any serious breakdowns.



Address:
Energo-Complex Ltd.
 ul. Lotników 9
 41-949 Piekary Śląskie
 Poland
 Tel. +48 32 775 6700
 Fax: +48 32 775 6702



Assessing
 The Technical Condition
 of Transformers

Fig. 7.
 Analysis of modernization costs based on technical condition for a typical 30 years old, 25 MVA, 110/15 kV transformer



There are several thousand medium power transformers being operated in Poland. More than half of these are over 30 years old. Despite this, most of these units are in relatively good condition (in terms of insulation) and can be used for another 10-20 years. However, the one condition which needs to be fulfilled is thorough renovation and modernization.

Risk assessment of further operation and evaluation of planned modernization profitability of transformers should be individually estimated for each unit. In this case, complex assessment of its technical condition is of great importance. Based on this, a range of renovation and life expectancy is formed which depends on a given load of transformer and its installation point in the power system. These elements have fundamental importance for the solutions described.

Thorough assessment of the technical condition of transformers is also an essential issue in case of rationalization of operating costs. Considering the strategic points of the power system allows transformers to be grouped in accordance with the impact on system reliability. Identification of units which have an essential importance to the power system enables the economic analysis of operation, modernization or purchase plan.

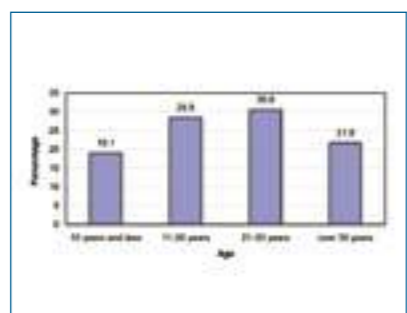


Fig. 1. Survey on the age of transformers operated by distribution companies

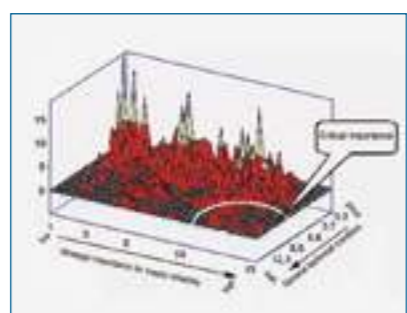


Fig. 2. Example showing identification of transformer groups having critical importance to power system operation

The main elements of reliable and complex assessment of the technical condition of transformers, apart from typical periodic inspections and tests, are:

- DIAGNOSTICS TRANSFORMER CONDITION BASED ON MODERN METHODS OF OIL ANALYSIS;
- DIAGNOSTICS OF MOISTURE CONTENT IN THE INSULATION;
- DIAGNOSTICS OF WINDINGS AND BUSHINGS;
- DIAGNOSTICS OF TAP CHANGERS.

Diagnostics of transformer oil

The main advantage of advanced oil tests is the possibility of early identification of detrimental physical and chemical processes occurring in transformers. The evaluation of causes and consequences of partial or complete discharges and thermal deterioration is possible by means of dissolved gas analysis in oil (DGA). Determination of physicochemical parameters of insulating oil and its furans content (especially 2FAL) allows for the estimation of oil and cellulose ageing level. It should be stated that very important stages of this analysis for the quality of the result is the method of sample collecting and its transport to the laboratory. Improper sample preparation leads to a large number of errors in analysis with the consequence of incorrect interpretation. Another important issue is the preparation and calibration of available chromatographs for the analysis of transformer oil. In this field Energo-Complex, in cooperation with the transformer oil manufacturer Nynas Naphtenics, has a brand new oil laboratory and equipment for fast and accurate DGA diagnostics in Poland.

Determining the level of moisture content in the insulation

An important factor influencing decisions on prolonging transformer operation is moisture content level in windings and insulating boards. Water content in cellulose higher than 2.5% results in signifi-

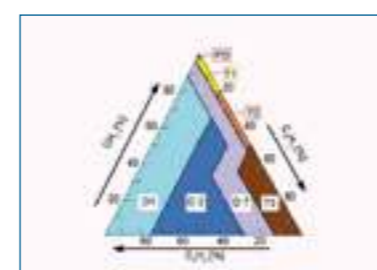


Fig. 3. Duvall's triangle for determining type of failure based on DGA analysis

- PD = Partial Discharges
- T1 = Overheating below 300 °C
- T2 = Overheating in range 300 +700 °C
- T3 = Overheating above 700 °C
- D1 = Low energy discharges
- D2 = High energy arc
- DT = Overheating and electric failures

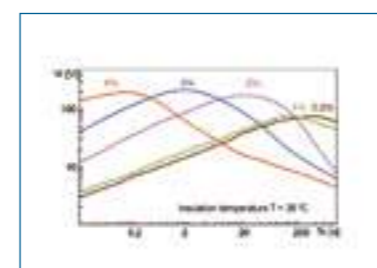


Fig. 4. Recovery Voltage Measurement (RVM) taken for five transformers with various moisture content in solid insulation

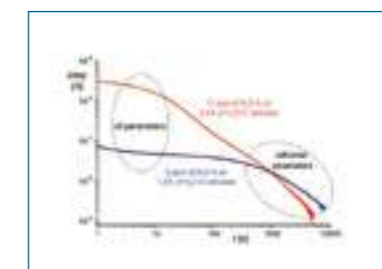


Fig. 5. The depolarization currents of two transformers with different moisture contents and ageing levels

During the 17th International Bielsko-Biala Power Industry Fair "ENERGETAB 2004", Energo-Complex was awarded the Gold Medal by the Polish Power Grid Company (PSE S.A.) for detection of mechanical deformation of transformer windings by Frequency Response Analysis (FRA)

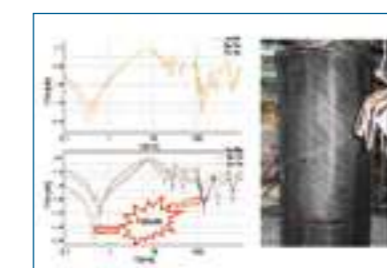


Fig. 6. The frequency response of HV winding recorded on 25 MVA, 115/6.6 kV power transformer, before and after winding deformation

cant intensification of deterioration processes which leads to loss of mechanical properties and causes the risk of the "bubble-effect" during short circuit and overload.

The level of moisture content in solid insulation of transformers can be found directly from various measurements of polarization phenomena. The methods which have gained practical significance are Recovery Voltage Measurements (RVM), measurements of tg frequency characteristics, Frequency Domain Spectroscopy (FDS) and Polarization and Depolarization Currents measurements (PDC).

Theoretically, all results of the previously mentioned test methods should be similar. However, practical experiences show that, depending on the method of measurement, moisture content results are diverse. Therefore, in order to obtain correct diagnosis, it is necessary to use at least two test methods. Energo-Complex has elaborated a method of joint RVM and PDC measurement, applied for standard tests for water content in cellulose. This type of measurement significantly increases accuracy of water content determination in transformer insulation, whilst retaining test time at an acceptable level.

Detection of winding deformation

A common problem during the operation of older units is the loosening and deformation of windings. These problems arise from effects of dynamical forces during short circuits. Winding deformation not always results in immediate and fatal damage of insulation, but significantly increases the risk of failure during subsequent short circuit or voltage surge.