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The improvement of DGA estimation by the criterion of maximum permissible concentrations of gases and their rate of growth

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This article describes the system of results evaluation of dissolved gas analysis (DGA) according to the permissible values (PV) and maximum permissible values (MPV) of gases concentrations and speed of their growth. The system is developed in 2017 as a an organization standard on the array of operational data of 35-220 kV transformers in the Russian Federation. Currently this system is being tested in JSC "Tyumenenergo" in the future it is planned to be used as a national standard.

All over the world the criterion of maximum permissible values (MPV) of concentrations of gases divides transformer fleet into "serviceable" and "with probability of developing fault". The systems of criteria for estimating the concentrations of dissolved in oil gases, given in international and national standards, differ not only in their values, but also in the factors by which MPVs are differentiated.

To study the degree of influence of factors on results of DGA was used analysis of variance. The purpose of the study is to develop a system of DGA evaluation according to the MPV gases criterion, dividing transformers into homogeneous groups. The analysis involved the following factors: voltage, power, type of oil protection system, brand of oil, type of cooling system, type of on-load tap changer, the transformer's lifespan.

PV gas concentrations and their trends shows the boundary separating "serviceable" and "with probability of developing fault" transformers/

The MPV concentrations of gases and their trends is a boundary detecting transformers with a high probability of failure.

The sample size of the results of the DGA made for transformers of voltage class 35 kV – 23020, 110 kV - 113890, 220 kV – 10510 results.

The conducted researches showed that all studied factors of influence: voltage class, power, oil protection system, oil brand, cooling system type, transformer lifespan, type of on-load tap-changer, to some extent influence DGA results. However, the degree of this influence, expressed by the ratio of residual and between-group variances, is different ($F = 1,5 \div 478$).

The most significant factors were:

• for all gases - voltage class and type of oil protection system;

• for hydrogen and methane - oil brands, producing by hydrocracking (Nytro 11GX, Nytro 10X, GK (local Russian oil brand)) with an operational lifetime up to 5 years;

• for CO and CO2 - power and lifetime are two independent factors, so both must be taken into account;

• for acetylene - the presence of RS-3 or RS-4 type of mounted on-load tap-changer.

Based on the results of the dispersion analysis, a system for estimating gas concentrations for 35-220 kV power transformers was calculated in accordance with the above conclusions, which is given in the article.

Further investigated the dynamics of changes in gas concentrations, expressed as relative and absolute growth rates. The growth rate of gases criterion reflects the rate of fault development and allows to evaluate the severity of the fault. The article briefly describes the methodology of the statistical analysis of speeds, taking into account the conditions for their reliable determination. The conclusion on the preference for using absolute values of the growth rates of gases in comparison with the relative ratios is substantiated.

Based on the results of the study of growth rates with the help of dispersion analysis, the design features of transformers that have the greatest influence on the rate of formation of gases, which must be taken into account when interpreting the results of DGA, are named. Taking into account the results of the variance analysis PV and MPV, absolute growth rates of gas concentrations for power transformers of 35-220 kV are proposed.

An algorithm is developed to determine the periodicity of the next DGA measurement and the necessary maintenance or repair operations, depending on the evaluation of the DGA result. Based on the definition of the technical state of the transformer by combining the concentrations of gases and the rates of their growth, which exceeded their PV and MPV (21 variants), 9 different options are proposed, including formulas for calculating the sampling interval and the maintenance and repair operations.

As a result of statistical analysis of DGAs from two manufacturers the concentrations of the gases after the factory tests for transformers of different voltage classes were calculated. These values are proposed to be used for the evaluation of the technical condition of transformer not only during production at the plant, but also when commissioning or after a major overhaul.

The proposed system for evaluating the results of DGA, taking into account the design features of the transformer and the period of its operation, reduces false negative and false positive in diagnosing equipment, improves the accuracy of calculations of the transformer's health index. The developed algorithm for determining the required periodicity of DGA monitoring and necessary maintenance operations helps staff to make the right decision on the further operation of the transformer.