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DIAGNOSTICS OF INSULATING SYSTEMS FOR ELECTRICAL MACHINES

Summary. The present work is concerned with the diagnostics of insulating systems for rotary electrical machines. The theoretical justification of the new diagnostic methods used as well as the description of the experiment itself and its evaluation are presented. The test results obtained are also evaluated by the method of cluster analysis.

Key words: diagnostics, diagnostic method, insulating system, electrical machine

1. INTRODUCTION

Recently, the enhanced requirements for the economy and life of electrical machines have brought about increasing demands on the output of electrical machines. This fact is associated primarily with the increased stress of an insulating system of electrical machines that becomes one of the machine parts showing the highest failure rate. Malfunctions of insulating systems are mainly caused by breakdown, which results in losing their insulating properties. As the life of any system is determined by the life of its weakest element, we focused attention on the problem of the diagnostics of insulating materials for the winding of electrical machines. Our primary objective is to find such diagnostic quantities that would reflect the condition of any insulating system monitored in a non-destructive and simple way.

If a diagnostic method has to be able to provide enough information, it has to be based on the knowledge of the physical nature of ongoing processes. The present work is concerned with the method for estimating the critical voltage of thermal breakdown, the method of the temperature dependence of internal conductivity, and the method of the activation energy of dominant polarization processes. This results in deriving diagnostic quantities in the form of factors U_K, B_v and B_a, and in analysing them with regard to their suitability for achieving our objectives. Therefore, in the present work we describe the principle of the methods used, test objects, the experiment itself and finally its evaluation, including the comprehensive discussion of test results.

2. PRINCIPLE OF THE DIAGNOSTIC METHODS USED

Principle of the diagnostic methods used in [1].

3. TEST OBJECTS AND THE DESCRIPTION OF THE EXPERIMENT ITSELF

All the above diagnostic methods were applied to the stator winding insulation of three-phase asynchronous (induction) motors. It is the shellac mica foil-base insulation of temperature class b.
The test motors were in continuous energy operation, with a total running period of 800 to 100 thousand hours. In the experiment described herein, we measured gradually 5 stator phases of motors with an output of 400 kW and 6 stator phases of motors with an output of 500 kW. The absorption characteristic of each phase was determined by the classic volt-ampere method at a voltage of 200 V and nominal temperatures of 130, 105 and 80^0 C with stators being cooled down. At the end of experiment, direct-current breakdown voltage was determined by gradually increasing voltage from zero until breakdown.

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4. EXPERIMENT EVALUATION AND THE DISCUSSION OF TEST RESULTS

Based on an algorithm described in [1], values R_K and T_K were derived from the values measured for each phase. Estimate U_K, which is proportional to the critical voltage of thermal breakdown, was calculated from these values according to relation (3). During the whole experiment, we placed much emphasis on determining the statistical dependence of the critical voltage of thermal breakdown versus direct-current breakdown voltage. Therefore, correlation analysis was performed. The test results obtained for 6 stator phases of motors with an output of 500 kW are graphically illustrated In Fig. 1, and the test results obtained for 5 stator phases of motors with an output of 400 kW are graphically illustrated in Fig. 2.

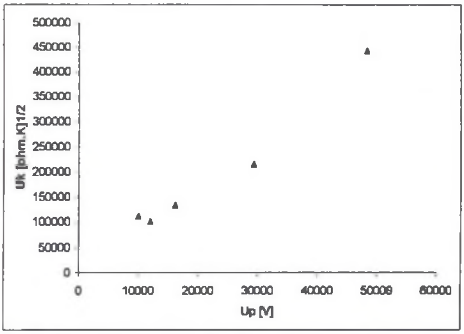

Fig.1. Dependence of factor U_k on the breakdown voltage U_P

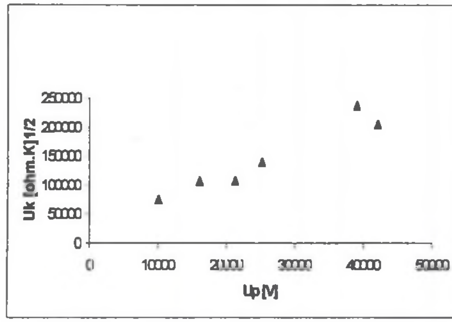

Fig.2. Dependence of factor U_k on the breakdown voltage U_P

Internal conductivity was calculated from the values of internal resistance that were measured in the above temperature range. From the data measured, the amount of B_V was determined for each phase by the least square method according to relation (6). Furthermore, the statistical dependence of this factor versus direct-current breakdown voltage was determined. The mean relaxation time of polarization was determined according to equation (9). The amount of B_a was calculated for each phase by the least square method in the above temperature range. During further evaluation, the statistical dependence of this factor versus direct-current breakdown voltage was determined. It is obvious from these illustrations that the dependence of the diagnostic quantities versus direct-current breakdown voltage is linear in the range evaluated, which was verified by statistical tests and by calculating the correlation coefficients. Regarding the dependence of U_K / U_P, the values are 0.96 and 0.99 for the phases of motors with an output of 500 kW and 400 kW, respectively. Regarding the dependence of B_V / U_P, the values are 0.99 and 0.89 for the phases of motors with an output of 500 kW and 400 kW, respectively. Regarding the dependence of B_a / U_P, the values are 0.99 and 0.98 for the phases of motors with an output of 500 kW and 400 kW, respectively.

The dependence of the diagnostic quantities may be also evaluated by other methods. The method of cluster analysis is one of them. Cluster analysis belongs to multidimensional statistical methods and enables a set of objects to be classified into several homogeneous clusters. There are lots of methods of cluster analysis. One of the aspects, by which the algorithms used may be classified, is the way of estimating the distance and similarity of objects. The most beneficial feature of cluster analysis is the possibility of its graphic presentation. The clusters are on one axis of the graph, and significance levels on the other axis. Significance levels are numbers which define the connection of individual objects to others according to complex relations. The Ward's method [7] is one of the most commonly used methods of cluster analysis. The results obtained by this method for the phases of motors with an output of 400 kW are shown in Fig. 3. It is obvious from this illustration that quantities U_K and U_P are the most similar to each other (significance level of 0.020202). Quantity B_a joins this cluster at a significance level of 0.141414, followed by quantity B_V that joins this cluster at a significance level of 0.808081. These results are in compliance with the conclusions obtained by correlation analysis.

5. CONCLUSIONS

The experiment described herein confirmed our theoretical presumptions. It is a follow-up to the satisfactory conclusions that were obtained by verifying the diagnostic methods tested in laboratory conditions. The fact that the linear dependence of the diagnostic quantities versus direct-current breakdown voltage exists in the range of values measured, is essential with regard to the applicability of the presented diagnostic methods in industrial practice. With both groups of motors, relatively high values of the correlation coefficient were obtained for ail relations tested. The results of correlation analysis were confirmed and complemented by cluster analysis. As the methods were applied to real objects in operation, a set comprising only a few motors could be used to verify these methods. Despite this fact, the experiment showed the real possibility of using these methods for the diagnostics of aged insulation systems for rotary electrical machines. The methods were found undemanding with regard to complex measuring equipment and experimental conditions.

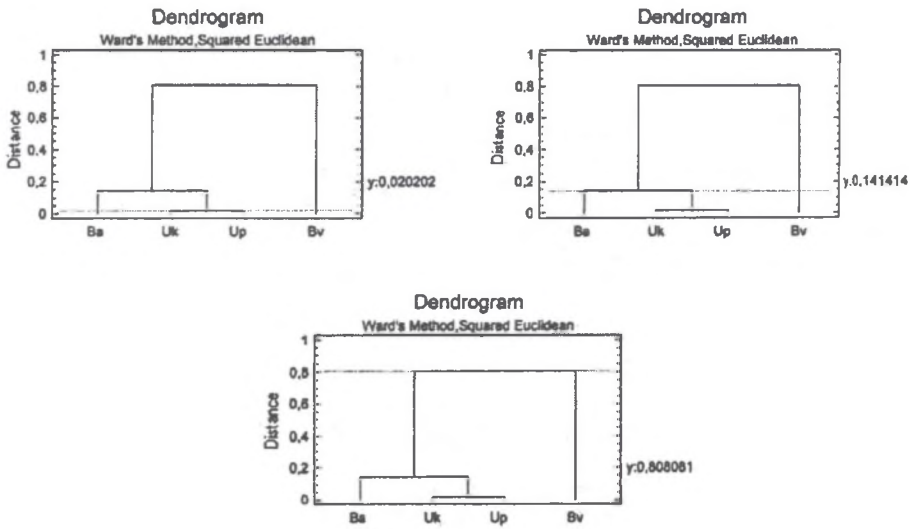

Fig. 3. Cluster analysis

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