TEMPERATURE HEATING OF THE TURBOGENERATOR TGV-200 ROTOR ELEMENTS WHILE EXCITATION WINDING DAMAGING

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Introduction. Turbogenerators (TG) that are being used in thermal and nuclear power plants, have almost completely exhausted their nominal lifetime. One of the important factors which determining the reliability of the TG is the allowable heating of elements of its structures. Reliability of the TG determines the reliability of the power plant in general. Damage of the TG rotor elements leads to its failure. Overheating of the rotor's elements can be caused by short circuit of the excitation winding, damaging the rotor winding isolation, violation of the cooling system, prolonged acceleration of excitation. Replacing and repairing of electric machine is very complicate and costly procedure. In view of this, there is a need to control the technical state of TG. Systems of control of a technical condition allow to reveal the causes of TG damages at the stage of occurrence and to prevent their further development. The temperature control of the heating TG rotor elements is carried out with the help of temperature sensors, which are installed in the corresponding construction sites.

One of the typical damage of the TG is the short circuit of the excitation winding. The presence of even a small number of short-circuited turns in the rotor can significantly effect on the work of TG and lead to a number of negative phenomena. Thus, due to the decrease in the excitation flow of the damaged rotor, the distribution of the magnetic field in the TG air gap becomes asymmetric, the EMFs, which are induced in separate parallel strings of the stator windings, have a different value, which leads to the appearance of equalizing currents, an increase in electrical losses and a decrease in the efficiency of the TG. The temperature distribution changes in TG, the heating of the stator windings increases, and on the individual sections of the design gradients of temperature increase, which leads to the appearance of additional thermomechanical stresses, and so on.

The analysis of the temperature state of TG is an urgent problem, since according to its results certain practical recommendations can be given for increasing the reliability of work and extending the life of the operation. The study of the temperature gradient in electric machines was carried out in [1]. The analysis of the temperature state of TG with excitation winding damage in this article is carried out using field methods of mathematical modeling.

The goal of the work. The goal of this article is to study the methods of mathematical modeling of the features of the temperature field distribution in TG, which arise as a result of short circuits in the excitation winding.

Material and results of the research. The research was carried out on an example of a turbogenerator TGV-200 with a capacity of 200 MW, with water-hydrogen cooling, which has the following parameters: the voltage of the rotor - 440 V; rotor current - 1880 A; number of teeth on the rotor, Z_2 = 36, rotor speed, n = 3000 rpm, rotor winding material - copper, class of heat resistance of the isolation stator and rotor windings - B (130 ºC).

The analysis of TG rotor heating (see pic. 1) allows to estimate the asymmetry of the temperature field picture and gives a quantitative estimate of its elements heating, with short circuits of winding of excitation turns at different volumes.

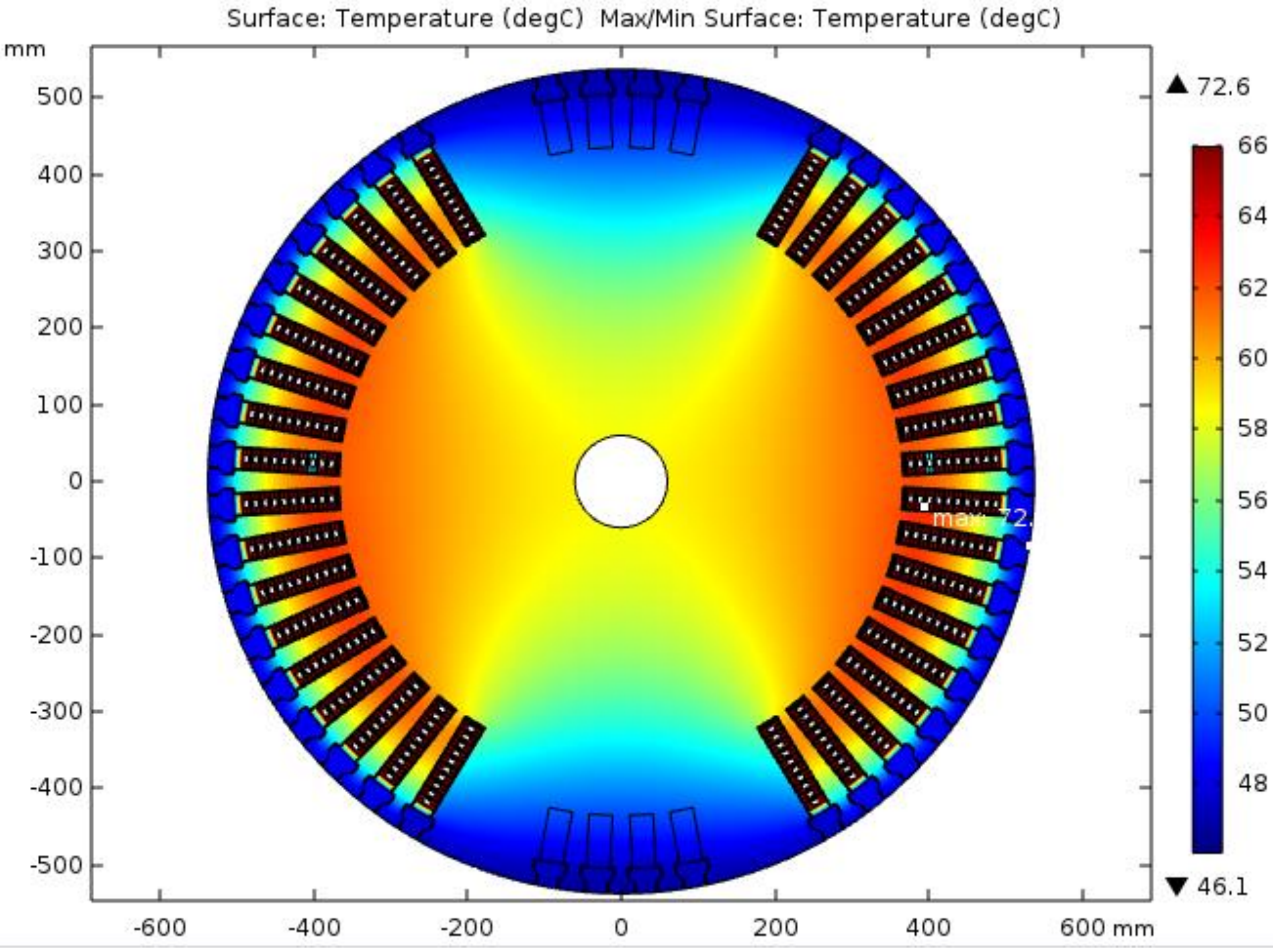
In calculations should take into account an increase in the excitation current due to a decrease in the total electrical resistance of the rotor winding, caused by the shortening of the part of the turns. The excitation winding current must be multiplied on coefficient of current increase of the excitation winding $k_{\text{ОЗ}I}$, which characterizes the ratio of the total number of turns to the number of intact:

$$k_{\text{ОЗ}I} = \frac{2p}{(2p-1)+1\cdot k_{\text{ПОЛ}I}},$$

where $k_{\text{ПОЛ}I}$ – coefficient characterizing the percentage of intact turns of pole $W_{\text{неушкоджених}}$ to number of one pole turns $W_{\text{пол}}$:

$$k_{\text{ПОЛ}I} = \frac{W_{\text{неушкоджених}}}{W_{\text{пол}}}$$

In the mathematical model, the realization of such damage is achieved by the fact that the excitation winding is turned off by setting the zero conductance σ. This is due to the fact that, the EMF in the excitation winding turns is not given.

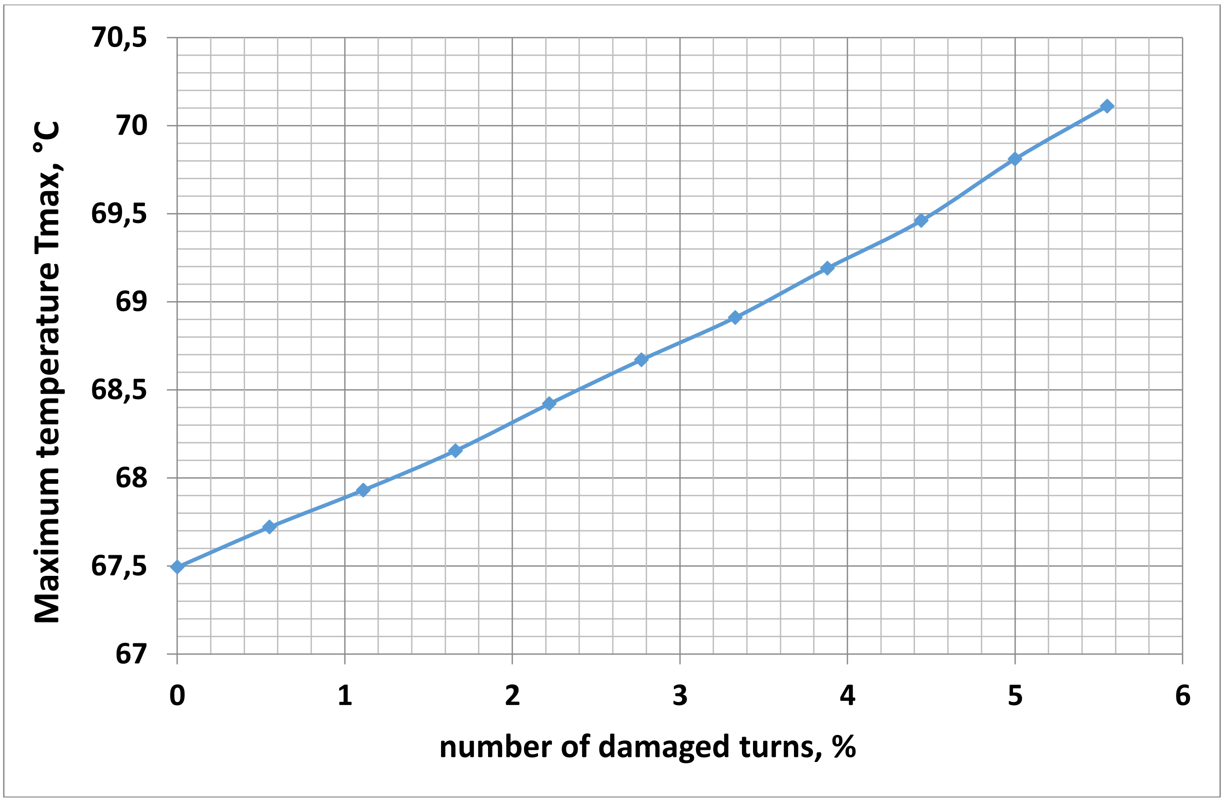


Picture 1 – Distribution of temperature field in TG with damages of one turn

The analysis of the temperature field of the TG rotor was made by changing the number of damaged turns of the rotor with a short circuit of the excitation winding from 0 to 5.5%. The results of the analysis of the temperature field in the rotor of TG with damage to the excitation winding are as follows.

If the winding of TG rotor is damaged, the maximum value of temperature throughout the active surface area is 67.72 °C. The minimum temperature across the surface of the rotor is 44.53 °C. The maximum temperature on the TG rotor surface with a damage of 5.5% of turns is 70.11 °C.

In pic. 2 shows the dependence of the maximum temperature across the rotor surface on the number of damaged turns. The maximum temperature throughout the TG rotor active surface with shortened 5.5% turns increased by 2.18 ^{o}C (by 3.2%).



Picture 2 – Dependence of the maximum temperature across the rotor surface on the number of damaged turns

Conclusions. In the article by methods of mathematical modeling have been used to study the distribution and temperature changes in the elements of the TG rotor. It is determined that temperature sensors should be installed in the grooves located near the q - axis, namely in the 3rd turn zone from the base of the groove, because in these turns the maximum heating of the TG rotor is localized. According to preliminary calculations, this will increase the accuracy of the rotor temperature measurement by about 3.05%.

References

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