TURBOGENERATOR STATOR WINDINGS FRONTAL PARTS DAMAGE DUE TO HIGH LEVELS OF VIBRATION

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Introduction. Turbogenerator (TG) are one of the most complex and critical objects at nuclear and thermal power plants. Time-varying currents flowing through the winding conductors and mechanical or electromagnetic interaction between different stator elements are the main cause of vibrations. Vibrations of the frontal parts of the stator winding of the TG have a component of 100 Hz - in normal mode and 50, 100, 150 and 200 Hz – in transient modes. The main reason for the increased vibration in normal and transient modes of operation of the TG is the presence of poorly damped resonances of the frontal parts of the stator winding near the frequencies of disturbing forces – 50, 100, 150 and 200 Hz. These resonances depend on the system and quality of winding fastening at the exit from the slot and on the heads. Vibrations of the winding frontal parts also depend on the jamming density [1]. The vibration of the frontal parts of the TG under the action of the magnetic field of its parts that are in direct contact with the stator winding can lead to insulation fraying, its breakdown and short circuit in the winding or on the body. Therefore, all parts that fasten the winding must be securely fastened. As a result of internal damage in the stator winding (short circuit between phases or on the body, violation of soldering in the frontal parts of the winding), a fire often occurs in the generator, because the high temperature of the arc at the closure ignites the insulation. Since even after the arc is stopped due to disconnection of the generator from the busbars under the action of protection, the insulation continues to burn intensively enough, and, as a result, the amount of damage of the generator increases. Therefore, if the differential protection does not automatically supply water to the generator, it is necessary to switch on the fire extinguishing device as soon as possible, which supplies water to the frontal parts of the generator winding. However, it is not recommended to supply water for too long. As soon as the burning of the insulation with the release of smoke stops, the water supply is stopped and it is ensured that the fire is completely extinguished by monitoring the absence of burning or smoldering of the insulation through the inspection hatches in the generator housing [5]. Such significant consequences can be caused by damage that occurred in the frontal parts of the stator winding of the TG due to the appearance of vibrations above permissible levels.

The purpose of work. To review the causes and consequences of the TG stator winding frontal parts damage due to high levels of vibration, as well as to describe the method of determining their vibration state.

The results of the research. Vibration is measured in the radial and tangential directions on the upper and lower heads of the stator winding front parts (if possible, not on the insulation boxes) and also in the vicinity - at its exits from the slot. It is recommended to include the vibration converters in the insulating cages glued to the winding fronts with epoxy glue [3]. Vibration converters are installed on at least ten cores of the winding. The stator winding of a modern powerful turbogenerator has a large number of cores and it is practically impossible to measure vibration on all cores. Usually the number of examined cores is no more than a few percent of their total number, which excludes the possibility of directly measuring the cores of the winding with higher vibration and comparing the magnitude of this vibration with the norms - to assess the vibration state of the winding as a whole. Therefore, the task arose to determine the maximum vibration of the winding based on the results of its measurements on a relatively small number of cores by calculation. To compare this calculated value with the norms, this problem is solved using the methods of probability theory and mathematical statistics. Obviously, with this approach, the value of the maximum vibration of the winding can be determined only with a certain confidence probability, which in such cases is taken high enough, equal to 0.95 [5].

To determine the vibration state of the frontal parts, their amplitude-frequency characteristics (AFC) are taken in the steady-state three-phase short circuit mode of the generator.

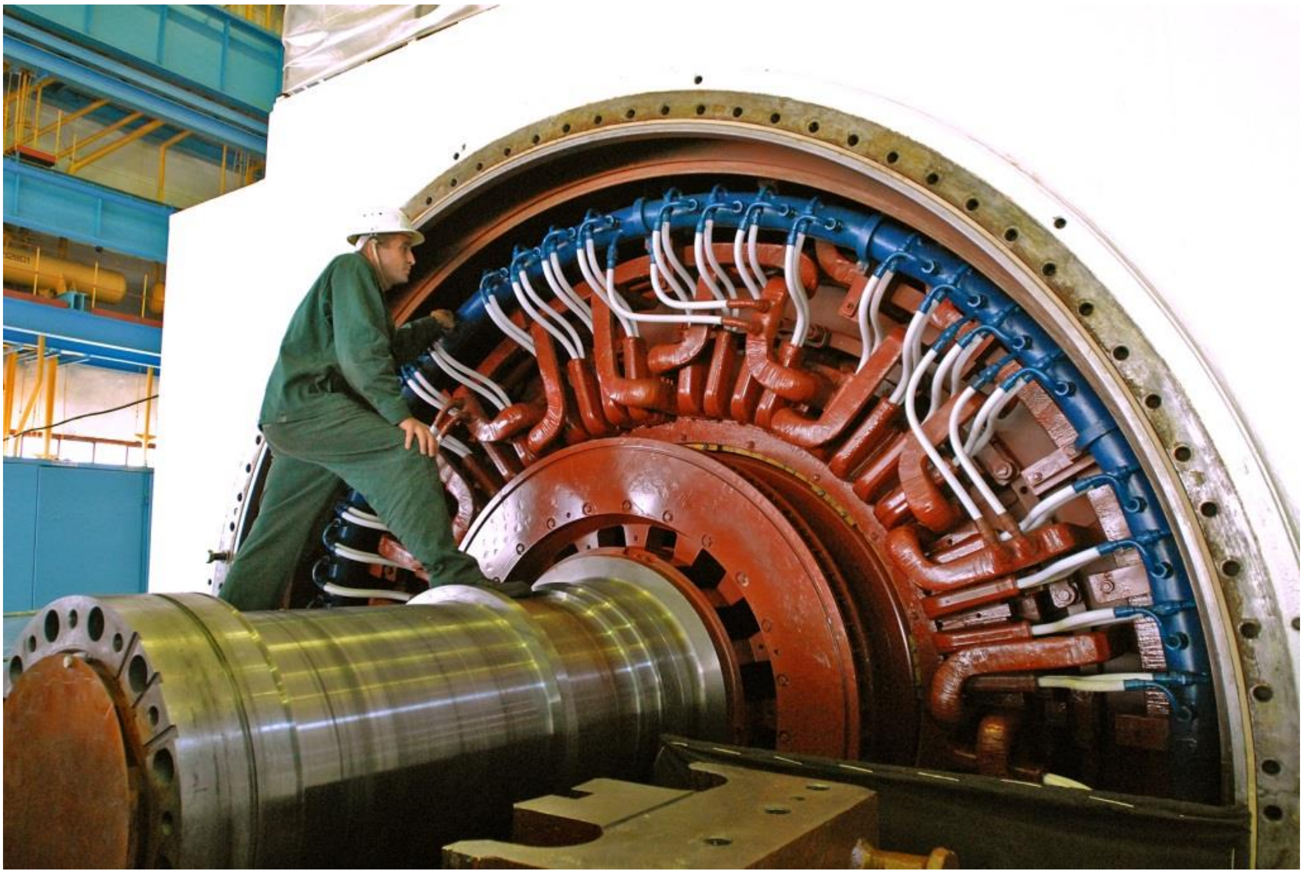

Figure 1 – Overview of the frontal part of the TG stator winding [6]

To remove the frequency response, oscillography of the vibration displacements of the frontal parts is carried out at the runout of the TG. The short circuit is installed at the outputs of the TG or behind the transformer. The rotor current must be constant, which ensures the constancy of the stator current. For this purpose, for the duration of the test, the TG is transferred to the reserve excitation, otherwise the excitation is supplied from the adjacent TG and the corresponding protections are taken out of operation. The excitation level is set so that at the nominal rotor speed the stator current is nominal. Vibrograms are taken approximately every 5% change in rotor speed in the range of 0.4 - 1.2 of the nominal value [5]. Vibration measurement is carried out at one thermal condition of the generator - "hot" (not less than 50°C) [4]. When inspecting the frontal parts of the stator winding, it is necessary to pay attention to the following defects:

a) loosening of jamming of rigid fastening elements (spacers, etc.);

b) loosening and breakage of bandage ties;

c) traces of abrasion of insulation or covering tape in places of contact with rigid elements;

d) cooling water leaks (for generator with direct water cooling);

e) violation of the integrity of fastening elements or stator winding rods (cracks, surface wear).

The design of the stator winding frontal parts under normal operating conditions allows to control mechanical vibrations well enough and prevents damage. Nevertheless, damage of the winding frontal parts may occur as a result of:

a) possible abrasion of the winding insulation due to the movement of one component relative to another;

b) deviations of operating modes from normal, such as short circuits, due to which spatial deviations and power stresses of winding components can exceed their mechanical limits [2];

c) poor system of frontal parts fastening.

Conclusions. The frontal parts of the stator winding are exposed to high voltage and must be protected from mechanical vibrations caused by electromagnetic forces. The stator grooves protect the stator winding well, but a more difficult task is to keep the winding stationary in the frontal part. Different methods are used to prevent the movement of the frontal parts, but despite this, the common problem is the need to provide a certain rigidity and at the same time they must have a certain flexibility. The stiffness is needed to prevent the movement of the frontal parts in normal and emergency operating conditions, and the flexibility is needed to allow for thermal expansion in the frontal parts due to temperature heating and cooling cycles.

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