Vibroacoustic monitoring and troubleshooting of the stators of turbogenerators

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Abstract. The essence of resource-saving technology of turbogenerators operation is to reduce the intensity of vibro-impact processes in defective mounting attachment up to their full blocking by changing the operating parameters of the generator, which do not affect the output of active power. The results on the example of 8 turbogenerators of thermal power plant are shown. It can be seen that the power of vibro-impact processes, and, therefore, the intensity of wear of the stator elements can be significantly reduced in most of the turbogenerators of this station.

1. Introduction

One of the main causes of turbogenerators’ damage, which is determine their reliability and service life, are the loosening defects of the mounting of stator elements. These are the loosening defects of the mounting attachments of the core in stator housing, mounting attachment in the stator housing, the windings in the frontal and slotted parts of the stator, crushing defects of active steel sheets of end packages.

Defects are characterized by the gap width and the starved spot length. The size of the gaps is usually tens to hundreds of micrometers, can reach several millimeters. Defects are local in nature, often occur in difficult-to-predict and hard-to-reach parts of the stator and developing during generator operation under load. The defects growth ultimately leads to the destruction of the stator elements, insulation abrasion of the winding and the occurrence of short circuiting in stator, damage and emergency shutdowns of the generators. During repair, defects are detected by the wear debris and destruction of the stator elements.

On the working generator, loosening defects of the mounting attachments are vibro-impact systems that excite the vibro-acoustic vibrations of the stator structure. In the places of impact, stress waves are excited, which propagating through the structural parts of the stator can be registered on the hull plating of the stator housing with the help of vibration acceleration sensors. The development of effective tools and methods for vibroacoustic diagnostics of stators of turbo-generators is an important task of increasing the reliability of the main electrical equipment of nuclear generating station and thermal power plant (NGS and TPP).

2. The method of vibroacoustic diagnostic of the turbogenerator station

Experimental and theoretical substantiation of the vibro-acoustic diagnostics of stators of turbogenerators method is given in [1]. Here, for the first time, a reliable estimate of the level of the vibro-acoustic signal on the stator housing from vibro-impact processes in defected mounting attachments was obtained by a formalized method and the similarity of the spectral diagnostic signs of
defects was shown. A technique for evaluating the possibility of detecting stator defects by the vibro-acoustic signal spectrum has been developed [2]. It has been proven that the power of the vibro-impact processes in the defective mounting attachments is sufficient to detect them from the vibration acceleration spectrum of the hull plating of the stator housing of a operating turbogenerator [1, 3].

The method of detecting, recognizing and managing the stator defects growth on an operating turbogenerator is built on the dependence of the power of vibro-impact processes in defective mounting attachments on the operating parameters of the generator. A change in operating parameters leads to changes in the excitation amplitude and/or boundary conditions for fixing elements in loosened attachment points. The essence of the method is clear from the results of experimental studies of vibro-acoustic oscillations of the stators of turbogenerators TVV-320-2, shown in Figure 1.

A parameter characterizing the power of vibration acceleration of the stator housing in the range of measurement frequencies from \( f_n = 200 \text{ Hz} \) to \( f_m = 5000 \text{ Hz} \). Is described in formula (1)

\[
M = \sum_{k=n}^{m} A_{u_2}^2(f_k)
\]  

A parameter (2) characterizes the total power of discrete harmonics of the spectrum in the measurement frequency range from 4 to 5 kHz.

\[
M_5 = \sum_{k=1}^{10} A_{u_2}^2(4000 + 100 \cdot k)
\]

Experimental dependences presented in Figure 1 provide convincing evidence of the possibility of effectively managing the loosening defects of the mounting growth by changing the operating mode parameters that do not affect the output of active power. This is the selection of the optimal values of reactive power and temperatures of cooling medium within the established parameters, based on the results of vibro-acoustic monitoring. Managing the defects growth is achieved by:

- performing two-stage operations to change the values of the mode parameter using the experimentally determined hysteresis loop (Figure 1e);
- imposing restrictions on the values of reactive power (Figure 1h) and temperatures of cooling medium (Figure 1g).

The method of operational vibroacoustic diagnostics was tested when conducting vibroacoustic tests of the stators of the turbogenerators of TVV series on more than 70 stators of the turbogenerators of TVV series.

3. System of vibroacoustic monitoring of stator defects, technological complex MoDeSt

Emergency, unplanned shutdowns and damage to turbogenerators of nuclear generating station and thermal power plant due to loosening defects of the mounting of stator elements can be prevented by equipping with the vibroacoustic monitoring tools that provide detection, recognition and control of the stator defects growth on an operating generator.

In Scientific and Technological Center “Resource” LLC, the program-technical complexes of vibro-acoustic monitoring of stator defects of the turbogenerator - technological complex (TC) MoDeSt was developed and successfully operated. This TC implements the method of vibro-acoustic diagnostics of stators of working turbogenerators and methods of detecting, recognizing and managing the defects growth protected by 5th Russian patents [4, 5, 6, 7, 8].
Figure 1. Spectrum of vibration acceleration of the TVV-320-2 case with a loosening defect in the mounting of the stator components (a - d) and the dependence between signal power and the load (e, f, h) and temperature (g)
The appearance of the system and the installation diagram of the sensors are shown in Figure 2. It consists of a signal processing unit and eight sensors, which continuously measure the vibration acceleration of the stator housing hull plating. TC MoDeSt performs:

- Continuous registration and calculation of vibration acceleration spectra of the hull plating of the stator housing of a working turbogenerator in the frequency range from 100 Hz to 5 kHz;
- Detection, recognition and location of loosening defects of the mounting attachments of the core in stator housing, mounting attachment in the stator housing, the windings in the frontal and slotted parts of the stator, crushing defects of active steel sheets of end packages;
- Continuous monitoring of the wear rate of the loosened stator elements;
- Assessment of the significance of the defect by exceeding the threshold values of the diagnostic parameters determined for each type of turbogenerator and the speed of defect growth;
- Software visualization of monitoring results over a local network and via the Internet.

TC MoDeSt is designed for:

- Improving the reliability of turbogenerators by planning the volume of maintenance work and issuing target designations about the defect’s location, which improves the quality of the planned maintenance works;

**Figure 2** Appearance of the measurement block TC MoDeSt on a 300 MW turbogenerator (a) and installation diagram of 8 vibration sensors (b)
• Extension of the service life of turbogenerators through the implementation of resource-saving operation technology, based on the ability to control the speed of stator defects growth;
• Reducing the risk of accidents by prediction of possible short circuits in the generator due to the stator defects growth.

4. Resource-saving technology of the turbogenerator operation (RSTTO)

According to the results of experimental studies, it was found that on most turbo-generators even a slight change in operating parameters can lead to the termination of the vibro-impact process, and, therefore, to suspend the process of accelerated wear. In this case, defects can be eliminated during scheduled maintenance work of almost without reducing the life of the generator. This ensures the prolongation of the service life of the main power equipment of power plants.

Therefore, the use of TC MoDeSt is most promising for controlling the stator defects growth on a operating turbogenerator using the method of performance optimization, i.e. for the implementation of resource-saving technology of turbogenerators operation (RSTTO) [9].

The essence of RSTTO is to reduce the intensity of vibro-impact processes in defective mounting attachment up to their full blocking by changing the operating parameters of the generator, which do not affect the output of active power. The RSTTO capabilities are studied on the example of 8 turbogenerators of one TPP are shown in figure 9. It can be seen that the power of vibro-impact processes, and, therefore, the intensity of wear of the stator elements can be significantly reduced in most of the turbogenerators of this station. The exception is TG-8, the moment of implementation of the RSTTO for this machine is already missed, and to eliminate the intensive wear of the frontal arc mountain attachment system of the stator winding and prevent possible accidents, an expensive maintenance works are required to upgrade the stator winding mounting attachments.

An example of using the results of the TC MoDeSt operation to assess the quality of assembly, maintenance works and the rate of stator defects growth is shown in Figure 3, 4. It can be seen that immediately after upgrading on the TVV-350-2 turbo-generator, the growth of a core suspension defect occurs at night, during generator unloading, to a minimum safe output of the unit. The intensity of vibro-impact processes for 150 days of operation of the generator has increased dozens of times to a critical level of the defect growth, and the dependence itself gives a failure curve, figure 5. After the maintenance work on fixing the upper keybar of the core, the vibro-impact processes in the stator ceased.

![Figure 3. RSTTO opportunities based on the example of the turbogenerators in one TPP](image-url)
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M, \( \frac{m}{s^2} \)^2

Night

Day

Figure 4. Daily chart of power measurement in time using 4 sensors (a), active P MW and reactive Q MVAr load (b) before the maintenance work of the suspension core

Figure 5. The chart of daily variation of the maximum value of the M parameter before and after the maintenance work of the suspension core

5. Conclusion

To introduce the developed innovative tools and methods for vibro-acoustic diagnostics and monitoring of turbogenerators, it is necessary to:

1. determine the threshold levels of significance of vibro-acoustic diagnostic parameters of turbogenerators by experimental evaluating the frequency characteristics of the stator structures during their general maintenance. One turbogenerator of each type is enough.

2. conduct periodic vibroacoustic tests of the turbogenerators stators to assess the intensity of wear of the mounting attachments, the degree of danger of defects and make recommendations for managing the speed of the defects growth.

3. equip the turbogenerators with TC MoDeSt for the implementation of resource-saving technology of their operation, diagnostics, assessment of the quality of assembly and maintenance work.

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