STUDY OF TURBOGENERATOR ROTOR MOVEMENT IN TRANSITIONAL REGIMES BY A PHASE CHRONOMETRIC METHOD

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Results are provided for recording transitional processes in a turbogenerator obtained by means of a phase chronometric system. Experimental data are compared with results of mathematical modelling.

Key words: diagnostics, phase chronometry, turbogenerator, mathematical model.

The shafting of each turbogenerator (TG) functioning within the unified power generation system of the country is constantly in a transient complexly stressed state under the action of the following factors:

- torsional moments distributed over the length of the shafting created on one hand by the pressure of a flow of steam in turbines, and on the other hand by electrodynamic forces of the interaction of rotor and stator currents in the generator;
- transient impulse torsional electrodynamic moments arising when the generator is connected/disconnected to/from a load, and also when there jumps in external load parameters;
- significant temperature drops over the extent of shafting;
- disturbance of balancing and assembly errors for shafting that determine its vibration activity.

One of the main phenomena of this transient complexly stressed state in TG operation appears to be torsional vibrations of the rotating shafting. Constantly excited by the action of the external grid bursts of these vibrations lead to gradual ageing of the TG moving parts, especially the shafting. In particular, sharp increases in the amplitude of torsional vibrations for shafting are initiated by processes that occur outside the station with breakdowns in the power system (29%), jumps in load (19%), under the influence of direct current inserts in the electricity transmission line (17%), and so on (7%) [1]. However, processes within the station may also cause excitation of torsional vibrations. Experience of TG operation has shown that the most critical are bursts of torsional vibrations that accompany TG synchronization (connection) and disconnection from the external grid. From the results of studies performed in power engineering it follows that the potential probability of the risk of a breakdown occurring with incorrect synchronization reaches 20%. In view of this, it is important that there is continuous metrological provision for TG operation, creation and introduction of a system for measuring the parameters of generator rotor movement and sections of the turbine shafting for torsional degrees of freedom. This system will supplement existing means for monitoring and make it possible to provide constant prediction of TG condition and its breakdown protection. In contemporary practice of TG operation torsional vibrations are not amenable for measurement by the standard equipment of stations [2].

Creation of a phase chronometric system makes it possible to obtain measurement information about the amplitude of torsional vibrations under conditions of an electric power plant machine hall with an absolute error of ±2°, and diagnostic information about torsional vibrations and transitional processes [3]. The system contains a measuring disk, located in the coupling of the TG generator-driver, a unit for forming the measuring signal and card installed in a computer for processing information. The measuring disk has grooves that with rotation modulate a light flux, i.e., they create a sequence of light pulses entering through a light guide the unit for forming the measuring pulse. The latter is transferred to a special processing card. The phase chron-
metric information obtained is recorded on a hard disk or in the operating memory of a computer in the form of a collection of experimentally determined values for rotation periods processed in the computer using a package of special application programs.

The phase chronometric system for determining shafting movement parameters makes it possible to detect interaction between the TG and the external grid. A typical example of this interaction may be the jerks in a periodogram on connection of the generator with the external grid (Fig. 1). Measurements performed confirm that the shafting of an operating TG is in fact constantly in an excited transient condition. Absence of a steady-state regime, as already noted above, is explained by a collection of actions both from the direction of the grid, caused by fluctuation in load parameters, and also the TG control system. The possibility of recording transitional processes makes it possible to consider their effect on fatigue accumulation in the shafting metal and to predict the technical state or to evaluate its residual life. An example of a typical “standard transitional” regime with a sharp change (increase) in load in the external grid is shown in Fig. 2. The curve was obtained as a result of converting variations in rotation period into oscillation angles [4].

Processes recorded by means of phase chronometry make it possible to identify a TG mathematical model. Accumulation of databases and their mathematical processing provides separation of diagnostic indices that assist monitoring of transitional regimes and the creation of new generations of prediction systems for TG breakdown protection.

The mathematical model of a generator is a set of Park–Gorev differential equations for a salient-pole synchronous machine with one field winding rigidly connected with the rotor [4]:

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\begin{align*}
rl_d + L_d \frac{d}{dt} I_d - \omega L_q I_q - k_h \frac{d}{dt} i_b &= -U \sin \theta; \\
\omega L_d I_d + r I_q + L_q \frac{d}{dt} I_q - k_h \omega i_b &= -U \cos \theta; \\
\eta_b I_b + L_b \frac{d}{dt} i_b &= U_b + k_h \frac{dI_d}{dt}; \\
J \frac{d\omega}{dt} + k_h I_q -(L_d - L_q) I_q I_q &= M_1; \\
\omega &= \omega_0 + \frac{d\Delta \theta}{dt},
\end{align*}
\]

Fig. 1. Periodograms obtained with connection of a turbogenerator with an interval of two months (1, 2). The broken line corresponds to a mathematical model: \(\Delta \theta\) is the change in angle of rotor and stator currents; \(N\) is the order number of shafting rotation period.