LITERATURE CITED


BALANCE OF THE ROTORS OF HYDROELECTRIC GENERATORS

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Increased vibrations of turbine–generator units are caused by mechanical, hydraulic, and electrical disturbing forces. Vibrations caused by centrifugal forces of rotating masses (rotor of the unit) occur upon imbalance of the turbine runner, generator rotor, and exciter rotor.

Turbine runners undergo static balancing at the plant or during assembly. This cannot be done with generator rotors owing to their large dimensions and weight, and they are balanced in their own bearings. Although each pole of the rotor before installation on the rim is weighed and stamped and then poles similar with weight are arranged diametrically opposite one another, it is not always possible to achieve an equality of the weight in every section of the rotor, which leads to the occurrence of mechanical imbalance. This is observed not only after assembling the units but also after overhauls. In addition to insufficient accuracy of assembly works on the installation of the poles other causes of imbalance of the rotor are also possible: displacement of the rim or individual poles of the rotor, misalignment of the axis of the generator rotor and turbine rotor, deviation of the axis of the rotor shaft from the vertical, difference in the temperature deformations of individual elements of the rotor, etc.

During rotation of the unit imbalance of the rotor causes increased radial vibrations with a frequency of revolution. The imbalanced mass \( m \) located at distance \( r \) from the axis of rotation causes a centrifugal force

\[
F = mj = mω^2r = (b/g)r(n/30)^2,
\]

where \( j \) is acceleration; \( ω \), angular velocity; \( b \), weight of the imbalanced mass; \( n \), rotational speed, rpm.

This force is located in a plane perpendicular to the shaft axis. For vertical units, the centrifugal forces are directed in the horizontal plane, and therefore the vibrations caused by these forces are also horizontal and in a pure form have a frequency of revolution. The amplitude of vibration is directly proportional to the disturbing forces: consequently, the double amplitude of vibration, as seen from (1), is proportional to the square of the rotational speed

\[
2A = kn^2.
\]

Mechanical imbalance is detected by tests of the idling unit with various rotational speeds of the rotor. The double amplitudes of vibration of the load-bearing components of

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the unit are recorded from oscillograms and the graph $2A = f(n^2)$ is plotted. If the points of this graph fit close to a straight line, then this means that vibrations with a frequency of revolution are caused by the presence of mechanical imbalance.

Imbalance can be static and dynamic. Static imbalance is most often observed for generators with a large diameter and small height of the rotor (generator with a small rated rotational speed). To eliminate it, it is sufficient to fasten on the rotor a balancing weight such that the moment of forces relative to the rotation axis is equal to zero, i.e., the moment of the imbalanced masses becomes equal to the moment created by the balancing weights.

The presence on the rotor of two imbalanced masses located in the plane passing through the rotation axis (whereupon the rotor is statically balanced) causes dynamic imbalance. This case is possible on generators with a large rated rotational speed, for which the height of the rotor is commensurate with its diameter. Balancing in this case amounts to placing weights creating a moment of forces relative to the transverse axis equal to the moment of centrifugal forces from the imbalanced masses, in which case the sum of the projections of the forces on the axis of the coordinates should be equal to zero; the weights are mounted in the upper and opposite lower sides of the rotor.

A theoretical calculation of the mass of the balancing weight is complex and not always accurate, and therefore a trial weight is at first mounted

$$P = k(b_r g/2 \omega^2 r),$$

where $b_r$ is the mass of the generator rotor, $k$; $\omega$, angular velocity, 1/sec; $r$, radius of attachment of the weight, m; $k = 0.01-0.05$.

Then on the basis of the change in the level of the vibrations the calculation of the total balancing weight is refined with consideration that the amplitude of vibration is directly proportional to the disturbing force. If the "heavy" point moved 180 on the oscillogram, the weight must be reduced.

On the No. 4 unit at the Chirkey hydrostation imbalance of the generator rotor (suspended type) occurred after overhauling, apparently due to displacement of the poles during their hot wedging. Balancing was carried out, during which the level of vibration was measured on the upper and lower generator bearings. After determining the "light" point, balancing weights with a mass of 210 kg were amounted on the spoke closest to it, as a result of which the level of horizontal vibration of the upper crosspiece in an idling regime decreased from 142 μm to 48 μm. During operation under a load the vibration was not more than 56 μm, whereas before balancing it reached 165 μm (Fig. 1). Table 1 gives comparative data on vibrations before and after balancing the rotor of the No. 4 unit of the Chirkey hydrostation.

It is not always possible to achieve a considerable effect by mounting on the rotor a comparatively small weight, as in the given example. For instance, on balancing the rotor of the No. 3 generator of the Chirkey hydrostation by mounting a 420-kg weight on the rotor, it was possible to reduce the level of vibrations of the upper crosspiece by only half — from