ROTOR STRUCTURE ELEMENTS DAMAGE OVERVIEW OF THE SALIENT POLE SYNCHRONOUS HYDROGENERATOR

Galisevych S.I., bachelor, Geraskin O.A., associate professor
Igor Sikorsky Kyiv Polytechnic Institute, Department of Electromechanics

Introduction. Hydrogenerator (HG) is an indispensable component for the functioning of the hydroelectric power station. Electric energy is produced by converting the mechanical energy of the hydroturbine into electrical energy at the outputs of the generator. Fig. 1 shows the components of the HG rotor of low power: the rotor consists of six main components: the upper shaft, the poles, the rotor rim, the rotor spider, the thrust ring, and the lower shaft.

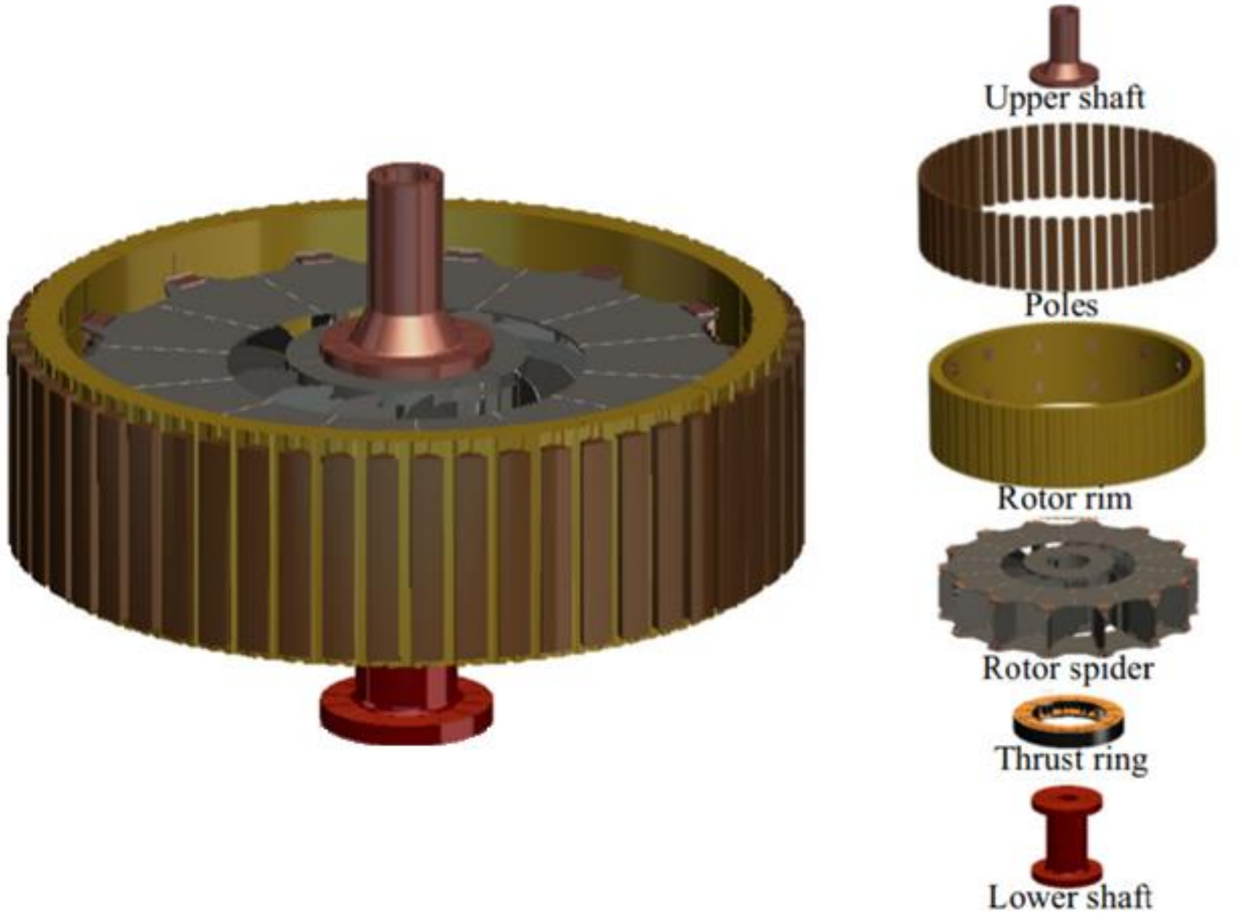

Figure 1 – Schematic image of the HG rotor and its components [1]

Each rotor detail has extremely important functions for the correct operation of the entire installation. The upper shaft has the function of connecting the rotor to the collector ring or exciter, and it usually has an expansion, the purpose of which is to transfer the radial forces from the rotating part to the upper guide bearing if it is structurally conditioned. The poles are responsible for creating a magnetic field that will produce the electromotive force (EMF) and generate current in the stator. They consist of a coil and a core.

Mechanical defects of the rotor significantly affect not only the reliability of the HG but also the reliability of the hydroelectric power plant in general. Their elimination takes a significant part of the total time of repair of HG. At the same time, the amount of attention paid to the definition, evaluation, and elimination of such defects is not always sufficient. Problems related to defects in the electric part of the rotors, including the insulation of the coils and the frame of the poles and the damper winding, as well as defects in the guide and support bearings should be considered only in connection with the main mechanical defects of the rotor. By origin, mechanical defects of HG rotors can be conditionally divided into structural (due to inaccurate manufacturing of parts), installation (due to inaccurate assembly of hydroelectric power plant components), and working (due to changes in the state of components under the influence of operational factors). Most HG defects are interconnected and can mutually affect each other. Defects and the labor intensity of their elimination during repair can vary significantly. Consider the rotor defects in the order of their occurrence frequency and their impact on the reliability of the HG and the labor intensity of their elimination.

Purpose of work. Analyze literary sources and make an overview of the rotor elements damage of the synchronous HG apparent pole.

Materials and research results. In this article, priority attention is paid to problems associated with mechanical defects of vertical-type hydro generators rotors.

Mechanical defects of the auxiliary generator can be as diverse as defects of the HG itself. Although the former is much less significant for the functioning of HG than the latter, in some designs, such as the umbrella type HG with a cross at the top (without a guide bearing), their defect can be significant. Since the excitation system of the machine in medium and high power during reconstruction can be replaced by thyristor excitation, defects associated with the auxiliary generator (exciter) are very rare.

Mechanical defects of the hydraulic unit brake system are mainly related to the reinforced beat of the discs, which can disrupt the attachment of the disc segments, cause increased wear of the brake pads, etc. The most common fault is the leakage of oil through the cups when the rotor is inhibited. Leaks are usually eliminated by replacing cups. However, there were cases when the damaged mounting of the torn pads caused serious failures. For example, during the reconstruction of the Novosibirsk HPP, the damaged attachment of the torn pad forced the pad to return across the brake disc. The pad cut off many of the lower ends of the pins located on the rim behind the brake disc, which caused the need to squeeze the pins and replace them. Currently, brake segments are designed and fixed to the rotor rim differently.

Defects in the ventilation system of the rotor are rare, but they are dangerous in the event of cracks, accompanied by the rupture of blades or air duct elements. Disconnected ventilation elements can enter the air gap and damage the rotor and stator winding.

The "wave" of the rotor rim can appear in the work due to the weakening of the rim pressing, the tightness of the rim, its thermal deformation, and other factors. Increased "waviness" at the rotor rim can cause axial dynamic forces acting on the stator core, and cause the disc to be beaten at the point of attachment to the bottom of the rotor rim.

Reducing the mechanical strength of rotor parts can be caused by a fairly large group of damage factors. It can be the imperfection of the structure of the detail, various defects, and ineffective (or inadmissible) methods of their elimination. The appearance of cracks and their spread can cause the failure of the structural elements and rotor in general or cause significant damage of the generator. The separation of some thin elements of the rotor parts can lead to their getting on the rotor or stator in the air space of the generator, followed by damage of the windings, the appearance of cracks. It is difficult to use effective methods for detecting such defects at the initial stage of their formation, and in most cases, they can only be detected by systematic fastening checks.

The mechanical imbalance of the HG rotor is a fairly frequent defect. This is due to the presence of unbalanced masses in the rotor. The imbalance can be caused by constructive reasons (for example, the low strength of the generator shaft, which leads to its bending and the appearance of significant centrifugal forces from the large mass of the rotor rotating), a technological process (for example, inaccurate geometry of some rotor parts), installation (primarily inaccurate assembly of components and uneven distribution of the segments and poles weight of the rotor rim). An unbalanced mass creates a centrifugal force acting in a plane perpendicular to the shaft axis. This force obtained by the supporting parts of the hydraulic unit is manifested by the radial vibration of the bearing parts at the rotor frequency. A characteristic feature of the mechanical imbalance of the rotor is the increase in the amplitude of the rotating component of the vibration of the supporting parts of the hydro-electric unit, which is proportional to the square of the rotor speed**.** As a rule, the mechanical imbalance of the rotor of the generator, which to some extent is always present in the HG, is the cause of the reinforced beat of the shaft on the bearings of the generator and the radial vibration of the bearing structures; imbalance is easily removed by balancing the rotor in its bearings by establishing balance loads on the rotor spokes. However, it happens that repair measures (in this case, necessary for balancing the rotor) are aimed not at eliminating the imbalance, but rather at correcting the shaft line or restoring the gaps in the bearings, while the gaps increase during operation due to the presence of a disturbing force, one of which is the imbalance of the rotor.

The eccentric position of the rotor in the stator bore is the cause of both static and dynamic rotor asymmetry in the HG air space (Fig. 2), which can cause significant forces of one-way movement between the rotor and the stator.

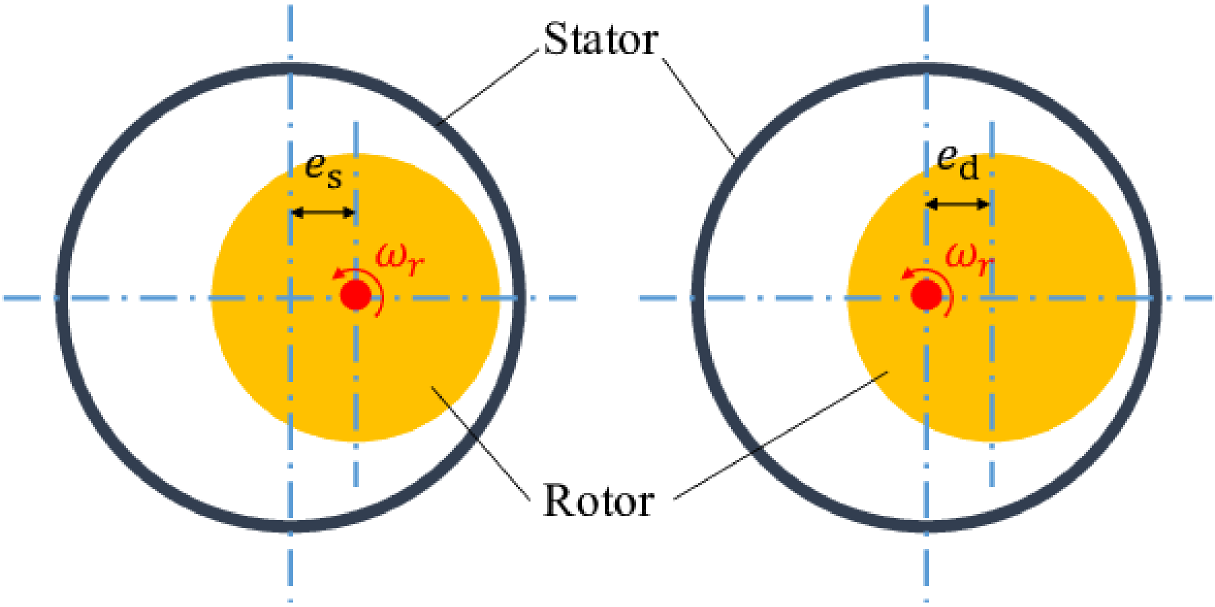

Figure 2 – Eccentric motion of the rotor in the stator boring at static and dynamic eccentricities of the rotor [2]

At high eccentricity, these forces can reach tens of tons and cause unilateral heating of the segments of guide bearings and even their failure. In addition, due to the eccentric position of the rotor in the stator boring, the rotor poles alternately fall into areas of small and large air intervals and can be exposed to significant dynamic forces, which can reduce the mechanical strength of the rotor parts and, consequently, change the shape of the rotor. The eccentric position of the rotor in the stator bore is manifested in the shift of the rotor during its operation and the unilateral pressure on the segments of the generator bearings towards the smaller air gap of the generator. The eccentricity can be the result of poor centering of the generator, changing the shape of the stator, or its radial shift over the foundation slabs during operation. Eccentricity can be avoided by centering the hydraulic unit. When the eccentricity is significant, the stator frame must be shifted. However, since the displacement of the stator and the correction of its shape are quite time-consuming operations, they are rarely performed. As a rule, the centering of the rotor and stator is limited to the possibility of entering the water wheel without displacement of the stator. The electrical imbalance of the HG rotor is usually a consequence of the rotational asymmetry of the rotor's magnetic field. In its turn, the latter can be caused by various structural reasons (for example, hydrogenators of Cheboksary and Nyzhniokam hydroelectric power plants were manufactured at the plant "Electrosila" with an increased interpolar distance [3]), installation causes (assembly of the rotor with deviations exceeding the permissible range) and operational factors (appearance of short-circuit). The presence of rotating asymmetry of the magnetic field of the rotor is manifested in the form of vibration of the stator core and the HG cross or in the form of a shaft beat on the generator bearings (in case of a significant electrical imbalance of the rotor, this can affect the bearing of the turbine of the hydraulic unit). Short circuits of coils in the winding of the poles can cause the appearance of low-frequency radial vibrations of the stator core. However, such defects are relatively rare. In addition, they are easy to detect and eliminate by simply replacing the pole winding or restoring the coil insulation. At the same time, there were cases when generators worked with short-circuited coils and even whole poles for a long time. For example, nine poles with short-circuited coils were identified during the overhaul of the generator № 2 Vygostrow HPP in 1986, and eleven short-circuited poles in 1996 during the overhaul of this same generator. Short-circuited coil groups near the poles are very dangerous in terms of the appearance of a significant electrical imbalance and, therefore, enhanced vibration of the stator core.

Defects associated with the reduction or complete disappearance of the rotor rim tightness constitute the largest group of rotor defects. Changes in the shape of the rotor due to deterioration in the tightness of the rim and the subsequent appearance of electrical imbalance of the rotor with the subsequent increase of low-frequency vibrations of the HG stator core occur quite often. Judging by the results of numerous vibration tests, a significant number of hydrogenerators work with low-frequency vibrations of the stator cores, which is significantly higher than the permissible level due to the poor shape of their rotors. For example, the results of vibration tests of all 16 hydrogenerators of the Nyzhniokam hydroelectric power plant, conducted in 1993, showed that many of them were unsatisfactory. The level of low-frequency radial vibration of the stator core on most proven generators exceeded the nominal value; some generators had to be repaired and two needed rotor reconstruction. Other data indicate the presence of defects associated with a decrease in the tightness of the rotor rim. According to the staff of the Nyzhniokam HPP, all 16 hydrogenerators have weakened wedges of spokes and cracks at the joints of structures, and in some cases, the braking of the hydro-electric unit is accompanied by the raising of the rotor rim relative to the rack. Other hydroelectric power plants also suffer from the same defects. At the same time, not every hydroelectric power plant systematically carries out vibration control. Reducing the tightness of the rotor rim, even if its shape remains concentric and does not increase the vibration of the structural elements of the hydroelectric power plant, can cause a decrease in the mechanical strength of the HG in combination with other factors, namely: vertical vibration of the hydraulic unit, the presence of "waves" on the stator core and rotor rim, as well as the reinforced beat of the brake disc. The decrease in the mechanical strength of the generator is manifested by the formation of cracks on the rotor body, in particular, in the roots of the supporting teeth of the rim, and the breakage of the supporting tooth, which are very dangerous phenomena [1].

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