EXPERIENCE IN MODERNIZING AND REEQUIPPING TURBINE EQUIPMENT AT THE KRASNOYARSK HYDROELECTRIC STATION

V. F. Malyshev

The Krasnoyarsk hydroelectric station (KHES) has served our country for 30 years, giving electricity to industrial and agricultural enterprises, heat and light to apartments. During this time more than 540 billion kWh of cheap electricity was produced. The people who were the source of the hydrostation created a pearl, which for many years to come will serve as the basis for the life and development of subsequent generations.

Today the hydrostation is experiencing a period of rejuvenation. The generators that have exhausted their life are being replaced, the components of the turbine plant are being modernized or replaced. During the long period of operation the main and auxiliary turbine equipment of the hydrostation completely exhausted its life, having used up its standard service life established by the manufacturing plants, was worn out and became obsolete, and requires replacement. The station has been engaged in modernization of the main equipment for a long time. On November 3, 1967 the generator was connected to the network. Operation began. The generators could not operate without forced lubrication of the thrust bearing. The generator could not operate in a synchronous capacitor regime. With increase of head to the design (93 m) it was found that the adjusting forces of the servomotors of the gate apparatus were not enough for controlling the units. An interdepartmental commission was organized. The plants decided to increase the operational capability and reliability of the units. The cylinders of the servomotors with a diameter of 650 mm were replaced by ones with a diameter of 750 mm on the turbine. Additional pipelines were installed for the possibility of converting the generator to a synchronous capacitor regime. Forced lubrication was installed on the thrust bearings of all units being assembled. The introduction of forced lubrication devices increased the reliability of their operation, but nevertheless there were one or two damages a year on the thrust bearings.

In October 1982 a meeting of power engineers was held in Cheboksary at the State Republic Plant for Supplying Spare Parts of Electric Power Stations (Elektrozapchast') concerning the matter of the reliable operation of thrust bearings and use of a fluoroplastic coating of the friction surface of the bearing segments. It was decided to replace the babbitt coating by an elastic metal-plastic coating as soon as possible. Between May 1983 and July 1985 the segments on all thrust bearings of 12 generators were replaced.

The State commission on problems of the operating reliability of the Krasnoyarsk hydrostation units functioned in 1987. It was decided to reconstruct the generators and modernize the turbine equipment.

The management of the station worked 6 more years at all levels on an in-depth substantiation of the need for reconstructing the main equipment of the station and such a decision was made. Reconstruction was planned by the general designer, the State Planning, Surveying, and Research Institute (Gidroproekt). In August 1991 the technical and economic design of reconstruction of the Khes, perfected to the working design, was approved by order the technical department of Sibir'energo. The Elektrosila Plant and Leningrad Metals Plant (LMZ) carried out the working design of reconstruction of the electrical and hydromechanical part of the unit. By the start of 1993 the plants completed the working design; however, the decision made about putting the new generator into production was postponed due to the unclear economic situation and other problems: the situation was analogous with the turbine equipment. Thanks to the deep understanding of the need to replace the generators, G. B. Pinskii, chief designer of the generators of the KHES, Elektrosila, and with the assistance of K. V. Pekler, deputy chief designer of LMZ, it was possible to coordinate the main problem of putting the generators into production, filling the order, and concluding an agreement on obtaining spare parts for reconstructing the turbines.

It should be noted that many assembly devices and rigging were absent at the time of reconstructing the first unit No. 2 at the KHES. Strenuous work on designing and manufacturing assembly devices was carried out in the station's shops. Eight assembly devices and more than 50 slings of various types were made during the preparation period. This work is continuing to this day. Using the potential of the local military-industrial complex, a fundamentally new power driver for pairing the rotor frame with the turbine shaft was designed and is in the

process of being manufactured; in this case it is seven time cheaper than LMZ's standard design, which today, when expenses have to be counted, is very important.

In November 1994 all preparatory works were completed, and on November 14, 1994, generator No. 2 was the first at the station to be taken out of operation for reconstruction. Wear of the stator winding of the main generator, increase of the number of failures of the generators because of damage to the winding on average up to four times a year, and increased cost of scheduled repairs with replacement of the bars were the primary reason for reconstruction at KHES. However, to disregard the main hydropower equipment, the replacement and reconditioning of which fitted in time into the period of replacement of winding of the main generator, was an impermissible luxury. The cost of purchasing turbine spare parts, which were eight times less than the cost of repairing the generator, wear and obsolescence of the turbine equipment, and new standard service life set by the State Standard from 1986 - 40 years - were taken into account.

It was decided to carry out comprehensive reconstruction in order not to return to complete dismantling of the units at the end of reconstructing the generators, planned for 2006-2007, because of complete wear of the turbine equipment.

At the KHES are installed 12 500-MV units; turbines made by LMZ of type RO-697-VM-750, \( H_d = 93 \text{ m} \), \( H_{\text{max}} = 100.5 \text{ m} \); generators made by Elektrosila of type SVF-1690/175-64. Start of operation, 1967. The plan for reconstructing the turbine plant does not call for changing the power parameters. The purpose of reconstruction is modernization or replacement of components of the turbine plant which are worn and obsolete and do not meet current turbine requirements. The gate apparatus, guide bearing, pipeline of the governor system, feedbacks, drain valves of the scroll casings, speed governor, and oil-pressure system with its automatic devices were modernized or replaced.

**Gate Apparatus.** Reconstruction provides for the use of almost all main components and parts of the apparatus. The main purpose of reconstructing the gate apparatus is replacement of the obsolete and worn support friction assemblies and bushing kinematic assemblies made of polymeric materials not requiring lubrication during the entire operating period. With consideration that the given material works reliably paired with stainless steel (i.e., in the absence of corrosion products and abrasive particles), the support surfaces of the guide vane journals were faced with sheets of corrosion-resistant steel. To protect the lower and upper vane journals from abrasive particles and to eliminate water leaks into the turbine cover, rubber sealing rings were installed on the journals.

To reduce leaks through the closed gate apparatus, the vertical support component of the vane was transferred from the lever to the upper end of the vane by installing special bronze rings on the lower end of the cast-iron sleeve. Furthermore, the lower end of the vane was additionally sealed by a bronze ring which was pressed against the vane by six springs. Adjacent vanes are sealed by their direct contact. The edges are trimmed during assembly of the component. The vane is hard-surfaced with stainless steel during modernization at LMZ. To increase the operating reliability of the regulating ring, the radial support was transferred to the upper flange of the turbine cover. The support surfaces were faced with stainless steel.

A positive result of modernization is the use of almost all main components and parts of the gate apparatus and modernization of the regulating ring and lower ring of the gate apparatus on site. The manufacture of one replacement set of vanes with levers, cover plates, etc., made it possible in a short time to carry out reconstruction on the first unit and advance modernization of the vanes on the subsequent ones – this in the presence of organizational problems. In a technical aspect – a reduction of leaks through the closed gate apparatus by about 1.5 m²/sec by installing end seals around the vane journals and so of a polyurethane seal in the turbine cover and lower ring of the gate apparatus; elimination of the cost of reconditioning the vane seals. Modernization of the bearings of the guide vanes and all friction supports of the turning mechanism made it possible to reduce the required adjusting forces of the servomotors. The expected effect was an increase of reliability and operating life of the friction pairs. Modernization of the regulating ring made it possible to reduce its deformation due to a more rational arrangement of the radial support, modernization of the lower ring of the gate apparatus made it possible to eliminate misalignment of the vane – a reduction of wear of the support components of the vanes is expected.

**Turbine Guide Bearing.** The cast-iron bearing housing was replaced by a steel one. It was equipped with a new set of rubberized bushings and fastening parts. The expected effect from modernization is an increase of reliability and operating life of the bearing.

**600-mm Diameter Drain Valve from the Scroll Casing.** All movable parts, servomotor, and seal bushing were replaced. The lining of the drain tube was replaced by a stainless steel one. The expected effect is an increase of service life.

Works were carried out on reconstrcuting the governor system. The governor with magnetic amplifiers were replaced by more modern ones made on integrated circuits (units Nos. 2 and 3). At present a new-generation governor with microprocessors will be used during reconstruction of unit No. 4. The expected effect is improvement of the regulating characteristics and decrease of operating expenses.