HYDROTECHNICAL CONSTRUCTION

SPECIFICS OF RECONSTRUCTION AND EXPANSION OF NIVA HPP-2 HYDROELECTRIC PLANT

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The practice of reconstructing and expanding a functioning hydrosystem in the Far North is discussed.

On the Kola Peninsula are 17 hydrosystems of capacity 1592.8 MW designed by Lengidroproekt function within the Kolénergo power system with an average annual electricity output of 6.3 billion kW · h/year.

All hydrosystems except for Niva HPP-2 are based on rocks. Niva HPP-2, which is the pioneer power project in the transpolar region, has operated since 1934. The power of the hydroelectric power plant (HPP) is 60 MW, it has 4 generator units, and its head is 36 m. The HPP flow rate is 200 m³/sec. The annual electricity output is 416 million kW · h.

The reconstruction of the HPP. A feature of Niva HPP-2 is that the plant and the supply canal 4.44 km long are based on morainic soils (Fig. 1).

Back in 1930s the heaving properties of morainic soils were little known; therefore, the design of the supply canal facing did not take into account this fact. The canal had a continuous nonreinforced concrete facing of thickness 15 – 25 cm placed on moraine with a transitional layer of 5 – 15 cm. Virtually since the beginning of operation, cracks originated in the solid facing in the variable horizon zone (up to 3.5 m from the dam crest) and by the beginning of 1970s the state of the canal slope facing was unsatisfactory; facing along the entire canal length broke into separate blocks, which fell on each other and were sinking toward the canal bottom.

In the course of research intended to reconstruct the canal facing (Fig. 2) the engineers considered different variants and came to the conclusion that the main reason for the destruction of the facing is the heaving of the moraine soil, and

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The heaving phenomenon in moraine attenuates at a depth of 1 m; therefore, moraine ought to be replaced by sand-gravel or rubble to a depth of 1 m, which was included in the reconstruction design: assembled ferroconcrete slabs of thickness 15 cm, length 4.0 m, and width 2.3 m were placed on top.

In 1976 the prototype segment of facing of length 400 m was reconstructed and has been in an excellent form for around 30 years. By today around 80% slopes on both banks of the supply canal have been reconstructed in the above way.

The canal reconstruction design included field inspection drives along the banks, where the canal passes in depressions, which was not originally planned. In places where the canal passes through dams filled with moraine soil, the dam body is extended from the tail-water side, and drainage prisms are reconstructed as well by additional loading with rocks. The 1930 design did not allow for the possibility of an unstable regime of the canal. During the reconstruction the dam crest was raised by 30 cm.

Since the beginning of service Niva HPP-2 had 4 wooden (larch wood) conduits of 4 m diameter and flow rate 50 m³/sec, made of staves of thickness 100 mm and width 142 mm; conduit bonding made of round steel of diameter 19 – 22 cm is placed with a spacing of 5 – 10 cm. The conduits rested on 38 saddle supports with a spacing of 2.5 m connected by a ferroconcrete ribbon placed on a quarrystone foundation.

In 1960 – 1970 the wooden staves of the conduits were replaced by new staves made of Murmansk pine tree, which is significantly inferior to larch; moreover the riveting quality was worse than originally. As a consequence, by the 1980s monitoring registered the nonreliable state of the conduits: the staves performed to the extent of 40 – 50% of their thickness, and leaks and flooding of the slope on which the conduit reposed were registered. The problem was to replace the wooden conduits by metallic ones. The difficulty consisted in the fact that the load of the conduit on the existing belt foundation and, accordingly, on the slope on which the conduit was located had to be maintained unchanged. Furthermore, all replacements had to be made under conditions of continuous performance of the HPP.

The new conduit preserved the diameter of 4 m, the supports are of the roll-type spaced after each 5 m, and the metal thickness is 12 mm. Another difficulty of the transition from a wooden to a metallic conduit was the fact that the wooden conduit had both upper compensators near the head-pond intake and lower compensators near the anchor support and, consequently, did not transmit the load to the anchor support, whereas the steel conduit has only upper compensators and is rigidly welded to the anchor support below. However, the switch-gear building rests on the anchor support and on the HPP building; therefore, considering that both structures rest upon soft moraine, rotation of the anchor support under the effect of the new conduit would be inadmissible. It should be noted that steel branch pipes of length 5.45 m, diameter 3.7 – 4.0 m, and thickness 16 mm were initially located between the anchor supports and the HPP building. An inspection revealed that they had no compensators at their ends and were welded near the HPP building and near the anchor support. After a series of calculations, it was decided that to prevent rotation of the anchor support and, accordingly, the destruction of the building, the steel branch pipes had to be coated with concrete, connecting the reinforcement to the anchor support and to the HPP building.

In 1986 – 1989 under conditions of the operating power plant, the wooden conduits were replaced by metallic ones with simultaneous concrete-covering of the steel branch pipes (Fig. 3). Another difficulty of laying concrete on the branch pipes was the fact that a reinforcement of diameter 40 mm had to be fixed to the HPP building and the anchor support and covered with concrete in constrained conditions of a structure located below the downstream level of the HPP (pumping out water, delivering reinforcement and concrete). Covering the branch pipes with concrete proceeded simultaneously with the replacement of the conduits, since only in this case could the new conduits be put into service.

The new conduits have demonstrated high reliability in service: in 15 – 18 years of their service no deformations in the switch-gear building nor anchor displacements have been registered.

In the design of the 1930s the HPP building had no protection from ruptures of wooden conduits. In the 1950s a ferroconcrete wall was designed and built in front of the plant building. The discharge of water in the case of breaking of the conduits is implemented along the left bank around the HPP building into the discharge canal. At the same time the drainage system near the HPP building was reconstructed.