EXPERIENCE IN THE OPERATION OF HYDRAULIC STRUCTURES AND EQUIPMENT OF HYDROELECTRIC STATIONS

REDUCTION OF WATER HAMMER IN PRESSURE CONDUITS BY PROGRAMMED CLOSING OF THE TURBINE GATE APPARATUS

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As is known, water hammer in pressure conduits occurring at hydroelectric stations following rapid unloading of the units can be reduced provided the turbine gate apparatus (GA) is closed according to a specially prescribed program [1]. However, until very recently there were no reliable designs not requiring extreme expenditures for their realization which could provide trouble-free operation of a programmed closing device (PCD). Therefore, such a possibility of reducing water hammer was not realized, and thereby the additional reserves for reducing cost and increasing the operating reliability and life of structures of hydrostations were not used. For this same reason the possibility of increasing the capacity of the units established in the design of the turbines without changing their guarantee of regulation was not used.

The All-Union State Trust for the Organization and Rationalization of Regional Electric Power Stations and Networks (Soyuztekhenergo) designed a PCD which eliminates the need to move elements of the device during its automatic action; the problem of ensuring a high reliability of the PCD was thus solved. The device was tested and put into operation on two turbines at the Charvak hydrostation.* The introduction of the PCD on these turbines, which was accomplished for the first time in the USSR, did not require any large expenditures of material means or complex reconstruction. At the same time, as the tests showed, on dropping the total load simultaneously from the two units operating with a common penstock a 25% decrease of water hammer was achieved without increasing the rotational speed.

The principle of operation of the PCD [2] consists in the following (Fig. 1). A throttle valve 3 is installed on oil pipeline 2 through which oil is drained from the main slide valve 1 of the speed governor when the main slide valve moves downward to close servomotor 5. A closed vessel 4 is installed on this same oil pipeline before the throttle valve on the path of the oil being drained. When the slide valve 1 moves for closing, the oil flows from the drain cavity of the slide valve through the throttle valve 3 into the drain tank and simultaneously fills vessel 4. In this case, before complete filling of vessel 4 the piston of servomotor 5 moves more quickly, and after filling the movement of the piston slows. Thus a

*A number of workers of the cascade of Middle Chirchik hydrostations participated in the manufacture and testing of the PCD; the tests were conducted with the participation of a representative of the Leningrad Metals Plant.

Fig. 1

Fig. 1. Schematic diagram of Soyuztekhenergo's programmed closing device.

Fig. 2

Fig. 2. Closing regimes of turbine gate apparatus at Nurek hydrostation.

change in the speed of closing the gate apparatus is provided at various time intervals, i.e., its programmed closing.

Testing and operating the units of the Charvak hydrostation with the PCD for more than 2 years confirmed the high reliability of trouble-free operation of the programmed closing device.

Soyuztekhenergo inspected six operating hydrostations with long (from 750 to 1900 m) pressure conduits. The purpose of the inspection was to determine, by calculation on the basis of the factory and on-site operating characteristics of the turbines, the possible magnitude of decrease of water hammer in the pressure conduits of the hydrostations following the introduction of the PCD and to determine the extent and content of works on reconstructing the governor for providing programmed closing. The Nurek, Kuban Nos. 1, 2, 3, 4, and the Krasnaya Polyana hydrostations were selected as the objects (Table I). The inspected hydrostations differ not only in head, capacity, and length of the penstocks but also in the design of the governors. Thus we can consider that the inspection gives a generalized idea about the efficiency and technical possibility of using programmed closing of the gate apparatus at operating diversion-type hydrostations, for which a decrease of water hammer in the penstocks is important. This is related to the fact that the majority of diversion-type hydrostations have been in operation for more than 20-25 years without replacement of the main equipment and penstocks. During this time the metal conduits as a consequence of corrosion and abrasion considerably lost their strength properties and in individual cases (Krasnaya Polyana, Kanaker, and other hydrostations) they had to be replaced.

A decrease of water hammer in the conduits and thereby a reduction of working stresses in the casing will make it possible to revise their permissible service life, reduce operating costs, and save metal on the repair and replacements of the conduits.

The following works were performed during inspection of the hydrostations:

The data of earlier investigations (Department of Hydropower Use of the Moscow Civil Engineering Institute (MISI) and Soyuztekhenergo) were analyzed and the transition operating regimes of the units on dropping the load were calculated with a determination of water hammer and maximum increase of the rotational speed;

The laws of optimal programmed closing of the GA of the turbines were determined approximately with the use of universal characteristics of turbines and their effectiveness were evaluated in comparison with the existing control;

Designs of PCD were studied in relation to the installed governors.

Of the number of units inspected, units of the Nurek and Kuban Nos. 3 and 4 hydrostations and two units of the Kuban No. 2 hydrostation were equipped with EGR-2M and EGR-100 electrohydraulic governors for which the design of the PCD introduced at the Charvak hydrostation was applicable.

Problems related to a determination of the technical effect from introducing the PCD at the hydrostations are examined below.

For the Nurek hydrostation Fig. 2 shows graphs of the process of closing the turbine GA upon dropping the total load. Figure 3 shows the calculated diagrams of the water hammer in the spiral casing and graphs of the change in rotational speed during dropping of the total load from three units having a common section of the penstock with a length of 463 m. The total length of the penstock from the intake to each turbine is 1175 m.

Fig. 3. Calculated characteristics of transition regime during dropping of 345-MW load from three units of the Nurek hydrostation. Relative increase of pressure: 1) for actual law of closing the GA; 2) for improved law of closing the GA. Relative increase of rotational speed: 3) for actual law of closing the GA; 4) for improved law of closing the GA.