CONCLUSIONS

It is necessary to note a number of features of the measurement methods used for the first time by Ukrgidroproekt for determining the deformations of hydraulic structures, which in our opinion can be used on other objects and under other working conditions.

1. The use of reverse plumb lines as fundamental geodetic points.

2. Determination of displacements, mainly of the structures of navigation locks, by the method of high-precision linear measurements.

3. Use of special devices for tensioning Invar wires, which eliminated the use of the cumbersome station equipment from the BP-2 kit (straining trestles).

4. Markers with automatic centering of instruments having designs compatible with the site of embedment and soil conditions were used on all fundamental and survey check markers.

5. The manufacture (by Ukrgidroproekt) and use of the string base-meter permits prompt and quick determination of the relative displacements of individual structures.

The technique of special survey measurements made it possible to solve the stated problem — to determine the absolute horizontal and vertical displacements of hydraulic structures of the Dnepr cascade of hydrostations with an accuracy of 1-3 mm.

ELECTRIC GOVERNOR OF KAPLAN TURBINES

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The electrohydraulic principle of guide-vane control of hydroturbines has been used for about 20 years in Soviet construction of regulating gear. At the same time the hydromechanical method is still used for controlling runner blades, which reduces the accuracy of realizing the governor relationship [relationship of runner-blade angle to the water flow admitted by the turbine gate apparatus] and makes it necessary to set a maximum (with respect to the conditions of stability of the control loop of the runner blades) value of the transfer function from the servomotor of the gate apparatus to the main slide valve of the runner and a minimum value of the overlaps on it. The latter is related also to an increase of oil leakage in the regulating system. Compared to the hydromechanical method, the electrohydraulic method of runner-blade control has the following advantages: if necessary, a change in the form of the governor system is considerably facilitated; the structure of the governor system makes it possible to provide sufficient accuracy in the case of relatively large overlaps on the main slide valve of the runner and relatively small value of the transfer function from the servomotor of the guide apparatus to the runner valve; the range of problems solved by the governor system is broadened.

In November 1978 the All-Union Power Engineering Industrial Association (Soyuztekhenergo) installed for the first time in the USSR an electronic governor system on the No. 3 unit of the Upper Tuloma hydroelectric station (Fig. 1).

The optimal governor relationship between the amount of opening of the servomotor of the gate apparatus (U) and head (H) is formed in the electronic governor system (EG), the output signal of which is proportional to the prescribed value of the runner-blade angle ($\theta_{\text{pre}}$). The signal of the prescribed value of the runner-blade angle ($\theta_{\text{pre}}$) or the signal of the starting angle sensor (SAS) and signal of the sensor of the actual blade angle ($\theta_{\text{act}}$) goes to the input of the adder ($\Sigma_i$). The output signal of the adder ($\Sigma_i$) goes to the input of the integrator $\int$ and can be sent in the form of a proportional component (K) to the input of the electromechanical (EMT) or electrohydraulic (EHT) transducer, the output signal of which goes to the input of the hydraulic servomechanism (HSM) of the runner, which consists of the slide-valve system, servomotor, and direct feedback.
The electronic governor (EG) represents (Fig. 2) a two-coordinate function generator,* the output signal of which is formed in the following way: the electrical signal of the sensor of the position of the servomotor of the gate apparatus (U) is sent to the input of the adder \( \Sigma \), the output of which is sent to the function generator \( F_1 \). At the output of this function generator is formed a signal proportional to the optimal runner-blade angle in conformity with the governor relationship for the minimum value of the head of the hydroelectric station. The function generator \( F_1 \) consists of six precision linear elements and output adder. The size of the linear section and the transfer function of each element can vary within wide limits. Upon an increase in the head (compared to the minimum value) the signal of the difference of heads \( AH \) goes to the input of the function generator \( F_2 \), whose output signal is proportional to the value of the correcting signal \( \Delta Y \). The input of the function generator \( F_1 \) thus receives the signal \( Y + \Delta Y \) changing equidistantly the output signal of this generator from \( H_{\text{min}} \) to \( H_{\text{eq}} \) (Fig. 3). In order for the output of the electronic governor to receive a representation of the governor relationship for a head differing from the minimum (at the limit for \( H_{\text{max}} \)) it is sufficient for each value of opening to multiply the output signal from \( F_1 \) by a coefficient equal to the ratio of the coordinates \( K = \phi_i/(\phi_i + 1) \). A sufficient accuracy of the representation of the governor relationship is provided upon calculating the value of this coefficient as the arithmetic mean of the values for six openings of the gate apparatus. The described operations are provided schematically in the following way (see Fig. 2). Simultaneously with input to the \( F_2 \) the head-difference signal \( AH \) goes to the input of the function generator \( F_3 \), at the output of which is formed a signal proportional to coefficient \( K \). This signal goes to one input of the multiplier \( M \), to the other input of which is sent a signal proportional to the governor relationship, corresponding to \( H_{\text{eq}} \).

In this case a signal proportional to the governor relationship for the prescribed head on the hydrostation is obtained at the output \( M \).

At a number of hydrostations with relatively high heads the electronic governor system can be simplified. For example, at the Upper Tuloma hydrostation it was possible to eliminate the function generator \( F_3 \) and the multiplier \( M \) in connection with the fact that the governor relationships for various values of the head are equidistant. The electronic

![Fig. 1. Diagram of the electronic governor system.](image1)

![Fig. 2. Electronic governor.](image2)