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MODELING LONG-TERM OPERATION OF THE ANGARA-YENISEI CASCADE HYDROPOWER PLANTS WITHIN ENERGY AND WATER SYSTEMS

The share of electricity generated by hydropower plants of the Angara-Yenisei cascade in the electric power (energy) system of Siberia is about 50%. Significant interannual and seasonal variability of water inflows into the cascade reservoirs makes it unique in terms of efficiency and operation of the power system under various water conditions. Currently, the energy and water systems in the Russian Federation are regulated and managed separately. Modeling the long-term operation of the hydropower plants requires comprehensive studies of their joint operation as part of the energy and water systems. The methodology for modeling the long-term operation of hydropower plants (cascades of hydropower plants) [1] developed at ESI SB RAS [1] is based on coordinated studies of five main blocks of models (Fig. 1).

These models allow considering the specificity of the water and energy systems during long-term planning for a period of up to 1 year. Each block includes several models (simulation, optimization, and multi-criteria). These models solve various problems and take into account the uncertainty of water inflows into reservoirs, the amplitude and frequency of temperature anomalies in the studied regions, the requirements of water users, the amount of electricity consumption, forced and planned repairs of electrical equipment and electrical networks, constraints on maximum transfer capability of individual sections of the electrical network in the controlled cutsets, and other factors and limitations.

Based on probabilistic long-term scenarios of water inflows into reservoirs and expected temperature conditions, the proposed approach suggests determining optimal balanced operating conditions of water management and energy systems while ensuring reliability and uninterrupted energy and water supply to consumers in any considered time interval.

Models of building long-term scenarios of water inflow and temperature use the results of processing the ensemble forecasts with different weights generated by global climate models [2]. They also employ the neural network methods to determine the most probable intervals of indices by varying a wide range of possible climatic, hydrological, and other data.

Models of water management system make it possible to determine the permissible flow ranges of each hydroelectric power plant in the considered time intervals for various water conditions. The system includes hydrological models based on water balance equations, hydraulic models for estimating the time it takes for the water flow to reach various points of the river network, taking into account the restrictions of all water users and water consumers, as well as environmental and social constraints.

Models of operating regimes of hydropower plants perform water-energy calculations using the generated scenarios of water inflows into reservoirs, and the results of hydrological and water management models calculations. The calculations can use various criteria for operation optimization. These are the maximum firm power of the hydropower plant cascade in winter or the entire water-management year, the minimum of idle discharges, the maximum supply of water users, and others. The calculations provide all the necessary parameters of the hydropower plant operation: flow rates through hydroelectric facilities, downstream levels, pressure, power, electricity output, and others.

Models of building long-term energy consumption scenarios are stochastic in nature and are based on accumulated statistics for various temperature conditions that make it possible to form regression relationships, with a focus on periods of maximum and minimum daily and seasonal consumption. Available planned targets of demand for electricity and capacity, commissioning of new large electricity consumers are also used.

The input parameters used in the models of energy system operation are long-term energy consumption scenarios in various resolutions (annual, seasonal, monthly, weekly, daily, hourly); repair schedules for electrical equipment and electrical networks; flow characteristics of generating plants; loads of consumers in load centers; network transfer capability; auxiliary power consumption and power transmission loss factors, and

others. The optimization criterion may be minimum electricity generation costs, minimum fuel consumption, maximum reliability and stability of the power system. According to the assumed criterion, the most optimal operating condition of the power system is selected. Based on the modeling results, prospective energy balances are determined. In the event of a shortage or surplus of the total electricity generated in the power system, the flows to neighboring power systems are estimated. The results of calculations for modeling the operating conditions of the energy system in the form of energy constraints are transferred to the block of hydropower plant operation to adjust the water-energy calculations.
The presented system of models allows monthly refinement of operating conditions of hydroelectric power plants and thermal power plants, given the risks of stochastic factor influence. With this in view, the proposals on the optimal long-term operation of the power system and the cascade of hydroelectric power plants are made to increase stability, reliability, and efficiency in their planning and management.

References

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