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To cite this article: E V Platonova *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **537** 062062

IOP Conf. Series: Materials Science and Engineering **537** (2019) 062062 doi:10.1088/1757-899X/537/6/062062

FIS model for optimization of hydro resources of hydroelectric reservoirs by the criterion of electrical energy maximum generation

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Abstract. The authors propose a model of fuzzy inference system (FIS) to determine the optimal consumption of hydro resources of hydroelectric reservoirs by the criterion of maximum generation of electrical energy. It is proposed to use a fuzzy controller that allows to develop optimal strategies to ensure the maximum energy output of hydroelectric power stations and passes to the downstream, to formulate proposals for creating a subsystem for calculating the regimes, schedules of drawdown and filling of reservoirs by the criterion of maximum generation of electrical energy. The use of fuzzy controllers and submission to their inputs of data on changes in the regimes of a cascade of hydroelectric stations in real time allows us to obtain a FIS system that will be an assistant for the operational management of hydroelectric reservoirs.

1. Introduction

Thanks to many years of research in the field of automated dispatch control systems for power plants and substations, significant success has been achieved and serious scientific results have been obtained in solving problems of managing power systems, including solving situational problems [1].

Modelling of long-term regimes of hydropower plants (HPP) taking into account probabilistic indicators of inflows using the metamodel was performed at the Institute of Energy Systems named after L A Melentyev of the Siberian Branch of the Russian Academy of Science (Irkutsk) [2], but the proposed model does not allow to reconcile all the restrictions that exist when the station's reservoir is drained. Requirements for managing the HPP mode by the criterion for granting maximum active power are formulated in [3].

Changes of operating equipment at the level of energy system control is determined mainly by the function of maintaining balance in the power system. In this case, the question of the number of generators in the work is solved, and fuzzy logic [1] is applied to meet the balance requirements.

Optimal control of the use of hydro resources of hydroelectric reservoirs by the criterion of maximum generation of electrical energy is a complex, weakly structured task, therefore, it is not possible to create an exact mathematical model based on differential equations. A unique tool for solving problems with fuzzy source information is fuzzy logic. This is the only theoretical concept that makes it possible, using computer technology, to use the most striking feature of human intelligence - the ability to make the right decisions in an environment of incomplete and fuzzy information.

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2. Sugeno-type fuzzy inference

Fuzzy logic is widely used in engineering. In [4, 5], options are considered for managing the consumption of water resources of reservoirs, taking into account the low water content in difficult climatic conditions. The study [6] develops a water management model for the integrated use of surface and groundwater using a fuzzy inference system (FIS), which uses the FIS-selection of samples of both surface and groundwater. There are also models where the distribution of water resources in the surface water system is modelled using linear programming methods, and the responses of the groundwater system to pumping are predicted using artificial neural networks.

The objective function in accordance with the maximum generation of electrical energy is as follows:

$$\sum F_{HPP}(P_1, P_2 \ldots P_n) \rightarrow \max \qquad (1)$$

where P_1, $P_2 \ldots P_n$ are parameters of the objective function.

The following technological limitations should be taken into account: the upstream reservoir levels, the rate of discharge and filling of the reservoirs, the downstream discharge, the total output of the HPP, the reservoir level at the end of the period. All restrictions can be formulated on the basis of the Rules for the use of water energy for individual periods of operation of hydroelectric power plants.

In the classic case of solving the optimization problem, all constraints require the compilation of a large number of non-linear equations that will take into account all the features, constraints, the predicted inflow and the actual inflow of water in the reservoir, the requirements imposed by the power industry, reliable operation of hydraulic structures of hydropower plants, non-energy water users and water users. Solving and making equations will be a very time consuming task.

The apparatus of fuzzy logic makes it possible to bypass the time-consuming process of drawing up and solving systems of nonlinear equations. Using linguistic variables, one can describe phenomena that are so complex or poorly defined that they cannot be described in generally accepted quantitative terms [7]. The main idea in this work is to train the system on the basis of data for the best economic indicators for the year, thereby creating an artificial intelligence model that will make a decision or serve as a decision maker to the person making decisions. Domestic inflow, uppersteram level (USL) and month were assigned as input variables, and the flow through the hydroelectric station will be an output variable. Household inflow of USL was represented by twelve therm-sets, which were defined by triangular membership functions. Each membership function describes the degree of ownership of a particular domestic flow of a particular month.

Months are represented by twelve therm-sets, which are given by Gaussian membership functions. Each membership function describes the degree of membership of a particular month to term sets. The consumption of hydroelectric power stations is represented by twelve therm-sets, which are defined by triangular membership functions. Each membership function describes the degree of ownership of a particular flow of a hydroelectric station for a specific month. By means of input data using subtractive clustering, a Sugeno-type fuzzy inference system is generated: fis = genfis2 (datin, datout, 0.9). For each year, a fuzzy model is created and its ANFIS training is produced (figure 1).

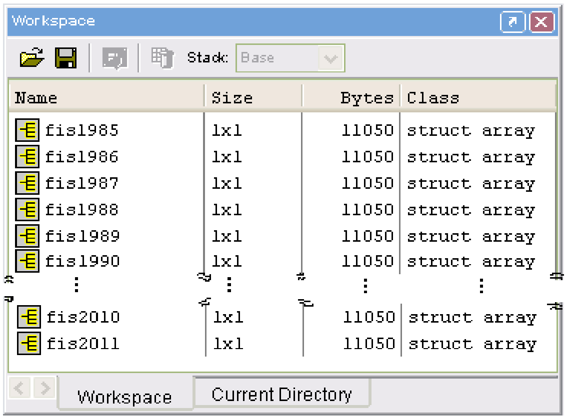

Figure 1. Fuzzy models by year of research.

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Based on the training and testing samples, a fuzzy controller model is generated using subtractive clustering followed by ANFIS training. ANFIS implements Sugeno-type fuzzy inference system in the form of a five-layer forward-propagation neural network. The purpose of the layers is the following: terms of input variables; antecedents (parcels) of fuzzy rules; normalization of the degrees of compliance with the rules; conclusion of the rules; aggregation of the result obtained by various rules.

3. Fuzzy controller application

To implement the work of a fuzzy controller, its model was made in MatLab Simulink. A subsystem consisting of input variables (defined by Constant blocks), output variables (visualized by Display blocks), a multiplexer (multiplexes data of input variables for processing by a fuzzy controller) and a demultiplexer (for outputting output variables to Display blocks) is created. The dynamic model of the controller, made in MatLab Simulink, is shown in figure 2.

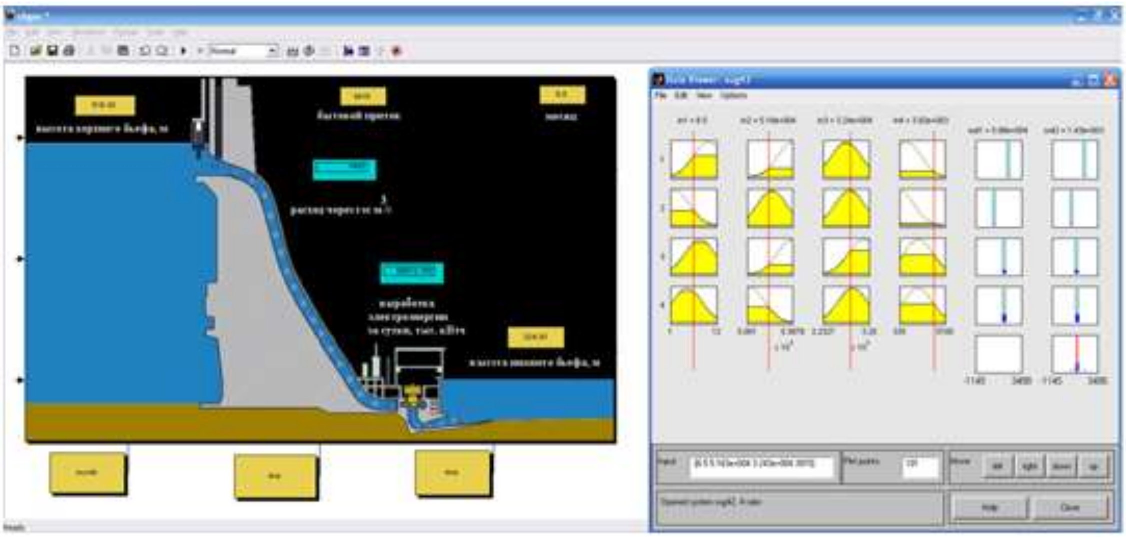

Figure 2. Dynamic model.

The moment corresponding to the middle of June is shown at a height of 518.30 meters in the upperstream, 324.30 meters in the downstream, and a 3915 meter cubic domestic tributary per second. Electricity production per day should be 59,872,150 kWh with a consumption of 1,433 meters per cubic meter through a hydroelectric station per second. It is noteworthy that the data obtained with the help of a fuzzy controller indicate a mode closely corresponding to the 2000 regime which is the most efficient in terms of energy.

4. Conclusions

By means of a fuzzy controller optimal strategies can be developed to ensure the maximum energy output of hydroelectric reservoirs and passes to the lower pool, proposals have been made for creating a subsystem for calculating regimes, schedules for draining and filling reservoirs by the criterion of maximum electrical energy generation.

The actual hydrological series of inflows to the HPP site, the volumes of electricity generation and the existing limitations of the reservoir filling regimes in accordance with the Rules for the Use of Hydro-Resource Hydroelectric Resources were used as the initial data in the development of controller algorithms.

Optimization of the use of hydro-resources of hydroelectric reservoirs by the criterion of ensuring the highest output is implemented subject to limitations. Recommendations on the management of the mode of operation of hydroelectric reservoirs can be used in the development and subsystems of rational management of the composition of HPP.

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In developing fuzzy rules, expert knowledge and operational policies in the field of water management are used. The result shows that the FIS model and models of imitational optimization of water resources are more efficient and effective. Using this model, it is possible to work out optimal strategies for ensuring the maximum output of the active power of hydroelectric power stations and passes to the lower reach, formulate proposals for creating a subsystem for calculating modes, schedules of drawdown and filling of reservoirs according to the criterion of maximum generation of electrical energy.

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