**Approach to Ensuring the Quality of Electricity Based on Elements of FUZZY Logic**

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**Abstract.** Modern electric power systems are characterized by a high degree of complexity, dynamism and nonlinearity. In such conditions, traditional methods of management and ensuring the quality of electricity can be not effective enough due to the incompleteness, inaccuracies and ambiguity of the initial information, as well as the variability of the operating modes of equipment. In this regard, intellectual methods based on elements of fuzzy logic are widely used, which allow you to take into account expert knowledge, formalize uncertainty and create adaptive and timid systems for the quality of electricity.

**INTRODUCTION**

The growth of electrification, the integration of renewable energy sources, nonlinear and non -stationary loads lead to serious problems.

The following problems can be noted as such:

• complexity of operational control and quality control

• need to work in conditions of uncertainty and data inaccuracy

• high interference, harmonic, resonant phenomena

• limited applicability of classical control methods

The implementation of intelligent control systems based on fuzzy logic allows you to increase the efficiency of the functioning of power supply objects and ensures adaptation to rapidly changing conditions of the energy system.

**EXPEREMENTAL RESEARH**

The aim of this work is to analyze the dependence of industrial electrical consumption on various factors (alternating current frequency, voltage quality, harmonic distortion, stress flicker, power coefficient, non sinusoidality) by fuzzy modeling. This method is especially suitable for modeling poorly defined systems in which there is significant uncertainty regarding the nature and range of key input variables and the main relationships between them. The work used methods of fuzzy modeling and machine learning. For the selection of predictors and for comparative analysis, an algorithm of random forest was used.

To solve the problem, the article used an approach based on fuzzy logic, the theoretical foundations of which were developed by R. Bellman and L. Zade . The object part of fuzzy logic is fuzzy sets, with the help of which uncertainty and fuzziness are described. Formally fuzzy many Ã on the universal set X is described by an ordered pair, , where *x* is an element of the carrier of the original set X, and - the degree of affiliation, which puts the function of belonging to each of the elements of x∈X from the interval [0, 1].

The most important part of the fuzzy modeling is the approximation of the dependence of the “entrance - output” as a result of logical operations on fuzzy sets. This approximation is a fuzzy logical conclusion. [1,2,3]. The system of fuzzy logical output includes elements such as a phasesifier, a fuzzy knowledge base, a function of belonging, a fuzzy output machine and a defazifier. In more detail about each of the above elements of the system of fuzzy logical output, you can find out from work [4,5,6,7,8]. The article examines the fuzzy system of Sugeno [9,10,11,12]. A feature of the fuzzy logical conclusion of the Sugeno is thatthe conclusions of the rules in the database of the knowledge of the Sugeno are set not fuzzy terms, but by the linear function from the input variables (predictors).

In other words,

(1)

where *dj* is the conclusion of the *jth* rules, *bj0*,…,*bjn* -actual numbers, *x1…xn* -elements of the vector of input variables.

**RESEARCH RESULTS**

When designing this fuzzy system at the first stage, a set of empirical data is divided into training and test samples and the synthesis of fuzzy rules from the training sample through subtratactive clustering occurs. At the second stage, the parameters of the fuzzy system are configured using anfis algorithm and improving the fuzzy model using anfis training in the appropriate sample the number of input variables (predictors) in the fuzzy Sugeno system should not exceed the number of customizable parameters of this system. The customizable parameters are the coefficients in the conclusions of the rules of the fuzzy knowledge base *bj0,…,bjn* in (1) and the parameters of the function of belonging to the terms of the input variables *x1…xn*. The number of parameters of the function of belonging is determined by their type. For example, for the Gaussian function of belonging.

(2)

The number of custom parameters is equal to two: the coordinate of the maximum *b* and the concentration coefficient *c*. Based on the said, the number of input variables is determined by the size of the training sample of empirical data. If the size of this sample is not large enough, then the number of input variables should be limited, taking into account the degree of importance of their influence on the output variable.

To justify the choice of the most important in the context of their impact on the electrics consumption of predictors in this article, an algorithm of random forest was used, using regression trees of solutions [13,14]. In addition, the method of random forest was used by us for predictive purposes to the initial data. A random forest is a method of collective machine learning that generates many trees through iterative segmentation [15,16]. It is applied to both classification tasks and regression tasks. In the tasks of classification in each wood node there is its belonging to the class (depending on which elements more entered this node), and in the tasks of regression - belonging to the target function, respectively. This procedure consists in taking a large number of training samples from the general population, building a predictive model for each sample and the averaging of the results. Creating many decisions trees, the method seeks to increase the value of the classification (reduce dispersion). The speed of obtaining an exact result increases with an increase in the number of trees. The root node is determined randomly, which is the main difference between the algorithm of the solutions from the random forest algorithm [15-24].

In the random forest algorithm, each tree is built using a learning boots-outlet from the available data set. The correlation between the trees is not allowed. The random forest method selects a tree of solutions with the best result from many trees that work independently of each other, that is, a tree that has gained the largest number of votes (Majority Vote) is selected. The predictions obtained on the basis of trained trees are then averaged. Using a model of random forest in the context of this article, you can overcome the restrictions of traditional linear models, identify nonlinear dependencies, evaluate the importance of variables and form a more complete understanding of complex relationships between electrical consumption and other socio-economic factors. Rounding the importance of variables, you can get an idea of the factors that have the greatest impact on electrical consumption.

The importance of variables is calculated as the average reduction in Gini index for classification tasks or as the average value of the amount of the squares of residues for regression tasks.

The results of fuzzy modeling were compared with the results obtained in the modeling of the analyzed dependence using multiple regression and when applying the method of random forest using regression trees of solutions for the studied data. It is shown that the modeling of the studied dependence through a fuzzy model in conditions of uncertainty is more adequate in comparison with the modeling of the analyzed dependence using regression methods (including the random forest method).

**CONCLUSIONS**

The developed fuzzy system (a fuzzy logical output system) can be used to study the effect of a change in any input factor or a combination of factors on a change in industrial electrical consumption. Using a fuzzy system, you can find out how much industrial power consumption will change when placing production capacities in certain regions, or analyze the feasibility of such a placement associated with the presence of resource potential.

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