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FORECASTING THE ELECTRICITY GENERATION OF PHOTOVOLTAIC PLANTS

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Introduction

Since 2019, the electricity market in Ukraine has moved to a new model of operation. Producers from Renewable energy sources (RES) make up an increasing share of the market. According to Ukrenergo [2], in March 2021 the installed capacity of RES in Ukraine was 6.97 GW, of which the largest share falls on solar power plants (SPP) – 5.51 GW, namely 10% of the total installed generation capacity in the country. RES producers sell electricity at a "green tariff", which is the highest among all others in Ukraine. From the beginning of 2021, RES producers began to compensate for the imbalance of electricity in the market a day in advance relative to the day-ahead hourly generation forecast that they provide before the start of the market day.

All these circumstances have increased the importance of the tasks of forecasting the generation of electricity from RES producers, in particular SPP, both at the level of the power system of Ukraine as a whole and at the level of producers.

The day-ahead hourly forecast of SES generation is referred to as short-term forecasts and it is used physical, statistical, and intellectual methods [1]. Among the intelligent forecasting methods, the most popular are models based on the Artificial Neural Networks (ANN) and Adaptive Neuro-Fuzzy Inference Systems (ANFIS), as well as combinations thereof. For example, in [5] and [6] new combined methods are presented, which include ANN and ANFIS for short-term forecasting of SPP generation.

The above publications describe the classical and new methods of forecasting and include assessment of their accuracy, but it is paid not enough attention to the study of the properties of the models themselves, in particular their structure and sensitivity to input error. The latter is especially true for models that use intelligent technologies, such as ANN and ANFIS, where it is impossible to explicitly express the relationship between input and output variables.

The aim of this work is to form an approach to the study of the forecast error dependence on the number of input membership functions and their form, as well as the sensitivity to input data error of the ANFIS-based day-ahead hourly forecast SPP generation model. The sensitivity of the model to input data error is particularly important because the input data for generation forecasting can come from meteorological forecast providers, which indicate the predefined forecast error.

Materials and Methods

In the study it was built a numerical model of the dependence of solar panel generation power on current solar irradiance based on ANFIS [3]. This model can be used for hourly day-ahead generation forecast based on solar irradiance forecast values from weather forecast providers, taking into account the cloud opacity.

The ANFIS methodology is based on a network of special structure that allow you to create and configure a set of fuzzy rules such as Takagi-Sugeno to approximate the relationship between multiple inputs and a single output. The author of ANFIS in [3] showed that it is a universal approximator of continuous functions of several variables defined on compact sets.

Data from the open dataset Photovoltaic (PV) Solar Panel Energy Generation from UK Power Networks from the London Datastore repository were used to train and test the model [4]. The input data of the model – current solar radiation (W/m2), measured at the local weather station, and the output data – the power of the solar panel (kW) from the location of Forest Road. For research, the sample was divided into training and test data.

The research was performed using numerical simulation in MATLAB with the use of Fuzzy Logic Toolbox. The first part of the research was devoted to the choice of the number of input membership functions and their form. In the second part of the study, the sensitivity of the model

to the input data error was determined for the selected number and form of membership functions from the first part. The results were evaluated by errors root mean square error (RMSE), mean absolute error (MAE) and normalized mean absolute error (NMAE).

Results and Discussions

It was calculated the table of dependence of RMSE, MAE and NMAE errors on the number of input membership functions and their forms for training, test and the whole sample. The number of input membership functions varied from 2 to 30, and the type of membership functions was chosen from the set (MATLAB notation): gbellmf, gaussmf, gauss2mf, trimf, trapmf, dsigmf, psigmf, pimf.

To determine the optimal number and form of membership functions, the NMAE error of the test sample was used, which was calculated to be in the range from 3.92% to 4.15%. A minimum was achieved on 5 triangular trimf membership functions.

The model was tested for sensitivity to the error of the input data using the chosen optimal number and the form of membership functions. A generated random sequence was added to the input data, which added an NMAE error of 1.81% to 8.19% to the input data. The NMAE error of the initial data in the test sample varied from 4.19% to 5.78%, i.e. the model studies showed a sufficiently low level of variation in the output values relative to the error of the input data.

Conclusions

The study demonstrates an algorithm according to which it is proposed to study the structure and sensitivity of ANFIS-based models for the problem of approximating the dependence of SPP generation power on solar irradiance. In this study, the best type of membership function was trimf, the number and shape of functions had little effect on the result - within 0.23% of NMAE.

Regarding the sensitivity of the model to the input error, it can be noted that for 5 input trimf membership functions, increasing the input error to 8.19% NMAE leads to an increase in the output error in the test sample to 5.78%, NMAE. The rather low sensitivity of the model to the input data error allows us to conclude that it can be used for forecast meteorological data with a pre-known fixed forecast error.

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