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OVERVIEW OF COMMONLY USED METHODS FOR FORECASTING POWER CONSUMPTION BASED ON MACHINE LEARNING

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Introduction

In recent years, the level of electricity generation has been growing very rapidly along with electricity consumption. In addition, not only the production and consumption of electricity, but also the field of forecasting electricity consumption is developing every day. The growth in the field of electricity consumption forecasting contributes to the fact that many enterprises not only measure their electricity consumption, but also achieve such important things as the annual calculation of electricity consumption. To solve the most pressing problems of production facilities, such as electricity consumption, power engineers use electricity forecasting methods. This article provides an overview of the most commonly used methods of electricity forecasting, discusses the results of their various works, and highlights the advantages and disadvantages.

Methods for forecasting power consumption

For the correct distribution of the generated electricity on the city electric networks, it is necessary to accurately account for their consumption. Therefore, the work carried out with the help of energy consumption forecasting methods should show maximum accuracy without errors and achieve the desired result in order to avoid the consequences of very large losses.

Speaking of forecasting methods, forecasting methods are divided into quantitative and qualitative methods according to the degree of formalization. Basically, quantitative methods are used, because of the information about the forecasting object is mainly quantitative, and the influence of various factors can be described using mathematical formulas.

Researchers used lots of different methods in many papers, such as time series models. Time series models are mathematical forecasting models that attempt to locate the future value's dependency on the past within the mechanism and measure the prediction based on this dependence. These models are universal across subject areas, in the sense that their overall appearance is unchanged by the nature of the time series. Time series (forecast horizon) distinguish short-term, medium-term, and long-term forecasting based on the number of expected values. The most used time series models include: Exponential smoothing models (SES – simple exponential smoothing, HES – Holt and HW-Holt-Winters); Regression models based on the influence of input variables on the output. The method of implementing regression models is mainly the method of least squares. Recurrent modifications of the method of least squares are often used, taking into account the weights of the previous values of the time series; Autoregressive models based on the dependence of the current value of the predicted variable only on the past values of the same variable. The ARIMA model, which includes the stages of autoregression, integration, and moving average estimation, has received the greatest development. The ARIMA model has several modifications: ARIMAX-includes some exogenous factors, SARIMA - takes into account the seasonality of data, VARIMA-multi-vector time series.

ARIMA (auto regression of the integrated moving average) methods are used in scientific papers [1, 2, 3, 4] in many ways of predicting energy consumption. The BP neural network and ARIMA models are used to predict the primary energy demand of three different major cities in China [1]. Their prediction results showed good accuracy on MAPE and RMSE. But the results showed that the BP neural network model gives a better prediction. In the article “Electricity consumption and generation forecasting with artificial neural networks” [2], ANN and stochastic methods (ARMA, ARIMA) are used to implement the forecast work using a data set of energy consumption of US cities in the period from January 1, 2014 to December 31, 2014. The results of this experiment showed that the great advantage of ANN methods is that they perform predictions with very good results in a short time, and are useful for short-term forecasting and short-term microgeneration forecasting. In the scientific work [3], a multi-window moving average algorithm for the decomposition of the specified time series and a new hybrid growth model for predicting the selected long-term growing trend are proposed. To evaluate the efficiency by comparison, the proposed model and three other models (RBF ANN, ARIMA) were used to predict the monthly electricity consumption in China between January 2011 and December 2012. The results showed that the proposed model presents the best performance with respect to MAPE (average absolute percentage error) and MaxAPE (maximum absolute percentage error). In another forecasting study [4], authors described a study of forecasting the energy consumption of an urban water pump station. Exponential smoothing and ARIMA methods were tested on real data. The ARIMA model showed acceptable accuracy in the range of 2-5%, which is quite enough for trading in the wholesale electricity market.

Regression analysis is a statistical research technique for determining the influence of one or more independent variables on a dependent variable. Determining the parameters of multiple regression requires time-consuming calculations using computer systems. However, the results obtained will be reliable and can be widely used in energy and management activities, primarily for making long-term forecasts, and the one-factor model can be used for short-term forecasts. As a result, we can note the following disadvantages of regression analysis: models that have too little complexity may be inaccurate, and models that have excessive complexity may be over-trained; this method is statistical and does not take into account the time argument, and therefore is not quite suitable for the case of predicting power consumption indicators.

The support vector machine (SVM) method is widely used in regression analysis and forecasting tasks. When applied to the problem of predicting complex and nonlinear data, the SVM method requires the choice of complex kernel functions rather than simple separation planes. However, such forecasts are unable to take into account the impact on electricity consumption of such irregular factors as weather events, fluctuations in fuel prices, equipment failures, so in practice, multi-factor forecasting should be used, which allows you to make a forecast with an accuracy significantly higher than the accuracy in time series.

If until recently, the most common forecasting methods were univariate time series forecasts based on regression methods, then among all the multi-factor approaches, the method based on artificial neural networks is particularly distinguished, which allows us to establish connections between the output characteristics of the system and the input factors. Such relationships allow you to calculate future values of parameters and accurately cluster groups of objects, for example, groups of electricity consumers. In addition, neural networks scale well and cope with the so-called curse of dimensionality, which does not allow you to model linear dependencies with a large number of variables. There are many ways to use artificial neural networks (ANN) in short-term forecasting. Neural networks may differ in their architecture, the number of layers and neurons, the use of a particular activation function, or the way they are trained. The following types of artificial neural networks are used in forecasting: feed-forward neural networks; backpropagation neural networks; recurrent neural networks (simple RNN, with long-term memory LSTM, with controlled GRU neurons); convolutional neural networks. The main disadvantage of ANN is the resource-intensive training of the network and the complexity of its identification.

Artificial neural networks are used in many scientific works and showed very good results and meet the expectations. The researchers from Turkey [5] showed a sharp increase in electricity consumption in Turkey between 1975 and 2016. Based on this data set, the authors made a forecast of electricity consumption from 2017 to 2030 based on ANN. In another electricity-related work [6], researchers showed the forecast of electricity consumption based on ANN at the Technological University of Corregidora from January 29 to November 3, 2015. With the help of the monitoring system installed at the university substation, an assessment of the system's performance was presented. After testing several methods, the results showed an estimated error. In research paper [7], the ANN model is used to model the relationships between input variables and expected electrical energy consumption, and the PSO algorithm is formulated to develop the ANN. The results show that the approach works better than some modern technological methods on historical data of equipment maintenance in China. The article [8] provided a meaningful overview of the four main ML approaches, including artificial neural network, support vector machine, Gaussian regression, and clustering, which are commonly used for forecasting and improving energy efficiency. The authors of scientific article “Forecasting electricity consumption with neural networks and support vector regression” [9] used modern computational methods for predicting electricity consumption in Turkey. In this study, the SVR (support vector machine) and ANN models were used to develop the best model for predicting electricity. Results based on test data which includes the two years period of 2010-2011 showed that SVR has a lower MAPE value 3.3%. The study showed that the seasonal SVR model is superior to the ANN model. In another study [10], researchers presented a method for predicting the energy of a building for cooling the load for three institutional buildings. The model was developed using two machine learning tools (artificial neural network and adaptive network based on fuzzy inference system). The results showed that both ANN and ANFIS predict the cold energy demand with good accuracy. The correlation coefficient between measured and predicted training data consumption was significantly higher than 0.98. The same was significantly higher than 0.96 for the test data.

Antonino Marvuglia and Antonio Messineo [11] presented a model based on an Elman artificial neural network (ANN) for the short-time forecasting (1 hour ahead) of the household electric consumption related to a suburban area in the neighbours of the town of Palermo (Italy). The results showed the percentage prediction error computed for a test week are respectively 1.5% for the mean error and 4.6% for the maximum error. Having considered the applications of recurrent neural networks to solving the forecasting problem, we can conclude that the recurrent model is the future of forecasting.

If we look at the work of recurrent neural networks, in article “Electrical energy consumption prediction is based on the recurrent neural network” [12], a recurrent neural network is trained to predict the amount of energy consumed. It’s use is better related to the adaptability of this type of network to the tasks of processing time sequences compared to other types of neural networks. The average relative error of the forecast was reduced to 2.10%, when used in comparison with the regression models, used in Russian practice. The constructed recurrent neural network provided more accurate prediction results than the widely used mathematical prediction models based on regression dependencies.

In another electricity-related research work [13], scientists from Portugal used artificial neural networks (ANN) for short-term load forecasting and, despite the unpredictability of consumption, it’s shown that it is possible to predict electricity consumption in households with confidence. For this study, a database was used with consumption data recorded in 93 real households in Lisbon, Portugal, between February 2000 and July 2001, including both weekdays and weekends. This article presented methods for predicting daily and hourly energy consumption using an artificial neural network. After determining a faster algorithm, such as Levenberg-Marquardt, the study showed that ANN are able to accurately predict daily and hourly energy consumption, as well as the load profile.

As a result, the following disadvantages of the ANN should be noted: lack of formalized network configuration algorithms due to the high complexity of the configuration procedure itself; ANN requires a lot of time to train it; opacity of the formation of the analysis results and their formalization in the established patterns; the high complexity of the internal network structure and the lack of a clear formalized apparatus for selecting the ANN structure.

Conclusion

As the above-mentioned studies show, the possibility of using neural networks and regression methods, in some cases it is possible to obtain an accuracy of forecasting electricity consumption at a level higher than 96%. This is significantly higher than traditional methods allow. It can be argued that systems based on artificial neural networks and regression methods are quite capable of solving the problem of predicting energy consumption on an industrial scale and ultimately this will improve the reliability, safety and quality of providing energy services to consumers. Building accurate consumption profiles and improving the accuracy of forecasting makes it possible to take into account the individual needs of customers and offer new services, which directly affects the profits of industrial enterprises and companies.

The potential of using neural networks is not limited only to forecasting and profiling-neural networks can be used to analyze the technical condition and assess the reliability of power generating equipment, diagnose and localize emergency situations, predict electricity prices, optimize load distribution, and solve other technological and economic problems facing electric power companies and enterprises.

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