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Entropy method combined with extreme learning machine method for the short-term photovoltaic power generation forecasting

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ABSTRACT

As the world's energy problem becomes more severe day by day, photovoltaic power generation has opened a new door for us with no doubt. It will provide an effective solution for this severe energy problem and meet human's needs for energy if we can apply photovoltaic power generation in real life, Similar to wind power generation, photovoltaic power generation is uncertain. Therefore, the forecast of photovoltaic power generation is very crucial. In this paper, entropy method and extreme learning machine (ELM) method were combined to forecast a short-term photovoltaic power generation. First, entropy method is used to process initial data, train the network through the data after unification, and then forecast electricity generation. Finally, the data results obtained through the entropy method with ELM were compared with that generated through generalized regression neural network (GRNN) and radial basis function neural network (RBF) method. We found that entropy method combining with ELM method possesses higher accuracy and the calculation is faster.

1. Preface

In the 21st century, the energy issue has been a major topic that people concern. The traditional non-renewable fossil fuels not only were increasingly scarce, but also showed the characteristic of low efficiency, serious carbon emission, and serious ecological environment pollution. Thus, people have to develop new energy sources. In those new energy sources, such as hydro, wind, ocean energy, geothermal energy, solar energy, and so on, solar energy is the most development potential, and it is an inexhaustible clean and safe renewable energy[1]. According to rough estimates, each year Earth's surface from solar radiation received at 5.4 × 1024 J, which is substantially equal to the energy that 1.8 × 1014 *T* standard coal combustion generated. *f* the amount of radiation to electrical energy, the annual generating capacity can reach staggering 5600 TWh, which is currently about 40 times of the world's annual energy consumption [2]. From the data above, the problem in the future energy needs of the world can be solved undoubtedly if large-scale photovoltaic power generation is able to combine with electric networks.

Since 1954, the first piece of silicon solar cells has appeared, photovoltaic power generation continues developing. In 1994, Japan began to develop photovoltaic roof construction plan, which is a large-scale solar power to lay a solid foundation; In 1997, the United States proposed the 'Million Solar Roofs Plan'; after a lapse of two years, followed by Germany, which begin the research of 'rooftop PV' program; Henceforth, Italy, India, Switzerland, the Netherlands, Spain and other countries have also developed a similar program [3].

In order to serve the photovoltaic power generation better and fulfill its large-scale photovoltaic power generation on net earlier, many scholars have done a lot of research.

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Ref. [4] combined with the principle of similar days in Manhattan and improved BP neural network, power generation power is forecasted based on historical weather information of photovoltaic power plants, and demonstrates the effectiveness of their approach by using the prediction error as the test results. Ref. [5] based on BP neural network, classified according to type of weather index, the different weather classified as a class, and weather patterns and historical weather data as input, the training network, the predicted and actual values are compared, this model has been calibrated predictive ability and strong adaptability. Ref. [6] combined the principal component analysis and neural network, principal component analysis was performed by dimension reduction operations, used of genetic algorithm to optimize the threshold value of BP network model, after testing, the method improves the prediction accuracy. Lingzhi [7] used PV cell temperature, sunlight intensity as a basis for decision making, parameters approximated by RBF neural network, the results showed that, RBF neural network effectively reducing forecast error. Shihui [8] in order to solve the low-light method effective power generation problems, a numerical correction using Markov after wavelet neural network prediction, after modeling and practice, finding is an effective solution to this problem. Hongzhu [9] used the time series of solar radiation and temperature as the basis, designed a least squares support vector machine model based on robust learning, and verify the validity of the model. Yadong [10] used the prediction tree models were introduced to the PV model, compared to the neural network, this method showed a better and greater accuracy of the explanatory. Ref. [11] by principal component analysis and extreme learning machine algorithm, used principal component analysis to find the optimal number of principal components and hidden layer nodes, numerical results show that this method compared to traditional methods have improved significantly in the computation time and accuracy. Nian and Qingxin [12] conducted a photovoltaic power generation prediction using extreme learning machine based on kernel function and the data after heavy processing, the results show that for tens of kilowatt units, the prediction error is only 16% to 18%. Ref. [13] Comparison of photovoltaic power generation based on incremental conductance and instantaneous designed a new maximum power point tracking algorithm (MPT), the simulation and experimental results show that this method has higher efficiency.

Prior to this paper, a number of scholars have predicted short-term photovoltaic power generation using physical or mathematical theory. Refs. [11] and [12] was also used for the short-term extreme learning machine method of photovoltaic power generation. But it was not before the weight calculation method used in conjunction with extreme learning machine. This innovation of the entropy method and extreme learning machine (ELM) together, photovoltaic power generation deal with the impact of data entropy method, such as radiation, ambient temperature, power generation battery temperature, wind speed, humidity, etc. weights treatment, improved the efficiency and convergence speed of the using model, predictive value were compared by generalized regression neural network(GRNN) and radial basis function neural network (RBF) methods, ELM model were observed before and after the predicted entropy method significantly improved the accuracy of the presence or absence. Experiments show that, entropy method for data processing model for predicting above ELM played improve forecast accuracy and speed up the convergence of purpose, it is an effective method. In addition, the weight of other treatment methods combined with ELM model, whether the same effect, to be of further study.

2. Entropy

Entropy is objective weighting method, which works by calculating the entropy of information to the relative degree of change indicators as the basis to determine the various indicators of major small to the entire system.

The basic steps are as follows.

(1) Entropy method is based on information load indicators to determine the size of the index weight.
Based decision-making matrix is

$$D = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{pmatrix}$$

x_{ij} is the ith index value of the jth index attribute.
Calculate p_{ij} , p_{ij} is the ith system of the proportion of the feature or the contribution of feature under the terms of the jth index. As the formula (1) shown.

$$p_{ij} = \frac{x_{ij}}{\sum_{i=n}^{j} x_{ij}} \tag{1}$$

(2) Calculate the entropy of the j-term indicator e_j.
e_j represents the total amount of entropy contribution of all programs on the jth indicators, such as the formula (2) below.

$$e_j = -k \sum_{i=n}^{j} p_{ij} ln p_{ij} \tag{2}$$

Where the constant k generally take $k = 1/ln$, so that can guarantee . When the contribution of a convergence of indicators for each program, e_j tends to one. Since the contribution of consistent, indicating that the index does not work when making decisions, especially when the whole is equal to the target, which can not be considered property of the target, the target can be considered property right weight for 0.

(3) Calculate the index difference coefficients g_j.
Difference coefficient g_j indicates the extent of the inconsistency index contribution under the jth degree programs, as determined by e_j, as the formula (3) shown.

$$g_j = 1 - e_j \tag{3}$$

Obviously, g_j the greater the emphasis on the role of the project indicators.

(4) Determine the weighting coefficients.