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Assessment of cyclical and stochastic wind flow to ensure power system reliability

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Abstract

This article highlights current issues related to the problem of variability of wind power generation, which is becoming increasingly important as wind power's contribution to the overall energy balance of many countries grows. Various aspects of wind flow volatility, including its random and deterministic components, are considered. The random component is associated with unpredictable changes in wind speed and direction, while the deterministic component is due to known patterns, such as daily and seasonal variations. The article proposes different methods for levelling the stochasticity of wind power flows. This is important for the stability and reliability of the power system, as it reduces the likelihood blackouts and ensures a more even distribution of load. The article also gives examples of the economic and environmental impact of using the proposed methods.

Keywords: renewable energy sources, wind energy forecast, stochasticity, wind power plant, quantile forecast, statistical test.

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确保电力系统可靠性的风流周期性和随机性评估

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摘要

本文章重点介绍了当前与风电场发电变异性问题有关的问题。鉴于风能在许多国家的总体能源结构中所占比例越来越大，这一点正变得越来越重要。作者考虑了风流波动的各个方面，包括其随机和确定成分。随机成分是由于风速和风向的不可预测变化造成的，而确定成分则是由于已知模式造成的，如昼夜和季节变化。本文章提出了来平抑风流能量的随机性的多种方法。这对确保电力系统的稳定性和可靠性非常重要，因为通过提供更均匀的负荷分配，降低了停电的可能性。本文章还说明了使用拟议方法的经济和环境影响例子。

关键词： 可再生能源、风能预测、随机性、风力发电厂、分位数预测、统计检测。

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Reliable operation of the energy system is the most important task for the normal functioning of all economic sectors and human life, which is ensured by a constant balance between electricity production and consumption.

In order to maintain a constant balance between electricity production and consumption, it is necessary to have an appropriate range of flexible tools to regulate the imbalance: hot reserve thermal power, flexible power plants, demand management, etc.

With increasing uncertainty in the power system, the demand for flexibile tools increases, which is associated with high costs for the power system.

One of the main factors in the growth of uncertainty is the increase in the amount of variable generation - wind and solar power plants.

The variability of wind speed and the energy produced limits its use in the electricity system to some extent. Therefore, many scientists are working on approaches to predict the output of wind power plants in order to know the arrival of wind energy in advance [Kamran, 2023]. As the forecast horizon lengthens, the forecast error increases.

In order to accurately model the arrival of wind energy, taking into account the stochasticity in the areas for which there is insufficient initial statistical information, it is necessary to determine the distribution of wind speeds over time by gradation and height [Zubakin, Kovshov, 2015].

The variability of the earth's surface roughness requires wind monitoring for at least one year prior to the construction of a wind farm in order to assess the main statistical parameters of the wind flow in the area where the station is located. At the same time, the accumulated data from one year of wind monitoring must be extrapolated for the entire expected operation time of the wind farm using various MCP (measurement - correlation - prediction) methods.

However, despite the stochastic nature of wind power generation, there are several ways to reduce the negative effects of variability in its output.

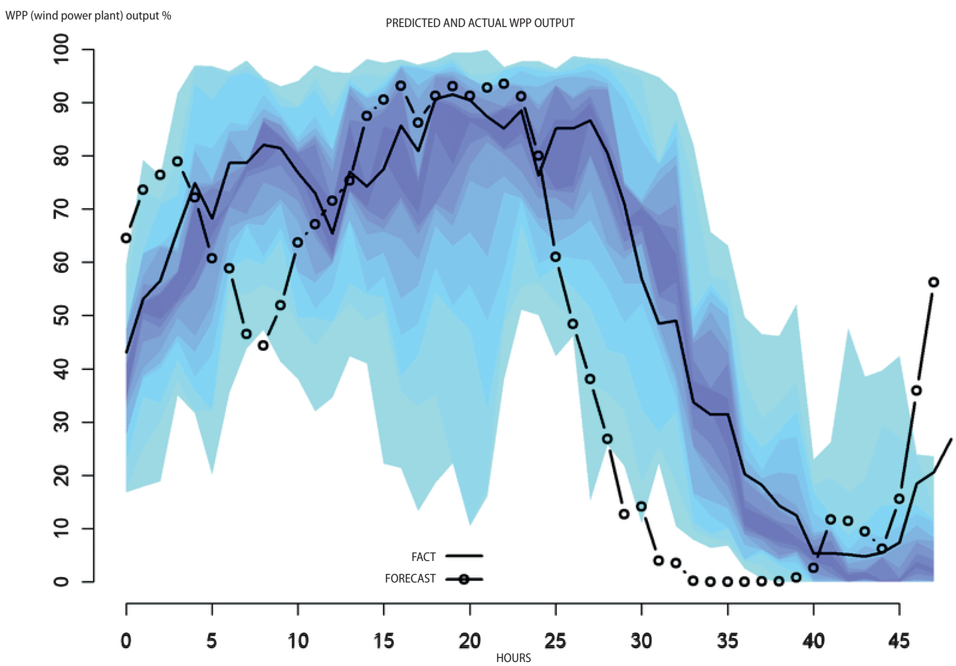
Thus, when assessing the behaviour of the wind flow at different time intervals, it is also necessary to take into account the probabilistic behaviour of the wind, which can be represented in the form of a quantile forecast [Bossavy et al., 2010] (Fig. 1).

If there is an unbiased forecast of the WPP production, the system operator can rely on the quantile forecasts (P05, P95) to plan the optimal reserve, which can significantly reduce its size. Thus, the system operator can use the lower value of the quantile forecast (P01, P05) as the guaranteed capacity of the WPP in the future.

Another effective management of the stochastic nature of WPPs is the integration of several WPPs into a virtual power plant, which leads to a reduction of the forecast error [Shuvalov et al., 2022]. At the same time, in aggregated WPPs, the quantile forecast has a smaller range, which is associated with a decrease in the dispersion of the total output of several WPPs.

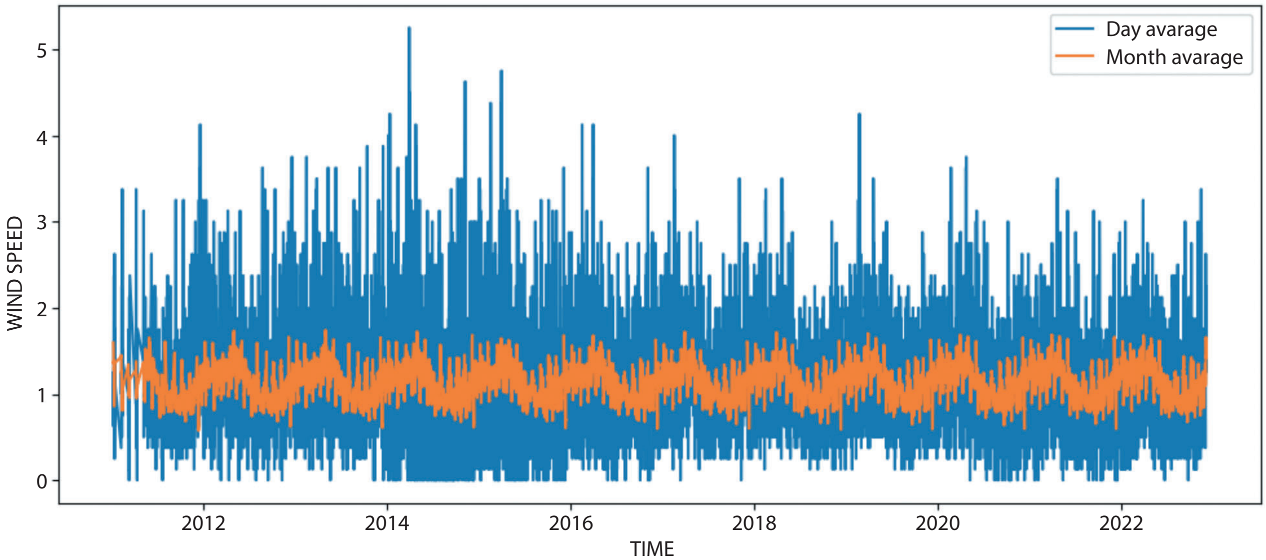
Contrary to popular belief, the long-term average energy density of the wind flow, distributed by month and by direction, presents a cyclical picture. Stochasticity increases at smaller time intervals (hours, minutes) and is manifested in the variability of a given local event (calm, low/medium wind, storm). This variability is due to the

Fig. 1. Actual and forecast values with consideration of uncertainty



Source: downloaded from the forecasting system.

Fig. 2. Time series of wind speed at the VDNKh weather station, 2012–2022



Source: downloaded from the forecasting system.

unstable and uneven movement of the wind flow layers caused by turbulent eddies, whose theoretical expression is predominantly random.

Thus, by analysing the autocorrelation component of the wind speed time series at the VDNKh (All-Union Exhibition of Achievements of National Economy) weather station, it is possible to determine the cyclicity in the data. The wind speed has a significant cyclicity with a period of about 24 hours. This is due to changes in air temperature during the day. There is also a cyclicity with a period of about 1 year (Fig. 2), which may be related to changes in climatic conditions. In order to assess the stationarity of the time series, the Dickey-Fuller statistical test was carried out. Consequently, the statistical value of the test was less than the p-value, which indicates that the time series is non-stationary. A time series has a time-varying mean and variance.

When considering models from the point of view of cyclicity, the main modelled indicator is the frequency of wind speeds $F(v)$, which shows what proportion of the time during the period under consideration the wind blew at one speed or another. The annual wind frequency is often approximated, especially in foreign practice, by the Weibull distribution or its modified version - the Weibull-Goodrich distribution:

$$F(v) = k\frac{v^{k-1}}{A^k}e^{-\left(\frac{v}{A}\right)^k},$$

where k – shape parameter (depends on the area, generally $k = 2$), A – scale parameter (depends on average wind speed, $A \sim 1.13$ v).

The Weibull-Goodrich distribution is the most universal and generally accepted method for modelling wind speeds. Many developments in the zoning of potential wind energy resources in Russia and individual regions have been made using this approach.

However, knowledge of the distribution law and the presence of high average wind speeds do not guarantee its effective use. In the case of wind energy, knowledge of the possible duration of lulls is of great importance. The probabilistic assessment serves as the main criterion for the efficiency of wind energy use. The structural characteristics of the wind regime can be considered as weakly dependent on the general level of intensity, i.e. in areas with significant wind intensity long lulls can be observed, making the use of wind ineffective. A calm is a period of so-called inactive wind speeds, which cannot be used for energy production. This characteristic, a necessary part of the wind energy cadastre, is considered to be one of the most important in assessing the prospects for wind energy use.

Therefore, assessing the cyclicity and stochasticity of the wind flow is important to ensure the reliability and efficiency of wind energy systems.

In conclusion, due to the dependence of wind power variability directly proportional to probabilities and periodicity, the use of methods to counteract the negative effects of wind power production probabilities and correctly identify the periodic components of wind speed time series can improve forecast accuracy using quantile wind power forecasting and WPP aggregation into virtual power plants. In the short term, reducing the reserve capacity required for the electricity grid could help to avoid the construction of new peaking power plants in the future.

In order to implement proposals to reduce generation stochasticity, further research is required using real data from several power plants to obtain a quantitative assessment.

References

Zubakin V.A., Kovshov N.M. (2015). Methods and models for analyzing the volatility of RES generation, taking into account cyclicity and stochasticity. *Strategic Decisions and Risk Management,* 4(91): 86-98. https://cyberleninka.ru/article/n/metody-i-modeli-analiza-volatilnosti-vyrabotki-viz-s-uchetom-tsiklichnosti-i-stohastichnosti.

Shuvalov N., Karasevich V., Velichko A. (2022). Improving the accuracy of forecasting renewable energy generation using neural network algorithms of a virtual power plant. In: *Materials of the D.I. Mendeleev International Scientific and Practical Conference:* Collection of articles, 1.

Bossavy A., Girard R., Kariniotakis G. (2010). Forecasting uncertainty related to ramps of wind power production. *European Wind Energy Conference and Exhibition,* Warsaw, Poland.

Kamran M. (2023). Fundamentals of smart grid systems. *Academic Press,* 365-392. https://doi.org/10.1016/B978-0-323-99560-3.00007-7. https://www.sciencedirect.com/science/article/pii/B9780323995603000077.

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