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Modern Wind Turbines Capacity Utilization in Real Conditions

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Abstract

The development of the national wind power industry in Ukraine faces a number of problems because of the lack of sufficient information on the peculiarities of the operating modes of wind farms under real-life conditions. This applies to wind load indices in different regions, estimates of the performance of wind power plants with different types of wind turbines. One of the important characteristics of the potential capabilities of a wind power plant in the grid is the time and rate of utilization of installed capacity (installed capacity utilization factor - ICUF), which are widely used in the design of power plants. The paper presents the results of calculating the characteristics of the production potential of wind power plants with generators of different types and capacities, which are defined in terms of time and coefficient of utilization of the installed capacity. It is shown that such characteristics of the wind power station uniquely characterize the efficiency of the application of a specific wind generator in real conditions for use in design calculations.

Keywords: wind turbine; wind station; time of use of installed capacity; coefficient of utilization of installed capacity.

1. Definition of a scientific problem

The current state of the world renewable energy is characterized by high dynamics of development. Significant features of this are many confirmed facts. In recent years, increased participation of renewable sources in the balance of electricity generation in the world's electricity systems continues. [1]. On 21 04 2017 a national energy company in the UK said that it can confirm that for the past 24 hours it supplied GB's electricity demand without the need for coal generation [2]. It happened for the first time since 1880. A similar situation occurs periodically in other countries. The State Energy Operator of the People's Republic of China said that according to the results of 2016, an indicator of 150 GW of power at wind farms was reached [3]. In addition, it should be noted the results of research on the prospects for the development of renewable energy in 139 countries [4] on the model of the world's energy, proving the possibility to transition to exclusively renewable energy sources by 2050. The above facts confirm once again that alternative renewable power, in particular wind energy, loses its alternating nature and becomes an important basic component of world electricity generation at the level of coal, atomic and oil and gas energy.

Wind and generally renewable energy in Ukraine is developing at a different pace, which is primarily due to the effects of crisis phenomena. In 2016, the installed capacity of Ukrainian wind farms amounted to 525 MW in the production of 925 thousand MWh and the share of 49% of the capacity of alternative and renewable sources [5]. The need for wind energy development in Ukraine is determined by the need to reduce the dependence on traditional types of fuel and its imports, reducing harmful emissions into the atmosphere, which can be solved by the increase in the rate of development of alternative renewable energy.

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2. Analysis of recent publications

Against the backdrop of intensive wind energy development, which is largely contributing to the economic situation and political support, information provision for economic and technical evaluation of energy efficiency indicators is important. The conducted researches [6] of the International Energy Association show the limited information on the efficiency of the operation of the wind farm in the grid with the appearance of erroneous and sometimes false representations in this direction.

In order to increase the rate of wind energy development in Ukraine, in particular, volumes of reliable information on the efficiency of wind farms in the grid should be expanded. Work [7] describes the methodology and results of calculation of technical and economic indices of different wind farms under real conditions of work for a site in the Ukrainian Carpathians, where high efficiency of operation of wind farms is shown. However, an overview of available sources shows a lack of actual performance indicators for using installed capacity in the Ukrainian grid for real operating conditions that are critical for technical and economic decision-making.

3. The purpose of the study

The efficiency of using the installed capacity of the wind power plant in the power grid can be characterized similar to the traditional types of power plants with the characteristics to use them in engineering calculations for the adoption of technical solutions. This characteristic of the power plant is the coefficient of utilization of the installed capacity K_{icu} (%) and the time of using the installed capacity T_{icu} *(h)*. For known relationships you can get:

$$K_{icu}=W_r / (P_n \cdot 8760), \quad T_{icu}=W_r / P_n, \tag{1}$$

where P_n is power station nameplate capacity, MW; W_r is annual energy production.

These characteristics are widely known and are used to assess the technical capabilities of different types of power plants. Use of installed capacity for the relevant period is an integral indicator covering both the technical capabilities of the power unit and the organizational and economic characteristics. For wind power plants, K_{icu} and T_{icu} contain the technical characteristics of wind turbines, taking into account the parameters of the wind load of a particular site, which maximally approximates the calculated parameters to the real operation conditions. This approach allows us to evaluate the application of the technical characteristics of the wind turbine under real conditions for the optimal choice of its type.

4. Results obtained

To determine these characteristics, we use well-known relationships for modern wind turbines [7]. WTG capacity is determined by the following parameters: average wind speed at the height of the rotor axis gondola, wind direction, air density, the daily maximum and minimum wind speed.

$$P = k \cdot \rho \cdot V^3 \cdot S/2, \tag{2}$$

where k is the coefficient of efficiency of the turbine; ρ is air density, kg/m³; V is wind speed, m/s; S is area of wind flow m². We can get performance characteristics for WTG models as follows, during the year:

$$W_r = \int_{v=0}^{n} \left[\frac{1}{2} \rho S V^3 C_p \Phi_V T \right] dV, \tag{3}$$

where ρ is density of air; S is area of propeller; C_p is- parameter characterizing the efficiency of wind turbine energy wind flow (power coefficient). For wind load data processing for future platform on the upper ridges in Turka region of Lviv oblast of Ukraine (investigated area coordinates - (lat., lon.) 49,2470; 22,8763), we can use the actual probability distribution of the known wind Weibull analytical division [7]:

$$\Phi_V = \frac{k}{C} \left(\frac{V}{C} \right)^{k-1} e^{\left(\frac{V}{C} \right)^k}, \tag{4}$$

where Φ_v is wind occurrence probability distribution function ,%; k is coefficient of dispersion; C is coefficient scale determined by the average speed of the wind, approximately $C = 2A/\pi^{1/2}$; V is wind speed, in m/s. Change in wind parameters at the SH altitude can be determined by Hellman exponential law:

$$V_{h2} = V_{h1} \cdot \left(\frac{H_2}{H_1} \right)^b , \quad (5)$$

where: H_2 is the altitude to which the reduction is made, H_1 is altitude for which wind measurements were carried out, V_{h1}, V_{h2} is appropriate wind speed, b is WTG installation terrain profile index ($b = 0,14 \div 0,30$).

To calculate the efficiency of using the installed capacity of a wind turbine in the grid, we will identify a group of modern wind turbines of the following producers: *Vestas Wind Systems, Gamesa Electric, ENERCON GmbH* [8,9,10]. The parameters of the selected wind turbines are determined from the characteristics in the open access documents (Table 1) of the producers in the form of dependencies (calculated power curve) $P=f(V)$, $C_p=f(V)$, also taking into account the height of the wind turbine tower h, the specific distribution of Weibull for the specified site. The input data for calculation is shown in Table 1. Here you can see rated power of the wind turbine P_n (MW), height of the tower h (m), start wind speed, m / s, switching wind speed, m / s.

Table 1. Input data of wind turbines.

WTG	*P_n, MW*	*h, m*	*Cut in wind speed, m/s*	*Cut out wind speed, m/s*
Vestas V105-3.45	3.45	94.0	3.0	25.0
Vestas V126-3.3	3.3	117.0	3.0	22.5
Gamesa G128	5.0	120.0	3.0	25.0
Enercon E-101	3.5	74.0	3.0	25.0
Enercon E-126	7.58	135	3.0	25.0
Enercon E-101EP4	4.2	135.0	3.0	25.0

The calculation results are shown in Table 2 with the calculation of annual energy production (AEP) for several WTG. The consideration of various types of wind turbine parameters provided by the manufacturer is due to the degree of approximation to the general conditions of application for the maximum probability of the parameters received.

Table 2. Results of calculations.

WTG	*AEP, MWh*	*K_{icu}*	*T_{icu}, h*
Vestas V126-3.45	11009.26	36.43	3191
Vestas V126-3.3	10667.32	36.90	3232
Gamesa G135	12429.25	28.38	2485
Enercon E-101	10768.84	35.12	3076
Enercon E-126	13744.48	20.70	1813
Enercon E-101EP4	11446.76	31.11	2725

The results obtained can be compared with a real wind power station [11], and, therefore, we can speak of the similarity of the results obtained in the absence of identical wind loads.

5. Conclusion

In this work, the calculation of the utilization of the installed capacity of a number of modern wind turbines for wind conditions of a real point of installation has been carried out taking into account the data of measurements of wind loads.

The obtained characteristics additionally demonstrate the connection with the power and design features of the wind turbine.

For the first time, the characteristics of using the installed capacity of wind turbines under the conditions of the site in the western Carpathians of Ukraine for further use in engineering calculations were obtained.

The obtained characteristics should contribute to the development of wind power in Ukraine to assess the parameters of wind farms under the conditions of the western part of the Ukrainian Carpathians.

They unambiguously characterize the efficiency of the application of a specific wind turbine under real conditions for use in design calculations.

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Використання потужності сучасних вітрогенераторів в реальних умовах

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Анотація

Розвиток національної вітроенергетики в Україні стикається з рядом проблем через відсутність у достатніх обсягах інформації про особливості режимів роботи вітростанцій в реальних умовах. Це стосується показників вітрових навантажень в різних регіонах, оцінки продуктивності вітрових електростанцій з різнотипними вітрогенераторами. Одною з важливих характеристик потенційних можливостей роботи вітростанції в енергосистемі є час та коефіцієнт використання встановленої потужності, що широко застосовуються в задачах проектування електростанцій. В роботі наведено результати розрахунку характеристик потенціалу виробництва вітроелектростанцій з генераторами різного типу та потужності, що визначено у вигляді часу та коефіцієнту використання встановленої потужності. Показано, що такі характеристики вітростанції однозначно характеризують ефективність застосування конкретного вітрогенератотра в реальних умовах для використання в проектних розрахунках.

Ключові слова: вітрогенератор; вітростанція; час використання встановленої потужності; коефіцієнт використання встановленої потужності.