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Assessment of regional wind energy resources over the Ukraine

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Abstract

Purpose of the paper is to provide preliminary assessment of wind resources for different regions of Ukraine. Investigation is based on thirty-minute wind observations collected through an 8-year period (2001 to 2008) for seven airports of Ukraine.
By applying of probabilistic analysis techniques to wind data series, different temporal variations of wind speed and direction are derived. The statistic characteristics obtained were compared with the correspondent values provided for 1936-1960 and 1961-1990 periods and site-related temporal changeability is determined.

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Keywords: wind energy resources, specific power of wind flow, statistic characteristics of wind velocity

1. Introduction and objectives

Energy is presently considered one of the most valuable commodities in the economic progress and wealth generation of a country, being one of the main driving forces of industrial development. Considering the escalating costs of the traditional fossil energy sources, supported by the growing global demand for energy production, an intensive search for alternative sources of energy (preferably renewable ones) has been pursued in the recent past [1,2]. Among the several available renewable energy sources, wind-derived energy is the one that has witnessed greatest growth in the recent years. The purpose of the study has been to provide a preliminary assessment of wind resources of different regions of the Ukraine.

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2. Data and methodology

Investigation is based on thirty-minute wind observations collected through an 8-year period (January 1, 2001 to December 31, 2008) for seven airports of the Ukraine such as Dnipropetrovsk, Donetsk, Kyiv, Kryvyi Rih, Lviv, Odesa and Simferopol. In the same period for two stations of Kyiv and Odesa the radiosounding data are used in order to determine the wind speed and direction at height of 1000 m by applying linear interpolation method. Wind speed at this height is often close to the geostrophic wind [3], which is an important characteristic for renewing wind profile. Statistic characteristics and frequency distributions are obtained by applying the probabilistic analysis techniques to series of wind data [4]. The Weibull distribution is fitted to samples of surface wind speed for all available airports and of wind speed at 1000 m for Kyiv and Odesa.

3. Results and discussions

3.1. Results of the probabilistic analysis of the surface wind speed

The highest annually mean wind speeds occur in Odesa (coastal zone) and Simferopol, which is situated in the hollow between mountain ranges. Such high values can be explained with impact of local circulation.

Table 1. Statistical characteristics of wind data for seven airports of the Ukraine.

	Dnipropetrovsk	Donetsk	Kyiv	Kryvyi Rih	Lviv	Odesa	Simferopol
$\overline{V}$	4.1	4.0	3.6	4.1	2.9	4.4	4.6
V_{max}	35	45	15	24	16	22	24
σ_x	2.28	2.50	1.98	2.02	2.26	2.31	2.64
C_V	0.55	0.62	0.56	0.50	0.78	0.53	0.57
Mo	3	3	3	3	0	5	3
Me	4	4	3	4	3	4	4
As	0.34	0.49	0.67	0.41	0.48	0.45	1.03
$(\overline{V})^3$	70.0	64.6	45.2	68.1	23.8	84.4	98.0
$\overline{(V)^3}$	138.3	147.8	92.6	121.6	73.3	160.2	212.9
				Weibull parameters			
γ	1.63	1.58	1.65	1.66	1.36	1.70	1.66
β	4.07	3.92	3.43	4.11	2.74	4.38	4.81

where $\overline{V}$ – mean wind speed; V_{max} – maximum wind speed; σ_x – standard deviation; C_V – variation coefficient; Mo – modal value; Me – median; As – coefficient of skewness; $(\overline{V})^3$ – cube of mean wind speed; $\overline{(V)^3}$ – mean cube of wind speed; γ and β – parameters of Weibull distribution .

In the steppe zone (Dnipropetrovsk, Donetsk and Kryvyi Rih) the wind speed is lower, but it is as yet high. Lowest wind speeds are observed in Kyiv, which are part of wooded steppe, and Lviv, which is a broad-leaved forest zone.

On applying the least-squares method the Weibull parameters are got. This method gives the better results than other ones [5]. Parameter of β is close to mean wind speed and it is high for Dnipropetrovsk, Kryvyi Rih, Odesa and Simferopol. For these stations value of $\overline{(V)^3}$ is high too and it shows that wind resources in these sites are high too. Parameter of γ characterizes form of distribution and it changes from 1,36 (Lviv, where lowest wind speed is observed and the modal value is null) to 1,70 (Odesa, where sufficiently high wind speed takes place).

Variation coefficients varies from 0,5 to 0,8 and such values show that wind speed greatly changes in time; therefore in all airports the unfavourable conditions for installation of wind generators are observed. It should be noted that in the regions with poor wind resources the variation coefficients increase [6].

The frequency distribution obtained for 2001-2008 period were compared with the correspondent distributions provided for 1936-1960 and 1961-1990 periods (fig. 1). The results obtained show that with the lapse of the time wind speed is decreased, because it is noticeable that the frequency of wind speed of 6 to 20 m/s is reduced and frequency of wind speed of 2 to 5 m/s is increased for all stations. Although for all stations, excepting Donetsk and Lviv, number of calms and wind speeds of 1 m/s is decreased.

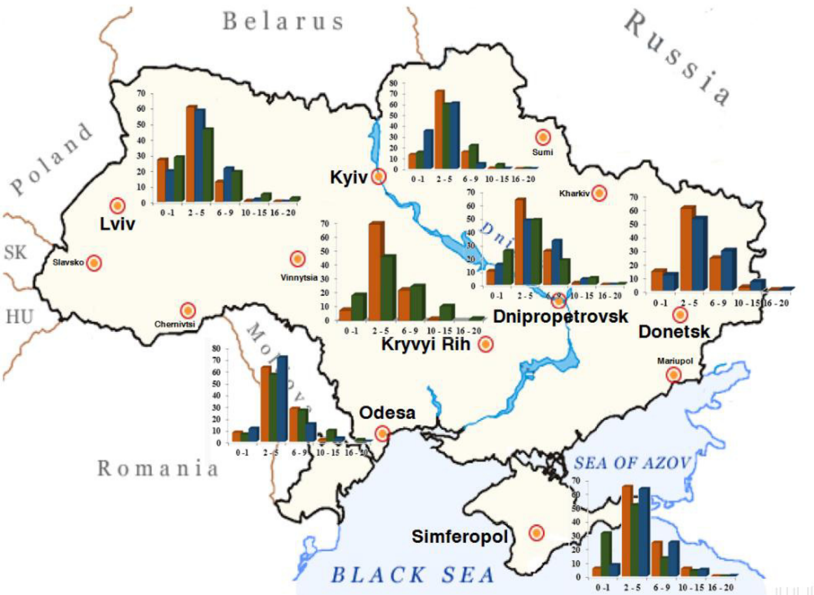

Fig. 1. Non-directional frequency distribution of the wind speed at seven airport of the Ukraine for different periods of 1936-1960, 1961-1990 and 2001-2008.

Figure 2 show directional frequency distribution of the wind speed. Such distribution can be used for optimization of operation of wind turbines.

In winter (fig. 2a) in Lviv, Kryvyi Rih, Dnipropetrovsk and Donetsk west winds are prevailed in 16 to 30% of all events. In Kryvyi Rih and Donetsk southern, eastern and southeastern winds have high frequencies too.

In Kyiv S-SW-W directions (about 50% of all events) are observed most frequently than others, and NW-N-NE winds (about 45%) prevailed over others in Odesa and northeastern wind has the highest frequency (30%) in Simferopol.

In spring (fig. 2b) in Dnipropetrovsk, Kyiv and Lviv distribution of wind directions remains the same, as well as in spring. Eastern wind becomes prevailing (21%) in Donetsk, and southern and northeastern directions are very frequently observed (about 35% of all events) in Kryvyi Rih.

In Odesa wind direction reversed and southern direction became prevailing (28%), there is a northeastern wind in Simferopol remains dominant, however frequency of eastern, southern and southern-eastern directions increased up to 17% for each.

In summer (fig. 2c) in Odesa contribution of N-NE and S winds is equal (16%). In Lviv distribution of winds is same as in spring. In Dnipropetrovsk and Kryvyi Rih the northeastern direction has the highest frequency (16%), and in Donetsk eastern wind are more frequently observed (18%).

In autumn (fig. 2d) in Donetsk, Dnipropetrovsk, Kyiv and Lviv distribution of wind directions is similar to the winter distribution, while in Odesa and Simferopol wind distribution is the same, as well as in summer. In Kryvyi Rih the south and north-eastern winds have the most high frequency, as well as in spring.

Thus, we can draw the conclusion that depending on season the direction distributions strongly changes in Kyiv, Kryvyi Rih, Odesa and Simferopol. Although it is noticed that there is directions which are observed constantly during year. In Kyiv and Odesa it is southern direction, in Kryvyi Rih it is southern and eastern ones, and in Simferopol it is northeastern one. It can be seen that in Lviv in all seasons western and southeastern directions are prevailed. In Dnipropetrovsk and Donetsk western and eastern winds are observed with equal probabilities during year, excepting warm period. Such stability in distribution of wind directions is favourable conditions for installation of wind turbines.

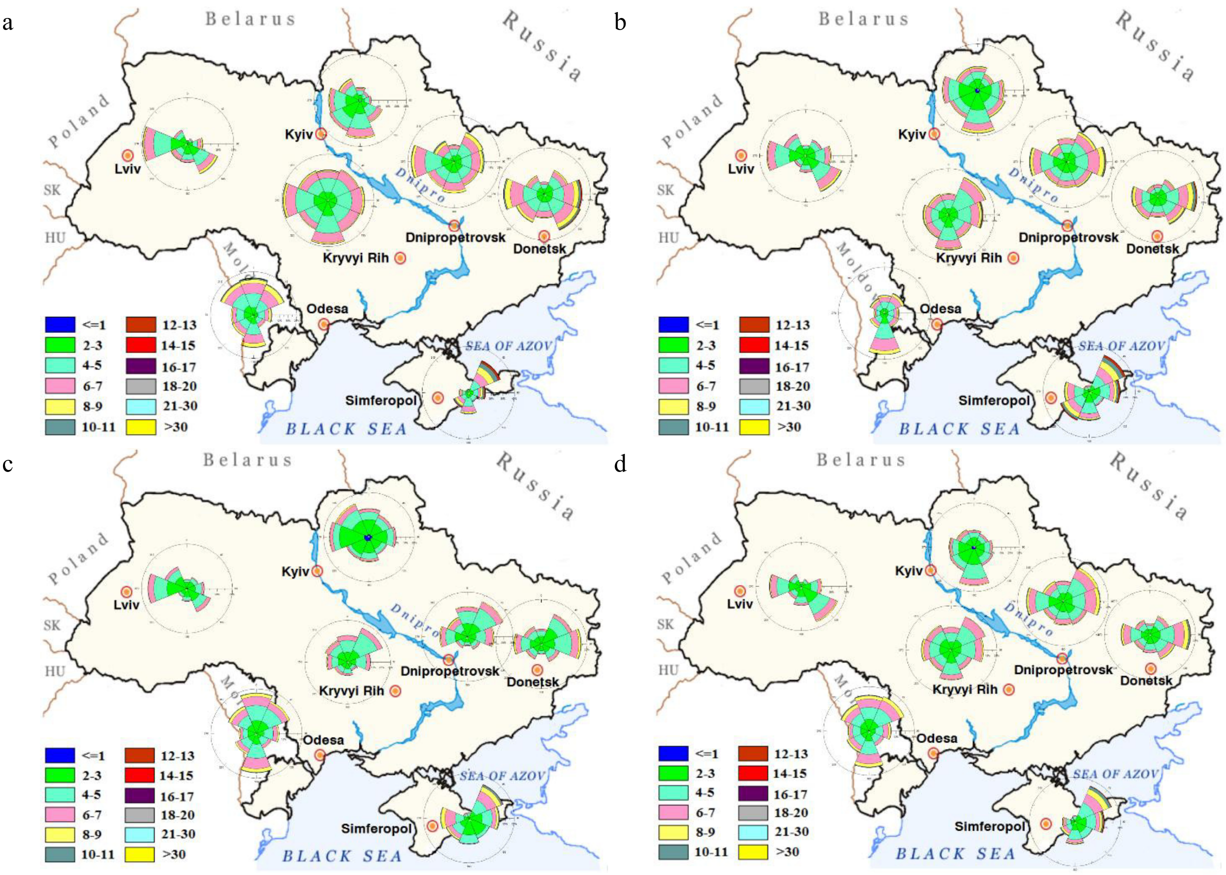

Fig. 2. Directional frequency distribution of the wind speed at seven airport of the Ukraine for the period of 2001 to 2008 for season of winter (a), spring (b), summer (c) and autumn (d).

Yearly variations of wind speed show that at all stations lowest wind speeds are observed in summer and highest ones take place in winter (January and February). During all years lowest wind speeds are registered in Lviv and highest ones occurs in Simferopol and Odesa (fig. 3).

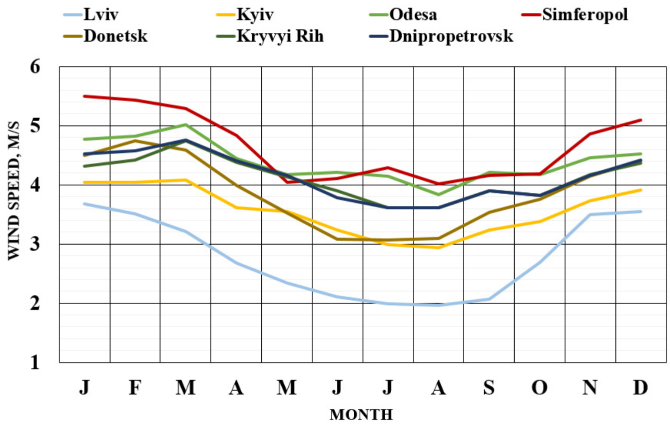

Fig. 3. Yearly variations of the mean wind speed at seven locations.

It is noticeable that daily variation of wind directions is insufficient, excepting Odesa and Simferopol. For all airports the distributions of wind direction in the various day period is close to the mean ones (fig. 4). In Odesa and Simferopol differences in distributions can be explained by influence of breeze and mountain-valley circulation.

Fig. 4. Daily frequency distribution of the wind direction at seven airport of the Ukraine for period of 2001 to 2008.

3.2. Change of wind resources in time and height

For all stations for available periods of observations, the assessment of wind resources was obtained. The results showed gradual and even decrease of wind resources in lapse of time for all stations, except Kyiv, Odesa and Simferopol. In Simferopol in lapse of time there is increase of wind resources almost in 1,6 time, and in Odesa and Kyiv a minimum occurs in the period of 1961 to 1990, and in the period of 2001 to 2008 wind energy potential grew in 1,2 times in Odesa and in 1,8 times in Kyiv.

For all stations, the specific theoretical wind power was determined at heights of 20-200 m, supposing, that wind changes according to a logarithmic and power law. It should be noted that if the wind changes with a height according a logarithmic law the specific wind power can be increased approximately in 2-3 times. In this case for installation of wind turbines Simferopol is the most perspective and all other stations, except Kyiv and Lviv, are partly perspective.

If the wind changes with a height according the power law the specific power can be increased approximately in 5 times. For installation of wind turbines all airports, except for Kyiv and Lviv, became most perspective.

Table 2. Change of specific wind power in time at seven airport of the Ukraine.

Airport	Kyiv			Kryvyi Rih		Lviv			Dnipropetrovsk			Donetsk		Odesa			Simferopol		
Period	1936-1960	1961-1990	2001-2008	1936-1960	2001-2008	1936-1960	1961-1990	2001-2008	1936-1960	1961-1990	2001-2008	1961-1990	2001-2008	1936-1960	1961-1990	2001-2008	1936-1960	1961-1990	2001-2008
Specific theoretical wind power, W/m^2	156	45	**85**	276	**110**	232	110	**70**	169	182	**123**	229	**129**	299	116	**135**	113	171	**180**

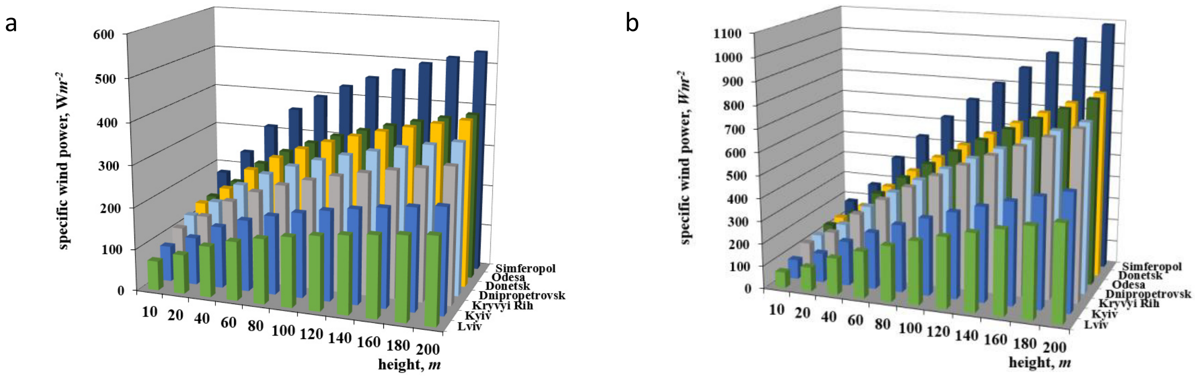

Fig. 5. Change of specific wind power in height according to a logarithmic law approximation (figure, a) and a power law approximation (figure, b) at seven airport of the Ukraine for the period of 2001 to 2008.

The probability distribution can be empirically calculated by classifying the sampled data and thereafter, based on such data, adjust and find the parameters of a known probability distribution. The probability distribution that usually adjusts better to the speed data is the Weibull distribution [3,7]. As regards the cases shown in figures the adjusted distribution to the raw data fits in very well onto the empiric distribution, thus duly representing the occurrence probability of a given wind speed for the profile in question (fig. 6).

Wind at the 1000 m height is close to the geostrophic one, which is used for renewal of wind profile [3]. Therefore, in the contribution empirical distribution at the 1000 m height was build.

The results obtained for the parameters of Weibull distribution at height of 1000 m show that frequency of operative wind speeds substantially increases and that small distinctions are between distributions of speed of wind at height of 1000 m in Odesa and Kyiv.

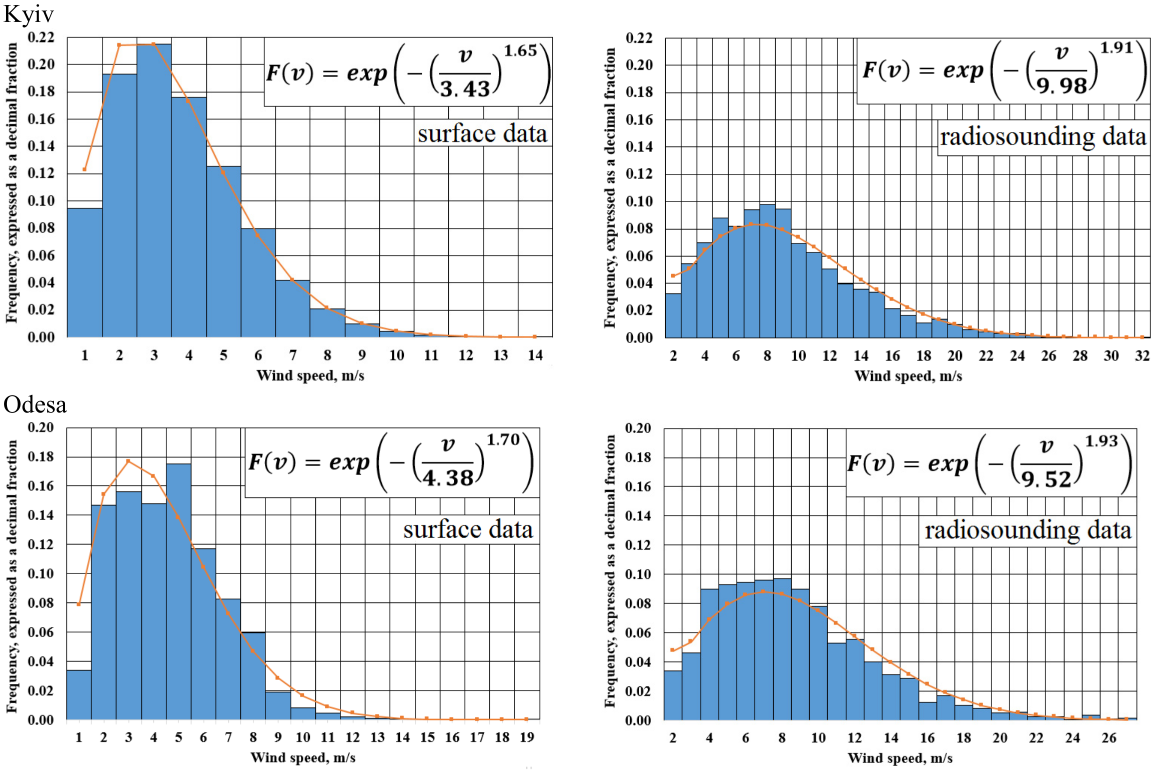

Fig. 6. Wind speed frequency with fitted Weibull distribution near the surface and at height of 1000 m at two airports of Kyiv and Odesa.

4. Conclusions and further development

The results obtained show that with the lapse of the time wind speed and wind resources is decreased half the size for the most sites in question. It is reflected general tendencies in the wind speed change over the European territory. Places, which are most perspective for wind turbine installation, are coastal sites such as Odessa, and sites situated in the Crimea Mountain (Simferopol) and the Donetsk ridge (Donetsk).

The results derived in the contribution may be used for modelling and mapping wind resources of Ukraine [8]. The analysis carried out for seven sites of the Ukraine allow identifying sites with a good wind energy potential and developing complex propositions for sites with poor wind resources for their efficient using. It is necessary to foresee the use of wind generators with substantially different parameters in different climatic regions. It is possible to put a question about the use of wind turbines with different parameters in the different seasons of year, or about the change of parameters of the same wind turbine from one season to other.

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