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GEOINFORMATIONAL SUPPORT OF WIND POWER DEVELOPMENT AT THE LOCAL LEVEL

The paper deals with the methodology of the potential wind energy generation forecasting for local areas. The results of its application in the Kharkiv region are analyzed.
Keywords: GIS modeling, average wind speed, wind and energy potential.

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ГЕОІНФОРМАЦІЙНЕ ЗАБЕЗПЕЧЕННЯ РОЗВИТКУ ВІТРОЕНЕРГЕТИКИ НА ЛОКАЛЬНОМУ РІВНІ
В роботі розглянуто методику прогнозування потенційного виробітку енергії для локальних територій та проаналізовано результати її апробації на території Харківської області.
Ключові слова: ГІС-моделювання, середні швидкості вітру, вітроенергетичний потенціал.

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ГЕОИНФОРМАЦИОННОЕ ОБЕСПЕЧЕНИЕ РАЗВИТИЯ ВЕТРОЭНЕРГЕТИКИ НА ЛОКАЛЬНОМ УРОВНЕ
В работе рассмотрена методика прогнозирования потенциальной выработки энергии для локальных территорий и проанализированы результаты ее апробации на территории Харьковской области.
Ключевые слова: ГИС-моделирование, средние скорости ветра, ветроэнергетический потенциал.

Introduction. Wind energy as a high-tech, cost- and environmentally-effective sector has developed significantly in many countries over the last 10-15 years. In 2013, the growth rate of wind power industry in Ukraine amounted to 56%. In such circumstances, the search of effective technologies and research methods of rational organization of work and the calculation of the perspective output power of wind turbines (WPP) is urgent. The geoinformation systems play an important role in the implementation of such studies, provide unique opportunities for the creation of wind energy development strategies at local and regional levels. Consideration of geographical factors in the prediction of WPP is necessary, but still optimal methods of calculation of their effect on the WPP operation are being developed. As based on the stochastic nature of wind, the analysis of large areas is irrational and unpractical.

Study background. The work is based on works of national and foreign researches in the forecasting of power output. The division of methods of forecasting of wind energy offered by M. Kuznetsov [2] is reasonable. According to it, there are two categories: physical methods, exploring a number of physical properties of the atmosphere and its interaction with the surface of the Earth, and statistical, based on statistical regularities among the array of results of direct measurements. Using both categories at the same time provides optimum accuracy of results. In the paper of Syrotiuk M. [3] The initial data for integrated assessment of wind power potential in Transcarpathia were measurements of wind speed based on hydrometeorological service network. The dependence of direction and wind speed on various factors (direction of mountain valleys, characteristics of the atmospheric circulation and relief) was taken into account. On the basis of calculations of power density of wind flow with the help of Monte Carlo method, three wind power zones were distinguished. It was found that the highest area (Polonynskyi spine) has the largest potential wind energy. In the paper of Smerdova A. and Bulba E. [4] the feasibility of using wind turbines to meet agricultural needs is analyzed. Statistical evaluation of the characteristics of the wind speed in Poltava was conducted in this work. Through calculation of the coefficients of the Weibull distribution the estimation of wind potential was made. In the paper of O. Achkasova and O. Tretyakov [1] the wind potential of plain area with the minimal forestation and the lack of reservoirs was studied. The result of the work was the creation of maps of wind power capacity and average wind speeds in the area of research. In the research there was used a wind speed modeling method, which was considered by the authors of the last paper [1]. The method of consideration of the terrain roughness, which was used in the research, was based on the method discussed in the work of American scientists [5]. Fundamentally new in the research are:

- The consideration of inhomogeneous areas for the research of wind turbine energy output;
- The use of energy output simulation for specific WPP accommodation options with consideration of environmental and resource factors.

The goals and the objectives of the research.

The aim of this paper is a comparative analysis of the energy output of wind turbines located in areas with a different combination of physical and geographical conditions, with the help of GIS.

To achieve this goal following tasks were completed:

- The analysis of preconditions of placement WPP in

Kharkiv region and determination of the optimal areas for the study was made;

- Wind speed and energy output modeling for specific areas within the selected area was done;

- A comparative analysis of some potential locations for wind turbines in areas with various qualities of the physical-geographical conditions was conducted.

Materials and methods.

The calculations of potential energy output were based on the value of wind speed. The more detailed information about the values of wind speed is available the more accurate the projected energy output will be. For this purpose the creation of statistical surfaces of average wind speed was used in the research. Each point of the surface met a certain calculated value of the average rate for the area.

In the research, the data obtained from anemometer measuring near the Golubovka village at an altitude of 22 m from the earth's surface (180 m above sea level) was used. The measurements were conducted within the study area during the period from 8.10.2008 to 9.03.2009 by the specialists of Geomonitoring and Conservancy Department of geological and geographical school of the V. N. Karazin Kharkiv National University together with employees of the French wind power company «Nerzh an Avel». To estimate the probability distribution of the obtained values of wind speed, Weibull distribution function was used; parameter $k = 2{,}4$ and parameter $p = 6.33$ was obtained for the investigated area.

Construction of the average wind speed distribution surface.

An important aspect of the wind resource assessment is related to the fact that the height of the wind wheel is higher from the wind speed measurement level. At the surface layer an increase of height leads to an increase in wind speed. To extrapolate the value of wind speed in the vertical and horizontal plane the logarithmic law of vertical wind profile construction was used, the roughness of underlying surface areas was taken into account. At the first stage of the study a total matrix of heights was constructed using GIS Map 2011 application. 1:10 000 scale topographic maps were taken as a basis for the construction of the matrix. Initially, the maps' vectorization was held with the help of GIS Map 2011 application, and later total matrix was constructed from each map sheet through the method of average heights interpolation. The equalization of matrices was held to smooth heights in areas of overlap. Then separate matrices were combined into one, which covered the whole area of study. The resulting map contained information about the total height of all points of the territory.

The size of the territory depicted on the map was within 275 km^2. This coverage is too large to handle with in the Wind Farm application. Therefore, the resulting map was divided into several parts, each of which was analyzed separately. The feature of the analysis in Wind Farm application was quite significant distortion of the results in marginal areas of the map. To ensure the best reliability of the final results, the overlapping of projects was made to the value of 50%; 31 matrices of heights from a large were obtained. The side of the square size within each project thus was 5 km, overlaying — 2500 m.

The last thing that was done at this stage was a conversion of the heights matrices into a text format for further use in other GIS environment. The surface of terrain roughness was built in the Wind Farm application on the basis of satellite image of the territory, which was found in the Google Earth environment. For those the bitmap based vectorization of terrain objects (forests, shelterbelts, shrubs, arable land, reservoirs, ponds, settlements) was made. The appropriate value of roughness was given to each object.

The next step was to create a Wind Farm project for each of the height matrices. Each project had to be snapped to geographic coordinates. The grids with the values of heights and roughness of the terrain were immediately placed into projects. Each project was linked with information about wind rose and wind speed in accordance with anemometer readings. At each site the location of anemometer was chosen at the same absolute (180 m) and relative height (22 m), as in that part of the site where it was stored during the measurements.

The next stage — the modeling of wind speed for which a WindFlow software module was used. During the modeling the mathematical calculation of wind speed for given parameters was made, and then the construction of wind speed averages surface for the area was held. The map of average wind speed for the study area is shown on Figure 1.

Modeling of the potential energy output.

On the basis of the distribution of wind speeds, average wind speed surface, wind energy installation specifications and layer in which the point of the placement of wind turbine was specified, the potential electricity generation was estimated. The calculation was carried out in the environment of Wind Farm application.

To calculate the energy that would be generated by the wind turbines, double integration of all directions and wind speeds at which this generator would work was made. Windrose included automatically calculated information about wind profile for each sector. For the hub height wind speed value was calculated by logarithmic law. So, the value of wind speeds at the anemometer site at a hub height was obtained. To calculate the value of wind speed at a particular place, the calculated matrix of wind speeds for the entire territory was used. The next step was to combine wind speed distribution by sectors with the repeatability of each direction throughout the year. According to the wind turbine power output curve (the output depending on wind speed), potential energy output in [kW · h] was calculated (Fig. 2).

Results. According to the results of construction, it can be concluded that the largest wind speed within the observed area was in the northern part of the watershed,

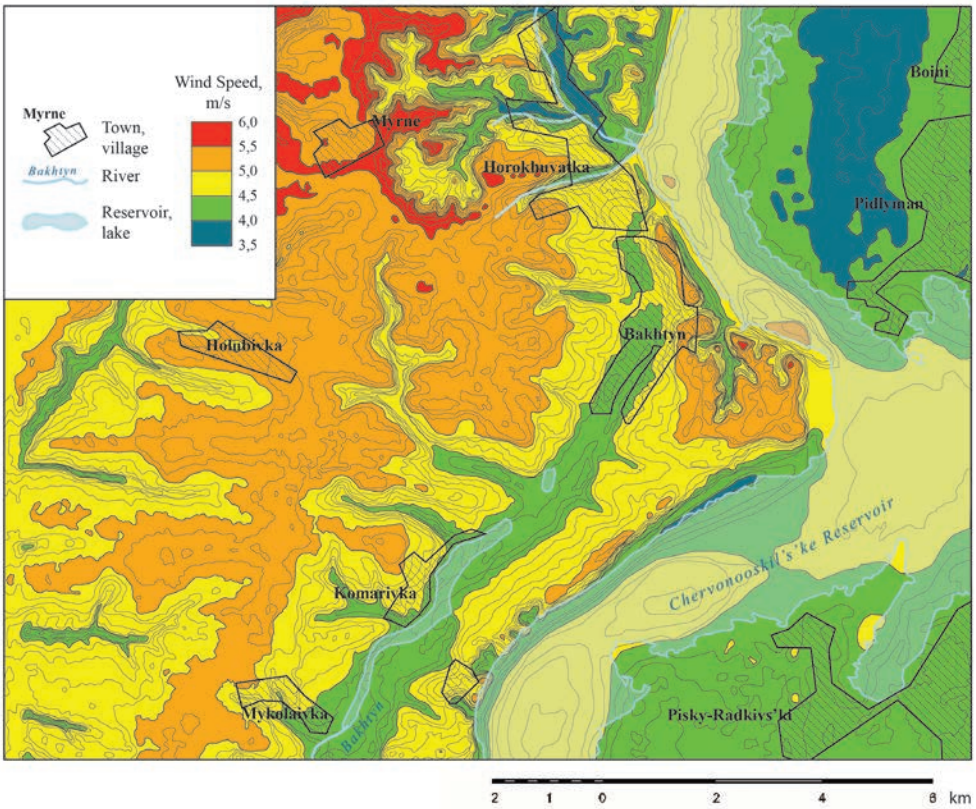

Fig. 1. Estimated average wind speed within the research area

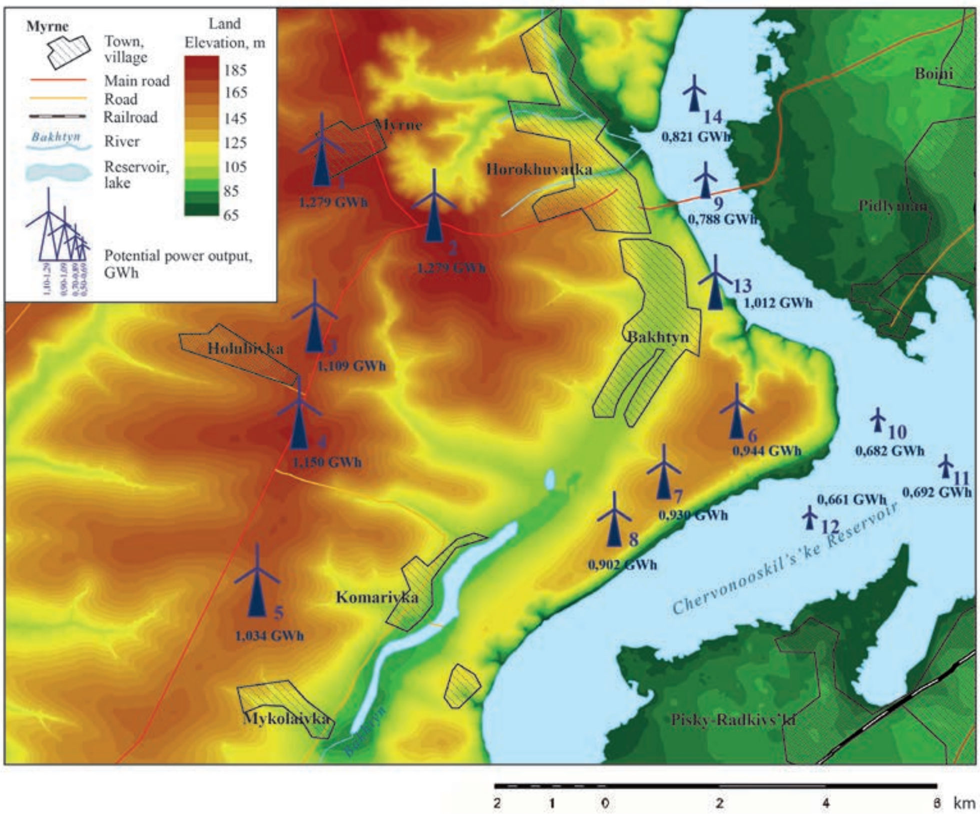

Fig. 2. Calculated output power and potential locations of wind turbines within the research area

which is characterized by the highest elevations of the area. A certain increase in wind speeds is also observed on the coastal slope (area near the Bakhtin village), which is caused primarily by the proximity of the reservoir. Winds are able to be dispersed over the surface of the reservoir to large values. This contributes to a large enough size of the reservoir, and the wind rose frequency distribution of winds. As the north wind direction has a higher frequency than the south one, higher values of wind speed in the northern coastal areas of the slope were observed. Lowest run rate was near the Pidlyman village (due to significant forest cover and small absolute height).

The largest potential energy output was observed for generators №1 and №2 at the highest points of the area. This result was related to the fact that the winds don't encounter significant obstacles (slopes, hills), and wind turbines can use air currents of different directions. The area within this site is fairly homogeneous, flat, which also improves results.

The disadvantage of placing on the coast was a fairly high degree of forestation on the slope and the possibility of turbulent motions of air that would slow wind flows down. As can be seen from the results in this case, the wind profile was high enough above the surface of the reservoir to gain high values of wind velocity at the site of wind turbines placement, and disadvantages mentioned above do not influence significantly. As a result of compaction of wind speeds on the slope, the value of output was significant. Because of this, among other potential provisions generator №13 was allocated, which had better energy efficiency than the three generators on the other side of the slope. This is due to the fact that the on north of the potential position of the generator the largest compared to any other point of the map area of the water surface is situated; this allowed northern winds to reach great speeds. This way, the generator on the northern slope is close to the output values of generators, situated on the watershed.

It should be noted that as a result of wind speeds surface construction some indications errors were indicated, which was negligible in the survey, but was taken into account while analyzing the results. This error is associated with a variety of roughness indications within the area and great differences of heights for the area. Size of error was set by combining surface distribution of wind speeds for various projects in the Golden Software Surfer application. The resulting surface has shown that, as the anemometer was placed at a height of 180 meters, the largest error was for the reservoir area.

Conclusions. The obtained values of potential wind turbines output indicate that in case of wind turbines installing on the area, total time of WPP work in equivalent to a full load will reach 1.5 – 2 thousand hours, what experts say is quite a high value for a wind energy.

Wind turbine energy output for various potential sites in different physiographic conditions was analyzed. It was determined that among the selected areas (watershed, slope, reservoir), the most promising for the use of wind energy is the highest area located on watershed where annual energy output reaches values of 1,279 GW·h. The smallest output was observed in a wide part of the reservoir, surrounded by forest plantations around all sides and coast scenic slope in the west.

The dominant parameter in the design of output power was absolute altitude. The higher the area the better the output is. But at the same time, the value of output can reach high values even in the point of terrain is not characterized by dominant heights. Under conditions of the same altitude of the area, the best power output will be in the area that has the lowest values of roughness and enough open space around to disperse the air flow.

Modeling with the use of GIS enabled to fully assess the prospects for placing wind farms at highlighted areas and the points of the area with the greatest wind energy potential.

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