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Technical note

Investigation of the wind energy characteristics and power generation in Lithuania

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ABSTRACT

In this article the wind flow characteristics, a current situation and future prospects of the wind energy use and power generation in Lithuania are investigated. During the last ten years the assessment of wind power resources was carried out, wind measurement data were collected and analyzed, whereas Lithuanian wind resources map was developed on the basis of the obtained results. A long-term (1945–1990) wind data for 19 meteorological stations and performed measurements in sites revealed that the most suitable region for building wind turbine (WT) of large-scale is the 10 km wide coastal strip near the Baltic Sea. Also, the investigations demonstrate that WT can be installed in the continental part of Lithuania. However, the efficiency of WT will be slightly less in the continental part as in the near-shore. The energy efficiency was evaluated by the capacity factor C_p, which was calculated for installed WT in different regions of the country. The aim of the work is to present the results of investigation of wind climate conditions in the coastal area of the Baltic Sea and other regions of Lithuania and evaluate wind energy generation in the country.

1. Introduction

During the last two decades, wind turbine industry can be treated as one of the fastest growing renewable energy technologies, if compared to other renewables [1,2]. In Lithuania, the first wind turbine (WT) of 0.63 MW in capacity was installed near Vydmantai on the coastal zone of the Baltic Sea in 2004. In 2006, WT installation increased and company "Vejo spektras" installed the first WT farm of 30 MW in capacity near Kretinga [3,4]. At the end of 2012, wind turbine (WT) installed capacity encompassed of 225 MW in Lithuania. Obviously, there is evident increase in the development of wind energy in Lithuania as well as in other countries [1,2].

One of the most important issues in this general context is the implantation of proper wind generation equipment for energy production [5–7]. A wind turbine can reach its maximum efficiency if it is selected in accordance with the region wind conditions [8,9]. Therefore in Ref. [5], the wind flow characteristics and its potential have been frequently analyzed in the European Union and other countries.

In this paper, we present the data on the investigation of the wind flow characteristics and the possibility to increase the use of wind energy in the coastal region of the Baltic Sea and other regions of Lithuania.

2. Wind data measurement site and equipment

The wind flow measurement characteristics were used for assessment of the wind energy resources in the sites. For more precise assessment of wind climate conditions in the coastal area of the Baltic Sea region German wind velocity measurement equipments "WICOM-C" and "WICOM 32" were used. These equipments registered three wind velocities and one wind direction [10].

The mean, maximum and minimum wind velocities of the log interval are stored in the memory of the Data Logger. The mean values of velocity are calculated by equation:

$$V_m = \sum_{i=1}^{k} V_i/k, \tag{1}$$

here k is number of scan values within the log interval; i is control variable within the log interval, with $i = 1, 2, 3\ldots k$; V_i is i-th scan values in the log interval.

Standard deviation is calculated by equation:

$$\sigma = \left[\sum_{i=1}^{k} (V_m - V_i)^2/(k-1)\right]^{0.5}. \tag{2}$$

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Wind power measurement equipment "WICOM-C", was positioned at 1.5 km distance from the Baltic Sea in Giruliai, on the hill being 24 m high above sea level. Here wind flow characteristics were measured every 10 s, integrated and every 10 min fed into the computer memory. Measurements of wind flow characteristics by "WICOM-C" were carried out at three heights above ground level: 10, 30 and 50 m. Measurements of wind directions were performed at the height 30 m above ground level with the accuracy of 1°. The measurement time period carried out from 1998 to 2003.

The other measurements of wind characteristics by "WICOM 32" were continued at the same location at 25, 45 and 65 m heights in time period from 2010 to the present. All wind characteristics for the specific time span were stored in the Dater Logger memory and after that they were transferred into personal computer for further calculations. Investigations were performed in accordance with the requirements of the European standards; this enables to choose optimal capacities and type of wind turbines and forecast their performance, to prepare work schedules and forecast their utilization feasibility and payback time.

3. Results and discussion

3.1. Analysis of meteorological stations data

Regular measurements of wind velocities and directions have been performed in Lithuania since 1945 in the meteorological stations that are distributed in a fairly regular network over the whole terrain. The measurements are performed round-the-clock every 3 h usually at 10 m above ground level. Some meteorological stations are erected close to living settlements and towns, which contradicts the standard demand of there being no buildings, trees or bush over the radius of 300 m around the site to avoid any distortions of the readings. Therefore a certain part of wind velocity readings for specific directions may be error-corrupted, in most cases they are underestimated.

All readings are averages over specified time spans. Monthly and annual averages are also determined. The average annual wind velocity, from the19 meteorological stations for the period of 1945–1990 is given in Fig 1. It was estimated that the long-term wind velocity averages do not differ very much from the averages of separate years. It was determined that with the increase of observation period from 23–27 years to 33–34 years calculation bias changes accordingly from 0.08–0.2 m/s to 0.07–0.15 m/s.

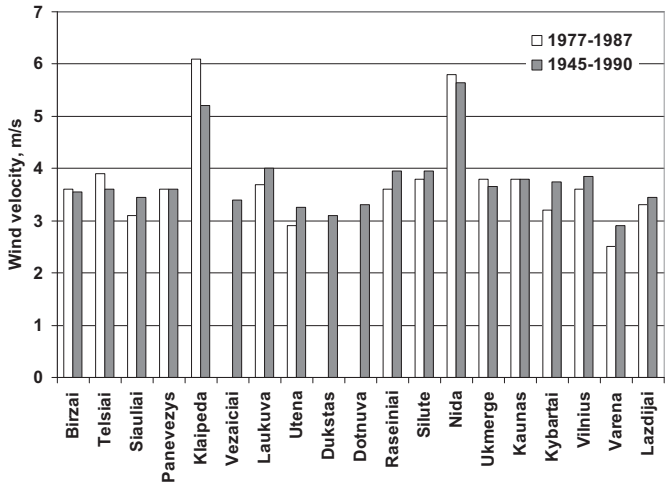

Fig. 1. An average wind velocity in the sites of Lithuanian meteorological stations at the 10 m height above a ground level for two time periods.

Data, gathered by meteorological stations in the period of 1945–1990, were used for evaluation of wind power resources in the Lithuanian territory. The obtained data revealed that the most suitable region for the development of wind energy is in the coastal area of the Baltic Sea (Klaipeda region), where wind velocity average is about 5.5 m/s at 10 m above ground level. In the bigger territory of Lithuania the average wind velocity is considerably smaller than in the coastal area.

3.2. Wind resources map of Lithuania

Wind energy potential estimation for Lithuania was given in the study based on the average wind velocities collected from meteorological stations elevated at 10 m above ground level and other measurements were performed in air and seaports and other sites. The measurements were used to extrapolate wind energy potential at 50 m height above ground level. The power law and the log law are the two most commonly used analytical models for extrapolating wind velocities to higher heights at a site [11]. The power law is shown in Eq. (3)

$$V_{\mathrm{h}} = V_0\left(\frac{h}{h_0}\right)^{\propto} \tag{3}$$

and a version of the log law is shown in Eq. (4)

$$V_h = V_0\frac{\ln h/z_0}{\ln h_0/z_n}, \tag{4}$$

here V_0 is the reference wind velocity measured at a height h_0; V_{h} is the new wind velocity at h (at considered hub heights); α is the wind shear exponent of the site; z_0 is the surface roughness height.

The average wind velocities for the period 1981–1990 and 1993–1998 were obtained from 19 meteorological stations (Fig. 2). Measurements at 10 m above terrain were extrapolated to 50 m above terrain. The measured data were analyzed according to the "Wind Atlas Method" using Wind Atlas Analysis and Application Program WAsP. Long-term regional wind climates ("Wind Atlases") were produced referring to a number of standard conditions: a number of standard surface roughnesses in combination with a number of standard heights above terrain. Data from meteorological station masts of the national meteorological institutes with long-term records as well as data for the short-term measurement period were used to provide data for the conversion from the short-term measurement periods to a long-term period. This way regional wind climates represent long-term wind statistics (>10 year).

Correlative analysis was carried out for meteorological stations measurement data and suitability of all regions of Lithuania for building wind turbines was evaluated.

After summarizing the results of all the investigations and the data from meteorological stations the wind resource map was developed (Fig. 2). Wind resource map shows that the average annual wind velocity in the coastal region of Lithuania reaches about 6.4 m/s at 50 m above ground level, which is similar to other countries of the Baltic Sea region. More detail analysis of the wind flow parameters this region is given in Ref. [12]. However, wind velocity in most of the continental area of Lithuania is only 4–5 m/s. Therefore the coastal region is most suitable territory for large-scale wind energy development in Lithuania. Wind resource map represents statistical data and only the main features of wind climate. The precision of wind resource map is judged to be 5–10%. The inland wind velocity values in the wind resource map should be taken with precaution and only used to judge how fast the wind resource decreases with distance from the coast of the Baltic Sea.