

ANALYSIS OF THE CHOICE AND LOCATION OF WIND TURBINES IN POLAND AND EUROPE

A dynamic development of wind power engineering has been observed in the European countries for many years, which is mainly due to the European Union policy and reduction of emission of harmful substances into the atmosphere. The most technologically advanced countries in the wind turbine industry include Spain, Italy, France, Germany and Great Britain. In recent years, offshore wind farms built along the coast have become increasingly popular. Because of the considerable wind speed, offshore wind farms are able to produce much more energy than land farms, what is more, a great advantage of offshore wind farms is the unlimited space. In a situation when we consider land wind farms, this space which can be used for the development is much smaller and it has to be determined by meeting a number of legal, social and also space criteria. A fast development of the wind turbine industry makes it necessary to rationally analyse the location of farms, therefore, the legal regulations must be clearly defined so as to work out suitable procedures which will, on the one hand, create clear and simple procedure of these installations location, and on the other hand, will provide grounds for rational spatial policy in relation to wind farms. The construction and installation of wind farms is a time-consuming enterprise which requires significant financial expenses. That is why, the phase of the choice of location constitutes one of the key stages of wind farm installation. The choice of wind farm location both in Poland and in other European countries must meet numerous requirements in terms of technical, economical and legal criteria. Planning a wind farm construction, it is necessary to consider a number of aspects relating to the wind potential or suitable distance from residential developments and to thoroughly analyze the financial benefits resulting from the planned investment.

Keywords: wind farm, renewable energy sources, location of wind farms.

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АНАЛІЗ ВИБОРУ ТА РОЗМІЩЕННЯ ВІТРЯНИХ ТУРБІН В ПОЛЬЩІ ТА ЄВРОПІ

Динамічний розвиток вітроенергетики спостерігається в європейських країнах впродовж багатьох років. Це пов'язано із політикою Європейського союзу щодо зменшення шкідливих викидів у атмосферу. Найбільш популярними та перспективними на сьогоднішній день є морські вітряні електростанції, побудовані вздовж берегової лінії. Для побудови максимально ефективної вітряної електростанції необхідно врахувати багато чинників, оскільки він потребує великої кількості ресурсів.

Ключові слова: вітрова ферма, відновлювальні джерела енергії, розміщення вітрових ферм.

Introduction

A dynamic development of wind power engineering has been observed in the European countries for many years, which is mainly due to the European Union policy and reduction of emission of harmful substances into the atmosphere. The most technologically advanced countries in the wind turbine industry include Spain, Italy, France, Germany and Great Britain. In recent years, offshore wind farms built along the coast have become increasingly popular. Because of the considerable wind speed, offshore wind farms are able to produce much more energy than land farms, what is more, a great advantage of offshore wind farms is the unlimited space. In a situation when we consider land wind farms, this space which can be used for the development is much smaller and it has to be determined by meeting a number of legal, social and also space criteria. A fast development of the wind turbine industry makes it necessary to rationally analyse the location of farms, therefore, the legal regulations must be clearly defined so as to work out suitable procedures which will, on the one hand, create clear and simple procedure of these installations location, and on the other hand, will provide grounds for rational spatial policy in relation to wind farms [5].

Wind farms in Poland

Presently, mainly traditional sources of energy are used to produce electricity in Poland, namely: coal, lignite or natural gas. Following the requirements of the European Union, member countries are obliged to reduce CO₂ emission, where by 2020, it has to be reduced by 20% within the whole Union. Thus, Poland is obliged to use the Renewable Sources of Energy as alternative sources of electricity generation. The possibilities of using RSE are quite extensive, we can list here, for example, biomass, biogas, geothermal, wave, tidal resources, solar and wind energy. The wind energy has been developing dynamically and it is used to produce electricity on a larger and larger scale. The potential for the energy development in our country is pretty big, which is proved by the results of examinations conducted by IMGW on the grounds of the observations of wind speed and direction made by the IMGW (Institute of Meteorology and Water Management). According to the report, the best conditions in terms of the wind resources are in the following regions: midlands, the northernmost parts of the coast from Koszalin to Hel, the region of the Wolin island, the Suwałki region, central Wielkopolska and Mazowsze, Beskid Śląski and Beskid Żywiecki, Bieszczady Mountains and Pogórze Dynowskie [1].

Location of wind farms in Poland

A construction of a wind farm is a very complex and complicated process, where already at the stage of a project, it is necessary to take into consideration a lot of criteria. Taking into account even the large size, moving elements of the construction, noise, flicker effect and other aspects, as for instance, those of natural, cultural or even tourist nature. The construction of wind farms should be planned in agricultural areas, wastelands or regions which

are not developed for house building. While planning a location for a wind farm, it is necessary to take into account the zones of nature protection and forests. The minimum distance of wind farms location from residential areas is also of great importance. Too small distances might increase the noise and intensify the stroboscopic effect. Another criterion, taking into consideration the areas which are attractive in terms of tourism, is the colour of the construction, height of towers and distance between the turbines. Analysing the above issues while planning the wind farms location, the following criteria must be fulfilled:

- wind power,
- adequate distance from buildings and road infrastructure,
- minimization of the flicker effect,
- economical aspects [2, 3].

It is estimated that in Poland almost 40% of the country area might be used for wind energy, taking into account the criterion of profitability 1000 kWh/m²/a year, with the assumption that the installation is 30 m above the ground and the roughness class is "0". The wind speed should be at least more than 3 m/s. The wind speed and direction at a given place depend on numerous factors, such as:

- natural topography of the land,
- air temperature,
- local state of atmosphere equilibrium,
- type of land surface (roughness),
- presence of water reservoirs,
- different kinds of land obstacles (buildings, trees, etc.).

The speed of wind is changing all the time, it is different during the daytime and at night, moreover, wind speeds in the summer tend to differ from those in winter. In the daytime, the highest wind speed is observed at midday, then there might also occur turbulences, also in the winter season higher wind speeds are observed. When investments are planned in a given area, special measuring masts are mounted which measure the wind speed and direction throughout the year. It allows to obtain a lot of data that change depending on the season of the year. When a wind potential change is taken into consideration over a wider period of time, the measurements are taken for three years. Thanks to the precise measurements of the wind force, it is possible to choose adequate turbine parameters and optimal height of the tower [4, 7].

Distance from build-up areas, read infrastructure

Planning wind farm installations, it is necessary to take into account the regulations and standards relating to wind farm construction. According to the Regulation of the Minister of the Environment of 2007, while planning a construction of wind farms, it is necessary to take into account the distance of the residential areas and the level of the noise produced. According to this regulation, the noise level at an adequate distance from its source should not exceed 40 dB, this distance ought to be properly calculated as it depends on the level of noise that is emitted by its source. In this way, an equal-loudness contour is drawn on a map of the selected area within which there should be no residential buildings. The noise emitted by modern turbines is generated primarily by the aerodynamic drag. In the modern construction of wind turbines the noise induced mechanically is reduced. The noise induced aerodynamically manifests itself as a uniform humming sound and may be perceived as an annoying noise. A factor which increases the range of such effect is the location of the moving parts a wind turbine at a considerable height ranging from several dozen to one hundred meters: with the wind farm height of 80–100 m and wind speed of 8–10 m/s, the sound power can vary from 101 to 106 dB. So as not to exceed the permissible noise levels, an appropriate distance between a wind farm and a residential area should be kept [6, 7].

Distance from a turbine [m]	Noise exposure for a turbine of 600 kW [dBA]	Noise exposure for a turbine of 1650 kW [dBA]
200	46,5	47,0
250	44,4	44,9
300	42,7	43,2
500	37,4	37,9

Fig. 1. A sample distribution of sound level for a wind farm [15]

The data collected show that the noise generated by turbines has no significant intensity. The problem results rather from its monotony and long-lasting impact on a human psyche. Planning a construction of wind farms, due to the minimization of costs connected with the construction of access roads, it is necessary to take into account the access conditions, the best solution is to situate the turbines as close to the public road and the roads connecting the turbines as possible. It also reduces the complications resulting from the preparation of adequately profiled curves of roads, curing the access roads and putting them to use [5].

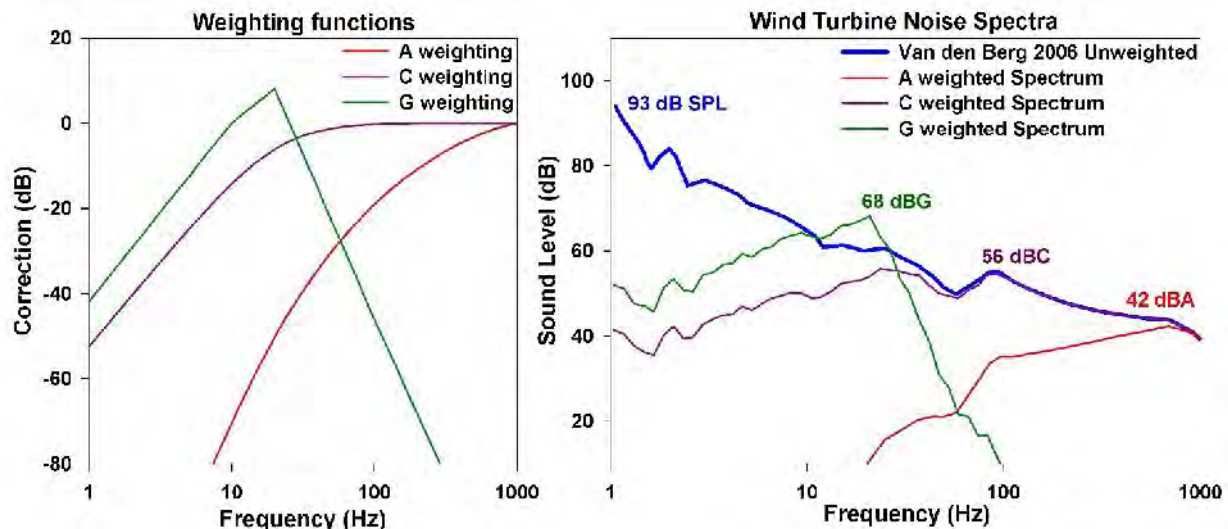


Fig. 2. Perception of noise of the same intensity emitted by Wind Turbine [8]

Distance from the residential and residential-commercial service development	min. 1000m
Distance from hospitals and social care centres	min. 1200m
Distance from buildings associated with permanent or temporary stay of children and adolescents	min. 1200m
Distance from spa developments	min. 1600m

Fig. 3. The distance from the build-up areas suggested for the location of wind farms [15]

Stroboscopic effect and shadow effect

The stroboscopic effect is observed when the rotating rotor blades periodically reflect the light beams. The light reflections might be treated as elements of emission distorting the vision of living organisms [5]. The stroboscopic effect is presently treated as a less important impact of wind farms because it has been virtually eliminated by using matt paints to paint the rotor blades. The shadow effect is caused by the shadow cast by the wind farms constructions (the tower and rotor blades). The factors affecting the intensity of the shadow flicker are the following:

- height of the tower and diameter of the rotor,
- cloudiness,
- distance of a wind farm from buildings,
- presence of trees between a wind farm and residential buildings,
- windows and doors exposition in residential buildings.

Modelling of the phenomenon of shadow flicker at the stage of designing a wind farm construction allows to plan a convenient location of turbines which will prevent an excessive impact of the above effect on humans [9, 10].

Economical criterion

A construction of a wind farm is a very expensive investment that is why its operation must be profitable. Therefore, when the location is chosen, the following factors have to be considered: the price of the land, the geological and engineering conditions, the state of the existing road infrastructure and a possibility to make a connection to the power network [6, 13].

Location of wind farms in the selected European countries

Denmark

In 2007 in Denmark about 16,2 % of the energy supply in this country came from the sources, nevertheless in the recent years installations of new wind farms decreased. The Danish government continues the energy policy introduced in 2006 which focuses on the problems of globalization and better use of renewable sources of energy. Denmark had to cope with the problem of the choice of appropriate location, where already in 1995 the Ministry of Energy and Environment issued a document called Local planning for wind energy in Denmark: Examples and experience. This document provided information on turbines location and the way they should be fitted in the landscape, as well as the necessity of mounting turbines in groups. The subsequent years of wind farms installation proved that the arrangements introduced previously had to be more precise due to the fact that the wind farms had been constructed in inadequate places. Denmark issued another regulation which defined places where wind farms should be installed with a precise indication of the surface and maximum height. Apart from that, a minimum distance of turbines from the closest building developments was determined as 4 x height of a tower. In the event a turbine was more than 80 m high, an environmental permit had to be obtained [14, 15].

Sweden

Sweden is an example of a country which recently has clearly accelerated the process of wind farms installation. The location of turbines is based on two legal acts: Act on Planning and Construction of 1987 and the

Environmental Code of 1998. Presently, a construction of a single turbine requires a building permit, and in case of wind farms, a detailed area development plan has to be accepted by the local authorities. However, according to the environmental regulations, bigger installations require an environmental consent and the smaller ones have to be only reported [10–12].

Germany

In Germany wind turbines are located outside the build-up areas. Already in 1986, the German government decided that wind farms were privileged constructions which could be erected in the areas situated beyond the urban areas. Nevertheless, in Germany there is still an unresolved problem relating to the definition of minimum distance from the build-up areas. Some Lands started to introduce their own regulations. For instance, in Bavaria some lawmakers want wind farms to be constructed at a distance from houses equal to minimum 10 times the height of their towers. Yet, individual districts are to maintain the right to define the areas for wind farms construction in their spatial development planning. However the authorities of Saxony decided that wind farms should be constructed at a distance at least 1 km from the residential buildings. In case of Baden-Württemberg, the authorities decided that the minimum distance of wind farms from the buildings was to be at least 700 m [12, 13].

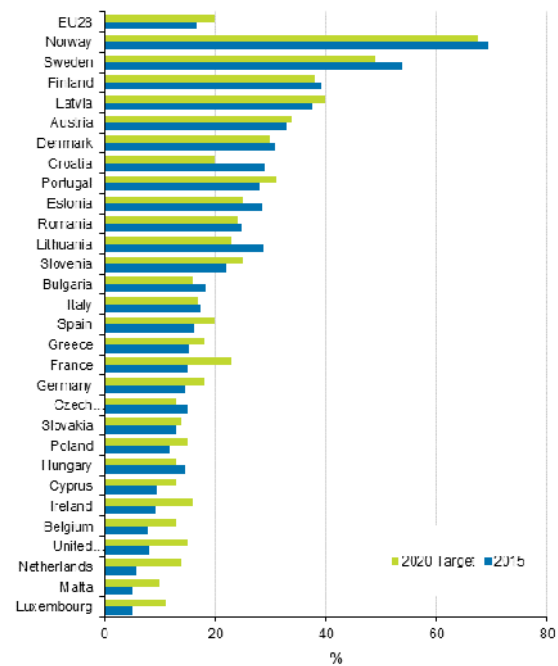


Fig. 4. Percentage of energy coming from renewable sources in total primary energy in the selected countries of EU % [12]

Conclusions

The construction and installation of wind farms is a time-consuming enterprise which requires significant financial expenses. That is why, the phase of the choice of location constitutes one of the key stages of wind farm installation. The choice of wind farm location both in Poland and in other European countries must meet numerous requirements in terms of technical, economical and legal criteria. Planning a wind farm construction, it is necessary to consider a number of aspects relating to the wind potential or suitable distance from residential developments and to thoroughly analyze the financial benefits resulting from the planned investment.

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