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RESEARCH AND ASSESSMENT OF WIND TURBINE'S NOISE IN VYDMANTAI

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Abstract. The decreasing reserve and growing costs of coal, oil and gas has persistently led us to use renewable energy resources. Using them environmental harm, air pollution and greenhouse effect can significantly be decreased. According to the European Union Parliament's and Council Directive 2001/77/EC approved in July 27, 2001, the member countries (Lithuania has been a member country from May 1, 2004) must seek to use not less than 12 per cent of renewable energy sources in total energy balance and 22,1 percent in the country's energy balance (including large hydroelectric power station). The numbers are significant. Thus, using wind energy can be one of the ways to fulfil the requirements. Lithuanian seaside, where the strongest winds are blowing, has been the most favourable place for the wind turbine's installation. However, usage and development of wind energy has been facing resistance from the society. One of the biggest arguments against the wind turbine is the noise which can cause inconveniences for the permanent residents and holidaymakers of the health-resort zone. Therefore, environmental impact of the wind turbine requires exhaustive investigations. The research was carried out in the vicinity around the only one presently active industrial wind turbine in Vydmantai (region of Klaipėda, Lithuania). During the investigation it was established that the highest noise level was registered opposite the airscrew. The smallest noise level was measured in both sides from the tower in windscrew plane. It has been measured that noise level is noticeably higher in Vydmantai wind turbine's zone than in the background, which does exceed 250–300 m (5–6 windscrew diameters).

Keywords: wind energy, wind turbine, wind turbine's noise, orientation of airscrew, noise level.

1. Introduction

Fast improvement of technologies, an increasing number of transport means, growth of people's living standard have been observed all over the world. Because of increasing electric energy consumption, intensive usage of natural resources environmental pollution is becoming much higher. If measures of pollution diminution and resources sustainablity development are not taken into accont, it is obvious, that the global catostrophe will become real. The results correction will require a few mankind generations.

Lately renewable energy resources are beeing used more widely than before. Wind energy is one of the most acceptable and significant natural resource. Although, with the increasing interest, distrust and causion are rising as well, caused by the wind turbine's environmental impact. These problems are noise, airsrew sparkling and vibration. These factors may have negative effect on people, pose a danger to flying birds, and harm local soil biocenoses. Besides ecological problem caused by the wind turbines the landscape's view can be disrupted.

Various technical, energy and economic wind turbine's aspects are often analysed in scientific literature. However, the noise, which is the main society disagreement argument, has not been widely emphasised (Petrauskas 2001; Petrauskas, Adomavičius 2001). To fill this gap, wind turbine's noise inVydmantai (region of Kretinga) was examined. The conclusions about wind turbine's noise levels were made after the measurements and generalisation of research results.

2. Possibilities of wind energy usage in Lithuania

In recent years wind energy usage has become very intensive in many European countries. Germany takes the precedence of wind turbines (WT), where installed power at the end of 2002 reached more than 12 000 MW, Spain took second place – 4 830 MW, Denmark reached 2 880 MW, etc. First place among the Baltic states belongs to Latvia where installed power has exceeded 22 MW during the last years. The stimulus to use wind energy in Latvia is a high purchasing price of the wind electric energy – 44 ct/kWh (Katinas 2003). For example, in Lithuania the price is 22 ct/kWh.

For centuries Lithuania has been a country of winds. Already in the 16th century wind energy was used for grain milling and boards cutting in the whole Lithuania and especially in the seaside region. Only during the Soviet period energy sector became centralised in all Lithuania.

The main cost part (82 %) of electric energy is spent on energy transmission from the country's eastern power plants to consumers. Electric energy in 400 kilometers

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way undergoes a lot of losses. Bringing electricity manufacturing closer to the consumers, supply distance becomes shorter and the losses of electricity are smaller. Therefore, decentralising renewable energy sources will be very cost-effective. Nowadays, as well as in 16th century, nearly every small town can be a wind turbine. The costs of electricity could lessen twice (in recent prices it is 14 cents per kWh). For consumers electricity prices will not rise taking into account todays wind turbine energy price which is 22 ct per 1 kWh. Because of constant improvements in the wind turbine's construction and manufacturing, wind energy cost has been going down and has become competitive with the price of mined fuel (Markevičius and Katinas 2003). Until the year 2010 200 MW sum power park of wind turbines will be built at the seaside. It will be enough to satisfy Klaipėda's needs for electric energy.

Until the year 2020 country's need for natural gas can be decreased by 50 % only by using the wind energy. The remaining 50 % will be acquired from the sollar, hydrogen and other renewable energy sourses. This is a broad ground for scientific investigations and innovation using European Union's financial support (Paulauskas 2006). In the research done, it was predicted that the highest electric energy increase would be reached by development of the wind energetics,for example, ~0 MW in the year 2002, 170 MW in 2010, 500 MW in 2020 (Jankauskas 2004). Because of mankind uncontrolled activities global climate warming is observed. It is a serious warning, which must be taken into account. According to the Kyoto protocol for Europen countries (for Lithuania as well) the task is to decrease the emission of carbon dioxide (CO_2) by 8 per cent in comparison with the level of the year 1990. In Lituanian National Energy Strategy it also is forseened to use more natural gas and more pure fuel instead of mazute (Burneikis 2002).

Wind energy development has started only in recent years. One of the first works about wind energy possibilities in Lithuania was research done by Lithuanian Energy Institute's scientists (Katinas and Tumosa 1995). Nevertheless, a part of society and some of its representatives individually are against wind energy, treat it suspiciously or indifferently.

During the first wind turbine construction at the Lithuanian seaside society testing was carried out. The results showed that more than half a thousand of inhabitants (73 % respondents) respnded the question, if they approved the development of wind energetics, positively and only 6,5 % showed their disapproval (www.takas.lt, 29-04-2003). Even though, the results of the questioning are favourable, wind turbine installation process is complicated.

Because of insufficient information about this modern energy producer for Lithuania, 20 percent of the examinees confessed knowing nothing about wind energy, its advantages and the modern technologies used.

During wind power plant building in Vydmantai the local press wrote about the hazards of the wind turbine's noise, landscape pollution, suffering birds and animals, irritation to people caused by shadows twinkling and electromagnetic disturbance (Gabartas 2005).

Therefore, during the development of the wind energy sector and taking into account the society's resistance, it is necessary to explain widely economic and environmental advantages, develop a reliable legal base, carry out necessary and exhaustive scientific investigations connected with wind power plants rational spreading out. The research results and their analysis must be accessable to everyone. Public opinion is very important and must be taken into account.

3. Investigation methodology

There are two potential noise sources in the wind power plant, i.e turbine blades, flying (crossing) the air, and a cabin with a transmission box and a generator. Constructors have paid a special attention to the turbine blades which noise was minimised after their construction improvement and applying special materials. Standing near the turbine, rotating blade's whizzle as well as transmission box and generator's noise can usually be heard. Nevertheless, moving away (increasing distance) from the power plant this mechanical noise is decreasing (or dying away).

Wind power plant's raised noise distribution, according to its nature, is shown in Fig. 1 (Shen, Sorensen 2001).

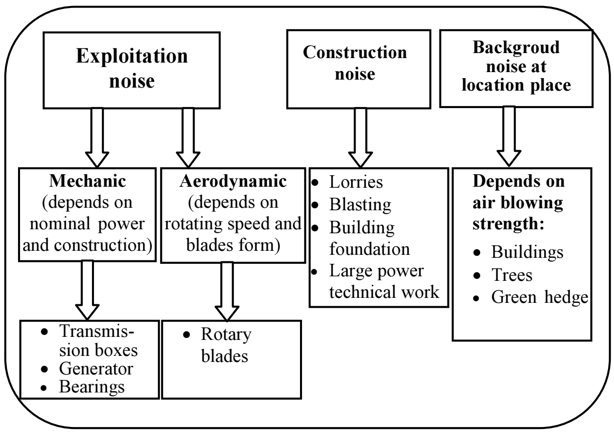


Fig. 1. Sources of the wind power plant's noise

After the improvement of the wind power plant's construction and manufacturing technologies, level of noise of the turbine has been reduced and will further decrease. For example, constructors changed blade thickness (made them thinner) and projected (built) turbines "opposite to the wind" instead of "against the wind", i.e. wind blows first of all to the rotary blade, then to the tower. Because of this innovation, aerodynamic noise has significantly been decreased.

Today the main wind turbine's noise source is produced by turbine's mechanic components (rotating parts, rotary). Low frequency noise has decreased significantly when transmission box was extracted because generators with a rotary were directly connected to the airscrew.

In the near future new-type wind power plants will be built, where noise in 300 meters distance from the plant will not exceed library noise level.

More exhaustive wind power plant‘s noise formation mechanism is described below. According to its construction, noise of the wind turbines is divided into two groups (McKenzie 2000):

– mechanic;
– aerodynamic.

Mechanic noise. Mechanic noise appears because of different moving the contact of surfaces and mechanic-dynamic phenomenon in these surfaces. The main mechanic noise sources of wind turbines are such as:

– support bearing of the airscrew axle;
– transmission box;
– generator;
– cabin rotating mechanism;
– cooling ventilator;
– other equipment (oil pumps, cooling devices compressors, serving motors, wind speed gauge, etc.).

Aerodynamic noise. Aerodynamic noise is divided into three main groups:

– low frequency noise;
– turbulent vertical noise;
– aerodynamic surfaces (profiles of blades) noise.

Low frequency noise is formed when airscrew blade is crossing different air speed streams and the latter appears near the tower (in a vertical plane). Air stream in this plane is driven by the wind and after reverberation to the tower air stream moving speed changes.

Turbulent vertical noise. When a solid body structure (in our case the airscrew blades) faces air turbulation streams, wide band noise named turbulent noise occurs. The level of this noise, which is heard by people like a wheeze, and spectric composition depend on airscrew blades' construction .The noise caused by rotating blade's edge and in this way "cutting" airstreams is called *own noise created by aerodynamic surface* (Wei 2005). It is formed when chaotically moving airstream is mixing because of the moving blade. Parameters of this noise depend on airstream speed, blade's profile, attack angle and blade's surface properties (especially smoothness). Spectrum of aerodynamic surface own noise is wide banded.

Measuring methodology. For measuring air turbine‘s noise any general noise making source measuring methodology can be used. So it can also be applied for measuring and investigating of any other noise making equipment sources. The methodology correspond with the hygiene standard HN 33-1:2003 (HN 33-1:2003), of the Republic of Lithuania Metrology Law (Žin. 1996, No. 74-1768) and the European Union legal requirements.

Air turbine's noise has to be measured when the wind speed is not less than 6–8 m/s. During the measurement microphone has to be covered by a special protecting screen and turned to the noise source, i.e. to the wind turbine. It is forbidden to carry out measurements during the rain, snow or fog. The measuring device microphone has to be at the height of 1,2–1,5 m from the ground level.

Besides, a frequency charcteristics filter must be used for the measurings, because wind turbine's made noise intensity is small (< 80 dB) and the filter sensitivity dependence is higher for small intensity noises than C characteristics filter.

Investigated object. The only active industrial wind turbine in Lithuania, of 630 kW power, was chosen for the investigation. The vicinity is a small town Vydmantai. The plant is equipped with rather up-to-date turbine produced by a German company "Enercon GmbH", which makes a very popular wind power plant E-40. There are more than 3500 wind turbines of this type in the world. General view of the wind turbine is showed in Fig. 2.

It's short characteristic is presented in Table 1.

A precision analyzer 2260, produced by a Danish company Bruel & Kjaer, has been used for noise measuring (Environmental Engineering 2005).

Fig. 2. Investigated wind turbine in Vydmantai

Table 1. Short characteristics of the investigated wind turbine (Nevardauskas 2005)

Tower height	76 m	Cabin mass	30 t
Windscrew axle equipment height	78 m	Minimum air speed	2,5–3,0 m/s
Airscrew diameter	43,3 m	Nominal power wind speed	11,5 m/s
Blade length	20,5 m	Maximum wind speed (electric resistance)	25 m/s
Maximum object height	99,5 m	Maximum wind speed as for the building (mechanical resistance)	52,5 m/s
Airscrew touched area	1472,5 m^2	Single blade's weight	1,1 t.
Airscrew rotation speed	18–34,5 turns per min.	Linear speed of blades' end flight	41,0–78,6 m/s

Wind turbine plant's noise measuring course. During the measurement of the wind power plant's noise, orientation of the airscrew was taken into accont, mainly direction "opposite the wind", "before the wind", "in one plane with airscrew", and etc. It was done so, because the noise level depends on the observer's position with respect to the airscrew, which is always oriented to the wind.

Noise level was measured in selected distances – 25 m, 50 m, 160 m and 200 m from the tower. The directions were chosen every 45 degrees starting at the wind tower basis, i.e. opposite the wind (opposite the tower), before the wind (behind the turbine's power), from the left and from the right side with respect to the tower. Noise was measured in 36 points totally. 10 minute time was allotted for every point.

Measuring the environment and conditions. The wind turbine has been built not far from Palanga roundabout near a small city Vydmantai. There is a small forest nearby. This is why strong winds are always blowing in the territory. Vydmantai is rather far from a possible acoustic noise zone boundary.

It was sunny during the investigation and a medium strength wind was blowing. According to the data of Hydrometeorologic Service for the day of the examination, wind speed was 5,1 m/s (average) and 9 m/s (maximum) at the height of 10,5 m. At the height of the wind turbine's shaft (78 m) the wind blowing speed was 7–12 m/s.

4. Results and analysis of investigation

During the investigation of noise, produced by the wind power plant in Vydmantai, such parameters were measured:

1. Average equivalent noise level L_{Aeq} which is usually expressed in decibels (dB).
2. Minimum and maximum noise levels- L_{ASmin} and L_{ASmaks} and their difference ΔL.

Moreover, a special programmining equipment 2260 inside the noise analyser allowed to measure such parameters:

– average equivalent noise level distribution;
– spectric noise composition which is calculated by rapid Furye transformation.

Measuring results in the main directions are presented in Table 2.

Table 2. Wind power plant's average equivalent noise level L_{Aeq} measuring results

Measuring points	Wind turbine is average equivalent noise level L_{Aeq}, dB				
Distance from the wind turbine, m	**0**	**25**	**50**	**100**	**200**
N (opposite the turbine's tower)	54,9	52,4	54,1	51,8	48,2
NE	-----	57,5	59,4	53,3	55,8
E (from the right side)	43,2	46,6	47,4	46,2	40,4
SE	-----	51,1	52,5	50,5	47,2
S (before the turbine's tower)	49,8	52,8	53,7	52,3	48,3
SW	----	51,5	52,3	50,1	48,5
W (from the left side)	42,7	49,5	47,6	46,4	43,3
NW	----	53,9	54,3	52,2	47,9

Foreign scientists investigation conclusions (Fig. 3) have been confirmed by the investigation results in Vydmantai (Fig. 4).

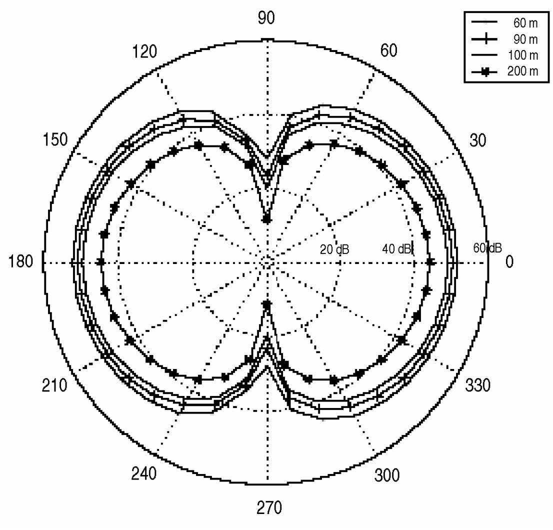


Fig. 3. Noise pressure level in different points in respect to the observer

It has been established that noise pressure level differs when observer's position is changing- when noise wave spreading direction is changed (Fig. 4). The receiver around the wind power plant, the center of which was a wind turbine, was moving in circles, and the circle rays changes were from 60 to 200 m. Wind blowing direction was from 180 to 0 degrees. The examination results showed that noise spreading depends on wind turbine's rotary position in respect with the receiver and purposefulness diagram resembles bipolar noise source purposefulness diagram. Taking this into account it becomes clear, that the nearest dwelling-houses location in respect to the wind turbine is the best when we draw in noise source purposefulness diagram tangentic lines (tangents). Therefore, it is necessary to evaluate exact direction of the wind and its impact on the noise purposefulness diagram.

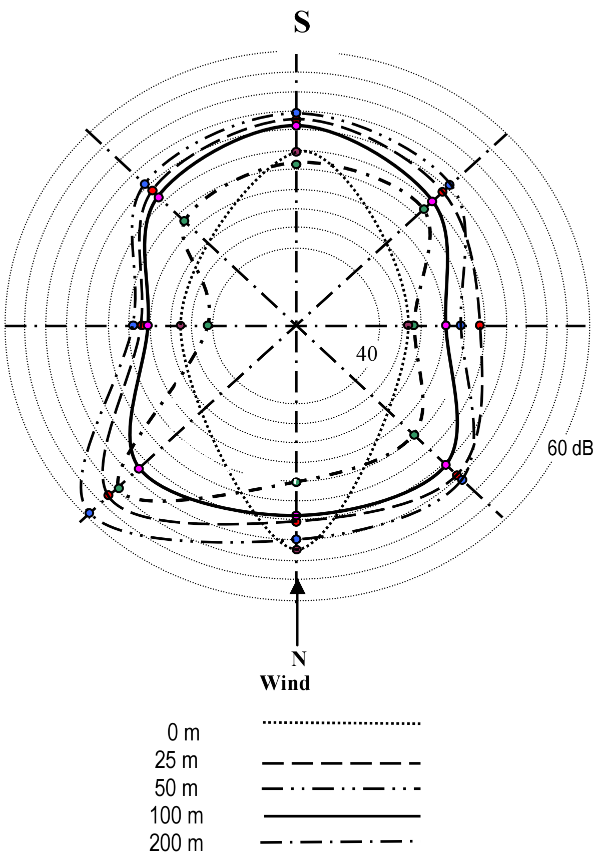
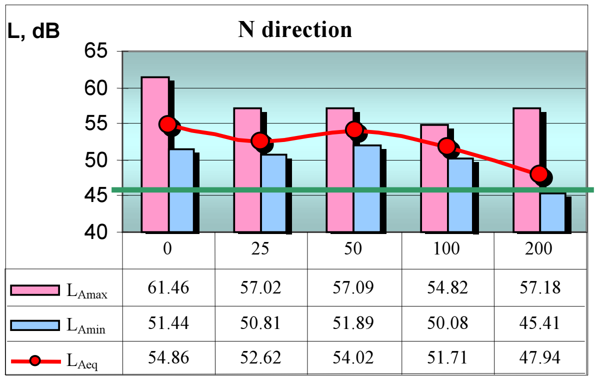


Fig. 4. Noise level dependence on measuring point's location in respect to the wind power plant's orientation

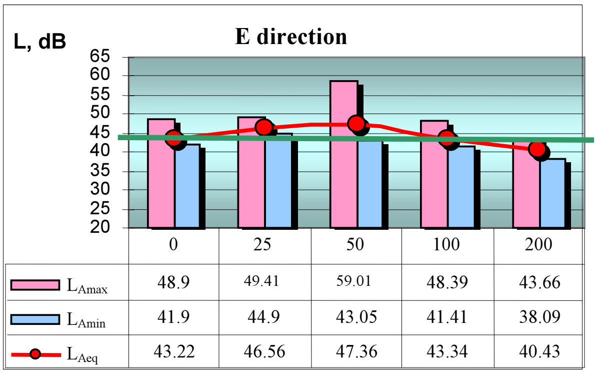
According to the wind turbine noise examining preliminar recommendations of the United Kingdom Economy and Industry Department, wind turbine's noise level has to maintain on average 5 decibels (A) difference level between evening and night time noise levels. Practically a lot of noise sources comply with these standards, except for the noise caused by transportation and building of the wind turbine, but these bigger noises usually are allowed, furthermore they are temporary. The lower noise level limit can be fixed between 35–40 dB (A).

Carrying out the measurements maximum wind turbines caused noise level was fixed L_{max} = 70,5 dB,on the other hand minimum fixed noise level during measuring time was equal to L_{min} = 38,1 dB.

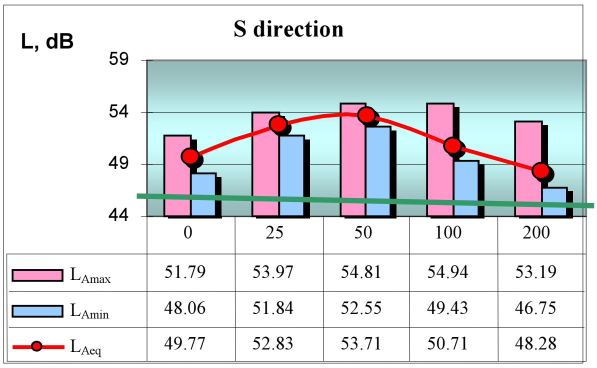
During the analysis of the measured results it was noticed, that noise level caused by the wind power plant depends on the distance from noise sources. Maximum noise level was registered when a measuring device was 25–50 m away from the wind turbine basis (Fig. 5 a, b, c, d).



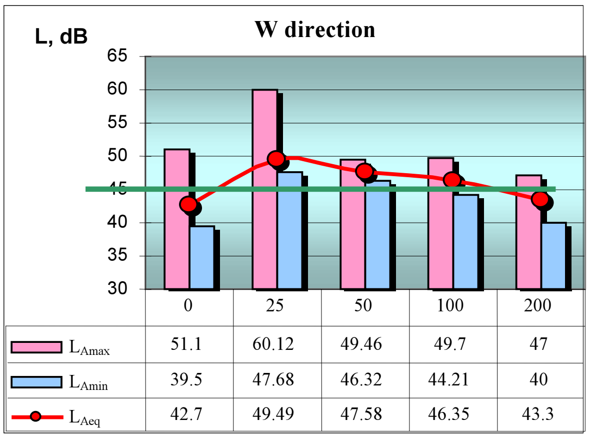
a – Opposite the wind power plant's tower



b – From the left side



c – Before the wind power plant tower



d – From the right side

Fig. 5. Wind turbine's caused noise level dependance on the distance from the noise source (allowed noise level 45 dB)

Analysing the wind turbine's noise spectric composition in 8 directions it was established, that two spectric components come to light near the wind turbine – low frequency (80–250 Hz) and high frequency (500–2000 Hz). Further from the wind turbine (1 > h) only high frequency noises ("wind wheese") remain. Attention must be paid to the spectric band of 500–2000 Hz which is clearly audible by people. However, no obvious dependence on any direction was observed. Therefore, an immediate conclusion can be made – that measuring noise spectric composition in any direction from the wind turbine, the results will be analogous.

Analysing the inconsistency of results some tendencies were observed. The biggest inconsistencies were noticed measuring the noise opposite the wind turbine's tower. The scattering was caused by the wind speed changes (gusty wind). The direction, which is opposite to screw orientation to the wind, distinguishes absolutely smallest discrepancy of the measured results. All in all two major causes were brought to light by the investigation:

1. The tower has influence on air stream movement, wind speed beyond the tower and air stream turbulent activity.

2. The tower is acting as a screen and decreases (obstructs) the noise formed before the tower. Therefore, the noise spreading is influenced by the air stream cutting with the wind screw. The noise is dispersed and only partially heard.

The noise spreading and the results are also influenced by other factors. Popular literature sources show that the terrain has a great impact on the noise level (Oškinis *et al.* 2004).

It is necessary to notice that the increased acoustic level is one of the most fundamental wind power plant factors having an environmental impact and raising concerns of the permanent residents of Vydmantai. According to the valid hygiene standard HN 33-1:2003 Acoustic noise. Allowed levels in dwelling and industrial environment. General requirements of measuring methodology, the highest wind power plant average equivalent noise magnitude is 45 dB in a residential area, and in recreative zones the highest level must not exceed 40 dB. As one can see from the received results (Table 2 and Fig. 5 a, b, c, d) in most cases this figure has been exceeded. However, this overfulfilment is best of all observed in radius of 25–50 metres around the wind turbine. Moving away from the wind turbine, the noise level noticeably decreases, however the standard (40–45 dB) is only reached in 200 metres from the turbine (Fig. 4). These figures can not be considered as final, because every turbine's acoustic indicators are summed up but another rules are valid for addition.

It has been proved that Lithuanian seaside is the most suitable place to develop wind energy. The fact, that it is a health resort, demands exceptional attention solving wind energy suitability for Lithuania.

To sum it all up it must be said, that science and advanced tecnologies, used in this area, can significantly decrease the impact of noise on the environment. A new wind power plant with vertical axle windscrew has already been made. Because of the up-to-date mechanisms, it does not rise sound noise (noise does not exceed background noise level) (Adomavičius, Balčiūnas 2003).

5. Conclusions

1. The main inconsistence of the measument results was caused by the changing wind speed which during the measuring changed from 6 to 9 m/s.

2. The measured results scattering is proportional to the wind speed changing magnitude, i. e. the higher wind speed changing amplitude is, the higher measuring meaning's scattering is.

3. The wind power plant can be kept as a purposeful noise source which purposefulness coefficient D is 9,1 dB. The biggest noise level was observed standing opposite the airscrew. The lowest noise level was observed in both directions from the tower in the plane of the windscrew.

4. In the zone of Vydmantai wind power plant, which power is 630 kW and height is 76 meters, noise level is noticeably higher compared to the background noise. Hovewer, noise level in this zone does not exceed 250–300m, i. e. about 5–6 windscrew diameters.

5. Wind speed in the direction behind the wind turbine's tower is minimal because the tower obstructs the airstream movement. Therefore, turbulence is the lowest here.

6. The tower acting as a screen (obstructor) decreases formation of the noise which is still formed in front of the tower when the airscrew is "cutting" air stream flow.

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VYDMANTŲ VĖJO JĖGAINĖS KELIAMO TRIUKŠMO TYRIMAI IR ĮVERTINIMAS

B. Jaskelevičius, N. Užpelkienė

Santrauka

Mažėjančios akmens anglies, naftos ir dujų atsargos elektros gamyboje verčia naudoti kitus energijos šaltinius, tokius kaip atsinaujinantieji energijos šaltiniai, kurie gali sumažinti aplinkos žalojimą, atmosferos teršimą, šiltnamio efektą. Remiantis Europos Sąjungos Parlamento ir Tarybos 2001 07 27 direktyva 2001/77/EB šalys narės (nuo 2004 05 01 ir Lietuva) turi siekti, kad 2010 m. atsinaujinančiųjų energijos išteklių dalis bendrame energijos balanse sudarytų ne mažiau kaip 12 %, o šalies elektros balanse 22,1 % (su didelėmis hidroelektrinėmis). Tai dideli skaičiai. Šis padidėjimas galimas visų pirma pasitelkus vėjo energetiką. Šiuo metu pastebėta, kad vėjo energetika susilaukia visuomenės pasipriešinimo. Vienas iš pagrindinių motyvų – šių jėgainių keliamas triukšmas. Atsižvelgiant į tai, kad vėjo jėgainių statybai Lietuvos pajūris yra palankiausia vieta, kur yra daug smulkių gyvenviečių ir poilsiaviečių zonų, šiam vėjo jėgainių poveikiui ištirti reikėjo papildomų išsamių tyrimų. Šie tyrimai buvo atlikti Vydmantuose (Klaipėdos rajonas) prie veikiančios pramoninės vėjo jėgainės. Tyrimais nustatyta, kad didžiausias triukšmo lygis buvo registruotas priešais vėjaratį. Mažiausias triukšmo lygis buvo išmatuotas į abi puses nuo bokšto vėjaračio plokštumoje. Vydmantų vėjo jėgainės zona, kurioje triukšmų lygis yra didesnis nei foninis, neviršija 250–300 m (5–6 vėjaračio skersmenys).

Reikšminiai žodžiai: vėjo energetika, vėjo jėgainė, vėjo jėgainių keliamas triukšmas, vėjaračio orientacija, triukšmo lygis.

ИССЛЕДОВАНИЕ И ОЦЕНКА ШУМА ВИДМАНТАЙСКОЙ ВЕТРЯНОЙ ЭНЕРГОУСТАНОВКИ

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Резюме

Уменьшающиеся запасы каменного угля, нефти и газа способствуют применению альтернативных источников энергии для её получения, например, возобновляемых источников энергии, которые могут уменьшить наносимый окружающей среде вред, а также снизить уровень загрязнения атмосферы и тепличный эффект. Руководствуясь директивой Европейского Союза 2001/77/ЕС, страны, входящие в его состав (с 01-05-2004 и Литва), должны стремиться к тому, чтобы к 2010 г. часть электроэнергии, получаемой из возобновляемых источников энергии, составляла не менее 12 % в общем энергетическом балансе и 22,1 % (включая крупные гидроэлектростанции) в энергетическом балансе страны. Это большие цифры. Их достижение возможно прежде всего благодаря использованию энергии ветра. Однако в настоящее время ветроэнергетика вызвала недовольство общественности. Одним из основных мотивов недовольства является шум, распространяемый ветряными электростанциями. В Литве наиболее приемлемым местом для строительства ветрогенераторов является приморье, где находится много мелких населённых пунктов, а также зон туризма и отдыха, поэтому фактор общественного недовольства требует серьёзных всесторонних исследований. С этой целью исследовался шум, распространяемый ветряной электроустановкой, находящейся в городе Видмантай (Кретингский р-он). Результаты исследования показали, что наибольший уровень шума наблюдался перед ветровиком, а наименьший – по обе стороны от башни установки в плоскости ветровика. Зона, в которой уровень шума выше фонового, не превышает 250–300 м (5–6 диаметров ветровика).

Ключевые слова: энергетика ветра, ветряная энергоустановка, ориентация ветровика, уровень шума.

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