24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

WORKPLACES IN WIND FARMS AND IN THEIR VICINITY – RECOMMENDATIONS FOR WIND TURBINE NOISE REDUCTION

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Development of wind energy should take into account requirements resulting not only from environmental protection, but also resulting from labour protection, related to occupational safety and health. This development is accompanied not only by an increase in the number of people employed in job positions associated with wind energy, but also by an increase in the number of people whose workplaces are located in the vicinity of wind farms. Thus, noise and infrasonic noise measurements at workplaces in three wind farms as well as in their vicinity were carried. The scope of the measurements at workplaces included the determination of the following parameters: the A-weighted sound pressure levels, the A-weighted maximum sound pressure levels, the C-weighted peak sound pressure levels and the G-weighted sound pressure levels. Besides, noise annoyance at workplaces was conducted by means of the questionnaire. The results of noise and infrasonic measurements and of surveys made it possible to lay down recommendations for wind turbine noise reduction at workplaces in wind farms.
Keywords: wind turbine noise, infrasonic noise, workplace

1. Introduction

The entry into force of the Act of 20 February 2015 on renewable sources of energy [1] implementing the Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources [2] results in an increase in investments in wind energy in Poland. That is because the share of renewable energy in final energy consumption in Poland must reach 15 % in 2020.

According to the latest data of the Polish Energy Regulatory Office [3] over the last 11 years, the installed capacity for renewable energy sources has increased from 115.537 MW in 2005 to 8 241.479 MW in 2016 and the biggest share have wind farms: installed capacity was 5 660.070 MW in 2016, while in 2005 it was only 83.280 MW. Published by that Office data on wind energy show that, in April 2016, there were 1039 installations (wind turbines) in Poland. In 2020, according to the government plans, the wind farms' capacity should be 6 650 MW [4].

According to [5] in January 2017 the list of Polish wind farms included 40 industrial wind farms with a capacity of more than 5 MW each, while the number of wind turbines in these 40 wind farms industrial varied from 2 to 60 and the highest rated power was 120 MW in the case of the wind farm in Margoninie located in Greater Poland Voivodeship (central-west part of Poland).

According to [6] at the stage of exploitation of wind farms their impact on the environment is seen inter alia through their impact on the acoustic climate of the environment, electromagnetic climate of the environment, avifauna, chiropteran fauna and on the landscape. At the same time, the noise, the infrasounds and the optical effects (the effect of shadow flicker) are the most frequently cited in the literature factors which may affect the health of people living in the vicinity of wind power plants [7].

The aim of the project was to carry out studies (tests) on assessment of exposure to noise and on assessment of infrasonic noise annoyance at workplaces in wind farms and workplaces located in the vicinity of the wind farms (i.e. within a distance of 3 km). Below the obtained results in these studies and general recommendations for wind turbine noise exposure reduction at workplaces in wind farms are described.

2. Test results

A methodology has been developed, which includes:

- environmental tests, that is to say direct measurements of noise and infrasonic noise at the workplaces,
- surveys (using the direct interview technique), i.e. surveys on working conditions and the subjective assessment of noise exposure at workplaces in wind farms and at workplaces located in the vicinity of the wind turbines.

Noise tests were carried out in wind farms on which the wind turbines of the three most popular in Poland manufacturers were installed: Vestas, General Electric (GE) and ENERCON. The tested items were the workplaces for the personnel involved in servicing wind turbines GE 2.5 MW, ENERCON E70-E4 and VESTAS V80 (2.0 MW). The test results, amongst other things, demonstrated that the noise levels and the infrasonic noise levels at the workplaces for servicing these wind turbines did not exceed respectively:

- the admissible values of quantities of noise (maximum allowable intensities (MAI) for noise) determined in the Polish Regulation of the Minister of Labour and Social Policy [8],
- the annoyance criteria for infrasonic noise defined in the Polish Standard PN-Z-01338 [9].

The determined daily noise exposure levels (or the weekly noise exposure levels) were between 74.6 dB and 83.9 dB, i.e. smaller than the value of MAI for noise which stand at 85 dB. However, it was found that during the performance of maintenance there are activities which were characterised by the equivalent A-weighted sound pressure levels with values close to 102 dB.

The determined G-weighted sound pressure levels (normalised to the nominal 8-hour working day or to the 40-hour average weekly working time) ranged from 91 dB to 92.5 dB and were smaller than the value of annoyance criterion for infrasonic noise which stand at 102 dB.

Examples of the results of the noise and infrasonic noise tests for the wind turbines GE 2.5 MW are summarised in Table 1 and Table 2.

Table 1: Noise exposure at workplaces in the wind farm with wind turbines GE 2.5 MW

Noise exposure level normalised to the nominal 8-hour working day, $L_{EX,8h}$ [dB]	A-weighted maximum sound pressure level, L_{Amax} [dB]	C-weighted peak sound pressure level, L_{Cpeak} [dB]
83,9	**103,2**	**117,3**

Table 2: Infrasonic noise exposure at workplaces in the wind farm with wind turbines GE 2.5 MW

G-weighted equivalent sound pressure level normalised to the nominal 8-hour working day, $L_{Geq,8h}$ [dB]
91,0

In turn, the results of the measurements carried out at workstations located at distances up to 3 km from the wind turbines showed that noise and infrasonic noise emitted by the wind turbine Vestas V80-2.0 MW, GE 2.5 MW and ENERCON E70-E4 did not exceed the values of MAI for noise and the values of the annoyance criteria for infrasonic noise. The values of the equivalent A-weighted

sound pressure levels were between 29.9 dB and 52 dB, and the values of the equivalent G-weighted sound pressure levels were between 48.4 dB and 79.4 dB.

Surveys have been carried out on 20 wind farms. The studies involved 50 workers in wind farms and 273 other workers (including farmers, teachers and persons involved in service activities and commerce) employed at a distance of up to 3 km from the wind farms.

The key question which formed the basis for the detailed analysis necessary to determine the regression and the correlation between subjective risk assessments of wind turbine noise, its determinants and felt hazards, was to identify wind turbine noise annoyance. Any respondent made a subjective assessment of wind turbine noise in accordance with a scale from 0 to 10, where the lower values mean that the noise is not too burdensome and higher values mean that the noise is very burdensome (Fig. 1).

The vast majority of participants assessed the noise annoyance as low. 73.7 % of the respondents gave the assessments from 0 to 3, including 38.7 % of the respondents gave the assessment of 1, 15.8 % of the respondents gave the assessment of 2, 13.6 % of the respondents gave the assessment of 3 and 5.6 % of the respondents gave the assessment of 0.

17.0% of the respondents assessed the wind turbine noise annoyance as average - from 4 to 6. 8.4 % of the respondents gave the assessment of 4, 5.0 % of the respondents gave the assessment of 5 and 3.7 % of the respondents gave the assessment of 6.

In contrast 9.3 % of the respondents assessed the wind turbine noise annoyance as highly annoyed, including 3.1 % gave the assessment of 8, 2.8 % gave the assessment of 7, 2.8 % gave the assessment of 9, while 0.6 % gave the highest score of 10. Average score of wind turbine noise annoyance on a scale from 0 to 10 was 2.67 and therefore the annoyance was low.

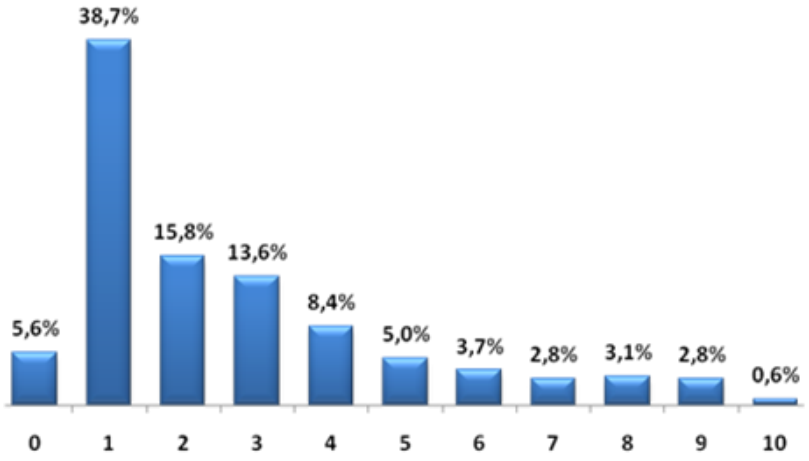

Figure 1: Wind turbine noise annoyance

The results of the statistical analysis and the examination of the relationships between objective and subjective factors that influence the wind turbine noise annoyance have shown that the assessment of wind turbine noise annoyance conditioned on:

- type of job: wind farm workers assessed higher the noise annoyance than persons performing other work,
- working conditions: persons with an average working conditions assessed the noise annoyance higher than persons with good working conditions,
- length of working time in the vicinity of the turbines: the longer working time, the noise annoyance was assessed as higher,
- distance from wind farms: the highest noise annoyance was assessed by persons not employed at wind farms, but working in their close vicinity - up to 500 metres,
- the state of health: noise was more annoyance for persons who determined their health as very good.

3. Reduction of noise at workplaces in wind farms

In order to fulfil the requirements of the European Directive 2003/10/EC [10] and the Polish Regulation of the Minister of Economy and Labour [11] where noise exposure levels exceed 80 dB, wind farm workers should be provided with hearing protectors. Moreover the workers should wear the hearing protectors where noise exposure levels exceed 85 dB. The hearing protectors should be appropriate selected to the noise spectrum (in accordance with the European Standard EN 458: 2016 [12]).

This selection is based on an estimate of the expected sound pressure levels under the hearing protector. This estimate is based on the acoustic parameters of the hearing protectors (such as sound attenuation and *H, M, L* and the signal-to-noise ratio), as well as the results of the noise measurements at the workplace. The method of selection depends on the type of noise: steady, variable or impulse. Unpleasant feeling of acoustic insulation cause the hearing protectors, which reduces the A-weighted sound pressure level under the protector to the level smaller than 65 dB. The hearing protectors are correctly matched to the noise level where the value of the A-weighted sound pressure level under the protector is in the range from 70 to 80 dB. Moreover, the A-weighted sound pressure level under the protector shall not be smaller than 70 dB due to the possible reception of useful sounds [13].

It should also be pointed out that the conditions determining the effectiveness of the well selected hearing protectors are:

- using the hearing protectors at all times when the worker is in the presence of noise. Interruption in the use of the hearing protectors may significantly reduce the degree of protection, which may be the cause hearing loss,
- correct wearing of the hearing protectors. Particular attention should be paid to the correct affixing earplugs. The worker should receive a training relating to the correct use of the hearing protectors.
- taking into account that the use of the hearing protectors together with other personal protective equipment (e.g. spectacles, protective helmets, respiratory protective equipment) may lead to a reduction of the effectiveness of the hearing protectors,
- regular monitoring of the condition of the hearing protectors. Damaged or worn out elements should be replaced by new ones. Even small deformations of cushions may cause a deterioration of their protective properties.

Due to the character of the work and the values of the sound pressure levels at the workplaces in wind farms, it is recommended to use:

- lightweight hearing protectors (possibly attached to the industrial protective helmet), or
- tri-flange earplugs or banded earplugs.

Workers should also be subjected to medical screening tests. Medical prevention covers initial and periodic medical examinations [14]. Medical examinations are aimed at eliminating the exposure to noise at work of persons whose state of health deviates from the norm since, as a result of the exposure to noise it may be substantially worsened. On the basis of the results of this analysis it will also be possible to identify early signs of hearing loss arising under the influence of noise exposure and to avoid aggravation of the disease.

4. Conclusions

It has appeared from the conducted studies that workers operating in wind farms belong to the group of the people who are the most exposed to noise from wind turbines. Although the measured values of the daily noise exposure levels (or the weekly noise exposure levels) does not exceed the values of MAI for noise, but the equivalent A-weighted sound pressure levels measured during certain operations (e.g. diagnostic work in the nacelle) can achieve a significant value (80-102 dB) and may therefore constitute a risk to hearing.

Additional factors in the risk of hearing damage at the workplaces of the workers in wind farm turbines can be chemicals and oils, which as a result of a combined action with noise can pose an extra risks to hearing. Exposure to these factors should be also assessed at the workplaces in wind farms.

5. ACKNOWLEDGEMENTS

The authors wish to thank Dr Danuta Augustyńska for cooperation on drawing up guidelines.

This paper has been based on the results of a research task carried out within the scope of the third stage of the National Programme "Improvement of safety and working conditions" partly supported in 2014–2016 – within the scope of research and development – by the Ministry of Science and Higher Education/National Centre for Research and Development**.** The Central Institute for Labour Protection – National Research Institute was the Programme's main co-ordinator.

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