8th International Conference
on
Wind Turbine Noise
Lisbon – 12th to 14th June 2019

Current regulations for the protection against noise from wind turbines in Germany

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Summary

The wind energy sector is growing steadily in Germany. With 29213 wind turbines and an installed capacity of around 52931 MW [1], Germany ranks first in Europe. For a successful realization of the transformation of the energy system it is necessary to increase the acceptance of wind turbines in the neighborhood. The basis for the approval of wind turbines in Germany is the German Federal Immission Control Act. According to this act installations subject to licensing shall be established and operated in such a way that this does not involve harmful effects on the environment. This requirement is specified in the "Technical Instructions on Noise Abatement, TI Noise" which contain noise immission values. The total noise exposure at a decisive immission point may not exceed these values. An important part of the noise assessment of wind turbines is a prediction of the noise immission. For this purpose, the TI Noise as well as the recommendations for the protection against noise exposure from wind turbines of the federal states are used in Germany. These recommendations have been fundamentally revised under consideration of the current state of knowledge in 2017. The procedure for the protection against noise from wind turbines in Germany will be explained in detail.

1. Introduction

Wind turbines are of great importance to meet the demand for electricity with renewable sources of energy. Therefore a successful realization of the transformation of the energy system in Germany is essential.

In Germany, wind turbines with a height of more than 50 m, are subject to licensing pursuant to the German Federal Immission Control Act [2]. Principally, installations subject to licensing shall be established and operated in such a way that this does not involve harmful effects on the environment or other hazards, considerable disadvantages and considerable nuisance to the general public and neighborhood. Moreover, precautions should be taken to prevent harmful effects on the environment. Within the scope of the licensing process not only environmental aspects are taken into account but also all other legal aspects in connection with the construction of a new wind turbine or the repowering of existing ones. For instance, building regulations as well as nature conservation requirements are also to be considered. One

important element of the licensing process deals with the protection against noise. The regulations are laid down in the Sixth General Administrative Provision to the Federal Immission Control Act, which is called “Technical Instructions on Noise Abatement, TI Noise” [3]. It is applied to various kinds of industrial plants as well as commercial installations. This wide range of applicability includes wind turbines. The regulations for wind turbines also comprise the “recommendations on the protection from noise of wind turbines” of the Federal States of Germany [4]

2. Determination of noise immissions

The determination of noise immissions of wind turbines is carried out according to the TI Noise and the additional “recommendations on the protection from noise of wind turbines” of the Federal States of Germany [4]. The main steps of the noise assessment procedure for wind turbines are shown in figure 1.

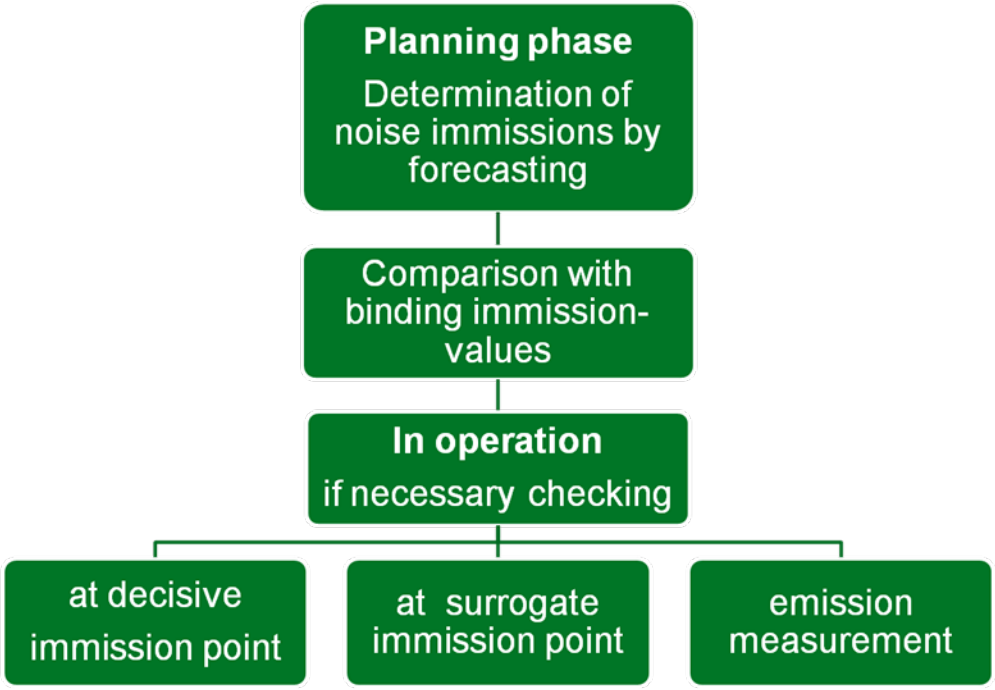

Fig.1: Noise assessment procedure according to TI Noise in Germany

The TI Noise contains criteria to identify and assess the noise immissions of installations subject to licensing, including wind turbines. The noise assessment procedure starts with the determination of noise immissions by forecasting.

3. Binding immission values according to TI Noise

For the approval of a wind turbine it is essential that the noise immission of the installation comply with binding immission values for points outside buildings which are defined in the TI Noise [3]. They depend on the type of land-use and are distinguished between daytime and nighttime. The immission values given are in table 1.

Table 1:
Binding immission values according to TI Noise in Germany

Types of areas	**Day** **6 a.m. - 10 p.m.**	**Night** **10 p.m. - 6 a.m.**
Industrial areas	70 dB(A)	70 dB(A)
Commercial zones	65 dB(A)	50 dB(A)
Urban areas	63 dB(A)	45 dB(A)
Core areas, village areas and mixed-use zones	60 dB(A)	45 dB(A)
General residential areas and small residential states areas	55 dB(A)	40 dB(A)
Purely residential areas	50 dB(A)	35 dB(A)
Spa areas, for hospitals and nursing homes	45 dB(A)	35 dB(A)

These types of areas correspond to the building areas, which are defined in a nationwide valid Federal Land Utilization Ordinance [5]. According to this ordinance, for example, purely residential areas are only used for living. In contrast to this, village areas may also contain agricultural and forestry holdings. Moreover, the further development of agricultural and forestry holdings is taken into consideration.

The binding immission values are applied during the day for an assessment period of 16 hours. The full hour with the highest rating level is the basis for nighttime assessment. The reason for this special regulation is that the protection against noise at night is very important because a sufficiently long period of undisturbed sleep is essential for mental and physical rest. Furthermore, the TI Noise contains regulations concerning short-term noise peaks. These peaks may exceed the values during the day by not more than 30 dB(A), and at night by not more than 20 dB(A).

The immission values displayed in table 1 must be met in order to obtain the license for the operation of a wind turbine. They refer to the forecast respectively measured rating level L_r ascertained at the immission point. In this context, it is generally assumed from the total exposure at the decisive immission point. This is the point in the area of influence of the installation at which binding immission values are most likely to be exceeded. The decisive immission points are defined as follows:

- In buildings, 0.5 m outside the middle of the open window of the room which is worst affected by noise.
- In undeveloped or built-up areas that contain no buildings with noise sensitive rooms, at the edge of the area where buildings with noise sensitive rooms may be built.

4. Examination of the sound propagation model

In the past the alternative method of DIN ISO 9613-2 [6] was used for the determination of the noise exposure caused by wind turbines. This standard is designed for sound sources with a height up to 30 m and a distance between source and immission point until 1000 m (Fig. 2).

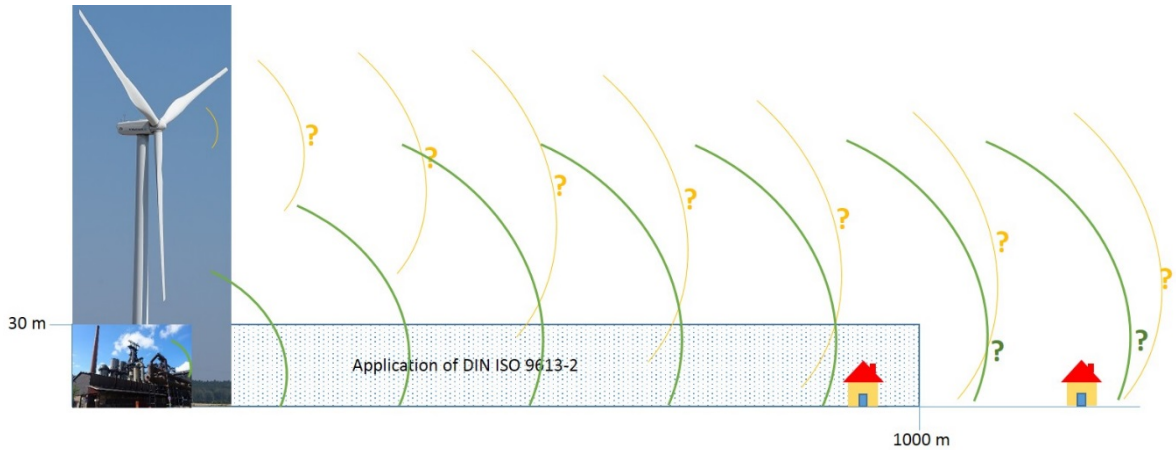

Fig. 2. Scope of DIN ISO 9613-2

Therefore, it is questionable whether DIN ISO 9613-2 is appropriate for calculating the sound propagation for modern wind turbines with a height of more than 100 m. For this reason, a research project [7] was conducted which was commissioned by the State Agency for Nature, Environment and Consumer Protection of the German Federal State of North Rhine-Westphalia. In this project, noise measurements have been carried out and compared with calculation results. This study has come to the result that up to 450 m from the wind turbine the calculation values are above the measured ones. For greater distances, the study shows contradictory results. With increasing distances from the wind turbine, the measurement results are higher than the calculation results. In view of these findings, the German organization for standardization DIN developed an interim method for the calculation of sound propagation at wind turbines [8]. This method considers the results of the above-mentioned research project and is based on a plain acoustic model. It describes the wind turbine as an omnidirectional point noise source which is frequency-dependent and located in the rotor center of the wind turbine. The input variable of the sound immission forecast is the specific octave band sound power level L_W of the wind turbine. For this purpose, the A-weighted third-octave band sound power levels $L_{WA,i}$ determined according to DIN EN 61400-11 [9] will be converted into the corresponding unweighted octave band sound power levels L_W. The equivalent continuous downwind sound power level L_{fT} is determined by the following equation [8]:

$$L_{fT}\,(\mathrm{DW}) = L_W + D_C - A \qquad (1)$$

where

L_W	octave-band sound power level produced by a wind turbine described as a point source [dB]
D_C	directivity correction [dB]
A	attenuation [dB]

with

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc} \qquad (2)$$

A_{div}	attenuation owing to geometrical divergence
A_{atm}	attenuation due to atmospheric absorption
A_{gr}	ground attenuation
A_{bar}	attenuation by a barrier
A_{misc}	attenuation caused by other effects

In equation (2), the attenuation due to the ground effect is set to -3 dB. This is based on the assumption that modern wind turbines with a height of above 100 m cause only one reflection from the ground. Furthermore, the meteorological correction in the equation for the determination of the long-term average A-weighted sound pressure level $L_{AT(LT)}$ is modified [8]:

$$L_{AT(LT)} = L_{AT(DW)} - C_{met} \quad (3)$$

where

$L_{AT(DW)}$ average A-weighted sound pressure level for downwind propagation

C_{met} meteorological correction, C_{met} = 0 dB

It is envisaged to replace the interims method by a new German guideline VDI 4101 part 2 [10] in the next years.

5. Recommendations on the protection from noise of wind turbines

In addition to the TI noise there exists “recommendations on the protection from noise of wind turbines” of the German Federal States [4]. They contain further details for the determination of the noise immissions of wind turbines and are also applied by the licensing authorities. In particular, the recommendations include the interim method for the calculation of sound propagation at wind turbines. Moreover, requirements on the input data and the quality of the noise prediction are described in detail. Additionally, some practical information for the licensing authorities are also given in these regulations.

5.1 Input parameter of the noise immission forecast

The input variable of the noise immission forecast for a specific wind turbine project is the specific sound power level of a wind turbine type in the corresponding operating mode. The input parameters are divided into two groups, namely parameters for the existing and the additional exposure.

Existing exposure is defined as the noise exposure at an immission point from all installations for which the TI Noise is applied, excluding immissions emanating from the installation under assessment. Consequently, all already approved wind turbines and other installations subject to the TI Noise are to be considered. Additional exposure is the immission that is anticipated with planned installations. The sum of both is the total exposure. According to German law [2] the protection against harmful effects on the environment due to noise is ensured, if the total exposure at the decisive immission point does not exceed the binding immission value shown in table 1.

For the determination of the input data there are three different options:

1. The sound power level is given by the manufacturer for normal operation. The appropriate octave spectrum is also provided.
2. Determination of the sound power level and the corresponding octave spectrum by measurements of the wind turbine type according to the Technical Guidelines for Wind Turbines Part 1[11] in combination with the German standard DIN EN 61400-11 [9].
3. Determination of the sound power level and the corresponding octave spectrum by measurements of at least minimum three wind turbines of the same type.

5.2 Determination of the noise prediction

The determination of noise immissions by forecasting is described in detail in the TI Noise and the “recommendations on the protection from noise of wind turbines”. These recommendations contain the interim method for the calculation of sound propagation at wind turbines [8]. This

procedure is carried out in a frequency-selective manner for the approval of wind turbines both for the existing wind turbines as a part of the existing exposure and for newly requested installations. For air absorption calculations, the atmospheric attenuation coefficient α according Table 2 of DIN ISO 9613-2 [6] shall be considered for 70 % relative humidity and 10 ^{0}C air temperature. To ensure that the legal requirements are met a quality assurance is carried out. Within the framework of this quality assurance it must be proved that under consideration of the uncertainty of the emission data as well as the uncertainty of the propagation calculation the upper limit of confidence level of the forecasted rating level is below the binding immission value. The upper limit of confidence level is calculated from the forecasted immission value plus the total uncertainty which results from the inaccuracy of the acoustic emission measurement and the fundamental uncertainty of the prediction model.

6. Consideration of low-frequency noise

The mechanisms of the sound generation and propagation of wind turbines are complex [12]. The noise emissions of a wind turbine consist of mechanically induced and aerodynamic noise components. The aerodynamic noise is often broadband and includes low-frequency and infrasonic components. For the determination and assessment of low-frequency noise, the German standard DIN 45680 “Measurement and assessment of low frequency noise immission” [13] and in the accompanying Supplement 1 are used [14]. The supplement contains reference values, which should not be exceeded. DIN 45680 contains an auditory threshold and the draft of DIN 45680 of 2013 [15] contains a hearing and perception threshold. These thresholds are illustrated in figure 3 together with the sound pressure levels of wind turbines with 2 to 3 MW in different distances. In the usual distances between wind turbines and residential dwellings in Germany, the infrasound emission generated by wind turbines is well below the threshold of human perception. This is confirmed by extensive noise immission measurements on wind turbines in the German Federal States of Baden-Wuerttemberg and Bavaria [16]. The impact of infrasound from wind turbines can be assumed to be very low in comparison with other natural and anthropogenic sources, so that according to the current state of research this does not have negative effects on health.

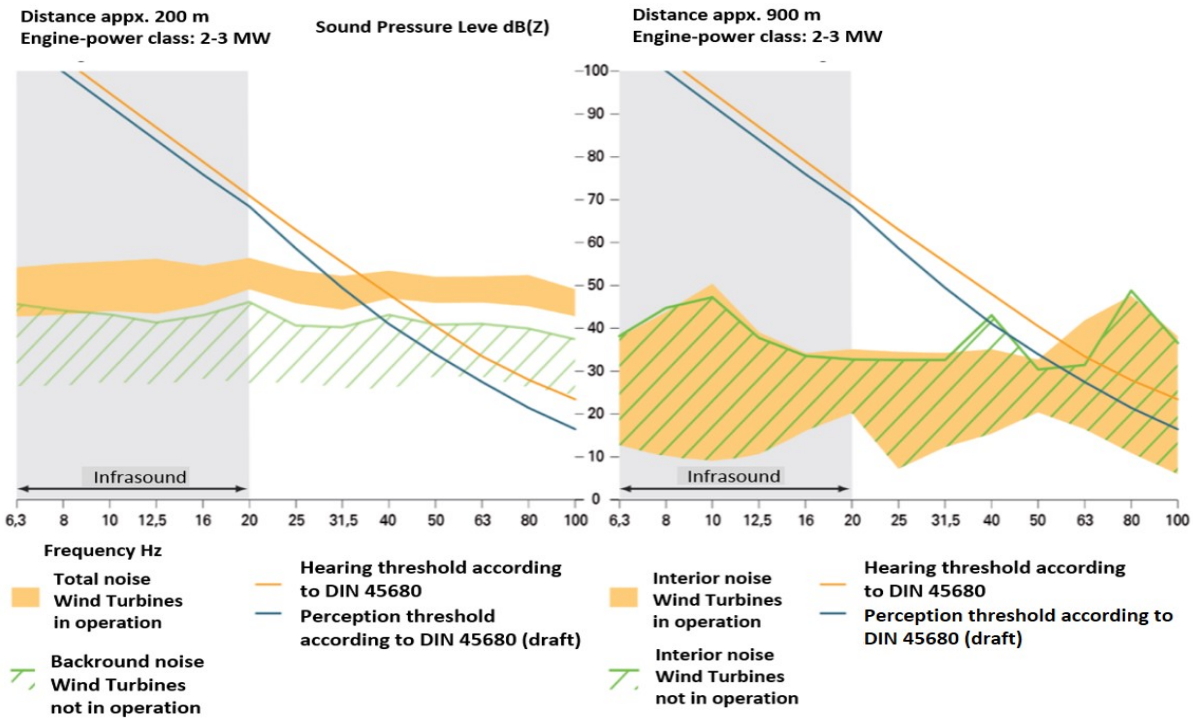

Fig. 3: Comparison of measurements results with hearing and perception thresholds. Measurements on modern wind turbines with a hub height of 140 m at wind speeds from 8 to 13 m/s, distance 200 m (left) and 900 m (right). [17] with own editing

7. Conclusions

The generation of energy by wind turbines is essential for the implementation of the energy transition. Especially in Germany, the number of these installations has continuously increased in the last years. Within this framework, the protection of the population from wind turbine noise has to be taken into consideration. Therefore, it is particularly important to have clear legal regulations for noise protection by wind turbines. The TI Noise especially contain area-related binding immission values for immission points outside buildings which may not exceeded during the operation of the wind turbine. In addition to the TI noise there exists “recommendations on the protection from noise of wind turbines” of the German Federal States.

References

1. Status of Land-based Wind Energy Development in Germany - Year 2018, Deutsche WindGuard GmbH, Varel (Germany) 2019, www.windguard.com
2. Bundes-Immissionsschutzgesetz (Federal Immission Control Act) in the version promulgated on 17 May 2013 (BGBl. I p. 1274) as last amended by Article 3 of the Act of 18 July 2017 (BGBl. I p. 2771)
3. Technische Anleitung zum Schutz gegen Lärm, TA Lärm (Technical Instructions on Noise Abatement - TI Noise), Sixth General Administrative Provision to the Federal Immission Control Act of 26 August 1998 (Joint Ministerial Gazette (GMBl.) No. 26/1998 p. 503), last amended on 1 June 2017 (BAnz AT 8 June 2017 B5)
4. Hinweise zum Schallimmissionsschutz bei Windenergieanlagen -WKA (Rekommandations on the protection from noise of wind turbines) Bund/Länder-Arbeitsgemeinschaft für Immissionsschutz (LAI), Germany 2016
5. Baunutzungsverordnung (Federal Land Utilization Ordinance) in the version promulgated on 21 November 2017 (BGBl. I p. 3786)
6. DIN ISO 9613-2: Akustik - Dämpfung des Schalls bei der Ausbreitung im Freien - Teil 2: Allgemeines Berechnungsverfahren (Acoustics - Attenuation of sound during propagation outdoors - part 2: General method of calculation), Berlin: Beuth-Verlag, October 1999
7. Engelen J., Wenzel P.: Schalltechnischer Bericht der erweiterten Hauptuntersuchung zur messtechnischen Ermittlung der Ausbreitungsbedingungen für die Geräusche von hohen Windenergieanlagen zur Nachtzeit und Vergleich der Messergebnisse mit Ausbreitungsberechnungen nach DIN ISO 9613-2 (Acoustic report on the expanded main investigation on measurements for the determination of sound propagation conditions of high wind turbines and comparsion with measurement results of sound propagation calculations according to DIN ISO 9613-2), Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen, Essen 2014
8. Dokumentation zur Schallausbreitung, Interimsverfahren zur Prognose der Geräuschimmissionen von Windkraftanlagen (Documentation on sound propagation, interim method for prediction of noise immission of wind turbines), Berlin: Beuth-Verlag, May 2015
9. DIN EN 61400-11; VDE 0127-11:2007-03, Windenergieanlagen - Teil 11: Schallmessverfahren (IEC 61400-11:2002 + A1:2006) (Wind turbines - part 11: Acoustic noise measurement techniques (IEC 61400-11:2012), Berlin: Beuth-Verlag, September 2013
10. VDI 4101-2: Schallausbreitung im Freien unter Berücksichtigung meteorologischer und topographischer Bedingungen, Blatt 2: Windkraftanlagen (Sound propagation outdoors

under consideration of meteorological and topographical conditions, part 2: wind turbines), ongoing project of the Association of German Engineers VDI
11. Technische Richtlinien für Windenergieanlagen - Teil 1: Bestimmung der Schallemissionswerte (Technical Guidelines for wind turbines, part 1: determination of noise emission), Fördergesellschaft Windenergie und andere Erneuerbare Energien [editor], Berlin
12. Leventhall G., Bowdler D.: Wind Turbine Noise: How it is produced, propagated, measured and received. Multi-Science Publishing, Brentwood (2011)
13. DIN 45680: Messung und Bewertung tieffrequenter Geräuschimmissionen in der Nachbarschaft (Measurement and assessment of low-frequency noise immissions in the neighborhood), Berlin: Beuth-Verlag, March 1997
14. DIN 45680, Beiblatt 1: Messung und Bewertung tieffrequenter Geräuschimmissionen in der Nachbarschaft (Measurement and assessment of low-frequency noise immissions in the neighborhood - Guidelines for the assessment for industrial plants) Berlin: Beuth-Verlag, March 1997
15. E DIN 45680 Entwurf: Messung und Bewertung tieffrequenter Geräuschimmissionen (Draft: Measurement and assessment of low-frequency noise immissions), Berlin: Beuth-Verlag, September 2013
16. Ratzel U., Bayer O., Brachat P., et al.: Tieffrequente Geräusche und Infraschall von Windkraftanlagen und anderen Quellen. Bericht über Ergebnisse des Messprojektes 2013-2015, Landesanstalt für Umwelt Baden-Württemberg (Low-frequency noise immissions including infrasound of wind turbines and other sources, report on the results of Measurement projects 2015-2015), LUBW, 2016
17. Windenergieanlagen - beeinträchtigt Infraschall die Gesundheit? (Does infrasound from wind turbines affects health?): Umwelt Wissen - Klima und Energie / Bavarian Environment Agency [editor] – 4th updated edition, Augsburg 2014, update: august 2016, Germany