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Noise Protection Regulations for Wind Turbines in Germany

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Summary
Many people are exposed to high levels of noise that adversely affect their health and quality of life. In order to prevent harmful effects on human beings and the environment, various industrial and commercial installations are subject to licensing in Germany. This includes wind turbines with a height of more than 50 m. The legal basis is the German Federal Immission Control Act and the "Technical Instructions on Noise Abatement, TA Noise". The TA Noise deals with the determination and the assessment of noise generated from industrial and commercial installations. Especially, it contains ambitious binding immission values for immission points outside buildings. The values depend on the type of land-use and are distinguished between daytime and night-time. For the protection against noise, the total noise exposure at the decisive immission point may not exceed the binding immission values.

1. Introduction
Wind turbines are of great importance to meet the demand for electricity with renewable sources of energy. In recent years, the number of wind turbines has continuously increased in Germany. In 2014, there are 24867 wind turbines with an installed wind power capacity of 38116 MW [1].

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 neighbourhood. 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, TA Noise” [3]. It is applied to various kinds of industrial plants as well as commercial operations. This wide range of applicability includes wind turbines. The TA Noise is therefore the most important instrument for the determination and assessment of noise from industrial plants and commercial operations in Germany.

2. Determination of noise immissions

The determination of noise immissions of wind turbines is carried out according to the the TA Noise and additional recommendations [4] of the federal states in Germany. The main steps of the noise assessment procedure for wind turbines are shown in figure 1.

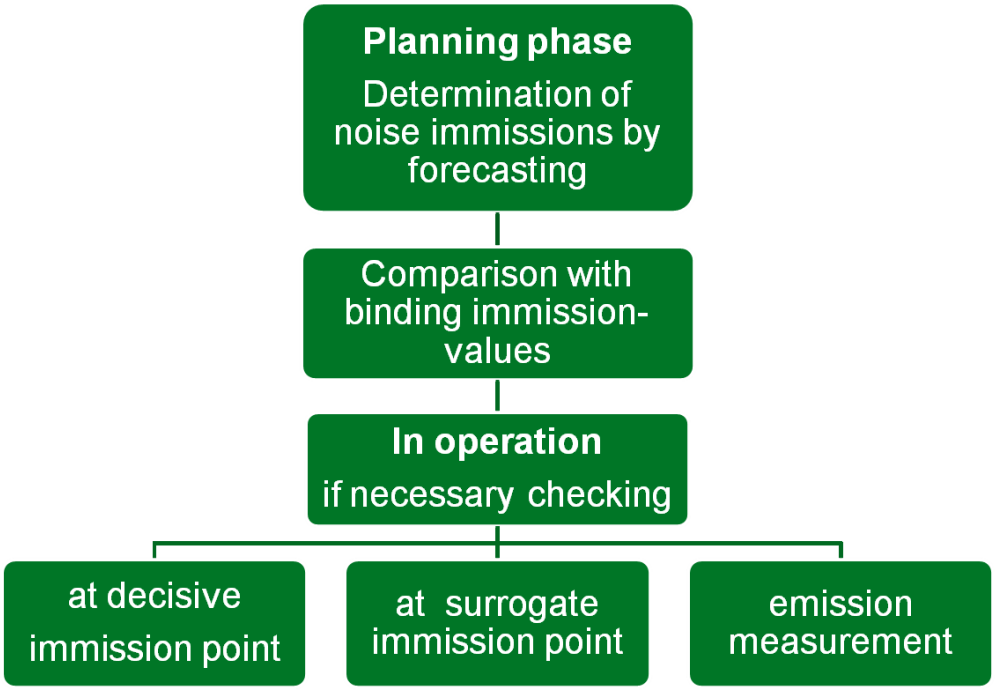

Fig. 1: Noise assessment procedure according to TA Noise

The TA 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. The calculation method is described in detail in the TA Noise. The noise emission of a wind turbine is made up of the sum of the sound power levels, the supplements for tonality, impulsiveness and a safety margin for the quality of the forecast. For these input data, measurement results as well as data from manufacturers can be used. If there are no data available, the determination of the emission values of a wind turbine is carried out in accordance with the Technical Guideline for Wind Turbines Part 1 [5] and the German standard DIN EN 61400-11 [6].

The determination of the noise immissions of wind turbine is based on the operation mode that produces the highest rating level L_r .In this context, supplements for

tonality and impulsiveness may be applied. The supplement for tonality K_T is determined from the supplement for tonality K_{TN} measured in the near-field of the wind turbine:

$0 \leq K_{TN} \leq 2$ supplement K_T: 0 dB
$2 < K_{TN} \leq 4$ supplement K_T: 3 dB
$K_{TN} > 4$ supplement K_T: 6 dB

The impulsiveness K_{IN} which is determined in the near-field leads to the following supplements for impulsiveness K_I:

$0 \leq K_{IN} < 2$ dB supplement K_I: 0 dB
$2 \leq K_{IN} < 4$ dB supplement K_I: 3 dB
$4 \leq K_{IN}$ supplement K_I: 6 dB

For the calculation of sound propagation, the alternative method of DIN ISO 9613-2 [7] is used.

The result of the noise calculation is a rating level L_r of the total noise exposure at the decisive immission point. The rating level will be compared with binding immission values for points outside buildings which may not be exceeded. To ensure that this requirement is met a quality assurance is carried out. Within the framework of this quality assurance it has to 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.

If no emission values of at least three wind turbines are available, then an uncertainty supplement of 2 dB is applied.

For the calculation of existing noise immissions of old wind turbines a supplement of 3 dB is applied if the emission data are only determined at a wind speed of 8 m/s in a height of 10 m

During the operation of the wind turbine, an additional noise measurement may be conducted in order to check that the calculated results comply with binding immission values. The method for this task is described in the German standard DIN EN 61400-11 [6], which is based on IEC 61400-11 [8].

3. Binding immission values according to TA Noise

An essential part of the TA Noise is binding immission values for points outside buildings. These values depend on the type of land-use and are distinguished between daytime and night-time. They are given in table 1.

Types of areas	Day 6 p.m. - 10 a.m.	Night 10 a.m. - 6 p.m.
industrial areas	70 dB(A)	70 dB(A)
commercial zones	65 dB(A)	50 dB(A)
core areas, village areas and mixed-use zones	60 dB(A)	45 dB(A)
general residential areas and small	55 dB(A)	40 dB(A)

Types of areas	Day 6 p.m. - 10 a.m.	Night 10 a.m. - 6 p.m.
residential states areas		
purely residential areas	50 dB(A)	35 dB(A)
spa areas, for hospitals and nursing homes	45 dB(A)	35 dB(A)

Table 1: Binding immission values according to TA Noise

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 night-time 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 and therefore healthy. Furthermore, the TA Noise contains special regulations concerning individual 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 type of areas of the binding immission values results from specifications in development plans. They correspond to the building areas, which are defined in a Federal Land Utilization Ordinance [9]. 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. For the individual types of land-use planning appropriate area-related binding immission values are defined.

The binding immission values have to 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. According to TA Noise the decisive immission points are defined as follows:

- for 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.

In principle, the binding immission values according to TA Noise may not be exceeded. Exceptions are only being made for the following cases:

- No harmful effects on the environment are to be assumed from the installation when the additional noise exposure from the facility is at least 6 dB(A) below the binding immission values
- It is permanently ensured that the binding immission values are exceeded not more than1dB(A)

4. Consideration of low-frequency noise

Wind turbines emit low-frequency noise. For the determination and assessment of low-frequency noise the German standard DIN 45680 “Measurement and assessment of low frequency noise immission” [10] and in the accompanying Supplement 1 is used [11]. The supplement contains reference values which should not be exceeded.

DIN 45680 contains an auditory threshold. Since some years the question is discussed in the scientific community as well as in the public whether the protection against low-frequency noise is sufficient. This is especially true for infrasound caused by industrial or commercial installations. A research project on behalf of the German Federal Environment Agency [12] has shown that DIN 45680 as well the international standard ISO 7196 “Acoustics - Frequency-Weighting Characteristic for Infrasound Measurements” have deficits [13]. For these reasons, DIN 45680 is currently under revision [14, 15]. Within this activity a noise perception threshold is developed. This threshold and the auditory threshold are shown in figure 2 together with the results of low-frequency noise measurements of a wind turbine in southern Germany. It can be seen that the results are below both thresholds.

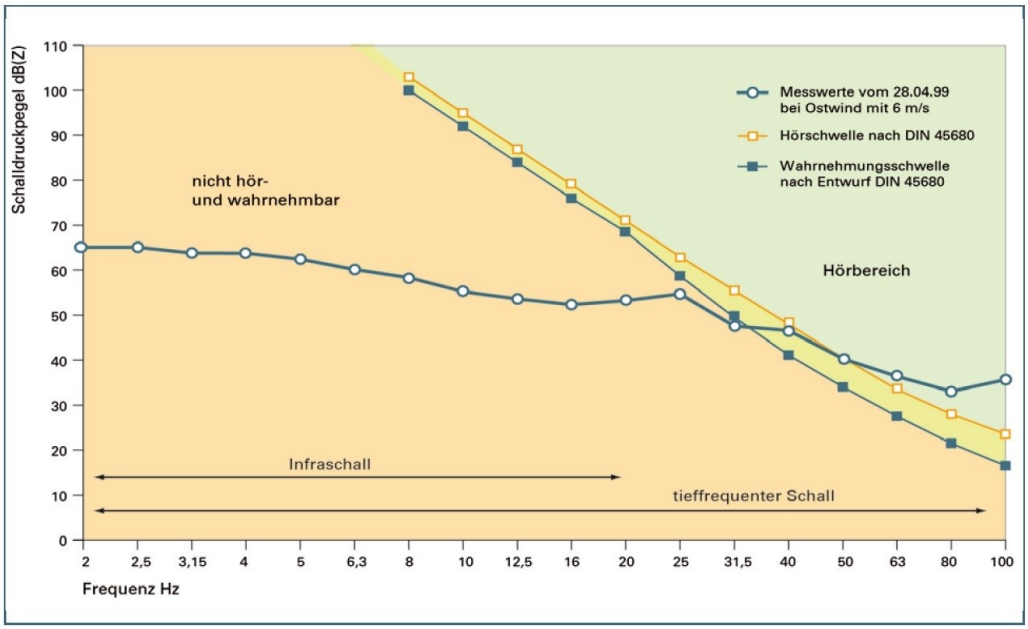

Fig 2: Comparison between low-frequency noise measurements results and audible and perception thresholds [16]

Figure 2 legend

Schalldruckpegel dB(Z)	sound pressure level dB(Z)
Frequenz Hz	frequency Hz
Infraschall	infrasound
Tieffrequenter Schall	low-frequency sound
Nicht hör- und wahrnehmbar	no audible and imperceptible
Hörbereich	range of audibility
Messwerte vom 28.04.99 bei Ostwind mit 6 m/s	measurement results of 28 April 1999 at a windspeed of 6 m/s from eastly direction
Hörschwelle nach DIN 45 680	audible threshold according to DIN 45 680
Wahrnehmungsschwelle nach Entwurf DIN 45 680	perception threshold according to draft DIN 45 680

5. Conclusions

Wind turbines are of great importance to meet the demand for electricity with renewable sources of energy. They should be operated in such a way that this does not cause harmful effects on the population. The determination and assessment of noise from wind turbines is described in detailed legal regulations in Germany. Technical instructions especially contain area-related binding immission values for immission points outside buildings which may not exceeded during the operation of the wind turbine. If these values are exceeded, measures to reduce noise are necessary.

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