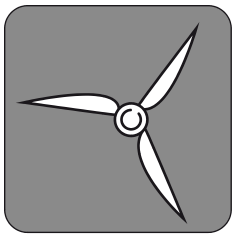
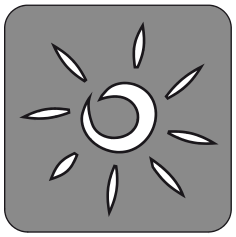
Technical Guidelines
for Wind Turbines

PART 1 (TG 1)
Determination of Noise Emission Values

Revision 19
Dated 01/03/2021

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und andere Dezentrale Energien

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In the interest of easier legibility, a gender-neutral differentiation is not used here. Any gender-specific terminology always refers to all genders.

The following parts of the FGW Technical Guidelines are available:

Part 1 Determination of Noise Emission Values

Part 2 Determination of Power Curves and Standardised Energy Yields

Part 3 Determination of the Electrical Characteristics of Power Generating Units and Systems, Storage Systems as well as for their Components in Medium-, High- and Extra High-Voltage Grids

Part 4 Demands on Modelling and Validating Simulation Models of the Electrical Characteristics of Power Generating Units and Systems, Storage Systems as well as their Components

Part 5 Determination and Application of Reference Yield

Part 6 Determination of Wind Potential and Energy Yields

Part 7 Operation and Maintenance of Power Plants for Renewable Energy

Category A: Miscellaneous section Definition of terms, normative references, basic process descriptions and system aspects

Category A1: Plant responsibility

Category B3: Specialist application notes for monitoring and testing foundations and supporting structures for wind turbines

Category D2: State Event Cause Code for Power Generating Units (Zustands-Ereignis-Ursachen-Schlüssel; ZEUS)

Category D3: Global Service Protocol (GSP)

Category D3 – Attachment A: XML Schema Documentation

Part 8 Certification of the Electrical Characteristics of Power Generating Units, Systems and Storage Systems as well as for their Components on the Grid

Part 9 Determination of High Frequency Emissions from Renewable Power Generating Units

Part 10 Determination of Site Quality after Commissioning

Foreword

The preparation of these Technical Guidelines for Wind Turbines (also known, since 1998, as FGW Guidelines) began in 1992 with the aim of presenting measuring methods allowing determination of reliable and comparable data for wind turbines (WTs) based on state-of-the-art technology. The measurements from the three fields of power curve, noise emissions and electrical characteristics should serve as the foundation for assessment of WTs, e.g. in permit issues, when assessing grid connection options or for preparing reliable yield calculations.

In addition, the data determined according to these guidelines are intended to provide a basis for the level of the funding for wind turbines under the auspices of the regional government support programme for German coastal federal states. This should also reward the development of quiet, high-performance systems with good power quality.

In the meantime, the individual Technical Guidelines as well as the measuring reports compiled independently by competent measuring institutions have become widely recognised in their fields. Power curves often form the basis for purchase agreements and finance commitments, measured noise emission values are adopted both for sales contracts and are used in the course of approval procedures. Measurements of electrical characteristics in accordance with these Technical Guidelines are required by the transmission system operators for the purpose of calculations with regard to connections to their supply grids.

Reference to other standards

The guidelines developed by the International Electrotechnical Commission (IEC) since the 1980s allow for a broad range of measurements and analyses. By specifying the requirements in more detail however, the Technical Guidelines were intended to create the conditions under which the measurement results are largely independent of the party carrying out the measurements.

They have already served as the basis for the IEC EN 61400 series of standards, which will more or less replace the Technical Guidelines by integrating their content. As part of the international harmonisation however, solutions may be implemented which do not adequately take all national requirements into account. In such cases, the provisions of the Technical Guidelines should remain in place, to ensure that the measurement results are recognised by the German approval authorities and transmission system operators.

All definitions are harmonised with the IEC series IEC 61400 and/or the International Electrotechnical Vocabulary IEV–415 (IEC 60050–415) as well as with IEV 161 (IEC 60050–161), provided that no serious reasons required to deviate from these.

Reference is made below to the round robin tests of the MEASNET group (Measuring Network of Wind Energy Institutes). Seven institutes from different European countries founded this group with the objective of harmonising important measurements within the wind energy sector so that the members achieve the highest possible quality of measurement and the measurement results are therefore comparable.

Compilation of these Guidelines

The contents of the Technical Guidelines are the responsibility of the respective Technical Committees and Sub-committees. The following were involved in the compilation of these Guidelines by the Sub-committees: measuring institutes and Immission protection agencies in the Federal Republic of Germany, manufacturers of wind turbines and their components, electricity providers, institutes and universities, engineering consultancies, the German Electricity Association (Verband der Elektrizitätswirtschaft (VDEW) and Fördergesellschaft Windenergie e.V. (FGW).

Measurements and their recognition

Measurements in accordance with the Technical Guidelines can be carried out by any qualified bodies. A test report covering the measurements must be compiled; the principal results can be summarised in a test report excerpt applying the specifications provided in this Guideline (FGW master data sheet).

It should be noted that, over and above the specifications described in these Technical Guidelines, the agency requested to recognise the measurements may place further demands on the measuring institute. Certifiers request, for instance, that wind turbine measurements are performed by a laboratory accredited according to DIN EN ISO/IEC 17025 [1] whereas some immission protection authorities alternatively request the measuring facility to be a notified body according to §29b BImSchG. In addition to the specifications within the Technical Guidelines, acoustic measurements will be recognised where they have been carried out by measuring facilities who are able to demonstrate their competence, e.g. through participation in regular round robin tests for acoustic measurement of wind turbines according to the Technical Guidelines.

FGW conformity

Independent measuring institutes can emphasise the quality of their work by the use of a conformity seal. The seal is applied at the bottom of the test report (or extract from the test report). After supplying a proof of certain quality characteristics, independent measuring institutes can apply for an entitlement to use the conformity seal. These are published on the FGW website.

These Guidelines are an English translation of a prior German version. In any case of distinction between both revisions of TR 1 the German version is valid.

Contents

Abbreviations used

BImSchG	Federal Immission Control Act (*Bundes-Immissionsschutzgesetz*)
DIN	Deutsches Institut für Normung e.V. (German Institute for Standardisation)
e.V.	registered association
Ed.	Edition
FGW	Fördergesellschaft Windenergie und andere Dezentrale Energien
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEV	International Electrotechnical Vocabulary
ISO	International Organisation for Standardization
LAI	Working Group of the Federal and Land Governments on emission protection
MEASNET	Measuring Network of Wind Energy Institutes
Rev.	Revision
TG 1	Technical Guidelines, Part 1
VDEW	German Electricity Association (Verband der Elektrizitätswirtschaft)
WT	Wind turbine

Symbols and units

Symbol	Meaning	Unit
A_{div}	Attenuation due to geometrical divergence in accordance with ISO 9613–2 [2]	dB
A_{gr}	Attenuation due to the ground effect in accordance with ISO 9613–2 [2]	dB
α	Atmospheric attenuation coefficient in accordance with ISO 9613–2 [2]	dB/km
Bin	Wind speed class	m/s
Bin,h_N	Wind speed class at hub height	m/s
$Bin_{10m,max}$	Highest usable integer bin of the underlying assessment in accordance with FGW TG 1 Rev. 18 [3] and/or IEC 61400–11 ed. 2.1 [4]	m/s
$Bin_{10m,min}$	Smallest usable integer bin of the underlying assessment in accordance with FGW TG 1 Rev. 18 [3] and/or IEC 61400–11 ed. 2.1 [4]	m/s
ΔL	Tonality as the difference between the tone level and the level of the masking noise per bin	dB
$\Delta L_{A,k}$	Tonal audibility in each wind speed bin	dB
$\Delta R_{O,I-E}$	Horizontal length difference between the place of immission and emission	m
f_c	Centre frequency of the critical band	Hz
h_N	Hub height	m
$h_{N,measured}$	Hub height of measured WT in metres	m
j	1/3-octave band	–
k	Bin (wind speed class)	–
K_{IN}	Impulse factor in locations close to the turbine	dB
K_{TN}	Tonal factor in locations close to the turbine	dB
L_A	A–weighted sound pressure level	dB
$L_{Aeq,T,k}$	Equivalent continuous A–weighted sound pressure level of the total noise per bin (wind speed class)	dB
$L_{Aeq,B,k}$	Equivalent continuous A–weighted sound pressure level of the background noise per bin (wind speed class)	dB
$L_{Aeq,C,k}$	Equivalent continuous A–weighted sound pressure with background noise correction per bin (wind speed class)	dB
L_p	Sound pressure level	dB
L_{pAFeq}	Equivalent A–weighted sound pressure level as a time function	dB
L_{pAFTeq}	Equivalent A–weighted takt maximal sound level	dB
L_{pt}	Sound pressure level of the tone	dB
$L_{pt,E}$	Sound pressure level of the tone at the emission measurement point	dB

$L_{pt,I}$	Sound pressure level of the tone at the immission position	dB
$L_{WA,k}$	A–weighted sound power level per bin (wind speed class)	dB
$\overline{L}_{WA}$	Average sound power level	dB
n	Number of random samples used	–
P_{tol}	Tolerance on the power reading	kW
R_O	Distance from the centre of the base of the wind turbine to the microphone position	m
R_1	Distance from the rotor centre to the microphone	m
S_O	Reference area	m²
S_k	Standard deviation per bin (wind speed class)	m/s
U_c	Total measurement uncertainty of an individual sample	dB
V_{10}	Wind speed at 10 m height	m/s
$V_{10,Bin}$	Wind speed with reference to 10 m height per bin (wind speed class)	m/s
$V_{10,Bin,max}$	Wind speed at 10 m height of the largest possible bin (wind speed class)	m/s
$V_{10,Bin,min}$	Wind speed at 10 m height of the smallest possible bin (wind speed class)	m/s
V_k	average wind speed in bin k	m/s
V_{k10}	average wind speed in bin k at a height of 10 m	m/s
v_n	Wind speed at hub height	m/s
$V_{P,n}$	Normalised wind speed derived from power curve under standard meteorological conditions	m/s
z_O	Reference roughness length = 0.05 m	m

Terms and definitions

Apparent sound power level L_{WA}: The A–weighted sound power level re. 1 pW of a point source at the rotor centre of the WT with the same emission in the downwind direction as the wind turbine being measured; L_{WA} is determined at bin centre wind speeds at hub height.

Sound pressure level L_p: 10 times the log10 of the ratio of the square mean sound pressure to the square of the reference sound pressure of 20 μPa.

A–weighted sound pressure level L_A: Sound pressure level in dB, measured with a frequency rating A in accordance with IEC 61672 specifications.

Tonal audibility $\Delta L_{a,k}$: The difference between the tonality and the audibility criterion in each wind speed bin, where k is the centre value of the wind speed bin.

(Wind speed) bin: A wind speed interval, 0.5 m/s wide, centred around integer and half-integer wind speeds open at the low end, and closed at the high end.

Bin centre: wind speed bin centre value.

Normalised wind speed derived from power curve $V_{P,n}$: The normalised wind speed derived from power curve under standard meteorological conditions.

Reference roughness length z_o: A roughness length of 0.05 m used for converting wind speed to meteorological reference conditions.

Maximum rotational speed: Highest rotational speed in one mode of operation with reference to 10-minute means.