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INTERNATIONAL STANDARD

AMENDMENT 1

Wind turbines –
Part 1: Design requirements

IEC 61400-1:2005/A1:2010(E)

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FOREWORD

This amendment has been prepared by IEC technical committee 88: Wind turbines.

The text of this amendment is based on the following documents:

FDIS	Report on voting
88/374/FDIS	88/378/RVD

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
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- amended.

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2 Normative references

Replace the existing list of normative references by the following new list:

IEC 60204-1, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60204-11, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60364-5-54, *Electrical installations of buildings – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements, protective conductors and protective bonding conductors*

IEC 60721-2-1, *Classification of environmental conditions – Part 2: Environmental conditions appearing in nature – Temperature and humidity*

IEC 61000-6-1, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity for residential, commercial and light-industrial environments*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61400-2, *Wind turbines – Part 2: Design requirements for small wind turbines*

IEC 61400-21, *Wind turbines – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines*

IEC 61400-24, *Wind turbines – Part 24: Lightning protection*

IEC 62305-3, *Protection against lightning – Part 3: Physical damage to structures and life hazard*

IEC 62305-4, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

ISO 76:2006, *Rolling bearings – Static load ratings*

ISO 281, *Rolling bearings – Dynamic load ratings and rating life*

ISO 2394:1998, *General principles on reliability for structures*

ISO 2533:1975, *Standard atmosphere*

ISO 4354, *Wind actions on structures*

ISO 6336-2, *Calculation of load capacity of spur and helical gears – Part 2: Calculation of surface durability (pitting)*

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ISO 6336-3:2006, *Calculation of load capacity of spur and helical gears – Part 3: Calculation of tooth bending strength*

ISO 81400-4, *Wind turbines – Part 4: Design and specification of gearboxes*

3 Terms and definitions

3.26 – limit state

Replace ISO 2394 *by* 2.2.9 of ISO 2394.

3.55 – ultimate limit state

Replace ISO 2394 *by* 2.2.10 of ISO 2394.

4 Symbols and abbreviated terms

4.1 Symbols and units

Switch the definitions of σ_2 and σ_3. The vertical wind velocity standard deviation should be σ_3, not σ_2.

6 External conditions

6.3.1.3 Normal turbulence model (NTM)

Replace the existing Figures 1a and 1b by the following new figures:

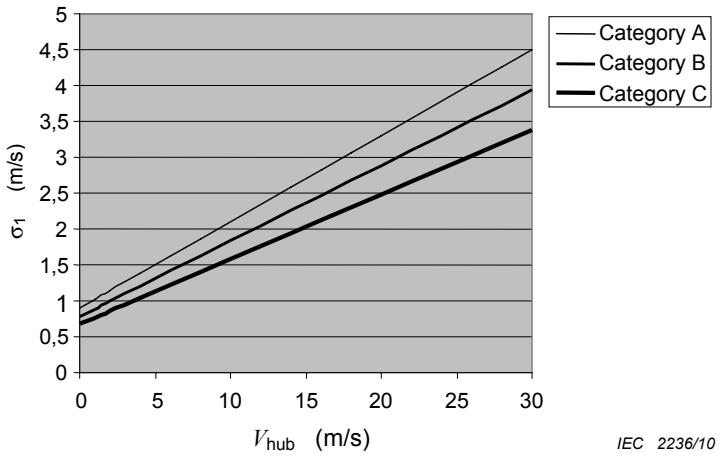

Figure 1a –Turbulence standard deviation for the normal turbulence model (NTM)

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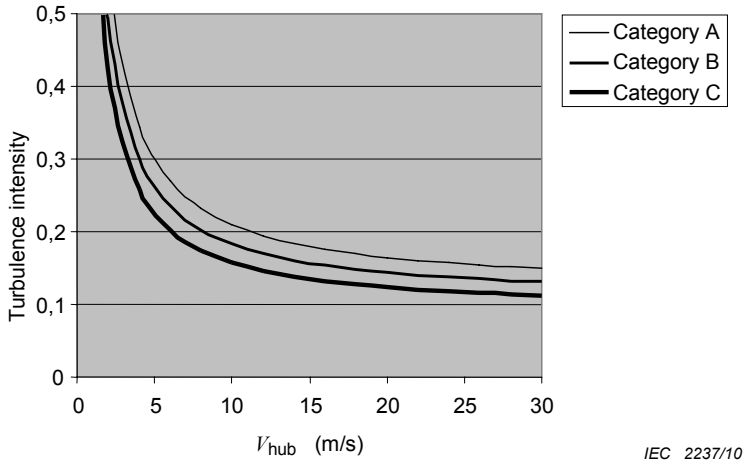

Figure 1b – Turbulence intensity for the normal turbulence model (NTM)

6.3.2.6 Extreme wind shear (EWS)

Replace the number 2,5 in equations (26) and (27) to 2,5 [m/s]. (The number 2,5 in equations (26) and (27) is not dimensionless.)

7 Structural design

7.4.2 Power production plus occurrence of fault or loss of electrical network connection (DLC 2.1 – 2.4)

Add, as 2nd paragraph, the following new text:

As an alternative to the specification of DLC 2.3 above and in Table 2, DLC 2.3 may instead be considered as a normal event (i.e. a partial safety factor for load of 1,35) to be analyzed using stochastic wind simulations (NTM - $V_{in}<V_{hub}<V_{out}$) combined with an internal or external electrical system fault (including loss of electrical network connection). In this case, 12 response simulations shall be carried out for each considered mean wind speed. For each response simulation, the extreme response after the electrical fault has occurred is sampled. The fault must be introduced after the effect of initial conditions has become negligible. For each mean wind speed, a nominal extreme response is evaluated as the mean of the 12 sampled extreme responses plus three times the standard deviation of the 12 samples. The characteristic response value for DLC 2.3 is determined as the extreme value among the nominal extreme responses.

7.5 Load calculations

Add, after second paragraph, the following new text:

When turbulent winds are used for dynamic simulations, attention should be given to the grid resolution regarding the spatial[1] and time resolution.

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1 Concerning the spatial resolution, the maximum distance between adjacent points should be smaller than 25 % of $\Lambda 1$ (Equation (5)) and no larger than 15 % of the rotor diameter. This distance is meant to be the diagonal distance between points in each grid cell defined by four points. In the case of a non-uniform grid, an average value over the rotor surface of the distance between grid points can be considered as the representative spatial resolution, but this distance should always decrease towards the blade tip.

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Replace the last paragraph by the following new text:

Ultimate load components may also be combined in a conservative manner assuming the extreme component values occur simultaneously. In case this option is pursued, both minimum and maximum extreme component values shall be applied in all possible combinations to avoid introducing non-conservatism.

Guidance for the derivation of extreme design loads from contemporaneous loads taken from a number of stochastic realisations is given in Annex H.

7.6.1.2 Partial safety factor for consequence of failure and component classes

Add, after the bullets defining the component classes, the following new text:

The consequences of failure factor shall be included in the test load when performing tests as for example full scale blade testing.

7.6.2 Ultimate strength analysis

Replace equation (31) by the following new equation:

$$\gamma_f F_k \leq \frac{1}{\gamma_n} \cdot \frac{1}{\gamma_m} f_k \qquad (31)$$

Add the following new paragraph after equation (31):

Note that γ_n is a consequence of failure factor and shall not be treated as a safety factor on materials.

Delete the last sentence in 5th paragraph ("For guidance see Annex F") and insert, after the 5th paragraph, the following two paragraphs:

Data used in extrapolation methods shall be extracted from time series of turbine simulations of at least 10 min in length over the operating range of the turbine for DLC 1.1. A minimum of 15 simulations is required for each wind speed from (V_{rated} – 2 m/s) to cut-out and six simulations are required for each wind speed below (V_{rated} – 2 m/s). When extracting data, the designer must consider the effect of independence between peaks on the extrapolation and minimize dependence when possible. The designer shall aggregate data and probability distributions to form a consistent long-term distribution. To ensure stable estimation of long-term loads, a convergence criterion shall be applied to a probability fractile less than the mode of the data for either the short-term or long-term exceedance distributions. For guidance, see Annex F.

The characteristic value for blade root in-plane and out-of-plane moments and tip deflection may be determined by a simplified procedure[2]. The characteristic value may then be determined by calculating the mean of the extremes for each 10-min bin and using the largest value, multiplied by an extrapolation factor of 1,5, while maintaining the partial load factor for statistical load extrapolation, see Table 3.

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2 This approach is considered conservative for 3-bladed upwind wind turbines. Caution should be exercised for other wind turbine concepts.

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7.6.2.1 Partial safety factor for loads

Replace the existing formula in the footnote of Table 3 by the following new formula:

$$\varsigma = \begin{cases} 1 - \left| \dfrac{F_{\text{gravity}}}{F_{\text{k}}} \right|; & |F_{\text{gravity}}| \le |F_{\text{k}}| \\ 0; & |F_{\text{gravity}}| > |F_{\text{k}}| \end{cases}$$

Add the following new text after Table 3:

The approach in 7.6.1.1, where the partial safety factor for loads is applied to the load response, assumes that a proper representation of the dynamic response is of prime concern. For foundations or where a proper representation of non-linear material behaviour or geometrical non-linearities or both are of primary concern, the design load response S_{d} shall be obtained from a structural analysis for the combination of the design loads F_{d}, where the design load is obtained by multiplication of the characteristic loads F_{k} by the specified partial load factor γ_{f} for favourable and unfavourable loads,

$$F_{\text{d}} = \gamma_{\text{f}} F_{\text{k}}$$

The load responses in the tower at the interface (shear forces and bending moments) factored with γ_{f} from Table 3 shall be applied as boundary conditions.

For gravity foundations, the limit states considering overall stability (rigid body motion with no failure in soil) and bearing capacity of soil and foundation shall be regarded and calculated according to a recognized standard. In general, a partial safety factor of γ_{f} = 1,1 for unfavourable permanent loads and γ_{f} = 0,9 for favourable permanent loads shall be applied for foundation load, backfilling and buoyancy. If it can be demonstrated by respective quality management and surveillance that the foundation material densities specified in the design documentation are met on site, a partial safety factor for permanent foundation load γ_{f} = 1,0 can be used for the limit states regarding bearing capacity of soil and foundation. If buoyancy is calculated equal to a terrain water level, a partial safety factor for buoyancy γ_{f} = 1,0 can be applied.

Alternatively, the check of capacity of soil and foundation can be based on a partial safety factor γ_{f} = 1,0 for both favourable and unfavourable permanent loads and the check of overall stability can be based on a partial safety factor of γ_{f} = 1,1 for unfavourable permanent loads and γ_{f} = 0,9 for favourable permanent loads, using in all cases conservative estimates of weights or densities defined as 5 % / 95 % fractiles. The lower fractile is to be used when the load is favourable. Otherwise, the upper fractile is to be used.

7.6.5 Critical deflection analysis

Replace the existing text by the following new text:

7.6.5.1 General

It shall be verified that no deflections affecting structural integrity occur in the design conditions detailed in Table 2.

The maximum elastic deflection in the unfavourable direction shall be determined for the load cases detailed in Table 2 using the characteristic loads. The resulting deflection is then multiplied by the combined partial safety factor for loads, materials and consequences of failure.

- Partial safety factor for loads

The values of γ_{f} shall be chosen from Table 3.

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