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INTERNATIONAL STANDARD

NORME INTERNATIONALE

AMENDMENT 1
AMENDEMENT 1

Wind turbines –
Part 13: Measurement of mechanical loads

Éoliennes –
Partie 13: Mesurage des charges mécaniques

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WIND TURBINES –

Part 13: Measurement of mechanical loads

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This amendment has been prepared by IEC technical committee 88: Wind energy generation systems.

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

Draft	Report on voting
88/795/CDV	88/821/RVC

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

The language used for the development of this Amendment is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available

at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications/.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This amendment to IEC 61400-13:2015 addresses the errors found in Annex B which impact a significant portion of that annex.

Annex B
(informative)

Procedure for the evaluation of uncertainties in load measurements on wind turbines

B.2.3 Total uncertainty

B.2.3.3 Total uncertainty

Replace Equation (B.7) with the following new equation:

$$u_{\mathrm{t}} = \sqrt{u_{\mathrm{cal}}^2 + u_{\mathrm{sig}}^2} \tag{B.7}$$

B.3 Uncertainties of binned averaged values

B.3.3 Uncertainty of the bin scatter

Replace Equation (B.8) with the following new equation:

$$u_{\mathrm{scat}} = stdev_{\mathrm{sig}} / \sqrt{N} \tag{B.8}$$

B.3.4 Uncertainty of the x-axis quantity

Replace Equation (B.9) with the following new equation:

$$u_x = u_{x,i} \times \frac{y_i - y_{i\text{-}1}}{x_i - x_{i\text{-}1}} \tag{B.9}$$

B.3.5 Uncertainty of bin averaged mean values

Replace Equation (B.10) with the following new equation:

$$U_{\mathrm{mean}} = \sqrt{u_{\mathrm{t}}^2 + u_{\mathrm{scat}}^2 + u_x^2} \tag{B.10}$$

B.5 Examples of an uncertainty evaluation

B.5.1 Example for analytical shunt calibration of tower torque

B.5.1.1 Uncertainty components

Replace Table B.1 with the following table:

Table B.1 – Uncertainty components

Quantity	Symbol	Uncertainty	Unit	Source of information	Category	Distribution	Comment
Material parameters, cross section geometry and gauges factor in an installation							
Gauges factor	u_k	1	%	Datasheet	B	Gaussian	–
Misalignment	$u_{F_{\text{sens}}}$	3	°	Estimation	B	Rectangular	–
Diameter at cross section	$u_{D_{\text{i}}}$	2,5	mm	Estimation	B	Gaussian	–
Wall thickness at cross section	$u_{T_{\text{w}}}$	0,1	mm	Estimation	B	Gaussian	–
Young modulus	u_E	5	%	Estimation	B	Gaussian	–
Poisson ratio	u_ν	5	%	Estimation	B	Gaussian	–
Amplifier calibration							
Amplifier and measurement uncertainty concerning gain	$u_{\text{sig}_{\text{gain}}}$	0,1	%	Datasheet / Calibration certificate	B	Gaussian	Measurement value
Amplifier and measurement uncertainty concerning offset	$u_{\text{sig}_{\text{offset}}}$	0,1	%	Datasheet / Calibration certificate	B	Rectangular	Upper value of the measurement range 10 V
Quantization resolution (Offset)	u_{Q}	≈0,3	mV	Datasheet	B	Rectangular	16 Bit A/D converter, measurement range ±10 V
Calibration device	$u_{R_{\text{SH}}}$	0,1	%	Datasheet / Calibration certificate	B	Gaussian	Value shunt resistant
Gauges resistance	$u_{R_{\text{SG}}}$	1	%	Datasheet	B	Gaussian	
Signal uncertainty							
Signal uncertainty	s_i			Tests, statistics, estimations	A	Gaussian	Evaluation according to B.2.3.2

B.5.1.2 Calibration uncertainty of an analytical calibration

Replace Equation (B.11) with the following new equation:

$$M = G \times SM_{\text{t}} \times \varepsilon \times 2 \tag{B.11}$$

Replace Equation (B.13) with the following new equation:

$$M = G \times SM_{\text{t}} \times \frac{2}{k} \times \frac{U_{\text{o}}}{U_{\text{i}}} \tag{B.13}$$

Replace Equation (B.14) with the following new equation:

$$S_{\mathrm{M}} = \frac{G \times SM_{\mathrm{t}} \times \dfrac{2}{k} \times \dfrac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.14}$$

Replace Equation (B.16) with the following new equation:

$$S_{\mathrm{M}} = \frac{G \times SM_{\mathrm{t}} \times \dfrac{2}{k} \times \dfrac{U_{\mathrm{o}}}{U_{\mathrm{i}}} \times F_{\mathrm{sens}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.16}$$

Replace Equation (B.18) with the following new equation:

$$\frac{\partial S_{\mathrm{M}}}{\partial E} = \frac{\dfrac{1}{2 \times (1+\nu)} \times SM_{\mathrm{t}} \times \dfrac{2}{k} \times \dfrac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.18}$$

Replace Equation (B.19) with the following new equation:

$$\frac{\partial S_{\mathrm{M}}}{\partial \nu} = \frac{E \times SM_{\mathrm{t}} \times \dfrac{-1}{2 \times (1+\nu)^2} \times \dfrac{2}{k} \times \dfrac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.19}$$

Replace Equation (B.20) with the following new equation:

$$\frac{\partial S_{\mathrm{M}}}{\partial SM_{\mathrm{t}}} = \frac{G \times \dfrac{2}{k} \times \dfrac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.20}$$

Replace the existing text "This lead" at the beginning of the sentence above Equation (B.22) with "This leads".

Replace Equation (B.22) with the following new equation:

$$\frac{\partial S_{\mathrm{M}}}{\partial D_{\mathrm{i}}} = \frac{G \times SM_{\mathrm{t}} \dfrac{2}{k} \times \dfrac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.22}$$

Replace Equation (B.23) with the following new equation:

$$\frac{\partial S_{\mathrm{M}}}{\partial T_{\mathrm{W}}} = \frac{G \times SM_{\mathrm{t}} \dfrac{2}{k} \times \dfrac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.23}$$

Replace Equation (B.24) with the following new equation:

$$\frac{\partial S_{\mathrm{M}}}{\partial k} = \frac{G \times SM_{\mathrm{t}} \times \frac{-2}{k^2} \times \frac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.24}$$

Replace Equation (B.25) with the following new equation:

$$\frac{\partial S_{\mathrm{M}}}{\partial R_{\mathrm{SG}}} = \frac{G \times SM_{\mathrm{t}} \times \frac{2}{k} \times \frac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.25}$$

Replace Equation (B.26) with the following new equation:

$$\frac{\partial S_{\mathrm{M}}}{\partial R_{\mathrm{SH}}} = \frac{G \times SM_{\mathrm{t}} \times \frac{2}{k} \times \frac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.26}$$

Replace Equation (B.27) with the following new equation:

$$\frac{\partial S_{\mathrm{M}}}{\partial F_{\mathrm{sens}}} = \frac{G \times SM_{\mathrm{t}} \times \frac{2}{k} \times \frac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.27}$$

Replace Equation (B.29) with the following new equation:

$$\frac{\partial S_{\mathrm{M}}}{\partial S_{\mathrm{gain}}} = \frac{G \times SM_{\mathrm{t}} \times \frac{2}{k} \times \frac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times S_{\mathrm{V}} \tag{B.29}$$

Replace Equation (B.32) with the following new equation:

$$u^2_{\mathrm{offset}} = u^2_{\mathrm{sig_{offset}}} \times \left(\frac{G \times SM_{\mathrm{t}} \times \frac{2}{k} \times \frac{U_{\mathrm{o}}}{U_{\mathrm{i}}}}{\Delta S_{\mathrm{shunt}}} \times R_M \right)^2 \tag{B.32}$$

Replace Table B.2 with the following table (uncertainty values modified for $u_{D_{\mathrm{i}}}$ and u_{Q} and calibration device unit value and value changed):

Table B.2 – Values and uncertainties for the calculation

Quantity	Symbol Quantity	Value	Unit Value	Symbol Uncertainty	Uncertainty	Unit Uncertainty	Comment
Material parameters, cross section geometry and gauges factor in an installation							
Gauges factor	k	2,1	–	u_k	1	%	
Misalignment	α	–	–	$u_{F_{sens}}$	3	°	See Figure B.1
Inner diameter at cross section	D_i	4	m	u_{D_i}	0,002 5	m	See Figure B.1
Wall thickness at cross section	T_w	0,03	m	u_{T_w}	0,000 1	m	See Figure B.1
Young modulus	E	210E9	N/m^2	u_E	5	%	
Poisson ratio	ν	0,27	–	u_ν	5	%	
Amplifier calibration							
Amplifier and measurement uncertainty concerning gain	–	–	–	$u_{sig_{gain}}$	0,1	%	Measurement value
Amplifier and measurement uncertainty concerning offset	–	10	V	$u_{sig_{offset}}$	0,1	%	Upper value of the measurement range 10 V
Quantization resolution	–	±10	V	u_Q	≈0,3	mV	16 Bit A/D converter, measurement range ±10 V
Calibration device	R_{SH}	1 00	kOhm	$u_{R_{SH}}$	0,1	%	Shunt resistance
Gauges resistance	R_{SG}	350	Ohm	$u_{R_{SG}}$	1	%	

Replace Equation (B.33) with the following new equation:

$$u_E^2\left(\frac{\partial S_M}{\partial E}\right)^2 = \left(1{,}05\times10^{10}\times3{,}55\times10^{-5}\,\frac{\text{m}^3}{\text{V}}\right)^2 = 1{,}39\times10^{11}\left(\frac{\text{Nm}}{\text{V}}\right)^2 \quad \text{(B.33)}$$

Replace Equation (B.34) with the following new equation:

$$u_\nu^2\left(\frac{\partial S_M}{\partial \nu}\right)^2 = \left(0{,}013\,5\times\text{-}5{,}88\times10^{6}\,\frac{\text{Nm}}{\text{V}}\right)^2 = 6{,}30\times10^{9}\left(\frac{\text{Nm}}{\text{V}}\right)^2 \quad \text{(B.34)}$$

Replace Equation (B.35) with the following new equation:

$$u_{D_i}^2\left(\frac{\partial S_M}{\partial D_i}\right)^2 = \left(0{,}001\,25\times7{,}46\times10^{6}\,\frac{\text{Nm}}{\text{V}}\right)^2 = 8{,}71\times10^{7}\left(\frac{\text{Nm}}{\text{V}}\right)^2 \quad \text{(B.35)}$$