SLOVENSKI STANDARD

SIST EN IEC 61400-6:2020/oprA1:2024

01-junij-2024

Sistemi za proizvodnjo energije na veter - 6. del: Stolp in obravnava temeljnih zahtev - Dopolnilo A1

Amendment 1 - Wind energy generation systems - Part 6: Tower and foundation design requirements

Windenergieanlagen - Teil 6: Auslegungsanforderungen an Türme und Fundamente

Systèmes de génération d'énergie éolienne - Partie 6: Exigences en matière de conception du mât et de la fondation

Ta slovenski standard je istoveten z: EN IEC 61400-6:2020/prA1:2024

ICS:

27.180	Vetrne elektrarne	Wind turbine energy systems

SIST EN IEC 61400-6:2020/oprA1:2024 en

88/1007/CDV

COMMITTEE DRAFT FOR VOTE (CDV)

PROJECT NUMBER: **IEC 61400-6/AMD1 ED1**	
DATE OF CIRCULATION: **2024-04-05**	CLOSING DATE FOR VOTING: **2024-06-28**
SUPERSEDES DOCUMENTS: **88/937/RR**	

IEC TC 88 : WIND ENERGY GENERATION SYSTEMS	
SECRETARIAT: Denmark	SECRETARY: Mrs Christine Weibøl Bertelsen
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.

FUNCTIONS CONCERNED:

☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY

☒ SUBMITTED FOR CENELEC PARALLEL VOTING

Attention IEC-CENELEC parallel voting

The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this Committee Draft for Vote (CDV) is submitted for parallel voting.

The CENELEC members are invited to vote through the CENELEC online voting system.

☐ NOT SUBMITTED FOR CENELEC PARALLEL VOTING

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Recipients of this document are invited to submit, with their comments, notification of any relevant "In Some Countries" clauses to be included should this proposal proceed. Recipients are reminded that the CDV stage is the final stage for submitting ISC clauses. (See AC/22/2007 or NEW GUIDANCE DOC).

TITLE:

Amendment 1 – Wind energy generation systems – Part 6: Tower and foundation design requirements

PROPOSED STABILITY DATE: 2027

NOTE FROM TC/SC OFFICERS:

In 88/926/RQ, Result of 88/914/Q: Proposed amendment to IEC 61400-6:2020, Wind energy generation systems - Part 6: Tower and foundation design requirements, it was concluded that MT 6 will have to further decide on the next step during the preparatory stage of the amendment.

MT 6 has during to the development of the amendment, decided to submit the document directly as CDV.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

WIND ENERGY GENERATION SYSTEMS –

Part 6: Tower and foundation design requirements

AMENDMENT 1

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

Amendment 1 to IEC 61400-6:2020 has been prepared by subcommittee MT 6: Tower and foundation design, of IEC technical committee TC88: Wind energy generation systems.

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

Draft	Report on voting
88/xxxx/FDIS	88/xxxx/RVD

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/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

Sections as given in this document are replacing or amending the respective sections of IEC 61400-6:2020. The main part of this amendment concerns updated knowledge for the design of L-flanges and modifications required due to changes to IEC 61400-1.

The previous method of fatigue assessment using the Schmidt/Neuper trilinear bolt force curve approximation has been removed from the standard. It has been replaced with a physically more accurate method.

The updated methodology for fatigue assessment of L-flanges has been calibrated such that the target failure probability defined in IEC 61400-1 is achieved. Where existing flange designs are checked with the updated method, over-utilization may be found, which in some cases may show an order of magnitude higher than nominally acceptable damage.

This does not impose an immediate risk for the turbines affected, though, due to the following factors:

a) In most cases such designs have significant conservatism in the fatigue loads assumed e.g. due to the assumption of uni-directional wind combined with type class turbulence conditions.
b) Experience shows that broken bolts are almost always found and replaced before a turbine collapses.

Existing flange designs need not be re-assessed using the new method, and existing type or project certification remains valid. In cases where broken bolts are found in operating turbines, the affected flange should be checked with the new methodology. Based on the assessment results and the root causes analysis for the failure, further measures should be defined (e.g. shorter inspection intervals).

2 Normative references

Add the following normative references to IEC 61400-6:2020.

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 898-1, Mechanical properties of fasteners made of carbon steel and alloy steel – Part 1: Bolts, screws and studs with specified property classes – Coarse thread and fine pitch thread

ISO 898-2, Fasteners – Mechanical properties of fasteners made of carbon steel and alloy steel – Part 2: Nuts with specified property classes

ISO 898-3, Mechanical properties of fasteners made of carbon steel and alloy steel - Part 3: Flat washers with specified property classes

ISO 16047, Fasteners - Torque/clamp force testing

ISO 4759-1, Tolerances for fasteners – Part 1: Bolts, screws, studs and nuts – Product grades A, B and C

ISO 4759-3, Tolerances for fasteners - Part 3: Washers for bolts, screws and nuts - Product grades A, C and F

ISO 965 (all parts), ISO general purpose metric screw threads

3 Terms and definitions

Add the following definitions to IEC 61400-6:2020.

3.1
Bolt assembly

Bolt assemblies comprise fastener, nut(s), optionally washer(s), preloading method and lubrication system

EXAMPLE A stud assembly for tension-tightening may comprise a stud and two roundnuts on each side, without additional washers

NOTE In this standard, the term "bolts" is used for the fastener elements. Instead of (head) bolts, also partially or fully threaded studs with nuts on both ends may be used, if they have the same nominal thread geometry and material properties as bolts from accepted standards.

3.2
Design gap height

k_{design}

Design gap height, defined as the 95% fractile value of the log-normal distribution defined by k_{mean} and COV_k (section 6.7.5.2)

3.3
Unloaded gap height limit

$k_{limit,unloaded}$

Allowable maximum gap height after mating of flanges, without influence of loading by dead weight of tower section(s) above the flange or preload of bolts

3.4
Loaded gap height limit

$k_{limit,loaded}$

Allowable maximum gap height after mating of flanges, and after application of e.g. dead weight of tower section(s) above the flange and/or partial preload of bolts

NOTE Conditions at time of measuring the loaded gap height shall be defined by the designer

3.5
Flatness deviation of individual flange

u_{tol}

Allowable flatness deviation as defined in section 6.7.3.1 for the individual flange

4 Symbols and abbreviated terms

Symbols

a	flange dimension (nominal distance from inside of flange to bolt circle diameter)
A	nominal area of the bolt shaft with diameter d
a*	auxiliary value to compute bolt bending moment
a'	reduced effective flange dimension according to Tobinaga/Ishihara
A_{cf}	flange cross section area in circumferential direction
A_S	nominal stress area of the bolt in thread
b	weld neck thickness (normally equal to the thickness of the connected tower shell) (in section 6.3.2.3 only)

b	flange dimension (nominal distance from bolt circle diameter to middle surface of connected tower shell)
$b'_{\{B,D,E\}}$	distance in between plastic hinges for failures modes B, D, E
c	flank height of the weld preparation (in section 6.3.2.3 only)
c	segment width measured at the middle surface of the shell (tower wall)
c_{bcd}	segment width measured at the bolt circle diameter
C_D	stiffness of the compression spring q (representing the compressed parts)
COV	coefficient of variation
COV_k	coefficient of variation of gap height
COV_p	coefficient of variation of preload force
C_S	spring stiffness of the tension spring (representing the bolts)
d	nominal diameter of the bolt
D	outer diameter of the flange connection
$D_{\{1,2\}}$	auxiliary values to determine coefficients for bolt force polynomial
d_b	diameter of the bolt hole
DFT_{sbw}	dry film thickness (DFT) of coatings applied to the flange surface beneath washers (sbw), i.e in the contact area between washers and flange
D_w	outside diameter of the washer
E	Young's modulus of steel
$F_{p,C}{}^*$	preload bolt force used for modified torque method
$F_{p,C}{}'$	preload bolt force used in the design calculations (design preload)
$F_{p,inst.,mean}$	mean preload force after installation
$F_{p,mean}$	mean preload after settlement
F_S	bolt force
$F_S(Z)$	bolt force as a function of external force Z applied on flange segment
$F_{S,\{0,1,2,3\}}$	bolt forces for determination of polynomial bolt force model
$F_{S,max,FLS}$	bolt force calculated for maximum FLS load level
$F_{S,min}$	minimum (constant) bolt force for theoretically fully closed connection under compression
$F_{S,loss}$	bolt force used to verify preload loss criterion
$F_S'(Z)$	slope (derivative) of bolt force curve as a function of external force Z on flange segment
$F_{t,R}$	design value of tension resistance of bolt
$F_{U,B}$	limit tension resistance for failure mode B
$F_{U,D}$	limit tension resistance for failure mode D
f_{ub}	ultimate tensile strength of bolt
F_V	preload
f_{yb}	nominal yield strength of the bolt material
$f_{yb,k}$	characteristic value for yield limit of the bolt
$f_{Z,tot}$	total amount of settlement in the connection
G	shear modulus of steel
G_{RNA}	dead weight of the RNA
G_{twr}	dead weight of tower above flange connection considered
h_n	flange neck height
h_{wp}	distance from flange surface to weld preparation
h_{wt}	distance from flange surface to weld toe
I_{cf}	flange moment of inertia in circumferential direction (bending moment vector pointing in radial direction)
I_{tg}	flange moment of inertia for a bending moment vector pointing in tangential direction
k	flange gap height
$k(l)$	gap height at position l of total gap length L_{gap}

k_{design}	design gap height
k_{fac}	stiffness factor to calculate meridional shell stiffness
k_{fl}	bending stiffness of the flange
$k_{gap,tot}$	total gap stiffness
$k_{limit,loaded}$	gap height after application of a defined load
$k_{limit,unloaded}$	gap height after mating of flanges without any load
k_{mean}	mean gap height
$k_{measured}$	measured gap height
k_{seg}	segment stiffness
$k_{shell,ini}$	meridional stiffness of the shell / initial shell stiffness
K	shell parameter
l	distance from transition radius to weld preparation (in section 6.3.2.3 only)
l	length of the bolt between the bolt head and the nut
$L_{30°}$	circumferential length measured at mid surface of shell over 30° sector
$l_k = L_{gap}$	spanning length of the gap
M	external bending moment
m	slope parameter of a fatigue resistance curve
M_0	bending moment at $Z = \Delta Z_{dw}$
$M_{max,FLS}$	maximum bending moment included in Markov matrix
$M_{mean,i}$	mean value of entry i in the Markov matrix
$M_{min,FLS}$	minimum bending moment included in Markov matrix
$M_{pl,3}$	plastic limit bending moment for flange or shell
$M_{pl,Bl}$	plastic limit bending moment for shell
$M_{pl,Fl}$	plastic limit bending moment for flange
$M_{pl,N,Bl}$	plastic limit bending moment for shell, including interaction with external tension force N
$M_{pl,V,Fl}$	plastic limit bending moment for flange, including interaction with shear force V
M_{loss}	bending moment used to calculate bolt force for preload loss check
$M_{range,i}$	moment range of entry i in the Markov matrix
M_S	bolt moment
$M_S(Z)$	bolt moment curve as function of external force Z
$M_{S,min}$	minimum bending moment for theoretically fully closed connection under compression
N	number of cycles
n	shell parameter
n_{bolts}	number of bolts in flange connection
$N_{pl,Bl}$	plastic limit normal force for shell
p	load factor of the tension springs
p_{95}	95% quantile of the log-normal distribution
R_{shell}	mean radius of shell (tower wall)
s	shell (tower wall) thickness
t	flange thickness
t_w	thickness of the washer
u	auxiliary displacement value for computation of flange segment stiffness
u_{tol}	flatness tolerance for individual flange
$u_{tol,1m}$	flatness tolerance per flange over a circumferential length of 1000mm
$u_{tol,30°}$	flatness tolerance per flange over 30° sector
$u_{tol,360°}$	flatness tolerance per flange around the entire circumference
V	shear force in flange
$V_{pl,Fl}$	plastic limit shear force
w	flange width

W_{twr}	section modulus of the tower with outer diameter D and wall thickness s
Z	tower shell force (external force on the segment)
$Z_{\{0,1,2,3\}}$	force values to construct tower bolt force model
Z_{close}	force at which the connection is theoretically fully closed
$Z_{max,FLS}$	max. segment force from the Markov matrix
$\tilde{Z}_2$	auxiliary value needed to compute segment stiffness k_{seg}
Z_{tot}	total segment force
$Z_{tot}(M)$	total segment force as a function of external bending moment M
$\alpha_{\{0,1,2\}}$	auxiliary values to determine polynomial coefficients
α_{gap}	circumferential angle of the gap
α_k	stiffness correction factor
α_S	flange surface inclination
β_S	bending resilience of bolt
δ_P	resilience of the clamped parts
δ_S	resilience of the bolt
ΔF_{pl}	expected reduction of preload force due plastic strain development
ΔF_Z	expected reduction of preload force due to settlements
ΔZ	range of external force applied to flange segment
ΔZ_{dw}	segment force resulting from the dead weight
ΔZ_{gap}	force for theoretical closure of flange gap
$\Delta\sigma$	combined stress range
$\Delta\sigma_{axial}$	stress range from axial forces in the bolt
$\Delta\sigma_{bending}$	stress range from bending moments in the bolt
$\Delta\sigma_c$	reference stress range of resistance S-N-curve
λ'	lever arm ratio taking the action point correction into account
μ_k	mean value of log-normal distribution for gap heights
ν	Poisson's ratio
$\chi_{ini,M}$	slope of bending moment function
$\chi_{ini,mod}$	modified initial slope of the polynomial approximation
$\chi_{ini,true}$	true slope of the polynomial approximation
γ_{M1}	partial safety factor (PSF)

Abbreviated terms

2K-PUR	2 Component Polyurethane
BTQP	Bolt Tightening Qualification Procedure
COV	Coefficient Of Variation
DFT	Dry Film Thickness
EP	Epoxy
FEA	Finite Element Analysis
FLS	Fatigue Limit State
HV	"Hochfest vorgespannt" (German designation for high-strength bolts intended for preloading)
PUR	Polyurethane
RNA	Rotor Nacelle Assembly
SCF	Stress Concentration Factor
TSM	Thermal Spray Metallizing
ULS	Ultimate Limit State

6.3.3 Bolts and anchors

Replace entire section 6.3.3 of IEC 61400-6:2020 with the following.

Generally, standardized bolt assemblies should be used as far as practicable.

NOTE A comparison of local design codes and industry design guidelines practice may be found in Annex A and Annex C.

The material property class for bolt assemblies and anchors shall comply with the requirements stated in ISO 898-1, ISO 898-2 and ISO 898-3. Material properties for bolt sets with metric sizes larger than M39 shall be derived with due consideration of size effects and manufacturing methods.

NOTE 1 Large diameters require different materials and manufacturing methods. ISO 898 testing is obtained directly on the fastener or on machined test pieces with max diameter reduction 25 %. For large bolt sizes, the test specimen would still be too large to be conveniently tested, so the specification should be adapted.

NOTE 2 The material properties derived as per above procedures are valid in the temperature range from -50 °C to +150 °C.

For preloaded connections only bolt sets with either property class 8.8 or 10.9 should be selected.

When non-standardized bolt assemblies are specified by the designer, the product characteristics of the bolt assembly shall be obtained through type testing on at least 5 samples for each required characteristic.

The type testing program shall include at least:

a) Material properties as per ISO 898-1, ISO 898-2 and ISO 898-3 as applicable
b) Product grade as per ISO 4759-1, ISO 4759-3, ISO 965-2 and ISO 965-5
c) Suitability for preloading as per ISO 16047

NOTE Non-standardized bolt assemblies may differ due to non-standardized components (fastener, nut, washer(s)), preloading method and lubrication system, among others.

Type testing should be repeated in case of different nominal diameters, manufacturing methods, material property class, coating type, type and source of material, tightening method.

6.5.2 Partial safety factor

Replace complete section 6.5.2 including footnote 8 with

Partial safety factors shall be chosen based on the applied verification method.

When using EN 1993-1-6:2007 or prEN 1993-1-6:2023, γ_{M1}=1.1 should be used.

When using the modified expressions for meridional buckling (D.1.2.2) according to EN 1993-1-6:2007+A1:2017, γ_{M1}=1.2 should be used.