

This is a preview of "IEC 61400-4:2012". Click [here](#) to purchase the full version from the ANSI store.



Edition 1.0 2012-12

INTERNATIONAL STANDARD



Wind turbines – Part 4: Design requirements for wind turbine gearboxes



This is a preview of "IEC 61400-4:2012". [Click here to purchase the full version from the ANSI store.](#)



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2012 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

Useful links:

IEC publications search - www.iec.ch/searchpub

The advanced search enables you to find IEC publications by a variety of criteria (reference number, text, technical committee,...).

It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available on-line and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary (IEV) on-line.

Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

This is a preview of "IEC 61400-4:2012". [Click here to purchase the full version from the ANSI store.](#)



Edition 1.0 2012-12

INTERNATIONAL STANDARD



Wind turbines – Part 4: Design requirements for wind turbine gearboxes

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE **XG**

ICS 27.180

ISBN 978-2-83220-506-8

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
2 Normative references	10
3 Terms, definitions and conventions.....	12
3.1 Terms and definitions	12
3.2 Conventions	15
4 Symbols, abbreviations and units	17
4.1 Symbols and units	17
4.2 Abbreviations	21
5 Design for reliability.....	23
5.1 Design lifetime and reliability.....	23
5.2 Design process	24
5.3 Documentation	26
5.4 Quality plan	26
6 Drivetrain operating conditions and loads	27
6.1 Drivetrain description	27
6.1.1 General	27
6.1.2 Interface definition.....	27
6.1.3 Specified requirements across interfaces.....	28
6.2 Deriving drivetrain loads.....	28
6.2.1 Wind turbine load simulation model	28
6.2.2 Wind turbine load calculations	29
6.2.3 Reliability of load assumptions	29
6.3 Results from wind turbine load calculations	29
6.3.1 General	29
6.3.2 Time series.....	30
6.3.3 Fatigue load	30
6.3.4 Extreme loads	31
6.4 Operating conditions	31
6.4.1 General	31
6.4.2 Environmental conditions.....	31
6.4.3 Operating strategies	32
6.5 Drivetrain analysis.....	32
7 Gearbox design, rating, and manufacturing requirements	32
7.1 Gearbox cooling	32
7.2 Gears	33
7.2.1 Gear reliability considerations.....	33
7.2.2 Gear rating	33
7.2.3 Load factors	34
7.2.4 Gear materials.....	36
7.2.5 Subsurface initiated fatigue	37
7.2.6 Gear accuracy	37
7.2.7 Gear manufacturing.....	37
7.3 Bearings.....	38
7.3.1 General	38

This is a preview of "IEC 61400-4:2012". [Click here to purchase the full version from the ANSI store.](#)

7.3.2	Bearing reliability considerations	38
7.3.3	Bearing steel quality requirements	39
7.3.4	General design considerations	39
7.3.5	Bearing interface requirements	42
7.3.6	Bearing design issues	43
7.3.7	Bearing lubrication	46
7.3.8	Rating calculations	47
7.4	Shafts, keys, housing joints, splines and fasteners	50
7.4.1	Shafts	50
7.4.2	Shaft-hub connections	50
7.4.3	Flexible splines	51
7.4.4	Shaft seals	51
7.4.5	Fasteners	51
7.4.6	Circlips (snap rings)	52
7.5	Structural elements	52
7.5.1	Introduction	52
7.5.2	Reliability considerations	53
7.5.3	Deflection analysis	53
7.5.4	Strength verification	53
7.5.5	Static strength assessment	54
7.5.6	Fatigue strength assessment	58
7.5.7	Material tests	62
7.5.8	Documentation	63
7.6	Lubrication	63
7.6.1	General considerations	63
7.6.2	Type of lubricant	64
7.6.3	Lubricant characteristics	65
7.6.4	Method of lubrication	66
7.6.5	Oil quantity	67
7.6.6	Operating temperatures	68
7.6.7	Temperature control	68
7.6.8	Lubricant condition monitoring	69
7.6.9	Lubricant cleanliness	69
7.6.10	Lubricant filter	70
7.6.11	Ports	71
7.6.12	Oil level indicator	71
7.6.13	Magnetic plugs	71
7.6.14	Breather	72
7.6.15	Flow sensor	72
7.6.16	Serviceability	72
8	Design verification	72
8.1	General	72
8.2	Test planning	72
8.2.1	Identifying test criteria	72
8.2.2	New designs or substantive changes	73
8.2.3	Overall test plan	73
8.2.4	Specific test plans	73
8.3	Workshop prototype testing	74
8.3.1	General	74

This is a preview of "IEC 61400-4:2012". [Click here to purchase the full version from the ANSI store.](#)

8.3.2	Component testing	74
8.3.3	Workshop testing of a prototype gearbox	74
8.3.4	Lubrication system testing	75
8.4	Field test	75
8.4.1	General	75
8.4.2	Validation of loads	75
8.4.3	Type test of gearbox in wind turbine	76
8.5	Production testing	77
8.5.1	Acceptance testing	77
8.5.2	Sound emission testing.....	77
8.5.3	Vibration testing	77
8.5.4	Lubrication system considerations	77
8.5.5	System temperatures.....	77
8.6	Robustness test	77
8.7	Field lubricant temperature and cleanliness	77
8.8	Bearing specific validation	78
8.8.1	Design reviews	78
8.8.2	Prototype verification/validation	78
8.9	Test documentation	79
9	Operation, service and maintenance requirements	79
9.1	Service and maintenance requirements	79
9.2	Inspection requirements	79
9.3	Commissioning and run-in	79
9.4	Transport, handling and storage	80
9.5	Repair	80
9.6	Installation and exchange	80
9.7	Condition monitoring	80
9.8	Lubrication	80
9.8.1	Oil type requirements	80
9.8.2	Lubrication system.....	80
9.8.3	Oil test and analysis	81
9.9	Operations and maintenance documentation	81
Annex A (informative)	Examples of drivetrain interfaces and loads specifications	82
Annex B (informative)	Gearbox design and manufacturing considerations.....	93
Annex C (informative)	Bearing design considerations	96
Annex D (informative)	Considerations for gearbox structural elements.....	122
Annex E (informative)	Recommendations for lubricant performance in wind turbine gearboxes.....	125
Annex F (informative)	Design verification documentation	140
Annex G (informative)	Bearing calculation documentation.....	143
Bibliography.....		151
Figure 1 – Shaft designation in 3-stage parallel shaft gearboxes.....		15
Figure 2 – Shaft designation in 3-stage gearboxes with one planet stage.....		16
Figure 3 – Shaft designation in 3-stage gearboxes with two planet stages		17
Figure 4 – Design process flow chart		25
Figure 5 – Examples of bearing selection criteria		39

This is a preview of "IEC 61400-4:2012". [Click here to purchase the full version from the ANSI store.](#)

Figure 6 – Blind bearing assembly	45
Figure 7 – Definition of section factor $n_{pl,\sigma}$ of a notched component	56
Figure 8 – Idealized elastic plastic stress-strain curve	57
Figure 9 – Synthetic S/N curve (adapted from Haibach, 2006)	60
Figure A.1 – Modular drivetrain	82
Figure A.2 – Modular drivetrain with 3-point suspension	83
Figure A.3 – Integrated drivetrain.....	83
Figure A.4 – Reference system for modular drivetrain.....	85
Figure A.5 – Rear view of drivetrain	86
Figure A.6 – Reference system for modular drivetrain with 3-point suspension	87
Figure A.7 – Reference system for integrated drivetrain.....	88
Figure A.8 – Example of rainflow counting per DLC	90
Figure A.9 – Example of load revolution distribution (LRD)	91
Figure C.1 – Load bin reduction by lumping neighbouring load bins	97
Figure C.2 – Consumed life index (CLI)	99
Figure C.3 – Time share distribution	99
Figure C.4 – Effects of clearance and preload on pressure distribution in radial roller bearings (from Brandlein et al, 1999)	102
Figure C.5 – Nomenclature for bearing curvature	103
Figure C.6 – Stress distribution over the elliptical contact area	105
Figure C.7 – Examples of locating and non-locating bearing arrangements.....	114
Figure C.8 – Examples of locating bearing arrangements.....	114
Figure C.9 – Examples of accommodation of axial displacements	114
Figure C.10 – Examples of cross-locating bearing arrangements	115
Figure C.11 – Examples of bearing arrangements with paired mounting.....	115
Figure D.1 – Locations of failure for local (A) and global (B) failure.....	123
Figure D.2 – Local and global failure for two different notch radii	123
Figure D.3 – Haigh-diagram for evaluation of mean stress influence (Haibach, 2006)	124
Figure E.1 – Viscosity requirements versus pitch line velocity	126
Figure E.2 – Test apparatus for filterability evaluation.....	134
Figure E.3 – Example for circuit design of combined filtration and cooling system.....	138
Table 1 – Symbols used in the document.....	18
Table 2 – Abbreviations	21
Table 3 – Mesh load factor K_γ for planetary stages	35
Table 4 – Required gear accuracy	37
Table 5 – Temperature gradients for calculation of operating clearance	44
Table 6 – Bearing lubricant temperature for calculation of viscosity ratio, κ	46
Table 7 – Guide values for maximum contact stress at Miner’s sum dynamic equivalent bearing load.....	49
Table 8 – Minimum safety factors for the different methods.....	50
Table 9 – Partial safety factors for materials	55
Table 10 – Partial safety factors γ_m for synthetic S/N-curves of cast iron materials.....	61
Table 11 – Recommended cleanliness levels	70

This is a preview of "IEC 61400-4:2012". [Click here to purchase the full version from the ANSI store.](#)

Table A.1 – Drivetrain elements and local coordinate systems	84
Table A.2 – Drivetrain element interface dimensions	85
Table A.3 – Interface requirements for modular drivetrain	86
Table A.4 – Interface requirements for modular drivetrain with 3-point suspension	87
Table A.5 – Interface requirements for integrated drivetrain	88
Table A.6 – Engineering data and required design load descriptions.....	89
Table A.7 – Rainflow matrix example	89
Table A.8 – Example of load duration distribution (LDD)	91
Table A.9 – Extreme load matrix example	92
Table B.1 – Recommended gear tooth surface roughness.....	94
Table C.1 – Guide values for basic rating life L_{h10} for preliminary bearing selection.....	96
Table C.2 – Static load factors for radial bearings	101
Table C.3 – Bearing types for combined loads with axial loads in double directions	110
Table C.4 – Bearing types for combined loads with axial loads in single direction	111
Table C.5 – Bearing types for pure radial load	112
Table C.6 – Bearing types for axial load.....	113
Table C.7 – Bearing selection: Legend.....	116
Table C.8 – Bearing selection: Low speed shaft (LSS) / planet carrier	117
Table C.9 – Bearing selection: Low speed intermediate shaft (LSIS).....	118
Table C.10 – Bearing selection: High speed intermediate shaft (HSIS)	119
Table C.11 – Bearing selection: High speed shaft (HSS).....	120
Table C.12 – Bearing selection: Planet bearing.....	121
Table D.1 – Typical material properties	122
Table E.1 – Viscosity grade at operating temperature for oils with $VI = 90$	127
Table E.2 – Viscosity grade at operating temperature for oils with $VI = 120$	128
Table E.3 – Viscosity grade at operating temperature for oils with $VI = 160$	129
Table E.4 – Viscosity grade at operating temperature for oils with $VI = 240$	130
Table E.5 – Standardized test methods for evaluating WT lubricants (fresh oil).....	132
Table E.6 – Non-standardized test methods for lubricant performance (fresh oil)	133
Table E.7– Guidelines for lubricant parameter limits	136
Table F.1 – Design validation and verification documentation	140

INTERNATIONAL ELECTROTECHNICAL COMMISSION

WIND TURBINES –

Part 4: Design requirements for wind turbine gearboxes

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 IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61400-4 has been prepared by IEC technical committee 88: Wind turbines, in co-operation with ISO technical committee 60: Gears.

It is published as a double logo standard.

This first edition cancels and replaces ISO 81400-4 published in 2005. It constitutes a technical revision of ISO 81400-4 with extended content and changes in all pertinent sections.

This edition includes the following significant technical changes with respect to the previous edition:

- a) extension of the scope to wind turbines above 2 MW rated power;
- b) considerations for converging differing approaches to reliability in gear, bearing and wind turbine standards;
- c) a new clause on wind turbine loads specific to drivetrains;
- d) new clause on testing and validation of new gearbox designs;

This is a preview of "IEC 61400-4:2012". [Click here to purchase the full version from the ANSI store.](#)

- e) updated bearing selection tables for different locations in a wind turbine gearbox;
- f) expanded design considerations on the use of bearings based on avoiding standard failures;
- g) a new clause on considerations and requirements in the design and analysis of gearbox structural elements;
- h) updated considerations and requirements on lubricants and lubrication systems.

The text of this standard is based on the following documents of IEC:

FDIS	Report on voting
88/438/FDIS	88/441/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table. In ISO, the standard has been approved by 11 P-members out of 12 having cast a vote.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61400 series, published under the general title *Wind turbines*, can be found on the IEC website.

The committee has decided that the contents of this 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,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual edition of this document may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

This is a preview of "IEC 61400-4:2012". [Click here to purchase the full version from the ANSI store.](#)

INTRODUCTION

IEC 61400-4 outlines minimum requirements for specification, design and verification of gearboxes in wind turbines. It is not intended for use as a complete design specification or instruction manual, and it is not intended to assure performance of assembled drive systems. It is intended for use by experienced gear designers capable of selecting reasonable values for the factors, based on knowledge of similar designs and the effects of such items as lubrication, deflection, manufacturing tolerances, metallurgy, residual stress and system dynamics. It is not intended for use by the engineering public at large.

Any of the requirements of this standard may be altered if it can be suitably demonstrated that the safety and reliability of the system is not compromised. Compliance with this standard does not relieve any person, organization, or corporation from the responsibility of observing other applicable regulations.