

© Copyright SEK. Reproduction in any form without permission is prohibited.

Vindkraftverk – Del 23: Mekanisk fullskaleprovning av rotorblad

*Wind turbines –
Part 23: Full-scale structural testing of rotor blades*

Som svensk standard gäller europastandarden EN 61400-23:2014. Den svenska standarden innehåller den officiella engelska språkversionen av EN 61400-23:2014.

Nationellt förord

Europastandarden EN 61400-23:2014

består av:

- **europastandardens ikraftsättningsdokument**, utarbetat inom CENELEC
- **IEC 61400-23, First edition, 2014 - Wind turbines - Part 23: Full-scale structural testing of rotor blades**

utarbetad inom International Electrotechnical Commission, IEC.

ICS 27.180.00

Denna standard är fastställd av SEK Svensk Elstandard, som också kan lämna upplysningar om **sakinnehållet** i standarden.
Postadress: Box 1284, 164 29 KISTA
Telefon: 08 - 444 14 00.
E-post: sek@elstandard.se. Internet: www.elstandard.se

Standarder underlättar utvecklingen och höjer elsäkerheten

Det finns många fördelar med att ha gemensamma tekniska regler för bl a mätning, säkerhet och provning och för utförande, skötsel och dokumentation av elprodukter och elanläggningar.

Genom att utforma sådana standarder blir säkerhetsfordringar tydliga och utvecklingskostnaderna rimliga samtidigt som marknadens acceptans för produkten eller tjänsten ökar.

Många standarder inom elområdet beskriver tekniska lösningar och metoder som åstadkommer den elsäkerhet som föreskrivs av svenska myndigheter och av EU.

SEK är Sveriges röst i standardiseringsarbetet inom elområdet

SEK Svensk Elstandard svarar för standardiseringen inom elområdet i Sverige och samordnar svensk medverkan i internationell och europeisk standardisering. SEK är en ideell organisation med frivilligt deltagande från svenska myndigheter, företag och organisationer som vill medverka till och påverka utformningen av tekniska regler inom elektrotekniken.

SEK samordnar svenska intressenters medverkan i SEKs tekniska kommittéer och stödjer svenska experters medverkan i internationella och europeiska projekt.

Stora delar av arbetet sker internationellt

Utformningen av standarder sker i allt väsentligt i internationellt och europeiskt samarbete. SEK är svensk nationalkommitté av International Electrotechnical Commission (IEC) och Comité Européen de Normalisation Electrotechnique (CENELEC).

Standardiseringsarbetet inom SEK är organiserat i referensgrupper bestående av ett antal tekniska kommittéer som speglar hur arbetet inom IEC och CENELEC är organiserat.

Arbetet i de tekniska kommittéerna är öppet för alla svenska organisationer, företag, institutioner, myndigheter och statliga verk. Den årliga avgiften för deltagandet och intäkter från försäljning finansierar SEKs standardiseringsverksamhet och medlemsavgift till IEC och CENELEC.

Var med och påverka!

Den som deltar i SEKs tekniska kommittéarbete har möjlighet att påverka framtida standarder och får tidig tillgång till information och dokumentation om utvecklingen inom sitt teknikområde. Arbetet och kontakterna med kollegor, kunder och konkurrenter kan gynnsamt påverka enskilda företags affärsutveckling och bidrar till deltagarnas egen kompetensutveckling.

Du som vill dra nytta av dessa möjligheter är välkommen att kontakta SEKs kansli för mer information.

SEK Svensk Elstandard

Box 1284
164 29 Kista
Tel 08-444 14 00
www.elstandard.se

EUROPEAN STANDARD

EN 61400-23

NORME EUROPÉENNE

EUROPÄISCHE NORM

May 2014

ICS 27.180

English Version

**Wind turbines - Part 23: Full-scale structural testing
of rotor blades
(IEC 61400-23:2014)**

Éoliennes - Partie 23: Essais en vraie grandeur
des structures des pales de rotor
(CEI 61400-23:2014)

Windenergieanlagen - Teil 23: Rotorblätter -
Experimentelle Strukturprüfung
(IEC 61400-23:2014)

This European Standard was approved by CENELEC on 2014-05-13. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Foreword

The text of document 88/420/CDV, future edition 1 of IEC 61400-23, prepared by IEC TC 88 "Wind turbines" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61400-23:2014.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2015-02-13
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2017-05-13

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 61400-23:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

| | | |
|--------------|------|---|
| IEC 61400-22 | NOTE | Harmonised as EN 61400-22 (not modified). |
|--------------|------|---|

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

| <u>Publication</u> | <u>Year</u> | <u>Title</u> | <u>EN/HD</u> | <u>Year</u> |
|--------------------|-------------|--|------------------|-------------|
| IEC 60050-415 | 1999 | International Electrotechnical Vocabulary - Part 415: Wind turbine generator systems | - | - |
| IEC 61400-1 | 2005 | Wind turbines - Part 1: Design requirements | EN 61400-1 | 2005 |
| ISO/IEC 17025 | 2005 | General requirements for the competence of testing and calibration laboratories | EN ISO/IEC 17025 | 2005 |
| ISO 2394 | 1986 | General principles on reliability for structures | - | - |

CONTENTS

| | |
|--|----|
| FOREWORD..... | 5 |
| INTRODUCTION..... | 7 |
| 1 Scope..... | 8 |
| 2 Normative references | 8 |
| 3 Terms and definitions | 9 |
| 4 Notation..... | 12 |
| 4.1 Symbols..... | 12 |
| 4.2 Greek symbols..... | 12 |
| 4.3 Subscripts..... | 12 |
| 4.4 Coordinate systems | 12 |
| 5 General principles | 13 |
| 5.1 Purpose of tests..... | 13 |
| 5.2 Limit states | 14 |
| 5.3 Practical constraints | 14 |
| 5.4 Results of test..... | 14 |
| 6 Documentation and procedures for test blade..... | 15 |
| 7 Blade test program and test plans | 16 |
| 7.1 Areas to be tested..... | 16 |
| 7.2 Test program | 16 |
| 7.3 Test plans..... | 16 |
| 7.3.1 General | 16 |
| 7.3.2 Blade description..... | 16 |
| 7.3.3 Loads and conditions..... | 17 |
| 7.3.4 Instrumentation..... | 17 |
| 7.3.5 Expected test results | 17 |
| 8 Load factors for testing..... | 17 |
| 8.1 General..... | 17 |
| 8.2 Partial safety factors used in the design..... | 17 |
| 8.2.1 General | 17 |
| 8.2.2 Partial factors on materials | 17 |
| 8.2.3 Partial factors for consequences of failure | 18 |
| 8.2.4 Partial factors on loads..... | 18 |
| 8.3 Test load factors | 18 |
| 8.3.1 Blade to blade variation | 18 |
| 8.3.2 Possible errors in the fatigue formulation..... | 18 |
| 8.3.3 Environmental conditions..... | 19 |
| 8.4 Application of load factors to obtain the target load..... | 19 |
| 9 Test loading and test load evaluation..... | 20 |
| 9.1 General..... | 20 |
| 9.2 Influence of load introduction | 20 |
| 9.3 Static load testing | 20 |
| 9.4 Fatigue load testing | 21 |
| 10 Test requirements..... | 22 |
| 10.1 General..... | 22 |
| 10.1.1 Test records | 22 |
| 10.1.2 Instrumentation calibration..... | 22 |

| | | |
|--|--|----|
| 10.1.3 | Measurement uncertainties | 22 |
| 10.1.4 | Root fixture and test stand requirements | 22 |
| 10.1.5 | Environmental conditions monitoring | 22 |
| 10.1.6 | Deterministic corrections | 23 |
| 10.2 | Static test | 23 |
| 10.2.1 | General | 23 |
| 10.2.2 | Static load test..... | 23 |
| 10.2.3 | Strain measurement | 24 |
| 10.2.4 | Deflection measurement | 24 |
| 10.3 | Fatigue test..... | 24 |
| 10.4 | Other blade property tests | 24 |
| 10.4.1 | Blade mass and center of gravity | 24 |
| 10.4.2 | Natural frequencies | 25 |
| 10.4.3 | Optional blade property tests | 25 |
| 11 | Test results evaluation..... | 25 |
| 11.1 | General..... | 25 |
| 11.2 | Catastrophic failure..... | 25 |
| 11.3 | Permanent deformation, loss of stiffness or change in other blade properties | 26 |
| 11.4 | Superficial damage | 26 |
| 11.5 | Failure evaluation | 26 |
| 12 | Reporting | 26 |
| 12.1 | General..... | 26 |
| 12.2 | Test report content..... | 27 |
| 12.3 | Evaluation of test in relation to design requirements | 27 |
| Annex A (informative) Guidelines for the necessity of renewed static and fatigue testing | | 28 |
| Annex B (informative) Areas to be tested | | 29 |
| Annex C (informative) Effects of large deflections and load direction | | 30 |
| Annex D (informative) Formulation of test load | | 31 |
| D.1 | Static target load..... | 31 |
| D.2 | Fatigue target load..... | 31 |
| D.3 | Sequential single-axial, single location..... | 34 |
| D.4 | Multi axial single location | 34 |
| Annex E (informative) Differences between design and test load conditions..... | | 36 |
| E.1 | General..... | 36 |
| E.2 | Load introduction | 36 |
| E.3 | Bending moments and shear..... | 36 |
| E.4 | Flapwise and lead-lag combinations..... | 36 |
| E.5 | Radial loads..... | 37 |
| E.6 | Torsion loads | 37 |
| E.7 | Environmental conditions | 37 |
| E.8 | Fatigue load spectrum and sequence | 37 |
| Annex F (informative) Determination of number of load cycles for fatigue tests | | 38 |
| F.1 | General..... | 38 |
| F.2 | Background | 38 |
| F.3 | The approach used | 38 |
| Bibliography..... | | 43 |

Figure 1 – Chordwise (flatwise, edgewise) coordinate system 13

Figure 2 – Rotor (flapwise, lead-lag) coordinate system 13

Figure C.1 – Applied loads effects due to blade deformation and angulation 30

Figure D.1 – Polar plot of the load envelope from a typical blade 31

Figure D.2 – Design *FSF* 33

Figure D.3 – Area where design *FSF* is smaller than 1,4 (critical area)..... 33

Figure D.4 – *rFSF* and critical areas, sequential single-axial test..... 34

Figure D.5 – *rFSF* and critical area, multi axial test 35

Figure E.1 – Difference of moment distribution for target and actual test load 36

Figure F.1 – Simplified Goodman diagram 39

Figure F.2 – Test load factor γ_{ef} for different number of load cycles in the test 42

Table 1 – Recommended values for γ_{ef} for different number of load cycles 18

Table A.1 – Examples of situations typically requiring or not requiring renewed testing 28

Table F.1 – Recommended values for γ_{ef} for different number of load cycles 38

Table F.2 – Expanded recommended values for γ_{ef} for different number of load cycles 41

INTERNATIONAL ELECTROTECHNICAL COMMISSION

WIND TURBINES –**Part 23: Full-scale structural testing of rotor blades**

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 61400-23 has been prepared by IEC technical committee 88: Wind turbines.

This first edition cancels and replaces IEC TS 61400-23, published in 2001. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC TS 61400-23:

- a) description of load based testing only;
- b) condensation to describe the general principles and demands.

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

| | |
|------------|------------------|
| CDV | Report on voting |
| 88/420/CDV | 88/448/RVC |

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

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 version of this publication 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.

INTRODUCTION

The blades of a wind turbine rotor are generally regarded as one of the most critical components of the wind turbine system. In this standard, the demands for full-scale structural testing related to certification are defined as well as the interpretation and evaluation of test results.

Specific testing methods or set-ups for testing are not demanded or included as full-scale blade testing methods historically have developed independently in different countries and laboratories.

Furthermore, demands for tests determining blade properties are included in this standard in order to validate some vital design assumptions used as inputs for the design load calculations.

Any of the requirements of this standard may be altered if it can be suitably demonstrated that the safety of the system is not compromised.

The standard is based on IEC TS 61400-23 published in 2001. Compared to the TS, this standard only describes load based testing and is condensed to describe the general principles and demands.

WIND TURBINES –

Part 23: Full-scale structural testing of rotor blades

1 Scope

This part of IEC 61400 defines the requirements for full-scale structural testing of wind turbine blades and for the interpretation and evaluation of achieved test results. The standard focuses on aspects of testing related to an evaluation of the integrity of the blade, for use by manufacturers and third party investigators.

The following tests are considered in this standard:

- static load tests;
- fatigue tests;
- static load tests after fatigue tests;
- tests determining other blade properties.

The purpose of the tests is to confirm to an acceptable level of probability that the whole population of a blade type fulfils the design assumptions.

It is assumed that the data required to define the parameters of the tests are available and based on the standard for design requirements for wind turbines such as IEC 61400-1 or equivalent. Design loads and blade material data are considered starting points for establishing and evaluating the test loads. The evaluation of the design loads with respect to the actual loads on the wind turbines is outside the scope of this standard.

At the time this standard was written, full-scale tests were carried out on blades of horizontal axis wind turbines. The blades were mostly made of fibre reinforced plastics and wood/epoxy. However, most principles would be applicable to any wind turbine configuration, size and material.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-415:1999, *International Electrotechnical Vocabulary – Part 415: Wind turbine generator systems*

IEC 61400-1:2005, *Wind turbines – Part 1: Design requirements*

ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

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