IEC 61400-5

Edition 1.0 2020-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Wind energy generation systems –
Part 5: Wind turbine blades

Systèmes de génération d'énergie éolienne –
Partie 5: Pales d'éoliennes

IEC 61400-5:2020-06(en-fr)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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WIND ENERGY GENERATION SYSTEMS –

Part 5: Wind turbine blades

FOREWORD

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International Standard IEC 61400-5 has been prepared by IEC technical committee 88: Wind energy generation systems.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
88/759/FDIS	88/767/RVD

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

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

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

A list of all parts of the IEC 61400 series, under the general title *Wind energy generation systems*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://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- withdrawn,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.

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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 International Standard, a minimum set of requirements for the design and manufacturing of wind turbine blades are defined.

An approach to a structural design process for the blade is set forth in the general areas of blade characteristics, aerodynamic design, material requirements and structural design. Furthermore, in order to efficiently facilitate the transfer of a blade design to the production environment, this document includes demands for designing for manufacturing.

The requirements for structural design of the wind turbine blade have been developed in a manner to reward innovation, validation, quality and testing. Specifically, the designer will be able claim lower partial safety factors based on, among other items, the diligence of the validation of models and the correlation to testing results.

To ensure a production environment that can facilitate the manufacturing of a blade in accordance with the design, the manufacturing requirements included in this document provide a minimum basis for a quality management system and workshop requirements. In addition, requirements for blade handling, operation and maintenance are described in the close of this document.

WIND ENERGY GENERATION SYSTEMS –

Part 5: Wind turbine blades

1 Scope

This part of IEC 61400 specifies requirements to ensure the engineering integrity of wind turbine blades as well as an appropriate level of operational safety throughout the design lifetime. It includes requirements for:

- aerodynamic and structural design,
- material selection, evaluation and testing,
- manufacture (including associated quality management),
- transportation, installation, operation and maintenance of the blades.

The purpose of this document is to provide a technical reference for designers, manufacturers, purchasers, operators, third party organizations and material suppliers, as well as to define requirements for certification.

With respect to certification, this document provides the detailed basis for fulfilling the current requirements of the IECRE system, as well as other IEC standards relevant to wind turbine blades. When used for certification, the applicability of each portion of this document should be determined based on the extent of certification, and associated certification modules per the IECRE system.

The rotor blade is defined as all components integrated in the blade design, excluding removable bolts in the blade root connection and support structures for installation.

This document is intended to be applied to rotor blades for all wind turbines. For rotor blades used on small wind turbines according to IEC 61400-2, the requirements in that document are applicable.

At the time this document was written, most blades were produced for horizontal axis wind turbines. The blades were mostly made of fiber reinforced plastics. However, most principles given in this document would be applicable to any rotor blade configuration, size and material.

2 Normative references

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.

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

IEC 61400-1, *Wind energy generation systems – Part 1: Design requirements*

IEC 61400-2, *Wind turbines – Part 2: Small wind turbines*

IEC 61400-3-1, *Wind energy generation systems – Part 3-1: Design requirements for fixed offshore wind turbines*

IEC 61400-3-2, *Wind energy generation systems – Part 3-2: Design requirements for floating offshore wind turbines*

IEC 61400-23, *Wind turbines – Part 23: Full-scale structural testing of rotor blades*

IEC 61400-24, *Wind energy generation systems – Part 24: Lightning protection*

ISO/IEC 17021-1, *Conformity assessment – Requirements for bodies providing audit and certification of management systems – Part 1: Requirements*

ISO 10474, *Steel and steel products – Inspection documents*

ISO 2394, *General principles on reliability for structures*

ISO 9000, *Quality management systems – Fundamentals and vocabulary*

ISO 9001, *Quality management systems – Requirements*

EN 10204, *Metallic products – Types of inspection documents*

ISO 16269-6, *Statistical interpretation of data – Part 6: Determination of statistical tolerance intervals*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-415 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
blade root
that part of the rotor blade that is connected to the hub/pitch-bearing of the rotor

3.2
blade subsystem
integrated set of items that accomplish a defined objective or function within the blade (e.g., lightning protection subsystem, aerodynamic braking subsystem, monitoring subsystem, aerodynamic control subsystem, etc.)

3.3
buckling
instability characterized by a non-linear increase in out of plane deflection with a change in local compressive load

3.4
characteristic value
value having a prescribed probability of not being attained (i.e. an exceedance probability of less than or equal to a prescribed amount)

3.5
chord
length of a reference straight line that joins the leading and trailing edges of a blade aerofoil cross-section at a given spanwise location

3.6
creep
time-dependant increase in strain under a sustained load

3.7
design limits
maximum or minimum values used in a design

3.8
design loads
loads the blade is designed to withstand, including appropriate partial safety factors

3.9
design properties
material and geometric properties (including design limits)

3.10
edgewise
direction that is parallel to the local chord

3.11
environmental conditions
characteristics of the environment (wind, altitude, temperature, humidity, etc.) which may affect the wind turbine blade behaviour

3.12
flapwise
direction that is perpendicular to the surface swept by the undeformed rotor blade axis

3.13
flatwise
direction that is perpendicular to the local chord, and spanwise blade axis

3.14
inboard
towards the blade root

3.15
lead-lag
direction that is parallel to the plane of the swept surface and perpendicular to the longitudinal axis of the undeformed rotor blade

3.16
limit state
state of a structure and the loads acting upon it, beyond which the structure no longer satisfies the design requirement

3.17
load envelope
collection of maximum design loads in all directions and spanwise positions

3.18
natural frequency
eigen frequency
frequency at which a structure will vibrate when perturbed and allowed to vibrate freely

3.19
partial safety factors
factors that are applied to loads and material strengths to account for uncertainties in the representative (characteristic) values

3.20
prebend
blade curvature in the flapwise plane in the unloaded condition

3.21
spanwise
direction parallel to the longitudinal axis of a rotor blade

3.22
stiffness
ratio of change of force to the corresponding change in displacement of an elastic body

3.23
strain
ratio of the elongation (or shear displacement) of a material subjected to stress to the original length of the material

3.24
sweep
blade curvature in the lead-lag plane in the unloaded condition

3.25
twist
spanwise variation in angle of the chord lines of blade cross-sections

3.26
critical to quality
CTQ
process or design value that is measurable and specifies critical acceptance criteria

4 Notation

4.1 Symbols

F	load
F_d	design value for the load
F_k	characteristic value for the load
R	resistance of material or structure against the corresponding limit state
R_k	characteristic material resistance
PSF	Partial Safety Factor
S()	function for structural response to the load
T_g	glass transition temperature
$p_{\perp\parallel}$ (−)	negative Puck inclination parameter
$p_{\perp\parallel}$ (+)	positive Puck inclination parameter

4.2 Greek symbols

γ Partial safety factor

4.3 Subscripts

m materials

m0 materials as a “base” material factor (to be included in all analyses)

m1 materials for environmental degradation (non-reversible effects)

m2 materials for temperature effects (reversible effects)

m3 materials for manufacturing effects

m4 materials for calculation accuracy and validation of method

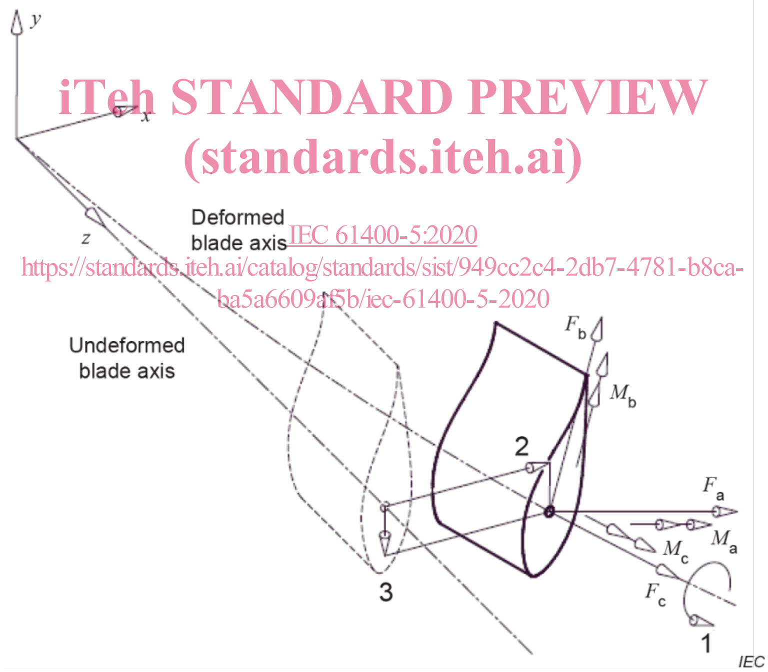
m5 materials for load characterization

n consequence of failure

f factor for loads

4.4 Coordinate systems

Coordinate systems for loads and design reference are shown in Figure 1 and Figure 2.



Loads are along and perpendicular to the local blade chord directions.

Key

M_a edgewise bending moment

M_b flatwise bending moment

M_c torsion moment

F_a flatwise shear force

F_b edgewise shear force

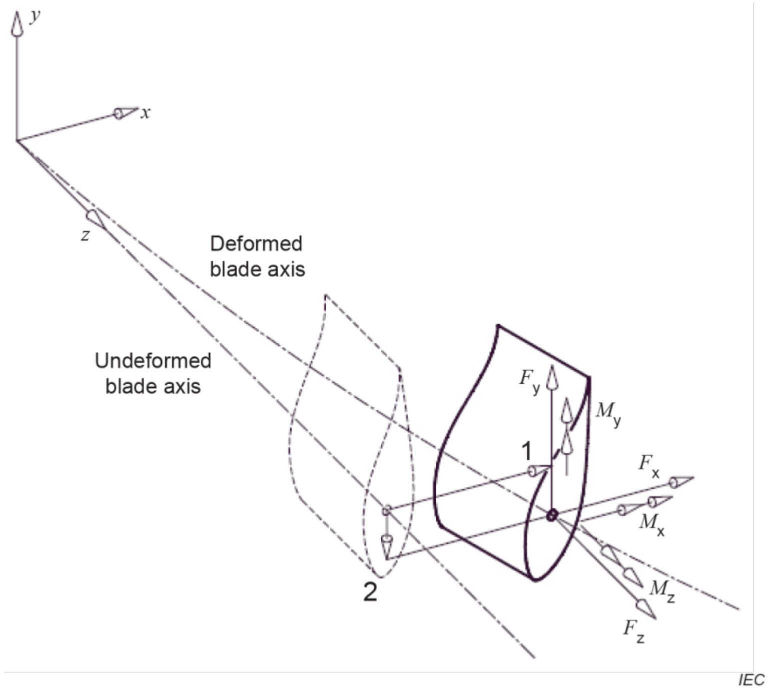
F_c axial force

1 torsion angle

2 flapwise translation

3 lead-lag translation

Figure 1 – Chordwise (flatwise, edgewise) coordinate system



Loads are along the rotor plane reference directions.

Key

M_x lead-lag bending moment

M_y flapwise bending moment

M_z torsion moment

F_x flapwise shear force

F_y lead-lag shear force

F_z spanwise force

1 flapwise translation

2 lead-lag translation

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

5 Design environmental conditions

Wind turbine blades are subjected to environmental conditions that may affect their loading, durability and operation. To ensure the appropriate level of safety and reliability, the design environmental conditions shall be taken into account and explicitly stated in the design documentation. This shall include but is not limited to the environmental conditions specified in IEC 61400-1, IEC 61400-3-1 or IEC 61400-3-2, and IEC 61400-24 (for lightning).

The environmental conditions are divided into normal and extreme categories. The normal environmental conditions generally concern recurrent structural loading conditions, while the extreme environmental conditions represent infrequent external design conditions. The design load cases defined in IEC 61400-1, IEC 61400-3-1 or IEC 61400-3-2 include combinations of these environmental conditions with wind turbine operational modes and other design situations.

When additional environmental conditions not listed in the above references are specified by the designer, the parameters and their values shall be stated in the design documentation.

It shall be taken into account that these environmental conditions may vary for different phases of the product lifecycle (manufacturing, transport/storage, installation, operation or dismantling).

6 Design

6.1 Structural design process

6.1.1 General requirements

The structural design process shall ensure that the required operation safety levels are met for the entire design lifetime and loading of the blade.

The design shall be sufficiently described and specified to ensure that assumptions made during the design process can be met and complied with during the manufacturing process.

The allowable manufacturing tolerances and acceptance criteria shall be defined by the designer and specified in the design documentation.

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

6.1.2 Building block approach for composite structural design

The traditional detailed design (analytic and numerical calculation together with validated material data and full blade testing) of FRP structures can be enhanced by a building-block approach, starting with coupon-level tests, analysis and testing of more complicated structures; and culminating in a full blade test. This relationship is shown in Figure 3, where increasingly more complex tests are developed to evaluate more complicated loading conditions and failure modes.

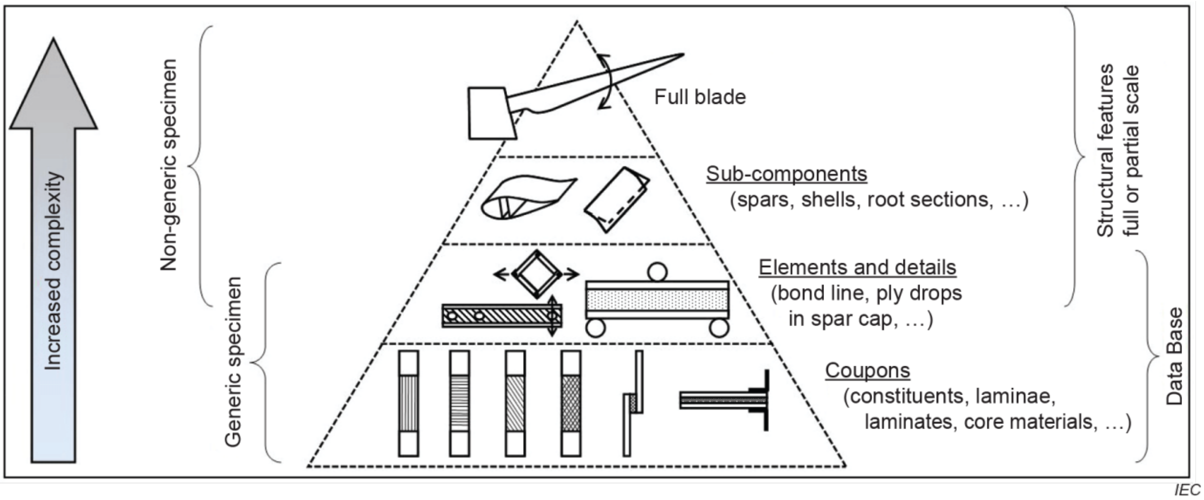


Figure 3 – The building block approach

The approach can be summarized as follows:

<u>Coupons:</u> A number of tests are conducted at the coupon level, where confidence in repeatable physical properties is developed. Procurement specifications are developed for the individual constituents, and allowable design variables developed for lamina/laminate combinations.