IEC TS 61400-28

Edition 1.0 2025-03

TECHNICAL SPECIFICATION

Wind energy generation systems –
Part 28: Through-life management and life extension of wind power assets

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.180

ISBN 978-2-8327-0295-6

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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IEC TS 61400-28 has been prepared by IEC technical committee 88: Wind energy generation systems. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
88/955/DTS	88/1053/RVDTS

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 Technical Specification 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.

A list of all parts in the IEC 61400 series, published 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 webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

The purpose of this Technical Specification (TS) is to define a common basis for the management of physical and digital assets associated with wind farms throughout the operating life. The objective is to ensure the integrity of the structure whilst operating, both within the design life and beyond. The focus of the guidance in this document is safety, defined as ensuring the structural integrity of the components in the primary load path of a given turbine or site and the continued function of critical systems. It is anticipated the reader will make an assessment of risks and uncertainties, aligned with safety, technical and commercial requirements of the particular project, in order to determine the level of detail justified for any assessments undertaken.

This document has been published to enable wind farm operators to manage the production of electricity from wind turbines for the longest possible safe time, delaying the unnecessary social and environmental costs of premature decommissioning. Defined here are the procedures for amassing the minimum body of evidence to justify continued operation.

It is highlighted that the cumulative uncertainty, as defined in ISO/IEC guide 98-3 and estimated using methods defined in this document, including uncertainties in calculations, are used to estimate the variability of the results. It is described how this variability is to be stated alongside any estimates of remaining life of components.

Regarding risks to personnel or third parties, no attempt is made to incorporate the many individual interpretations by regulatory authorities in different regions or jurisdictions.

The earlier in the wind farm operational life the guidance in this document is implemented the better, but suitable procedures can be developed and followed, by any stakeholder, at any point in the life of a wind farm. The guidance should be applied to each mode of failure for each component in the primary load path and associated critical systems. Estimates of life can be made, relating to the most significant mode of failure and taking full account of specific conditions at the site and operational practices. Phases of operation, at which this guidance can be applied, include amongst others the following:

- reviews of site-specific assessed life prior to construction,
- site specific expected life at end-of-warranty,
- points of re-financing and sale,
- proposed extended operation beyond the site-specific assessed life.

The guidance can be used by designers, manufacturers, developers, operators or third parties and can be used as part of due diligence. Application by stakeholders of practices and techniques specified in this document can be used to minimise costs of operation and maximise safe, useful, productive life. In particular, recommendations are given and approaches described for the assessment of the following examples of situations:

- historical duty, usage and working life consumed,
- current component health, and
- expected future remaining life.

These could be used to assess the condition and productivity of individual turbines, safety systems and the primary structure at specific turbine locations within a wind farm or comprehensively for all locations of a site. The principles defined, practical guidance and theoretical techniques described could be used to update the expected useful life of the assets. Additionally, assessments of expected technical availability, reliability and safe operation beyond the end of the design life could also be made.

IEC 61400-1, IEC 61400-2, IEC 61400-3-1 and IEC 61400-3-2, contain minimal requirements for design, ensuring structural integrity of wind turbines, under standardized classes of meteorological conditions and operational practices. Also included are many other contextual conditions affecting loading and expected life. IECRE OD-502 describes the certification of a wind farm project. If the wind farm is certified, loads analysis will be used to estimate site specific life prior to construction. IEC TS 61400-28 is the only document amongst the IEC 61400 series which describes the following:

- method for updating the lifetime (estimated prior to construction) for a specific site,
- which is being operated under specific site conditions and management procedures,
- which shows symptoms of degradation, having experienced specific modifications, faults or failures, taking into account evidence of turbine reliability, changes of operational status, including starts, stops, errors, warnings, curtailment, sector management and grid outages.

It is recommended to re-assess the lifetime on this basis at regular periods during the life of the wind farm. In particular, it should be assessed whether or not it would be safe to continue operation of the wind farm, beyond the expected lifetime or beyond that stated in the type certificate, if available for the wind turbine. Turbines could prove to be safe and suitable to produce additional electricity, either during or beyond the site-specific lifetime. It is important to note that these are estimates of remaining lifetime, whether based on observations, measurements, statistical methods or simulations. The actual lifetime, with respect to the most significant mode of failure, can be longer or shorter.

It could be appropriate to adjust the values of factors of safety or uncertainties, which were applied prior to construction at the design stage, associated with key parameters required to estimate integrity and life. Evidence to support any such adjusted values is provided, whether through applying best practices of wind farm operation, collecting information about the conditions at each turbine, the production, the maintenance tasks undertaken, the condition of critical components, the modes of failure and their consequences.

This document may be used to define the technical inputs to any economic assessments, developed by stakeholders to value assets throughout their lifetime, but does not describe any particular economic models.

The focus of this document is on components in the primary load path and the safety system. For loading and structural integrity, accumulation of fatigue damage is described. Regarding ultimate limit states, however, comprehensive guidance is not given about methods to reassess and update the statistics of extreme conditions, faults and failures which contribute to the ultimate limit state. Detailed analyses of the reliability of components outside the primary load path are not described here, even though these aspects could contribute to the objectives of this document. It is left to the reader to extend the methods described in this document if relevant to topics relating to component reliability, with reference to IEC TS 61400-26-4.

WIND ENERGY GENERATION SYSTEMS –

Part 28: Through-life management and life extension of wind power assets

1 Scope

This part of IEC 61400, which is a Technical Specification, sets out minimum requirements for actions, investigations and assessments to ensure the continued structural integrity of wind farm assets, particularly wind turbines, aimed at verifying that they remain safe for personnel to operate. The document describes how to maintain those assets and collect suitable evidence to demonstrate to third parties that risks are minimised, particularly where risks are related to collateral damage or injury, such as could be suffered by personnel or structures neighbouring the wind farm.

Covered in this document are assessments of current condition and remaining useful life, resulting in the technical basis for justifying extended operation beyond the design life (defined in 3.1.3) and also beyond the site specific assessed lifetime, whichever is shorter, for structural or major components and systems contributing to primary layer of the safety system. Guidance is also given on how best to manage a wind farm throughout the operational life.

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 60300-3-11:2009, *Dependability management – Application guide – Reliability centred maintenance*

IEC 60812:2018, *Failure modes and effects analysis (FMEA and FMECA)*

IEC 61400-1:2019, *Wind energy generation systems − Part 1: Design requirements*

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

IEC 61400-3-1:2019, *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 61400-6, *Wind energy generation systems – Part 6: Tower and foundation design requirements*

IEC 61400-12-1, *Wind energy generation systems – Part 12-1: Power performance measurements of electricity producing wind turbines*

IEC 61400-12-2, *Wind energy generation systems – Part 12-2: Power performance measurements of electricity producing wind turbines based on nacelle anemometry*

IEC 61400-13, *Wind turbines – Part 13: Measurement of mechanical loads*

IEC 61400-25-1:2017, *Wind energy generation systems – Part 25-1: Communications for monitoring and control of wind power plants – Overall description of principles and models*

IEC 61400-25-2:2015, *Wind turbines − Part 25-2: Communications for monitoring and control of wind power plants − Information models*

IEC 61400-26-1, *Wind energy generation systems − Part 26-1: Availability for wind energy generation systems*

IEC TS 61400-26-4, *Wind energy generation systems − Part 26-4: Reliability of wind energy generation systems*

IEC 61511 (all parts), *Functional safety − Safety instrumented systems for the process industry sector*

ISO/IEC Guide 98-3 *Uncertainty of measurement − Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO 13381-1:2015, *Condition monitoring and diagnostics of machines – Prognostics – Part 1: General guidelines*

ISO 13822, *Bases of design for structures – Assessment of existing structures*

ISO 2394:2015, *General principles on reliability for structures*

EN 1990, *Basis of structural design*

WMO-TD No 1186, *Guidelines on Climate Data and Homogenization*