A Revised International Standard for Gearboxes in Wind Turbine Systems

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IEC TC88/ ISO TC60 revision of IEC 61400-4

- Joint working group between IEC TC88 Wind Energy & ISO TC60: Gears
- Strong participation - ISO TC4: Rolling bearings & ISO TC28: Lubricants
- Created four documents for clarity and to simplify revision process
- **To be circulated soon for ballot and comment**

Document	Title	Type	Status	Pub?
IEC 61400-4	Design requirements for wind turbine gearboxes	International standard	Submit as CDV	‘23
IEC/TS 61400-4-1	Reliability assessment of drivetrain components in wind turbines	Technical specification	CD	‘23
IEC/TR 61400-4-2	Lubrication of drivetrain components in wind turbines	Technical report	CD	‘23
IEC/TR 61400-4-3	Explanatory notes on IEC 61400 4 - Supportive information for wind turbine gearbox design	Technical report	CD	‘23

IEC TC88 WTG standards influencing Ed. 2

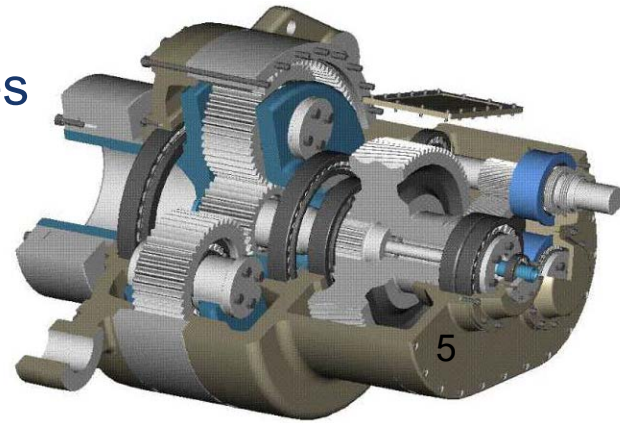
Standard	Title/Subject	Modifications to Edition 2
IEC 61400-1:2019	**Design requirements**	some partial safety factors on materials and loads changed in edition 4
IEC 61400-3-1	Design requirements for **fixed offshore wind** turbines	supplemental reference to IEC 61400-1, component designers should recognize more complex loading and environment
IEC CDV 61400-3-2	Design requirements for **floating offshore wind** turbines	supplemental reference to IEC 61400-1, designers should recognize added floating degrees of freedom
IEC CDV 61400-8	Design of wind turbine **structural components**	removed structures design clause and informative Annex, replace with reference to 61400-8

ISO TC60 Gear standards influencing Ed. 2

Standard	Title/ subject	Modifications to Edition 2
ISO 6336-2:2019	Part 2: Calculation of surface durability (**pitting**)	revisit minimum safety factors compared to 2006
ISO 6336-3:2019	Part 3: Calculation of **tooth bending** strength	revisit minimum safety factors compared to 2006
ISO/TS 6336-4:2019	Part 4: Calculation of **tooth flank fracture** load capacity	added new tooth flank fracture (TFF) risk recommendations

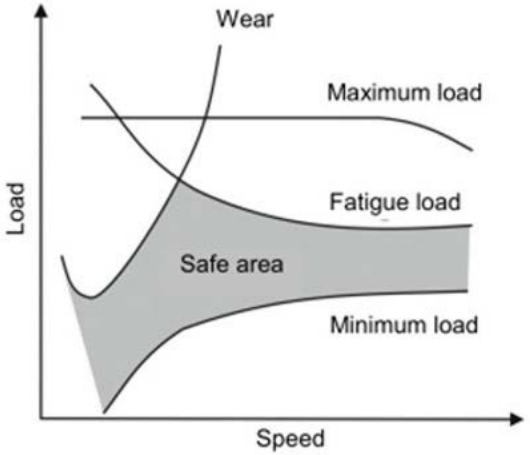
Changes in Edition 2

- Reduced main document to just design requirements
- Moved informative content to technical reports for clarity
- Encourages use of design FMEA to identify failure mode risks and inform verification process
- Ensure that design requirements are objectively verifiable
- Changed selected gear clause requirements based on updated ISO 6336 standards
  - Changed min. safety factors for pitting and tooth bending fatigue life
  - Considerations for tooth flank fracture and scuffing risk
- Added plain bearings clause
- Removed structures clause and Annex
  - deferred to new IEC 61400-8: WTG Structures
- New Reliability model TS
  - For comparing different design options
  - Or different operating conditions
  - Only includes calculable failure modes



Changes in Edition 2: Rolling bearings

- Clause on WECs and potential mitigation methods
- Clarifications provided on use of ISO /TS 61281 life estimation
- Allow only static rating calculations using “stress-based” analysis with actual load distributions
- Increased the a_{ISO} (L_{nmr}/L_{nr}) limit from 10 to 15
- Allowable contact stress table updated for consistency
- Bearing Annex C (simplified analysis) moved to Explanatory NotesTR
- Bearing selection tables removed



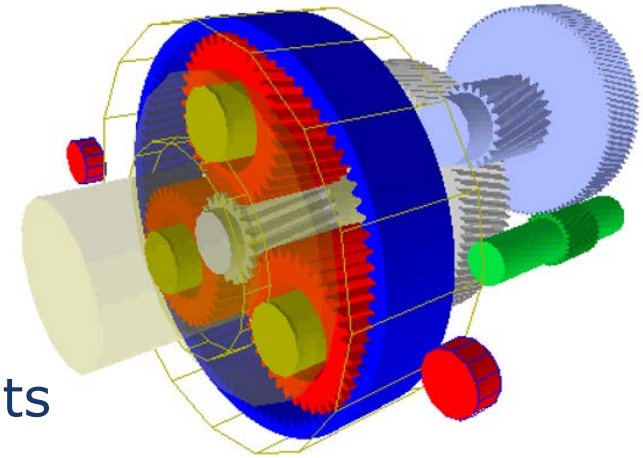
Edition 2 changes – Lubrication

- Lubrication main clauses – just requirements
- Created lubrication Technical Report for recommended practices on
  - lubrication selection,
  - condition monitoring,
  - additives,
  - properties,
  - filtration,
  - lubricant system design,
  - maintenance, etc.

Photo by Shawn Doner, Flender Corporation, NREL 49750

Edition 2 changes – Explanatory notes TR

- Explanation of gear fatigue life analysis factors and history of the minimum life factors
- Description of comparing gear life rating using Ed. 1 vs. Ed. 2 approach w/ ISO standards
- Background for bearing contact stress limits and use of a_{ISO} life modification factor
- Retained stress-based bearing analysis approach from Ed. 1 annex
- Some guidance on bearing arrangements, but selection tables were removed
- Background on robustness and accelerated life testing and how it changed through editions



Edition 2 changes – Verification & Validation

- Goal: reduce design uncertainty and confirm design assumptions
- Testing is to be performed based on the critical systems analysis at the design phase (e.g., FMEA)
- Failure modes for all critical elements are identified and categorized
- Ed. 2 includes a description of 4 tests with increasing levels of integration – from a gearbox test to a complete nacelle or turbine
- Depending on the failure mode different tests can be used to verify performance to the design requirements
- Alternative methods such as similarity (to previously tested and demonstrated designs) and simulated testing are allowed in some modes

Failure mode categorization

	A1	A2	B	C
Load/ stressor profile	Deterministic (loaded by defined stress)	Deterministic (loaded by defined stress)	Stochastic (loaded by friction, abrasion, extreme temps, debris)	Stochastic (randomly loaded by impacts, friction, etc.)
Assessment/ calculation	**Validated models available**	Validated models not available	Some models available	**No models available**
Type	Cumulative	Cumulative	Non-cumulative	Cumulative/ Non-cumulative
Failure mode examples	Tooth bending, bearing rolling contact fatigue	Tooth flank fracture, bearing WEC	Scuffing	Debris damage, fluting

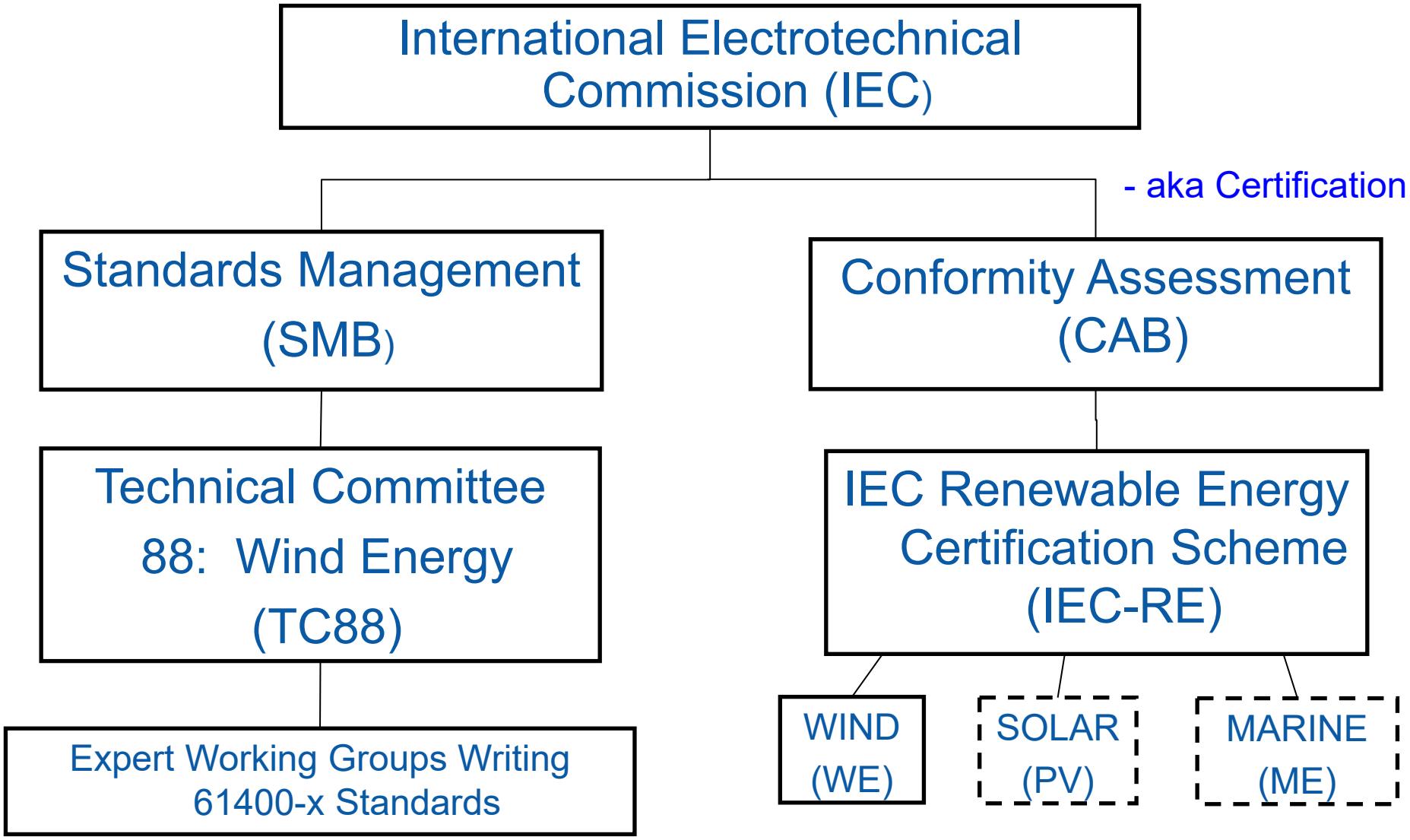
Physical tests prescribed in Edition 2

Test	Type	Outcomes	Configuration and Loads
T1	Functional tests	K-factors, deflection, temperature stability, dynamics	**gearbox only** test environment, apply min. 120% reference torque min. 1 hr, speed sweeps, torque steps
T2	Robustness test	non-calculable failure modes	various levels of **drivetrain integration**
T3	Climate tests	temperature, lubricant, bearings	**extreme climactic conditions**
T4	Integrated system test	influences from whole system integration	**complete turbine in-field or full nacelle** in test rigs, start up, shutdown, e-stops, grid events, low load, electrical events

Verification matrix for gear failure risks

Failure mode	Type	Detection	Simulation	Similarity	Testing	Acceptance criteria
Load distribution for planetary stages	F	Load distribution magnitudes	Y		T1 or T4	Measured K_{Hb} and $K_v K_g$ load factors less than or equal to requirement
Load distribution - parallel stages	F	Visual inspection	Y		T1 or T4	Contact area within ±10% of simulated area
Surface durability	A1	Visual inspection		Y	T2	No pitting as per ISO 10825-1
Tooth root fatigue fracture	A1	Visual inspection		Y	T2	No tooth breakage or initial cracks as per ISO 10825-1
Scuffing	B	Visual inspection		Y	T2	No scuffing as per ISO 14635-1:2000
Micropitting	B	Visual inspection		Y	T2	No micropitting as per ISO 10825-1
Tooth flank fracture	A2	Visual inspection	essentially A1	Y	T2	No fracture as per ISO 10825-1
Tooth rim fracture	A2	Visual inspection		Y	T2	No surface crack

Organizational Structure for IEC International Standards and Certification



You are invited to participate by contacting your national standards organization. Find via IEC.ch or ISO.org

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