IEC 61400-3 Design Standards for Offshore Wind Turbines

Status of the Second Edition

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Design Standards Process, IEC 61400-3

International Electrotechnical Commission (IEC)

- Based on and extension of IEC 61400-1→
- Prepare preliminary design (“PD”)
- Develop/apply structural dynamic model of PD
- Specify external conditions
- Specify load cases
- Determine structural loads and stresses
- Check that stresses are acceptable, given chosen material
- Adapt design if necessary and repeat

Scope of IEC 6100-3

- Specifies additional requirements (beyond IEC 61400-1) for:
  - assessment of the external conditions at an offshore wind turbine site and
  - it specifies essential design requirements to ensure the engineering integrity of offshore wind turbines

Scope (2)

- Engineering integrity of the structural components of an offshore wind turbine
- Subsystems such as control and protection mechanisms, internal electrical systems and mechanical systems

Scope (3)

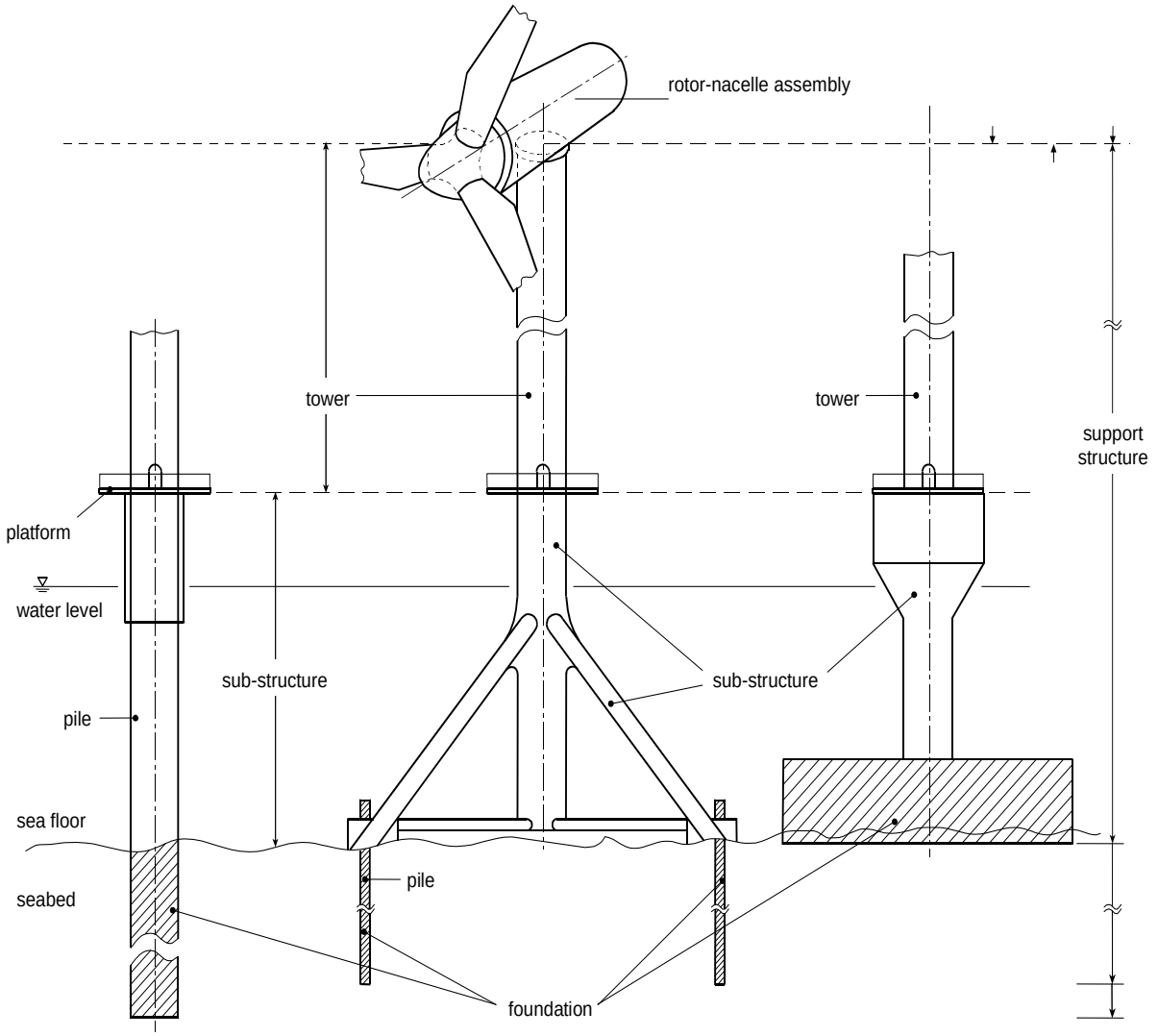
- A wind turbine shall be considered as an ***offshore wind turbine*** if the support structure is subject to hydrodynamic loading.
- Not sufficient for floating offshore wind turbines
    - 61400-3 is now being supplemented by a recommend practice (RP) for FOWTs

Scope (4)

- To be used together with other standards, including but not limited to:
  - IEC 61400-1, *Wind turbines – Part 1: Design requirements*
  - Other IEC standards
  - International Standard Organization (ISO) standards

Parts of an Offshore Wind Turbine

- Defined here
- Includes:
  - Rotor/nacelle assembly (RNA)
  - Support structure
  - Substructure
  - Foundation



Preliminary Design

- Assessment done on preliminary design (PD)
- PD based on application, with reference to design process discussed previously

Design Methods

- Requires the use of a structural dynamics model of PD to predict design load effects
- Load effects to be determined for all relevant combinations of external conditions and design situations
- Design of support structure to be based on site-specific external conditions
- Design of RNA to be based on IEC 61400-1 (to extent possible)

Safety Classes

- Normal safety class
  - When failure results in risk of personal injury or other social or economic consequence
- Special safety class
  - Local regulations and/or as agreed upon by the manufacturer and the customer

External Conditions

- Wind conditions
- Marine conditions
  - **Waves**, sea currents, water level, sea ice, marine growth, seabed movement and scour
- Soil properties at the site
  - Including time variation due to seabed movement, scour and other elements of seabed instability
- Other environmental conditions

External Conditions (2)

- Normal
  - Recurrent structural loading conditions
- Extreme
  - Rare external design conditions

Wind Turbine Classes

- Follows that of IEC 61400-1 (on shore)
- Based on: wind speed and turbulence parameters (I, II, II) and special conditions (S)

Table 1 – Basic parameters for wind turbine classes[2]

Wind turbine class		I	II	III	S
V_{ref}	(m/s)	50	42,5	37,5	Values
A	I_{ref} (-)	0,16			specified
B	I_{ref} (-)	0,14			by the
C	I_{ref} (-)	0,12			designer

- Design lifetime: at least 20 years

Loads to be Considered

- Gravitational and inertial loads
- Aerodynamic loads
- Hydrodynamic loads (due to waves)
- Actuation loads (assoc. with control)
- Floating sea ice loads
- Other loads:
  - Wake loads, impact loads, blade ice loads, etc.,

Load Cases: Overview

- Ultimate loads/fatigue loads
- Normal conditions/unusual conditions
- Operating/non-operating
- Categorized according to “situation”

Types of Loads

- Ultimate (U)
  - Normal (N), abnormal (A), or transport and erection (T)
  - Consider: material strength, blade tip deflection and structural stability (e.g. Buckling)
- Fatigue (F)
  - Fatigue loads/fatigue strength

Typical Example

Design situation	DLC	Wind condition	Waves	Wind and wave directionality	Sea currents	Water level	Other conditions	Type of analysis	Partial safety factor
2) Power production plus occurrence of fault	2.1	NTM $V_{in} < V_{hub} < V_{out}$	NSS $H_s=E\,[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL	Control system fault or loss of electrical network	U	N
	2.2	NTM $V_{in} < V_{hub} < V_{out}$	NSS $H_s=E\,[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL	Protection system or preceding internal electrical fault	U	A
	2.3	EOG $V_{hub} = V_r \pm 2$ *m/s* and V_{out}	NSS (or NWH) $H_s=E\,[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL	External or internal electrical fault including loss of electrical network	U	A
	2.4	NTM $V_{in} < V_{hub} < V_{out}$	NSS $H_s=E\,[H_s \mid V_{hub}]$	COD, UNI	No currents	NWLR or ≥ MSL	Control, protection, or electrical system faults including loss of electrical network	F	*

Ultimate Strength Analysis

- Find characteristic **load effect**, L, from analysis
- Find design **load effect**, S_d, using load safety factor, γ_L

$$S_d = \gamma_L L$$

- Find characteristic **material resistance**, R, from literature (or other source)
- Find design **material resistance**, R_d, using material safety factor, γ_R

$$R_d = \frac{1}{\gamma_R} R$$

Ultimate Strength Analysis (2)

- Material resistance must exceed load effect:

$$\gamma_L L \leq \frac{1}{\gamma_R} R$$

Other Considerations

- Control and protection system
- Mechanical systems
  - drive train (gearbox, shafts couplings, etc.)
  - auxiliary items (brakes, pitch controls, yaw drive)
- Electrical system
  - See IEC 61400-1
- Foundation
  - See ISO 19901-4

Assessment of Metocean External Conditions

- Wind speeds and directions;
- Significant wave heights, wave periods and directions;
- Correlation of wind and wave statistics;
- Current speeds and directions;
- Water levels;
- Occurrence and properties of sea ice;
- Occurrence of icing;
- Other parameters: air, water temperatures, densities; water salinity; bathymetry, marine growth, etc

Assessment of Soil Conditions

- Not discussed in detail in 61400-3
- Other documents are referred to

Topics in 61400-3 (1st ed.) Reconsidered

- Load calculations and simulations
- External design conditions
- Assessment of external conditions
- Support structure and foundation design
- The various annexes on design approaches
- Text referring to issues treated by IEC 61400-1

Most Significant Changes

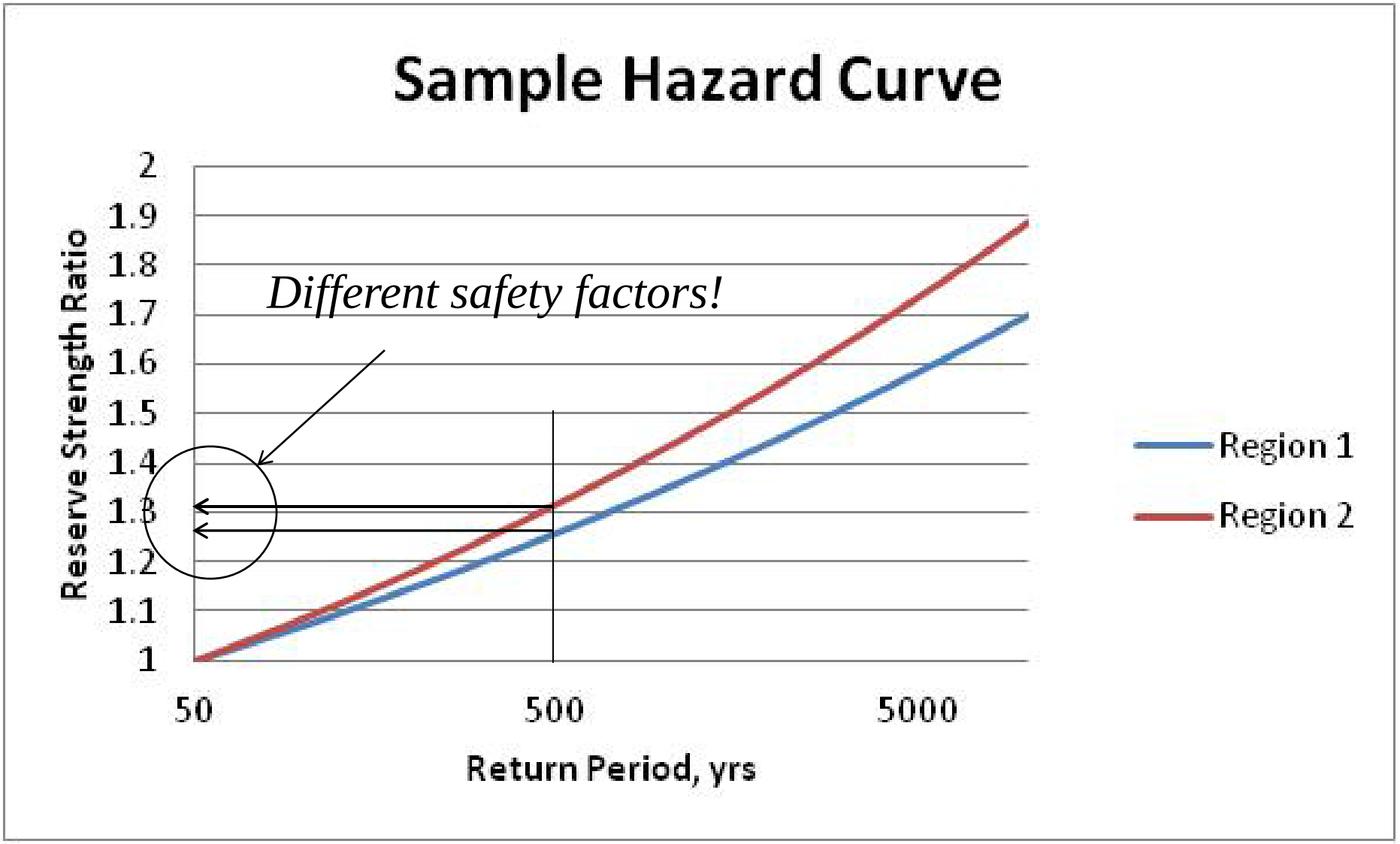
- Explicit consideration of hurricanes/tropical cyclones
- Revised floating ice section
- Revised waves section
- New offshore normal turbulence model (still under consideration)
- More use of references to other documents

Example: Hurricanes/Cyclones

- Robustness check method of API RP 2A and API 2MET recommended
- Must be able to survive 500 year storm
- Characterized by:
  - "Reserve strength ratio", RSR

$$\mathbf{RSR} = \frac{\mathbf{Ultimate\ Resistance}}{\mathbf{Design\ Load}}$$

  - "Hazard curve"→load vs. return period

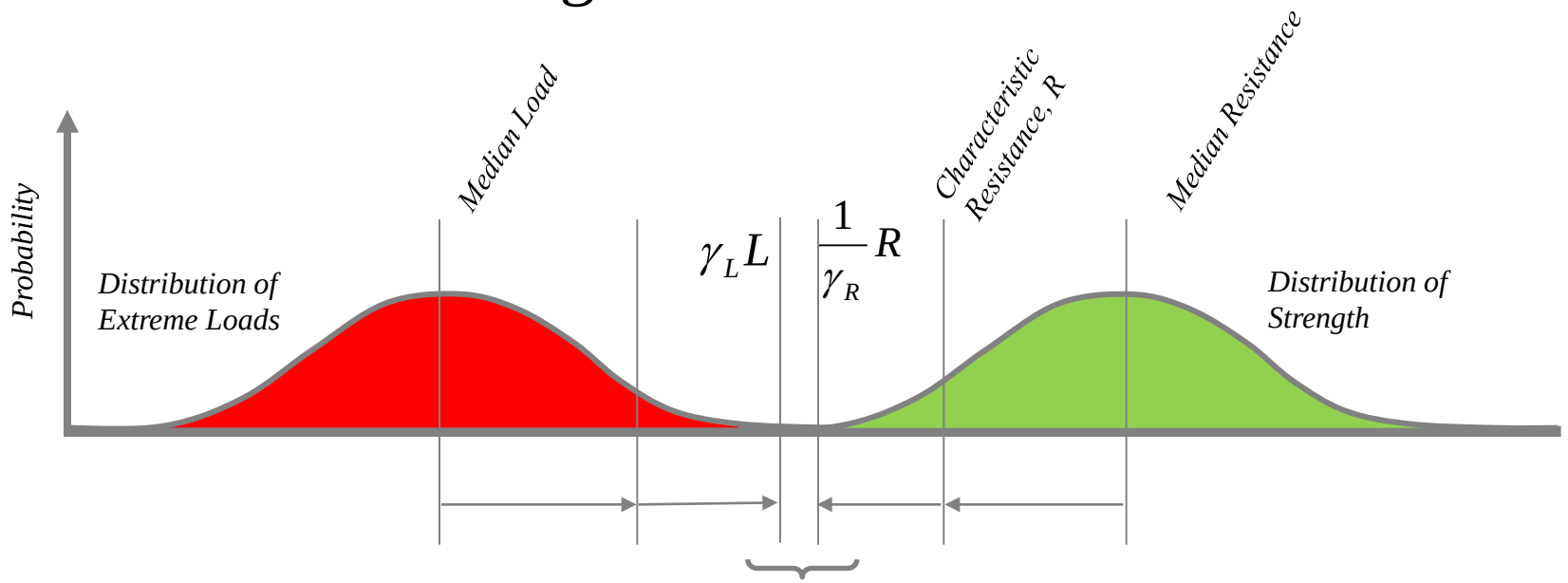

Sample Hazard Curve
Reserve Strength Ratio
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
Different safety factors!
50
500
5000
Return Period, yrs
Region 1
Region 2

IEC 61400-1

- Fourth edition nearing completion
- Relevant areas of revision→
  - Cold climate
  - Tropical Storms
  - Wakes
  - Safety Factors
    - (target reliability → failure probability = 5.0×10^{-4})
  - Design Load Cases
  - Site Assessment
  - Electrical

Example: Safety Factors

- Background document on partial safety factors
- Update of text related to safety factor
  - Probabilistic design considered→



Status of IEC 61400-3

- Next meeting to be held June 24-25
- Committee Draft (CD) near completion
- Consistency check with 61400-1
- Final Draft International Standard (FDIS) should be complete within 12 months