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Germany

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Design basis for the feasibility evaluation of four different floater designs

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LIFES50+

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Design Basis

- Design Basis forms the first step towards design

- The European Union-funded project LIFEs50+ as part of Horizon2020 framework.

- Contributors to Design Basis include:
  - *DNV GL*
  - *University of Stuttgart*
  - *Iberdrola IC*
  - *IDEOL*
  - *Nautilus*
  - *Olav Olsen*
  - *Tecnalia*

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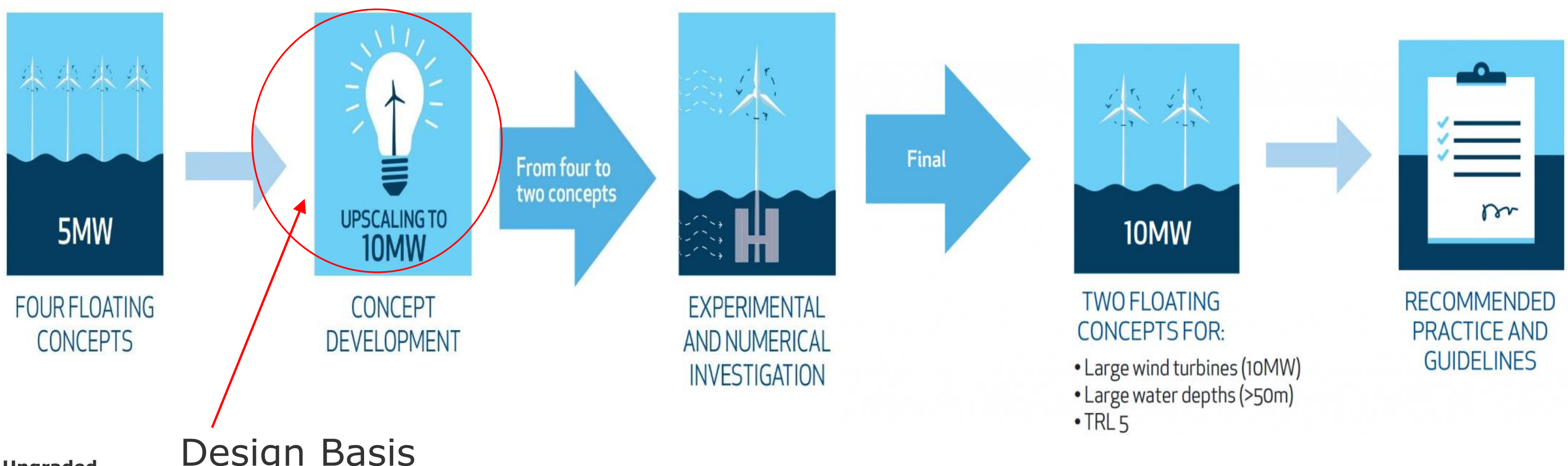
Introduction – LIFES50+ project

- LIFEs50+ Project Objectives:
  - Optimize and qualify to a TRL of 5, two innovative substructure designs for 10MW turbines
  - Develop a streamlined and KPI-based methodology for the evaluation and qualification process of floating substructures
- The Design Basis serves as the fundamental part for the above process. This provides a generic design basis for the design of floating wind turbines / farm.



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Overview

- Introduction
- Floater concepts
- Sites and site conditions
- Wind turbine
- Serviceability Limit States (SLS)
- Design Load Cases (DLCs)
- Sensitivity analysis
- Conclusions

Floater Concepts

- **Four Floater Concepts**
  - Barge platform with moon pool from Ideol
  - Semi-submersible platform from Nautilus
  - OO Star semi-submersible concept from Olav Olsen
  - Tension Leg Platform, TLPWIND, from Iberdrola IC

Sites and Site Conditions

- Three generic sites are identified
  - Site A – mild sea states (e.g. Golfe de Fos area, France)
  - Site B – moderate sea states (e.g. Gulf of Maine area, USA)
  - Site C – severe sea states (e.g. West of Barra area, Scotland)
  - Site conditions are based on the publicly available data for the example sites blended with the assumptions in the standards (where ever data was lacking)

Sites and Site Conditions (Contd..)

Parameter	Site A	Site B	Site C
Water depth, m	70	130	100
Annual avg. wind speed, $V_{av,h}$, m/s	9.0	6.214	9.089
10 min. mean reference wind speed (50-years return period) at hub height, V_{ref}, m/s	37.0	44.0	53.79
Extreme Sea States (ESS)			
50-year significant wave height, $H_{s50,3h}$, m	7.5	10.9	15.6
50-year peak period range, $T_{p50,3hmin}$ - $T_{p50,3hmax}$, s	8.0 – 11.0	9.0 – 16.0	12.0 – 18.0
Severe Sea States (SSS)*			
Significant wave height up to the rated wind speed, m	4.0	7.7	11.5
Significant wave height beyond the rated wind speed, m	7.5	10.9	15.6

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Wind turbine

- **DTU-10MW reference wind turbine**

Parameter	Unit	Value
Rated power	kW	10000 (IEC Class IA)
Rotor diameter	m	178.3
Hub height (w:r:t: MSL)	m	119.0
Rated rotor speed	rpm	9.6
Rated wind speed	m/s	11.4
Rotor mass	Tons	228
Nacelle mass	Tons	446
Tower mass	Tons	628
Life time	Years	25

Comparable with that of NREL-5MW specifications

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Serviceability Limit States (SLS) – Values

Designers requested to establish SLS limits for the wind turbines.

Values were selected based on previous experience from floating and bottom fixed projects

- **Inclination of tilt**
  - Max. tilt during operational load cases is limited to **5 deg** (mean value) and **10 deg** (max. value)
  - Max. tilt during non-operational load cases is limited to **15 deg** (max. value)
- **Maximum acceleration**
  - Max. acceleration during operational load cases is limited to **0.3g** (max. value)
  - Max. acceleration during non-operational load cases is limited to **0.6g** (max. value)

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Serviceability Limit States (SLS) – possible limit exceedance

Operational parameters: the wind turbine operations may be curtailed

- It is assumed that an alarm will stop the turbine. However, this capability shall be demonstrated.

Impact of these parameters on loads are quantified and assessed

- Compare the main load components with the design envelope loads when the turbine is in the bottom fixed condition.

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Design Load Cases (DLCs) for Preliminary Evaluation – Selection

- **Selection of a subset of load cases for preliminary evaluation of the concepts**
  - In the case of production cases:
    - DLC 1.2 contributes to the major part of fatigue
    - DLC 1.4 – as the deterministic gust is sensitive to the platform period and hence it could be important. Further, it is common that DLC 1.4 drives the critical blade deflection
    - DLC 1.6 – the severe sea states could trigger some of the substructure loads
  - In the case of fault case, DLC 2.3 would be critical as both the amplitude and period of the EOG could be sensitive and might drive the design
  - 6.1/6.2 case for ULS.

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Design Load Cases (DLCs) setup

- **For the normal production cases (DLC 1.2)**
  - As per standards, the simulation length => 3 hrs for ULS. Simplification – through sensitivity analysis, for fatigue => 1 hr or les depending on the sensitivity
  - Wind speed bin width => 2 m/s
  - 3 seeds per wind speed

- **For the DLCs dealing with deterministic gusts (DLC 1.4 and 2.3)**
  - ECD – DLC 1.4, gust amplitude, period – most relevant platform period such as yaw period shall be considered.
  - EOG – DLC 2.3, same conditions above + calculate gust amplitude as function of gust period. Timing of grid failure => shall results in conservative loads

- **DLC 1.6**
  - Limited number of wind speeds, 3 seeds per wind speed
  - Simulation length => 3 hrs

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DLCs for Preliminary Evaluation (Contd..)

- **DLCs 6.1 and 6.2**
  - Same external conditions for both idling cases with the exception of wind direction and safety factor
  - At least 3 seeds per wind direction
  - Simulation length => 3 hrs
  - In the case of DLC 6.2, a sensitivity analysis can be carried out to evaluate the most severe yaw error and consequently to reduce the number of simulations.

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DLCs – Simplified fatigue analysis for preliminary evaluation

- **The FLS verification will include:**
  - RNA loads based on simulations using Ieff for m=4
  - Tower base bending moments
  - Station keeping system – the focus should be on the attachment or the line tension in the moorings / tendons depending on the design.
  - If the design of one of the above parts is driven by FLS, hot spot checks on the floater is recommended.

  - **Assumptions**:
    - Only loads during normal production are considered (DLC 1.2)
    - The wind turbulence are assumed as per type class
    - Normal sea states (NSS) representation is design-independent
    - Only aligned wind / wave conditions

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Design Load Cases – SLS and ALS for preliminary evaluation

Only valid for the concepts having a redundant station keeping system

- For the transient load case:
  - Simulation length can be reduced in order to include the transient event
  - Environmental conditions => 1-year return period
  - Both the idling and operational conditions
  - At least 3 seeds per case

- For the post-failure conditions:
  - Simulation length => 3 hrs
  - Environmental conditions => 1-year return period
  - At least 3 seeds per case

Sensitivity Analysis

- Sensitivity analysis for ULS:

  Effect of the following parameters shall be investigated:

  – Wind/wave misalignment
  – Wave peak period/significant wave height
  – Swell (if relevant)
  – Mooring line orientation, with respect to the wave direction
  – Wind direction, with respect to the platform orientation
  – Water depth
  – Gusts and periods
  – Currents
  – Ice, marine growth, or any other factor relevant for the site (but not included in the DLC set up)

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Sensitivity Analysis (Contd..)

- Sensitivity analysis for FLS:

  Effect of the following parameters shall be investigated:

  – Wind/wave misalignment

  – Wind direction, with respect to the platform orientation

  – Ice, marine growth, or any other factor relevant for the site (but not included in the DLC set up)

Observations / Conclusions

- Key aspects of the design basis for the design (for the 3 generic sites) are detailed.
- Possible simplifications, its consequences, and requirements relevant for a preliminary design and evaluation are discussed.
- Preliminary load cases are identified.
- Potential sensitivity studies are listed.
- Limits for SLS and ALS cases are proposed.
- Recommendations on SLS and ALS load cases are provided.

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References

- www.lifes50plus.eu
- DNV-OS-J103, (2013), Design of floating wind turbine structures.
- IEC/TS 61400-3-2 Ed.1.0 Wind turbines – Part 3-2: Design requirements for floating offshore wind turbines.
- www.statoil.com
- Ramachandran G K V, Krieger A, Vita L, Gomez Alonso P, Berque J, and Aguirre G. (2016) Design Basis, LIFES50+ Deliverable D7.2, available at: http://lifes50plus.eu/results/.
- DTU Wind Energy Report-I-0092, (July 2013), Description of the DTU-10MW reference wind turbine.
- DNV-OS-J101, (2014), Design of offshore wind turbine structures.
- IEC 61400-1, Ed.3 (2005), Wind turbines – part 1: Design requirements, incl. Amendment:2010.

Acknowledgements

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Thank you for your kind attention..

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