DNV·GL

Revised floating stability requirements for floating wind turbine structures

DeepWind 2021

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Introduction

- Industry standards:
  - Important for the success story of wind power during the last decades
  - Have supported the continuous decrease in levelized cost of energy while the target safety level has been maintained
- Examples of industry standards:
  - International standards like the IEC61400-series
  - Standards from certification bodies such as DNV GL

Floating wind – a 10 years journey

Selected reference projects

Hywind demo (2008)

Pelastar FEED (2013)

VolturnUS – concept (2014)

aerodyn SCD nezzy – concept (2014)

ACS - concept (2014-2015)

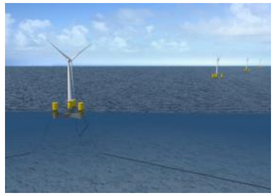
WindFloat Atlantic (2015- 2018)

Hywind Scotland (2015-2017)

Nautilus – concept – SoF (2017)

Hywind Tampen
(ongoing)

Groix & Belle-Ile wind farm
(ongoing)



1st JIP:
DNV-OS-J103
Design standard
(2011-2013)

2nd JIP:
DNVGL-RP-0286
Coupled analysis
(2016-2019)

2018/2019:
DNVGL-SE-0422
DNVGL-RP-0286
DNVGL-ST-0119

2021:
Currently DNV GL is working on the 3rd revision of the standard **DNVGL-ST-0119**

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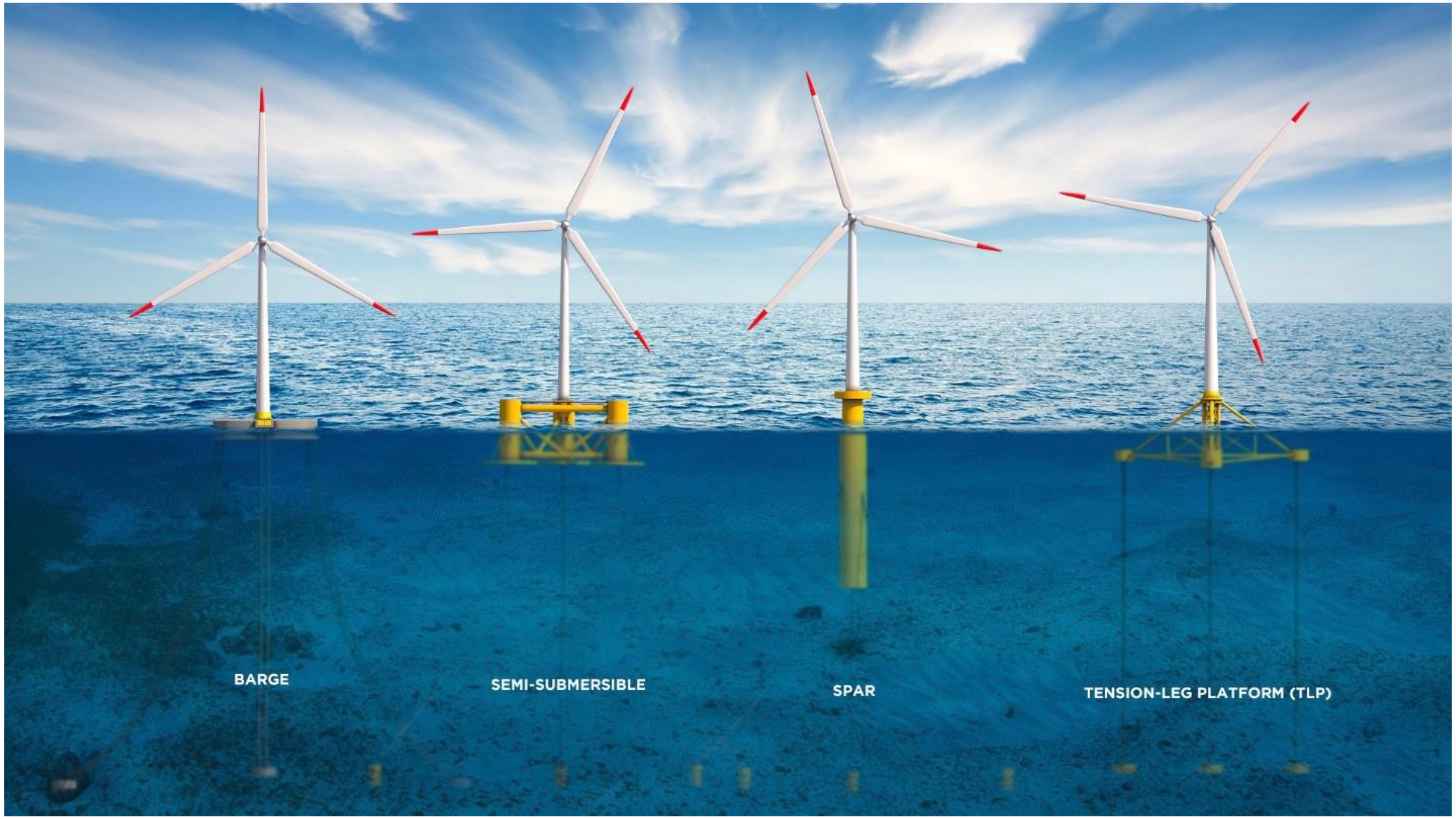
DNVGL-ST-0119 – application and content

- Worldwide application
- Primarily concerned with the design of the **main** floater types and their moorings
- Provides:
  – **Principles**
  – **Technical requirements**
  – **Guidance** for design, construction and in-service inspection



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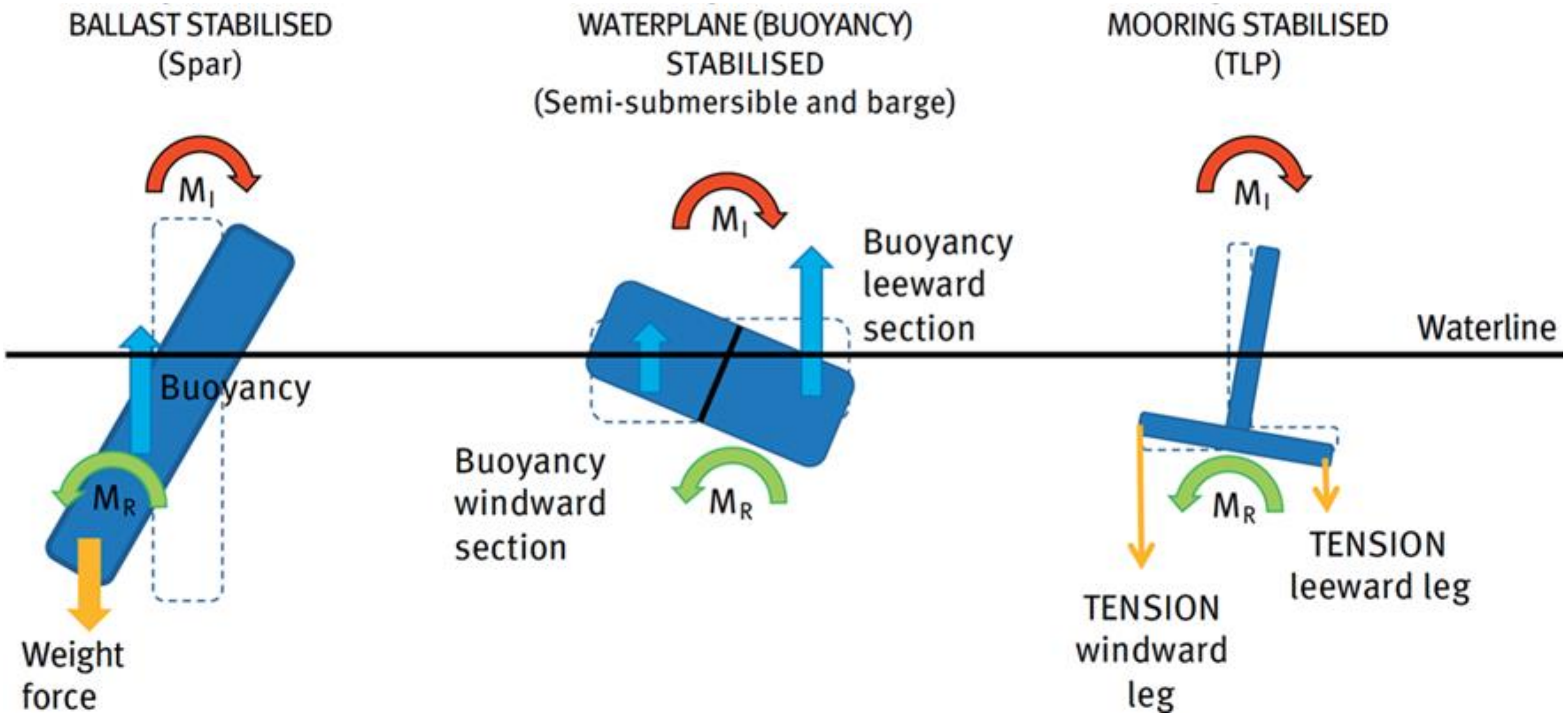
Floating stability - New revision in progress

- Motivation for revised requirements:
  - Improve on the concerns from the industry
  - Incorporate new experience within DNV GL

- Topics for improvement:
  - Simpler floater categorization
  - Better definition of load cases for stability, e.g.:
    - Whether to use site specific metocean data?
    - How to ensure stability in transient load cases, e.g. when the turbine shut down?
  - Allow for evaluation of floating stability using time domain simulations

Revised floater categorization

Different design "philosophies" to obtain stability



- Hydrostatically stabilized structures (spar, semi and barge)
- TLP

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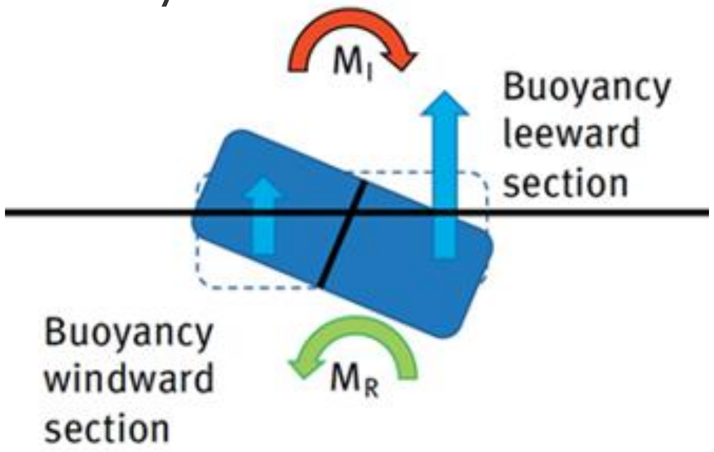
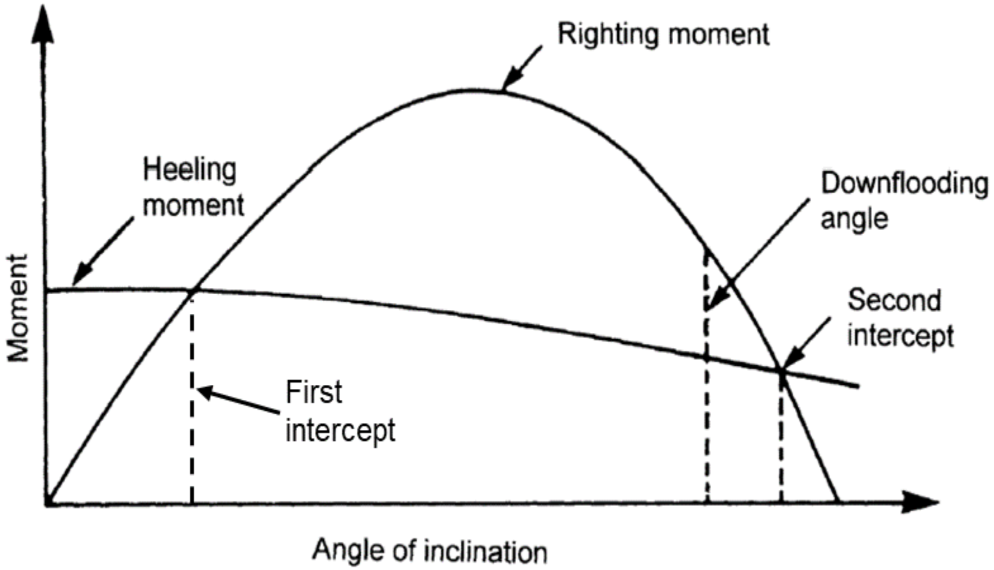
Floating stability - Introduction

- Floating stability implies a stable equilibrium and reflects a total integrity against downflooding and capsizing

- Quasi-Static evaluation
  - Curves of righting and over-turning moment
  - The standard approach from maritime and Oil&Gas industry





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Load cases for intact stability

- **Present load cases**:
  - Power production
  - Parked condition in extreme sea states

- **Revised load cases** will be related to the general table of Design Load Cases (DLCs) (which is used for design of the structure components and mooring lines)
  - Site specific data may be used
  - A wider selection of DLCs relevant for stability shall be considered

Selection of Design Load Cases

DLC	Description
1.6	Power production
2.2	Power production with fault after generator loss
3.X	Start-up
4.3	Shutdown due to exceedance of motion safety limits
5.1	Emergency shut-down
6.1	Parked
7.X	Parked with fault (yaw misalignment, 0-180deg)

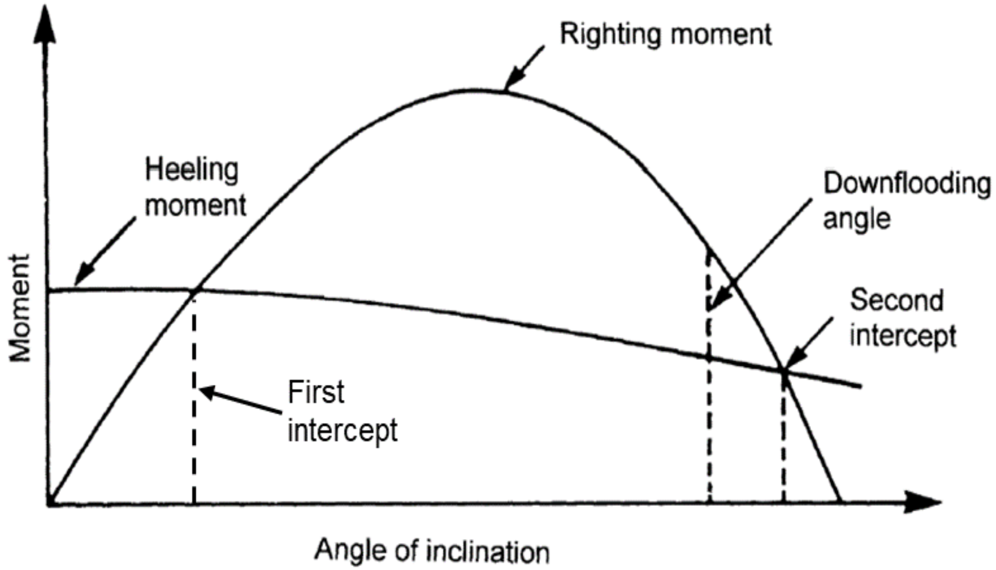
Note that load cases are either:

- Stationary
- Transient

Quasi-Static evaluation

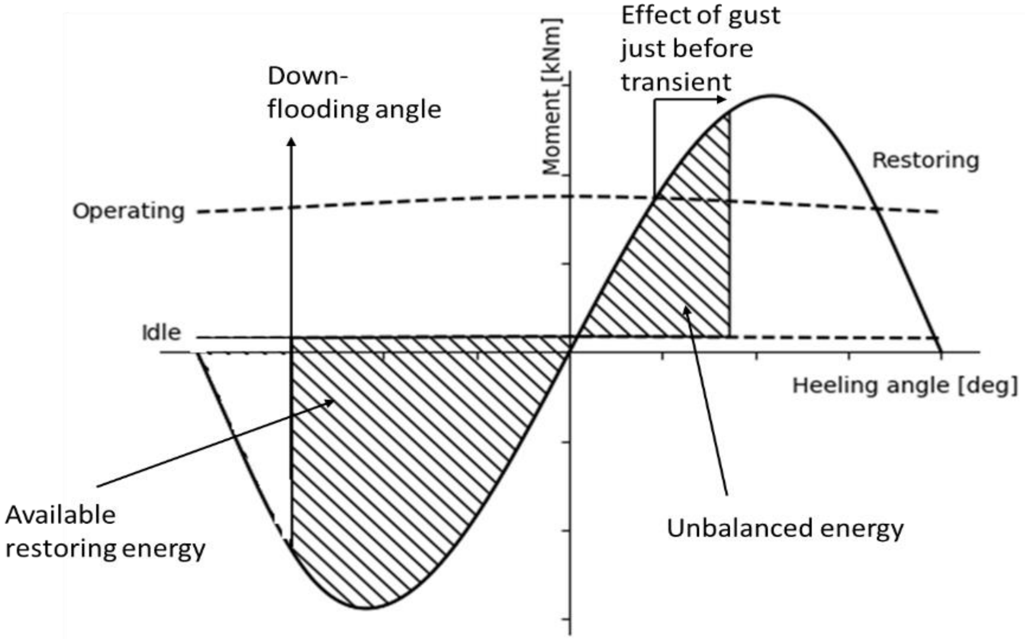
- **Stationary**
  - This is the criteria as found in all standards, with SF = 1.3 for semi-submersibles

$$A_{RM} \geq SF * A_{OT}$$



- **Transient**
  - New revision provide guidance and requirements

$$A_{Rest.} \geq SF * A_{Unb.}$$



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Time domain simulations – Floating stability

- Required for design of structural components (floater, mooring etc.)
  - All DLCs shall be run
- Beneficial to also implement the evaluaton of floating stability in these DLCs
- The Transient cases might be easier to study through the time domain simulations

- Viscous damping on the floater and damping on the wind turbine will be included
  - Therefore, regarded less conservative compared to Quasi-Static evaluation

- **Requirements**:
  - Non-linear restoring forces shall be considered
    - Linear hydrostatic stiffness matrix may not be sufficient
  - The heeling about the critical axis shall be studied, which might combine roll and pitch

How to set the stability criteria for time domain simulations?

Time domain simulations – Criteria

- Time domain simulations are already an option in:
  IMO MSC.267(85) - International code on intact stability from 2008

  – **Open criteria:** Designer to demonstrate sufficient stability using time domain simulations

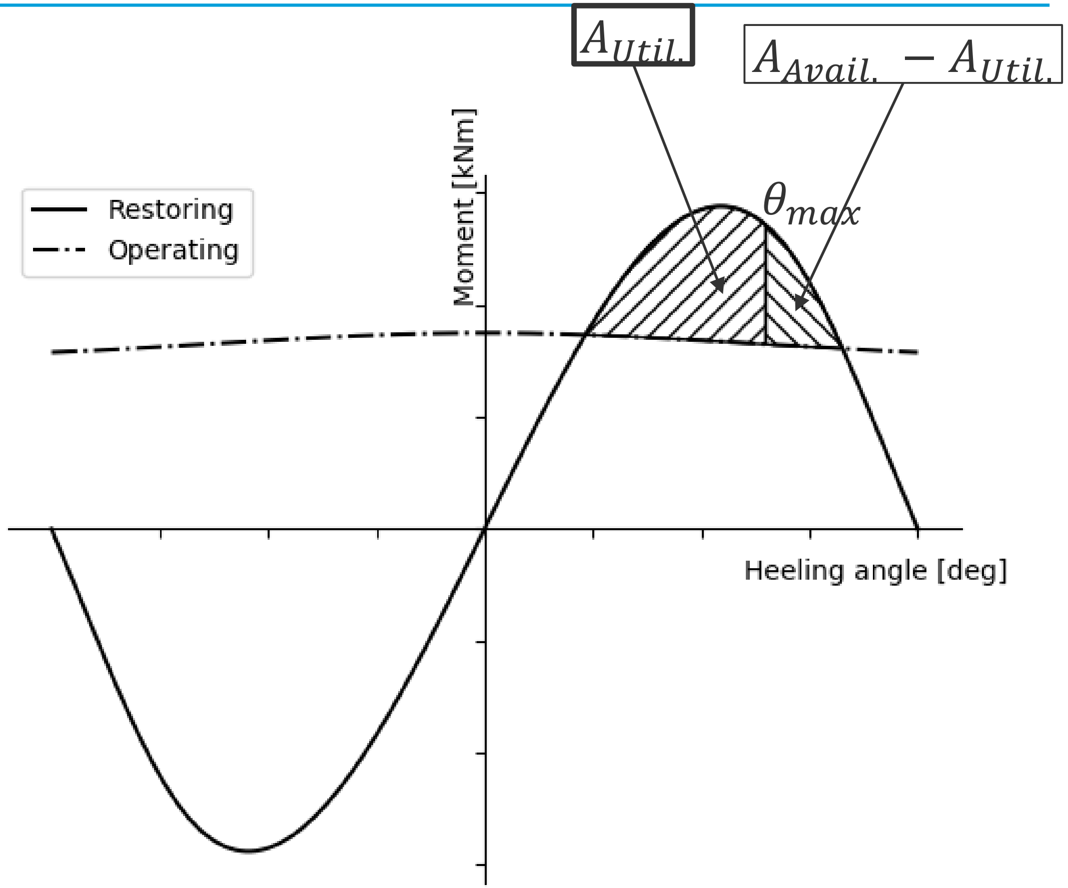
  – **Specified criteria:** Quasi-static criteria for rest stability shall be satisfied at the max heeling angle, θ_{Max}, obtained from time domain simulations
    – Provided only for certain type of semi-subs
    – θ_{Max} is not clearly defined

- Based on this: Challenging to set a general criteria for any floating wind structure when using time domain simulations

Time domain simulations – Proposed criteria for ST-0119

- A complete design format is not ready to be provided for this revision of the standard:
  - This requires a larger study with different type of floaters (Joint Industry Project)

- An open criteria is proposed:
  Designers must demonstrate sufficient safety against capsize
  - Annual probability of failure of 10^{-4}
    (target failure probability for overall structure in consequence class 1)



$$A_{Avail.} \geq SF * A_{Util.}$$

Summary - Revised section on floating stability

- Wider range of DLCs to be considered
  - Site specific data may be used

- Guidance and requirements provided for transient load cases

- Allow for time domain simulations
  - Designers shall demonstrate sufficient safety against capsize

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