Floating Offshore Wind Subgroup

Floating Substations Webinar

24th August 2023

DeepWind
North of Scotland Offshore Wind Cluster

offshore wind Scotland

Image source – BW Ideol

Agenda for today's webinar

14.00 - Welcome and webinar functionality, **Jeya Calder**, Highlands and Islands Enterprise
14.05 - Introduction**, Ole Stobbe**, BW Ideol and Subgroup Co-chair
14.10 - Enabling Scaling of Floating Wind, **Frida Mattson** DNV
14.30 - Scalable and Market Ready Floating Substations, **Mathieu Roualdes,** BW Ideol
14.45 - Floating Substation Concept Development - **Justin Jones,** Petrofac
15.05 - Floating Substations – **Juan Antonio Gonzalez Diaz,** Semco Maritime
15.25 - Q&A Session, chaired by **Lucy Green**, Genesis Energy and Subgroup Co-chair
15.35 - End of webinar

DeepWind
North of Scotland Offshore Wind Cluster

Frida Mattson

DNV

WHEN TRUST MATTERS

Enabling scaling of floating wind

Floating Substation - Joint Industry Project

Frida Mattson, Consultant

Floating wind innovation and standards development

Activities

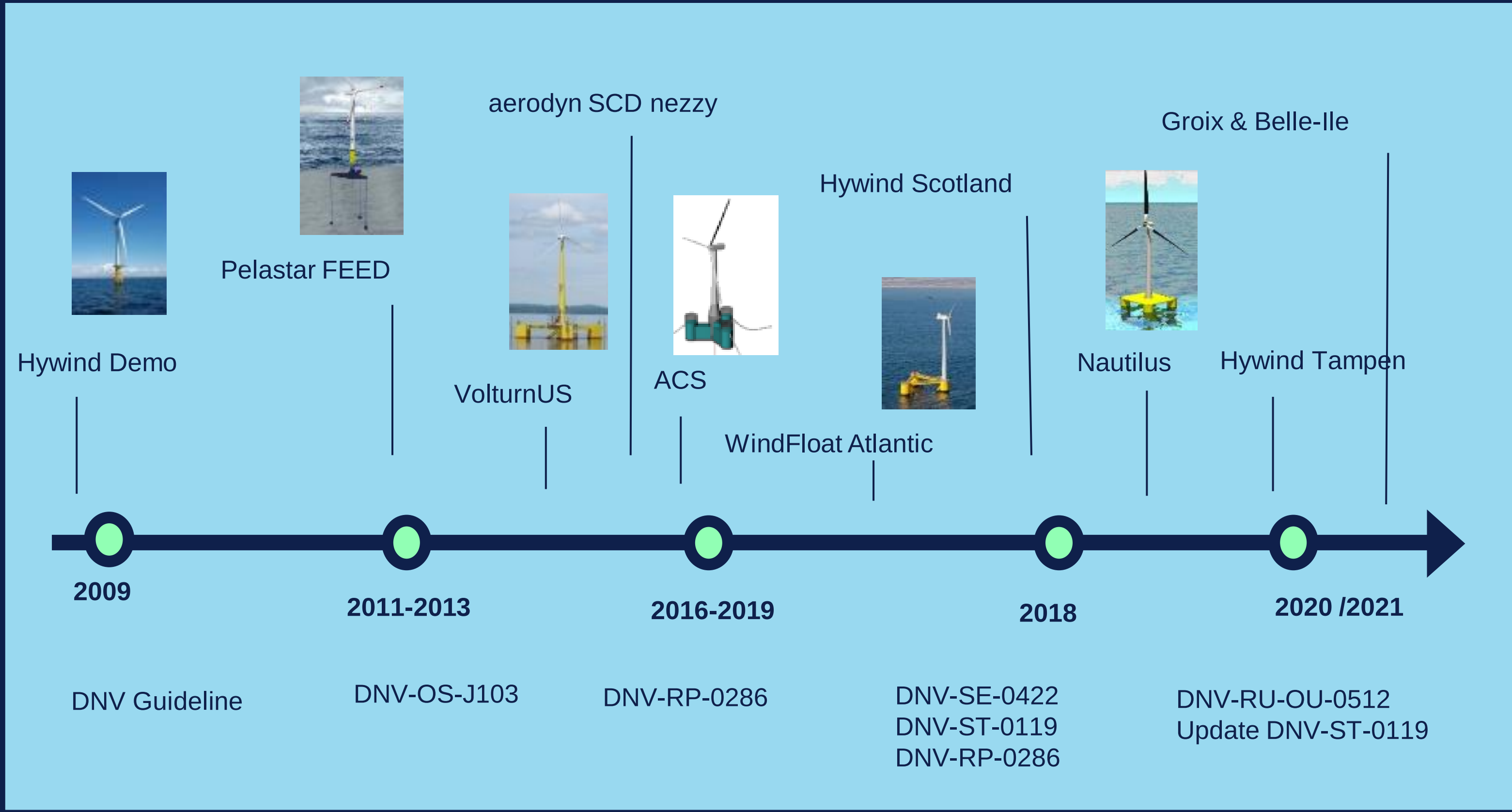
Research & Development (R&D)

Participation in national and international consortia, working with academia and industry partners

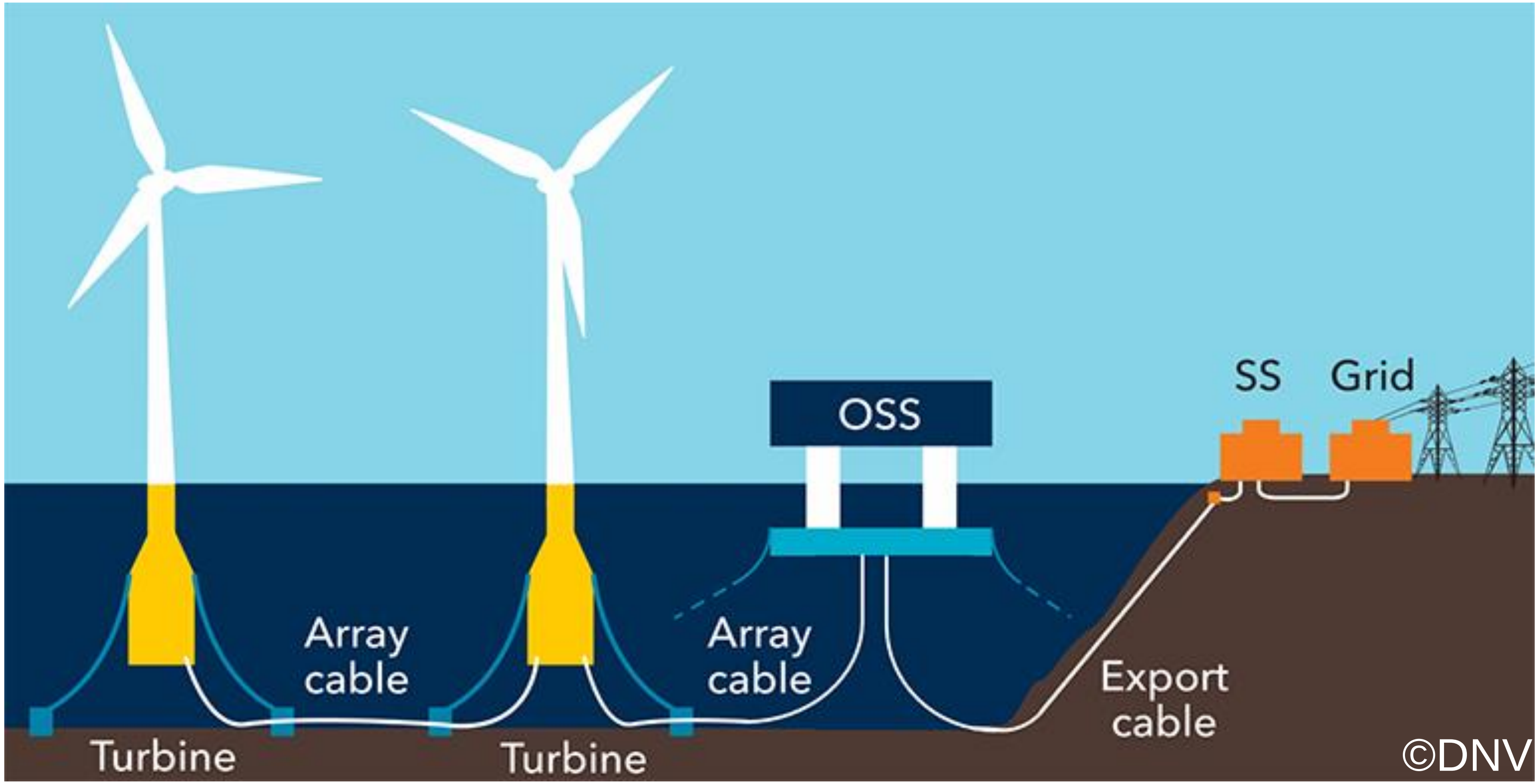
Joint Industry Projects (JIP)

Joint Development projects (JDP)

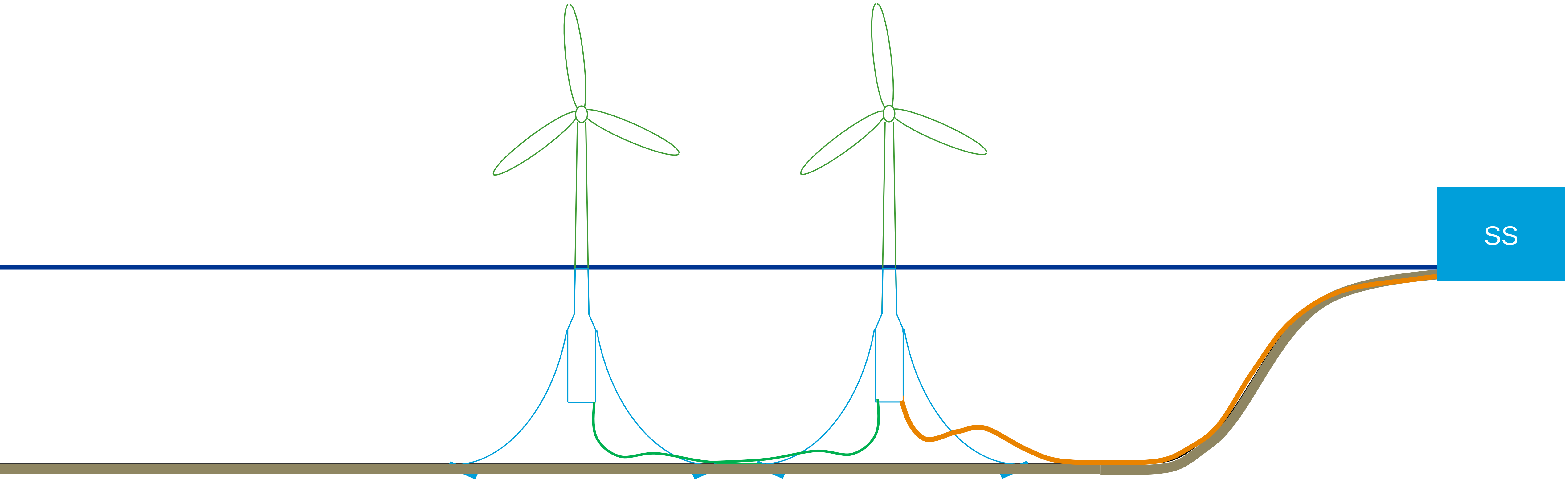
Timeline



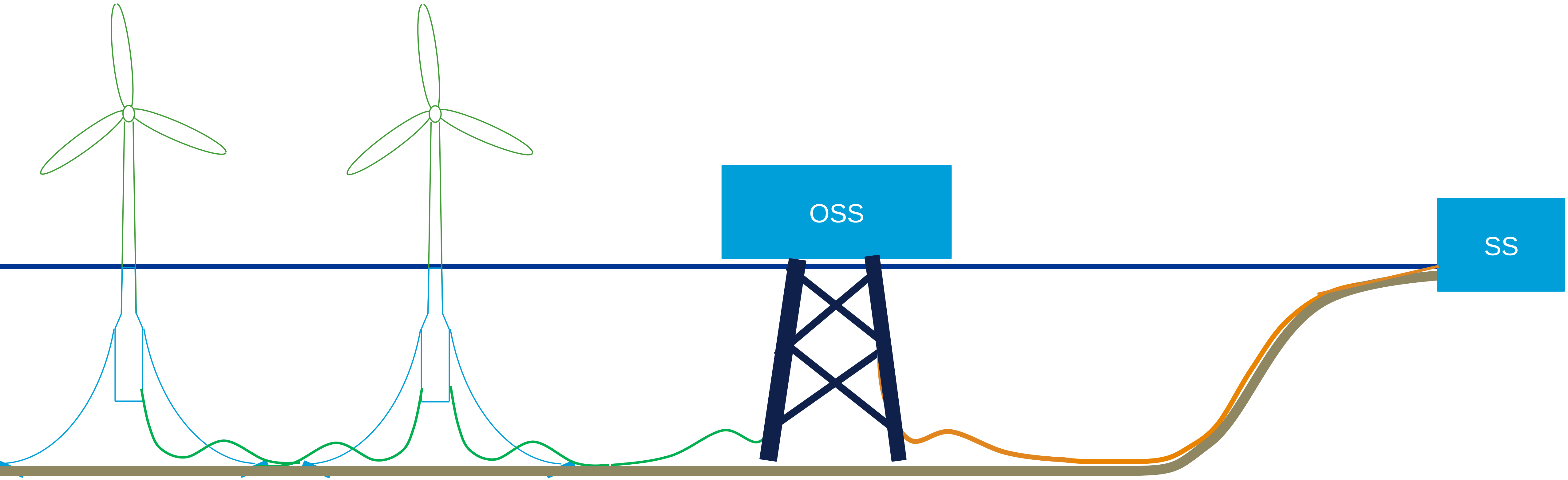
Floating substations
– an enabler for scaling floating wind



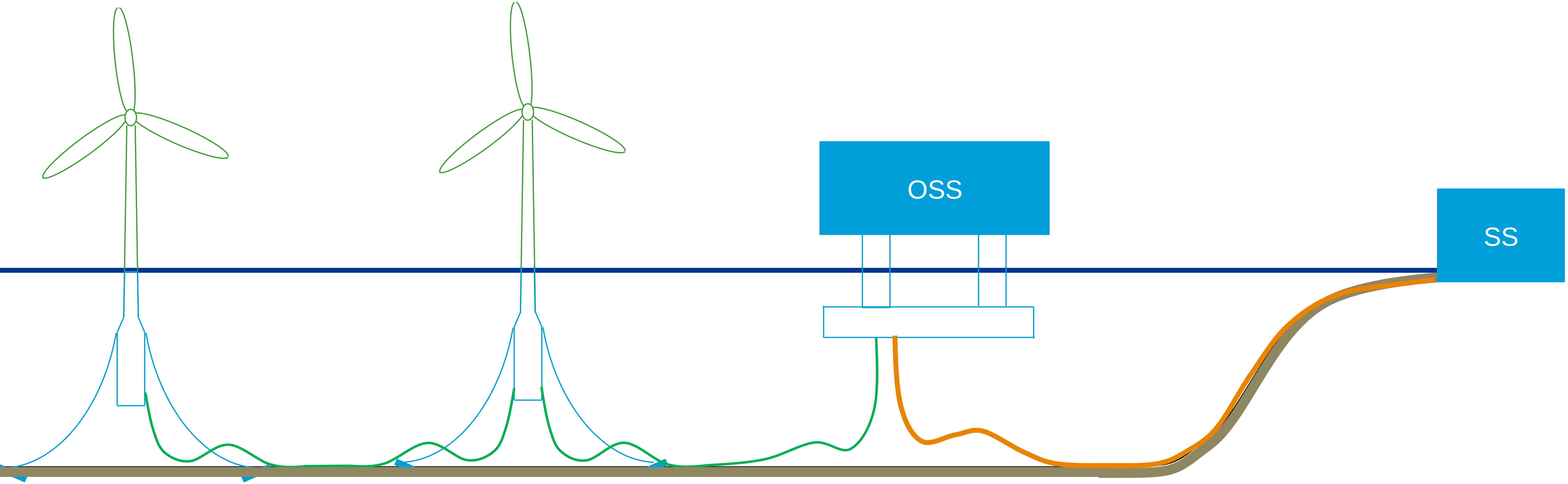
… demonstrators and pilot farms, close to shore



… commercial scale, further from shore



… commercial scale, OSS in deep water



Offshore Substation development

>100 fixed HVAC OSS

9 fixed HVDC OSS

+ 4 under construction

Only 1 Demo Floating, Fukushima 2013, 2 MW, 66kV

Complexity

Stakeholders:

Wind farm developers

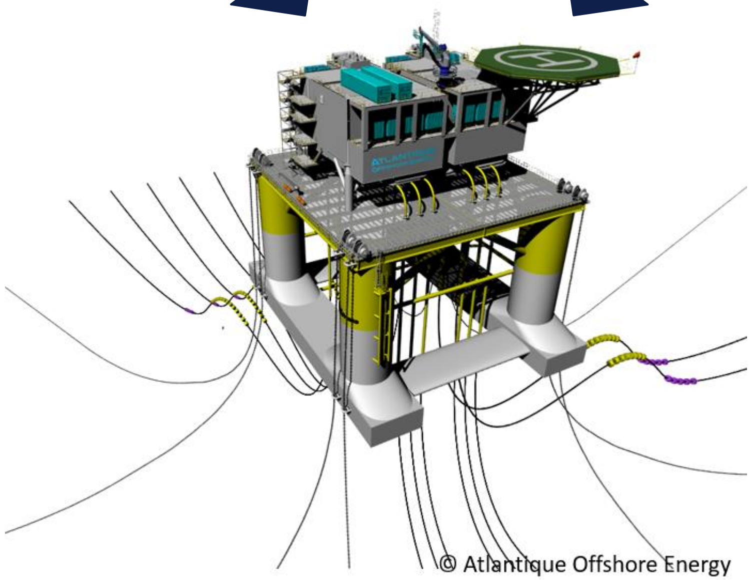
Transmission System Operators

HV equipment suppliers

Cable suppliers

Designers, EPCI, yards

Societies



Technical drivers:

Water depth

Distance to shore

Metocean

Wind farm size

Input/Output voltage

<- Criticality and acceptable probability of failure ->

JIP vision

Enable scaling of floating wind with an acceptable level of commercial, technical and HSE risk,

through suitable standards and guidelines for floating offshore substations

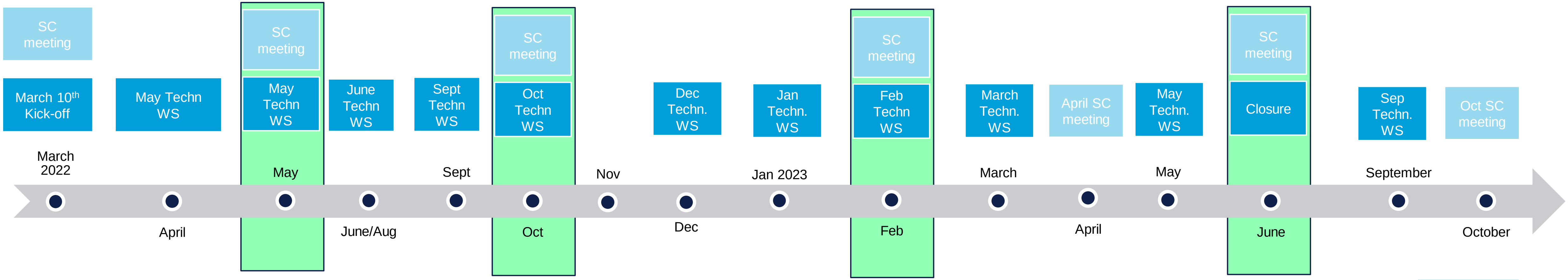
JIP objectives

- ✓ *Identify gaps in technology*
- ✓ *Identify gaps in standards*
- ✓ *Establish joint understanding of best industry practice and technical requirements*

DNV

Phase 1: Participants and timeline

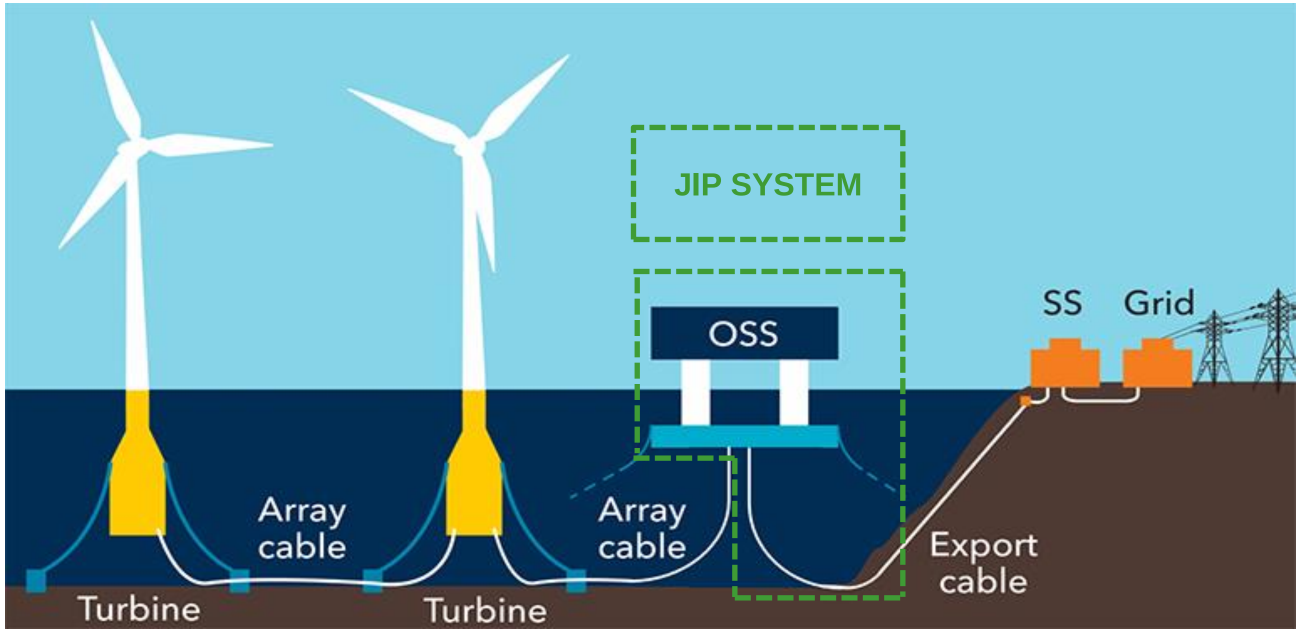
GE Renewable Energy
Chantiers de l'Atlantique
Burns McDonnell
EDF
OW Ocean Winds
red eléctrica
Siemens energy
ABB
Offshore & Energy
wood.
States
Ørsted
Renantis
Rte
elia group
Prysmian Group
Terna
Hitachi Energy
TechnipFMC
TotalEnergies
equinor
Iberdrola
Navantia
Mitsubishi Electric
subsea 7
AkerSolutions
aibel
Northland Power
bp
Worley energy | chemicals | resources
sse Renewables
RWE
EOLFI Société du Groupe Shell
GICON
SBM Offshore
Saipem
kent
T.EN Technip Energies



DNV

Scope and Deliverables

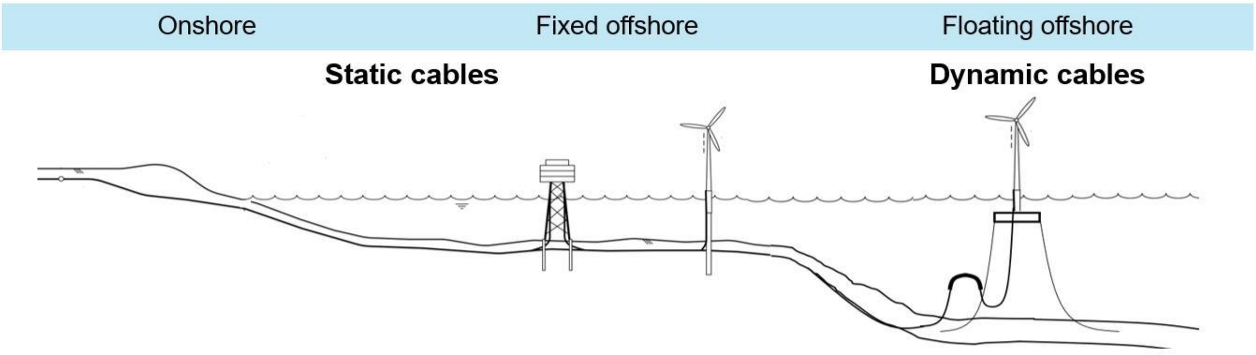
- Six defined activities:
  1. Technology gaps
  2. Standards gaps
  3. Design basis
  4. Safety level
  5. Floater motions
  6. Dynamic export cable feasibility



- Developed content to feed into:
  - DNV-ST-0145 Offshore substations
  - RP for HV cables
- A final report with a summary of each activity will be published later this year

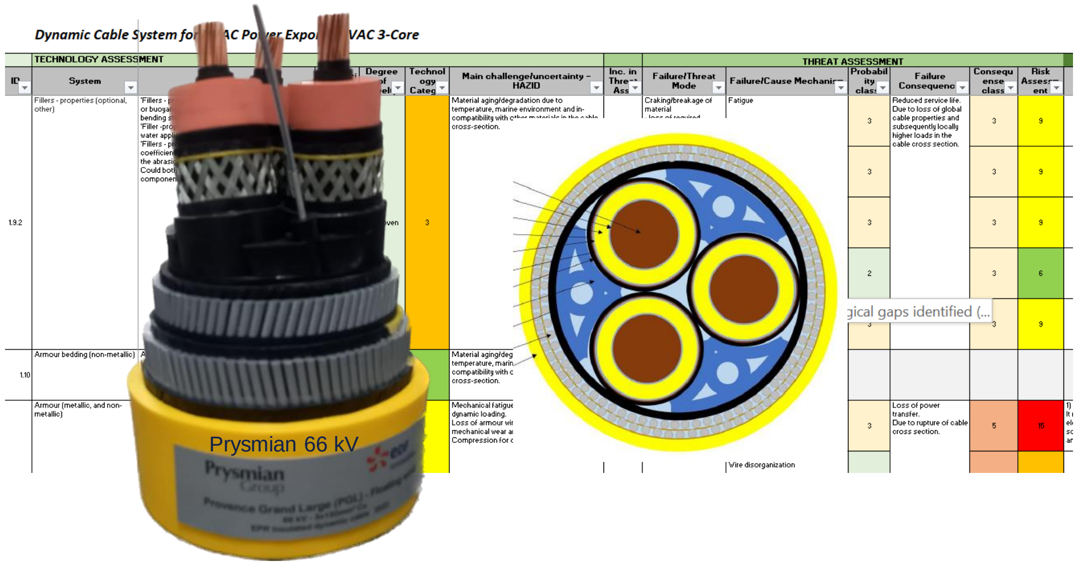
Technology maturity overview

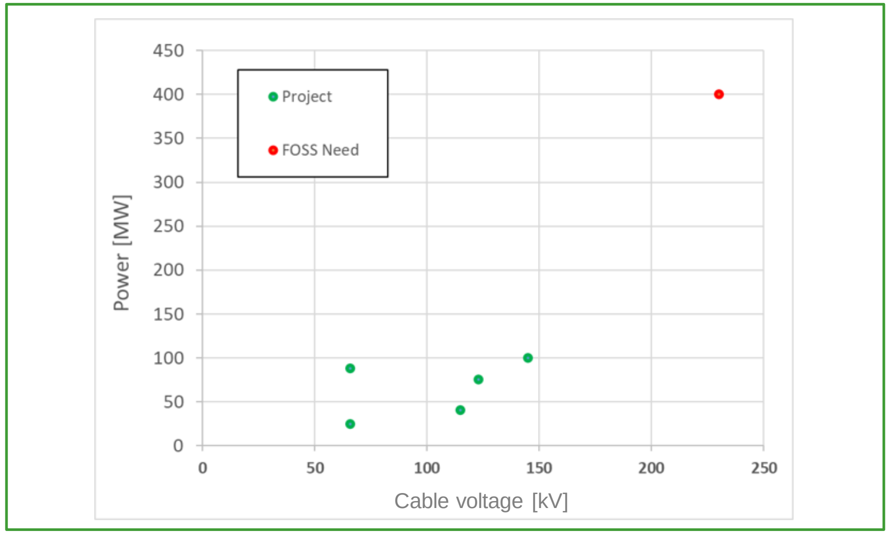
- ✓Floaters, station keeping and ballast
- ✓Power system architecture
- ✓HVAC equipment
- ✓HVAC dynamic cables
- ✓Design process for optimal system cost-benefit
- ✓HVDC equipment
- ✓HVDC cable

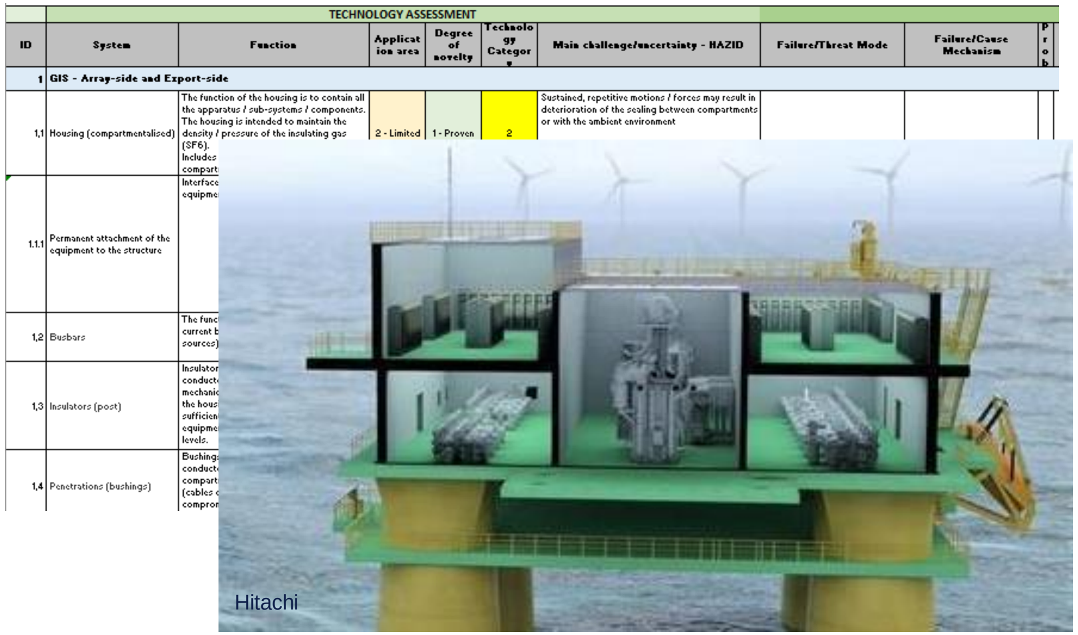


Technology gaps HVAC

- Dynamic Subsea Cables
  - Experience exists from O&G
  - Export Cables (>200 kV): Under development
- HV equipment (transformers, switchgear,..)
  - Higher voltages and capacities than O&G/maritime
  - Uncertainties w.r.t. motions, fatigue, vibrations







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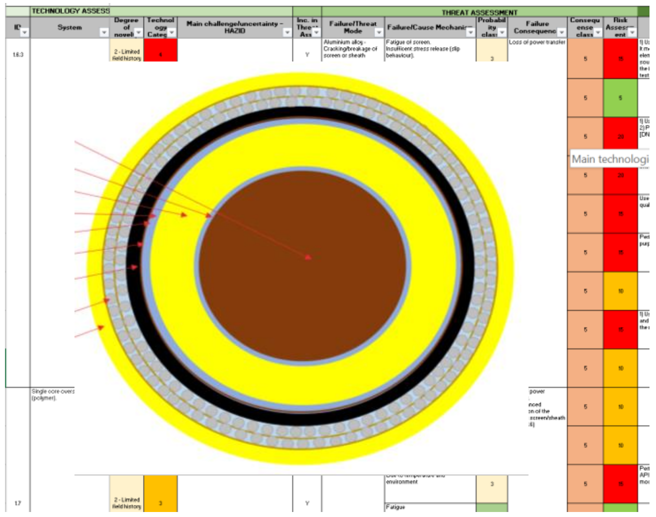
Technology gaps HVDC



- Dynamic subsea cables
  - No experience to date for dynamic
- HV equipment (transformers, converters, switchgear, reactive equipment)
  - Larger and heavier
  - Limited/no experience with floater motion tolerance
  - Uncertainties w.r.t. equipment function, integrity, fatigue

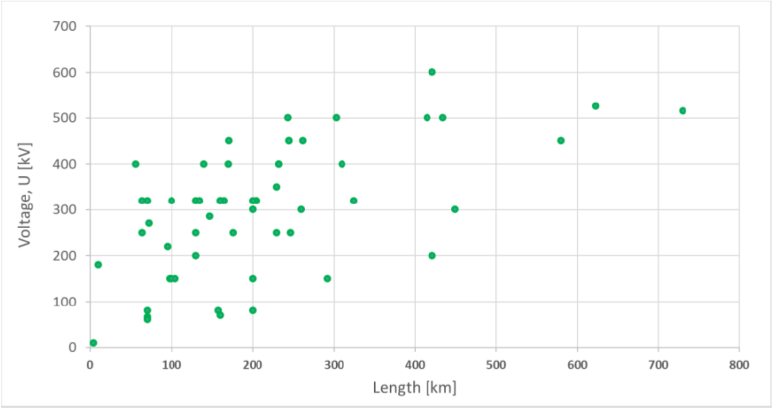
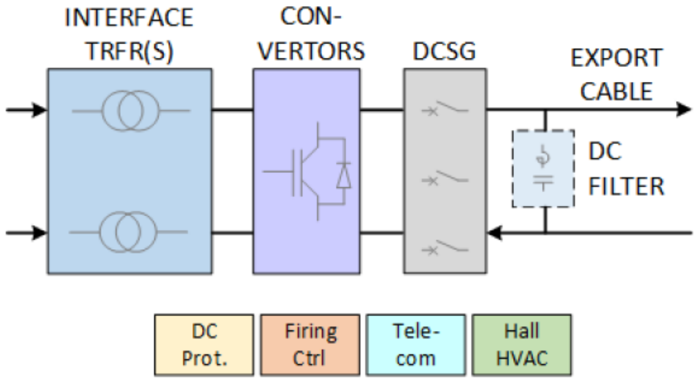
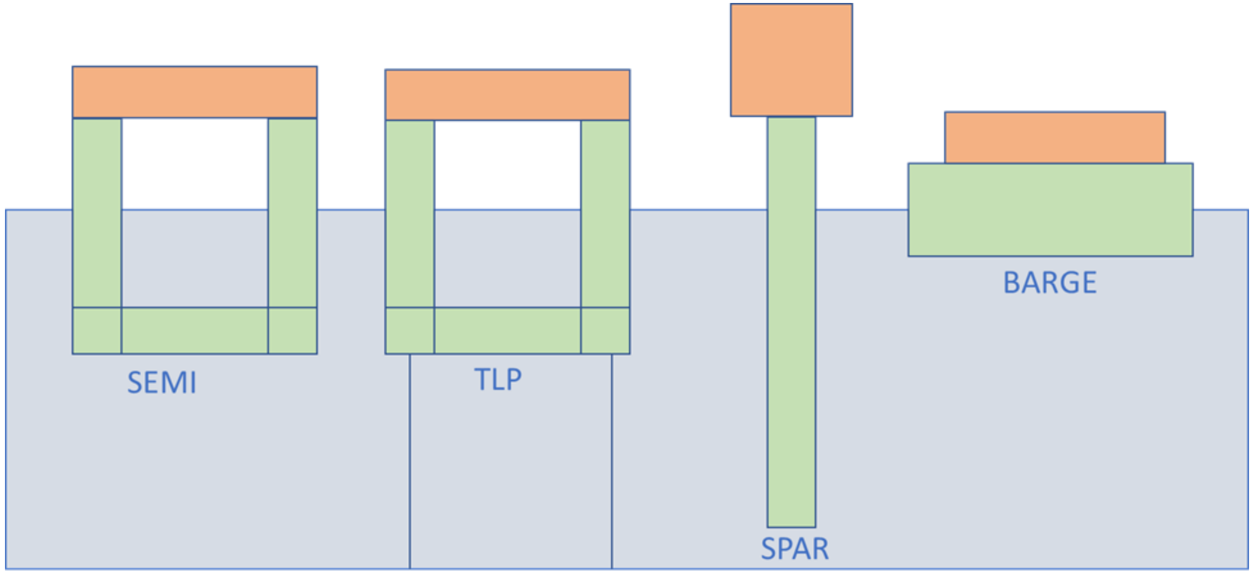


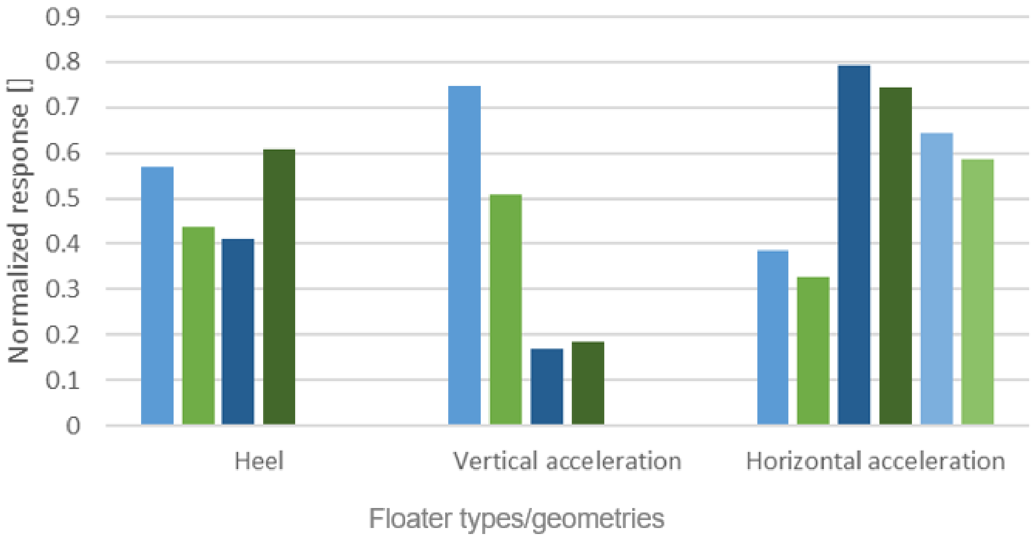
Figure 6-3 Voltage and length of existing HV DC projects in Europe /18/.



Floater motions

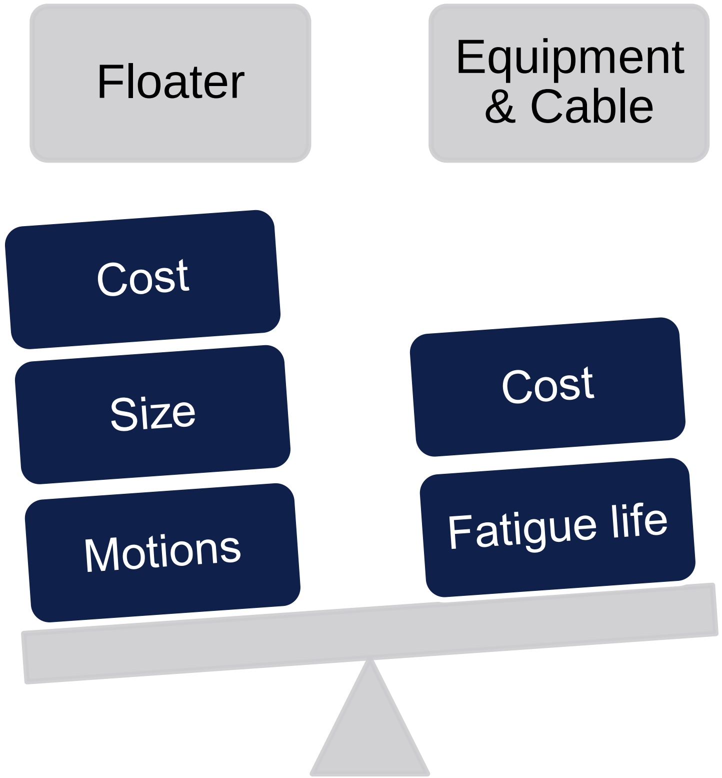


- Feasibility of 4 main concepts, for various
  - Topside weights and dimensions
  - Water depths
  - 100 year significant wave height
- 6 semis, 6 TLPs, 6 SPARs, 4 barges
- Analysis to determine motions (accelerations, heel)
- Compare to ‘JIP HV motion limitations’



- Also used in cable suitability study

Summary & remaining challenges



- Floating substations are feasible
- AC more mature than DC
- We expect to see the first FOSS in the water by 2030 (AC)

- Closing technology gaps and qualifying technology
- Establishing a good design process; **Floater – HV equipment – Cable**

- …prepare for next phase of the project

Thank you!

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DeepWind
North of Scotland Offshore Wind Cluster

Mathieu Roualdes

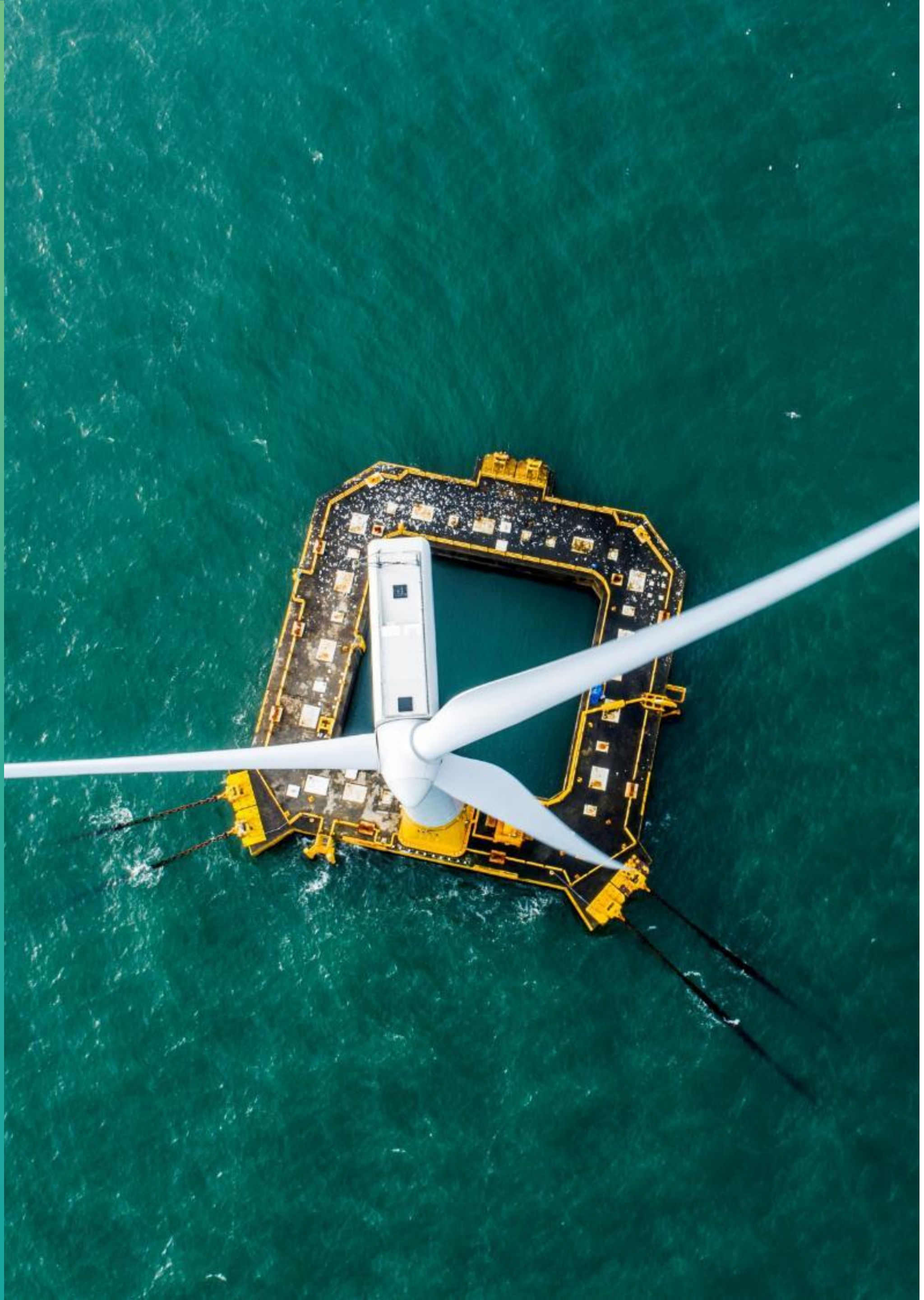
BW ideol

Scalable and market-ready: Floating Substations based on the BW Ideol Concept

24/08/2023

1

Who we are



An internationally acclaimed floating offshore wind leader

A **proven technology** with a unique **competitive edge** and an **unparalleled return on experience**

A **pure-player** and **early mover** in key **strategic markets** for floating wind

A **multi-GW pipeline** in partnership with **leading local utilities** and **project developers**

An **extensive track-record financing** and **delivering complex** and **capital-intensive** offshore **projects**

ideol ▶ BW ideol ◀ BW OFFSHORE BW ideol

A two-leg strategy

Sharing development risk and **asset ownership**

Supply EPCI and O&M services in conjunction with our patented Damping Pool™ technology

2 main objectives

Winning tenders and **delivering on-time** and **on-budget** floating offshore wind **assets**

Projects on all continents and in all key markets

South-Brittany Tender

Up to 270 MW

ScotWind *under development*

960 MW (NE8)

Mediterranean Tender

2 X 250 MW

Japan

5 site-specific and technology-exclusive joint development agreements with leading Japanese utilities and developers

EolMed *under construction*

3 X 10 MW

Taïwan

Design and engineering services contract for a commercial-scale wind farm with an undisclosed party

Target of **at least 10 GW** under development, under construction and in operation **by 2030**

+ soon to be disclosed commercial-scale projects in several European and Asian countries

First full-scale **offshore wind turbine** installed **in France**

First full-scale **foreign floating wind technology** installed **in Japan**

Pioneer and leader in **concrete hulls** and **synthetic mooring** solutions

Buildable in **steel** or **concrete**

Outstanding power production and seakeeping **performance**

The **most compact** and shallow-draft **solution** when fitted with tomorrow's XXL offshore wind turbines

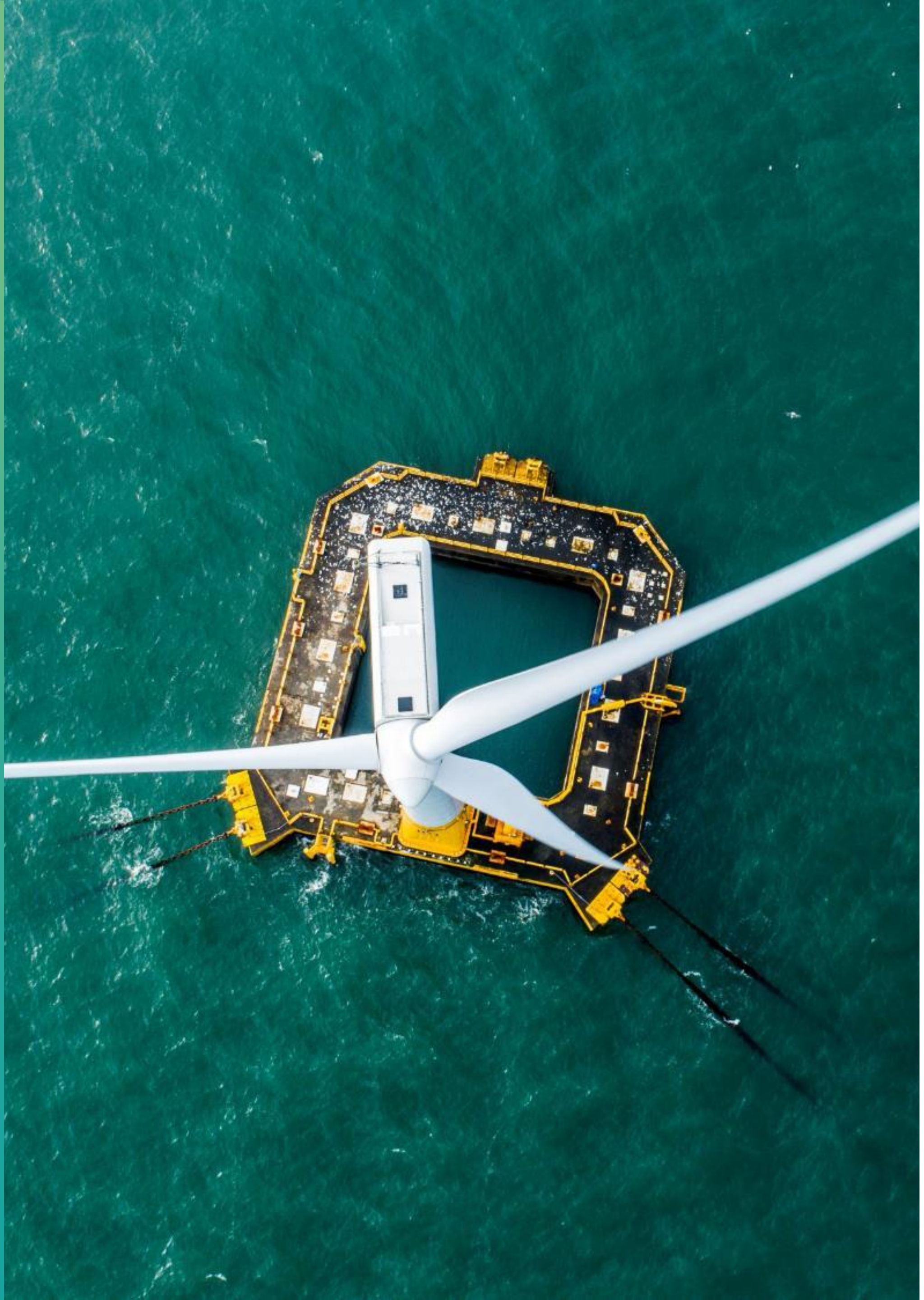
Dozens of ongoing **R&D projects** to **accelerate** the **cost reduction** trajectory of floating wind

BW ideol

The missing link for commercial scale floating wind farms

2

Optiflot



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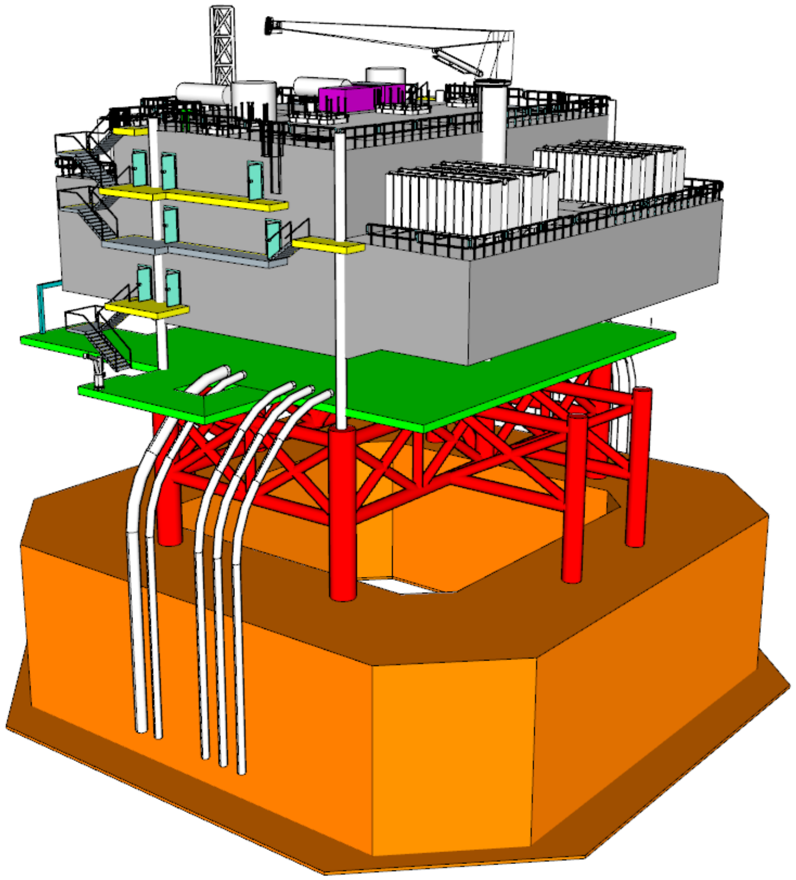
Origin: Optiflot concept

- First presentation to an expert audience in June 2019 after 2 years of engineering and design towards a Floating Offshore Substations concept
- Lead together with Hitachi Energy (then ABB) and Atlantique Offshore Energy
- Participation from other specialist from Dynamic Cable Industry, Insurance and Finance
- Demonstrating that a market-ready solution is available to TSO and floating offshore windfarm developers



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Main functional requirements

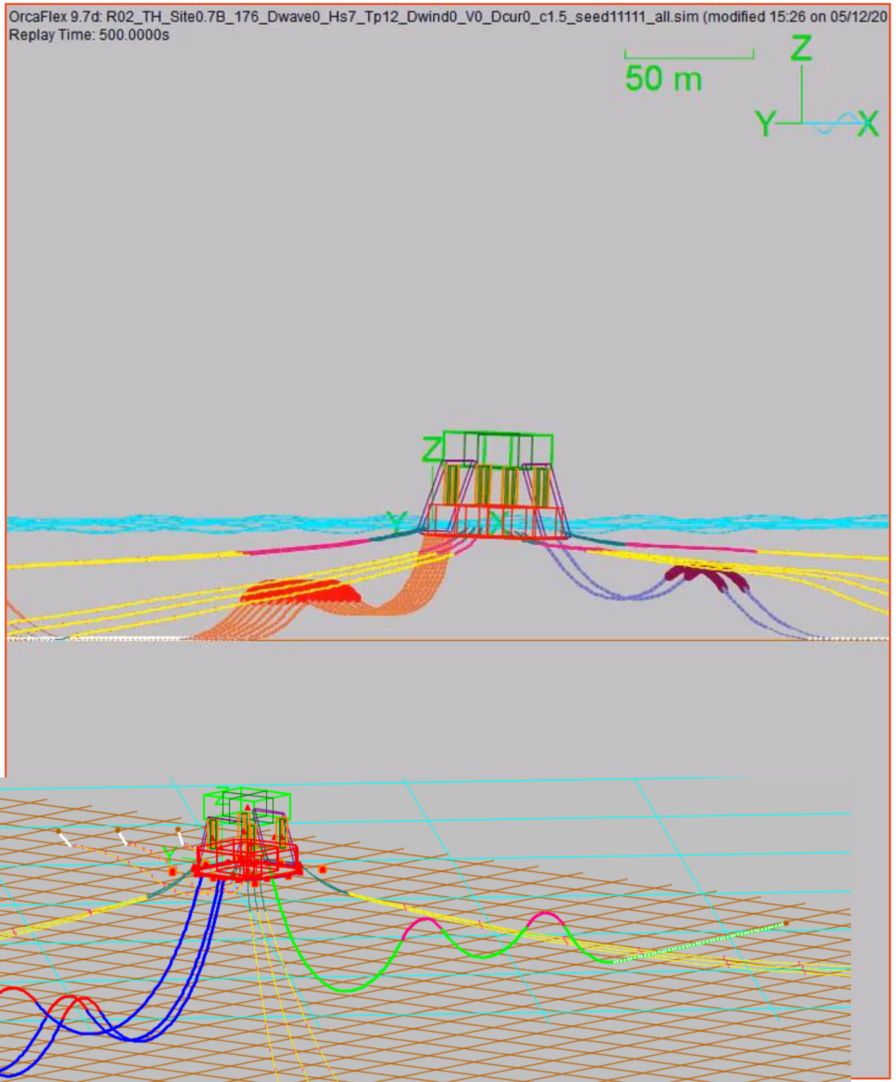
- Standard design suitable for global deployment
  - topside payload and dimensions suitable for 200- 900 MVA capacity
  - Water depth from 60 m to ∞
  - Various severe metocean conditions: Typhoons, North Sea, North Atlantic
- Standard HV equipment (with modifications to structural supports)
- Dynamic subsea cables:
  clash cable/cable, cable/mooring,
  fatigue calculation with x10 safety factor
- Deployable in shallow waters
- Propose all conventional substation functions (accommodation, power back-up, maintenance, access, etc.)

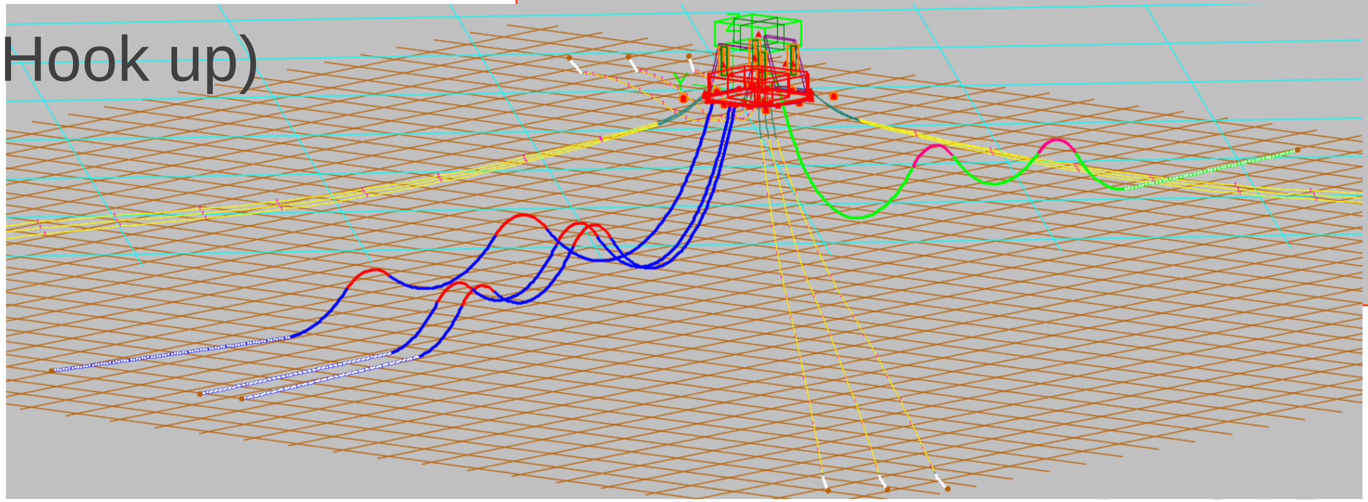
Water depth	Max significant wave height	Peak period	Wind speed at 10m	Surface current
45 m	10.0 m	12 s		
100 m	13.0 m	14 s	41 m/s	1.5 m/s
60 m	8.7 m	10 s		

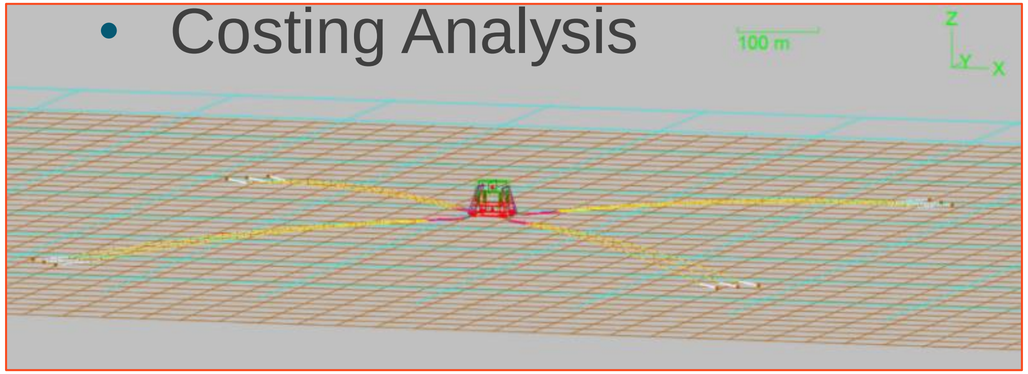
BW ideol

Main Design Activities

- System Layout
- Hull Design: Breadth, Draught, Freeboard, Access
- Structure Design
- Dynamic Cable Configuration
- Mooring System Design
- Construction and Installation Methods (incl Cable Laying and Hook up)
- Costing Analysis

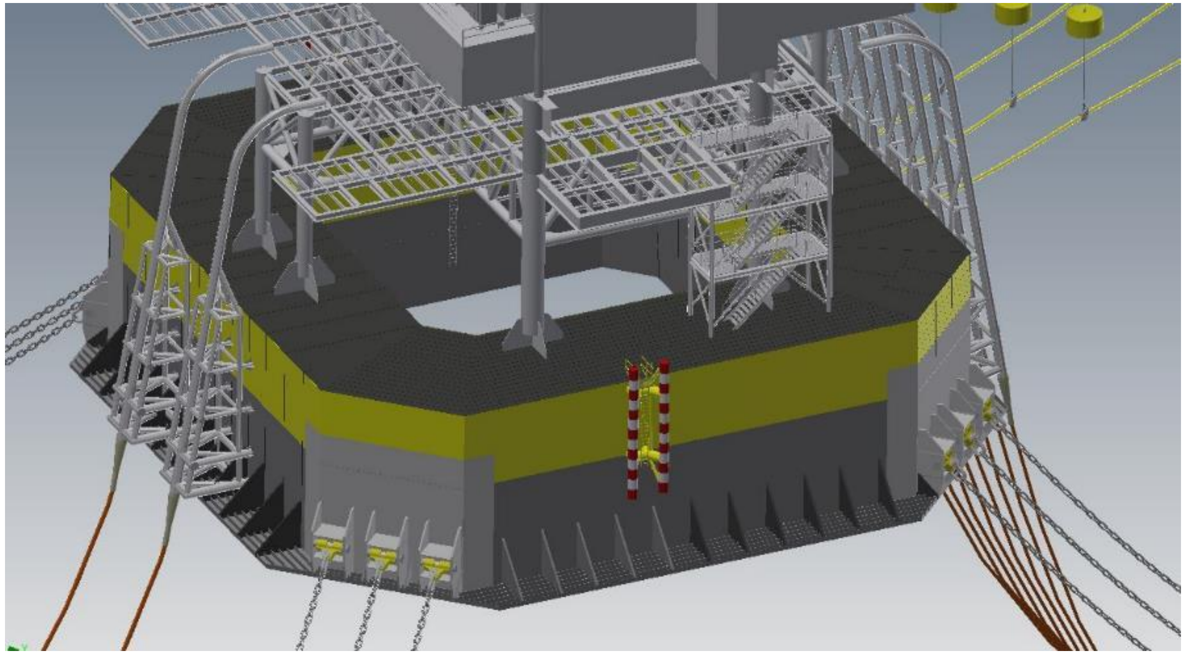






Access

- Boatlanding for CTV/SOV, access ladders
- Accessible from 2 direction
- Helicopter hoisting possible from topside roof
- Subsea position of mooring connectors allows vessels approach from either side



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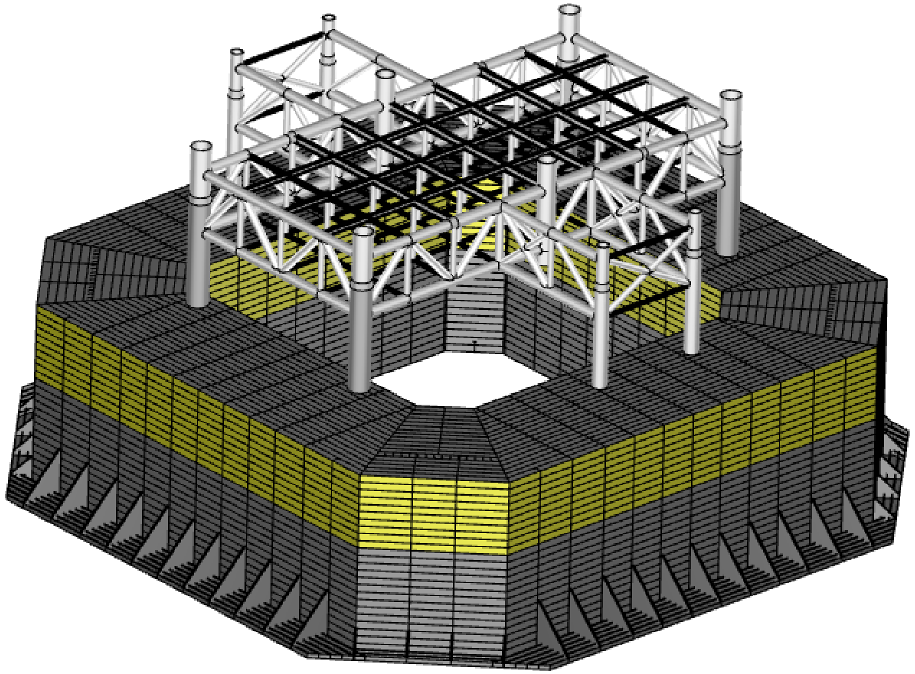
IDEOL floating substructure

- Hull dimensions:
  - Breadth 43 x 43m
  - Height 12m
  - Moonpool width 25 x 25m
  - Skirt 3m (1m in corners)
  - Operational draft 7m
  - Floater z CoG 16m
  - Displacement 8150t
  - Max allowable topside weight : 4000t
- Topside support structure:
  - Integrated cable deck
  - Weight 350t
  - Topside air-gap 20m
  - Can accommodate several topside sizes
- I-tubes, cable ancillary structure, etc:
  - Weight 400t



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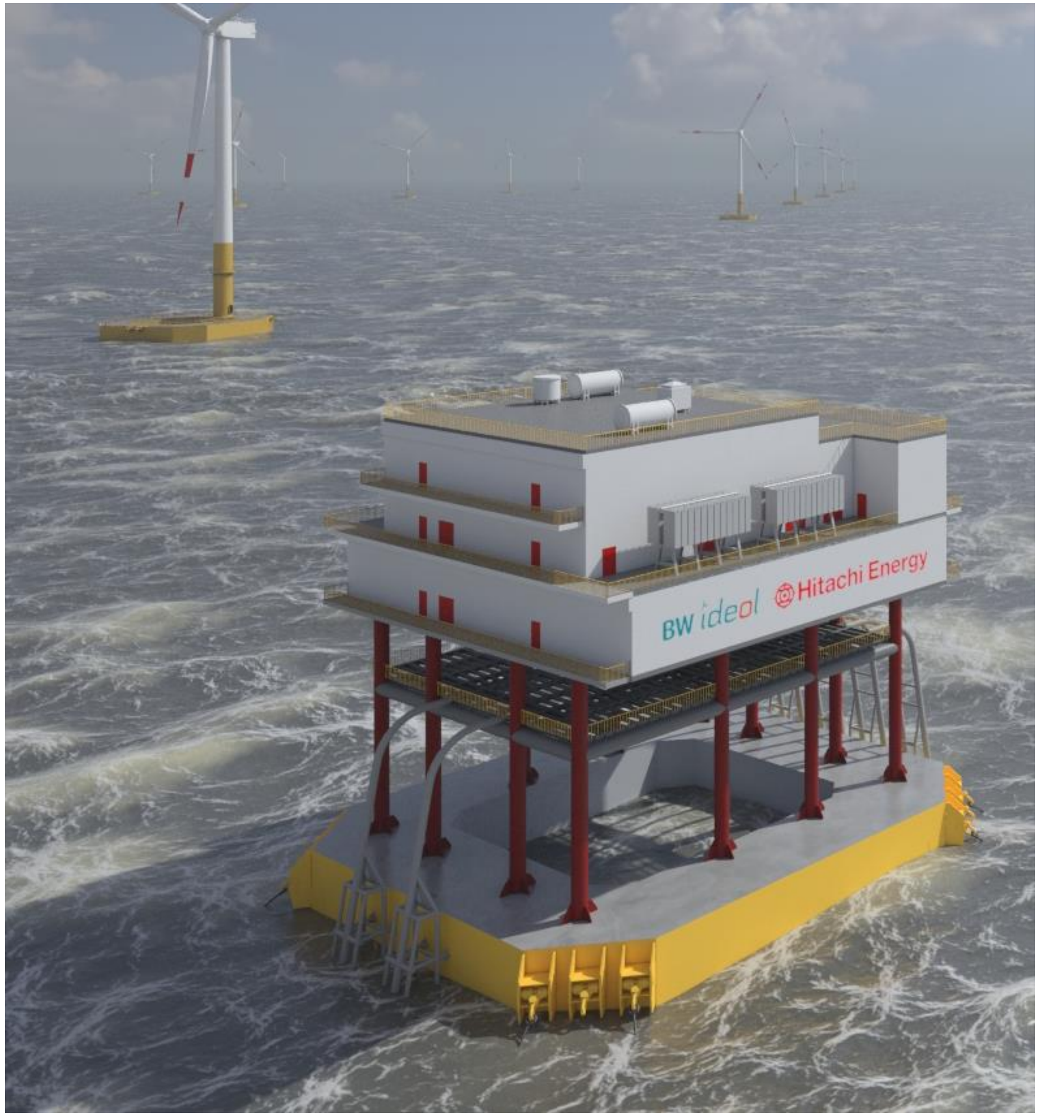
Conclusions & Key Advantages

- High level of modularization and standardization to reduce cost and lead times
- Scalable modularized design adaptable to meet local content requirements, standards and certification requirements
- Well-adapted industrial solution with existing supply chain
- Equipment accelerations and motions confirmed with Hitachi Energy
- Quayside mating of hull and top-side and testing/ pre-commissioning
  → no offshore heavy lifts
  → lower weather risk
- Low-cost tow to offshore wind farm sites



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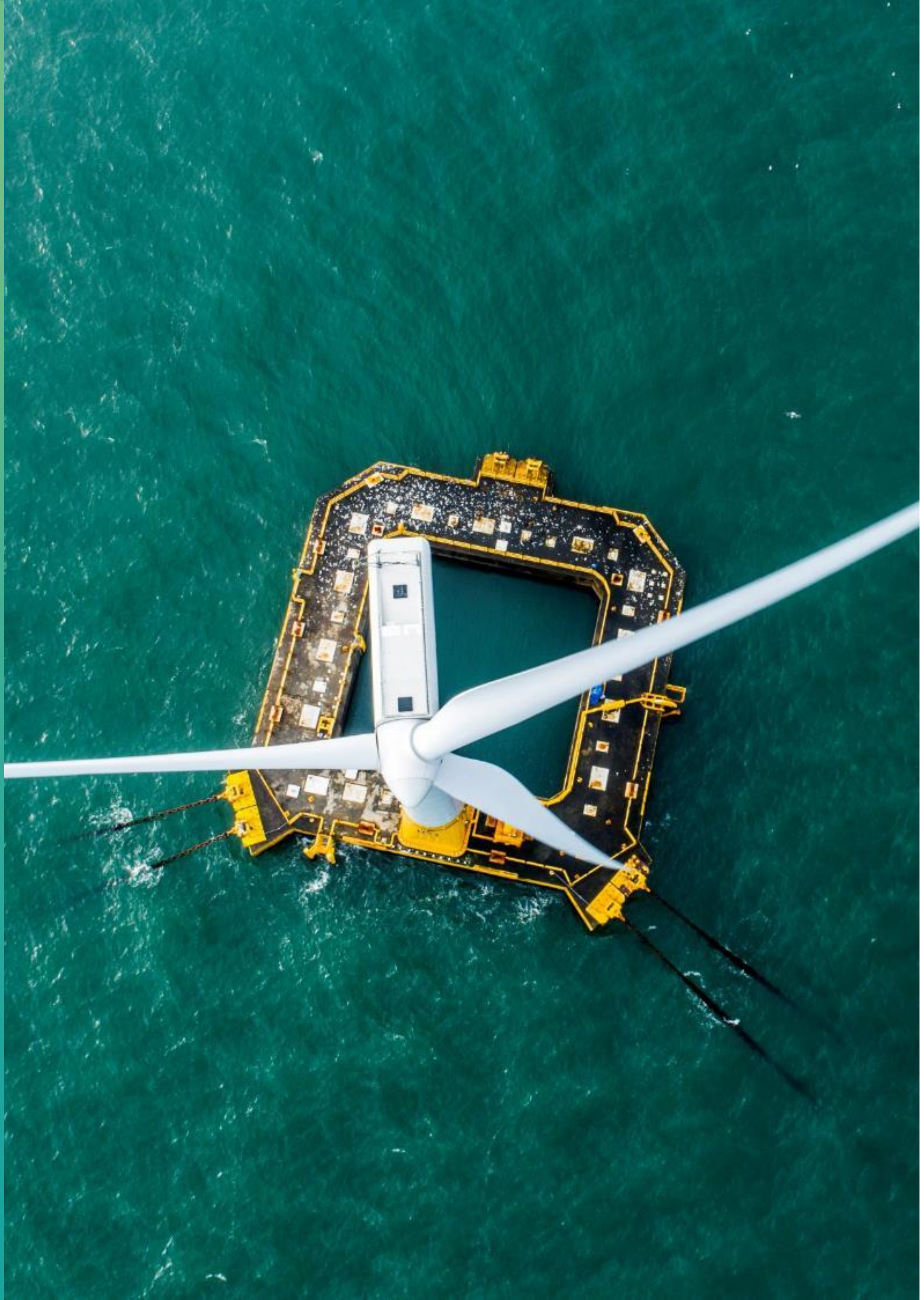
Examples from the Real World



Project A

Windfarm:

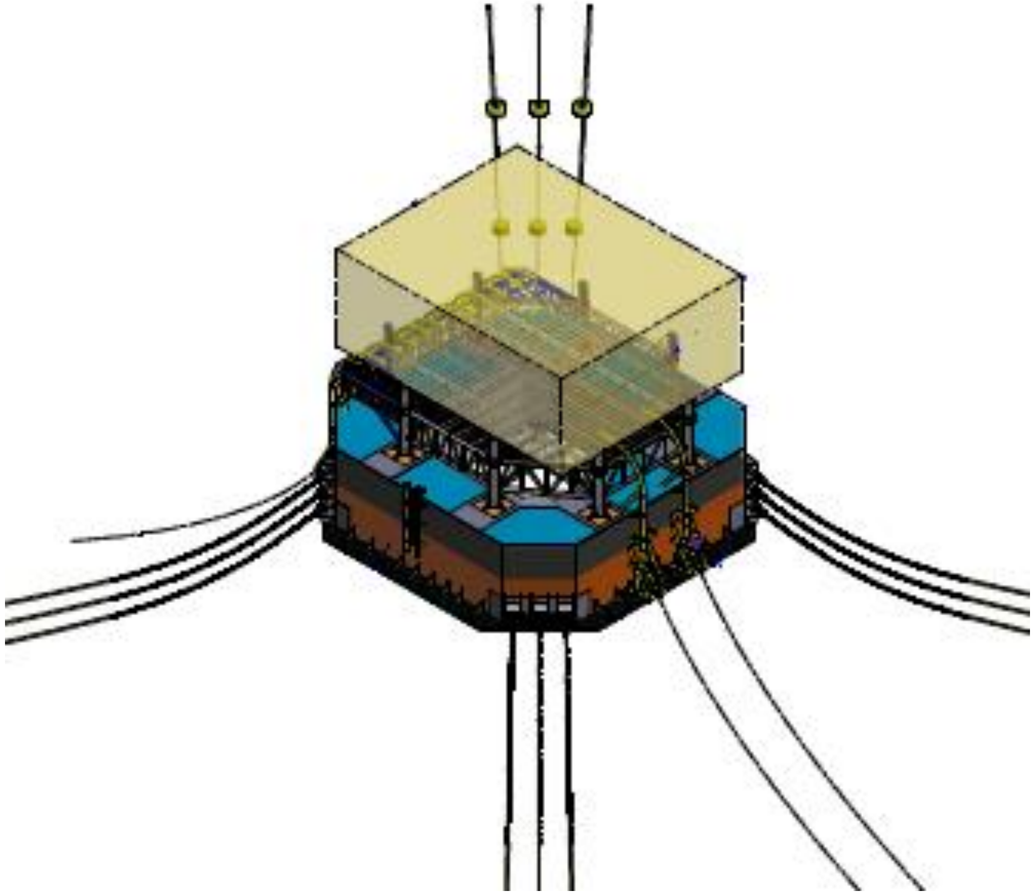
- Total capacity: ~750 MVA
- Metocean Parameter: medium sea conditions

Topside:

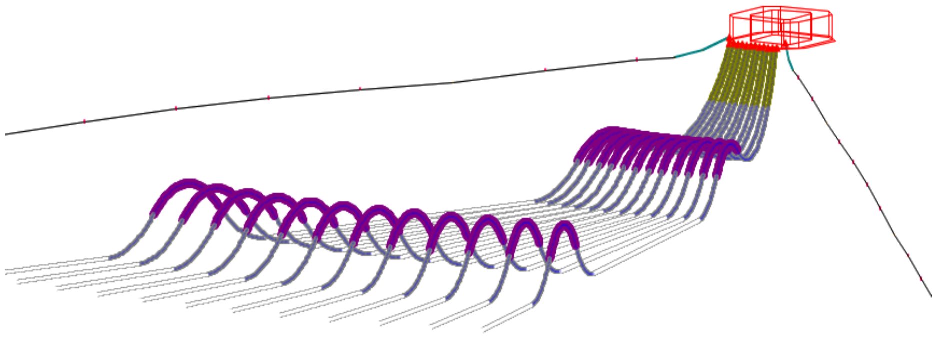
- Total mass : 4000t
- Overall dimensions: 40m x 32m x 15m
- CoG and Inertia as input data

Dynamic cables:

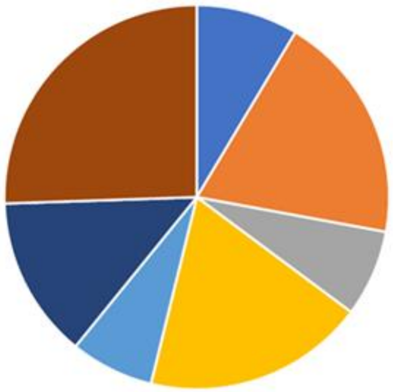
- 12 Intra Array Cables 66kV 3x800mm² Cu
- 2 Export Cables 220kV 3x1600mm² Cu

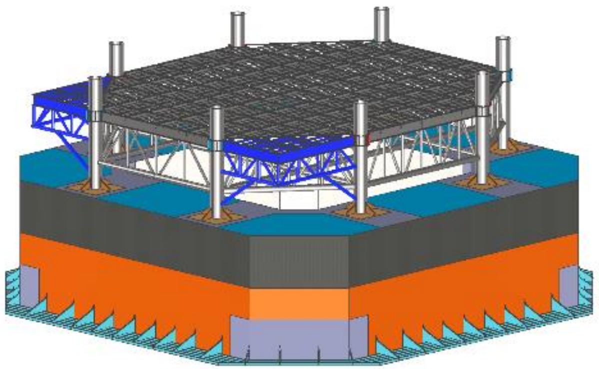


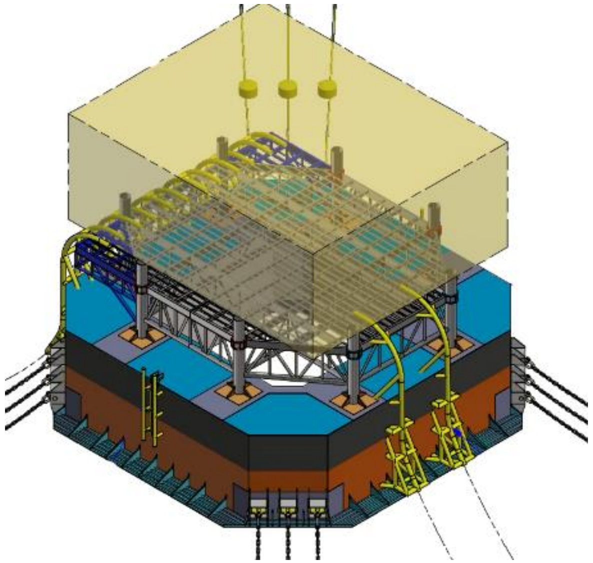
Project A: Scope



A) Naval architecture and overall design
B) Mooring system design
C) Dynamic Cable design
D) Hull design
E) Topside support structure design
F) Preliminary Costing Study







Project B

Windfarm:

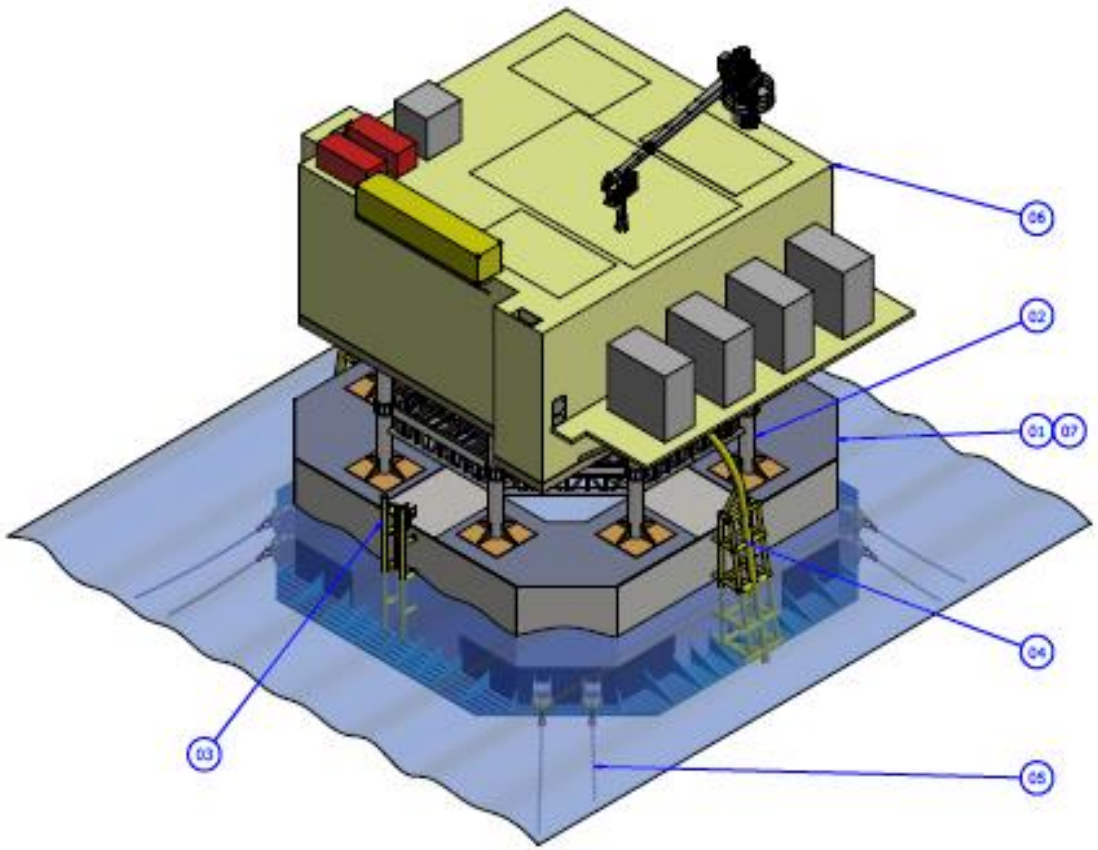
- Total capacity: 250 MVA

Site:

- Metocean Parameter: “moderate” sea conditio
- 200m sea depth
- 50km distance to shore

High Voltage:

- SLD
- 4 incoming cables 66kV
- 2 export cable 220kV



Project B: Scope

A) Possible Technical design (incl hull, hv equipment and topside)

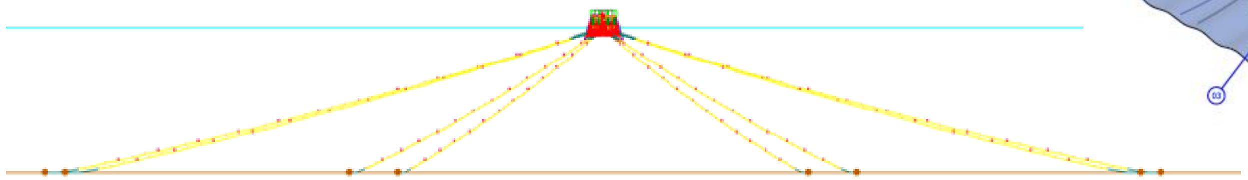
B) Preliminary Layout Drawings

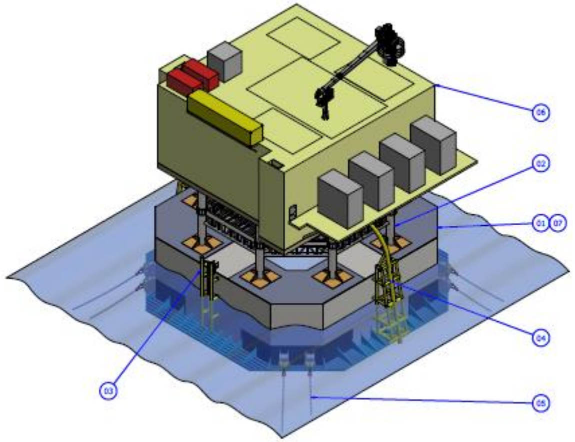
C) Project Time Schedule

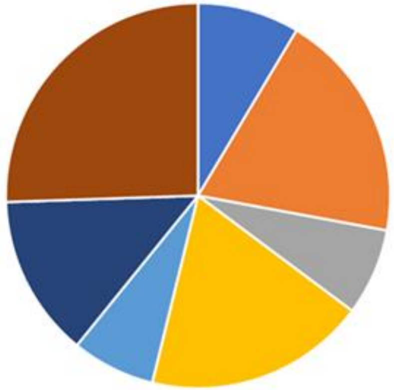
D) Local Content Potential Assessment

E) Preliminary Costing

Hitachi Energy







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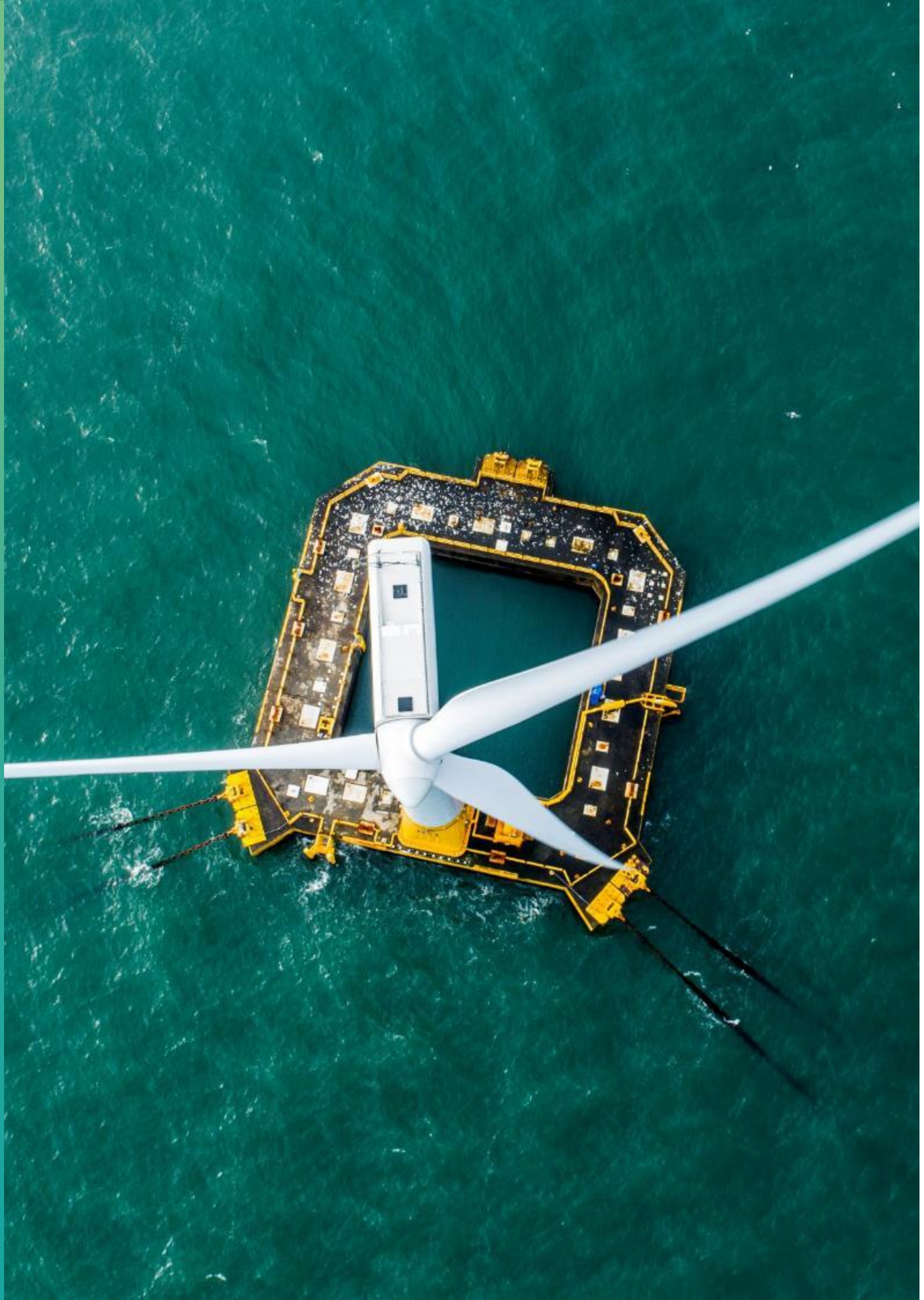
Lessons learned



FAQ TSO & Developer Interactions

- Technology Readiness Level
- Compatibility with HV equipments: Inclination, acceleration & vibration
- Scaleability / Maximum size
- Operability
- Local Content Requirements
- Cost Competitiveness

Technology Readiness Level (TRL)

Overall TRL

Whole floating substation	
TRL EU scale	Proof of TRL
6	Design completed and individual components designed
7	Completion of construction
8	Commissioning
9	After three years successful operation

Hull and Topside TRL

Component	TRL EU scale	Proof of TRL
Damping Pool	9	Two demonstrators at sea, seakeeping performance proven and approved by Third Party (ABS)
Hull construction	9	Regular steel hull, similar to that of NEDO project demonstrator
Hull / topside adaptation structure	9	Regular truss structure, analysed by FEM
Mooring system	9	Same mooring system as oil and gas platforms: chain-polyester. Conventional anchors.
Cable connections	9	Same as riser supports on oil and gas platforms

HV equipments TRL

Component	TRL EU scale	Proof of TRL
66kV inter-array cables	9	Already in use in farms / oil and gas.
220kV dynamic export cable	6	Cable design operated up to 125kV. Fatigue mechanical testing of 220kV conductors missing.
Main transformers	9	No new component qualification, only fatigue-driven reinforcement required.
Shunt reactors	9	No new component qualification, only fatigue-driven reinforcement required.
66kV gas insulated switch gear	9	Already in use on floating wind turbines.
220kV gas insulated switch gear	6	Proof of switching under low frequency accelerations required.
Utilities	9	All utilities similar to ship-type structures.

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Compatibility & Scaleability

Compatibility with HV equipments:

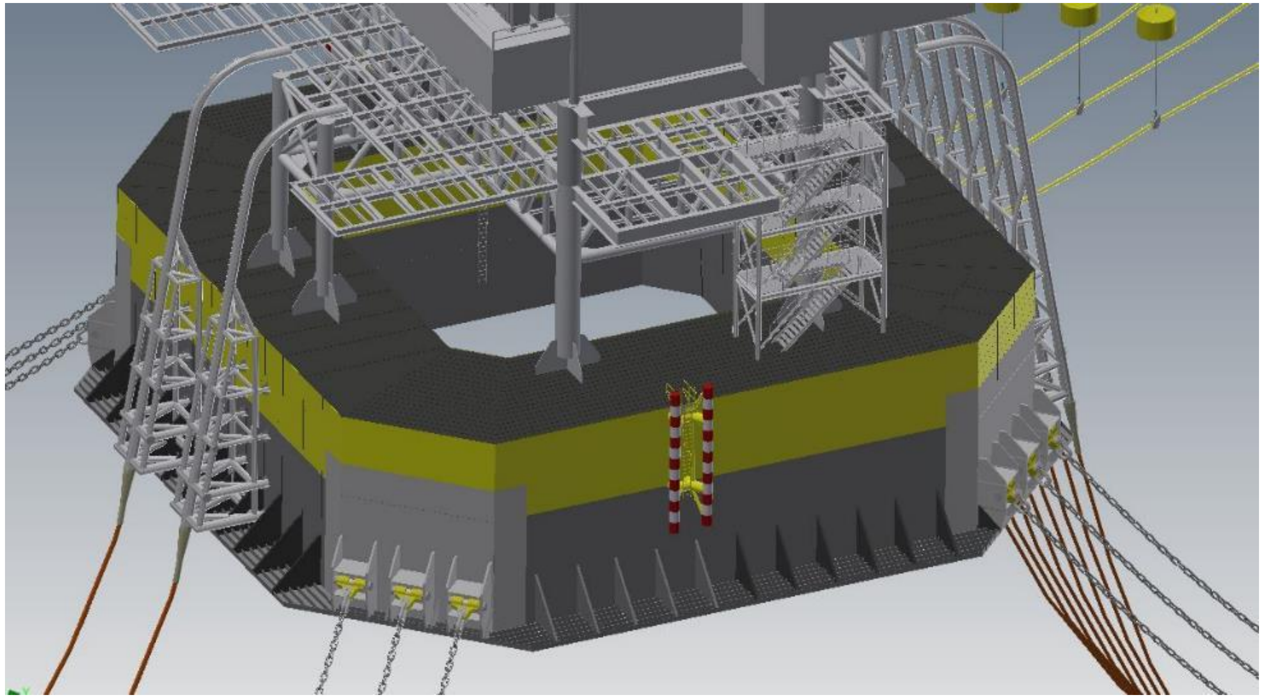
- fully verified and confirmed with Hitachi Energy

Scaleability / Maximum size

- Initial design for 200-900 MVA range substation (4000t topside)
- No limit in terms of floater size and capacity
- Optimised cabling/Redundancy to be considered

Operability

- **Major Component Replacement**
- **Minimum downtime period (mooring line replacement)**
- **Extreme conditions: typhoon, tsunami**



Local Content & Competitiveness

Local Content Requirements

- Supply chain studies to maximize local content

Cost Competitiveness

- Good feedback from the market on CAPEX, benefits in insurance and installation cost need to be verified
- Specific to site and project configuration: difficult soils, seismic loads etc. likely to improve business case of floating
- When possible: utilize FOW Hull construction infrastructure synergies for increased competitiveness

BW ideol

Thank you.

BW ideol

Mathieu Roualdes
Pre-Sales Project Manager
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QUALITY SYSTEM CERTIFICATION
DNV·GL
ISO 9001

DeepWind
North of Scotland Offshore Wind Cluster

Justin Jones

Petrofac

FLOATING SUBSTATIONS

24th August 2023

Petrofac

INTRODUCTION

Petrofac

Introduction - Petrofac

Petrofac

#27
ENR Top 250 International contractors of the world

+200
Major projects delivered

7,950
worldwide employees

>4.5 MILLION
Annual engineering man-hours

>US$2 BILLION
Procurement spend (on average per year)

>200 MILLION
Average annual direct construction man-hours

40 year
Track record

31offices
Worldwide 29 countries

Introduction – Petrofac wind EPC track record

Petrofac

2009

TenneT BorWin 1

O&M Consultancy

Moray Firth, Scotland

Concept Design Studies

2010

TenneT DolWin 1

Design verification and construction management

2013

TenneT HelWin1, BorWin2

Commissioning support, platform support and maintenance services

2014

TenneT BorWin3

EPCI Offshore Substation HVDC

2015

RWE Innogy Galloper

EPCI Offshore Substation HVAC

2018

TenneT BorWin3

First successful float over installation in Germany

2019

TenneT HKZ Alpha / Beta

EPCI for HVAC Substations

SSE Seagreen

FEED & EPCI for HVAC onshore and offshore substations

2019 / 2020

TenneT HKZ Alpha / Beta

Substation construction

2023

TenneT 2GW HVDC platforms

EPCI Offshore transmission stations

Selected offshore substation designs

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Project	Location	Completion Date	Description
Confidential	Irish Sea	2023	Concepts for AC substations of 400MW and 800MW
Confidential	Offshore Korea	2022	Concepts for AC floating and fixed substations of 400MW, 800MW and 1.2GW in 140m water depth
HKZ	North Sea, Holland	2023	EPCI of two AC substations, Alpha and Beta, of 700MW each, in around 20m water depth
Confidential	North Sea, Germany	2022	Pre-FEED for 225MW and 400MW AC substations
Seagreen	North Sea, Scotland	2022	EPCI of the topside, jacket and piles for the substation for the 1075MW wind farm
BorWin3	North Sea, Germany	2019	EPCI of an HVDC convertor station
Parkwind Arcadis	Baltic Sea, Germany	2019	Stressed skin topsides design for a monopile-based substation
Scotwind bid	Scotland	2019	Development of jackets and floating concepts for AC and DC substation options
Moray West	Scotland	2019	Concept design for an 800MW OSS in 46m water
Triton Knoll	The Wash	2016	Concept design for a monopile substructure and topsides
East Anglia One	Suffolk	2016	Concept, FEED detail design and EPCI for the jacket of a 700MW substation

FLOATING SUBSTATIONS

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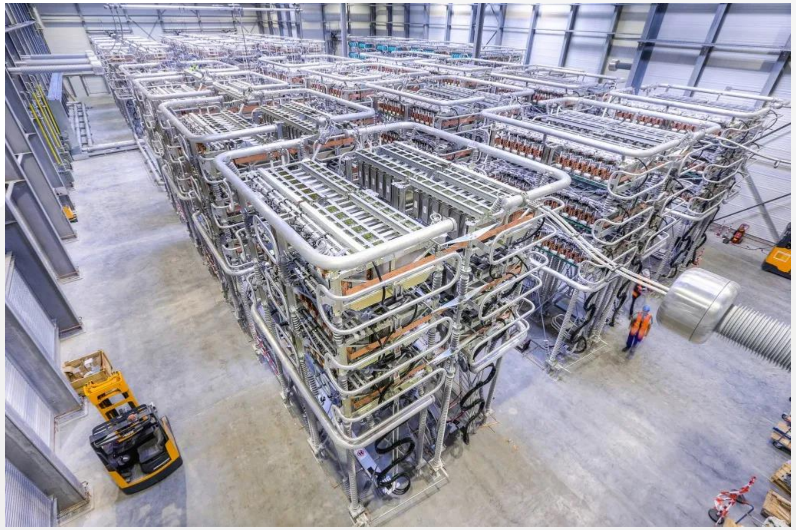
Floating substation function

- Connect to the arrays at 66kV, up to 80MW per circuit
- Export to shore at 220kV, up to 400MW per circuit
- Key equipment
    - Array switchgear
    - Transformer
    - Shunt reactor
    - Export switchgear
- Unlikely to be used as a service hub for the windfarm

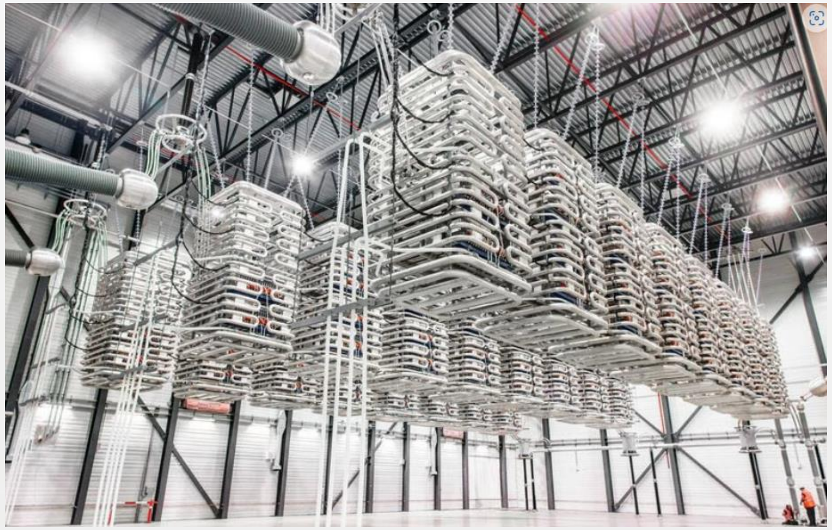
AC vs DC

- Used offshore in O&G applications
- Limited modification for floating
- Structural stiffness/isolation
- AC export cables (e.g. 220, 275kV) yet to be developed

- Large enclosed space
- Sensitive converter equipment
- Floor or ceiling mounted
- Likely to be fatigue issues
- DC export cables further away



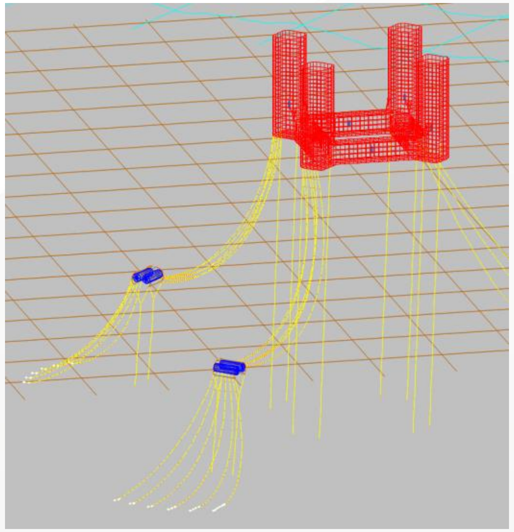
Courtesy Siemens

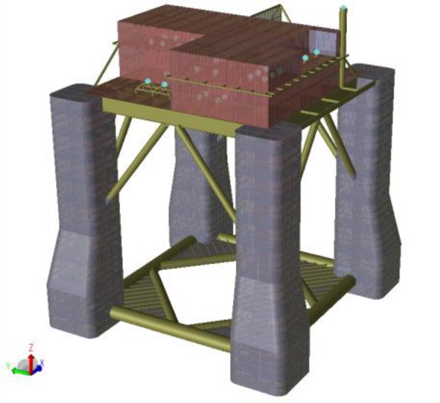


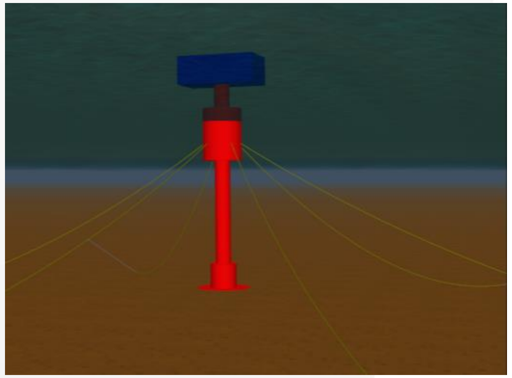
Courtesy ABB

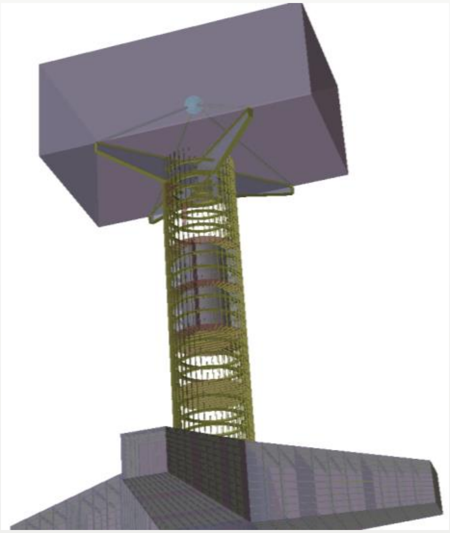
Hull design

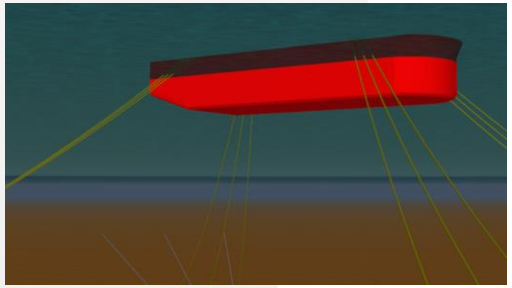
- Hull form
  - Semi-submersible
  - Tension leg platform
  - Spar
  - Barge/ship shaped
- Current and wave conditions
- Separation of cables and moorings
- J-tube protection
- Electrical equipment accelerations











Hull design – semi-submersible example

- Early design decisions
- Integrated topside or separate
    - Construction and yard capability
    - Enclosed or in open transformers
- Interfaces vs structural efficiency
- Re-use of O&G vessel?

Topside design choices

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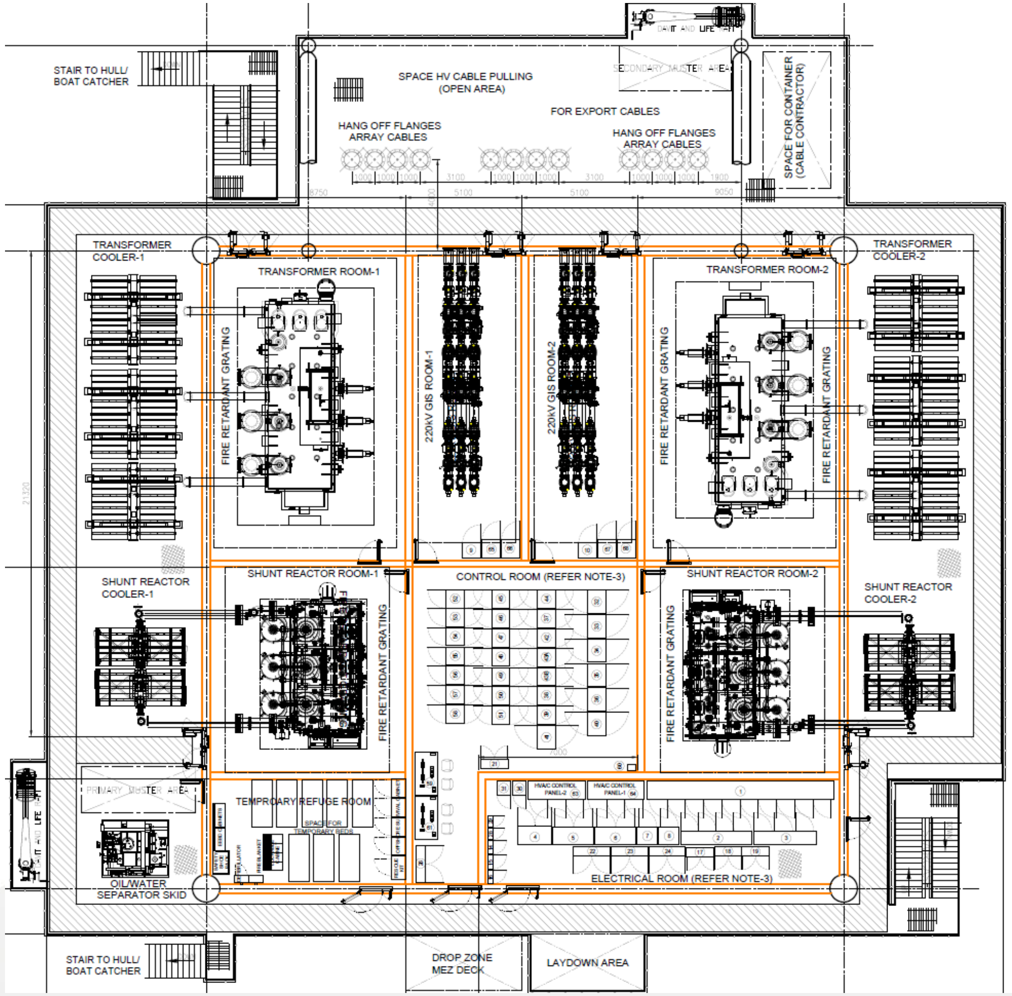

- Balance
- 2/3 equipment mass in transformers
- Efficient mass distribution
- Flow of power through the design
- Transformer/shunt reactor coolant
- Separation and firefighting
- Designs need to be developed for offshore ester transformers
- Access and egress
- Cranes, boat landings and laydown

EXAMPLE

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Floating substation - Parameters

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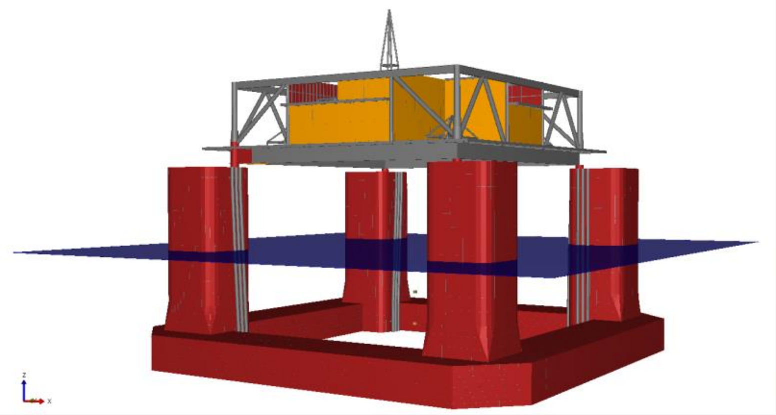
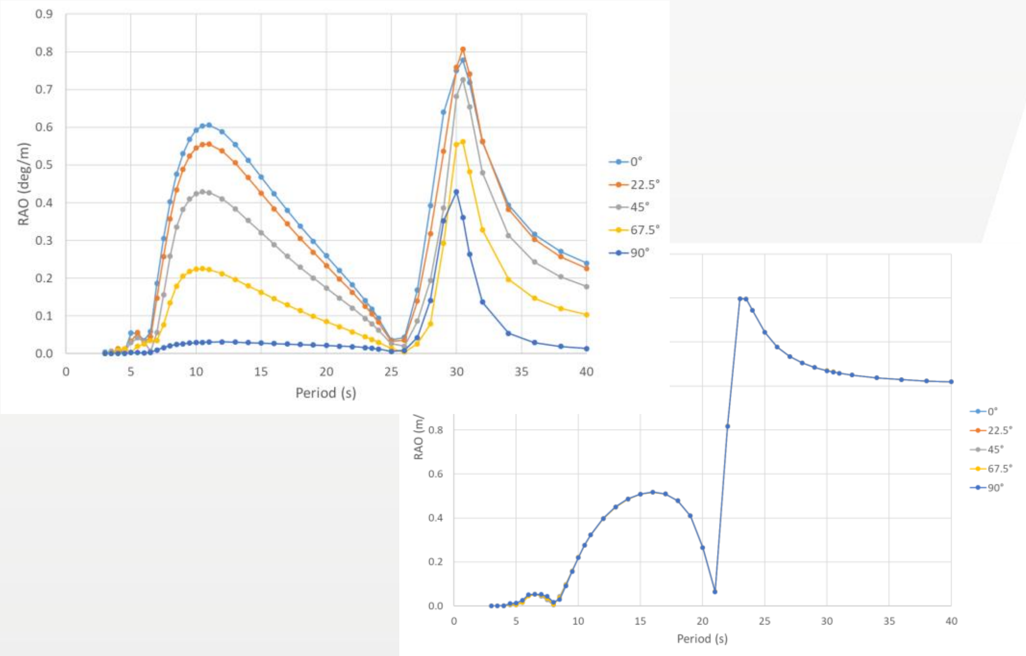
- 140m water depth
- AC, 1.2GW capacity, three export circuits
- High current area with high storm seastate
- Semi-submersible and TLP options investigated
- Semi-submersible selected by client
- Transformers in the open ~500 tonnes each
- Shunt reactors ~150 tonnes each

Floating substation – Hull development

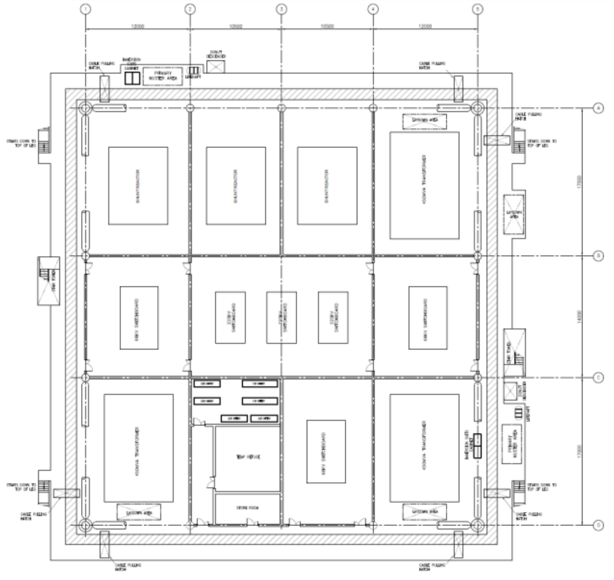
- Different hull options tested
- J-tubes supported/protected by hull
- Set up for cable pulling after installation
- Hydrodynamic analysis
- Aim for heave, pitch out of wave range
- Sets the column size and spacing

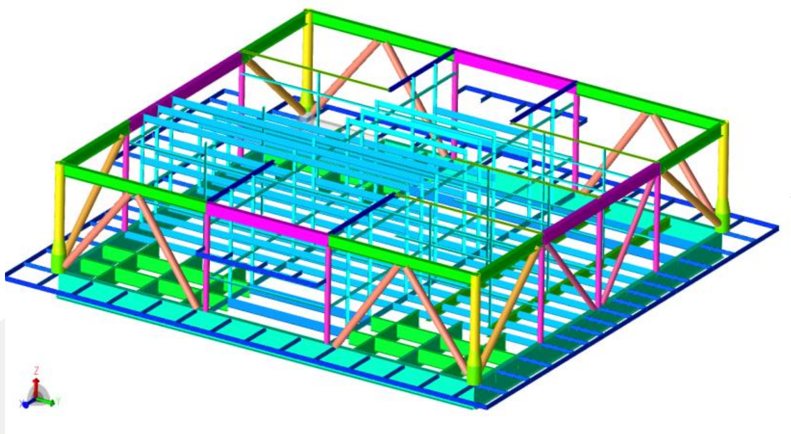


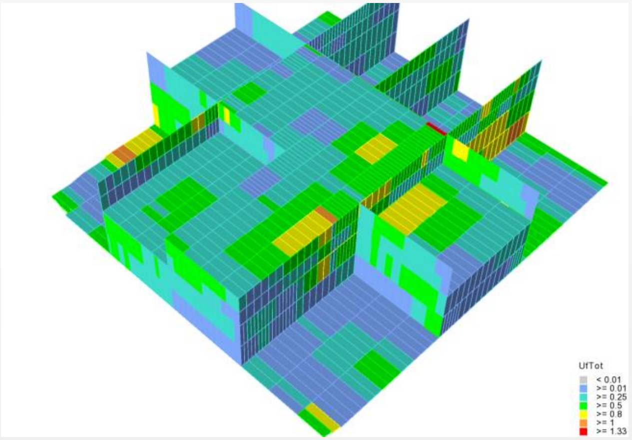


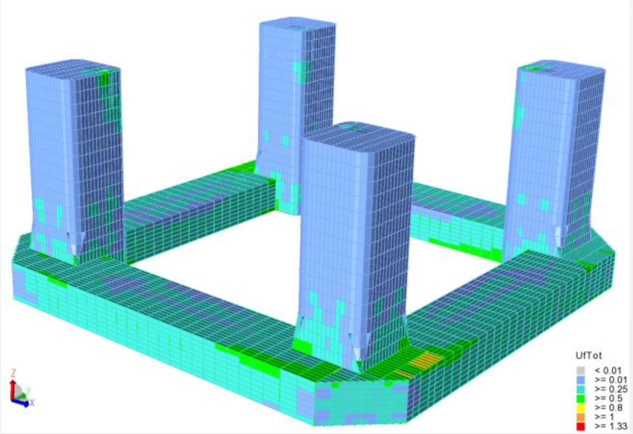
Floating substation – Structural design

- Topside independently constructed
- Heavy lift for topside installation
- Structural assessments in Sesam
- Stressed-skin spine to the topside



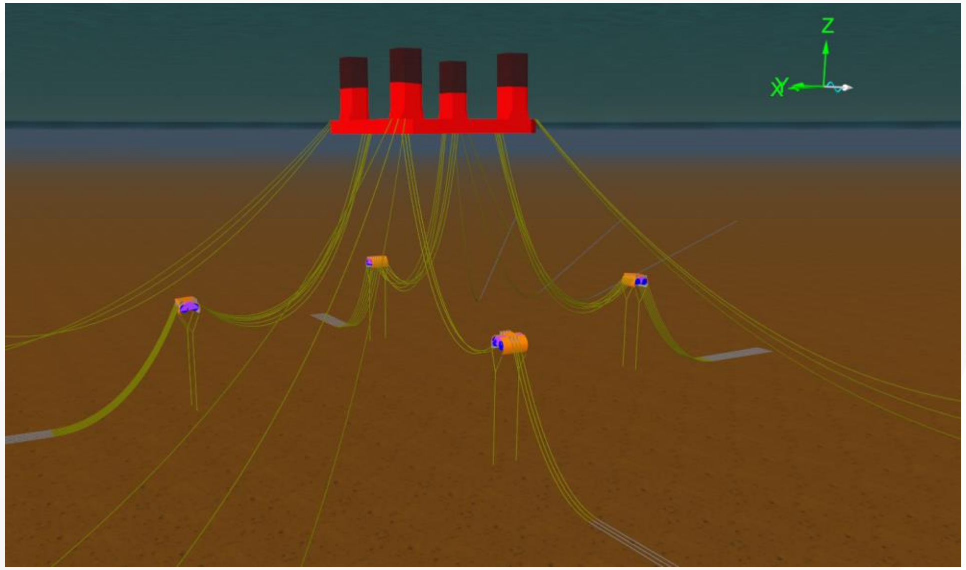


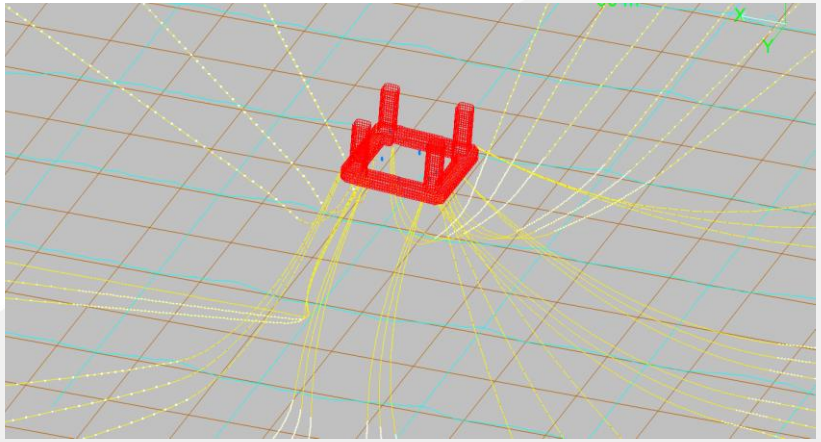


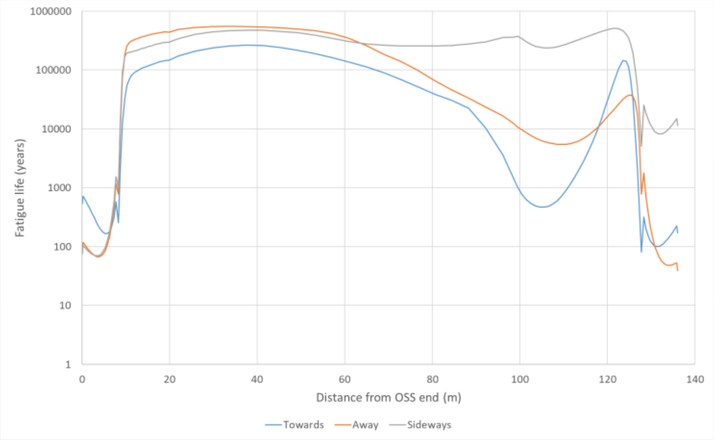


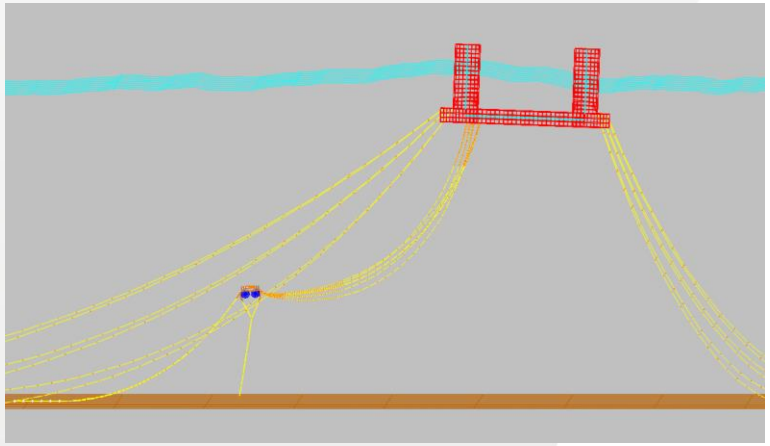
Floating substation – Cable and moorings

- Orcaflex analysis for motions, design of moorings and cables
- Cable design a balance between offsets, displacement in high current, fatigue
- Potential for clashing









Conclusion

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- 1.2GW AC substation concept developed
- Design choices specific to the location
- Largest barrier is the development of export cables
- Mass 9,500 tonnes vs 15,000 tonnes for bottom fixed
- Costing (vessel and mooring construction, installation, commissioning) showed a small difference between the fixed and floating options

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Q&A Session

24th August 2023

DeepWind
North of Scotland Offshore Wind Cluster

offshore wind Scotland

Image source – BW Ideol