Conference:
Marine Construction Engineering Deepwater Development
Novotel London West, Hammersmith, London, W6 8DR, UK
12th to 14th April 2022

FLOATING OFFSHORE WIND TURBINES INSTALLATION METHODS

By Alan Crowle*[1] and Professor P.R. Thies[1]
*Email: ac1080@exeter.ac.uk

[1] University of Exeter, College of Engineering, Mathematics and Physical Sciences, Renewable Energy Group, Penryn Campus, Treliever Road, TR10 9FE, UK

Decarbonizing Deepwater Production

MCEDD

DEEPWATER DEVELOPMENT

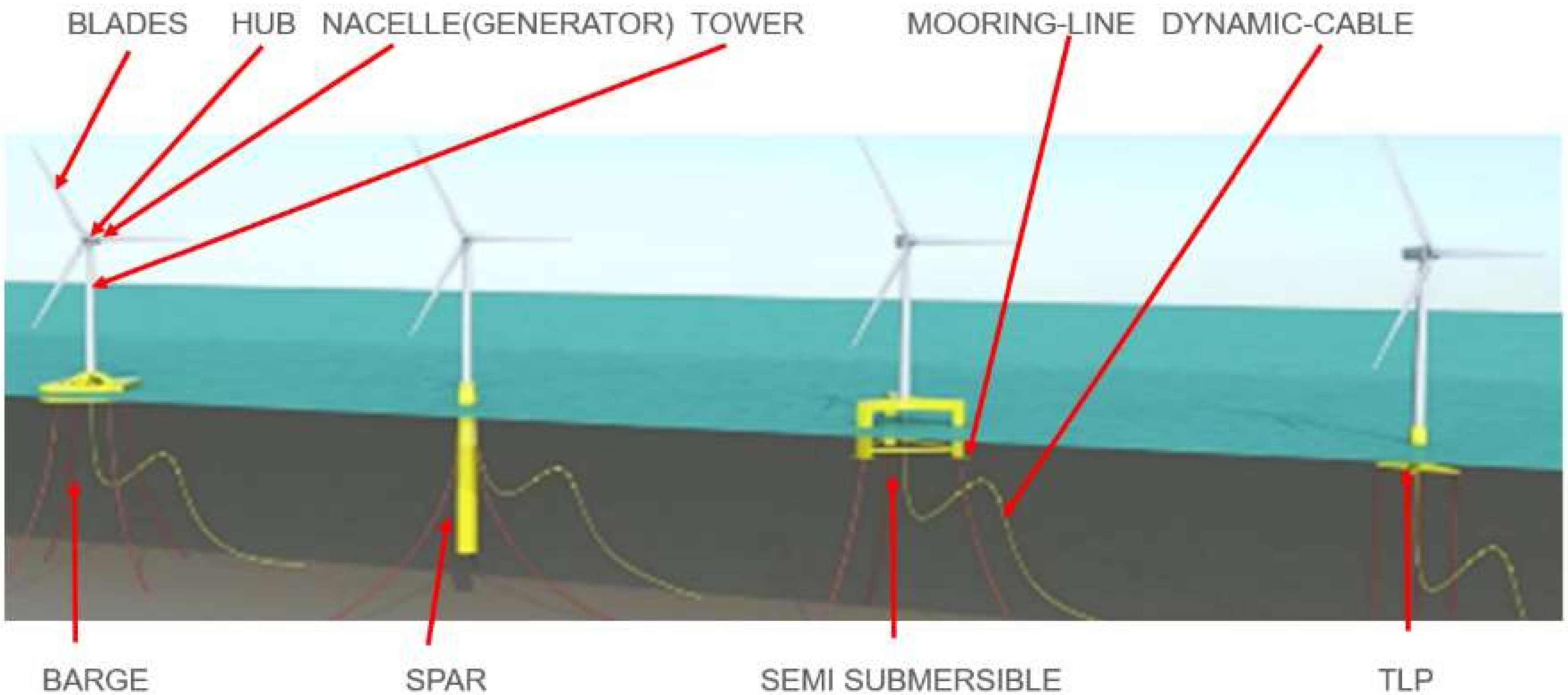
ORGANIZED BY: GULF QUEST · Quest Offshore · World Oil

INTRODUCTION

Floating offshore wind turbines are an emerging source of marine renewable energy, in deep water offshore locations, with minimal visual impact from the shore. The presentation reviews the installation methods for floating wind types such as barges, Spars, semi submersibles and TLPs, Ref[1].

MAIN FOWT TYPES Ref[2]

MCEDD DEEPWATER DEVELOPMENT



FOWT TYPE	BARGE	SPAR	SEMI SUBMERSIBLE	TLP
No. in operation	1 concrete 1 steel	5(straight) 1(Submerged keel)	8 Windfloat 1 Wison	None
Advantages	Small draft so can be moored in many ports for fit out	Good intact stability during tow out	Good intact stability during tow out	Small area of moorings on the seabed
Disadvantages	a. Long mooring lines b. Small freeboard so weather restricted during towout	a. Deep draft, 70 to 80m means fit out needs to take place in sheltered deep water e.g. Norwegian Fjords b. Long mooring lines c. Requires solid ballast specific gravity 2.5 to 4.0 t/m3 d. Long mooring lines e. Requires large crane vessel or spacer barge with crawler crane for turbine installation inshore	a. High substructure weight b. Long mooring lines	a. Very low intact stability during tow out b. Turbine is in the centre so reducing crane capacity during turbine fit out c. Installation on tethers is weather restricted and time consuming d. Drag anchors not possible e. May need temporary buoyancy for towout f. May need crane vessel to assist offshore mooring connection

MCEDD
DEEPWATER DEVELOPMENT

SURVEYS

Survey are required for the export cable route and offshore wind farm

- Metocean
- Geophysical including water depths
- Geotechnical
- Shifting seabed
- UXO
- Grapnel dragged along the cable export cable route
- AUV with LIDAR

Looking for:

- Wrecks
- Lost fishing gear
- Pipelines
- Cables electric, Telecomms

GEOPHYSICAL SURVEY Ref[3]

Dedicated vessels map the characteristics of the seabed and bedrock to assess the conditions around the wind farm site and the potential export cable locations.

Accurate measurements are made of the bathymetry

GEOTECHNICAL SURVEY Ref[3]

MCEDD DEEPWATER DEVELOPMENT

The detailed site geotechnical investigations include, downhole cone penetration testing (CPT), seismic cone penetration testing (SCPT),

ENVIRONMENTAL SURVEY Ref[12]

- Bird migration
- Fisheries Surveys
- Fish spawning studies
- Plankton Surveys
- Fish behaviour surveys
- Electronic monitoring and sampling of fish to evaluate their behaviour in regards to sub-sea power cables
- Surveys to investigate the behaviour of fish species during offshore piling activities
- Sampling survey to examine the behaviour of fish species in regards to unburied sub-sea pipelines
- Commercial fishery mitigation and management surveys

METOCEAN SURVEY Ref[3]

MCEDD
DEEPWATER DEVELOPMENT

- Habitat mapping and marine mammal monitoring
- Metocean measurement
- Real-time ocean current profiling
- Integrated real-time buoy monitoring systems
- Derivation of metocean statistics for installation, operational and design support

METOCEAN SURVEY Ref[4]

The long term measurements include:

- Wind speed
- Wind direction
- Wave height
- Wave period
- Wave direction
- Tide heights
- Tidal current speed
- Tidal current direction

ROUTE CLEARANCE Ref[11]

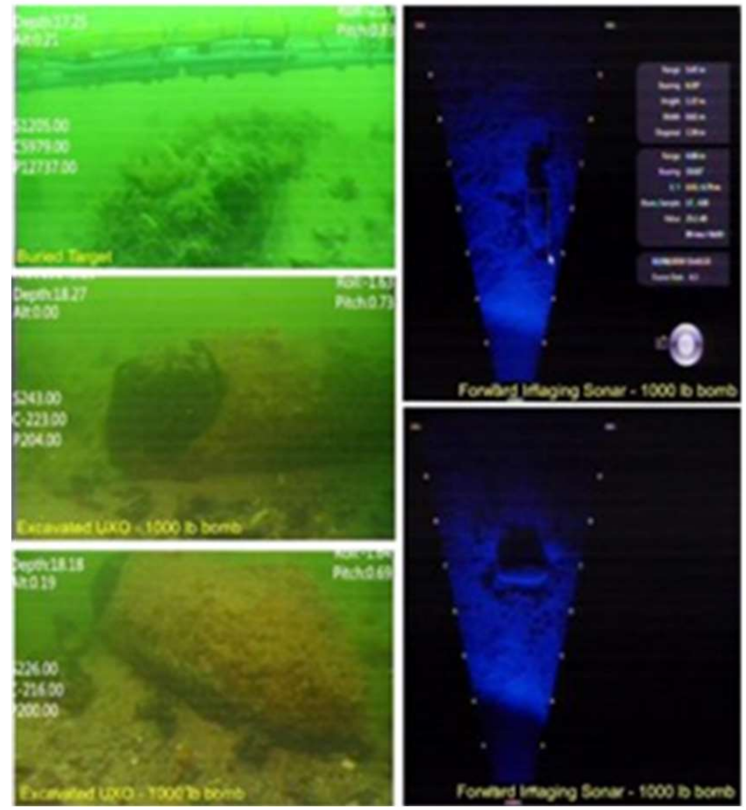
MCEDD
DEEPWATER DEVELOPMENT

Route clearance is required ahead of site preparation and cable installation. The assets to swiftly, accurately and safely remove boulders, old cabling and other debris and obstacles from all compositions of seabed, include:

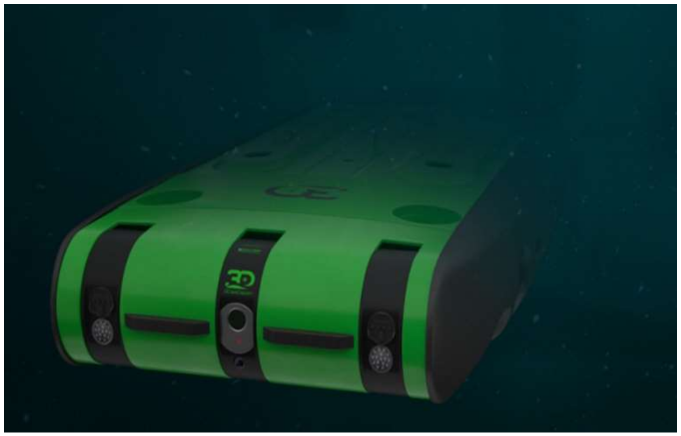
- Pre-Lay Grapnel Runs to remove surface debris (including fishing nets, redundant wiring and ropes) from the cable route, creating a clear path for the submerged plant and burial vehicle during trenching.
- Removal ofout-of-service cables found within the installation corridor to create a clear and safe passage for new cable installation.
- Removal and relocation of boulders, using a multi-purpose work class ROVs to clear obstructions from both low and high-density areas

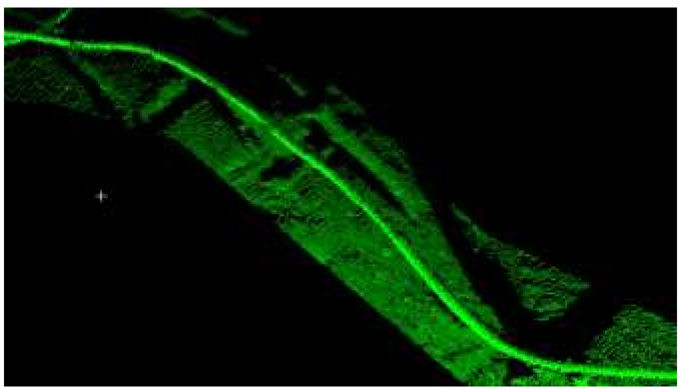
UNEXPLODED ORDNANCE Ref[11]

A UXO solution, from initial survey through to subsequent positive explosive ordnance disposal (EOD) on designated targets, using the latest technologies and techniques to deliver results safely, efficiently, and cost-effectively. Detection, identification, removal and disposal Innovation in disposal including bubble curtain noise attenuation



3D AUV Ref[22]



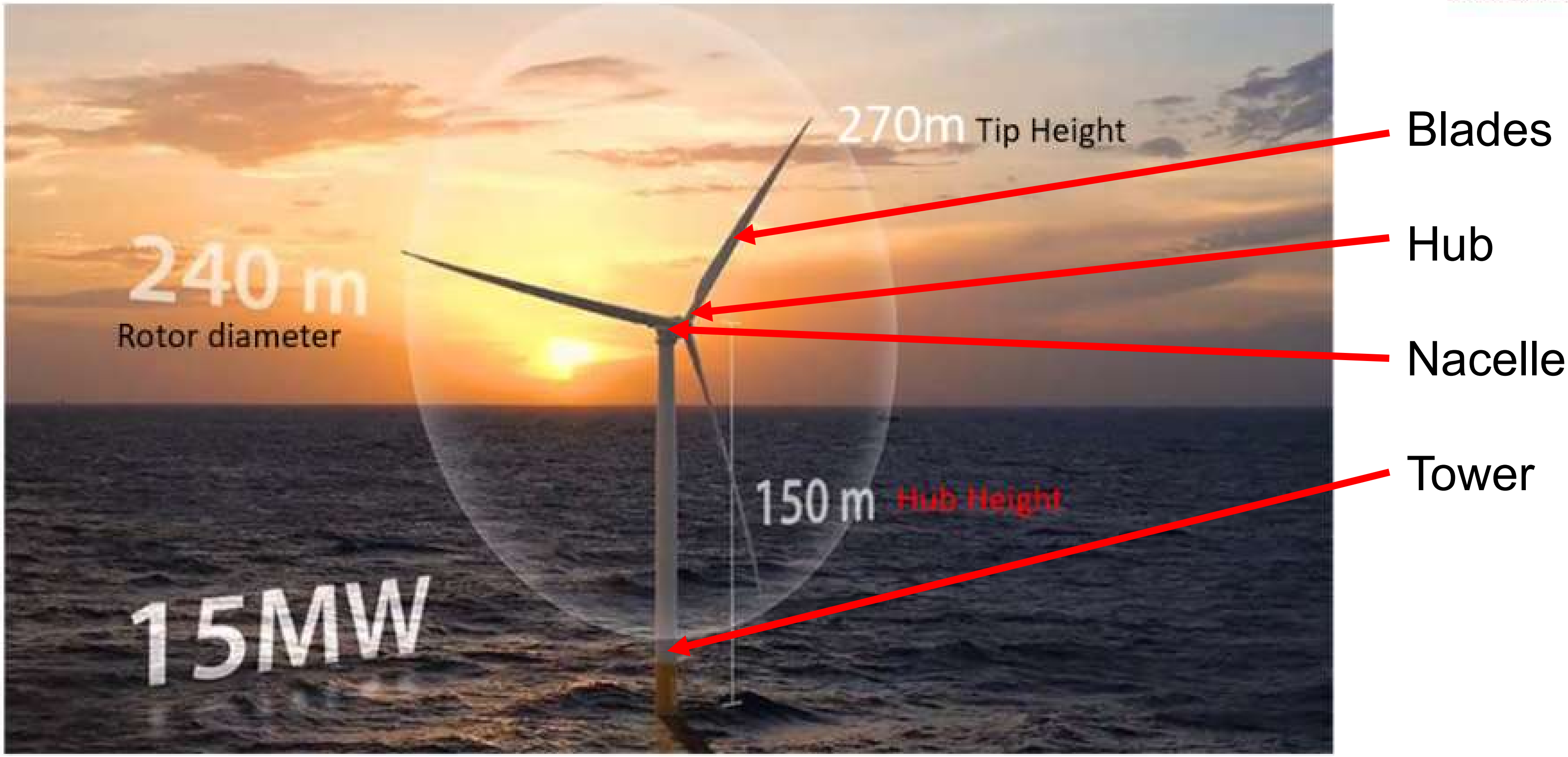


Hydrography and Geophysics are central to any site investigation or seabed mapping project. Securing accurate and precise 3D data sets to assess, measure, evaluate, document and monitor are important to the success of any underwater program. measure subsea topography, assets and the marine environment are important. From establishing baseline audits to long term documentation and monitoring, the subsea LiDAR SL systems provide touchless, log range – up to 45 meter 3D scans with low impact to the surrounding environment

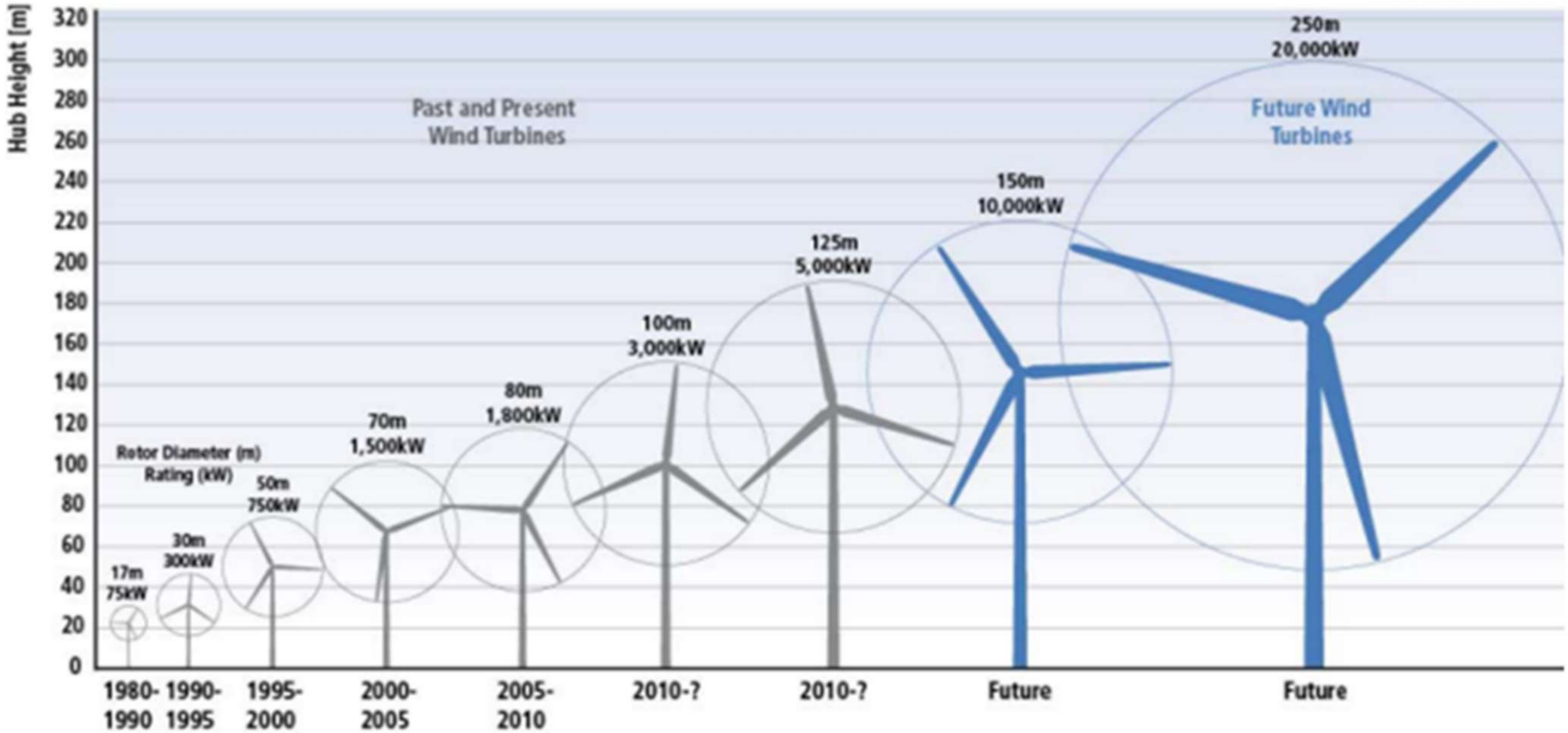
TURBINES

Floating offshore wind turbine, maximum so far	9.6MW
Fixed offshore wind turbine, on order	13.0MW

TURBINES Ref[13]



TURBINES Ref[13]



BLADE TRANSPORT   Ref[9]

NACELLE TRANSPORT Ref[5,10]

STEEL BARGE (2 blades) Ref[19]

BW-IDEOL

Completed-structure with 2 blades

Sheer leg crane vessel used to install tower, nacelle and blades

Steel substructure

EQUINOR STEEL SPAR   Ref[21]

Semi submersible crane vessel (SSCV) Saipem S7000 , ref[17} lifting the Hywind Spar turbine

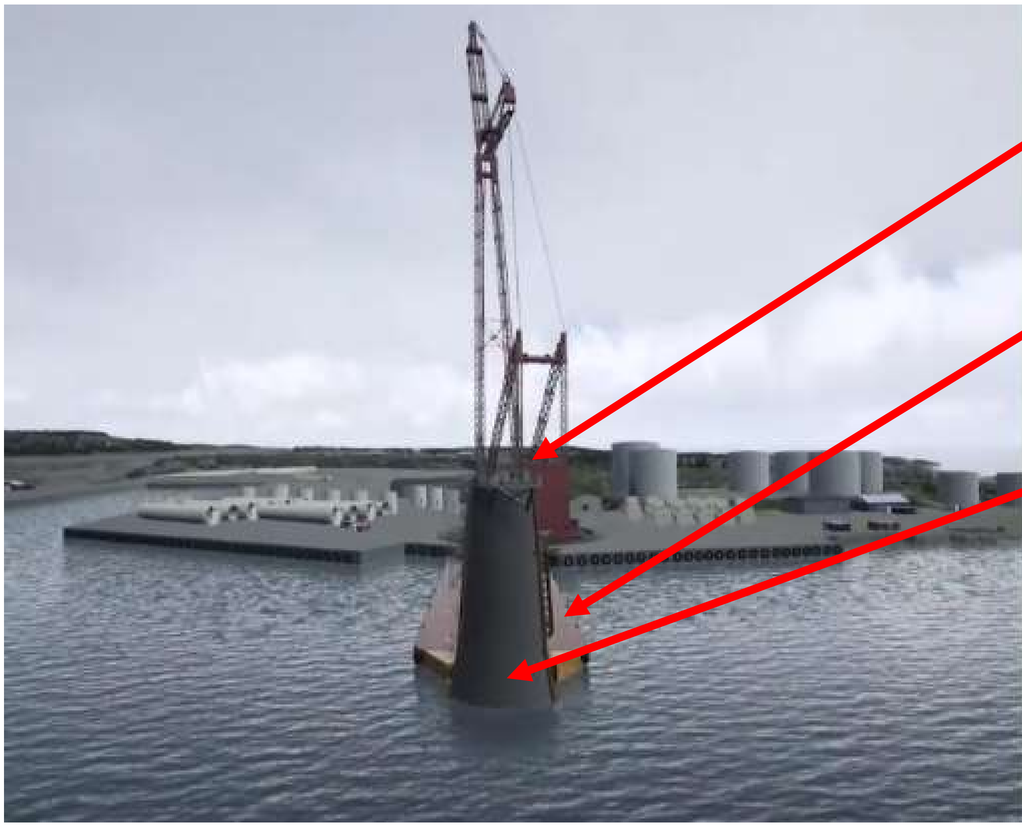
EQUINOR STEEL SPAR Ref[21]

Outfitted Steel Spar,
70m draft. Topsides installed
by SSCV

Temporary moorings for barge
Spar moored to barge

Outfit barge

EQUINOR CONCRETE SPAR Ref[21]



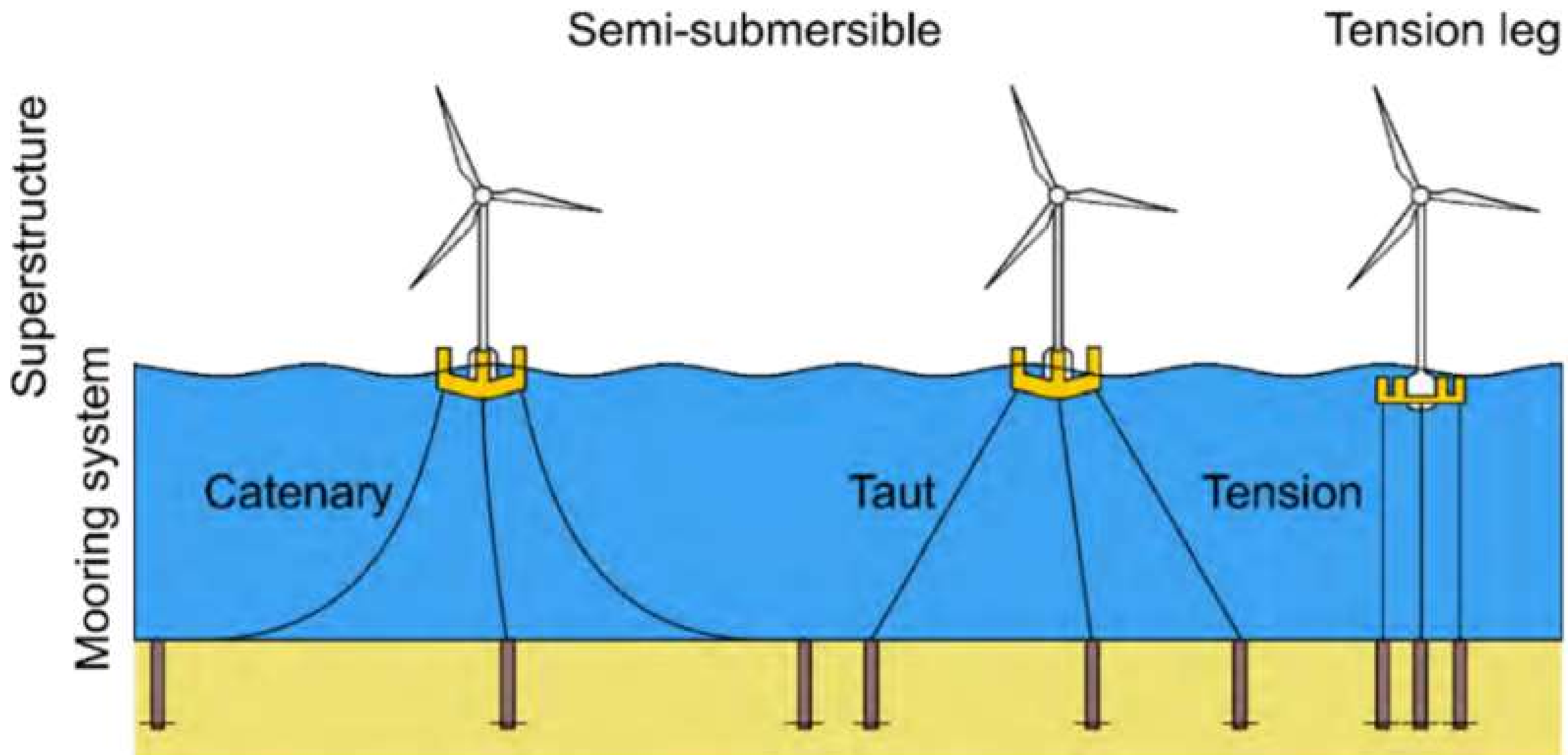
Large onshore crane to lift turbine

Spacer barge

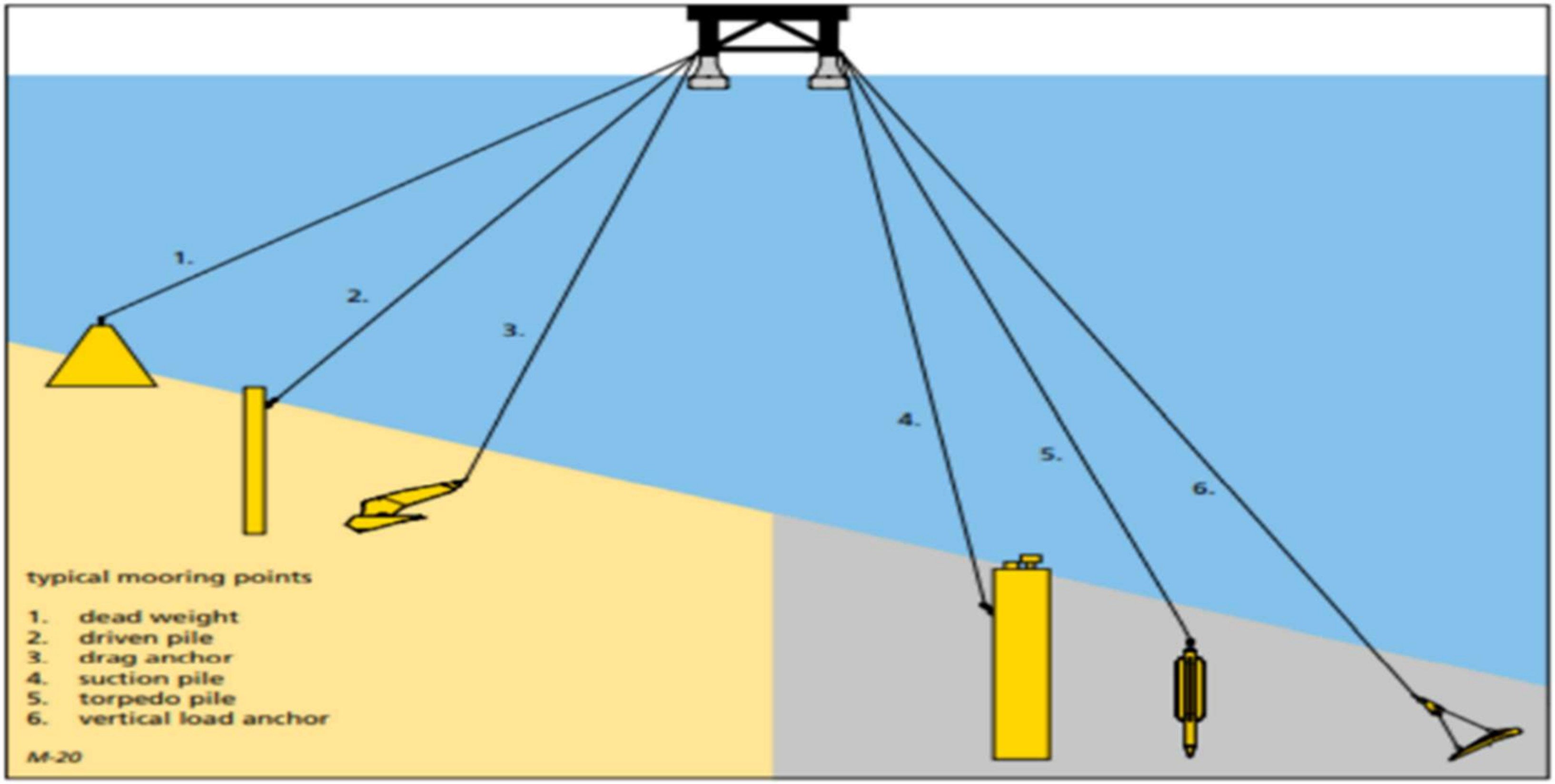
Concrete substructure, 80m draft

MOORINGS

MOORING TYPES Ref [14]



OFFSHORE ANCHOR TYPES Ref [15]



ANCHORING SYSTEMS Ref [15]

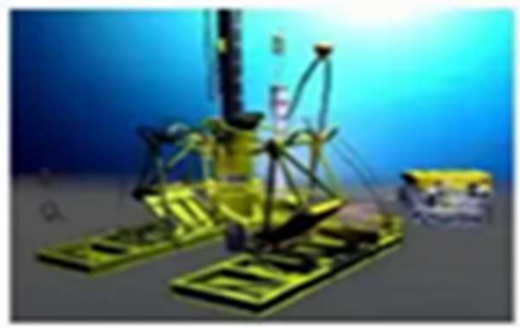
MCEDD DEEPWATER DEVELOPMENT

Torpedo anchor Ref[24]
Needs soft/hard mud

Suction Caissons
Needs ~ > 1*D NC Clays and/or Sands

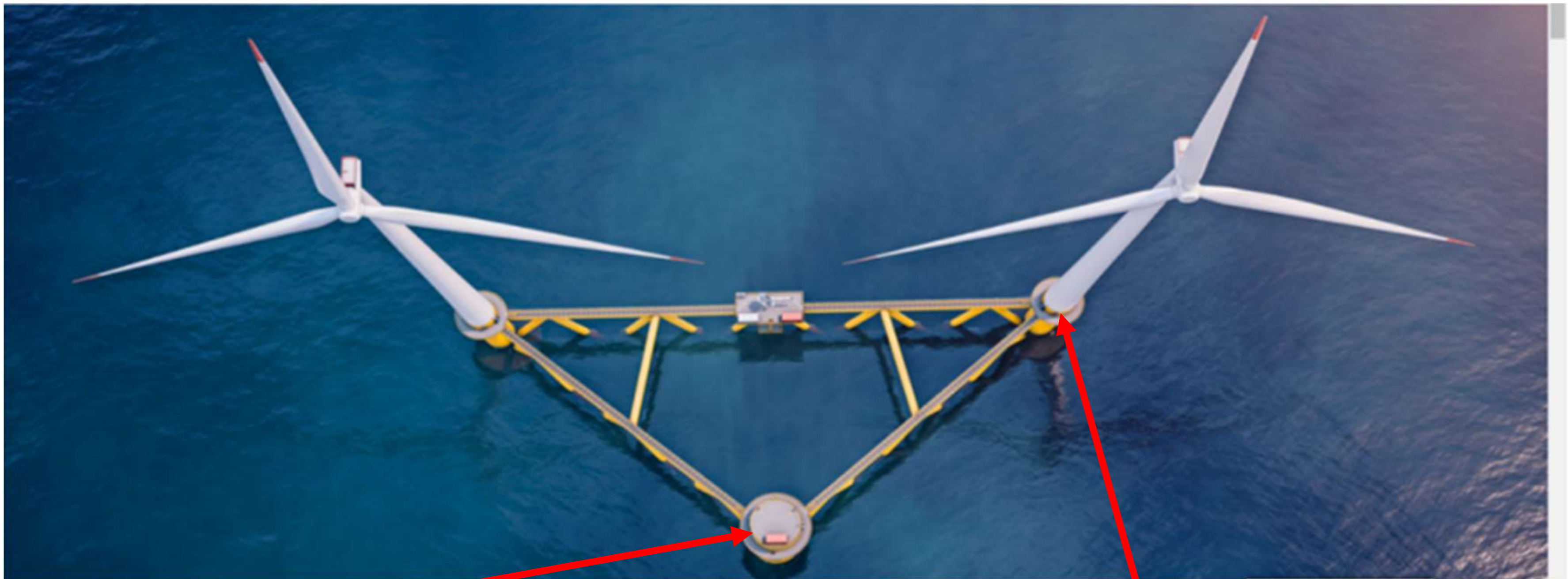
Drag Embedment Anchors
Needs Adequate Soil Layering/Depth to Hold

Anchor Piles
Steel Driven or Drilled & Grouted: Costly



HEXICON TURRET MOORING Ref[16]

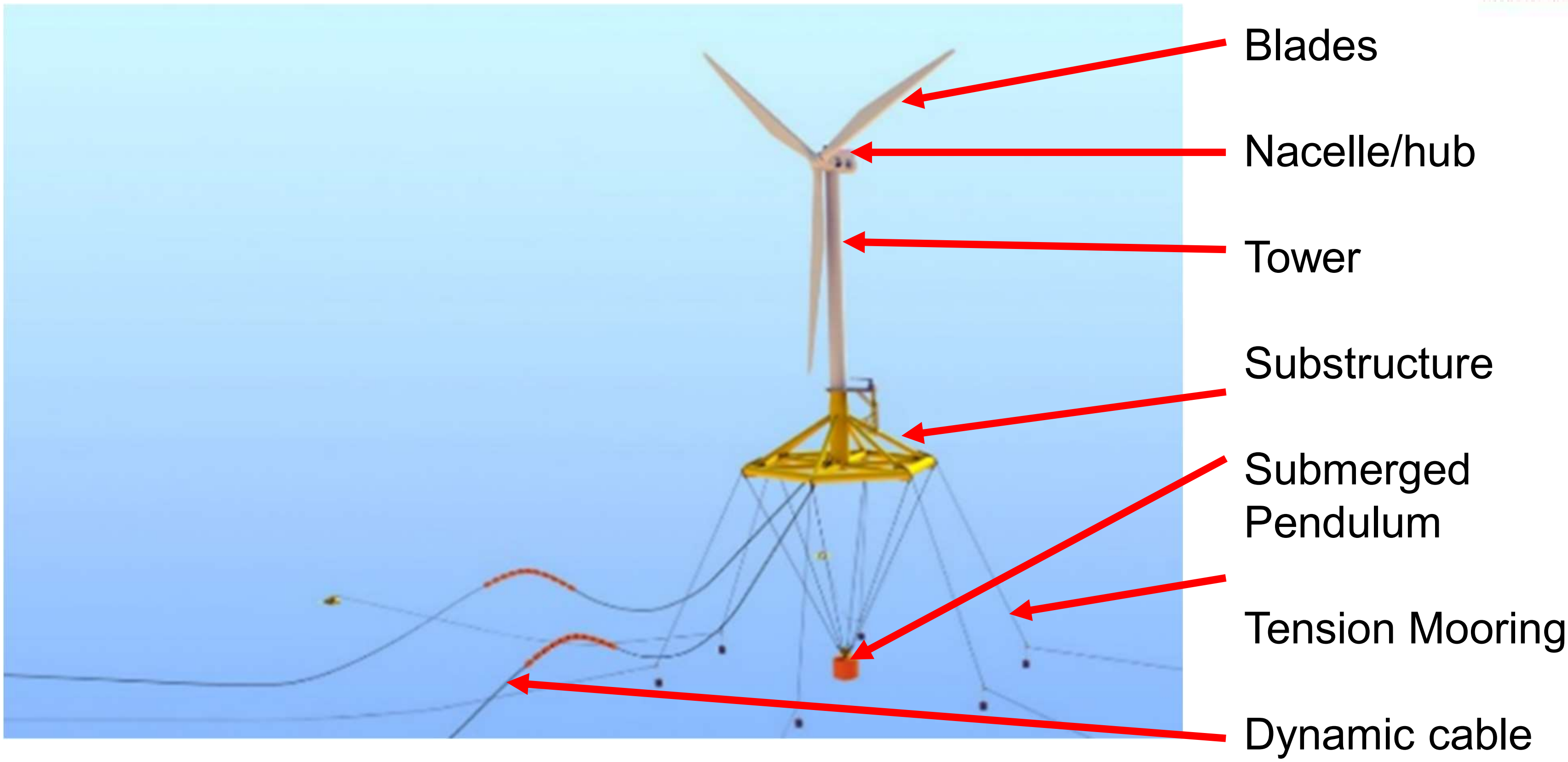
MCEDD
DEEPWATER DEVELOPMENT



Turret, with fixed moorings and electrical swivel.

Turbines fixed.

SAIPEM HEXAFLOAT Ref[17]



SBM Ref1[8]

Tension (chain) tethers, ballast down and re-tension

Tow out shallow draft
Large 2nd moment of
Water plane area

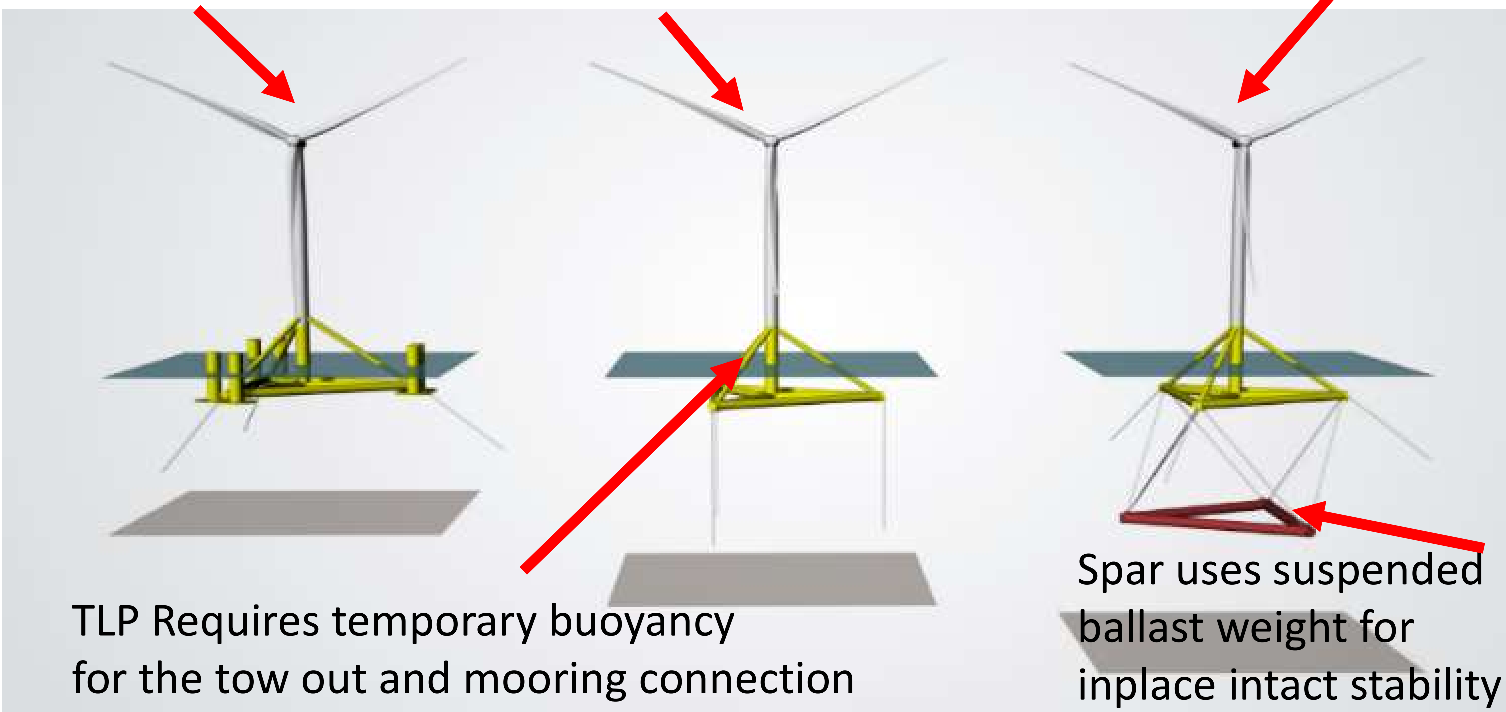
TLP
Variable
Draft

STIESDAL OPTIONS Ref[19]

TetraSub:
semisubmersible

TetraTLP:
Tension Leg

TetraSpar:
Spar



SEMI SUBMERSIBLE INSTALLATION

LOADOUT Ref[5]
(Offshore China)

MCEDD
DEEPWATER DEVELOPMENT

Substructure

Length 91m

Width 91m

Depth 31m

Brace

Column

Heave plate

ON SUBMERSIBLE BARGE Ref[5]

Substructure

SPMT Trailers

Submersible Barge

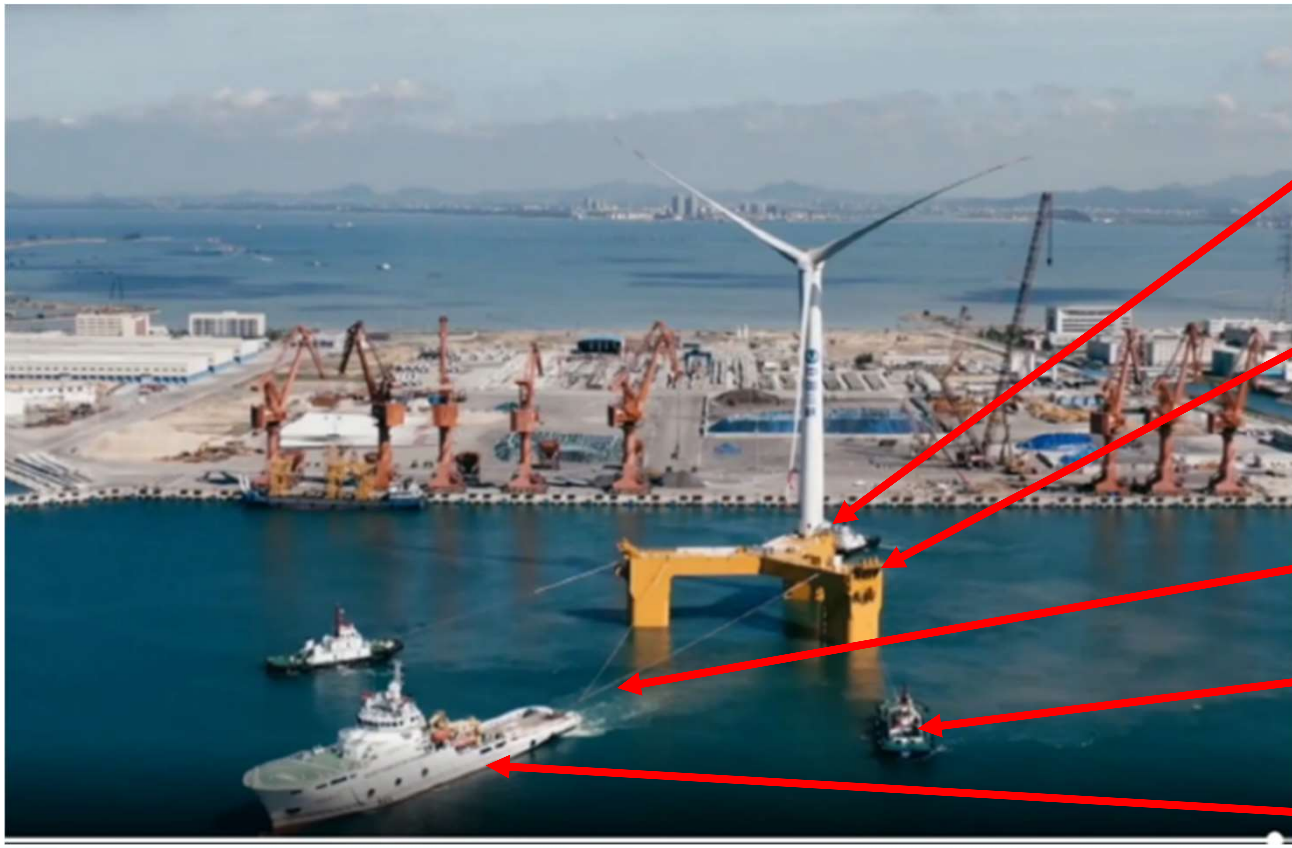
Harbour Tug

TOW OF SUBSTRUCTURE Ref[5]

LIFTING TOWER SECTIONS Ref[5]

Tower on corner
To maximise
onshore crane
capacity

TOWOUT STRUCTURE Ref[5]



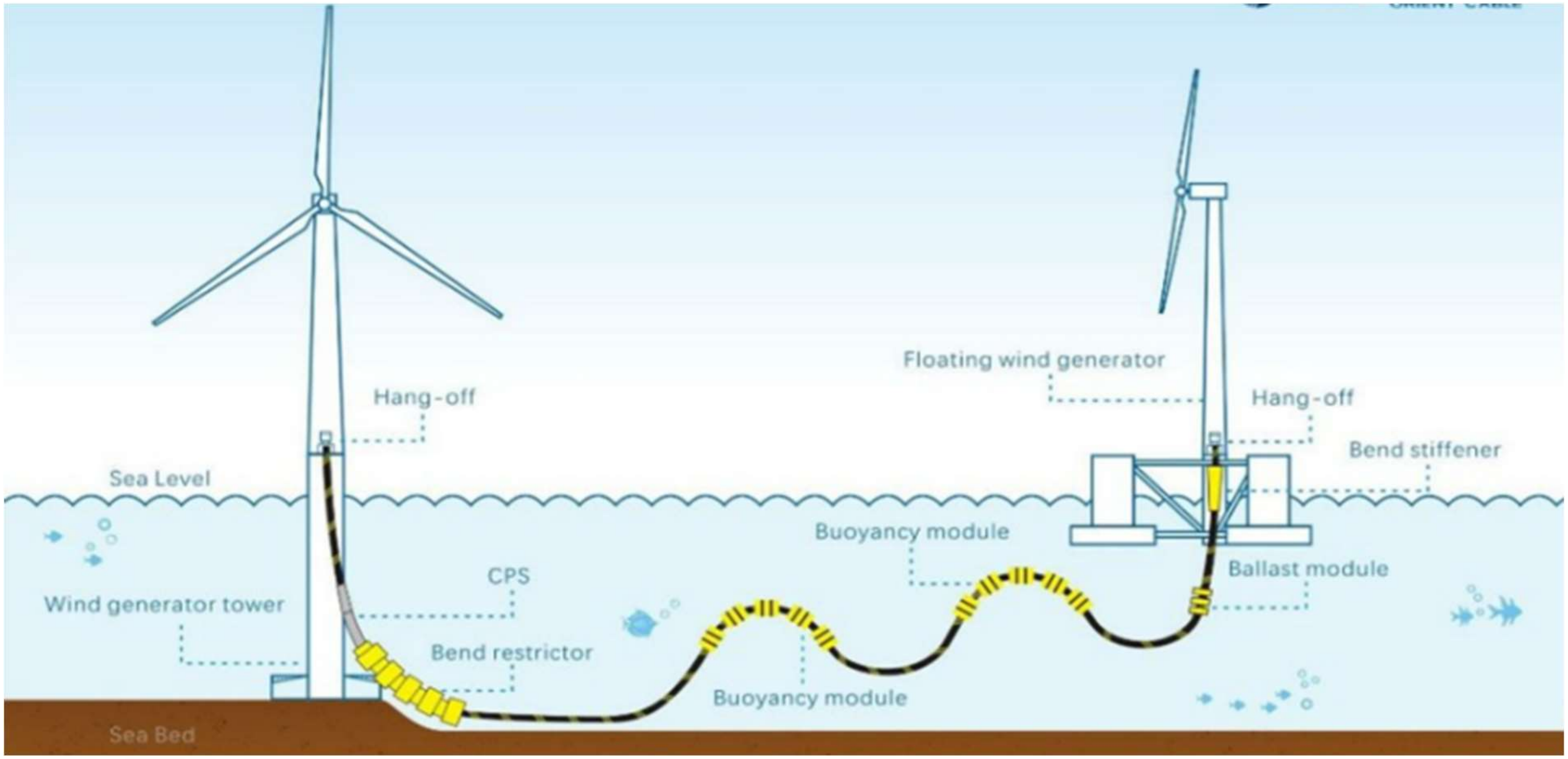
CONNECT MOORINGS Ref[5]

Mooring lines
(3 per column)

Moorings being
tensioned

Tugger lines

DYNAMIC CABLE Ref[5]



DYNAMIC CABLE CONNECTION Ref[5]

CONCLUSIONS

To facilitate the installation process and minimize costs, the main installation aspects have to be considered:

- > Floating offshore wind turbine type (each substructure is different)
- > Inshore vessel requirements (inshore floating crane)
- > Shipyard location can be anywhere in the world
- > Blade and nacelle manufacture can be anywhere
- > Distance from fit out port to offshore wind farm site (3 day tow)
- > Semi submersible type has least weather downtime during installation
- > Number of anchor handling vessels for mooring connection (3 or 4)
- > Whether an offshore crane vessel is required (TLP)

THANK YOU FOR YOUR TIME

DO YOU HAVE ANY QUESTIONS?

email ac1080@Exeter.ac.uk

REFERENCES

1. 'www.principlepower.com, accessed February 2022
2. 'www.deme.com', accessed 16th Feb. 2022
3. 'www.fugro.com' accessed 17th Feb. 2022
4. 'www. Eolos.com' accessed 17th Feb. 2022
5. 'www.myse.com.cn
6. 'https://www.world-energy.org/article/21889.html video of Chinese floating offshore wind turbine
7. 'https://www.world-energy.org/article/18936.html video of floating offshore wind turbine
8. 'https://www.offshorewind.biz/2021/12/10/floating-to-fixed-wind-turbine-connection-comes-online-offshore-china-video/
9. 'http://following-the-wind.com/de/2021/05/24/envision-liefert-300-windturbinen-nach-vietnam/
10. 'https://www.offshorewind.biz/2021/06/08/saint-nazaire-nacelles-start-arriving-by-sea/
11. 'www.james-fisher.com accessed 17th Feb. 2022
12. 'www.brownandmaymarine.com accessed 18th Feb. 2022
13. 'www.ge-wind.com, accessed November 2021
14. 'www.intermoor.com,   accessed December 2021
15. 'www.vryof.com, accessed 17th Feb. 2022
16. 'www.hexicon.eu, accessed 17th Feb. 2022
17. 'www.saipem.com, accessed 17th Feb. 2022
18. 'www.sbm.com, accessed 17th Feb. 2022
19. 'www.bw-ideol.com, accessed 17th Feb. 2022
20. 'www.stiesdal.com, accessed 17th Feb. 2022
21. 'www.equinor.com, accessed 17th Feb. 2022
22. 'www.3datdepth.com, accessed 13th April 2022
23. 'www.boskalis.com, accessed 13th April 2022

Abbreviation	Meaning
AHTS	anchor handling tug supply (large towing tugs)
AUV	autonomous underwater vehicle
CSV	Construction support vessel
FOWT	Floating offshore wind turbine
ROV	remotely operated (underwater) vehicle WROV – work class ROV
SSCV	semi submerrsible crane vessel
SPMT	self propelled modular transporter

No	Question		Reply
1	How many boreholes are required in the geotechincal survey?		Boreholes are required across the whole site because if there is rock in some places and soft mud in other places then completely different anchors are required
2	What about drilled and driven piles installation?		Drilled and driven piles work for soft mud, hard mud, sand, soft rock and hard rock. A construction support vessel (CSV) with crane for working in deep water is required for installation. An AHTS is required to lay the mooring line on the seabed.
3	What about suction piles installation?		Suction anchors work in soft mud, hard mud and sand. A construction support vessel (CSV) with crane for working in deep water is required for installation. An AHTS is required to lay the mooring line on the seabed.
4	What about drag anchors installation?		Drag anchors work in soft mud, hard mud, sand and soft rock. Drag anchors can be installed and tensioned with a AHTS. The maximum water depth is about 1500m
5	What about torpedo anchors installation ?		Torpedo anchors work in soft mud, hard mud and sand. A construction support vessel (CSV) with crane for working in deep water is required for installation. An AHTS is required to lay the mooring line on the seabed. The minimum water depth is 100m. But there is limited information on their use

MCEDD DEEPWATER DEVELOPMENT

No	Question		Reply
6	Ports for fit out of turbine onto the substructure?		The Cromarty Firth currently has the best existing facilities for fit out of barges and semisubmersibles. It has heavy construction, potential quays fro fit out and has sheltered waters for wet storage.
7	Typical design life?		A typical FOWT design life is 25 years
8	Major maintenance, blade and nacelles, for the Spar?		It is unlikely that Spars can be returned to port, for heavy maintenance, because of the the large water depth required.
9	Major maintenance, blade and nacelles, for the TLP?		It is unlikely that a TLP can be returned to port because of the difficulty of attaching temporary buoyancy offshore and the complicated moorings.
10	Major maintenance, blade and nacelles, for the barge		A barge might be returned to port, for heavy maintenance, if the dynamic array cable is not 'daisy chained'
11	Major maintenance, blade and nacelles, for the semisubmersible		A semi submersible might be returned to port, for heavy maintenance, if the dynamic array cable is not 'daisy chained'
12	What about demolition of FOWTs.		TLPs and Spars will be difficult for demolition and may need offshore crane vessels. The barges and semi submersibles demolition is a reverse of the installation process.

CONSTRUCTION SUPPORT VESSEL Ref[23]

MCEDD DEEPWATER DEVELOPMENT

ROV Hangar:
ROV hangar for 2 x WROV
Hydraulic controlled gate 2 x ROV workshops

120 t Active heave compensation
Offshore knuckle jib crane

Dynamic positioning class II or III,

MOORING USING 3 AHTS Ref[23] and Ref[1]