Study Committee B3

Substations and electrical installations

Paper B3_PS1_10890_2022

Distributed subsea substation for ORE[1] collection architectures and compliance with normative references

Isabelle NAJARRE, Frank JACQUIER, Alain GIRODET, Martin HENRIKSEN, Léo DALMAR

SuperGrid Institute

Motivation

- FOW[2] is expected to provide a strong relay and alternative to bottom-fixed assets. It provides the direct perspective to harvest energy from further locations where bottom-fixed is not viable providing access to 80% of world's offshore energy potential.
- In current offshore wind farms, wind turbines are generally interconnected in daisy chain formation. Moreover, substation equipment such as metal-enclosed switchgear apparatuses are exclusively installed at topside level on the offshore substation platform or in wind turbine towers.
- New studies suggest that innovative collection grids, referred to as Fishbone, could decrease costs, increase wind farms availabilities and ultimately support the floating offshore wind industry's growth.
- Such optimised architectures require the installation of new High Voltage (typically 66 kV AC and higher) subsea equipment referred to as Smart Hubs for which a standardisation framework is still to be defined.
- The Smart Hubs' reliability being a paramount criterion for the Fishbone's performance, it is of the utmost importance to perform a critical review of typical metal-enclosed switchgear's normative reference for this specific distributed subsea substation application. Any discrepancy must be highlighted and alternatives to fill-in any gaps must be proposed so that it may be guaranteed the Smart Hubs will be able to fulfil their purpose efficiently and safely.

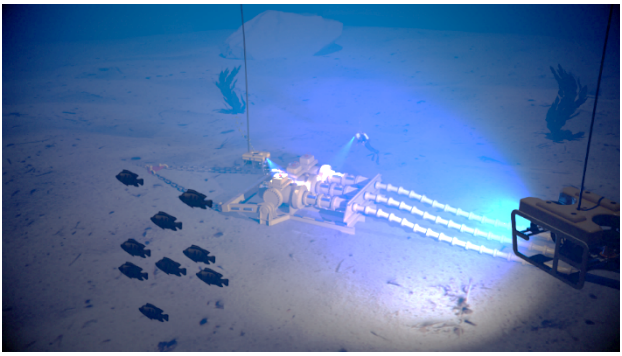
Approach

The purpose of this publication is to introduce and assess the operations of the so-called Fishbone architectures from a switchgear point of view :

i. Current offshore floating wind farm architecture description
   - **What are the challenges they face today?**

ii. Fishbone collection grid system description
   - **How can it solve the floating wind challenges?**

iii. Existing standard requirements assessment
   - **Highlight their limitations for designing and qualifying subsea apparatuses such as Smart Hubs**
     - From a cable system point of view
     - From a high voltage equipment point of view
     - From a subsea equipment point of view



An artist's rendering of a Smart Hub on the seabed

Acronyms

- [1] ORE : Offshore Renewable Energy
- [2] FOW : Floating Offshore Wind

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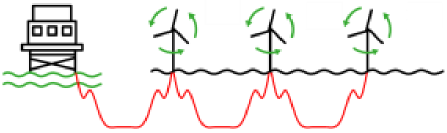
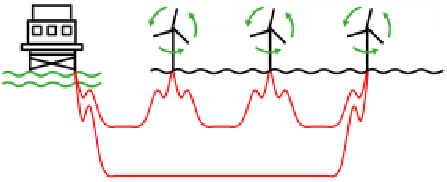
Floating offshore wind farm conventional architectures



Radial Daisy Chain architecture



Loop Daisy Chain architecture

Floating offshore wind farm current challenges

i. Reliability and cost of dynamic cables
   - Mechanical fatigue
   - Higher failure rates
   - More expensive technology

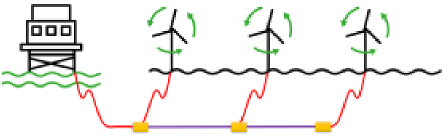
ii. Loss of production in case of dynamic cable failure
   - Serial arrangement
   - Main power flow going through dynamic cables
   - Lower wind farm availability

iii. Complexity of risk management (dynamic cables)
   - Difficult to predict ageing
   - Dynamic (current and mechanical) loadings may be different from one turbine to the other
   - Complex spare part management

iv. Complexity and impacts of wind turbines or floating unit heavy maintenance
   - Floating unit and turbine regular maintenance
   - Serial arrangement of wind turbines
   - Lower wind farm availability

Fishbone architecture functional analysis

- The Fishbone architecture is a novel configuration that enables inter-array systems cost reduction.
- It is composed of a static cable-based backbone to which the multiple wind turbines are connected to through a single dynamic cable
- It is made possible and economically viable through several key enabling innovations: a complete range of subsea HV connectors, the introduction of underwater Smart Hubs and the associated system engineering.



Fishbone architecture

i. CAPEX reduction
   - Single dynamic cable per turbine
   - Decrease of dynamic cable cross section
   - Standardisation of Dynamic cable

ii. Increase of power availability
   - Decreased number of failures
   - Main power flow relies on mature static cable technology

iii. OPEX reduction
   - Simplified spare part management through standardised dynamic cable designs and lengths
   - Less and simplified offshore operations

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Standards critical review

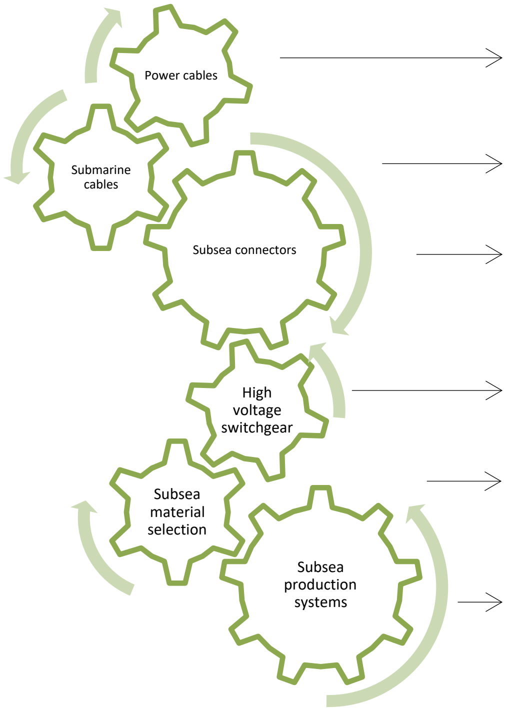
- The introduction of new farm architecture can only be accepted if the system as a whole, and more specifically all necessary technologies, are duly qualified.
- With the introduction of Smart Hubs, the collection grid becomes an inherent part of the substation.
- Hubs can be viewed as fit-for-purpose designed equipment consisting of cable systems, subsea connectors, metal enclosed switchgear and subsea systems, and as such shall comply with all of the associated standards and reference documents – some of which have been identified as partly relevant (cf below)

Standards critical review (cont'd)

Reducing constraints to specific purpose results in:

- Subsea environment : gas tightness, operating pressure conditions, maintenance or on-site test requirements
- Electrical constraints : different than those of conventional substation equipment, e.g. the expected absence of direct lightning impulse.

This allows for a more optimised design, better coverage and potentially optimised cost whereas simply applying them will lead to un-optimised or inappropriate designs which may render this solution uncompetitive.



Reference	Relevance	Limitations
IEC 60840	Cable systems for the relevant voltage range	Only land cable systems
TB 490 & TB 623	Submarine cable systems	Not for connection solutions
IEC 61886-1	Subsea AC power connections solutions	•Low voltage range •O&G applications
IEC 62271 series	Metal-enclosed switchgear for the relevant voltage range	Not for subsea applications
Norsok M-001 & M-501	Subsea environment	O&G applications
ISO 13628-6		

Conclusion

Transverse efforts, including wind farm operators, contractors, installers and manufacturers, are necessary to re-specify the Fishbone architecture and converge towards the most appropriate recommended practices to supply Smart Hubs.