Conceptual and preliminary design of a spar for 5MW VAWT

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1. Introduction

Need to develop Offshore Wind:

- **Reduce the GHG emissions:**
  Paris agreement for Climate;
  UK aims to reduce by 80% by 2050
- **Very high offshore wind resources in Europe**

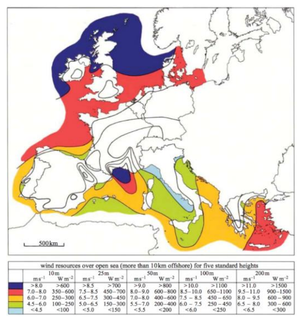


Fig.1: Offshore wind resources in Western Europe (Leithead, 2007)

2. Aim of the project

Designing a spar for 5MW Vertical Axis Wind Turbine:

- Preliminary sizing, preliminary scantling & hydrostatic analysis
- Cost analysis through CAPEX & LCOE
- Selection of the design

3. Methodology and design

PRELIMINARY SIZING
- 50 years return max wave
- Geometrical characteristics
- Inertial characteristics

PRELIMINARY SCANTLING
- Loading on structure
- Preliminary structural analysis

HYDROSTATIC
- Floatability
- Max inclination angle

50 years return design wave:

$$H_{max} = 31.5\ m$$

Geometrical and inertial characteristics

	Classic spar	Slim spar	Truss spar
Freeboard Height [m]	15	10	10
Draft [m]	77	94	92
Mass [t]	17,752.1	15,665.2	9,176.9
CoG [m]	-51	-46	-51
CoB [m]	-48	-43	-44

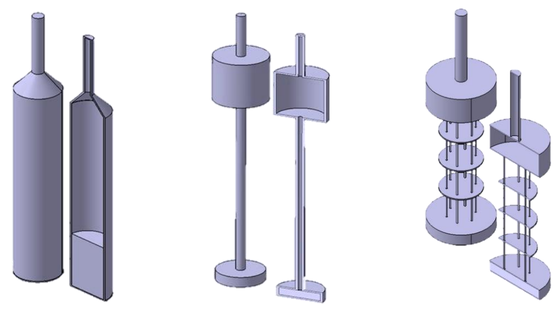


Fig.2: (a) Classic spar (b) Slim spar (c) Truss spar

Loading on structure

	Classic spar	Slim spar	Truss spar
$F_{H,max}$ [kN]	6.42E+04	8.58E+04	4.96E+04

Preliminary structural analysis

	Classic spar	Slim spar	Truss spar
Min thickness [m]	2	2.3	2.8

✓ **Floatability requirement** is met for the three designs

Restoring moment & max angle

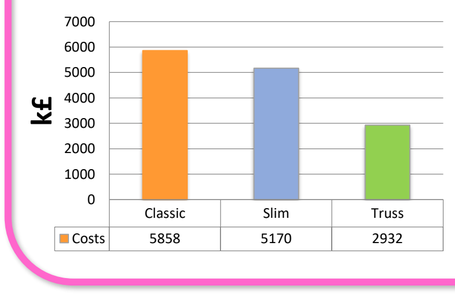
	Classic spar	Slim spar	Truss spar
GM [m]	3.08	3.21	4.76
$C_{55,min}$ [N/m]	12,516,638	9,101,425	11,347,228
C_{55} [N/m]	12,516,738	20,129,261	11,513,439
θ_{eq} [°]	5.02	2.26	4.95

Frequency study (heave movement)

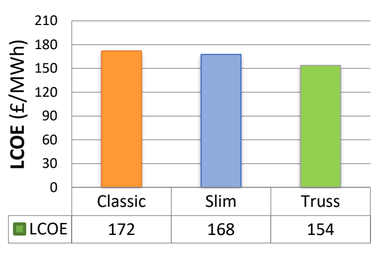
	Classic spar	Slim spar	Truss spar
ω_0 [rad/s]	0.0618	0.0973	0.117
ω_d [rad/s] (β = 10%)	0.0615	0.0968	0.116
ω_d [rad/s] (β = 15%)	0.0611	0,0962	0.115

4. Cost analysis

Manufacturing cost (k£)



LCOE (£/MWh)



The Truss spar has the lowest CAPEX and lowest LCOE.

5. Conclusion

- Preliminary sizing, preliminary scantling and hydrostatic analysis has been carried out with all the requirements fulfilled
- We recommend the truss spar design for further investigations (lowest CAPEX, lower mass)
- Further work: hydrostatic numerical simulations, and hydrodynamic numerical simulations to get the Response Amplitude; If the truss is chosen, CFD analysis could be done to estimate the damping due to the heave plates

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