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An innovative Floating Wind Turbine with lightened structure reducing LCOE up to 20%

EOLINK

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1 – Motivation

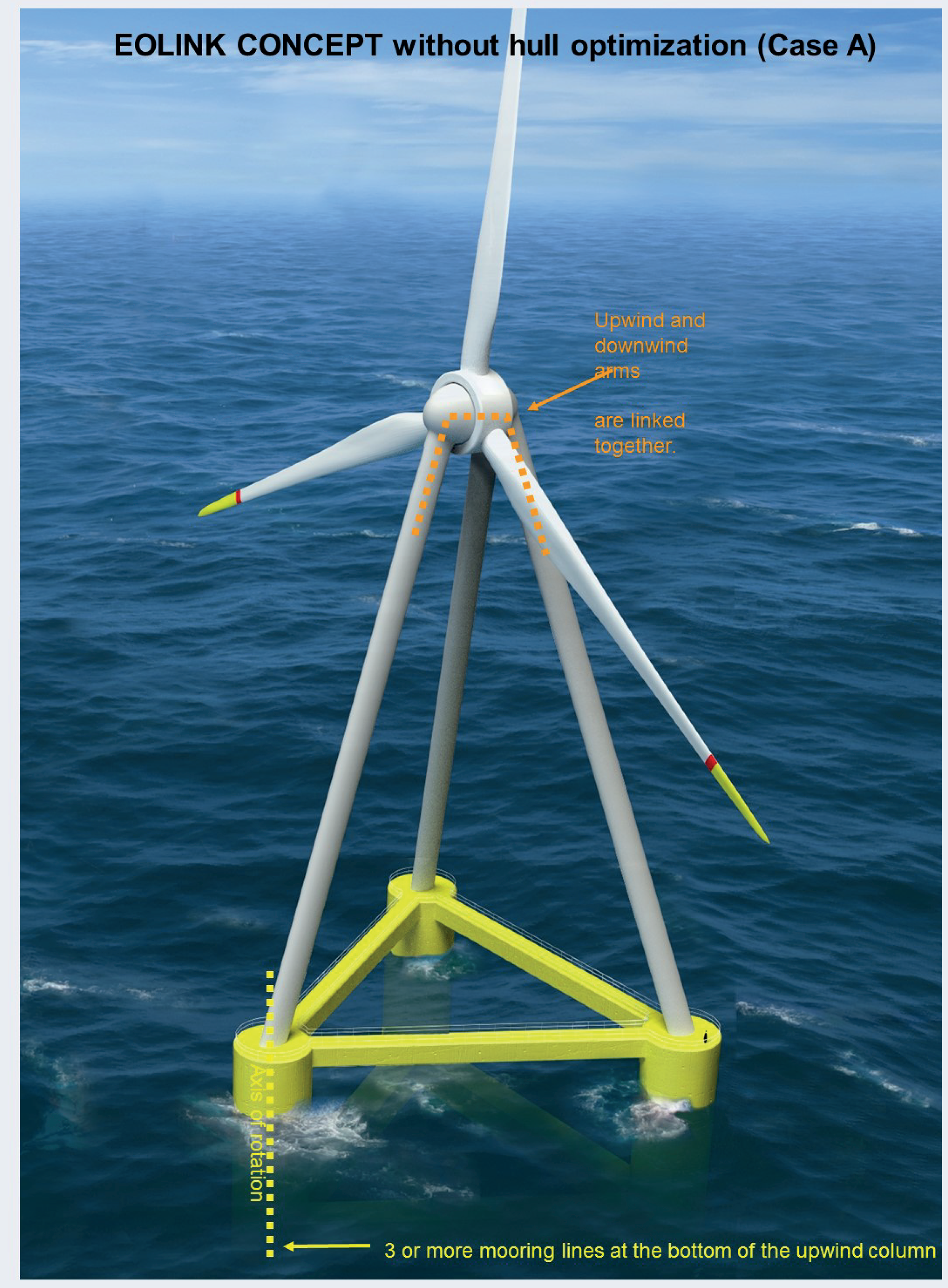
- Fixed turbines have a single tower in order to let the rotor faces the wind. This technology is not considered as the most appropriate for Floating Wind Turbines (FWT) due to specific constraints such as floater's motions or installation process. Fatigue is a main design issue.
- **EOLINK proposes simple and innovative design** : the whole structure rotates to face the wind using a single point mooring or a turret mooring system. The structure is also stiffener and lighter than those using a single tower.
  - Eolink concept "Case A" *(image on the right hand side) :* The Rotor Nacelle Assembly (RNA) is supported by three thin, profiled arms instead of the tower.
  - Eolink concept "Case B" : There is only one upwind arm and one downwind arm.
- EOLINK aims to reduce the Levelized Cost Of Energy (LCOE) :

  1/ Less steel thanks to a better stress distribution,

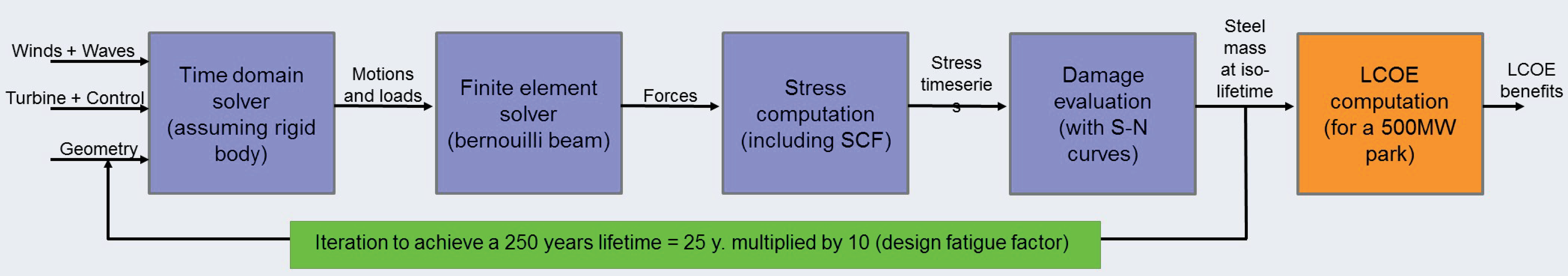
  2/ Less steel thanks to a narrower hull, designed to sustain wind thrust in one direction only (case B),

  3/ Less resonance issue with blades' rotor excitation thanks to higher structure's first eigen frequency,

  4/ Reduced installation costs : mooring lines setup is decoupled from turbine commissioning,
- At this stage, the present work quantifies only LCOE benefits related to steel mass reduction.

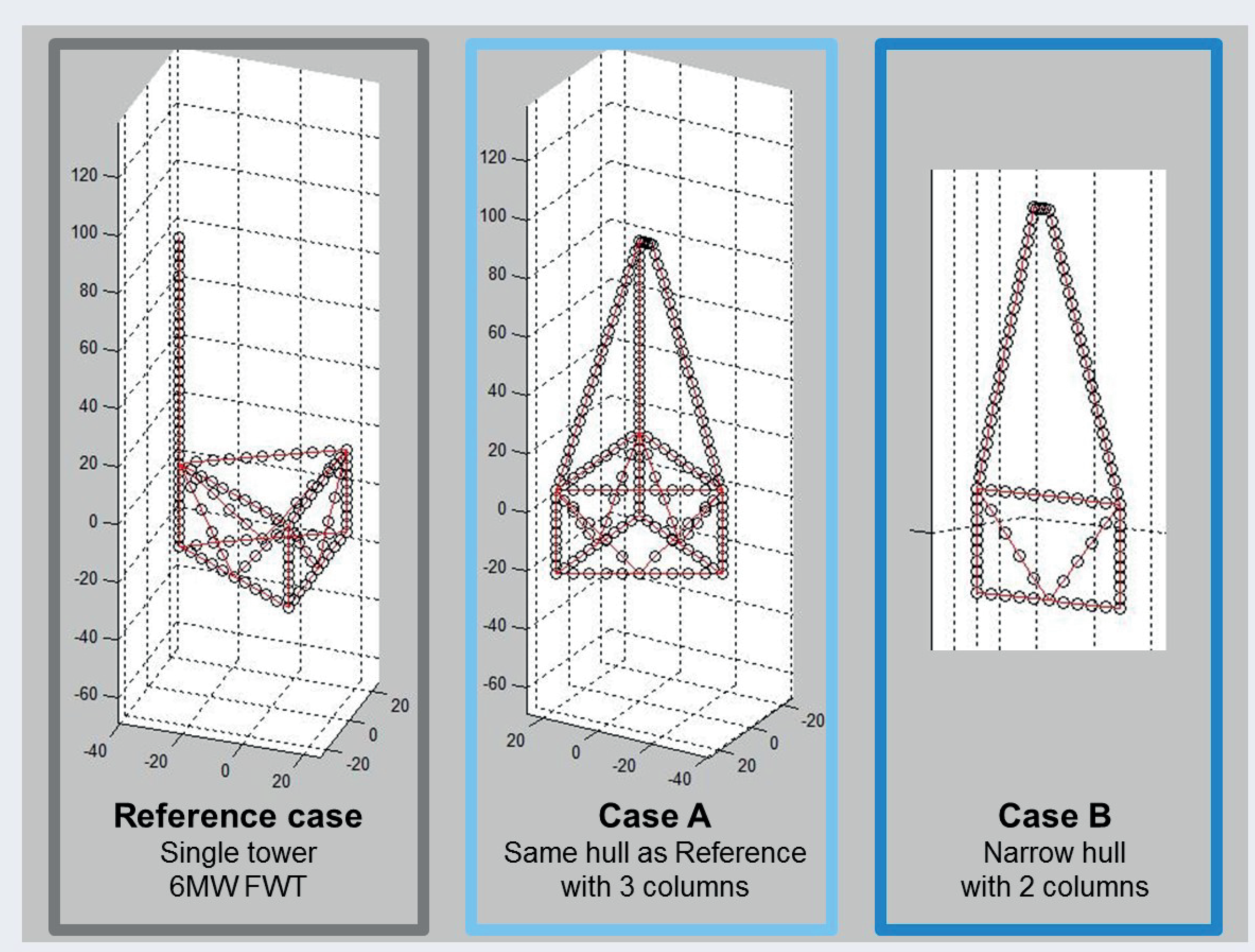


2 – Methodology



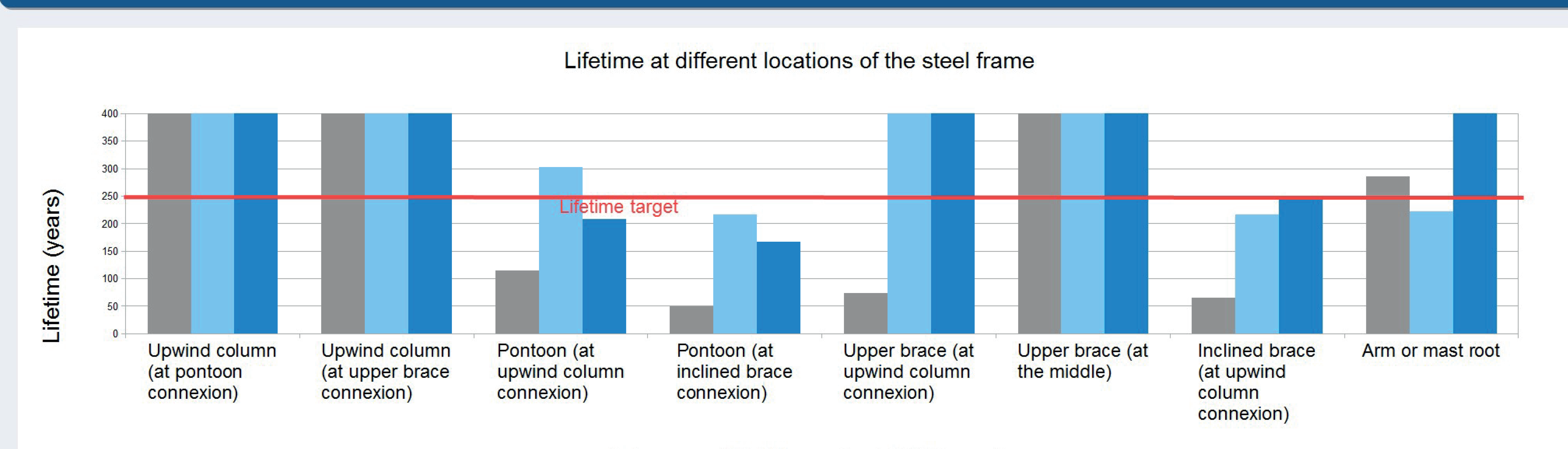
- **Steel fatigue is computed using an homemade aero-hydro-servo-structural code** :
  - Aerodynamic torque and thrust are function of TSR and blade pitch (Cp and Ct from NREL 5MW data),
  - Hydrodynamic forces are computed using Morison formulation,
  - Closed loop control with targets : minimal RNA acceleration & optimal TSR while nominal power is not reached,
  - Stress timeseries computed with beam finite elements and fixed Stress Concentration Factors (SCF),
  - Damage analysis using rainflow counting and S-N curves from reference [2].
- **Beams' thickness and diameters are optimized** in order to get the same damage and the same lifetime for the 3 structures described in § 3: "Reference case", "Case A" and "Case B". Computation are performed under 6 Dynamic Load Cases (DLC) with various seastates and IEC turbulent winds.
- Finally, the reduction of steel mass is an input of an **Excel spreadsheet dedicated to LCOE evaluation**. Costs data and methodology from reference [3].

3 – Description of the studied cases

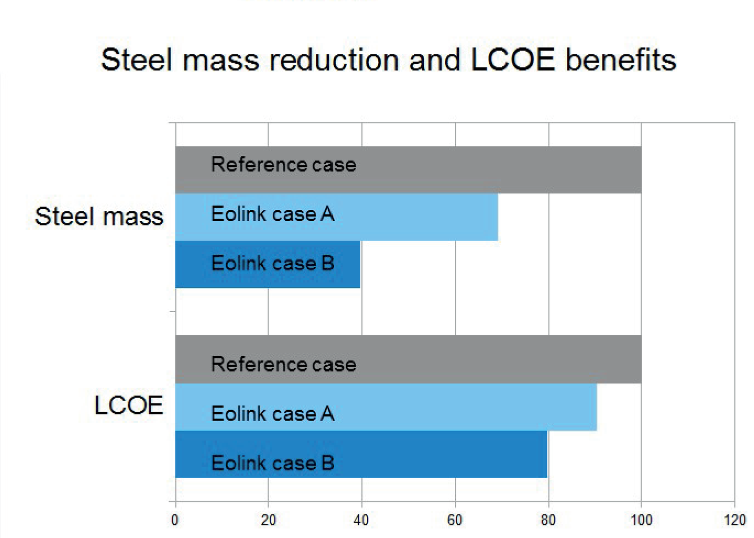


- **The Reference case is a single tower 6MW FWT** with a semi-submersible floater closed from reference [1] (Rotor 154m, hub height 89m above mean sea level, pontoons' length 52m, draught 20m, columns' diameter 11m).
- **Case A : Both EOLINK and conventionnal FWT use the same hull shape and the same hydrodynamic.**
- **Case B** : EOLINK hull is optimized because weather-vaning capabilities permit to design a floater which needs to sustain wind thrust in only one direction. **The narrower hull is made of only 2 columns, 2 arms to hang the RNA and 1 pontoon.**

4 – Results



- As shown in the graph above, lifetime target in several locations of the "Reference case – Single tower" is not achieved, while it is much better with EOLINK structures.
- With EOLINK, lifetime is improved while **steel mass is consequently reduced by 31% and 63%** respectively for case A and case B.
- This directly impacts the **LCOE which decreases by 20% in case B** considering a 500MW FWT park.



5 – Conclusions

- **EOLINK patented concept provides a stiffer and lighter structure enabling LCOE reduction by 20% with a narrower hull (case B) and by 10% using a conventionnal semi-submersible floater (case A).**
- This innovative structure also provides additionnal benefits such as reduced installation costs, no more cantilevered RNA, aerodynamic efficiency and first eigen frequency higher than blades' excitation.
- Experimental tests of a 10MW scale model are planified in 2016 at IFREMER-Brest facilities in a tank test with misaligned winds.

6 – References

[1] Windfloat : a floating foundation for offshore wind turbines Part III Structural analysis – A. Aubault, C. Cermelli and D. Rodier – Proceedings of the ASME 28th International Conference on Ocean, Offshore and Arctic Engineering – OMAE 2009

[2] Recommended practice – DNV-RP-C203 – Fatigue Design Of Offshore Steel Structures – Det Norske Veritas – April 2010

[3] Levelised cost of energy for offshore floating wind turbines in a life cycle perspective – A. Myhr, C. Bjerkseter, A. Agotnes and Tor A. Nygaard – Renewable Energy 2014