Assessment of the dynamic responses and allowable sea states for a novel offshore wind turbine installation concept based on the inverted pendulum principle

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ABSTRACT

A novel OWT and RNA installatin concept was introduced in [1], where it was shown to be feasible and an attractive alternative for procedures using jack-up vessels. For the critical installation activities and corresponsing limiting parameters it is necessary to assess their dynamic responses with the aim of establishing the operational limits and providing information for cost-effective design of structural components. Non-stationary time domain simulations are used to compute response statistics of limiting parameters for various installation phases and sensitivity to key modeling parameters is also investigated.

METHODOLOGY

Limiting parameters (for the critical installation activities) → Assessment of dynamic responses (for limiting parameters) → Asessment of allowable sea states

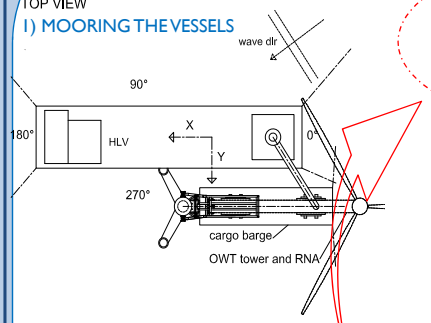
- TD simulations
- Upcrossing rate

Limit state for the limiting parameters: R allow=S charact.

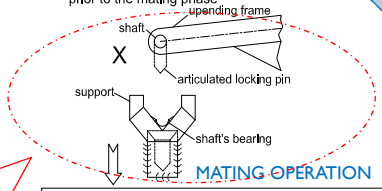
INSTALLATION ACTIVITIES AND LIMITING PARAMETERS

TOP VIEW

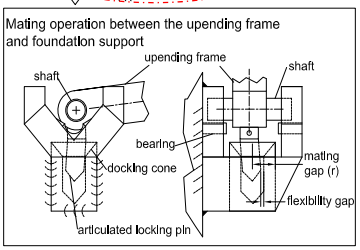
1) MOORING THE VESSELS



Monitoring of motion responses prior to the mating phase



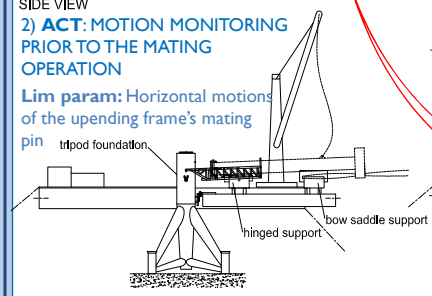
MATING OPERATION



SIDE VIEW

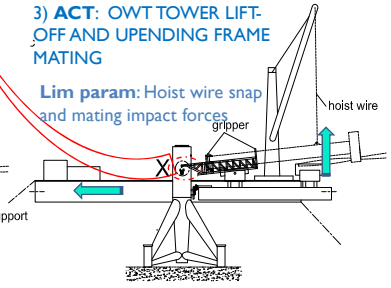
2) **ACT**: MOTION MONITORING PRIOR TO THE MATING OPERATION

Lim param: Horizontal motions of the upending frame's mating pin



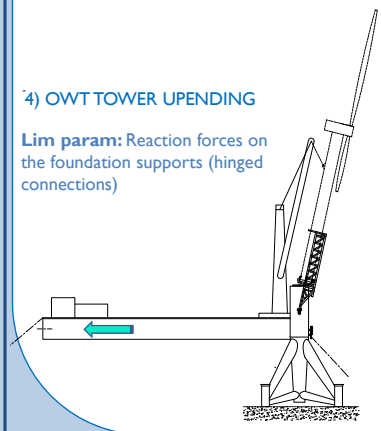
3) **ACT**: OWT TOWER LIFT-OFF AND UPENDING FRAME MATING

Lim param: Hoist wire snap and mating impact forces

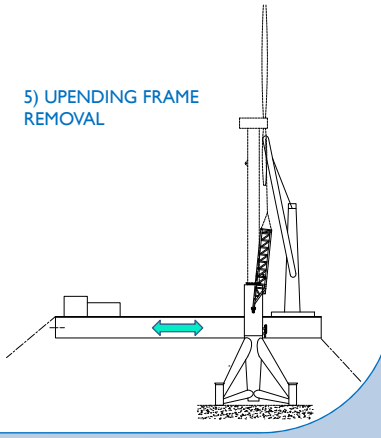


4) OWT TOWER UPENDING

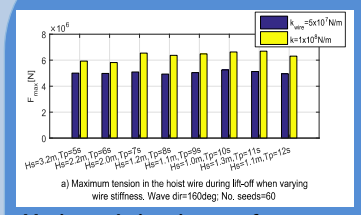
Lim param: Reaction forces on the foundation supports (hinged connections)



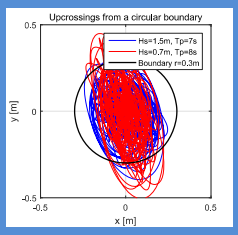
5) UPENDING FRAME REMOVAL



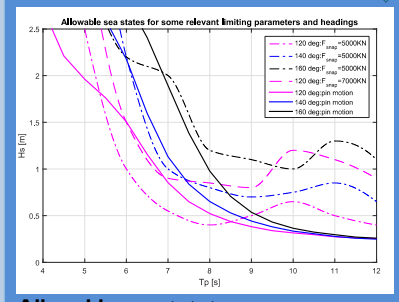
RESULTS



Maximum hoist wire snap forces during lift-off

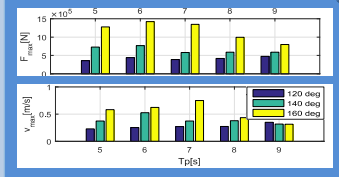


Upending frame´s pin crossings from a circular boundary

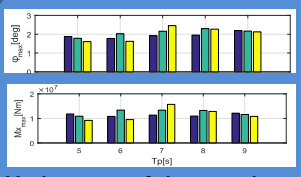


Allowable sea statates

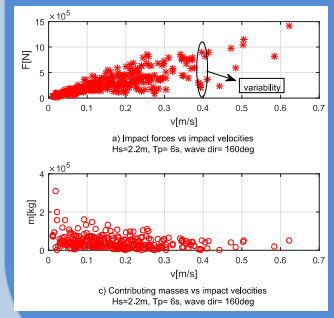
Allowable sea states are established for the OWT tower lift-off and monitoring phase of the upending frame pin (prior to the mating phase) because the allowable limits (of the limiting parameters) are known explicitly



Maximum impact forces and velocities during the mating phase



Maximum out of plane reaction moment and tower inclination during the final upending stage



Contributing impact mass during impact events

Impact forces during the mating phase and reaction forces on the foundation support (docking cone) are computed for the allowable sea states corresponding to the lift-off and mating operation (conservative approach).

Impact velocities and contributing masses are provided (after balancing the kinetic and elastic energy of the contact elements) for future FEM of structural components

CONCLUSIONS AND FUTURE WORK

- A preliminary assessment of the dynamic responses (for the limiting parameters) and allowable sea states (for installation activities) for a novel OWT tower and RNA has been presented
- A crane with at least 700tons at 32m outreach radius is required to lift a 5MW NREL offshore wind turbine
- If the capacity of the crane is increased, the snap force on the hoist wires will not longer limit the operation
- Impact velocities and contributing masses are provided for cost-effective design of structural components of the foundation support (docking cone) and locking pin (of the upending frame)
- The foundation support and locking pins of the upending frame should have a rotational spring coefficient larger than $5x10^9$Nm/rad in order to achieve acceptable OWT tower inclinations at the final upending stage
- FEM of structural components should be carried out in a cost effective manner

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[1] Guachamin Acero W., Gao Z. and Moan T. Feasibility study of a novel concept for the installation of the tower and rotor nacelle assembly of offshore wind turbines based on the inverted pendulum principle. Submitted for review to the Journal of Ocean Engineering