NC STATE UNIVERSITY

Coastal Studies Institute

Natural Frequency of Offshore Monopile-Supported Wind Turbines and Hybrid Energy Systems

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1. Introduction

The U.S. offshore renewable energy (ORE) is at turning point to begin to reach its enormous potential

- Biden's administration goal of generating **30GW** offshore wind electricity by 2030
- 1st major offshore wind project, Vineyard Wind, has been approved.
- N.C. governor urged the BOEM to accelerate leasing the Wilmington sites and find additional areas for offshore wind.

Integrated system offers a unique opportunity for **improving cost-effectiveness and sustainable development** ORE

- Combined exploration of marine energy sources (wind, wave,…)
- Optimizing costs: inspection, installation, O&M, infrastructure
- Boosting MHK industry development by reducing costs

Studies on engineering aspects of integrated system have not been published

2. Design of monopile wind turbines

Monopile is a dynamically sensitive structure. Frequency is considered to avoid resonance and structural fatigue damages

Design of monopile is generally **over-conservative** due to

- Underestimation of natural frequency (Kallehave, et al., 2015)
- Uncertainly in estimating monopile accumulated deformation (Bhattacharya, 2014)

Improvements in design of monopile can **decrease LCOE** of ORE:

- Reduction in installed costs (material usage, installation)
- Using monopile at deeper water
- Forming integrated system without additional cost for mooring

Major problem: evaluating **soil stiffness and damping**

- Short-term and long-term stiffness: effect of cyclic load
- Variation of loads: amplitude , direction and frequency
- Development of local scour

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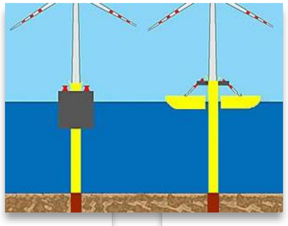
3. Objectives

Natural Frequency of Monopile | Natural Frequency of Hybrid System

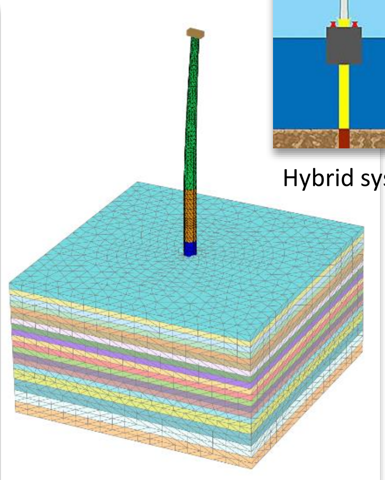
Soil Properties | Monopile Dimensions | Local Scour Depth | Weight of MHK devices

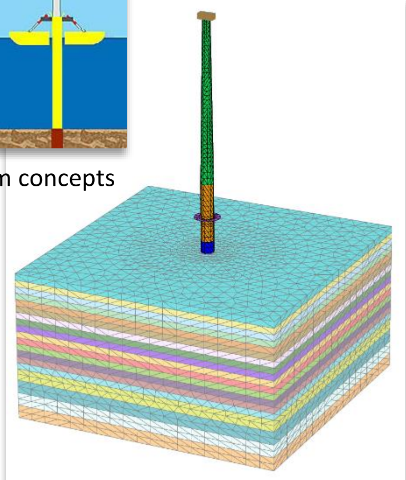
4. Methodology

- 3D numerical simulation
- Procedure
  - Model calibration: static and dynamic
  - Parametric study on natural frequency of monopile
  - Parametric study on natural frequency of hybrid system



Hybrid system concepts

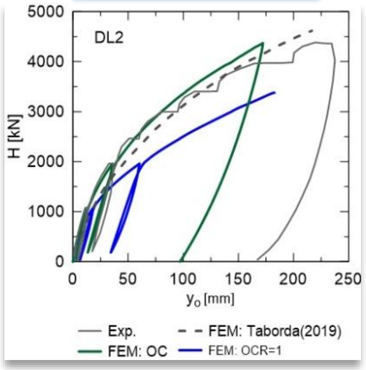




Numerical models for monopile (left) and hybrid system (right)

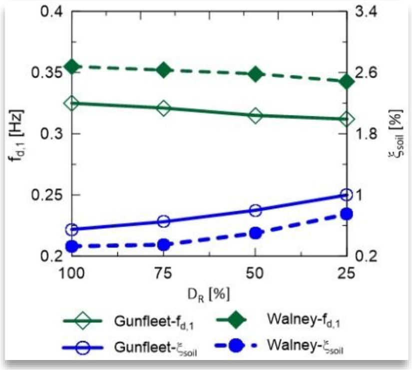
5. Preliminary Results and Conclusions

Calibration



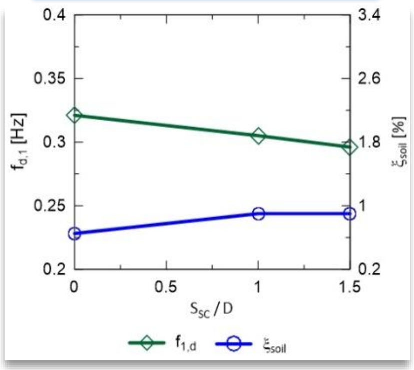
- Ground loading history improves accuracy of modeling,
- Dynamic: obtained $f_{d,1}$ is within 3% error compared to site measurement

Effect of Soil Relative Density



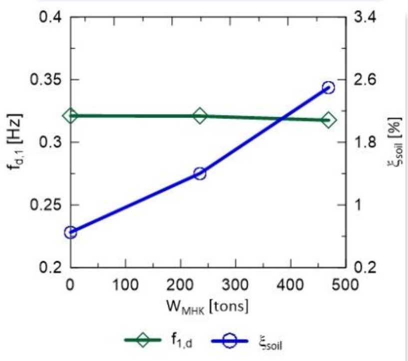
- $f_{d,1}$ reduces by up to 4% as D_R decreases from 100% to 25%

Effect of Local Scour Depth



- $f_{d,1}$ reduces by 8% as scour develops to depth of 1.5D

Effect of MHK mass



- $f_{d,1}$ reduces by 1.2% with MHK device weighted 490tons

- Greater impact on soil damping by relative density, scour depth and MHK mass is observed
- Additional analyses with others pile dimensions are needed to examine comprehensively impacts of the factors