

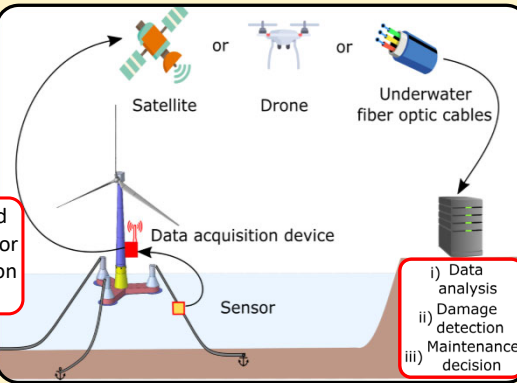
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### The problem and its importance

Damages in synthetic fiber rope mooring lines of semi-submersible wind floaters supporting Floating Offshore Wind Turbines (FOWTs) under varying environmental conditions → stress increase → mooring line loss, damaged power cable, high maintenance cost → Early damage detection being vital

### What is needed

- Remote operating vehicles → Sporadic & costly monitoring, not effective for fiber mooring lines
- Bad weather → No access to FOWTs



Automated SHM method based on vibration data from sensors for early & remote damage detection in synthetic mooring lines

Less cost & continuous stream of SHM data

- Data analysis
- Damage detection
- Maintenance decision

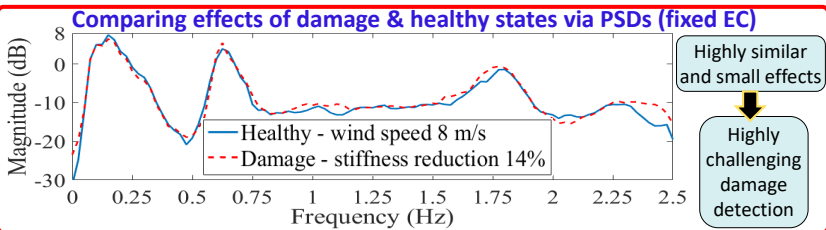
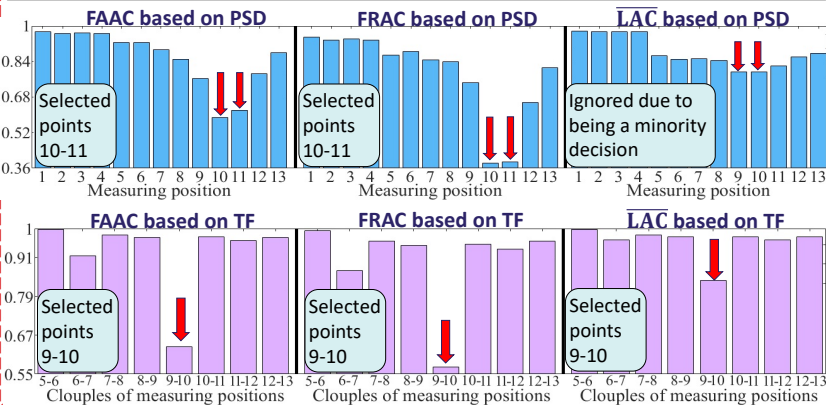
### Fundamental principle of vibration based methods for damage detection

Changes in structural dynamics due to a damage → changes in vibration characteristics

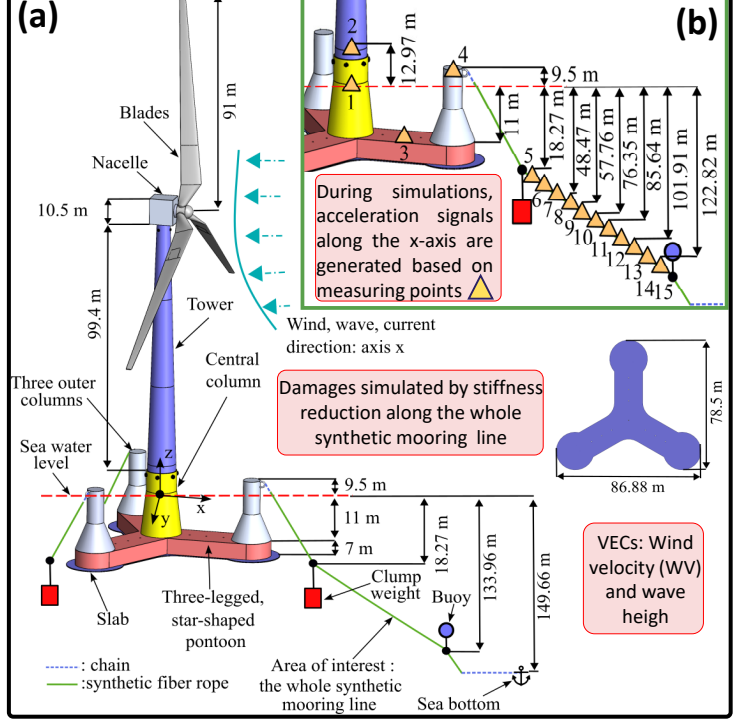


Varying Environmental Conditions (VECs) → "Masking" the effects of damages on the structural dynamics → Highly challenging damage detection

**Measuring points selection.** Criteria based on the discrepancies of Power Spectra Density (PSD) or Transmittance Function (TF) from healthy & damage states are used for selecting the two most 'sensitive to damages' measuring points: Frequency Response Assurance Criterion (FRAC), Frequency Amplitude Assurance Criterion (FAAC) & average Local Amplitude Criterion (LAC). PSD is based on one signal whereas TF is the ratio of the Cross-Spectral Density over the PSD of two response signals. Simulations from the healthy FOWT under the 6 WVs [7, 8, 9, 10, 11, 12] m/s & simulations from a damaged FOWT based on [10, 20, 30, 40, 50] % stiffness reduction under the 6 WVs are used in each criterion.



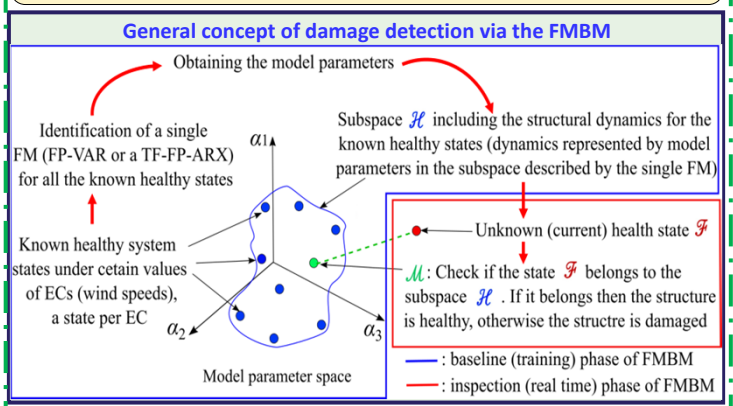
### 10 MW FOWT based on the semi-submersible OO-STAR wind floater



### The SHM method for damage detection

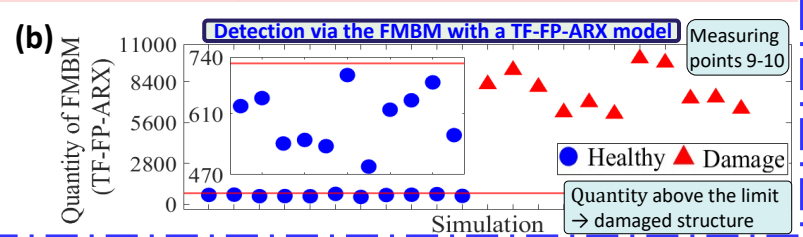
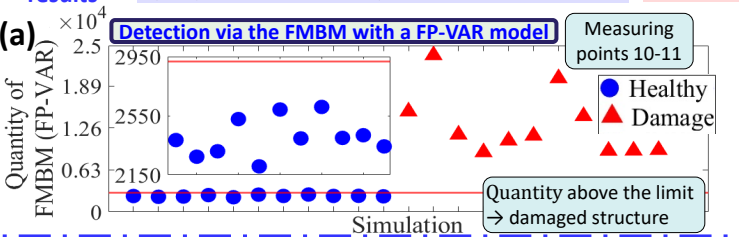
**Functional Model Based Method (FMBM)** equipped with a single statistical Functional Model (FM). Two FM types examined: a **Functionally Pooled-Vector Autoregressive (FP-VAR)** model based on multiple response signals (one signal per measuring point) & a **TF type FP-AutoRegressive with exogenous excitation (TF-FP-ARX)** model based on two response signals (one signal per measuring point) with one of them used as response and the other one as excitation

FMBM includes two phases, an one-time training phase based on data from the healthy FOWT under VECs & the inspection phase based on data under an unknown health state



### Detection results

Training: 7 simulations from the healthy FOWT (one signal per simulation), one per WV [7,8,9,10,11,12] m/s  
 Inspection: 11 simulations from the healthy FOWT, one per WV [7, 7.4, 8, 8.6, 9, 9.5, 10, 10.7, 11, 11.4, 12] m/s & 11 simulations from a damaged FOWT based on 14 % stiffness reduction under the 11 WVs



**Conclusion:** The automated FMBM with both of the FM types detects remotely all the considered damages in synthetic mooring lines of wind floaters