Analytics for Asset Integrity Management in Wind farms (AIMWind) : Low-cost solutions for turbine structural health monitoring

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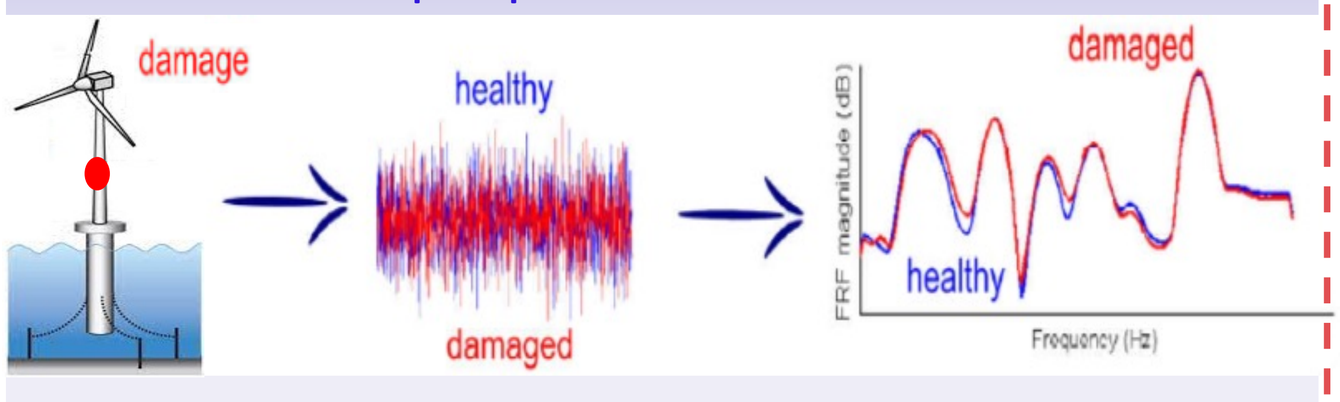
Importance of Structural Health Monitoring (SHM)

Damage → alteration the structure's performance → dire consequences for structure's integrity & human safety → SHM being important

SHM levels

- Level 1: **Damage detection**
- Level 2: **Damage localization**
- Level 3: **Damage quantification**
- Level 4: **Remaining useful life (RUL) estimation**

Fundamental principle of vibration based SHM methods



Changes in structural dynamics due to a damage → discrepancies in vibration responses

Goals

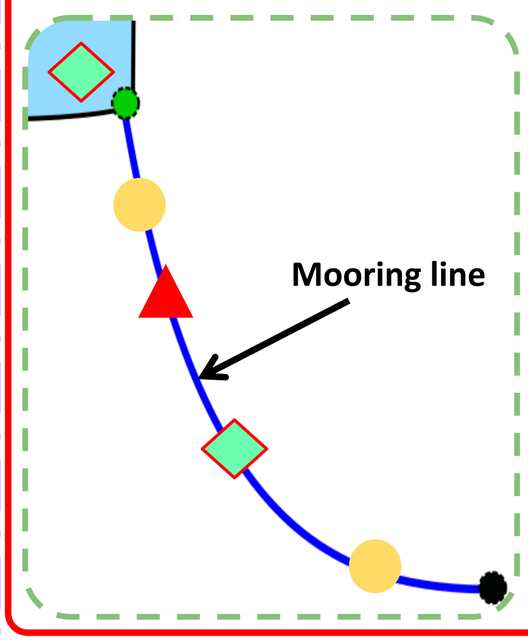
Structural Health Monitoring (damage diagnosis and damage prognosis) on the tower and the mooring lines of a OO-star Floating Offshore Wind Turbine (FOWT) under varying Environmental & Operating Conditions (EOCs)

	FOWT's mooring lines	FOWT's tower
Damage diagnosis	Damage detection	Damage detection
	Damaged mooring line identification	
	Damage (precise) localization	Damage (precise) localization
	Damage (precise) quantification	Damage (precise) quantification
Damage prognosis	RUL estimation	RUL estimation

Vibration-based damage diagnosis and prognosis under varying EOCs

Treatment of damage detection as a classification problem through the Multiple Model (MM) - AutoRegressive with eXogenous input (ARX) method [1], **the Principal Component Analysis (PCA)-MM-ARX method** [1] **and the Functional Model Based Method (FMBM)** [2]

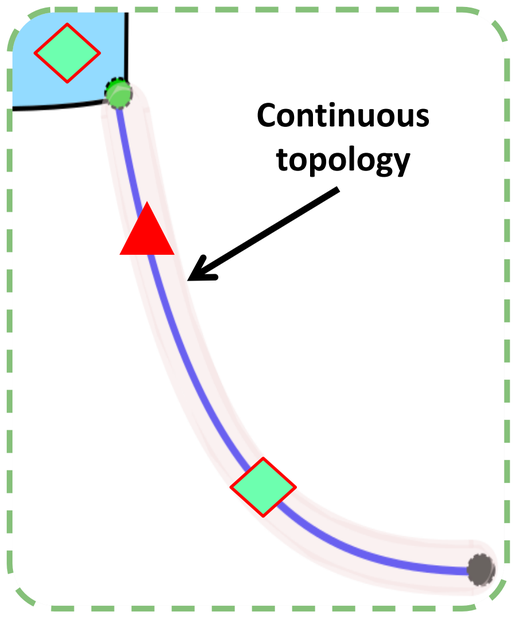
Treatment of damage localization & quantification as classification problems



: Pre-specified damage
: Sensor
: Unknown detected damage

- **MM-ARX method** [1] and **PCA-MM-ARX method** [1] → **damage localization** and **quantification** though the classification of the unknown detected damage to one of pre-specified damages at specific locations and of specific magnitudes

Treatment of damage localization & quantification as precise estimation problems



- **FMBM** → **damage precise localization** within a continuous structural topology and **precise quantification** [2] within continuous damage magnitude ranges
- **Functional Model (FM)** → representation of structure's dynamics under varying EOCs and damage at any location and of any magnitude by using a small number of sensors (even a single one)

Treatment of damage prognosis as a classification problem through the FMBM

Fatigue analysis for obtaining the:
Remaining Useful Life (RUL) of the structure for known damage states (location and magnitude) under varying EOCs

Baseline (training) phase of FMBM

FM identified based on the known damage states

Inspection (online) phase of FMBM

Unknown detected damage → Damage precise localization & precise quantification based on FM → Classification of the detected damage to one of the known damage states

References

[1] Vamvoudakis SKJ, Sakellariou JS et al. , **Vibration–based damage detection for nominally identical structures: Unsupervised multiple model (MM) statistical time series type methods**. *Mechanical Systems and Signal Processing*. 2018; 111:149-71.

[2] Sakaris CS, Bashir M, Sakellariou JS, et al., **Structural health monitoring of tendons in a multibody floating offshore wind turbine under varying environmental and operating conditions**. *Renewable Energy*. 2021; 179:1897-914.