This work presents a novel methodology to identify the optimal maintenance strategy for an offshore wind structural component, providing a flexible and reliable support to decision-making and balancing inspection, repair and failure costs.

The methodology is tested for a tubular joint through a 60-states POMDP, obtaining the optimal maintenance policy in low computational time and in good agreement with common Risk-Based Inspection (RBI) methods.

1. INTRODUCTION

Context:
Wind farms farther from shore
Complicated maintenance tasks

Research Aim:
To identify the optimal maintenance strategy

Impact:
O&M cost (≈ 25% LCOE)
Lifetime Extension

2. FATIGUE DETERIORATION MODEL

The calibration of the fracture mechanics (FM) model based on the SN-Miner’s model provides a deterioration framework where inspections outcomes can be incorporated while keeping the model related to SN empirical data which is employed during the design stage.

SN-Miner’s model - Limit state:
\[ g_{SN}(t) = \frac{\int_{0}^{t} \frac{q^{3/2}}{S_{n}^{1/2}} \right) \Gamma \left( 1 + \frac{m}{2} \right) \Delta n_{a} + \frac{m}{2} \right) \frac{S_{n}}{\left( \frac{q}{\eta} \right)^{1/2}} \]

Fracture mechanics model - Limit state:
\[ g_{FM}(t) = \frac{q_{c} - \left( (1 - \phi) K_{II}^n \pi^2 q^{m/2} \Gamma \left( 1 + \frac{m}{2} \right) \Delta n_{a} + \frac{m}{2} \right) \frac{S_{n}}{\left( \frac{q}{\eta} \right)^{1/2}} \}

given \( q_{c} \)

SN-Miner’s model - Variables
- \( m_{a} \):
  - Deterministic
  - 3

Fracture mechanics model - Variables
- \( q_{c} \):
  - Deterministic
  - Lognormal
  - \( \mu = 12.88 \) ; \( \sigma = 0.2 \)

3. RISK-BASED POMDP MODEL

- The influence diagram below displays how the sequential decision problem is approached. The damage evolving over time is represented by the chance node \( D_{1} \) and it is possible to choose an inspection method in the node \( I_{2} \).

- The chance node \( Z_{1} \) indicates the quality of the inspection method. Additionally, the node \( E_{1} \) tracks the failure probability. The utility nodes \( C_{P} \) and \( C_{I} \) assign a cost of failure and a cost of inspection, respectively. The chance node \( R_{t} \) represents the decision of whether to perform a repair or not.

4. RESULTS – POMDP POLICY

The optimal maintenance strategy for a tubular joint is identified by a 60-states ”point-based” Partially Observable Markov Decision Process (POMDP). The obtained POMDP policy provides similar results as a common risk-based heuristic model.

5. CONCLUSION

The 60 states infinite horizon POMDP has been solved providing the optimal maintenance policy for a tubular joint in only 0.32 seconds of computational time.