Failure analysis of floating offshore wind farms

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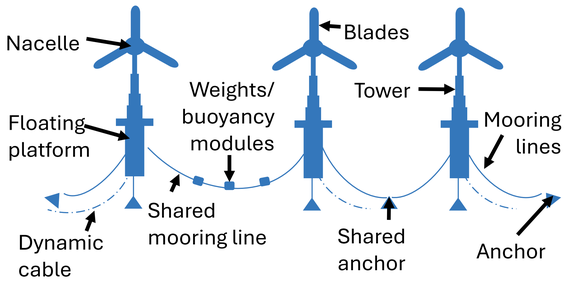
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Overview

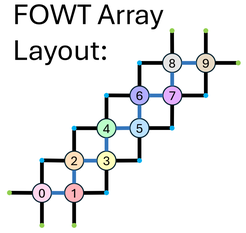
- Matrices determine connections between component failures of floating offshore wind turbines (FOWT)
- Graph theoretical methods model FOWT failure interactions
- Using conditional and time-dependent probability measures, we create a Bayesian Network for a FOWT farm
- The objective of this study is to quantify the interaction of failures between turbines in a FOWT farm

Floating Offshore Wind Turbine

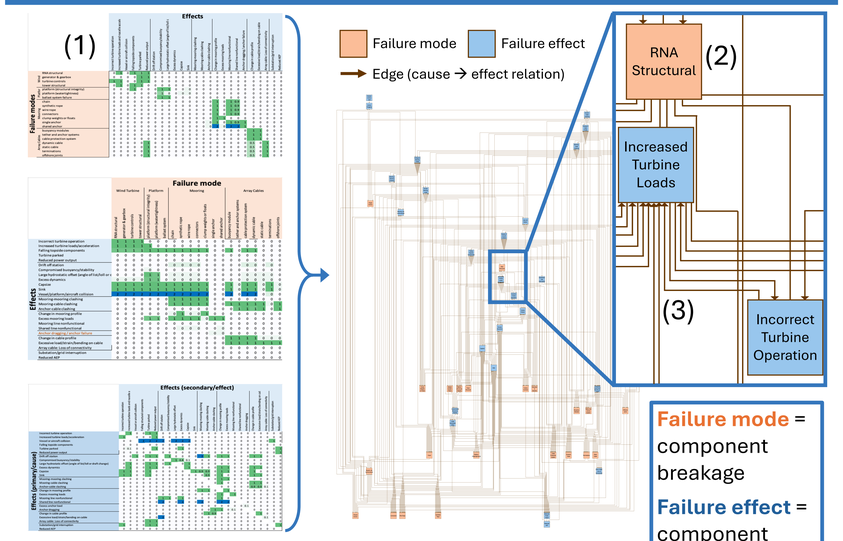
Basic Components of FOWT:



FOWT Array Layout:



Failure Matrices and Graph



Failure mode = component breakage

Failure effect = component phenomena

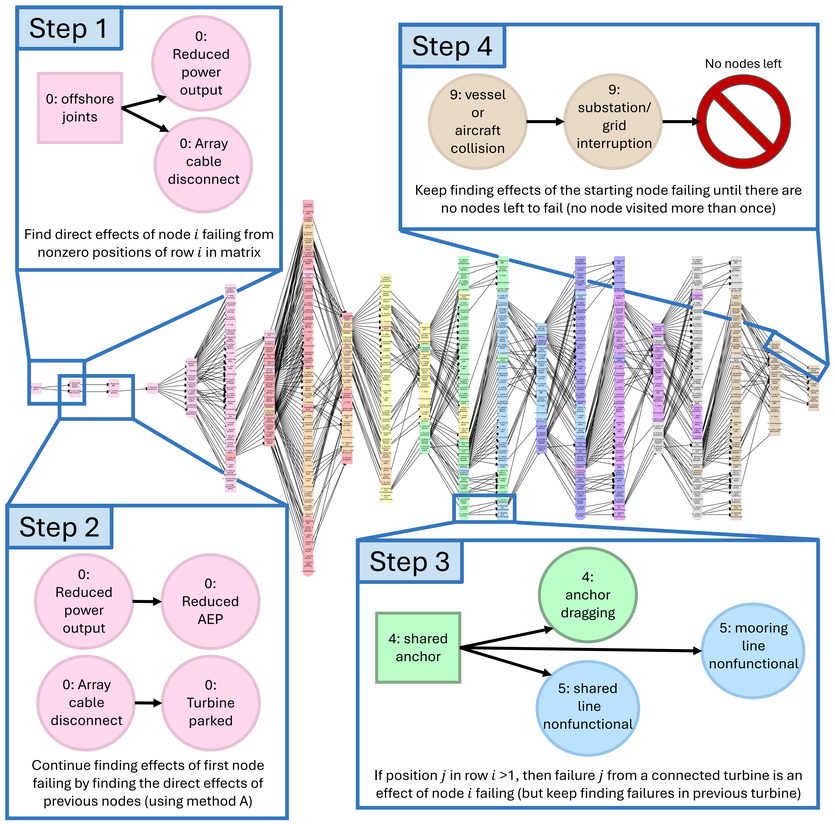
(1) Combine matrices into adjacency matrix M

(2) Convert failure modes and effects into nodes (i.e. points)

(3) Place edge (i.e. arrow) between nodes i and j if $M[i,j] > 1$

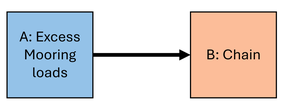
Network Construction

Using Steps 1-4, create a network that describes how failure spreads in a multi-turbine after single failure:



Probability Calculation

Begin with starting failure probability equal to its initial probability. Then for each node B, calculate …



Estimated probability of two parent failures:

$$\Pr(a_1 \,\&\, a_2) \cong \frac{\Pr(a_1)\Pr(a_2) + \min(\Pr(a_1), \Pr(a_2)))}{2}$$

Joint probability for all parent failures:

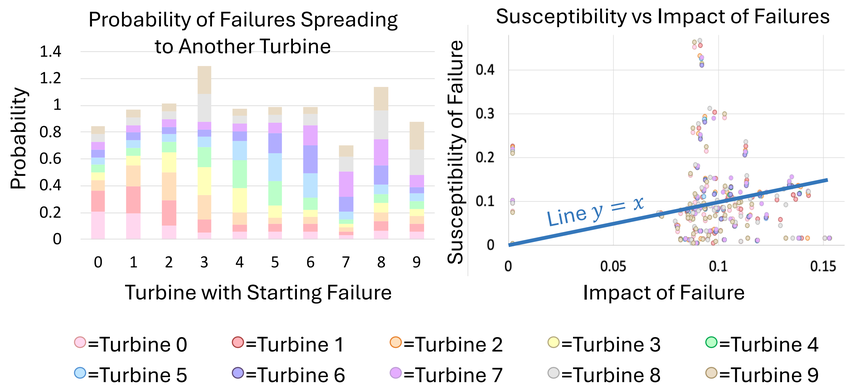
$$\Pr(\overrightarrow{a_j}) = \Pr(a_1, a_2, \dots, a_n) = \prod_{i=1}^{n} \frac{\Pr(a_i \,\&\, a_{i_1} \,\&\, \dots \,\&\, a_{i_k})}{\Pr(a_{i_1} \,\&\, \dots \,\&\, a_{i_k})}$$

Probability of failure B given failure A:

$$\Pr(b|a) = \alpha \sum_{\forall a_j} \Pr(b, a, \Pr(\overrightarrow{a_j}))$$

for $\alpha = \frac{1}{\Pr(b,a)+\Pr(\neg b,a)}$ and $a_1, a_2, \dots, a_n$ the parents of B.

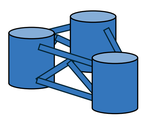
Results



- Averaging probability of failures across turbines shows us how failures interact at the array-level
- Susceptibility of failure i = average probability of failure i occurring as result of a failure j
- Impact of failure i = average probability of additional failures occurring because of failure i
- Plotting susceptibility and impact shows how failures interact at the component-level

Discussion and Conclusions

- Location of turbine in array does not greatly impact its failure probabilities
- Turbines are more likely to be caused by than cause failures in another turbine
- Failures spreading between turbines is not likely in this array layout
- Future work will add further design and material specification to this model



Semisubmersible floating platform (Option for future research)

References & Acknowledgements

Hall, M., et al. (2022). Design and analysis of a ten-turbine floating wind farm with shared mooring lines. *Journal of Physics,* 2362, (1), 012016.

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