# Effect of hydrodynamic load modelling on the response of floating wind turbines and its mooring system in small water depths

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## Abstract

The focus of this paper is on the environmental loads and responses of mooring systems for a semi-submersible at water depth of **50 m, 100 m and 200 m**. Preliminary design has been carried out to determine mooring line properties, mooring system configurations and document the static performances. A fully coupled time domain dynamic analysis for extreme environmental conditions was performed using Simo-Riflex-AeroDyn. Four different load models were applied in order to check the influence of different load components including the effect of wind, current and second order wave forces by means of Newman's approximation and a full QTF method.

## Challenges

- Mooring design for moderate water depths is relatively easy to achieve, but it is challenging for **shallow water**. Mooring line tension increases in a **nonlinear** manner when the offset is large and it is more significant in shallow water.
- The highly **non-Gaussian** responses in shallow water indicates possible extreme mooring line tension and floater motion especially.

## Methodology

Newman's approximation is good if the frequency difference is small, which is normally the case for horizontal motions for floating structure especially in deep water. Newman's approximation becomes uncertain when it comes to shallow water. In this paper, Newman's approximation will be considered in horizontal motions while full QTF method will include contributions from all six degrees of freedom.

### Load models

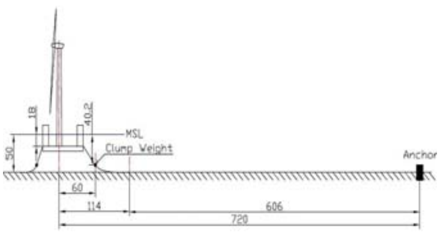
1, 2, 3: Newman's approximation vs full QTF
3, 4: Influence from wind force

| | Wave | | Wind | Current |
|---|---|---|---|---|
| | first-order | second-order | | |
| 1 | Yes | No | No | Yes |
| 2 | Yes | Newman | No | Yes |
| 3 | Yes | Full QTF | No | Yes |
| 4 | Yes | Full QTF | Yes | Yes |

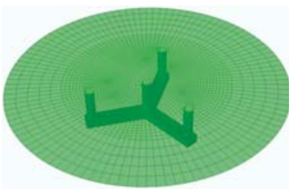
### Load cases

The wind and wave conditions correspond to 50-year return period and current condition refers to 10-year return period.

| | ULS-1 | ULS-2 |
|---|---|---|
| $U_w$ (m/s) | 41.86 | 38.37 |
| $H_s$ (m) | 13.4 | 15.6 |
| $T_p$ (s) | 13.1 | 14.5 |
| $U_c$ (m/s) | 1.05 | 1.05 |

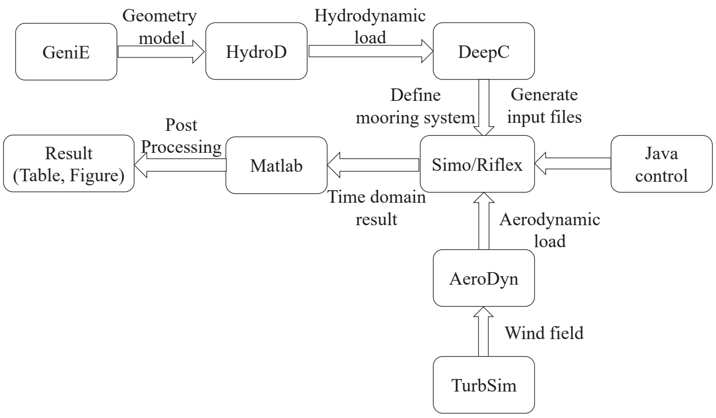



Mooring system in 50 m



HydroD model

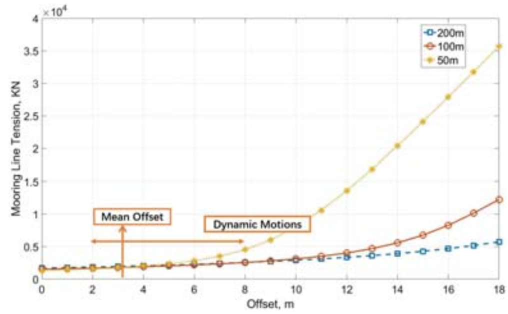
### Fully coupled dynamic analysis

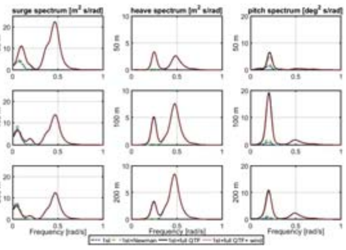



Flowchart of the analysis process and software used.

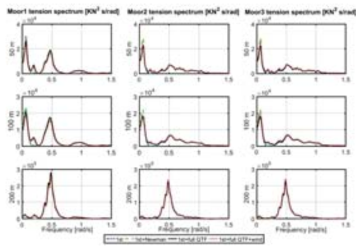
## Results and discussions

Mooring line tension increases nearly **linearly** when the offset is small, then it increases in a **nonlinear** manner for all three water depths. The phenomenon becomes more significant when water depth decreases.




Floater motion spectrum in ULS-1 condition




Mooring line tension spectrum in ULS-1 condition

### Non-Gaussian response

$$M = \mu + k * \sigma$$

$M$: Maximum response
$\mu$: mean response
$k$: coefficient
$\sigma$: standard deviation

| | ULS-1-0 | | | ULS-2-60 | | |
|---|---|---|---|---|---|---|
| | Mooring line 1 | | Surge | Mooring line 3 | | Surge |
| | *k* | *Kurtosis* | *Kurtosis* | *k* | *Kurtosis* | *Kurtosis* |
| 50 m | 4.3 | 3.4 | 3.5 | **14.7** | **49** | **3.7** |
| 100 m | 4.4 | 3.5 | 3.2 | **10.8** | **19** | **3.2** |
| 200 m | 5.7 | 5.4 | 3.1 | **6.0** | **6.1** | **2.9** |

- Non-Gaussian nature of mooring line tension is influenced by the nonlinearity of the mooring system.
- Wave parameters e.g. significant wave height and wave peak period also affect the Gaussian nature of the response.
- Kurtosis are close to 3 for all cases in surge motion – Gaussian process.
- Least loaded mooring line tension almost follows Gaussian process in less severe environmental condition.
- Kurtosis and k value increase with decreasing water depths and more extreme sea states – highly non-Gaussian process.

## Conclusions

- During mooring system design phase, two factors that can influence mooring line tension significantly were mainly considered: geometrical effect and increased stiffness for large offset.
- As water depth decreases, the contribution from difference frequency part becomes increasingly more significant . Therefore in order to capture the low-frequency response accurately, a full QTF method is recommended while Newman's approximation will underestimate the response.
- The highly non-Gaussian responses in high sea states indicates possible extreme mooring line tension and floater motion, which makes it quite challenging to design mooring system for extreme environmental conditions especially in shallow water.

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## Reference

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