Design of mooring systems for large floating wind turbines in shallow water

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Introduction

Green energy production is a hot topic in the scientific society, and offshore wind energy is a promising field. Hywind Scotland is the first operational floating wind turbine farm in existence, and a pilot project developed by Statoil. To make floating offshore wind energy competitive against other energy production methods, the cost of installation and production must be kept to a minimum.

For areas where the water depth is above 70m, the cost of a bottom fixed monopile solution starts to be too expensive, and the mooring of floating turbines below 100m is a challenging task. Feasibility of mooring systems at these depth will open up areas were the cost of installation traditionally has been to high.

Today, Hywind Scotland represents the newest installation of the sort, and the mooring system is a traditional chain system. This is an expensive system, and today, no operational floating wind turbine utilizes synthetic fibre ropes. If this proves feasible, the cost of development could be decrease and more potential areas for production becomes available.

Objective and Scope

The main objectives of this Master's Thesis are:

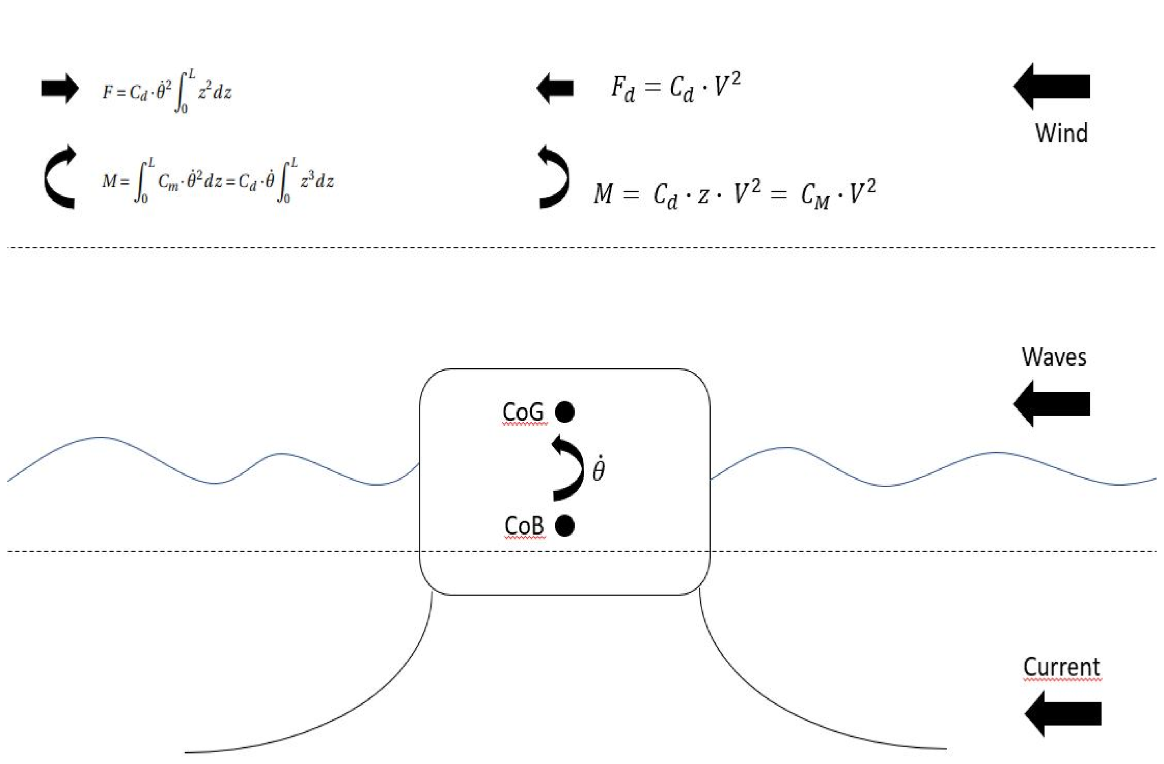
- Describe possible mooring and station keeping systems for floating units in general and floating wind turbines in particular.
- Describe the design limit states for mooring systems of floating wind turbines with corresponding acceptance criteria outlined in rules and regulations [6].
- Describe the time-domain analysis methods for mooring systems and how extreme wind turbine motions and line tension can be estimated.
- Based on an existing SIMA model, establish a simplified model in the SIMO/SIMA with the objective of performing numerical time-domain simulations of wind turbine motions and mooring line tensions.

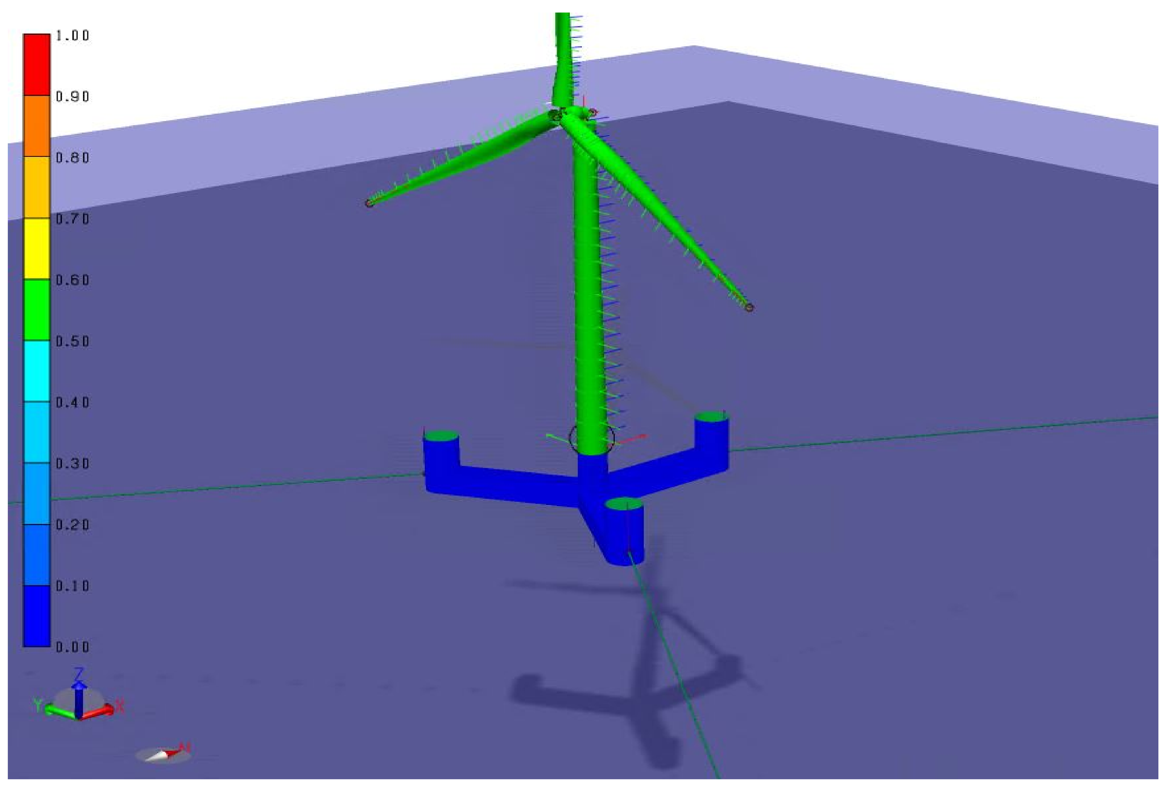
Method

- Calculate ralevant coefficients from the turbine so that the structure can be removed.
- Comparrison of selected results with the orignal model to ensure the accuracy of the simplified model.
- Mooring analysis by simulations with the SIMA software [1].

Model

The model in question is a 10MW wind turbine, with a towerheight of 119m and blade length of 89m. The semi-submersible structure has a radius of 50m, column diameter of 10m and a draugth of 20m. The get an efficient model, the slender elements which functioned as the structure of the wind turbine (modeled below) were removed and replaced with combined thrust coefficients. To calculate these the wind is assumed to follow the profile $U_{(z)} = U(H)(\frac{z}{H})^{\alpha}$ where $\alpha = 0.12$ [6]. The thrust and damping coefficients acting on the tower is obtained by integrating the drag of each section and combining them into one coefficient to be used in SIMA. The thrust on the tower and turbine is assumed to follow $T = C \cdot V^2$. The turbine thrust coefficient is obtained by inserting the thrust from the thrust curve given in Wangs master thesis [5] and solving for C. The mooring system is shown in the picture below with one mooring lines from the tip of each side column fastened at -15m.





The implications of simplifying the model in this manner is that the number of RIFLEX elements is reduced considerably, time spent on simulation is decreased and more simulations can be evaluated to strengthen the statistical foundation of the results.

Results

The results shown is for the polyester rope mooring analysis. The heading of the environment is set to -x direction to ensure the largest possible tension that can occure in one line. The line in question is the 281mm superline polyester [4] with a 21582 kN max breaking strength. The characteristic tension (Td) [6] is obtained with the most probable max line tension from a gumbel distribution [3] developed by 20 simulations for each case. The weather condition is for a 50-year return period, wind=35.4m/s, Hs=10.4m and Tp=14s [2].

Length [m]	500	500	500	600	600	600	800	800	800
Pretension [kN]	1000	1500	2000	1000	1500	2000	1000	1500	2000
Td [kN]	23241	23442	20400	19297	19244	19171	19271	19213	19142

Conclusions

- By comparison the simplified model operates with considerably lower simulation time than the original model, making it an efficient model for large mooring analysis. It is also shown that the forces on the model is acceptable with respect to the original model.
- Many of the line lengths with different pretension has a acceptable Td and can withstand the forces from a 50-year condition.
- For the other two lines the tension will go below 0 and slack will ocure. This finding shows that the dimensioning factor for the polyester line is slack and not Td.
- To ensure that the system will be within acceptable strength with respect to rules and regulations [6] the pretension and possibly line length has to be elevated to get sufficient tension at all times and a system that can absorbe the motions of the weather condition.

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