PO206

The benefit of the teetering rotor in an offshore wind turbine and floating platform system

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Abstract

The paper investigates the dynamic behavior of two-bladed, teetering-hinge, yaw-control wind turbine, on top of a concrete semi-submersible floating platform (OO-Star Wind Floater by Olav Olsen). The paper discusses the role of the teetering rotor on the pitch (roll) damping of the offshore floating system and focuses on the turbine loading trade-off between offshore and onshore.

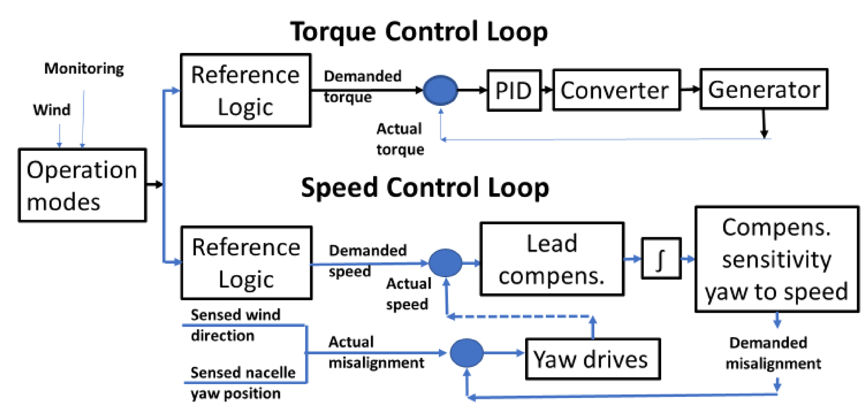
Objectives

The work addresses three questions:
- Does the operation at wind speed above the rated cause negative damping of the platform pitch (and roll) mode leading to amplify tower deflection and turbine and tower loading?
- Does the platform pitch and roll mode amplify the rotor wind loads compared to onshore?
- How does the teetering hinge affect the system loading?

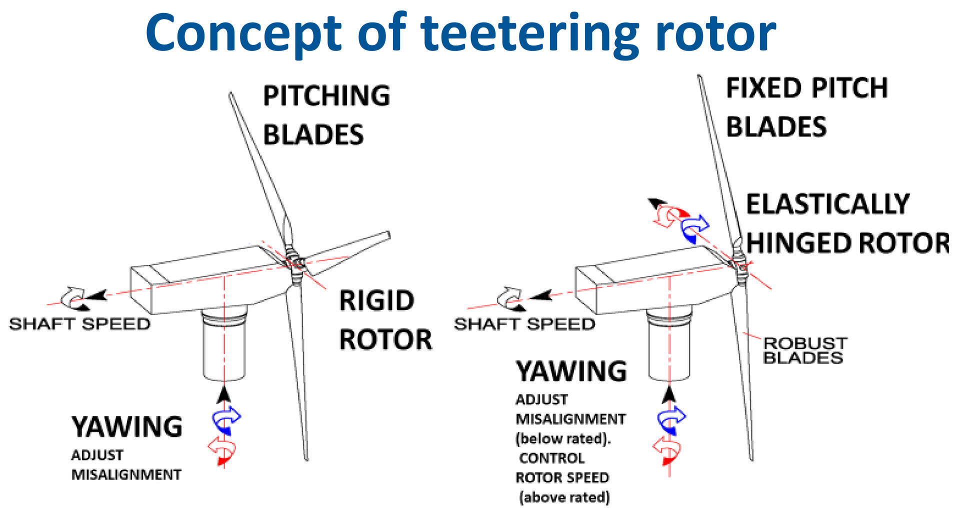
Reference offshore system

Rated Power 6,2 MW.
Rated running speed 20,8rpm.
Cut in 3,5m/s; Cut out 25m/s.
Rotor Diameter 126 m.
Teetering hinge with bumper.
Hub Height from WL 89 m.
Tower frequency 0,5 Hz (between 1P_2P).
Concrete semisubmersible (OO-Star Wind Floater by Olav Olsen)

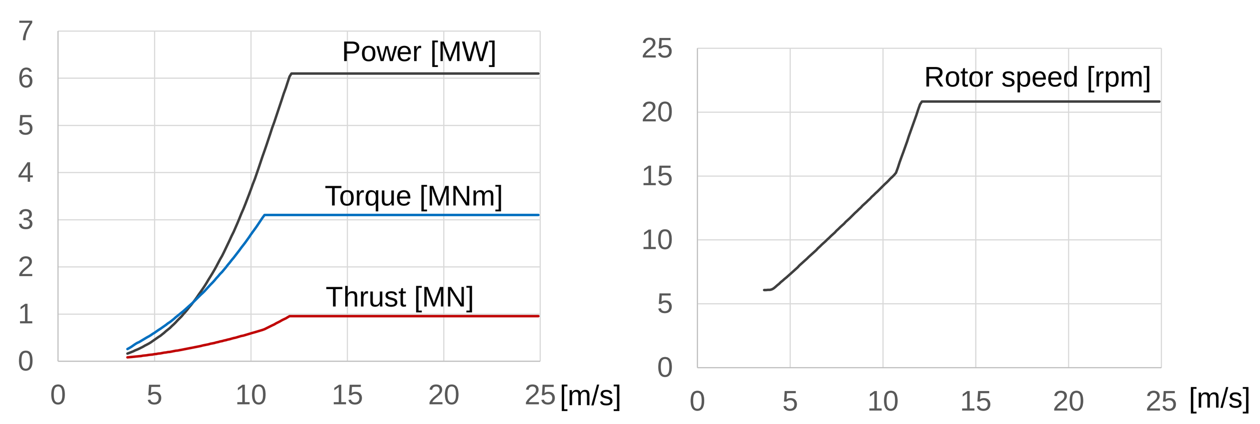
Controller philosophy



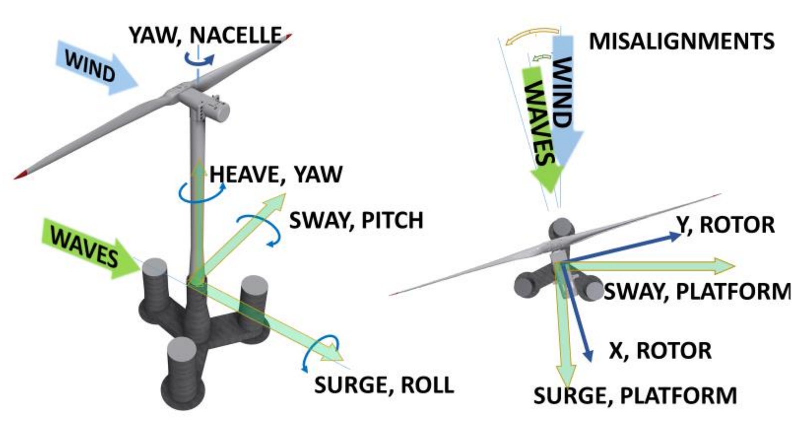
Concept of teetering rotor



Performance of reference turbine



System coordinates



Reference site

Site K13	Wind [m/s]	Hs [m/s]	Tp [s]
Operating conditions	3,5 to 25	1,2 to 3,5	5,8 to 7,8
Parking 50-year	50	12,9	16,0
	Horizontal blades pointed to wind±15° and wind/waves misalignment.		

Methods

Analyze the System motion and loading for various wind speeds above rated and various periods of Hs, for:

- Offshore without wind; with constant wind; with turbulent wind in operation and parking.
- Onshore with turbulent wind.
- Offshore with turbulent wind, assuming rigid rotor.

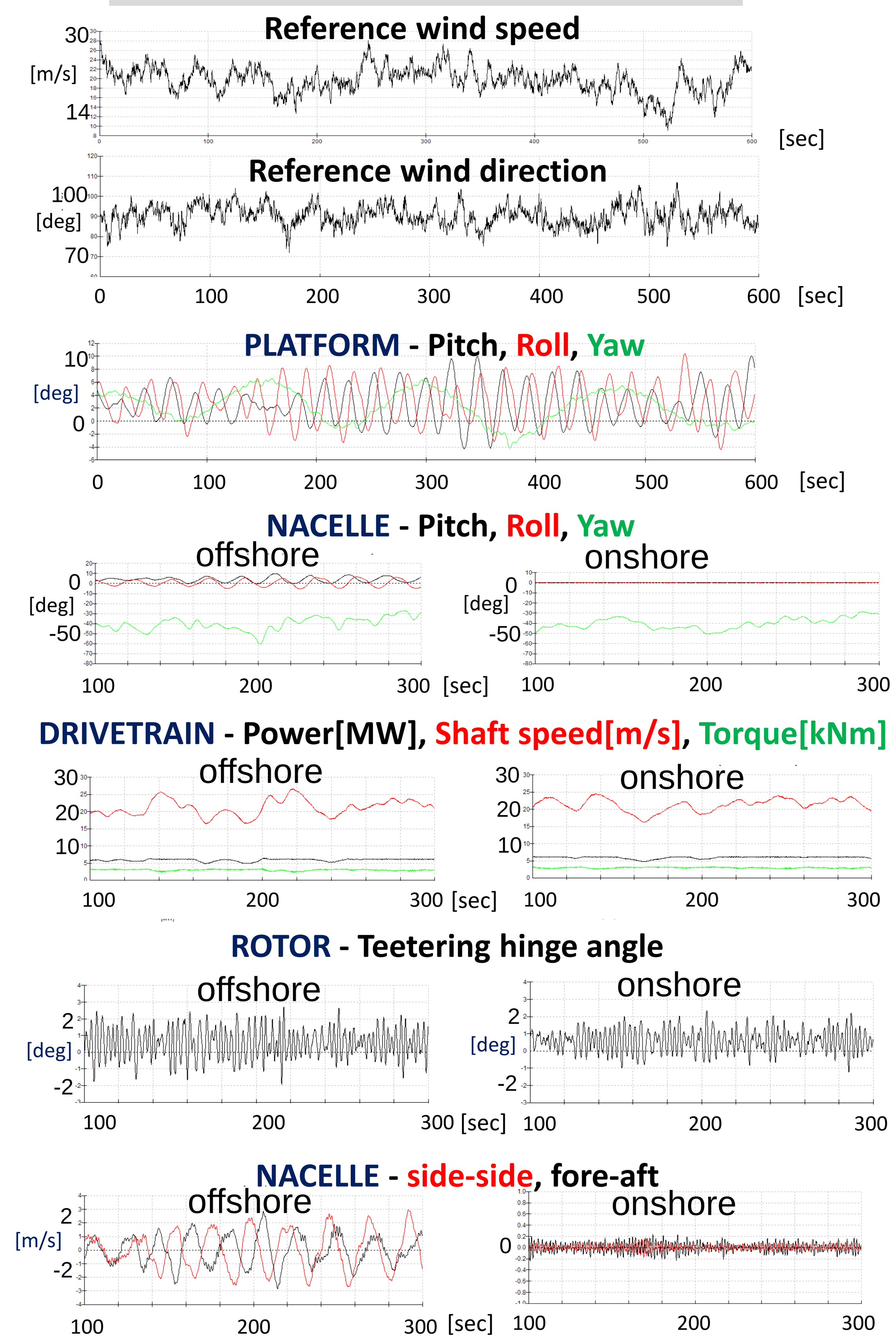
Main cases examined

Offshore	Hs[m]	Tp[s]	Wind[m/s]	Onshore
1off	6	20	Only waves	
2off	6	20	20 constant	2on
3off	6	5	20 normal turb.	
4off	6	10	20 normal turb.	
5off	6	20	20 normal turb.	5on
6off	6	20	20 normal turb. Shutdown	6on
7off	12,9	16	50-years	7on
8off	6	20	20 extreme turb.	8on
9off	6	20	20 norm.turb. Rigid rotor	

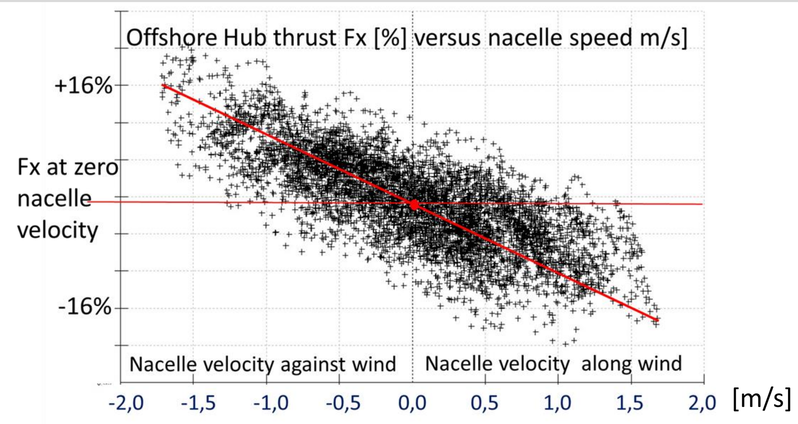
Results

Case	Pitch (Roll) Platf. [deg]		Pitch (Roll) Top Tower[deg]		Yaw Platf. [deg]		Platform period
	Ave	Δ/2	Ave	Δ/2	Ave	Δ/2	[sec]
1off	-0.3 (-0.2)	2.2 (4.1)	-0.4 (0)	3.2 (4.4)	0.3	5.2	Higher than wave period
2off	2.7 (3)	4.4 (6)	4.2 (0.5)	4.7 (6)	2.4	4.2	
2on	-	-	0.2 (0.1)	0 (0)	-	-	
3off	2.7 (3)	4.5 (5.3)	4.3 (0.6)	4.6 (4.8)	2.2	5.6	
4off	2.6 (3)	3.7 (5.5)	4.3 (0.6)	4.9 (4.4)	3.2	4	
5off	2.6 (2.9)	7.2 (7.4)	4.1 (0.5)	8 (6.1)	2.2	5.4	
5on	-	-	0.2 (0.1)	0.3 (0.1)	-	-	
6off	0.6 (1.2)	4 (5.1)	1.1 (0.6)	5.4 (3.8)	1.3	1.7	
6on	-	-	0 (0)	0.4 (0.2)	-	-	
7off	-0.3 (2.3)	5.7 (17.4)	-0.3 (2.3)	5.6 (17.5)	-0.7	8.6	
7on	-	-	0 (0)	0 (0)	-	-	
8off	2.6 (3)	4.5 (4.5)	4.2 (0.7)	5.2 (3.5)	2.7	1.9	
8on	-	-	0.1 (0)	0.3 (0.1)	-	-	
9off	2.3 (2.8)	7.4 (8.8)	3.8 (0.6)	6 (9.7)	4.4	6.5	

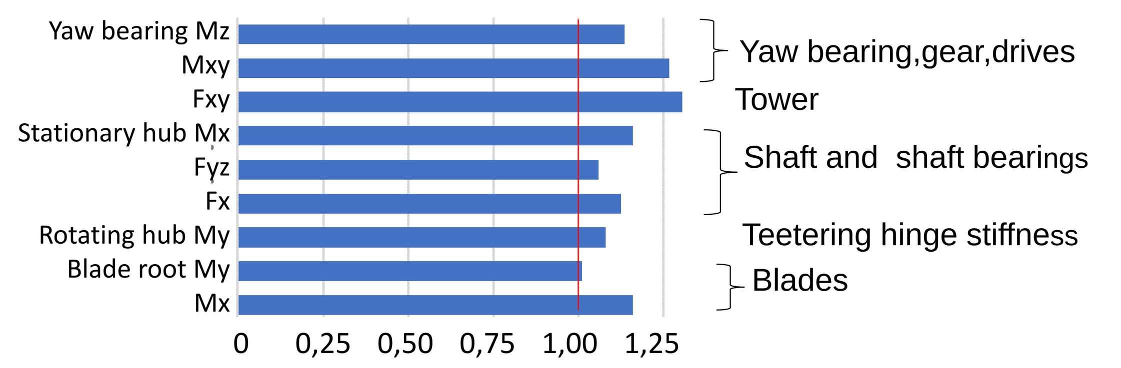
Time histories of cases 5off, 5on



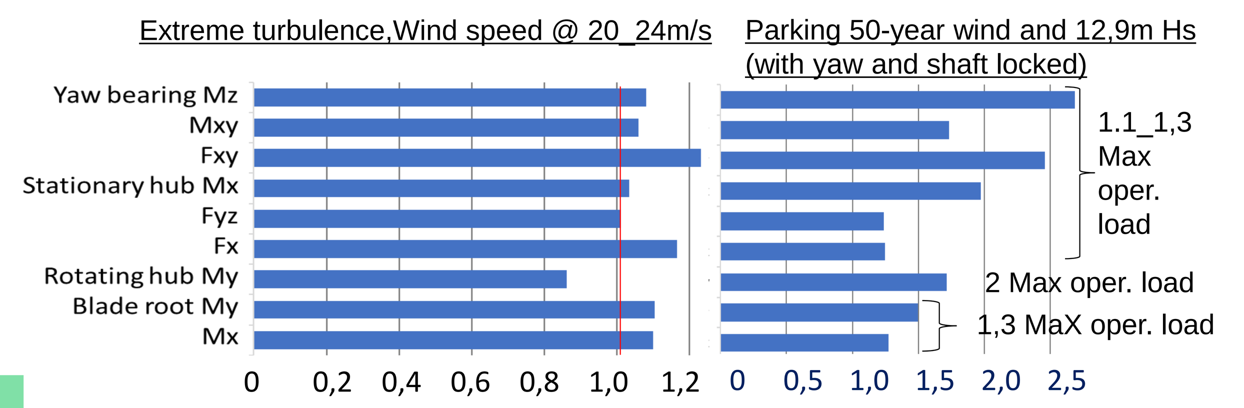
Sensitivity of hub Fx (thrust) to floating pitch



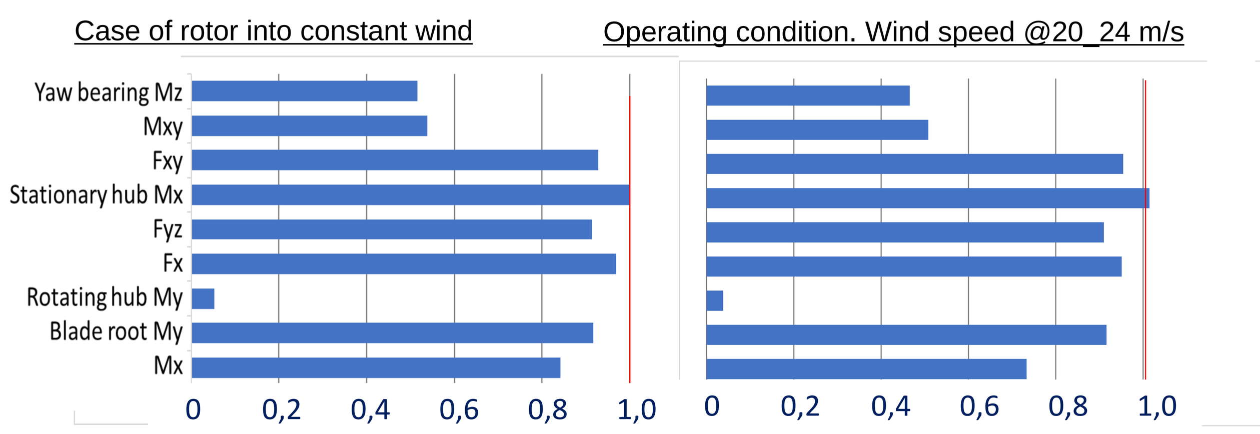
Ratio offshore DEL to onshore (fatigue)



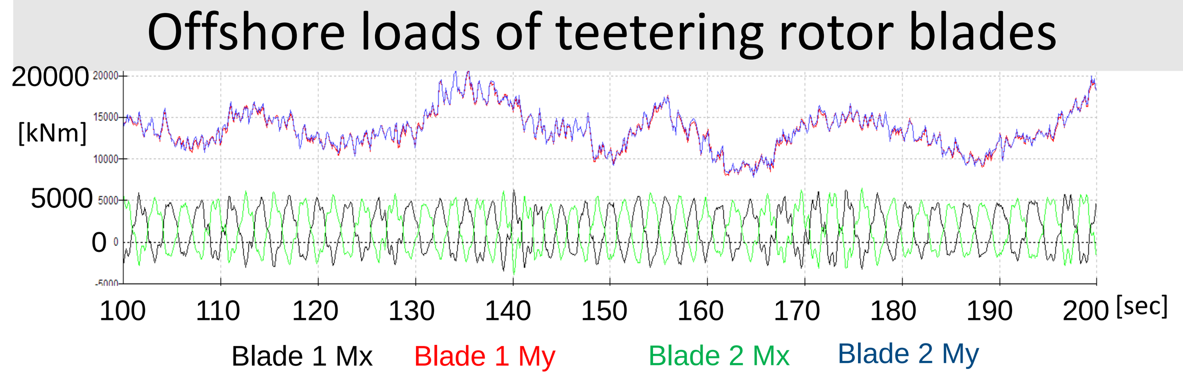
Ratio offshore UL to onshore (driving DLC)



Ratio offshore loads of Teetering to Rigid rotor



Offshore loads of teetering rotor blades



Conclusions

The two-bladed teetering hinge, yaw-control turbine, on top of Olav Olsen's OO-Star Wind Floater, doesn't add negative damping to the system.

The teetering rotor and the high inertia of the concrete floating platform play an important role in lowering the offshore system loading.

Offshore UL and DEL loads are slightly higher than onshore.

The rotor bumper is never hit, except for extreme parking condition and wind-wave misalignment.

The teetering hinge leads to symmetrical flapping loads of the two blades, irrespectively of the rotor-wind misalignment.

Loads to be substantiated by tests in basin.

References

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2. Bladed, Version 4.5
3. ETI DIWET5, Two-bladed floating WT, Feasibility studies 2005
4. S. Caruso, Wind Turbine Technology Forum, Venice May 2011
5. S. Caruso, P.O.W.E.R.E.D. Ancona Conference, May 2013
6. DNV GL, Offshore Standards

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