A Comparison of Two and Three Bladed Floating Wind Turbines

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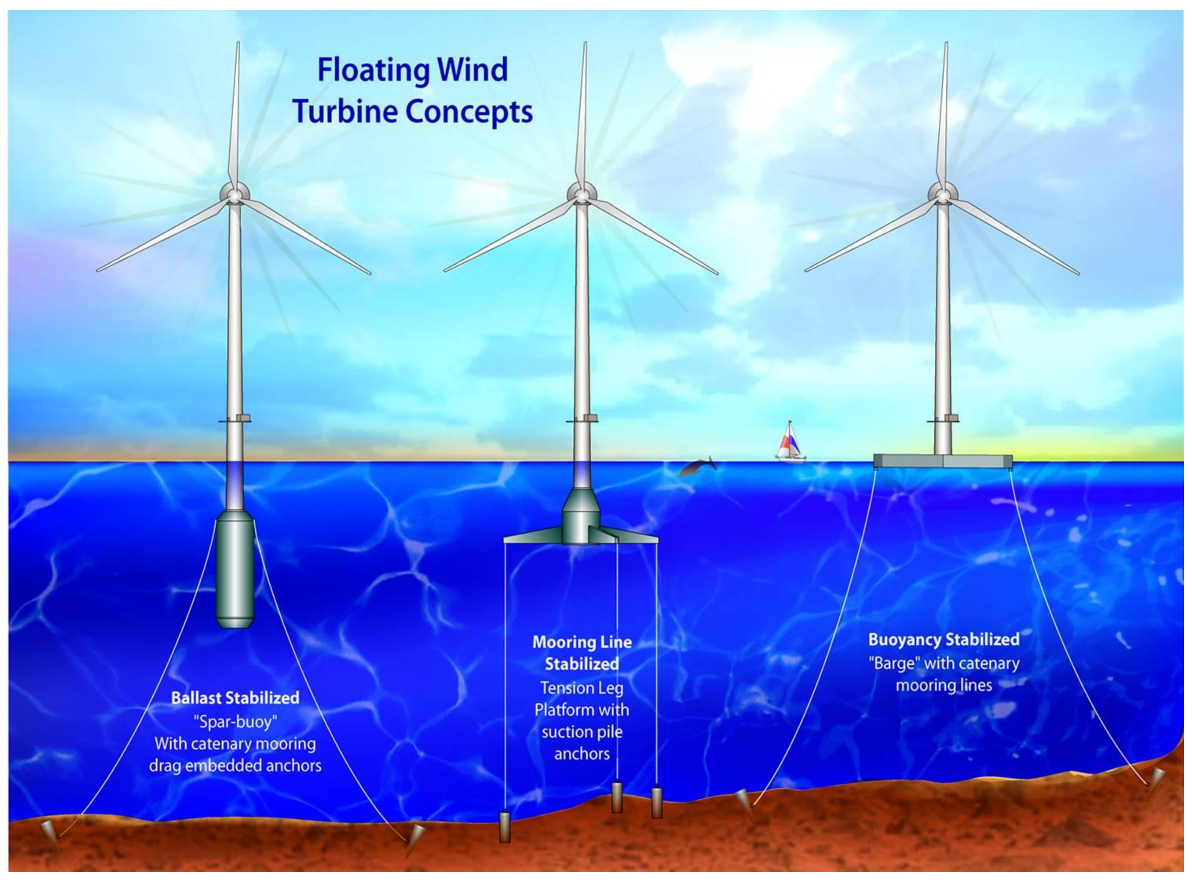
Types of Floating Platforms

The DOE National Renewable Energy Laboratory (NREL) and others have classified three types of floating platforms based on the physical properties to achieve static stability.:

1. Spar buoy
2. Tension Leg (TLP)
3. Barge



Floating Platform Concepts (buoyant components not accurate scale compared to turbine)

Image courtesy of NREL

Why Consider Two Bladed Turbines?

The US government and industry successfully designed and operated large two bladed wind turbines in the 1980's until leaving the market when energy prices decreased by 60%.

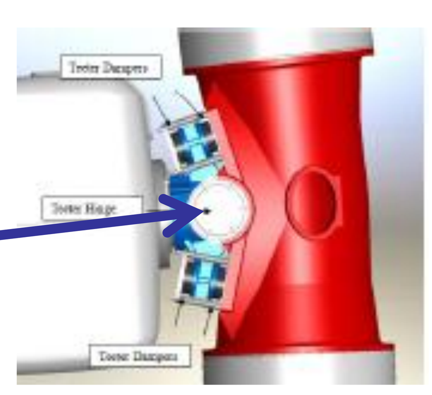
Two bladed wind turbines offer the following advantages over three bladed:

- Cost savings of one blade
- Lower weight further reduces system costs
- Easier rotor lift and assembly
- Greater rotor speeds reduce drivetrain stress

4 MW WTS-4 in 1982 (held the world's record for power output for over 20 years)

Photo courtesy of NASA

Two blade rotors usually feature flexible blades or a teetered hub with a pivot point. This is especially important for floating wind turbines because the teeter pin effectively decouples the motion of the rotor plane from the tower motion, reducing damaging cyclic bending moments in the drive train.



Analytical Model

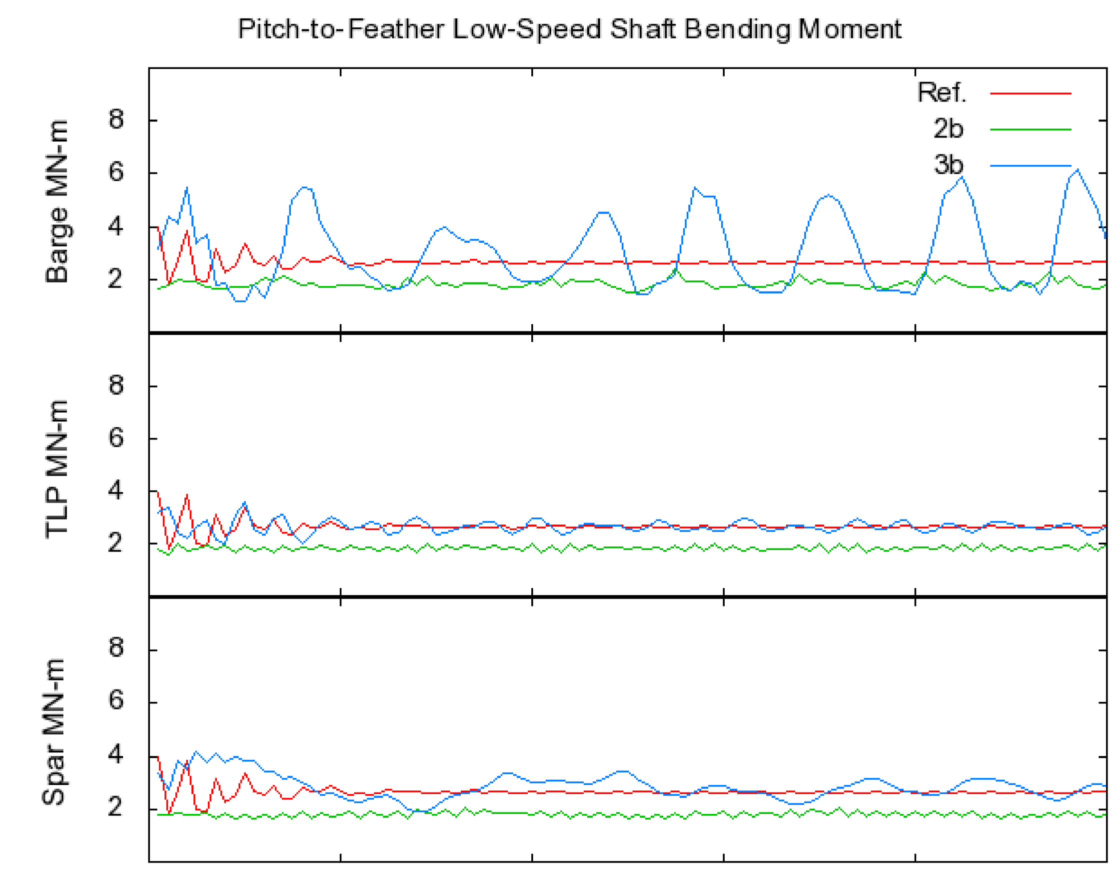
For this study, the following models were used:

- NREL WT_Perf program for power and energy calculations
- NREL FAST program for fully coupled aero-hydro-servo-elastic analyses
- NREL's 5MW Reference offshore wind turbine model
- ITI Energy Barge, MIT/NREL TLP, and OC3-Hywind platforms

The baseline three bladed models were compared to two bladed, teeter hub models. A number of conditions were analyzed. For this poster, a time simulation of 100 seconds is shown for a steady wind speed of 13 mps with an unsteady sea state driving platform motions. The rated rotor speed of the three bladed turbine models was 13 RPM and the two bladed turbines were 16 RPM. The Reference wind turbine was rigidly connected to the inertial reference plane.

Results

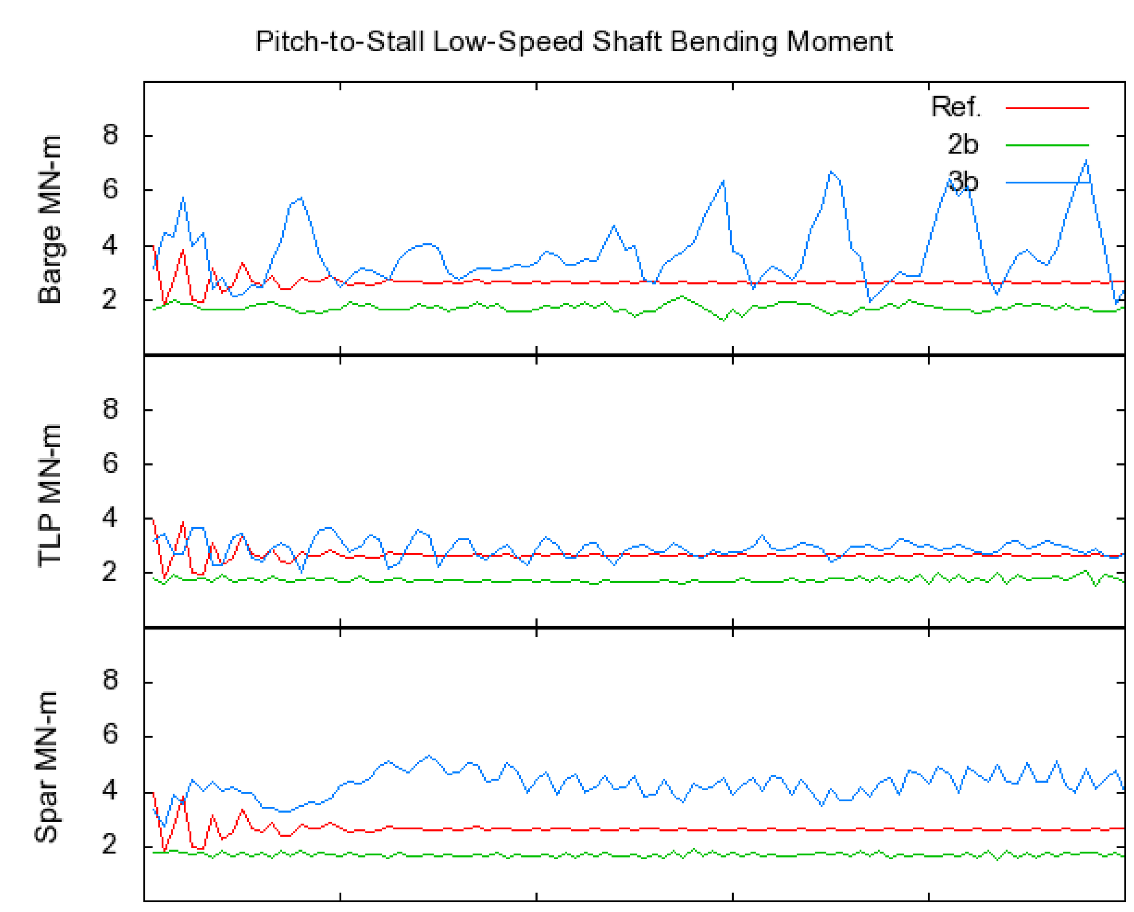
Analysis of power output and energy production showed the two bladed turbine produced 1.6 percent less energy than the three bladed turbine, showing that the performance is quite comparable even though the blade dimensions and twist were not optimized for two blades.



Low-Speed Shaft Bending Moment (Feather)				
	3BLand(Ref.) - Model	Model/3BLand(Ref.)	range	Model/(Ref.)
3BBarge(F)	-496.10	1.19	4746.32	38.83
2BBarge(F)	817.19	0.69	844.82	6.91
3BTLP(F)	2.81	1.00	654.18	5.35
2BTLP(F)	808.99	0.69	348.50	2.85
3BSpar(F)	-161.97	1.06	1341.22	10.97
2BSpar(F)	833.62	0.68	414.95	3.39

Analysis of bending moments into the low-speed shaft of the drive train showed significant reductions in both the mean and cyclic values for two bladed turbines. This is especially important to increasing life of bearings and gears, given that the wind industry is challenged by drive train reliability.

Two new control algorithms were created and studied for the two bladed turbines. The first was the standard pitch-to-feather. The second was a pitch-to-stall algorithm to assess its possible added damping and small pitch range for gusty winds.



Low-Speed Shaft Bending Moment (Stall)				
	3BLand(Ref.) - Model	Model/3BLand(Ref.)	range	Model/(Ref.)
3BBarge(S)	-1173.57	1.44	5311.33	43.45
2BBarge(S)	934.55	0.65	893.84	7.31
3BTLP(S)	-215.72	1.08	1153.39	9.44
2BTLP(S)	911.94	0.65	534.80	4.38
3BSpar(S)	-1729.22	1.66	1643.33	13.44
2BSpar(S)	946.28	0.64	375.81	3.07

Future Work

Analysis of new designs for floating foundations such as Nautica Windpower's AFT (Asymmetric Floating Tower) that offers the possibility of significant weight and cost reductions will require modeling of downwind rotors and asymmetry.