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Abstract

This study uses the open-source WEC-Sim code to model a 1:7 scale wave energy converter device called SeaRay of Columbia Power Technologies (CPwr). WEC-Sim is intended to run quickly on standard desktop equipment and provide a very gentle learning curve for WEC modeling. This paper focuses on the linear implementation of WEC-Sim as that requires the least simulation time and is often the starting point for basic system design. WEC-Sim results are compared against the SeaRay's experimental data. Two studies were conducted: comparison of WEC-Sim predictions versus experimental data across 285 trials of varying sea-states to determine overall average power and energy production; and a determination of WEC-Sim's accuracy in predicting the experimental ranges of position, speed, torque, and power. The study of average power production across many sea states shows the WEC-Sim predicts the average power of the aft float well, within 15 %, but the error in the fore float is larger at 34 %. The error in total predicted power is 24 %. The detailed analysis of range of motion shows WEC-Sim predicted 95th percentile outliers (which dominate the design considerations) in position, speed, and torque by +15 %, +14 %, and +17 %, respectively, for the fore float and -1 %, -9 %, and -6 %, respectively for the aft float.

Experimental Setup

- The data collected from the Puget Sound. The data set from June 2011 is chosen since it contains more data.
- Fore and aft generator torque, speed, and position were recorded in 512 seconds segment at a 0.04 second sample rate. The final data set for comparison is 285 trials.

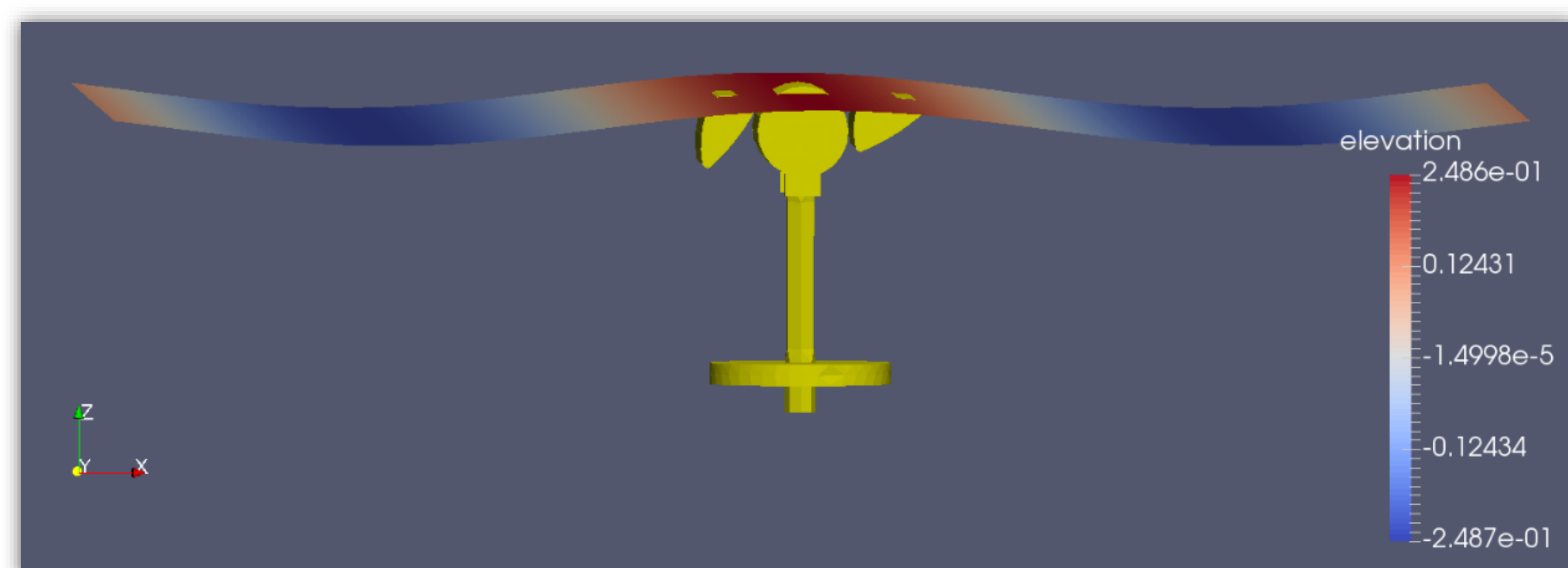


[Image courtesy of CPwr]

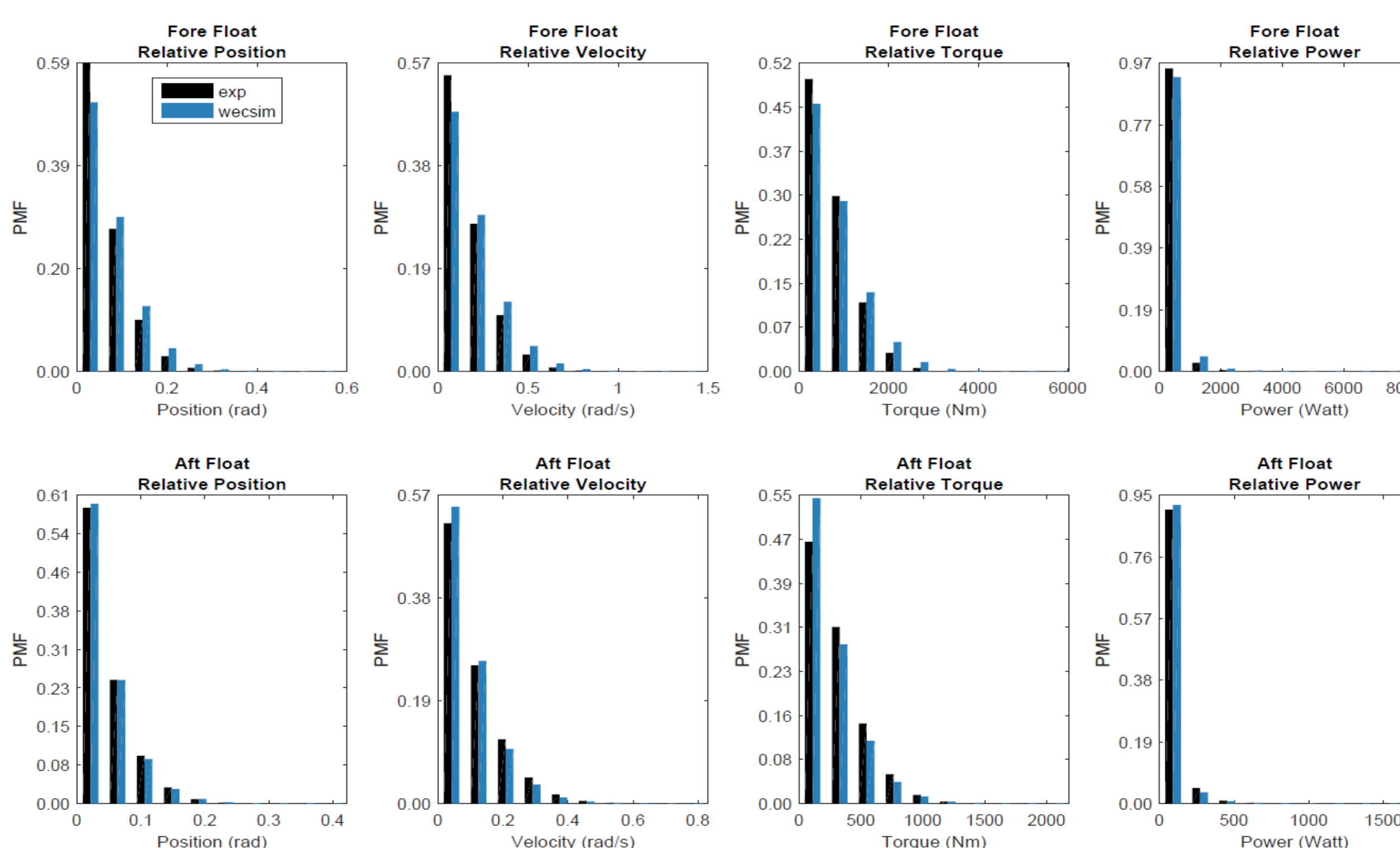
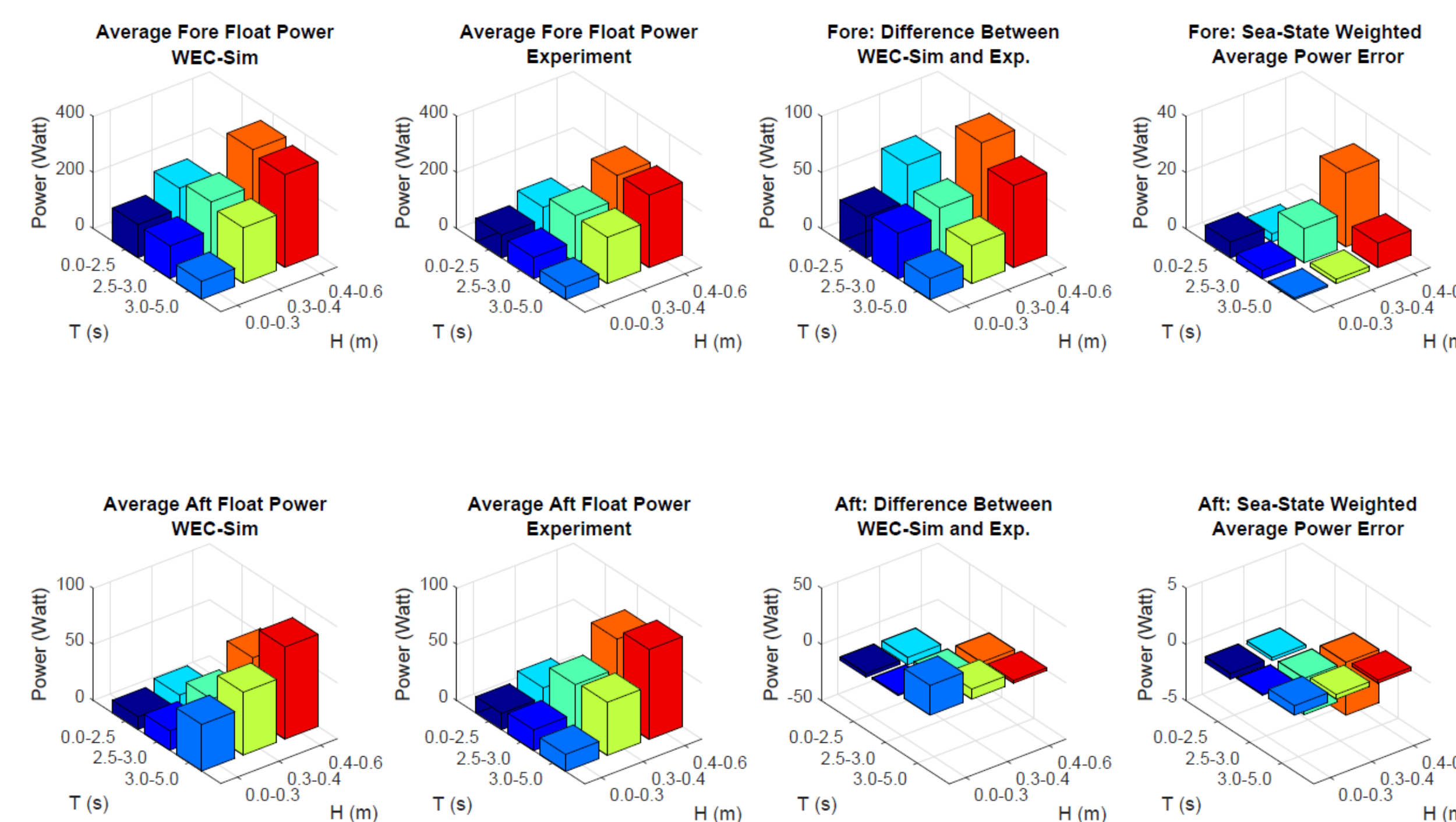
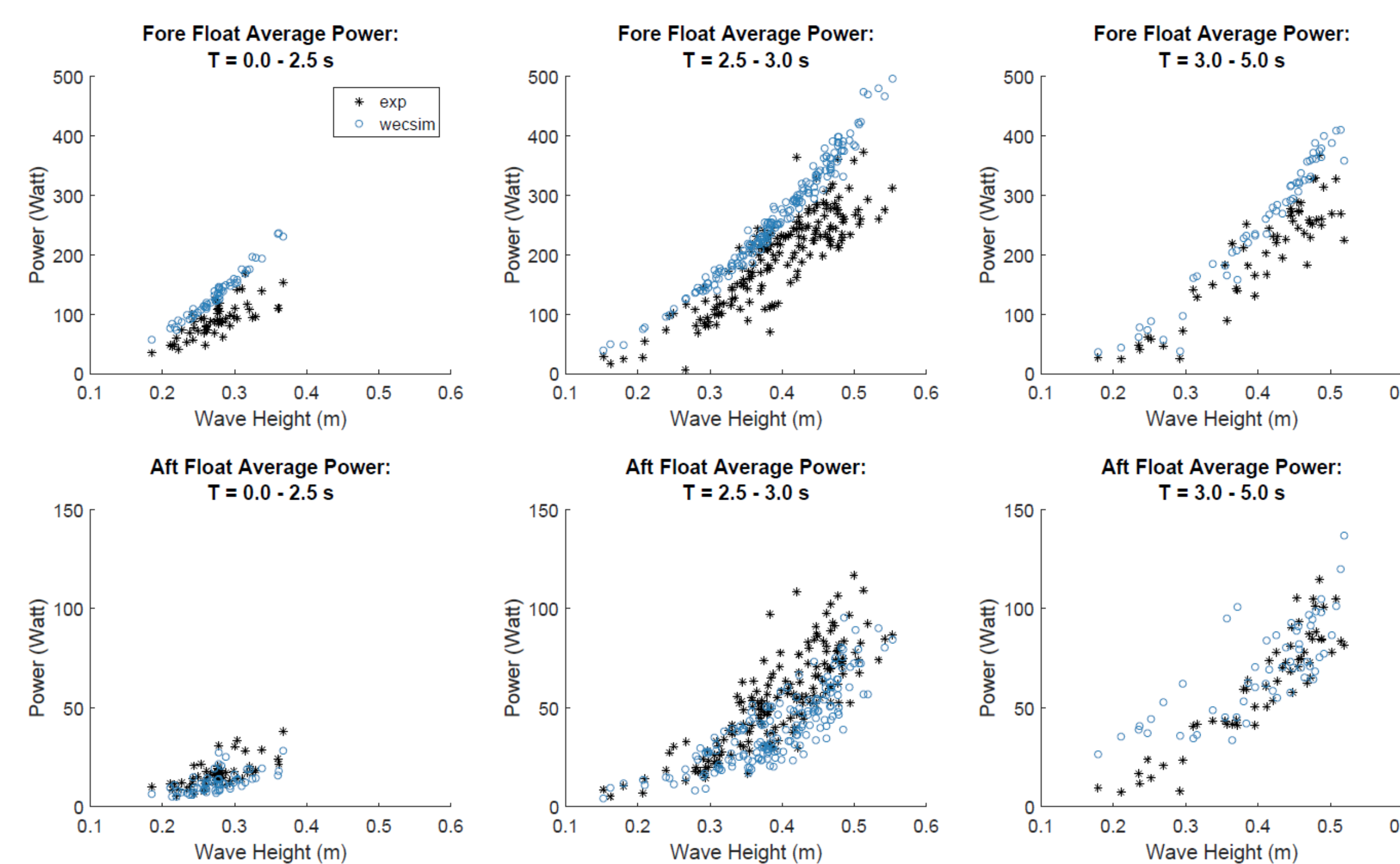
- Several requirements are established to down-select the data. Only those trials that are head on (absolute value of relative wave heading less than 22.5 degrees) with relative little directional spreading and are within the operational PTO damping cases are considered.

Simulation Setup

- Sequentially select one of the 285 experimental test trials.
- Run a 1000 second simulation at a 0.05 second simulation step in WEC-Sim for a sea state of the same spectrum, with the same fore and aft generator damping.
- Compare the statistical measures of generator position, speed, and torque of the experimental data versus the simulation.



Graphs



Tables

Table I: Difference in average power (watt) between WEC-Sim and Exp. for fore float and aft float

Peak Period [s]	Wave Height [m]						Peak Period [s]	Wave Height [m]					
	0.0 - 0.3		0.0 - 0.4		0.4 - 0.6			0.0 - 0.3		0.0 - 0.4		0.4 - 0.6	
0.0 - 2.5	36.7	-3.3	68.3	-6.5	N/A	N/A	0.0 - 2.5	5.7	-0.5	2.9	-0.3	N/A	N/A
2.5 - 3.0	40.5	-1.2	48.6	-13.0	92.4	-16.5	2.5 - 3.0	3.0	-0.1	12.1	-3.2	26.3	-4.7
3.0 - 5.0	18.7	26.4	33.7	8.9	73.0	2.3	3.0 - 5.0	0.6	0.8	1.5	0.4	8.7	0.3

Table II: Weighted difference in average power (watt) between WEC-Sim and Exp. for fore float and aft float

Table III: The mean, standard deviation, and 95th percentile for fore and aft float

	Fore		Aft	
	WEC-Sim	Experiment	WEC-Sim	Experiment
Position (rad)				
Mean	0.070	0.060	0.043	0.043
Std. Dev	0.058	0.051	0.039	0.039
95 %ile	0.186	0.162	0.121	0.122
Velocity (rad/s)				
Mean	0.183	0.152	0.092	0.097
Std. Dev	0.150	0.137	0.081	0.093
95 %ile	0.479	0.420	0.254	0.280
Torque (kNm)				
Mean	0.782	0.667	0.251	0.278
Std. Dev	0.630	0.541	0.215	0.228
95 %ile	2.017	1.718	0.677	0.719
Power (W)				
Mean	0.237e3	0.176e3	40.641	47.751
Std. Dev	0.382e3	0.281e3	74.428	78.476
95 %ile	0.964e3	0.719e3	0.171e3	0.201e3

Conclusion

- WEC-Sim did reasonably well in estimating the overall energy, estimating the total energy converted to within 24 % (over-prediction). The aft float power alone was better predicted, within 15 %.
- An analysis of average power by sea-state weighted by sea-state PMF shows that the primary source of prediction error for both the fore and aft float was for large height, medium length waves.
- The operational ranges and limits were generally well predicted, with errors in prediction of the outliers of fore float actuation between +14 % to +17%, and errors in the aft float actuation between -1 % and -9 %.

Acknowledgment

This research was made possible by support from the Wind and Water Power Technologies Office within the DOE Office of Energy Efficiency & Renewable Energy. The work was supported by Sandia National Laboratories and by the National Renewable Energy Laboratory. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. Special thanks to Kelley Ruehl (SNL) and Yi-Hsiang Yu (NREL) for their support on WEC-Sim.

Special thanks to Ken Rhinefrank of Columbia Power Technologies (CPwr) for support on the experimental data.