SAND2016-3206C

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Sandia National Laboratories

On the Short-Term Uncertainty Performance of a Point Absorber Wave Energy Converter

Lance Manuel[1], Jarred Canning[1], Ryan G. Coe[2], and Carlos Michelen[2]
[1]The University of Texas at Austin
[2]Sandia National Laboratories

April 25, 2016

GOAL

Quantification of uncertainty in the performance of a two-body wave point absorber (Reference Model 3 or RM3), wave energy converter (WEC).

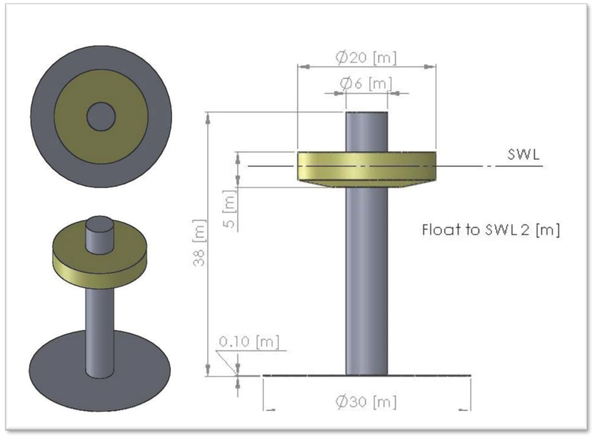
1. Obtain short-term reliability of power-take-off (PTO) extension
2. Analyze dependence of this response on the specific sea state

METHODS

1. WEC-Sim simulation tool is used to establish short-term relationships between any performance parameter of the WEC device and wave height for two sea states
2. Monte Carlo Simulation (MCS) and First-Order Reliability Method (FORM) employed.
3. When combined with metocean data quantifying the likelihood of different sea states, easy to extend to long-term studies and in reliability-based design.

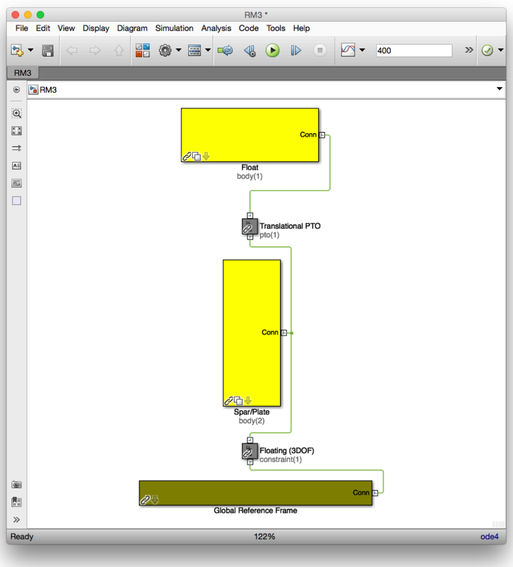
CONCLUSIONS

1. FORM approach to estimate reliability of the PTO extension works well as compared with MCS
2. Importance of uncertainty parameter in simplified model is demonstrated



Schematic representation of the Reference Model 3 (RM3) point absorber [1].

WEC-Sim block diagram model of RM3 device.



Simplified model for PTO extension

$$d(h,\epsilon) = (ah^2 + bh + c) + \epsilon$$

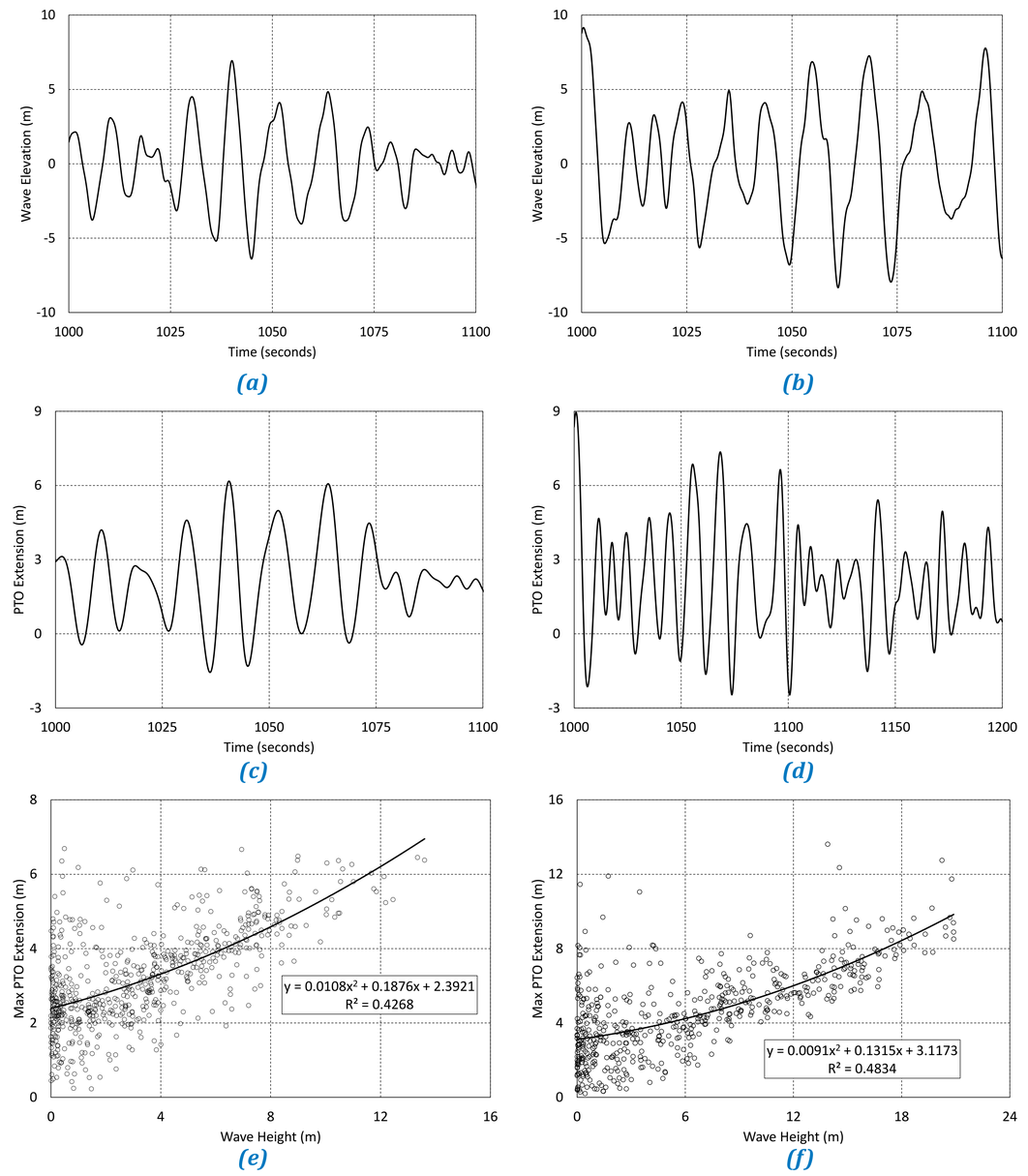
h: instantaneous wave elevation
ϵ: uncertainty
a, b, c: model parameters

Rayleigh distribution for wave heights

$$F_H(h) = 1 - \exp\left[-\frac{1}{2}\left(\frac{h}{\alpha}\right)^2\right]$$

Reliability function

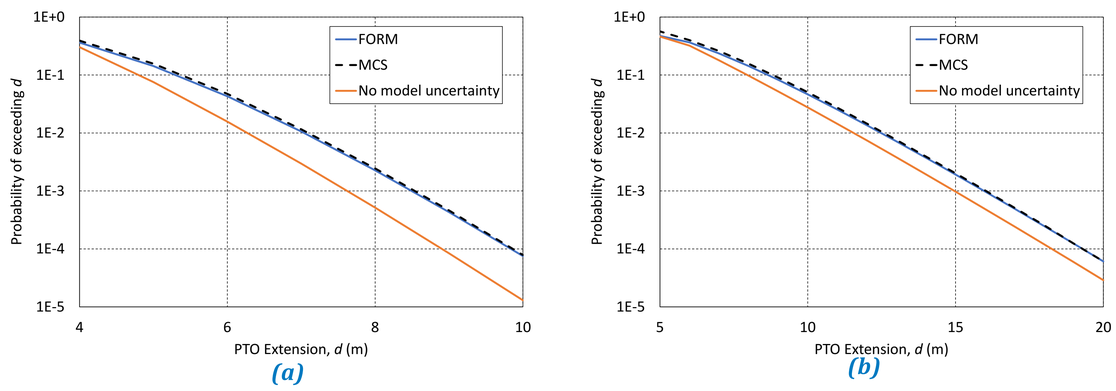
$$g(\boldsymbol{X}) = d_{allowable} - d(h,\epsilon)$$



Representative 100-sec segments from 1-hr simulations of the wave elevation process and the RM3 PTO extension for two sea states and established statistical relationship between maximum PTO extension and wave height. Plots (a), (c), and (e) are for the sea state with H_s = 8.2 m, T_p = 11.0 s; plots (b), (d), and (f) are for H_s = 16.0 m, T_p = 13.3 s.

Parameters describing wave height, h, PTO extension, d, and model uncertainty variable, ε.

H_s (m)		8.2	16.0
h (m)	a (m)	4.10	7.99
d (m)	a (1/m)	0.01	0.01
	b (-)	0.19	0.13
	c (m)	2.39	3.12
σ_ε (m)		0.98	1.71



Probability of exceeding specified PTO extension levels computed using FORM and MCS for two states: (a) H_s = 8.2 m; (b) H_s =16.0 m.

ACKNOWLEDGEMENTS

This work was funded by the U.S. Department of Energy's Wind and Water Power Technologies Office. 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.

REFERENCES

- V. S. Neary et al., "Methodology for Design and Economic Analysis of Marine Energy Conversion (MEC) Technologies," Sandia National Laboratories Report SAND2014-9040, March 2014.
- Y. Yu, M. Lawson, K. Ruehl, and C. Michelen, "Development and Demonstration of the WEC-Sim Wave Energy Converter Simulation Tool," Proceedings of the 2nd Marine Energy Technology Symposium, Seattle, WA, 2014.
- A. C. Eckert-Gallup, C. J. Sallaberry, A. R. Dallman, and V. S. Neary, "Modified Inverse First Order Reliability Method (I-FORM) for Predicting Extreme Sea States," Sandia National Laboratories, SAND2014-17550, 2014.
- C. Michelen and R. Coe, "Comparison of Methods for Estimating Short-Term Extreme Response of Wave Energy Converters," OCEANS '15 MTS/IEEE, Washington DC, October 2015.
- H. O. Madsen, S. Krenk, and N. C. Lind, "Methods of Structural Safety," Prentice-Hall, 1986.
- J. Fogle, P. Agarwal, and L. Manuel, "Towards an Improved Understanding of Statistical Extrapolation for Wind Turbine Extreme Loads," Wind Energy, Vol. 11, No. 6, pp. 613–635, November/December 2008.
- K. Saranyasoontorn and L. Manuel, "A Comparison of Wind Turbine Design Loads in Different Environments using Inverse Reliability Techniques," Journal of Solar Energy Engineering, Transactions of the ASME Vol. 126, No. 4, pp. 1060-1068, November 2004.
- P. Agarwal and L. Manuel, "Simulation of Offshore Wind Turbine Response for Ultimate Limit States," Engineering Structures, Vol.31, No. 10, pp. 2236-2246, October 2009.