Performance Assessment of Large-Scale WECs Array with the Consideration of Disturbed Wave Field

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Introduction

Challenges: There are many challenges need to be addressed to improve the economic index of WEC. One of the major concerns is the poor power quality generated by WECs. It is found in recent research that the produced wave power quality can be improved by placing WECs in an array. However, both the modeling and control of WECs array are not sufficiently studied. Specifically, it is very challenging to evaluate the disturbed wave field when modeling the WECs array (especially for large scale array).

Therefore, we **proposed** a new simulation framework to evaluate the array performance with the consideration of disturbed wave field in a scalable manner.

Contributions: 1) A new simulation framework which couples SWAN and ProteusDS; 2) Analysis of array performance with different WECs and realistic ocean conditions; 3) Experimental data validation/calibration

Methodology: WEC dynamics

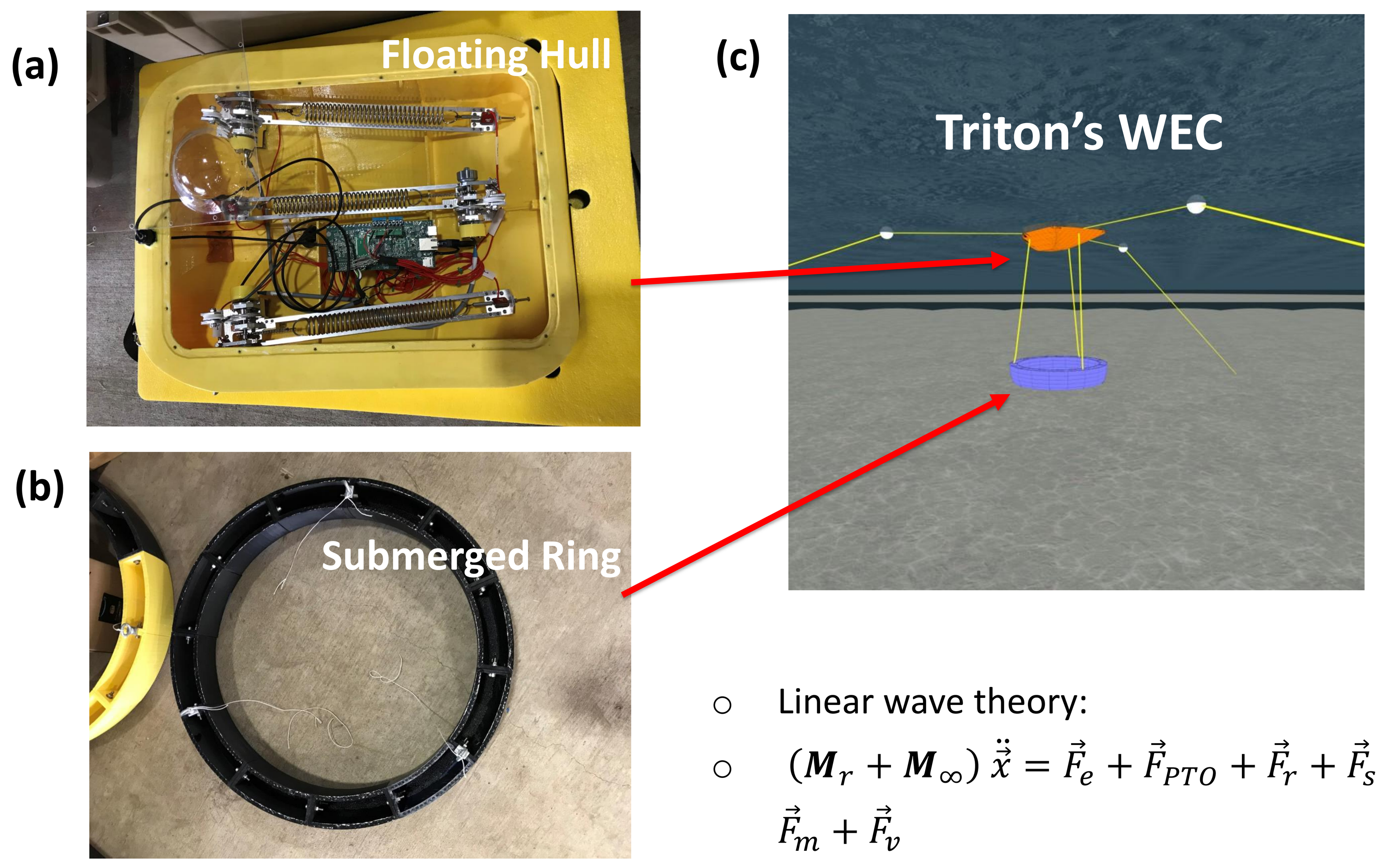
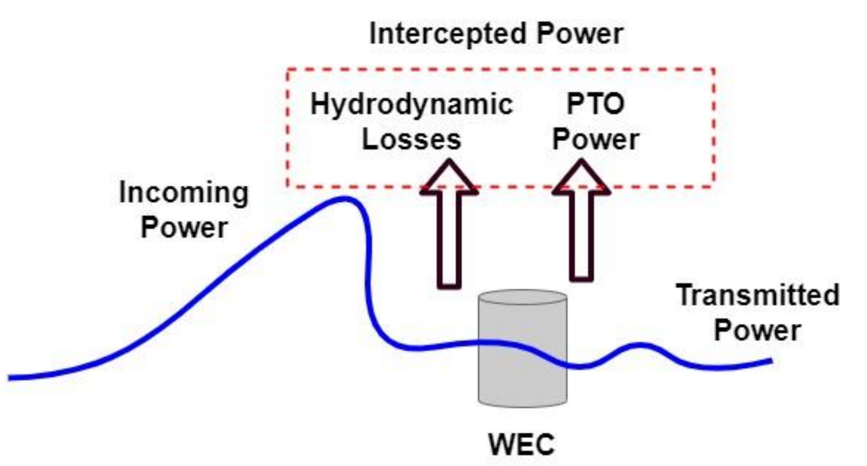


Figure 1: Experimental and numerical configuration of Triton's WEC which is composed by a floating hull (shown in (a)) and a submerged ring (shown in (b)), connection tendons, and mooring systems (shown in (c)).

- Linear wave theory:
- $(\boldsymbol{M}_r + \boldsymbol{M}_\infty)\ddot{\vec{x}} = \vec{F}_e + \vec{F}_{PTO} + \vec{F}_r + \vec{F}_s + \vec{F}_m + \vec{F}_v$
- Software: ProteusDS
- Calibrated based on experimental data

Methodology: Transmission Coefficient

- **Intercepted power** by summing PTO power and hydrodynamic losses
- Hydrodynamic losses are not negligible
- Transmission coefficient is therefore modified as:
- $K_{t,n} = \sqrt{1 - \frac{P_{icp}(\omega_n)}{P_{inc}(\omega_n)}}$



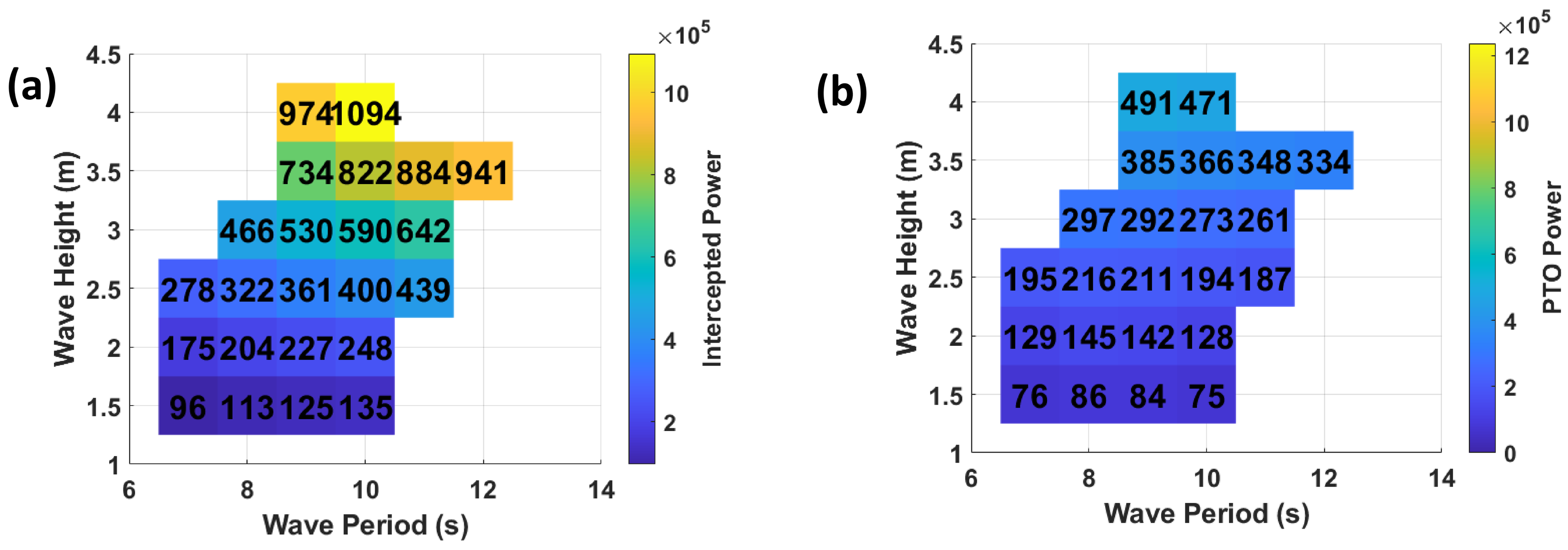


Figure 2: Comparison between the PTO power production (as shown in (b)) and the intercepted power (as shown in (a)). In some sea states, the intercepted power could be 5 manifold the PTO power which represents the significance of hydrodynamic losses

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Methodology: Wave field solver

- Software: Simulating Wave Near Shore (SWAN)
- Phase non-resolved solver
- Spectrum domain instead of time domain
- Rapid solution even for large wave field
- Use Transmission Coefficient to represent the presence of WECs

Methodology: Simulation Framework

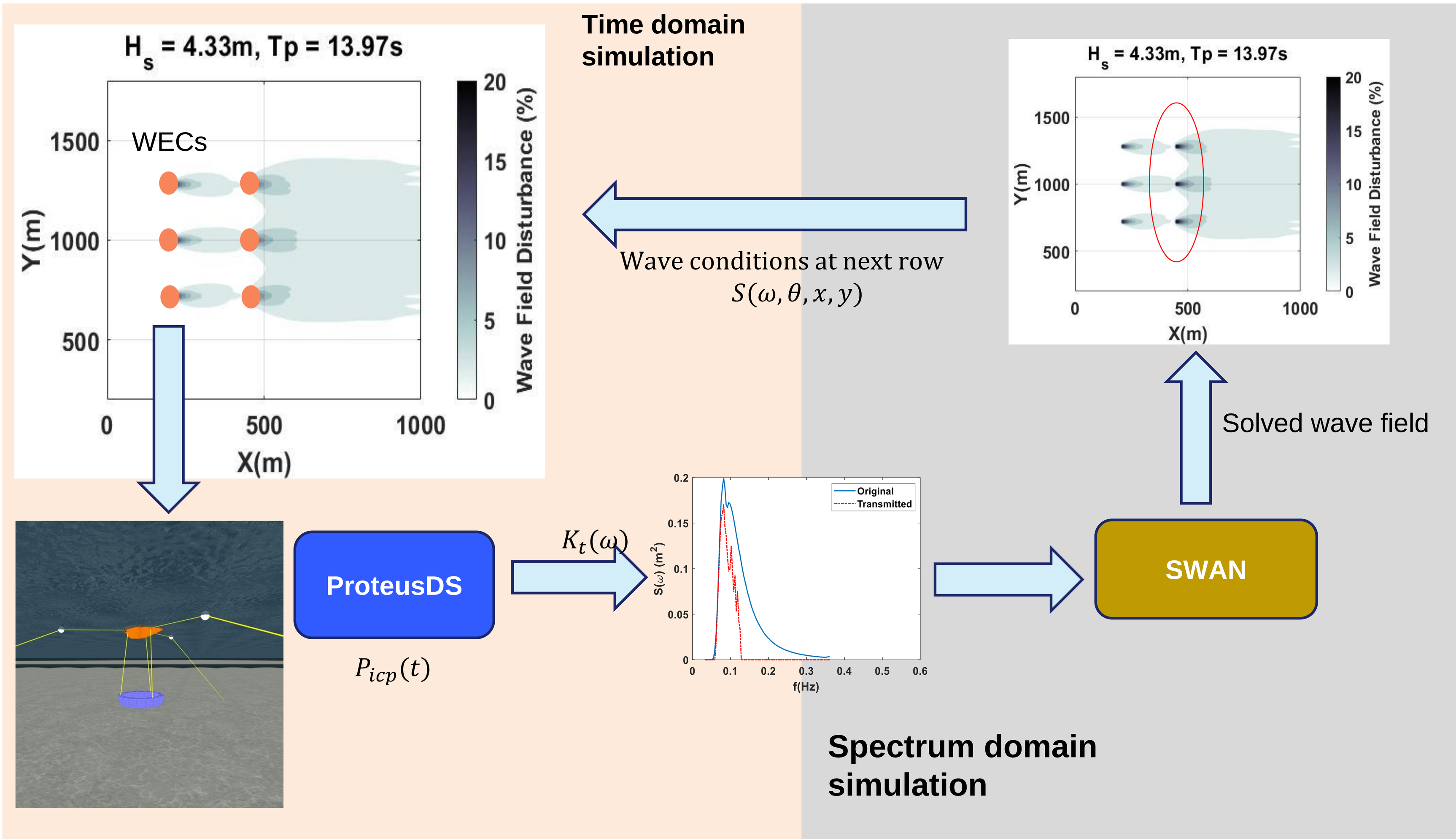

Figure 3: Layout of the simulation framework. First of all, the free field wave conditions will be applied to time domain simulation for the first row of WECs in the array. The obtained time domain system response will be utilized to compute the transmission coefficient. These transmission coefficients will then be used for SWAN simulation to obtain the disturbed wave conditions at next row of WECs. The above-mentioned steps will be repeated until the last row of WECs array.

Simulation Results

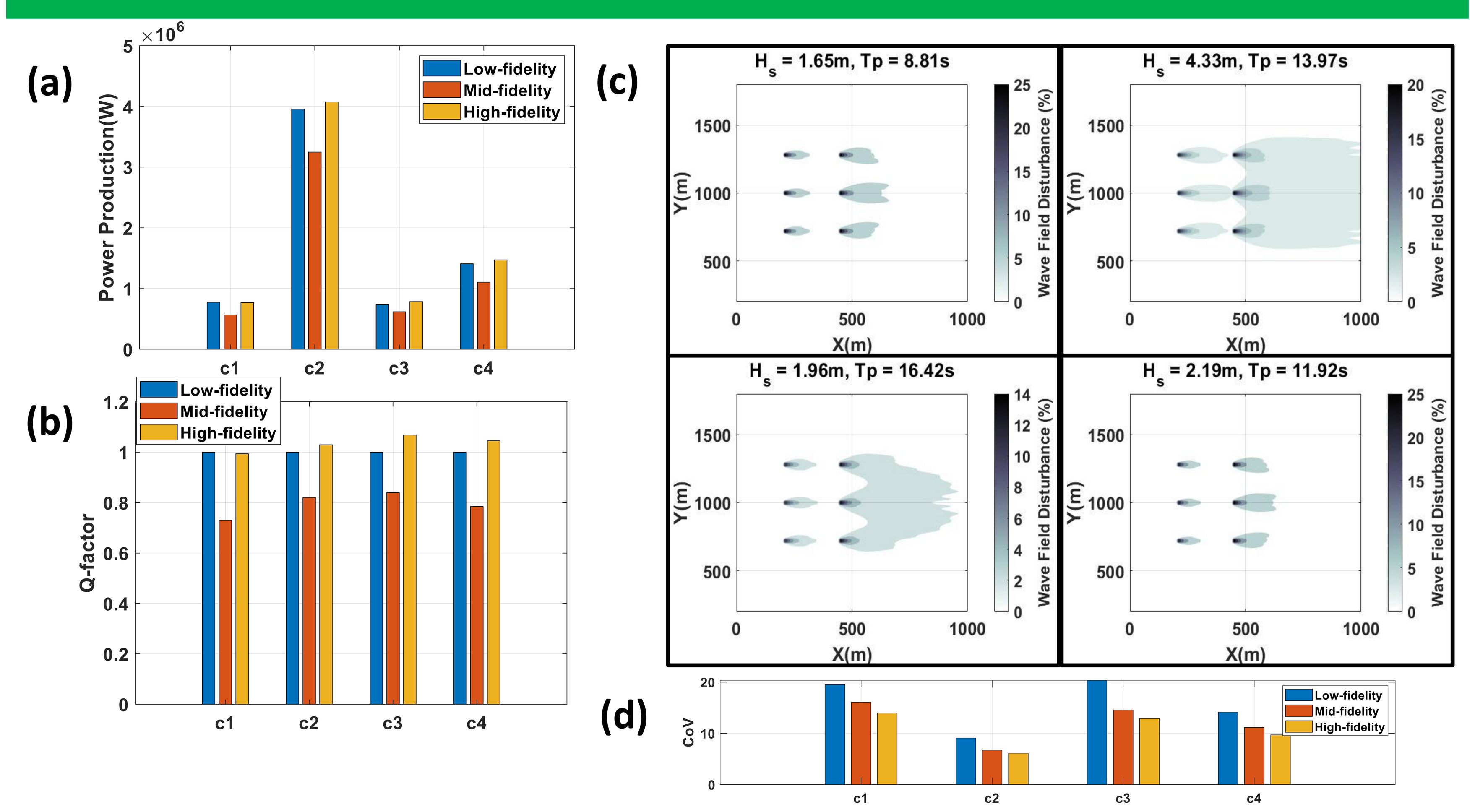

Figure 4: (a) power production of the WECs array predicted by different model-fidelities; (b) Q-factor predicted by different model-fidelities; (c) wave field disturbance due to the presence of WECs (high-fidelity model); (d) power quality predicted by different model-fidelities

- The **high-fidelity model** (in the figures) considers both wave attenuation and refraction (as presented).
- The **mid-fidelity model** (in the figures) only considers wave attenuation but not wave refraction.
- The **low-fidelity model** (in the figures) only considers isolated WECs
- Wave field disturbance: $\delta H_s(\%) = \frac{|H_{s,dis} - H_{s,inc}|}{H_{s,inc}} \times 100$

Conclusion

- The wave field disturbance due to the presence of WECs is significant (up to 25%)
- Wave field disturbance needs to considered in array modeling
- Power quality is significantly improved by placing WECs in an array
- Power production will be underestimated if wave refraction is not considered.
- Need to be updated to 2-way coupling in the future by including radiation coupling