Wave-to-Wire WEC Model

- One main aim of WS7: To enhance an existing wave-to-wire (Matlab/Simulink) model developed in SuperGen Marine 1

- Generic marine energy converter model
- Independent functional components
- “Standardised” variable exchange among blocks
- Can be “cloned” to create WEC farms
Brief Front-End Description & Present Application of Model

- Resource Modelling:
  - PM Spectrum for Irregular Seas: 
    \[ S(\omega) = 0.11 \frac{H_{m0}^2 T_1}{2\pi} \left( \frac{\omega T_1}{2\pi} \right)^{-5} \exp \left( -0.44 \left( \frac{\omega T_1}{2\pi} \right)^{-4} \right) \]
  - Non-Stationarity: 
    \[ H_{m0} = H_{m0}(t) \quad \& \quad T_1 = T_1(t) \]
  - Multidirectional Waves: 
    \[ S(\omega, \theta) = S(\omega) D(\theta) \]

- Time-Domain WEC Model:

- Power Take-Off Model:

- We have used the model to investigate the effects of WEC arrays connected to weak rural electricity networks.
Configuration of Array and Optimal Spacing in Monochromatic Seas

Array Setup

Power Smoothing

Question: What happens in irregular seas?
Aggregate Mechanical Power from the Array (6 WECs, $\alpha = 0^\circ$, various WEC spacings $d$)

(a) $d = 0.25\lambda_{\text{peak}}$

(b) $d = 0.375\lambda_{\text{peak}}$

(c) $d = 0.5\lambda_{\text{peak}}$
Effect of Accumulator Size on Electrical Power Output

<table>
<thead>
<tr>
<th>Accumulator Capacity (m³)</th>
<th>Avg. PweC (kW)</th>
<th>Avg. Pfarm (kW)</th>
<th>Avg. Pfarm/Avg. PweC</th>
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<tr>
<td>0.50</td>
<td>539</td>
<td>489</td>
<td>0.908</td>
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Effect of DFIG Excitation Control on Output Voltage Fluctuations

PF = 0.95 leading

PF = 0.98 leading

UPF

PF = 0.98 lagging

PF = 0.95 lagging
Improvements to the Simulation

- Better model of the multi-directional sea spectrum.
- Non-stationary sea conditions.
- Increased simulation time.
- Varying local load.
- Improved network model.
- Inclusion of hydrodynamic interaction between array members.
Time Domain Modelling of Arrays 1

- Start in the Frequency Domain
- $N$ bodies – $6N$ Degrees of Freedom (dofs):
  
- Each of the $6N$ dofs considered a separate oscillator.
- Complex amplitudes denoted by $^\wedge$, i.e.

\[
x(t) = x_0 \cos(\omega t + \varphi) = \text{Re}\{\hat{x} e^{i\omega t}\}
\]
Time Domain Modelling of Arrays 2

Total hydrodynamic force on oscillator \( i \):

\[
\hat{F}_{t,i} = \hat{F}_{e,i} - \sum_{j=1}^{6N} Z_{ij} \hat{u}_j
\]

or in matrix form

\[
\hat{F}_t = \hat{F}_e - \hat{Z}\hat{u},
\]

where,

- \( \hat{F}_{e,i} \) — excitation force on oscillator \( i \) due to the incident wave and the diffraction effects from all the bodies (\( i.e. \) when they are fixed).
- \( -Z_{ij}\hat{u}_j \) — radiation force on oscillator \( i \) due to oscillation of oscillator \( j \).
- \( \hat{u}_j \) — (complex) velocity (amplitude) of oscillator \( j \).
- \( \hat{Z} \) — radiation-impedance matrix (\( 6N \times 6N \)).

c.f. Electrical impedance:

\[
\hat{V} = Z \hat{I}
\]

\[
Z = i\omega L + R + \frac{1}{i\omega C}
\]
Thank You!

Any Questions?