SuperGen UK Centre for Marine Energy Research
Annual Assembly 2015

Modelling of Marine Energy Converter Arrays

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Wave-to-Wire Modelling of Arrays of WECs - Updates

- Included a vector-controlled induction generator in the model – no longer a fixed speed generator.
- Allows speed/torque control of the generator (more flexibility), independent of the hydraulic power take-off unit.
Wave-to-Wire Modelling of Arrays of WECs - Updates

Optimal generator speed (pu)

Percentage improvement in average power output from optimal resistive control to variable speed generation
Power quality aspect of arrays of WECs

- W2W model of array of 6 WECs with Doubly Fed Induction Generators used to study voltage fluctuations introduced by the array in electricity networks.
- Effects of DFIG inertia on the smoothing in the net power produced analysed.
Optimising Network Design Options for Marine Energy Converter (MEC) Farms

- Techno-economic analysis framework to assess transmission options for MEC farms.
  - Technical feasibility –
    - Supply quality constraints.
    - Optimal sizing of reactive power compensation.
  - Economic factors –
    - Component and installation costs.
    - Costs associated with electrical losses.
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<table>
<thead>
<tr>
<th>Distance from the shore (km)</th>
<th>33 kV</th>
<th>132 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.27</td>
<td>0.44</td>
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<tr>
<td>15</td>
<td>1.77</td>
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<tr>
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Percentage energy lost over a year
Optimising Network Design Options for Marine Energy Converter (MEC) Farms

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### 33 kV

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Relative cost of the transmission network (base case 1MW farm, 10 km from the shore, using a 11kV network)
The PolyWEC Project - Update

- Wave energy converters with Dielectric Elastomer Generators (DEG) PTOs (termed PolyWECs).
- Working principle of Dielectric Elastomer Generators:
First Generation PolyWECs

Existing WEC concepts – replace PTOs with DEGs

PolyBuoy

PolyOWC

PolySurge
Second Generation PolyWECs

Direct interaction between fluid and DEG.

Closed Membrane WEC

Open Membrane WEC

Submerged Pressure Differential WEC
Optimised PolyOWC

Improved:
• Impedance matching (OWC and DEG dynamics);
• OWC collector hydrodynamics;
• Energy harvesting controller.

**DEG:**
- \( R = 125 \text{ mm} \)
- \( \lambda_p = 4 \)
- \( t = 93 \mu\text{m} \)

Max. harv. power: 0.67W (\( H=4.5\text{cm} \) \( f=0.7\text{Hz} \))

Energy density: 109 J/kg (w-t-w efficiency: 20%)

Eq. full-scale sys. power: 270kW (\( H=1.8\text{m} \) \( T=9\text{s} \))

**DEG:**
- VHB elastomer
- CG electrodes
- Harvesting cycle at constant charge with in-parallel external capacitor ([Shian et al., Adv. Mater. 26, 6617-6621, 2014])

**Diagram:**
- Scale: 1/40
- Wires and connections
- Control PC
- Relays Driver
- Parallel capacitor
Non-Optimised Floating PolyOWC

Scale: 1/50

DEG:
- $R = 95$ mm
- $\lambda_p = 3.66$
- $t = 74$ $\mu$m

Max. harv. power: 0.25W ($H=10$cm $f=0.5$Hz)
Energy density: 106J/kg (w-t-w efficiency: 10%)
Eq. full-scale sys. power: 220kW ($H=5$m $T=12.6$s)

DEG:
- VHB elastomer with CG electrodes;
- Pressurized air-chamber;
- Harvesting cycle with parallel capacitor.

[results in the process of publication]
System performed well also in:
• Polychromatic waves;
• Extreme loading conditions.

Next: design and test of a 1/35 scale prototype! study of Poly-OWC arrays!
[results in the process of publication]

Polychromatic sea
$H_s = 10 \text{ cm} \ T_e = 1.82 \text{ s}$
Modelling 2nd Generation PolyWECs

- **Modelling:** Combined hydro-elastic-electrical modelling.
- **Example:** Vertical frame on seabed with Dielectric Elastomer (DE) membrane stretched across it:

  - Above figure shows “panelling” of membrane for numerical modelling (in WAMIT).
  - Time-dependent deformation of membrane obtained by superposition of multiple modes (i.e. multiple degrees of freedom):
Modelling 2nd Generation PolyWECs

- A frequency-domain simulation:

Currently performing time-domain simulations.
Water to Wire Modelling of Tidal Turbine Arrays

Experimental investigation of hydrodynamic and electromechanical interactions between turbines and the electrical network for a three machine array
Water to Wire Modelling of Tidal Turbine Arrays

- Turbine models are 1.2m in diameter and based on a proven design developed during the X-med project.
- The controller for the power take-off system and the electricity network will be simulated using the OPAL-RT OP5600 real time simulator.
- Test to be carried out at FloWave.
Thank You &
Any Questions?