Current needs for currents for Marine Renewable Energies

Globcurrent –March 7th 2012

Yann-Hervé De Roeck - France Energies Marines Project Manager
Marine energies
THE FULL SET OF OFFSHORE, MARINE AND OCEAN ENERGIES

- Fixed offshore wind turbines
- Wave energy converters
- Tidal dams
- Tidal turbines
- Floating offshore wind turbines
- OTEC
- Osmotic energy
- Heat pump & Air conditioning
- Salt
- Temperature

MRE industrial sector has various maturity levels
Challenges and opportunities of the MRE development
AN IMPORTANT CONTRIBUTION TO THE FUTURE ENERGY MIX

Commitments to reduce CO₂ emissions
- European commitment (20/20/20)
- Grenelle de l’environnement (23% EnR, 3% MRE)

A very large energy potential worldwide
3 600 TWh/yr of technical potential by 2030
(France electrical energy generation: 600 TWh/yr)

<table>
<thead>
<tr>
<th>National data</th>
<th>Fixed offshore wind</th>
<th>Floating offshore wind</th>
<th>Tidal</th>
<th>Wave</th>
<th>OTEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020 Objectives (inst’d capacity in GW)</td>
<td>6</td>
<td>1</td>
<td>0,5</td>
<td>0,2</td>
<td>0,2</td>
</tr>
<tr>
<td>Practical resource, TWh/an</td>
<td>50 ?</td>
<td>200 ?</td>
<td>15</td>
<td>40</td>
<td>20 000 ?</td>
</tr>
<tr>
<td>Investment (excl. R&amp;D costs) 2020, md€</td>
<td>10</td>
<td>3</td>
<td>1,5</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: updated Ifremer foresignt study
Surface currents
- Installation/Access for maintenance
  - Local sea-state
  - Travel time optimization
- Storm surge
  - Tidal dam opt.
  - Onshore/nearshore systems

Water column shear currents
- Loads on lines
  - Anchored platforms (pendular, SPAR)
  - OTEC water pipes (Ø 5 to 10m)

Bottom currents
- Piles or foundations of fixed structures
  - Erosion/accretion of sediments
- Vibrations on power cables
  - Ageing/acoustical impact
First estimation for power take-off

\[ W (\text{kW}) = \frac{(0.3 \cdot \rho \cdot S \cdot V^3)}{1000} \]

\( \rho = 1 \text{kg/m}^3 \) (air) ; \( \rho = 1030 \text{ kg/m}^3 \) (sea water)

\( V \) (m/s) fluid speed

\( S \) (m²): surface of the turbine

Source CSER Bretagne 2009
**Initial spin sometimes needed**

**minimal diameters wrt fluid speed**

**DIAMETRE EOLIENNE / HYDROLIENNE (minimum théorique)**

<table>
<thead>
<tr>
<th>kW</th>
<th>RO-Air kg/m³</th>
<th>RO-Eau kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>1</td>
<td>1025</td>
</tr>
</tbody>
</table>

| V - km/h | 36 | 54 | 72 | 90 | 108 |
| V - nœuds | 2 | 4 | 6 | 8 | 10 |
| V - m/s | 1 | 2 | 3 | 4 | 5 | 10 | 15 | 20 | 25 | 30 |
| Surf-Eol - m² | 333 | 988 | 417 | 213 | 123 |
| Surf-Hydr - m² | 3252 | 407 | 120 | 51 | 26 |
| V - m/s | 1 | 2 | 3 | 4 | 5 | 10 | 15 | 20 | 25 | 30 |
| Diam-Eol - m | 65 | 35 | 23 | 16 | 13 |
| Diam-Hydr - m | 64 | 23 | 12 | 8 | 6 |

Source J. Marvaldi
Cinetic energy of tidal currents

France & UK share the largest resource

Predictable
450 TWh/y (world)
10 TWh/y (France)
10 MW/km² max density?

wt sea-state: overseas lagoons

Resource estimation
UP TO DATE TECHNOLOGY

Sites attractifs:
courant > 2 m/s

Vitesse en cm/s

Source M. Paillard
Resource assessment
EXAMPLE AT VARIOUS SCALES
Resource assessment
EXAMPLE AT VARIOUS SCALES

Tidal Energy Tool by ASA on East Coast of USA
Resource assessment
EXAMPLE AT VARIOUS SCALES

A high resolution study by Artelia
High resolution
CURRENTS FROM THE REAL LIFE

Realistic marine conditions:
non-uniform flow induced by
the bathymetry and
unstationary motions induced
by waves and turbulence

Ideal case:
uniform and stationary flow
### Real data

**AT BREHAT SEA-TRIAL TEST-SITE**

<table>
<thead>
<tr>
<th><strong>Location</strong></th>
<th>Bréhat island</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instrument used</strong></td>
<td>AWAC 1MHz</td>
</tr>
<tr>
<td><strong>Ping rate</strong></td>
<td>1Hz</td>
</tr>
<tr>
<td><strong>Burst duration</strong></td>
<td>10mn</td>
</tr>
<tr>
<td><strong>Interval between burst</strong></td>
<td>1hour</td>
</tr>
<tr>
<td><strong>Deployment date</strong></td>
<td>From 25/03/08 to 06/05/08</td>
</tr>
<tr>
<td><strong>Water depth</strong></td>
<td>30.3m (25m-35.5m)</td>
</tr>
<tr>
<td><strong>Depth cell size</strong></td>
<td>1.5m</td>
</tr>
<tr>
<td><strong>Number of cells</strong></td>
<td>18</td>
</tr>
<tr>
<td><strong>First and last cell range</strong></td>
<td>0.9m - 27.9m</td>
</tr>
</tbody>
</table>

**Ifremer data**
Real data
AT BREHAT SEA-TRIAL TEST-SITE

High resolution bathymetry

Gradient of bathymetry

(NTM from EDF data)
Real data
AT BREHAT SEA-TRIAL TEST-SITE

High resolution bathymetry

Gradient of bathymetry

(NTM from EDF data)
Real data
AT BREHAT SEA-TRIAL TEST-SITE

2D model (Telemac)

Neap tide, flow

Spring tide, flow

Neap tide, ebb

Spring tide, ebb
At the selected test site

2D model (Telemac)
Direction roses

Real data
AT BREHAT SEA-TRIAL TEST-SITE
The current direction differs between bottom and top layers but always lower than 10° (except for lowest speeds)

(Guinot, Le Bouluec, 2008)
Shear occurs, especially at the surface layers

(Guinot, Le Bouluec, 2008)
Real data
AT BREHAT SEA-TRIAL TEST-SITE

Ebb

Normal tide

Linear shear occurs

(Guinot, Le Bouluec, 2008)

Flood
Over the linear shear, bottom layer effect at ebb occurs

(Guinot, Le Bouluec, 2008)
Real data
AT BREHAT SEA-TRIAL TEST-SITE

Vertical shear
(Guinot, Le Bouluec, 2008)
Unstationnary motions: influence of the waves
(Guinot, Le Bouluec, 2008)
Real data
AT BREHAT SEA-TRIAL TEST-SITE

Unstationnary motions: horizontal wave-induced velocities ($U_c=0.6m/s$, $H_{1/3}=2.8m$, $T=8s$)
(Guinot, Le Bouluec, 2008)
Hence, many current needs for Marine Renewable Energies...

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