Characterisation of the Agulhas Current as a Resource for Marine Energy Extraction

Renewable Energy Post-Graduate Symposium

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Content

- The Agulhas Current
- Measurements and Assessment Method
- Results
- Technology Readiness
- Capacity Factor
- Conclusion
Ocean Current Energy around SA

Agulhas Current is the Southern Hemisphere’s strongest ocean current

Transport of $-69.7 \text{ Sv} \pm 4.3 \text{ Sv}$ is achieved by the Agulhas Current at $31^\circ \text{S}$

Viability for energy extraction?
the current is situated 20 km from the coastline (at ~200 m bathymetry line) at the surface and 70 km wide
Agulhas Current: Characteristics

- Poleward flowing Under Current
- The continental shelf narrows between Durban and Port Elizabeth
  - also helps stabilize the Agulhas Current in this region and no regular wide meanderings are present.
- Destabilizing Region: The Natal Bight
  - This area has a wider continental shelf and the shelf’s morphology change destabilizes the current, resulting in infrequent formation of Natal Pulses
  - Large cyclic meanders which travel down the coast and can displace the current core by 150-200 km seawards
Some basic findings

<table>
<thead>
<tr>
<th></th>
<th>Location 1 CM</th>
<th>Location 2 EL</th>
<th>Location 3 PE</th>
<th>Location 4 FR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>-32.507, 28.832</td>
<td>-33.150 28.099</td>
<td>-31.196, 30.175</td>
<td>-33.703, 27.298</td>
</tr>
<tr>
<td><strong>Sea bed depth [m]</strong></td>
<td>84.16</td>
<td>84.16</td>
<td>85.00</td>
<td>61.00</td>
</tr>
<tr>
<td><strong>Mean [m/s]</strong></td>
<td><strong>1.48</strong></td>
<td><strong>1.46</strong></td>
<td><strong>1.4</strong></td>
<td><strong>0.95</strong></td>
</tr>
<tr>
<td><strong>Median [m/s]</strong></td>
<td>1.59</td>
<td>1.6</td>
<td>1.54</td>
<td>1.03</td>
</tr>
<tr>
<td><strong>Standard Deviation [m/s]</strong></td>
<td>0.53</td>
<td>0.59</td>
<td>0.61</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>Maximum [m/s]</strong></td>
<td>2.7</td>
<td>2.82</td>
<td>2.83</td>
<td>1.92</td>
</tr>
</tbody>
</table>

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CENTRE FOR RENEWABLE AND SUSTAINABLE ENERGY STUDIES

2015/07/13
How to Analyse the data?

<table>
<thead>
<tr>
<th>Location</th>
<th>Bin Resolution</th>
<th>Distance from Shore</th>
<th>Time Period</th>
<th>Sounding Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-shelf</td>
<td>2 m</td>
<td>14 km</td>
<td>2012/01/24 - 2013/06/30</td>
<td>91 m</td>
</tr>
<tr>
<td>Edge of shelf (off-shore)</td>
<td>6 m</td>
<td>19 km</td>
<td>2012/01/24 - 2013/06/30</td>
<td>255 m</td>
</tr>
</tbody>
</table>

**Parameters of Interest**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Formula/Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity magnitude</td>
<td></td>
</tr>
<tr>
<td>Probability of Exceedance</td>
<td></td>
</tr>
<tr>
<td>Current Direction</td>
<td>Directional Roses</td>
</tr>
<tr>
<td>Percentage Current Reversals</td>
<td>$\sum_{i=1}^{N}</td>
</tr>
<tr>
<td>Power Density</td>
<td>$P_d = \frac{1}{2} \rho \nu_{ins}^3$</td>
</tr>
<tr>
<td>Capacity Factor</td>
<td>$C_f = \frac{\sum_{i=1}^{N} Power \ produced}{\sum_{i=1}^{N} Turbine \ rated \ power}$</td>
</tr>
</tbody>
</table>
Results: Current Magnitude

- Notice the presence of Natal Pulses
- The affects of this phenomenon on the extractable power will be significant
Results: Current Direction

Current Speed in m/s:
- $C_v \geq 3$
- $2.5 \leq C_v < 3$
- $2 \leq C_v < 2.5$
- $1.5 \leq C_v < 2$
- $1 \leq C_v < 1.5$
- $0.5 \leq C_v < 1$
- $0 \leq C_v < 0.5$

Direction Rose: Midshelf Deployment 80m

Direction Rose: Midshelf Deployment 50m

Direction Rose: Midshelf Deployment 30m

Direction Rose: Off Shore Deployment 80m

Direction Rose: Off Shore Deployment 50m

Direction Rose: Off Shore Deployment 30m

Mid-shelf

Off-shore
Results: Percentage Current Reversals

![Graphs showing percentage current reversals for Mid shelf and Off Shore Deployment.]
Results: Power density

- **Mid shelf deployment**
- **Off Shore Deployment**

**Mean Power Density (W/m²)**

- **Standard Deviation of the Power Density (W/m²)**
Technically Extractable Power

- Capacity factor depends on the available technology
- Ocean current technology very immature
- Can transfer lessons learnt and some technology development from the tidal industry
- Challenges? Mooring depth, lower velocity current
Rated speeds
~2 to 2.5 m/s
## Results: Capacity Factor

<table>
<thead>
<tr>
<th>DG-12</th>
<th>DG-14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated: 500 kW</td>
<td>Rated: 850 kW</td>
</tr>
<tr>
<td>Cut-in speed: 0.4 m/s</td>
<td>Cut-in speed: 0.4 m/s</td>
</tr>
<tr>
<td>Rated speed: 1.6 m/s</td>
<td>Rated speed: 1.73 m/s</td>
</tr>
</tbody>
</table>

The price of energy availability coupled with the price per kWh of generated electricity must also be examined when selecting the rated power size of the turbine.
Although the capacity factor of the off-shore site is higher than that of the mid-shelf location, the economics of the longer sea cable and increased mooring challenges must be taken into consideration when deciding on an optimal deployment location.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Minesto 850 kW Deep Green rated speed of 1.73 m/s</th>
<th>Minesto 500 kW Deep Green rated speed of 1.6 m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mid-Shelf Location</td>
<td>Off-Shore Location</td>
</tr>
<tr>
<td>30 m</td>
<td>48.5%</td>
<td>71.0%</td>
</tr>
<tr>
<td>50 m</td>
<td>28.6%</td>
<td>65.1%</td>
</tr>
</tbody>
</table>

Other Renewable Energy Capacity Factors:
- Tidal: 20-30%
- Wave: 15-22%
- Wind: 30-45%
Other contributing factors

- Geotechnical and Mooring Concerns
- Shipping Routes
- Commercial fishing activities
- Existing infrastructure that can consume the generated energy
- Environmental concerns
Conclusion

• The found estimated capacity factors compare well to other renewable energy resources

• Although promising capacity factors can be achieved with the Minesto Deep Green turbines, there is great uncertainty surrounding the survivability and mooring challenges of this technology.
Further Research

• It is recommended that further technology development be carried out with specific focus on suitable technology for ocean current applications.
• It is recommended that a detailed economic assessment be carried out to determine whether the increased mooring challenges and longer length of undersea cabling is justified by the increased power output at the off-shore site.

*It has been shown that this current holds potential to make a significant contribution to the South African electricity grid.*
Questions?
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