Introduction to Marine Renewable Energy

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• Introduction: Richard Karsten

• First Part: Understanding the Ocean
  • Turbulence measurements: Justine McMillan
  • Wake characterization: Joel Culina

• Discussion

• Second Part: Designing MKE Devices
  • Turbine technologies: Guy Dumas
  • Flapping dynamics: Rajeev Jaiman

• Third Part: Wave Energy
  • Wave energy modelling: Anthony Truelove

• Discussion
Introduction to Marine Renewable Energy

Outline
• What is Marine Renewable Energy
• What is the resource?
• Some challenges and some mathematics
• Conclusions: Some Headlines

MCT in Strangford Lough
What is Marine Renewable Energy

- Energy from currents ... Marine Kinetic Energy
  - Tidal Currents

Minas Passage, Bay of Fundy

OpenHydro Deployment, 2017
What is Marine Renewable Energy

- Energy from currents ... Marine Kinetic Energy
  - Tidal Currents

Mavi Innovations Mi1 floating turbine deployed at Blind Channel, British Columbia.
https://marinerenewables.ca/
What is Marine Renewable Energy

• Energy from currents ... Marine Kinetic Energy
  • Tidal Currents
  • Rivers Currents

Ocean Renewable Power Company
Alaska

New Energy Corp.
What is Marine Renewable Energy

• Energy from currents ... Marine Kinetic Energy
  • Tidal Currents
  • Rivers Currents
  • Ocean Currents

Okinawa Institute of Science and Technology Graduate University
What is Marine Renewable Energy

• Energy from Waves
What is Marine Renewable Energy

Others, that are not being discussed ...

• Tidal Barrages
• Ocean Thermal Energy Conversion (OTEC)
• Sea Water Air Conditioning (SWAC) projects
• Salinity Gradient

Other water energy:
• Offshore Wind
• Hydroelectricity
• Run of River
A fully renewable world

Globe and Mail Report on Business

Tidal energy:
490,000 turbines
1% of Total
(10-20 turbines)

Wave Energy:
720,000 devices
1% of Total
(30-50 devices)
What is the resource? Tidal

High Potential Areas for Tidal Resources

Canada: British Columbia, the Bay of Fundy and the St. Lawrence seaway are some of the world’s best tidal current resources and are close to significant electricity demand.

UK: ~18 TWh/yr of technically extractable tidal current resource. 40% of it is concentrated in the far north of Scotland (Pentland Firth and Orkney Islands).

India: The Gulf of Kutch and the Gulf of Kambhat in the State of Gujarat both have significant tidal power resource >250MW.

Korea: In the south, around Mokpo, the tidal currents are amongst the fastest in the world. According to KORDI, the Korean resource for tidal current power is 500MW.

Japan: Excellent resources between the islands.

China: has enormous tidal current resources as well as river resources. Best large tidal sites found in Shanghai and Zhejiang province region.

Chile: At least 500MW potentially available.

France: Strong tides around the Channel Islands.

Australia: King Sound in the North West has some of the highest tides in the world (~10m).
What is the resource? Wave
Marine Renewable Energy: Challenges

- Difficult Ocean Environment
- Intermittent Power Production
- Environmental Impacts
- Device Design: capacity vs durability vs cost
- Financial Viability
Calculating the resource

• Mathematical Models: Garrett and Cummins (2005)

Simply physics and calculus => \[ P_{max} = \frac{1}{4} \rho g a Q \]
(Direct analogy of Maximum Power Law of electric circuits)
Calculating the resource


Conservation Laws => Algebraic Equations
(extension of Betz Law, Linear Momentum Actuator Disc Theory)
Calculating the resource


Combine models together
Calculating the resource

- Numerical Models: Simulate the tidal currents

Mathematically: Making appropriate approximations in modelling both the ocean and the extraction of energy
Calculating the resource

- Numerical Models: Simulate Extracting Energy

Mathematically: Making appropriate approximations in modelling both the ocean and the extraction of energy
Calculating the resource

- Mathematical Models: Models and theory agree

![Graph showing extracted power vs. impact of percent reduction in flow]
Optimization: Turbine Farm Design

Optimize the location of turbines in a farm: MeyGen

Map

Domain and farm area

Simon Funke, 2014
Optimization: Turbine Farm Design

Optimize the location of turbines in a farm

Model inputs
Initial layout of turbines

Evaluation step
Solve shallow water eqs
Evaluate farm performance

Optimisation step
Improve turbine design

Sensitivity step
Solve adjoint shallow water eqs
Evaluate sensitivity

Simon Funke, 2014
Optimization: Turbine Farm Design

Optimize the location of turbines in a farm

Simon Funke, 2014
Observing Marine Life

Haley Viehman, Acadia / FORCE

Gemini Imaging Sonar
Observing Marine Life

Haley Viehman, Acadia / FORCE

Volume Backscatter with Depth and Time

Mathematics: Signal processing, Machine Learning
Modelling Marine Life Interactions

Fish around OpenHydro test turbine
Modelling Marine Life Interactions

• Individual Behaviour Models (IBMs)

A minimal model of predator–swarm interactions
Yuxin Chen and Theodore Kolokolnikov

Figure 4. (a) The empty region surrounding the shepherd from figure 1a is shown with a curve. (b) Similar region observed in simulations of (1.1) and (1.2). (Online version in colour.)
Modelling Marine Life Interactions

Simulating Harbour Porpoise Habitat Use in a 3D Tidal Environment

Thomas Lake, Ian Masters, T. Nick Croft
Swansea University

(i) Wider start distribution, responding to food, depth and noise
Conclusions: Challenges

• Headlines from last year:

New attempt to harness Bay of Fundy tidal power

Cape Sharp Tidal installing new turbine in Minas Passage

CBC News - Posted: Jul 20, 2018 2:39 PM AT | Last Updated: July 20, 2018
Conclusions: Challenges

• Headlines from last year:

Naval Energies exits tidal energy, OpenHydro seeks liquidation

July 27 (Renewables Now) - Just a day after successfully deploying an in-stream tidal turbine in Canadian waters, Naval Energies has decided to cease all investments in tidal turbines as it has determined that the market for this technology is closing.

The French marine renewables specialist announced its decision today, saying that it plans to focus on
Conclusions: progress

Headlines from last week:

Atlantis and GE to Build World’s Largest Tidal Turbine

https://marineenergy.biz/2019/05/19/highlights-of-the-week-19/
Conclusions: progress

Headlines from last week:

Nova Gets New €5 Mln Tidal Energy Project

https://marineenergy.biz/2019/05/19/highlights-of-the-week-19/
Conclusions: progress

Headlines from last week:

OPT Achieves Power Generation Milestone in Adriatic Sea

https://marineenergy.biz/2019/05/19/highlights-of-the-week-19/