MARIN experience with offshore energy
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MARIN’S ACTIVITIES
OUTLINE

• **Introduction**
  - Wave energy potential
  - History
  - Challenges

• **WEC types**

• **WEC design**

• **Questions? Discussion**
• **World wave energy potential:**

- Wave energy generally considered most concentrated and least variable form of renewable energy

- World Energy Council estimates that approximately 2 terawatts can be produced from wave power.

- Wave power per meter wave crest \([W/m]\):

  \[
  P = \text{energy density} \times \text{group velocity} \\
  = \begin{cases} 
  \frac{\rho g H^2}{8} \times \sqrt{\frac{T}{\lambda}} & \text{for shallow water} \\
  \frac{\rho g H^2}{8} \times \sqrt{\frac{T}{\lambda}} / 2 & \text{for deep water}
  \end{cases}
  \]
World wave energy potential: 2000 GW
• **Challenges of wave energy conversion:**

  ✓ Wear and tear
  ✓ Mooring, installation and maintenance
  ✓ Survival in extreme conditions
  ✓ Irregularity and omnidirectionallity of waves
  ✓ Performance in combination with current and wind
  ✓ Complex transformation of energy (PTO):
    • Design
    • Robustness
    • Control

*The WEC industry is a relatively new sector (which has not matured yet). There are lots of ideas and concepts, but very few operational systems.*
Unlike the case in the wind turbine industry, there are as many types of WECs as there are ideas:

- OPT PowerBuoy
- WaveDragon
- Oyster
- Pelamis
- DanWEC
- Mighty Whale
- Pico
• Oscillating Water Column (OWC):

RenewABLE concept (floating)
• **Floating oscillator (in heave): Wavebob**

- 2 body buoy
- Energy extracted from relative motions between 2 bodies
- Spread moored
- Omnidirectional

1/4th scale model, Galway Bay (Ireland), 2008.
• **Attenuator: Pelamis**

- Multibody with hydraulic joints
- Energy extracted from relative motions between 2 bodies
- Weathervaning

3-unit farm, Portugal, 2008.

**Hydraulic PTO**
Overtopping device: Wave dragon

- Large collector to focus wave energy
- Reservoir above MWL
- Water turbine acts as PTO

1/4th scale model, Denmark, 2005.
• Use existing offshore knowledge and tools to assess design of wave energy converter:

✓ Model tests
  ✓ Influence of irregular (short scrested) waves
  ✓ Influence of wind and current
  ✓ (Non-linear) PTO-floater-mooring interactions
  ✓ Array testing
  ✓ Survivability

✓ Numerical simulations
  ✓ Optimization of floater geometry
  ✓ Influence of different PTO settings

✓ Analysis of PTO control strategies
Sensors and PTO

- Motion capture LEDs
- Submergence level: resistance gauges
- Linear motor PTO
- 6DOF accelerometer
- 6DOF force frame
Numerical simulation example:

Renewable concept

✓ Floating OWC type WEC
✓ Parameter study in frequency domain:

GOAL: maximize the vessel motions
• Numerical simulation example (Renewable concept):

**Displaced water per wave cycle at moonpool fore (wave dir. = 180 deg)***

- with 20m² moonpools
- with 30m² moonpools
- with 40m² moonpools
- with 50m² moonpools
• **Numerical simulation example (Renewable concept):**

Relative water motion due to pitch..
• Numerical simulation example (Renewable concept):

Relative water motion at moonpool natural frequency..
MARIN’S ACTIVITIES IN OFFSHORE WIND

- Development
- Fabrication
- Transportation
- Installation
- Production
- Removal
- Maintenance & Support
**MARIN’S ACTIVITIES IN OFFSHORE WIND**

**Challenging phases where MARIN helps:**

- **Maintenance:**
  - Offshore maintenance JIP
  - Logistics simulation tool

- **Installation:**
  - Wind Jack JIP
  - Impact loads on jack-up legs

- **Operation:**
  - WiFi JIP
  - Impact loads on fixed wind turbines

**Alternative to fixed offshore turbines:**

- Floating wind turbines JIP
Advantages:
- Water depth > 50m
- Higher wind speed
- Increase size to >10MW
- Large repair in the harbour

Disadvantages:
- No proven technology
- A large no. of designs in the market

Energy Technologies Institute (ETI) 2009

source: Carbon Trust Floating offshore wind market and technology review June 2015
Floating wind is interesting from water depths >50m

source: Carbon Trust Floating offshore wind market and technology review June 2015
>14 commercial floating wind turbine projects:

- Sway floating wind
- Cantabria floating wind
- DeepCwind Maine floating wind (2011-2013)
- EU project Deepwind (2011)
- GustoMSC-ECN-MARIN floating wind tool MIP project
- Gicon floating wind turbine
- OC4 model tests (2013)
- Hexicon 2015
- .......
The DeepWind vertical-axis wind turbine in front of the high quality wind generator set-up
The DeepWind vertical-axis wind turbine in front of the high quality wind generator set-up
DIFFERENT TYPE OF FLOATING WIND TURBINES

Spar:
Ballast Stabilized
Spar buoy with catenary mooring, drag-embedded anchors

Semi:
Buoyancy Stabilized
Barge with catenary mooring lines

TLP:
Mooring Line Stabilized
Tension leg platform with suction pile anchors

Turbine with Spar floater
Turbine with Semi floater
Turbine with TLP floater
DIFFERENT TYPE OF FLOATING WIND TURBINES

- **Ballast Stabilized**: Spar buoy with catenary mooring, drag-embedded anchors
- **Buoyancy Stabilized**: Barge with catenary mooring lines
- **Mooring Line Stabilized**: Tension leg platform with suction pile anchors
CONCEPTS UNDERDEVELOPMENT

Figure 2.5.1. Typologies under development

- Semi-sub, 14
- TLP, 7
- Spar, 6
- Multi-turbine platform, 3
- Hybrid wind/wave, 3

source: Carbon Trust Floating offshore wind market and technology review June 2015
FLOATING WIND TURBINE MODEL TESTS

- [http://www.marin.nl/web/file?uuid=95681c77-ff2f-4f79-91bc-b31467d56a5f&owner=686da46b-6ba6-48da-ad3e-633be762da3e](http://www.marin.nl/web/file?uuid=95681c77-ff2f-4f79-91bc-b31467d56a5f&owner=686da46b-6ba6-48da-ad3e-633be762da3e)
COST BREAK DOWN

source: Carbon Trust Floating offshore wind market and technology review June 2015
• Floating wind turbines with multiple wind turbines:
QUESTIONS?