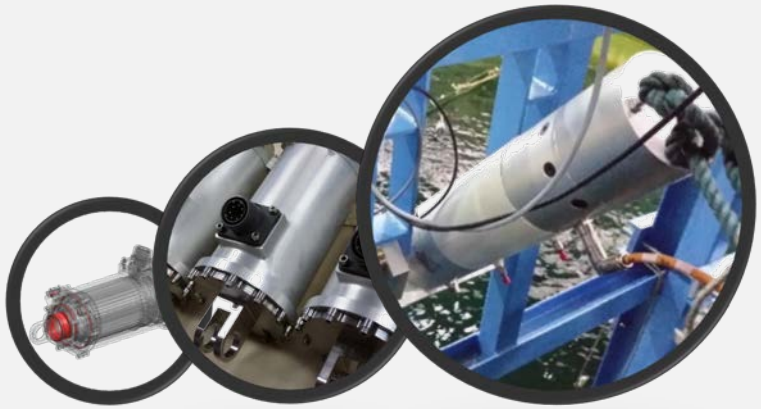
2017 OCEAN ENERGY EUROPE
25-26 October, Nantes, France

Wave Power Take Off: Have we cracked it?

Ballscrew Electro-Mechanical Generators

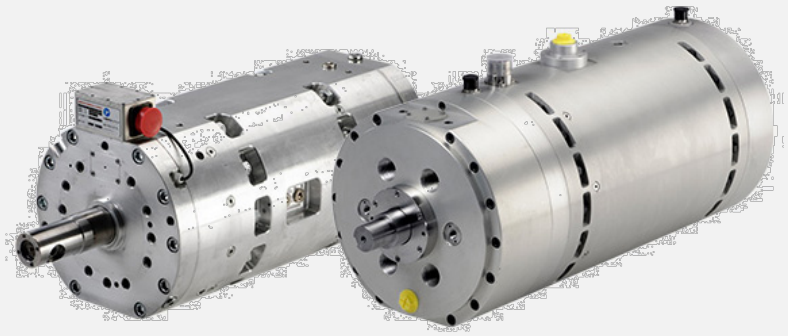
Luca Castellini - R&D Manager for Energy Applications UMBRA GROUP



Outline

Content of this presentation

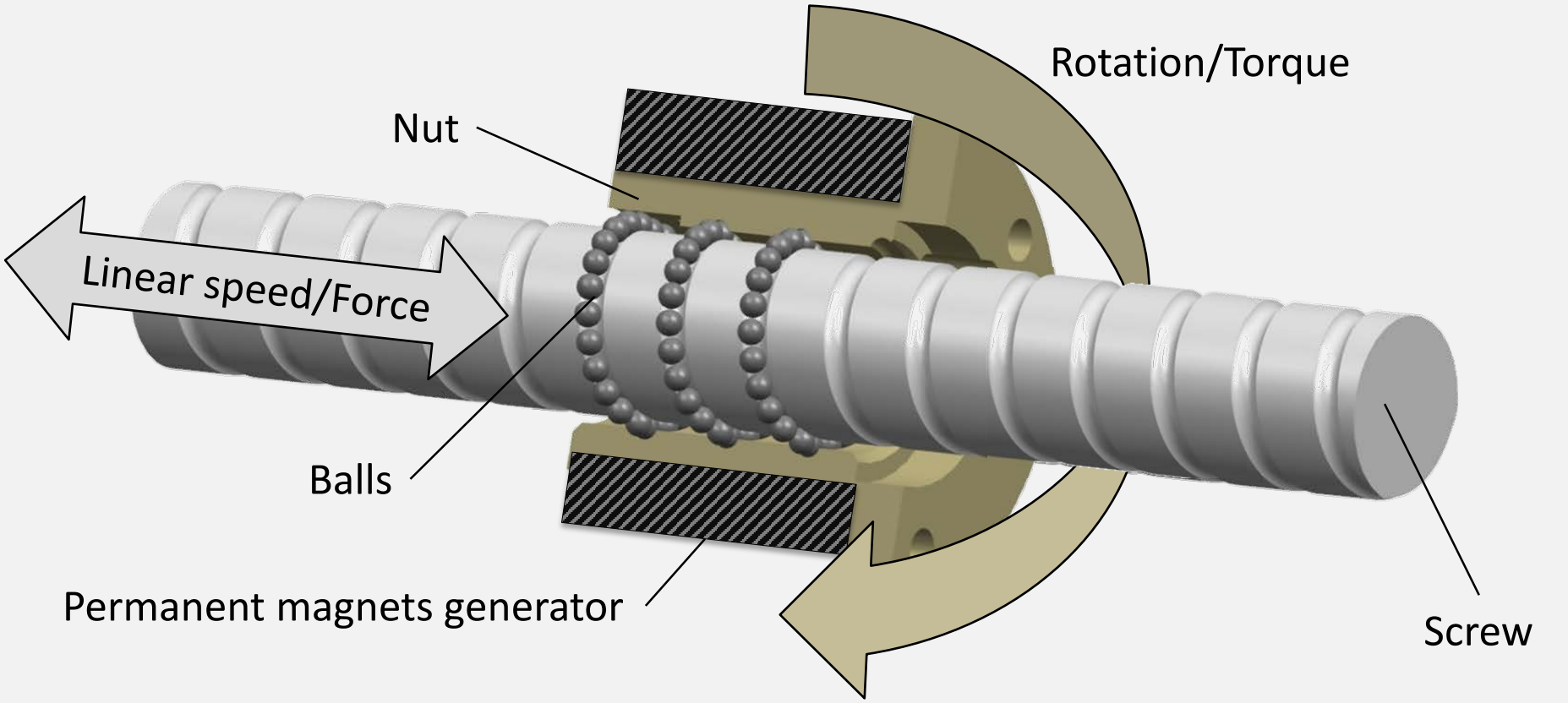
- The Electro-Mechanical Generator (EMG)
- Experimental investigations
- Considerations and Conclusions



The Electro-Mechanical Generator (EMG)

The Electro-Mechanical Generator (EMG)

The concept



Mechanical power (linear)
Linear speed, v;
linear force, F

→ **Recirculating ballscrew** →

Mechanical power (rotational)
Angular speed, ω;
torque, T

→ **Permanent magnets generator** →

Electrical power
Three-phase;
120 deg. shift

UMBRAGROUP

2017 OCEAN ENERGY EUROPE

The Electro-Mechanical Generator (EMG)

Advantages compared to state-of-the-art PTOs

Linear motion

Three-phase electric power

Hydraulic systems

- No intermediate ***power conversion step*** (hydraulic)
- Reduced ***number of components*** (no plumbing, accumulators, pumps etc.)
- No use of pressurized fluids

Linear electrical systems

- Ferro-magnetic materials ***active*** at all time (cheaper for long-strokes)
- High ***induction rate*** at low linear speed (due to ballscrew conversion)

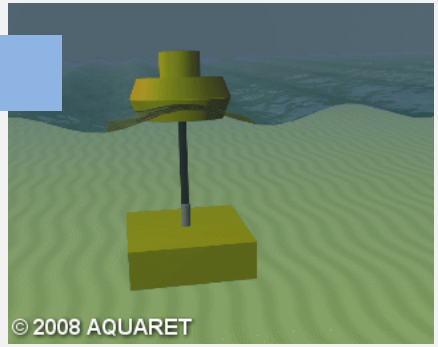
Geared mechanical

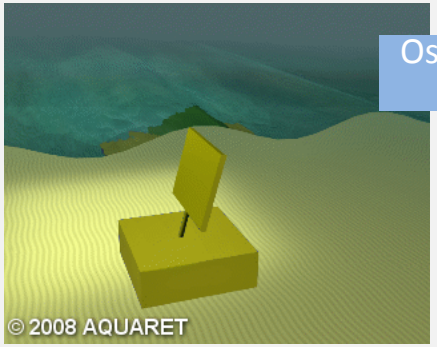
- Higher ***efficiency*** due to ***rolling friction only***
- Higher ***reliability*** due to ***rolling friction only***

The Electro-Mechanical Generator (EMG)

Applicability in wave energy

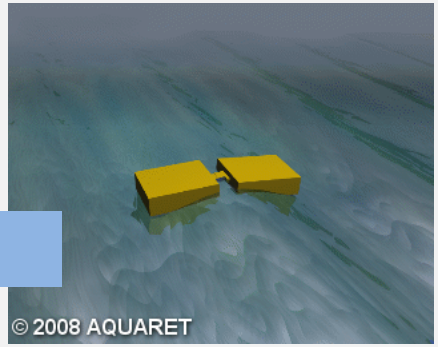
Point absorber

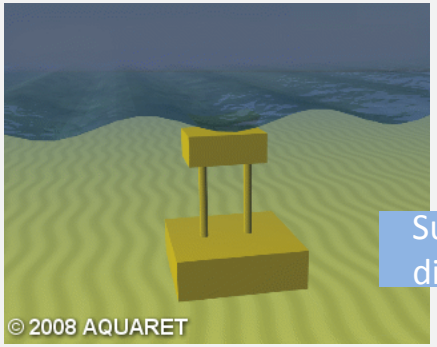




Oscillating wave surge concepts

Attenuator





Submerged pressure differential concepts

The Electro-Mechanical Generator (EMG)

Development of a 2-5-10-20-60-100 kW units

Parameter	Units	2 kw	5 kW	10 kW	20 kW	60 kW	100 kW	250 kW
Application	-	-	Water proof	-	-	Water proof	Water proof	Under DEV.
Length pin-to-pin retracted	mm	410	410	500	850	2200	2200	Under DEV.
Useful Stroke	mm	220	220	135	380	1200	1000	Under DEV.
Peak Force	kN	15	25	180	35	120	150	Under DEV.

Experimental investigations

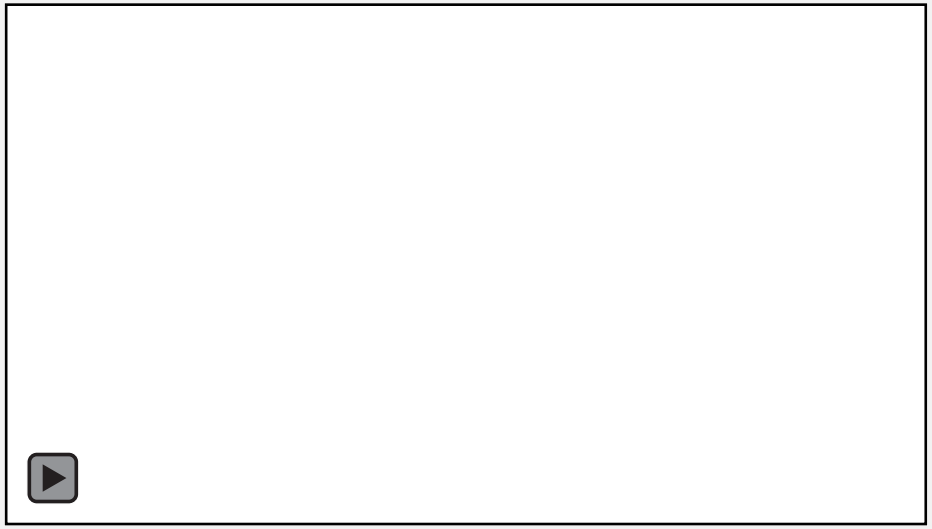
Experimental investigations

Different test setups at Umbra Cuscinetti S.p.A. facilities (Extended and Performance tests)

- Full electric and HWiL benches using **Electro-Mechanical Actuator (EMA)**
- **Electrical load** provided by a **resistive bench or regerative inverters**
- Load cell, axial position, voltage and current transducers
- Different linear speed inputs: **constant**, **sinusoidal** and **irregular**

Dry rig test

(up to 3m/s and 250KN)



Pressurized tank test

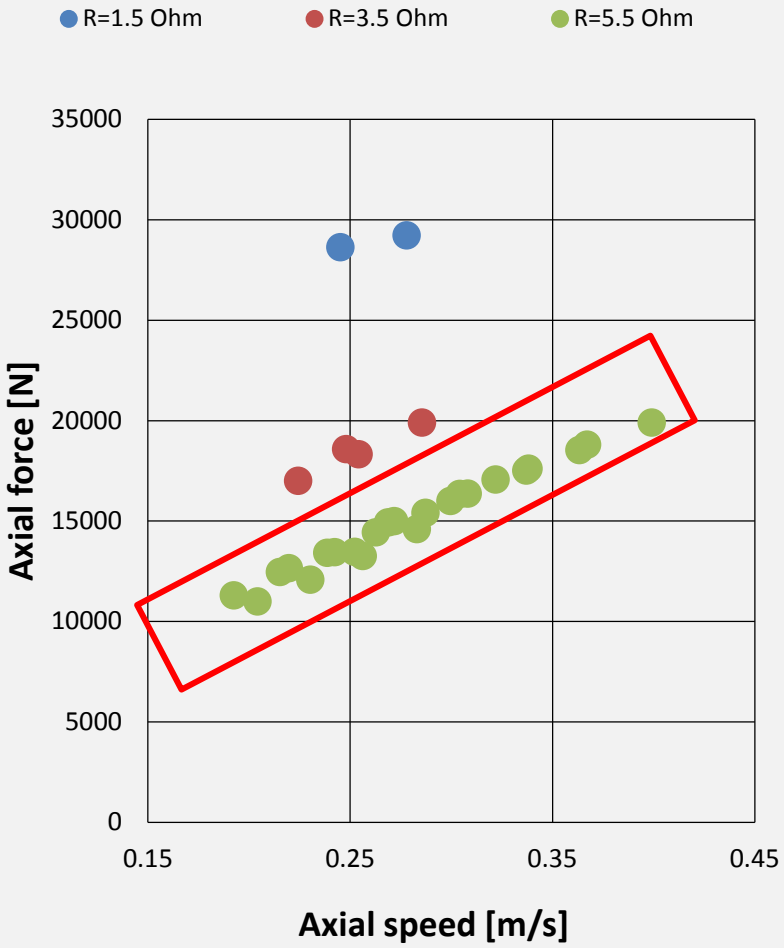
(up to 40m depth working condition)

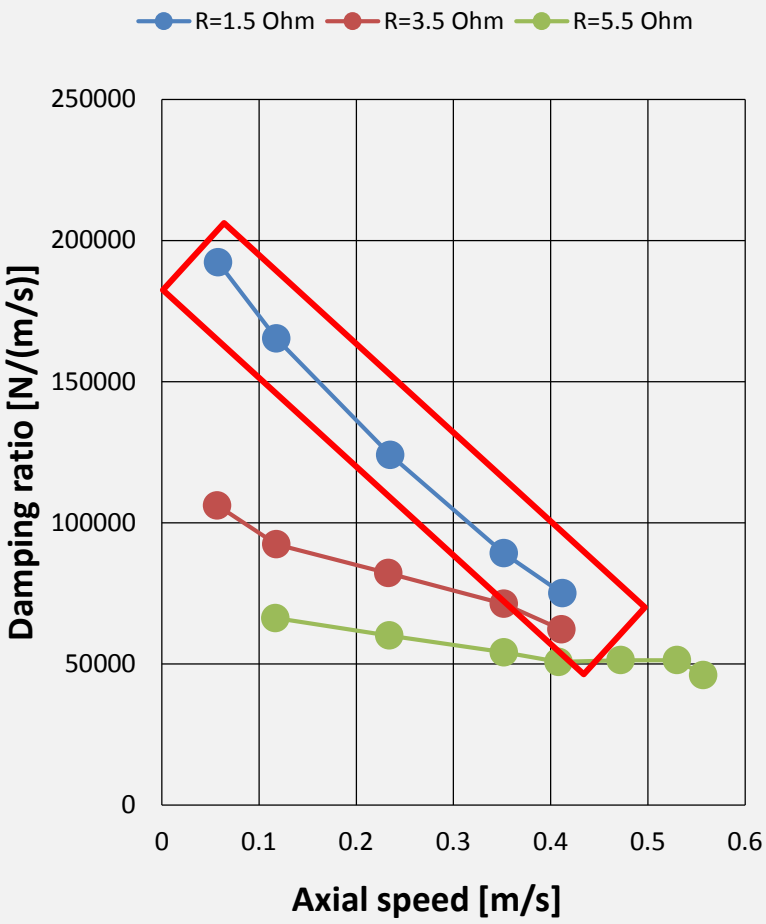
Experimental investigations

Wet tests video in regular waves

Experimental investigations

Dry test results – EMG characterization

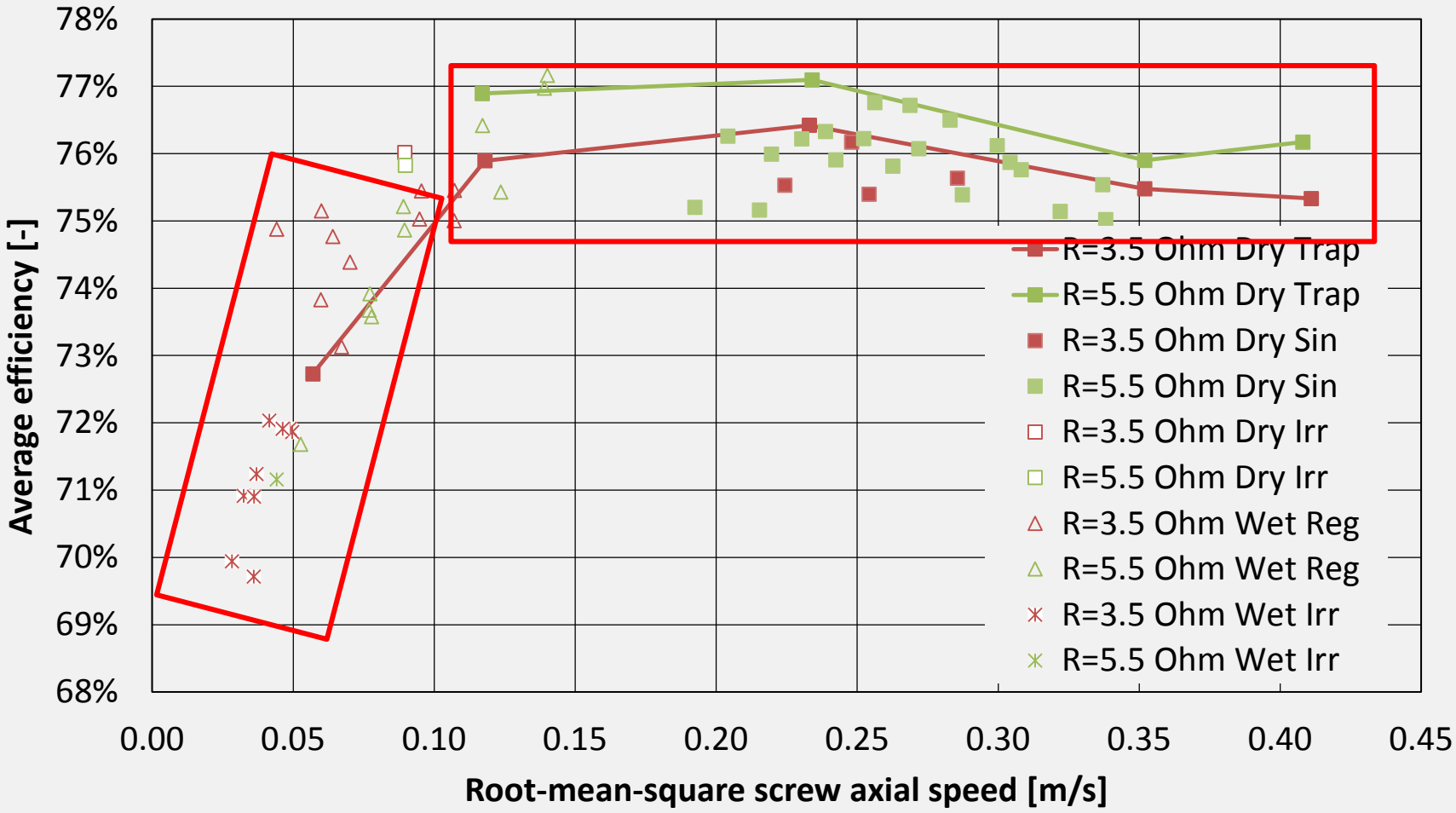




Damping force, damping coefficient variable with load and speed

Experimental investigations

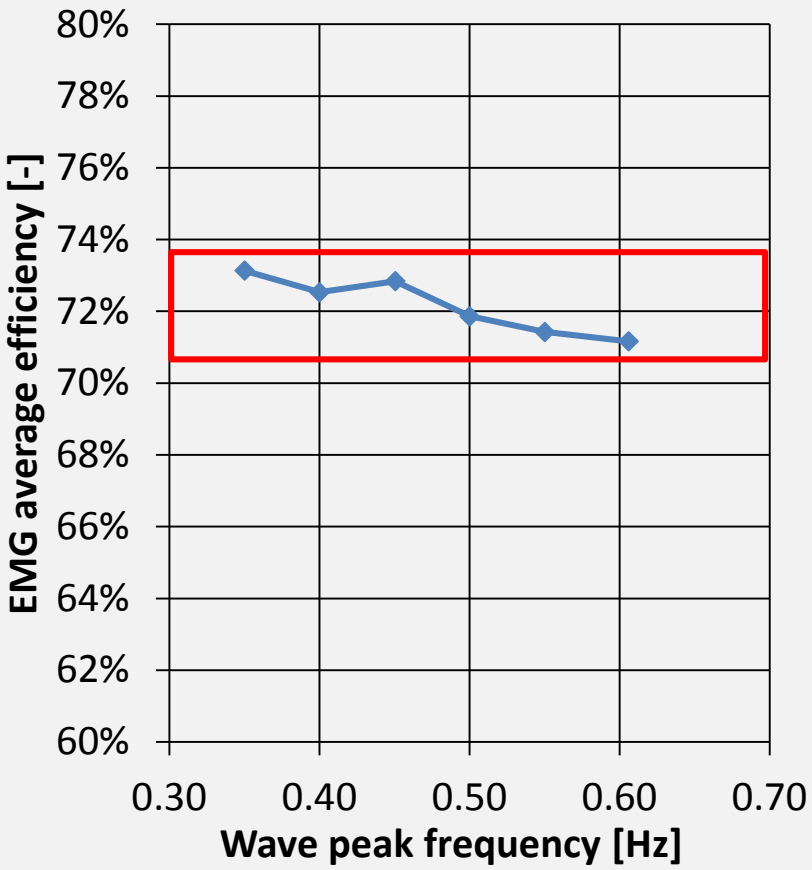
Comparison dry-wet tests: EMG average efficiency as function of axial speed



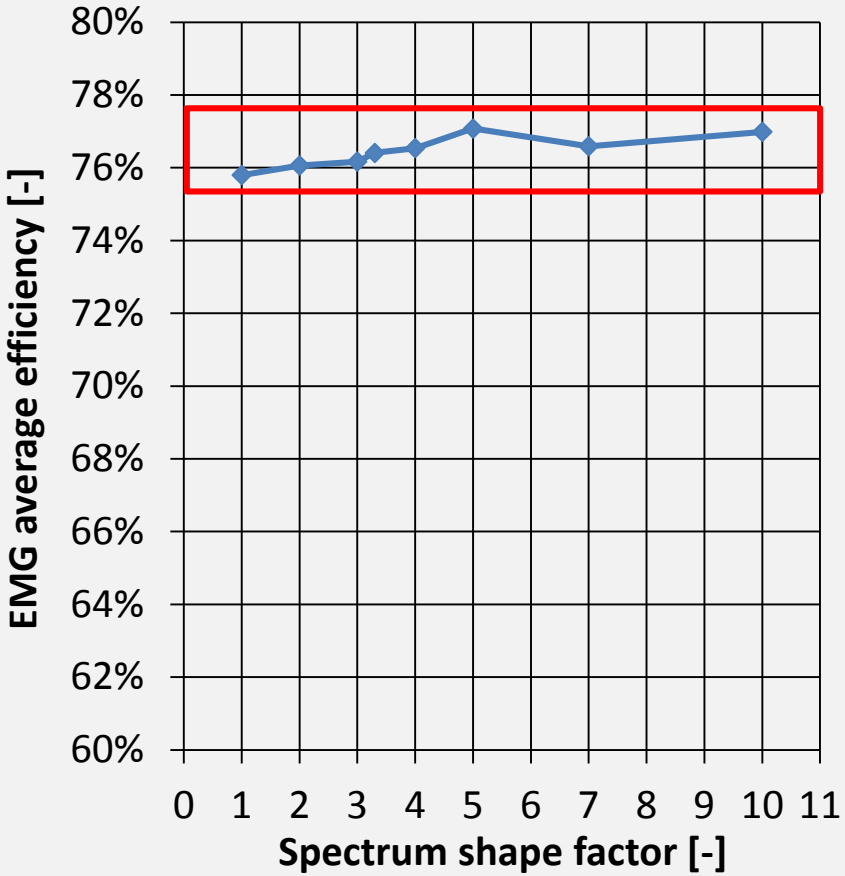
Constant effiency, no dependency on input speed profile

Experimental investigations

Wet test results – EMG average efficiency in irregular waves



(Hs = 0.25 m; R = 2.5 Ohm)



(Hs = 0.20 m; R = 4.5 Ohm; fp = 0.35 Hz)

No dependency on wave period and spectrum shape

Considerations and Conclusions

Considerations

Comparison with others R.E. Where are waves?

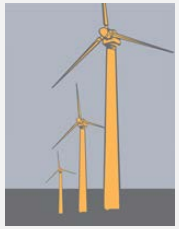
700 BC
Nimrud Lens used as a magnifying glass, or as a burning-glass to start fires by concentrating sunlight

1884
The first solar cell, consisting of a layer of selenium covered with a thin film of gold, was experimented by Charles Fritts, but it had a very poor efficiency (1%)

1980s
World's 1st commercial concentrated solar power plants developed

2015
253 TWh Solar Electricity generated

2000s
15 million U.S. homes powerd by wind energy



July 1887
The first wind turbine used for the production of electricity was built in Scotland *

1900s
World's 1st offshore wind farm began operations

2,000 BC
According to historical data, windmills were used to pump water in China

1600 BC
Using of wind power for irrigation in Babylonia

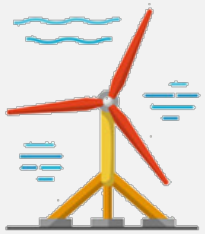
100 AD
Using a wind-driven wheel to power a machine in Egypt

***the invention never really caught on as the technology was not considered to be economically viable. Now wind power is economically competing with nuclear**

Considerations

Comparison with others R.E. Where are waves?

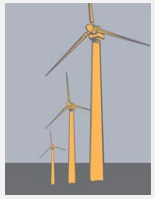
700 BC
Nimrud Lens used as a magnifying glass, or as a burning-glass to start fires by concentrating sunlight



1607
A mill powered partially by tidal energy was built in Nova Scotia

1984
North America's first tidal generating station was built in Nova Scotia producing 20 MW

2009
North America's first commercial-scale in-stream tidal turbine deployed



2,000 BC
According to historical data, windmills were used in China

1910
First oscillating water column was built by Bochaux-Praceique to power his house

1799
First patent of a device designed to use ocean waves to generate power

2004
Wave power was delivered to an electrical grid for the first time

Considerations

Challenges

… to be fixed:

Challenge #1 – WEC concepts are not few as well as PTO solutions:

- need time to have a natural selection
- Some WECs need to demonstrate survival capability

Challenge #2 – Find an effective solution for converting AC into DC with a good power continuity:

- local storage
- transformation in other form (i.e. H_2)

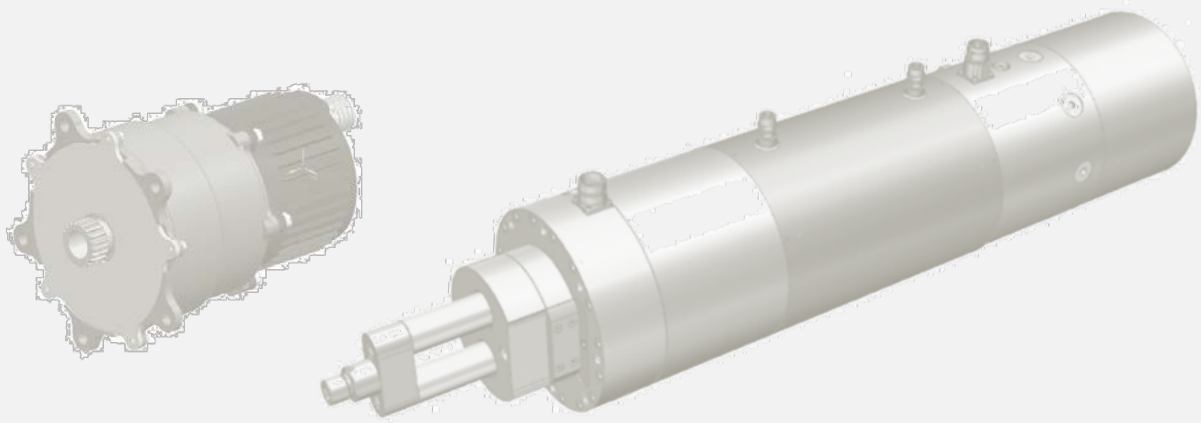
Challenge #3 – no established standards are available in a mature stage:

- IEC TC 114

Conclusions

The Electro-Mechanical Generator (EMG)

- Electro-Mechanical Generator (**EMG**): **linear motion into electricity**
  - Integration of recirculating **ballscrew** and **permanent magnet generator**
- **Proven performance** under various load conditions
  - Efficiency between 70% and 80%
- Design and development of EMG **from 2 kW up to 250 kW**
- **Ongoing customized development FOR/WITH WEC developers:**
  - Linear PTO
  - Rotative PTO



THANK YOU FOR THE ATTENTION

LUCA CASTELLINI
R&D Manager Energy Application
lcastellini@umbragroup.com