EDRIVE: Developing an all-electric power take off for Wave Energy Converters

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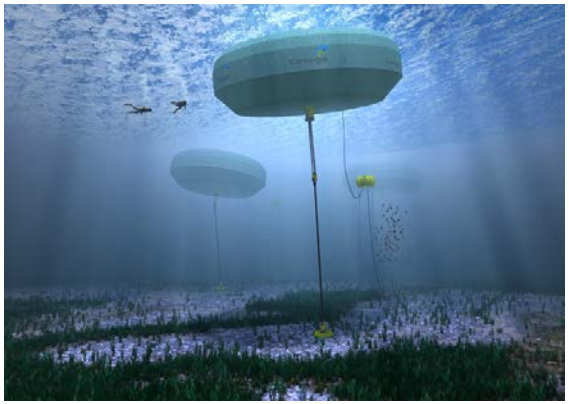
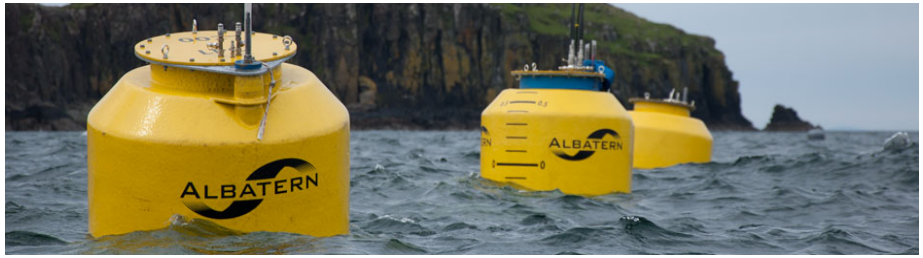
- Team
- Aims
- Work Packages (3 / 7)
- Summary



Carnegie CETO 6
http://carnegiewave.com/projects/ceto-6/



Albatern WaveNet
http://albatern.co.uk/wavenet/wavenet/

Key people

PI	Nick Baker	PI	Markus Mueller
RA	Steve McDonald	RA	Richard Crozier
PhD	M. Raihan +	PhD	B. McGilton
	A. Almoraya		

Associates

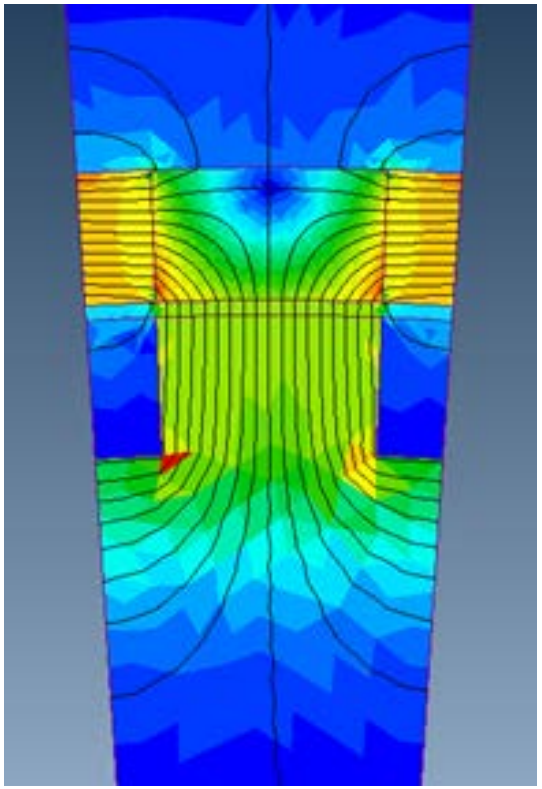
Dr Aristides Kiprakis
Henry Jeffrey
(Edinburgh)

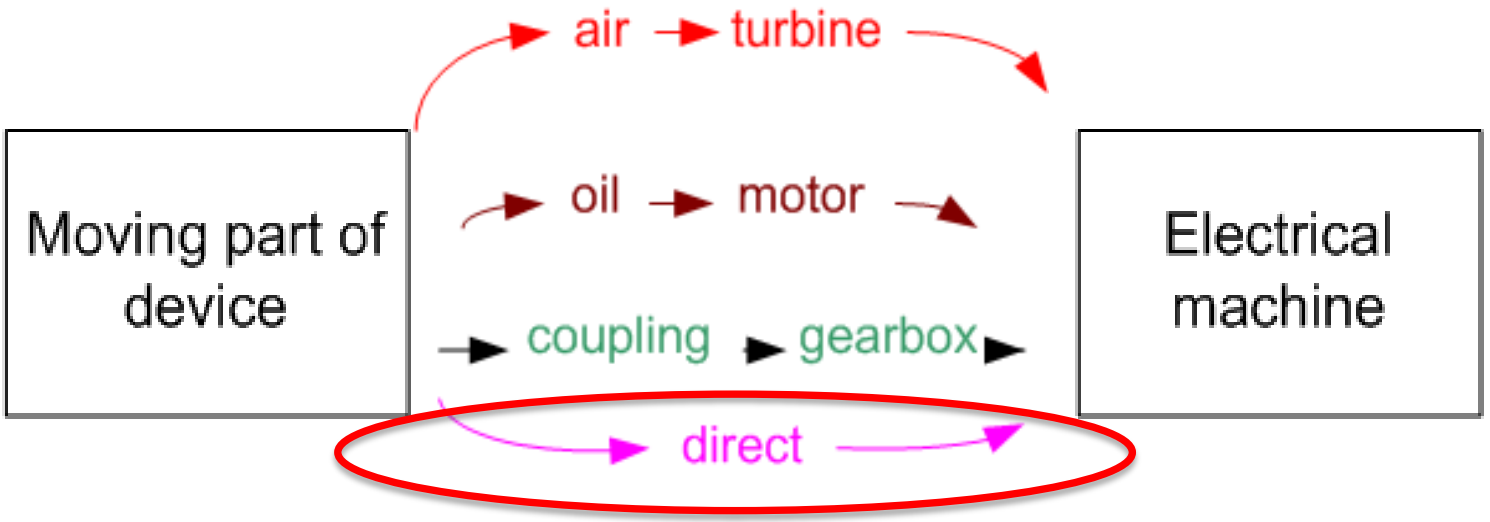
Prof Volker Pickert
(Newcastle)

- “tackle a fundamental weakness of Wave Energy Converters, namely the electro-mechanical Power Take Off (PTO)”
- Improving the PTO chain, from the generator through to the grid interface to create an all-electric solution.
- Addressing reliability and maintainability along the way.

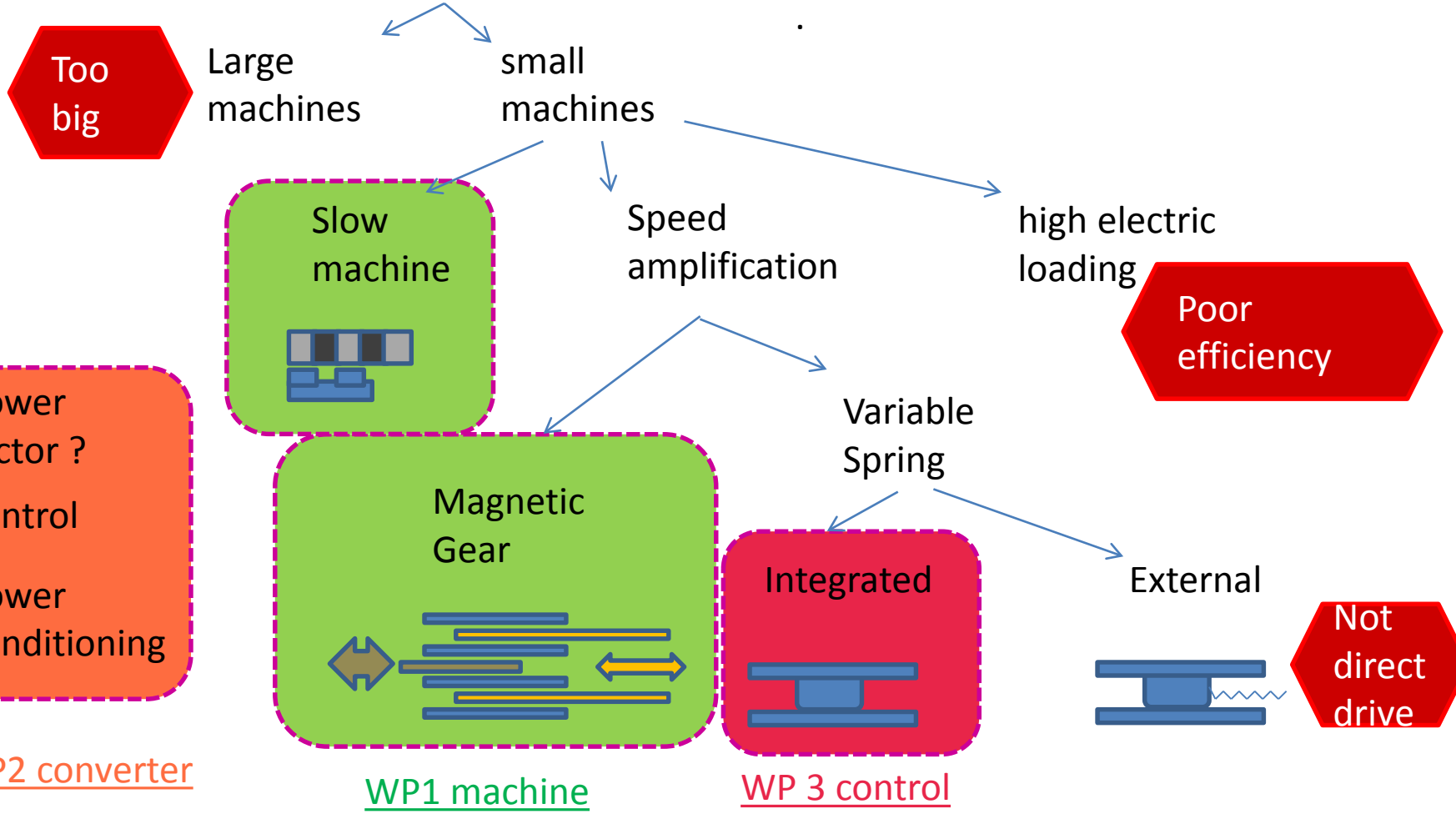
Electrical Conversion

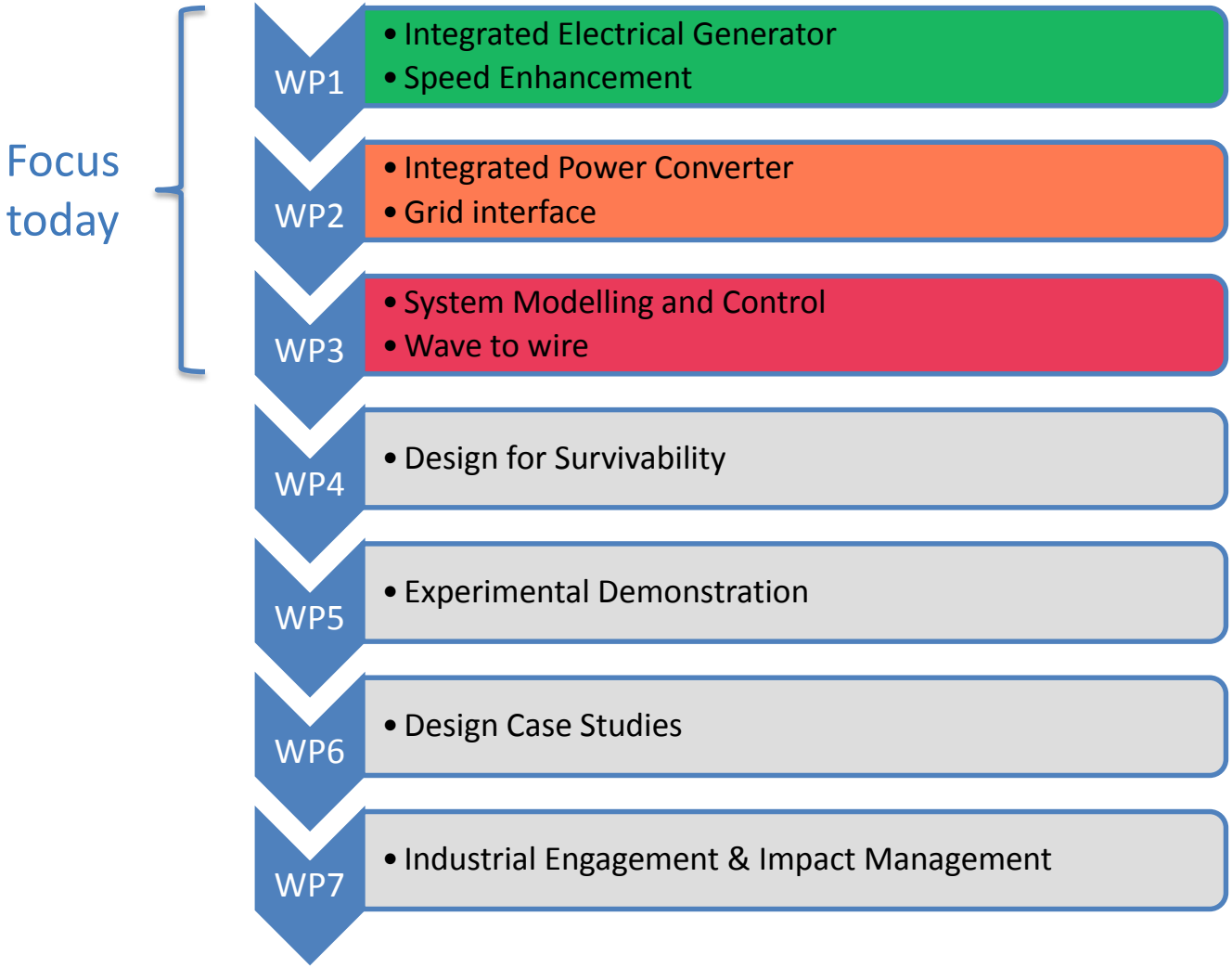
- Electrical machines work best with **high speed rotary motion**
- Eg 3000rpm electrical machine active diameter of 200mm has an air gap speed of **30 m/sec**.
- Typical WEC **linear oscillatory** velocities ~ **0.5-2m/s**

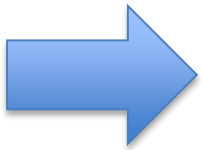



air
turbine
oil
motor
coupling
gearbox
direct
Moving part of device
Electrical machine

EDRIVE options




Focus today
WP1
• Integrated Electrical Generator
• Speed Enhancement
WP2
• Integrated Power Converter
• Grid interface
WP3
• System Modelling and Control
• Wave to wire
WP4
• Design for Survivability
WP5
• Experimental Demonstration
WP6
• Design Case Studies
WP7
• Industrial Engagement & Impact Management



WP1

- Integrated Electrical Generator
- Speed Enhancement

WP2

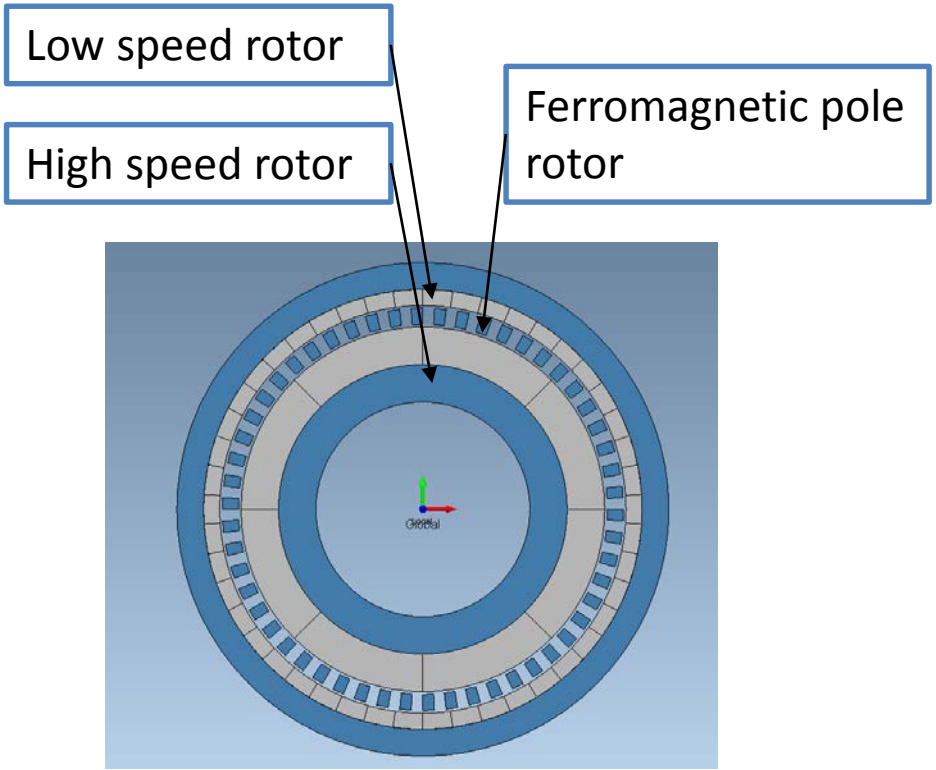
- Integrated Power Converter
- Grid interface

WP3

- System Modelling and Control
- Wave to wire

Magnetic gears

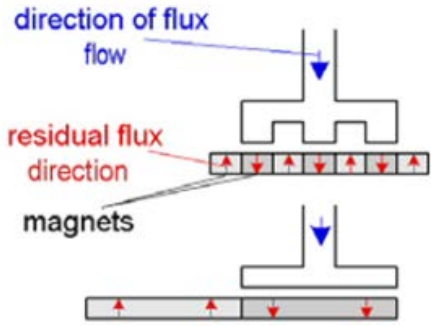
- Contactless torque transfer
- Reduced wear of mechanical elements
- Reduced lubrication requirements
- Inherent overload protection

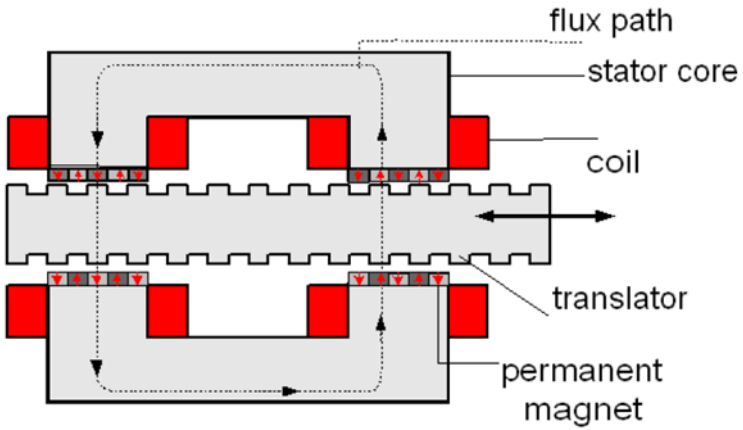


Ben McGilton (Edinburgh)

Linear generators

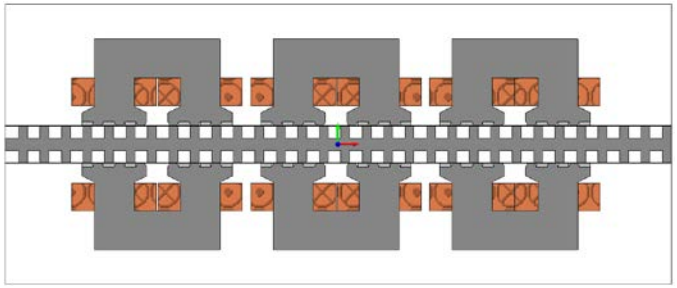
- Vernier hybrid machines
  - Inherent magnetic gearing
  - Construction is challenging
  - Low power factor is an issue

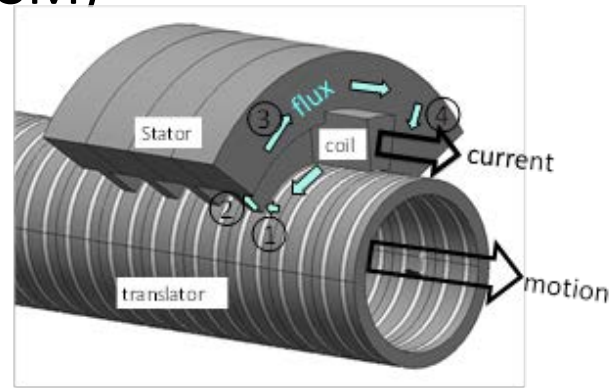


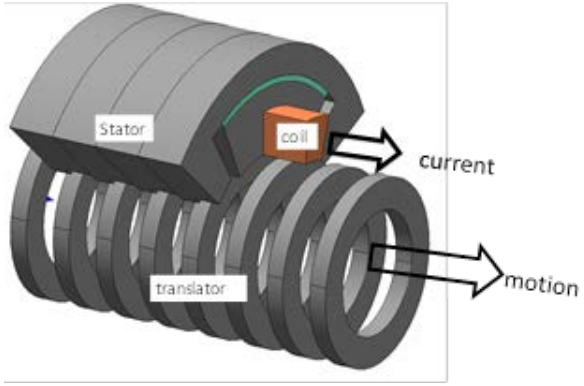


Linear generator development

- Various topologies being designed and built including:
  - Consequent pole Vernier hybrid machine (VHM)
  - Transverse flux (TFM)
  - Flux switching (FSM)



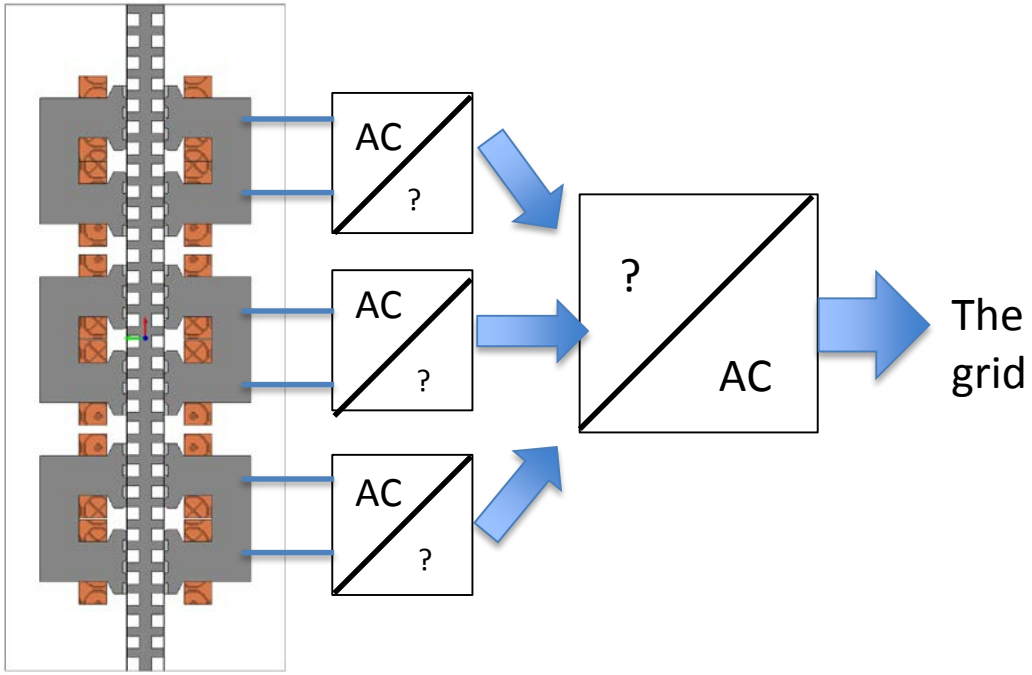


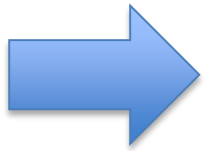


M. Raihan, A. Almoraya (Newcastle)

Modular Generator

- Multiple sections of the generator
- Each section has its own generator interface converter
- Failure of a number of sections will reduce wave device maximum power only
- Option to “shut off” sections when not needed for efficiency improvement in low sea-states





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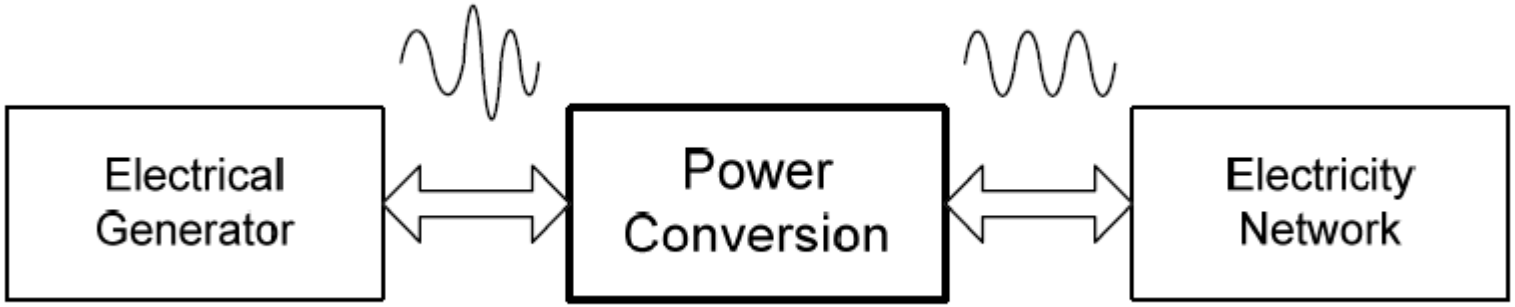
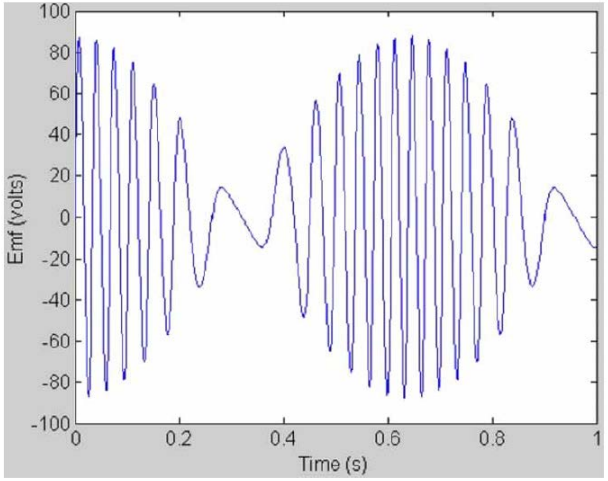
The Electrical power converter (EPC) top level specification

- Generator interface **(Converter)**
  - Optimal power flow and 4Q control of the generator
- Electrical Energy Storage **(EES)**
  - Integrated with the DC link
  - High cycle capacity
- Grid interface **(Inverter)**
  - High power quality
  - 11kV to minimise losses in cable

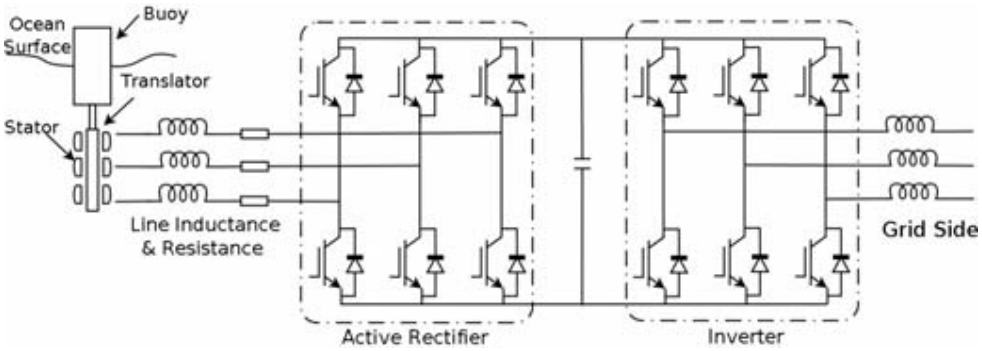
Challenges for Converter

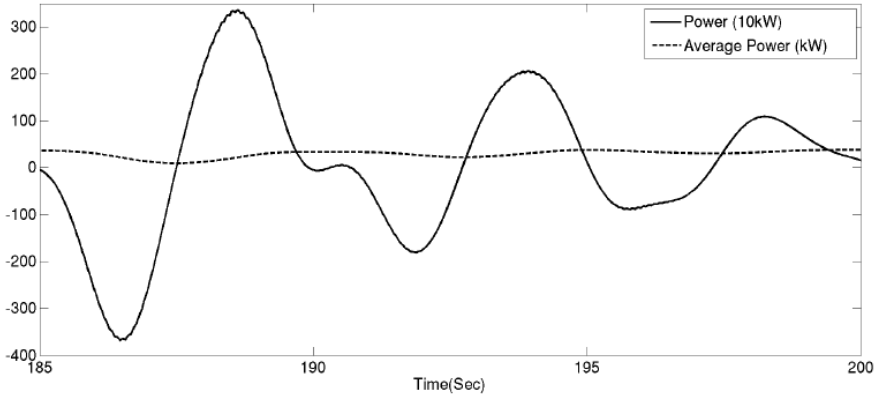


- Pulsating EMF from generator reflects motion of waves
- Reactive power required for device mechanical tuning



Power required to achieve tuning



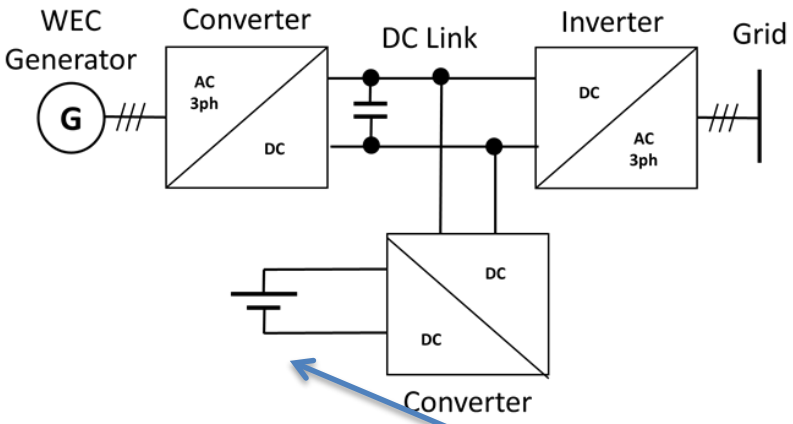


"Instantaneous power for mechanical tuning can be hundreds of times more than the average power extracted" [1]

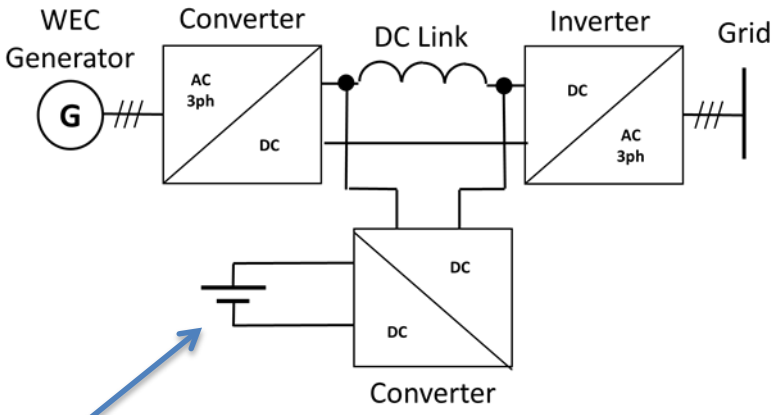
[1] B. Li, D. E. Macpherson, and J. K. H. Shek, "Direct drive wave energy converter control in irregular waves," in *Renewable Power Generation (RPG 2011), IET Conference on*, 2011, pp. 1-6.

Topology selection

Voltage source



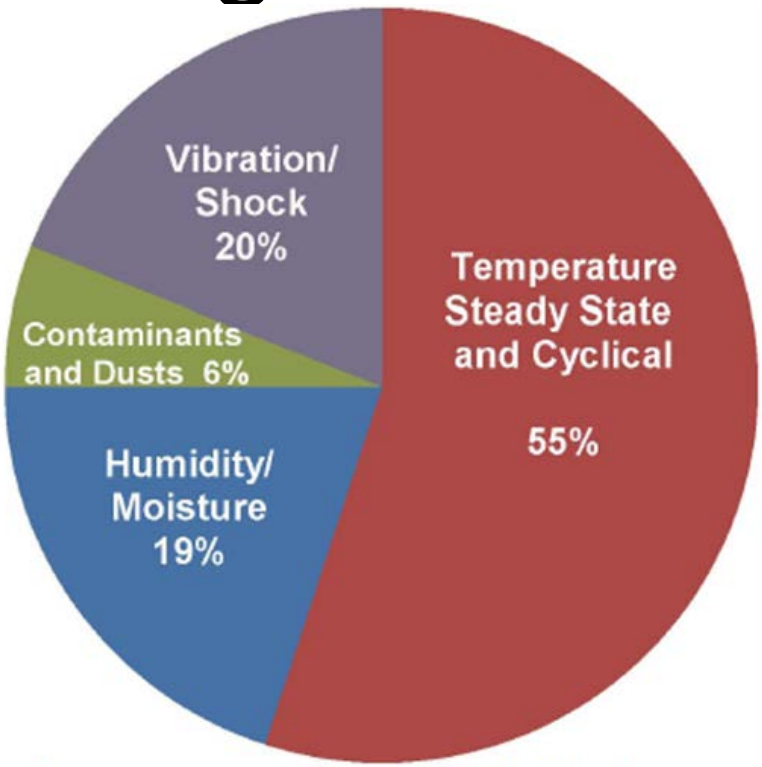
Current source



Storage

Steve McDonald (Newcastle)

Addressing converter reliability

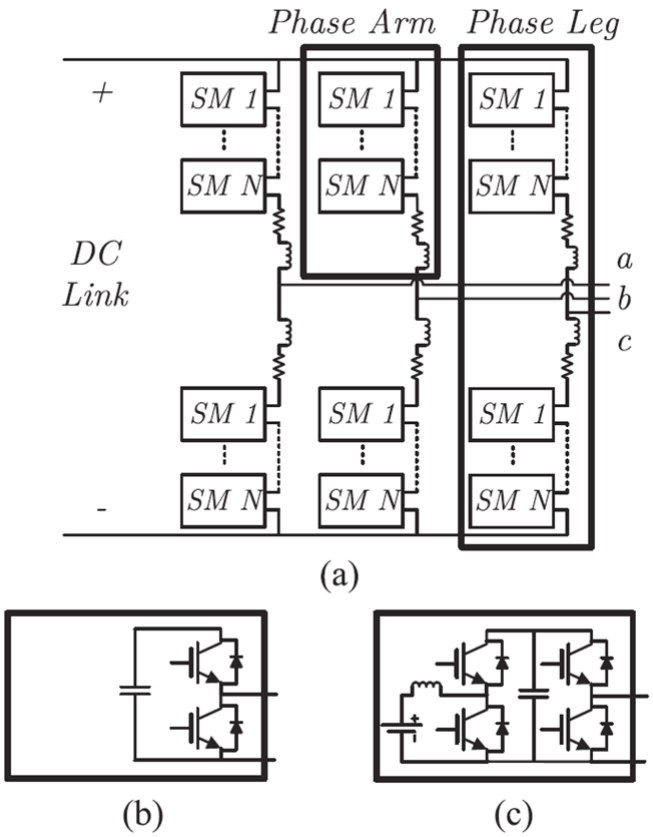


(b) Source of stresses distribution.

S. Yang, A. Bryant, P. Mawby, D. Xiang, L. Ran, and P. Tavner, "An industry-based survey of reliability in power electronic converters," in *2009 IEEE Energy Conversion Congress and Exposition*, 2009, pp. 3151-3157.

Grid interface

- multiple modules of the generator converter and EES & multilevel grid



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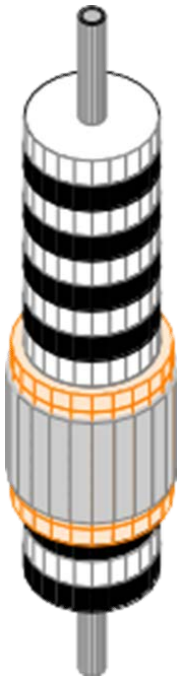
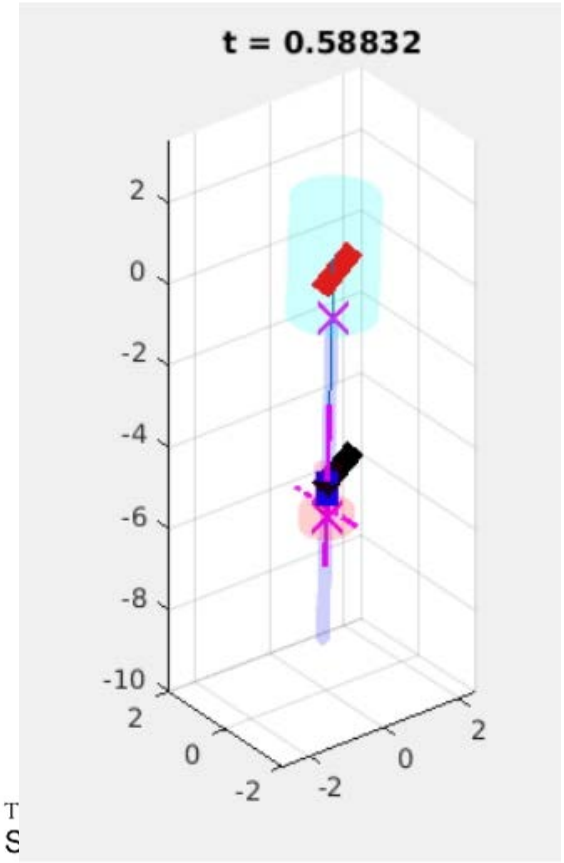
WEC PTO modelling

- Buoy 2m diameter, 1m draft
- Air Cored Tubular Machine
- Multibody Model
  - Buoy
  - Translator
  - Stator
  - Base (fixed body for ref)
  - Hinge joint
  - Sliding (prismatic) joint
  - Sensors
- Waves: single frequency 0.5m amplitude, 0.2Hz

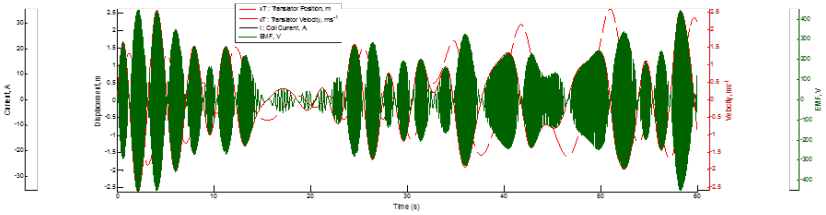


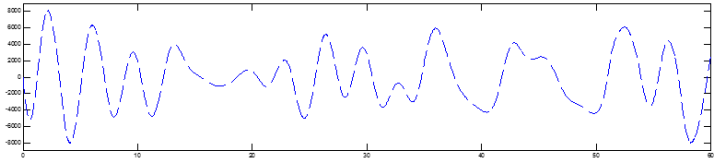


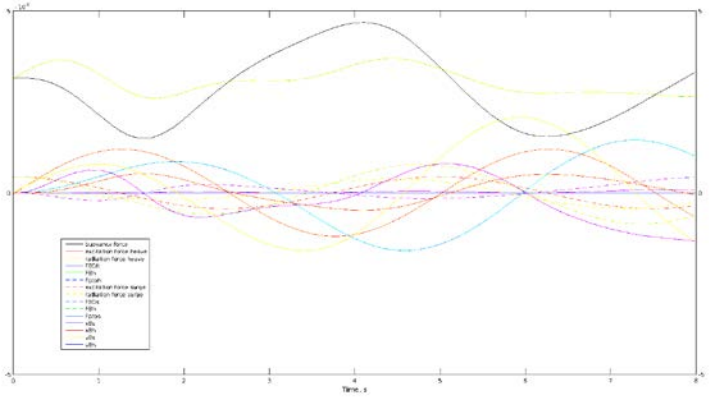
Dr. R. Crozier (Edinburgh)

System modelling and Control

- Linking Together
  - Generator model
  - Multibody dynamics model
  - Hydrodynamic model
  - Grid/Transmission Network Model
- Creating multi-rate model
- Generator takes multiple steps between each multibody/hydro model step







Summary

- Develop an all electric (electromagnetic) power take off
- magnetic gearing
- machine design
- converter development
- optimal energy storage
- reliability

Laboratory drivetrain testing

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