EDRIVE - MEC

EPSRC Supergen Marine

Grand Challenge

1st April 2016 – 31st March 2019

3.2 System modelling – Sizing tool development

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Overview

- E-Drive WEC sizing tool
  - Why we need it
  - Aims and limitations
- Dimensioning a representative WEC
  - Tool development
  - Tool predictions
- Next steps and discussion

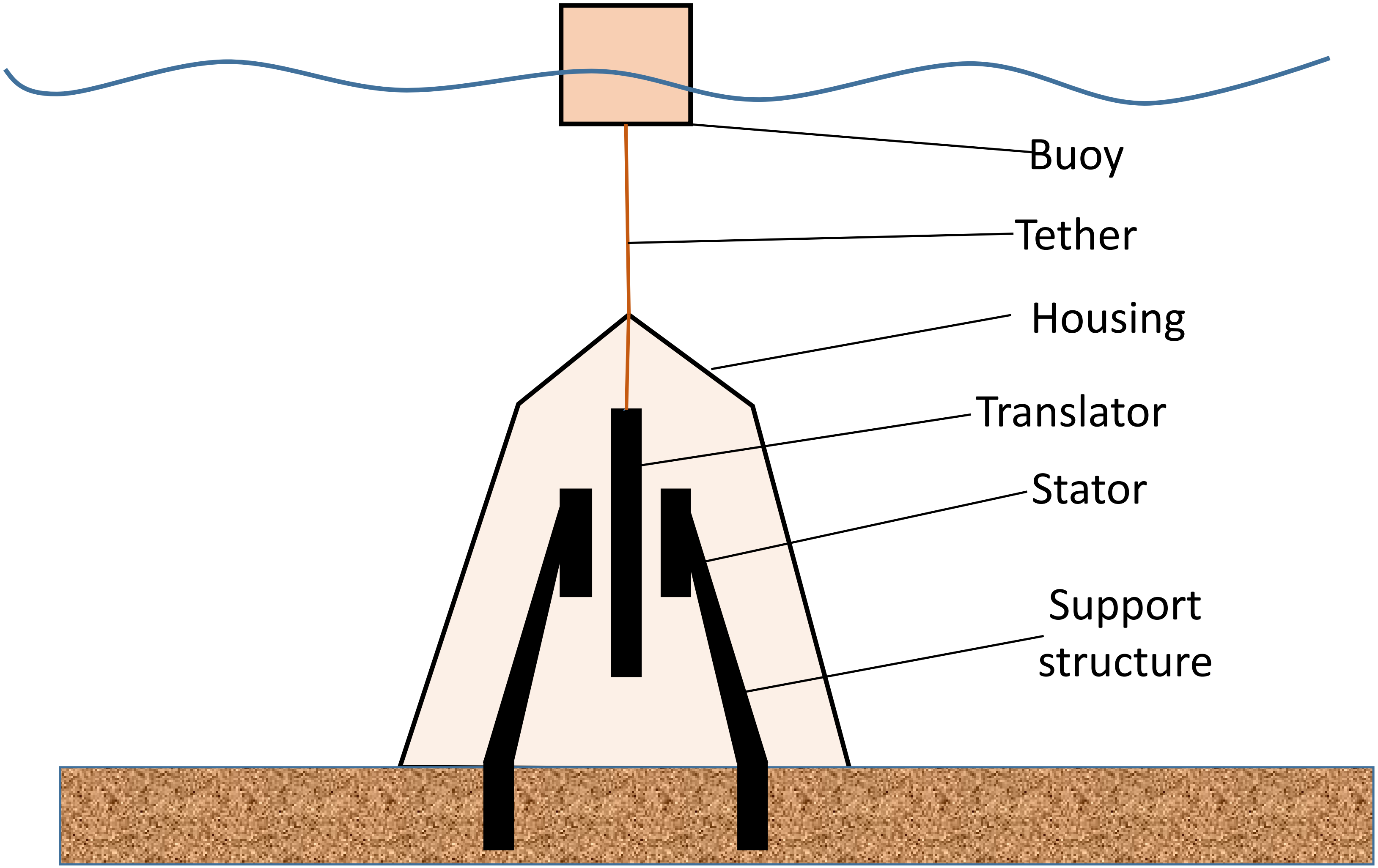
Why do we need this tool?

- Wide range of variables in WEC's
  - designs, application, wave resource, location, PTO control method etc
- Manufacturer specific data difficult to apply
  - Unique to their own devices, typically IP sensitive
- E-Drive representative WEC and PTO simulation tool required
  - Enables hardware dimensioning and ongoing simulation development for the PTO components
  - Can be used for basic case studies
  - Publishable results

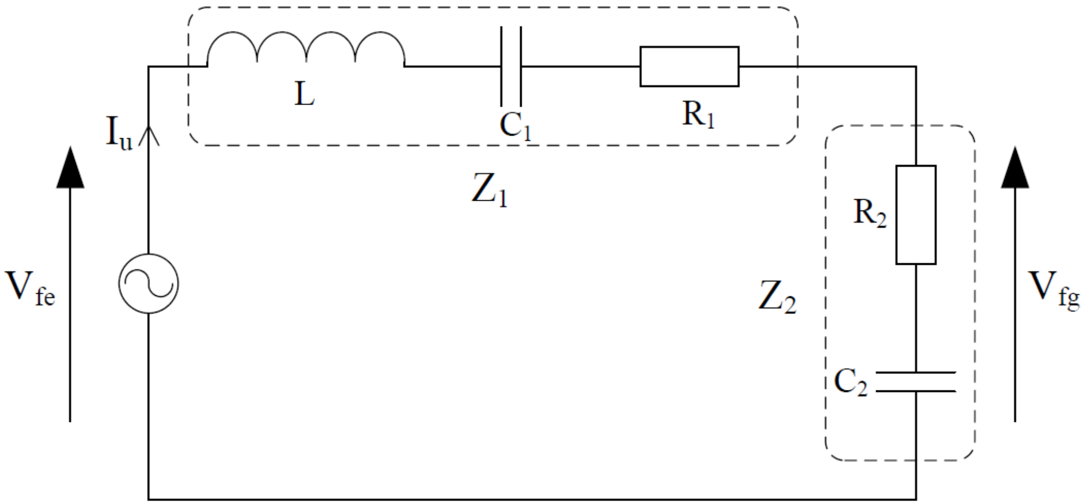
Tool Aims

- Develop much simplified time-domain model for subsequent application in E-Drive PTO development
- Assume monochromatic, deep seas
- Dimension a suitable point absorber WEC for E-Drive
- Enable ongoing simulation of a 25kW rated WEC in typical sea-states

Point Absorber



RLC based Model of WEC and PTO



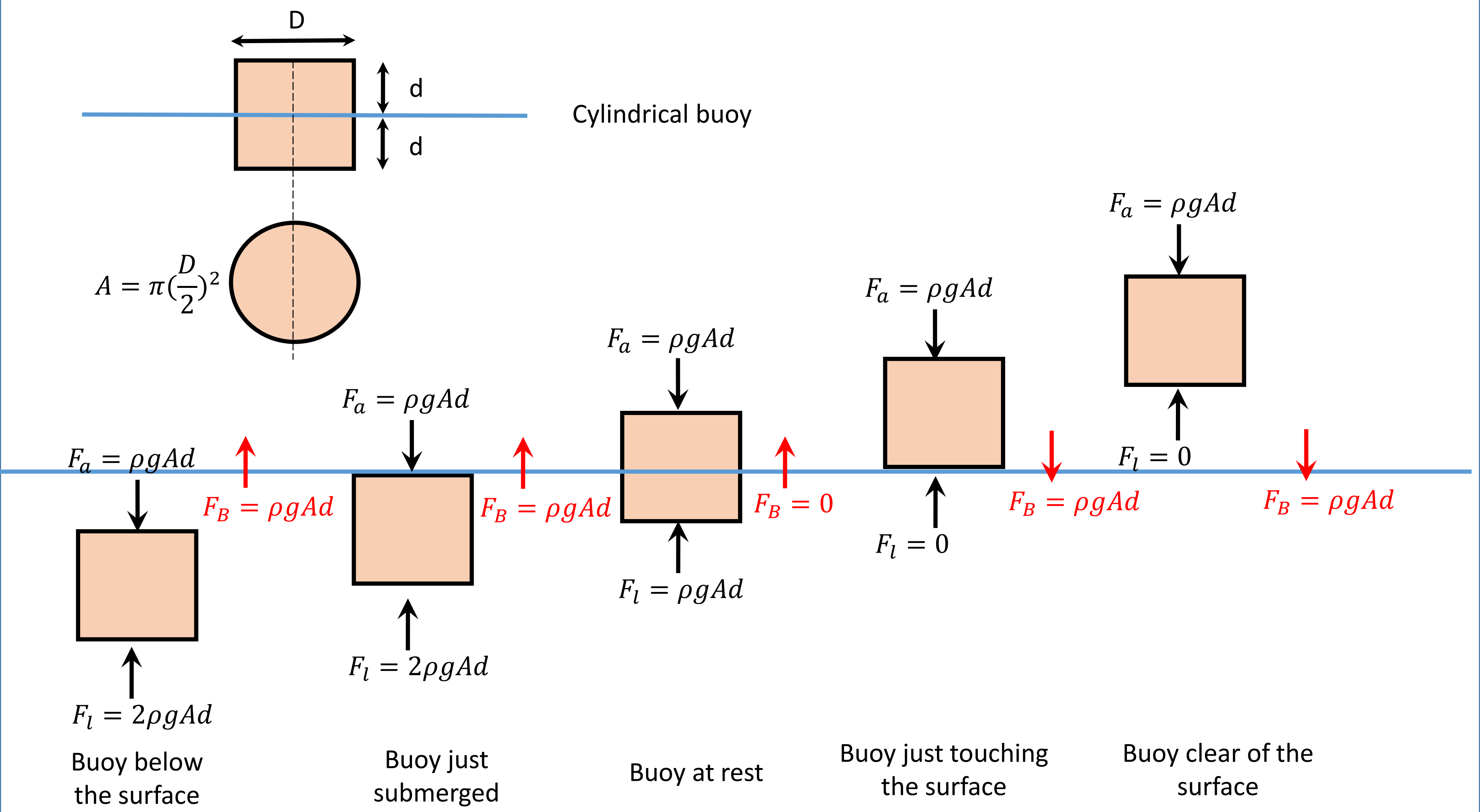
Parameter	Electrical	Mechanical Equivalent
V_{fe}	Supply voltage	Force applied to buoy due to the incoming wave
V_{fg}	Generator voltage	Force applied on buoy by the Generator
I	Current	Velocity of buoy
L	Inductance	Mass of buoy. Voltage in inductor equivalent to force due to any change in momentum (stored energy as kinetic energy $\frac{1}{2}MV^2 \equiv \frac{1}{2}LI^2$)
C_1	Capacitance	Spring stiffness – Voltage in capacitor is equivalent to variation in buoyancy due to position of buoy in water. (stored energy as potential energy $\rho gAh \equiv \frac{1}{2}CV^2$)
R_1	Resistance	Drag due to viscous friction and losses due to wave generation by the buoy
R_2	Generator resistance	Generator drag, a representation for the real power extracted or injected by the linear machine and converter
C_2	Generator reactance (capacitance)	Generator reactive power, a representation for the reactive power extracted or injected by the linear machine and converter.

[1] J. K. H. Shek, D. E. Macpherson, M. A. Mueller, and J. Xiang, "Reaction force control of a linear electrical generator for direct drive wave energy conversion," *IET Renewable Power Generation,* vol. 1, pp. 17-24, 2007.

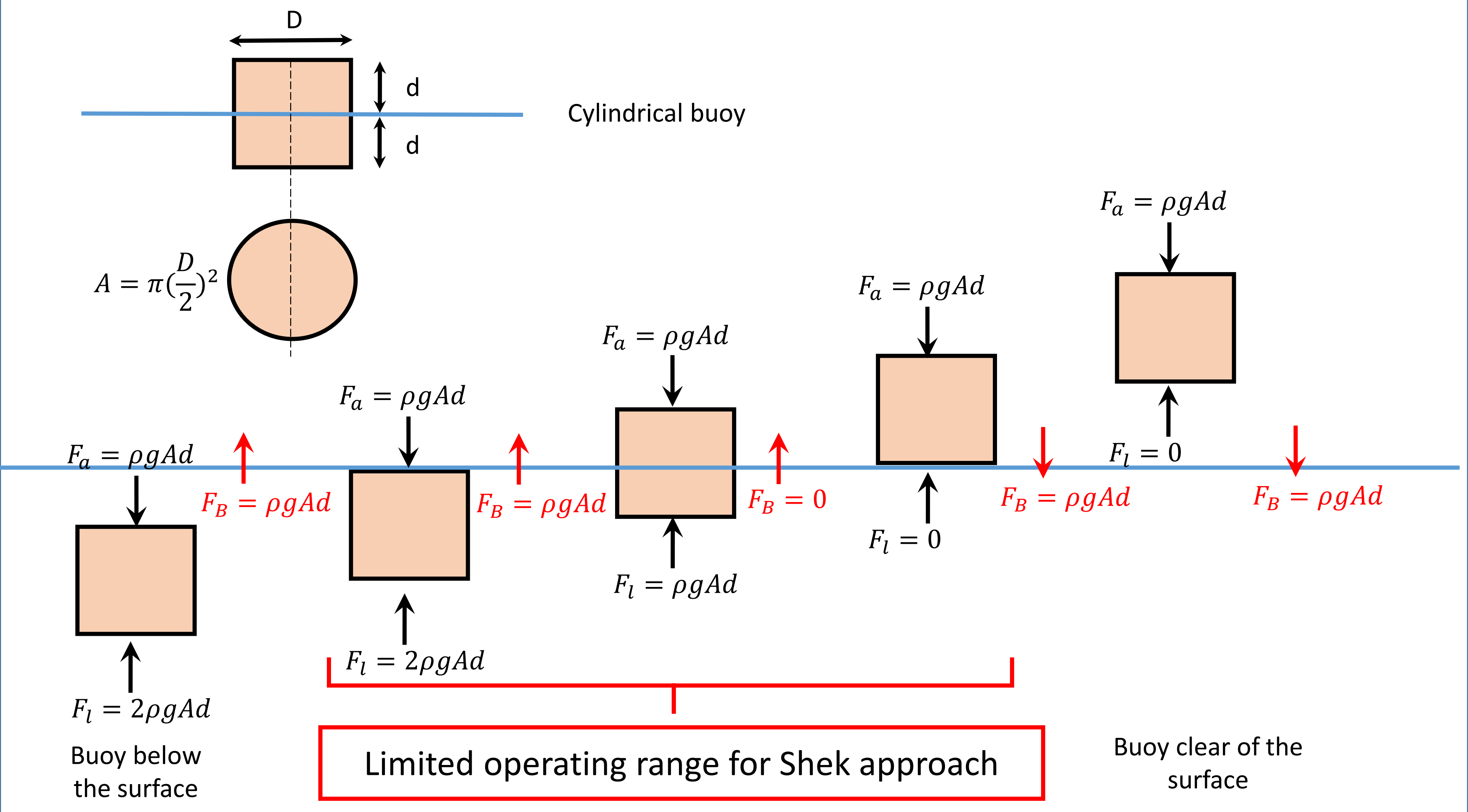
Limitations of 'Shek' approach

- Assumptions in Shek paper:
  - Buoy is small compared to wavelength
  - Force applied by wave is constant i.e $K_w \cos(\omega t + \emptyset)$
  - Drag force is simple function of velocity
  - Heave motion only considered.
  - Assume monochromatic, deep seas
  - Buoy and generator tightly coupled
- But,
  - drag force will vary as a function of buoy:
    - Displacement
    - Frequency
- And,
  - Buoy forces vary due to boundary violations:
    - Buoy restoring force is a assumed to be a linear function of position within the water
    - Turbulence and other complex fluid interactions ignored
- Also,
  - No account taken of pitch and surge forces

Example of restoring force issue



Example of restoring force issue



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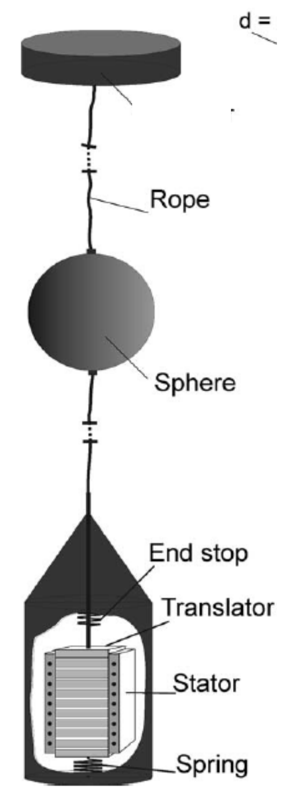
Enhancements to basic SHEK approach

- Basic ‘Shek’ approach over-predicts buoy motion at or near resonance, Solutions:
  - Detect major discontinuities
  - Modify relevant forcing/restoring functions accordingly
    - e.g if buoy is out of the water or completely submerged , it can’t have a varying buoyancy force.
  - Discontinuities can introduce positional offsets which need to be compensated for by the PTO
  - Incorporate end stops/springs in PTO model

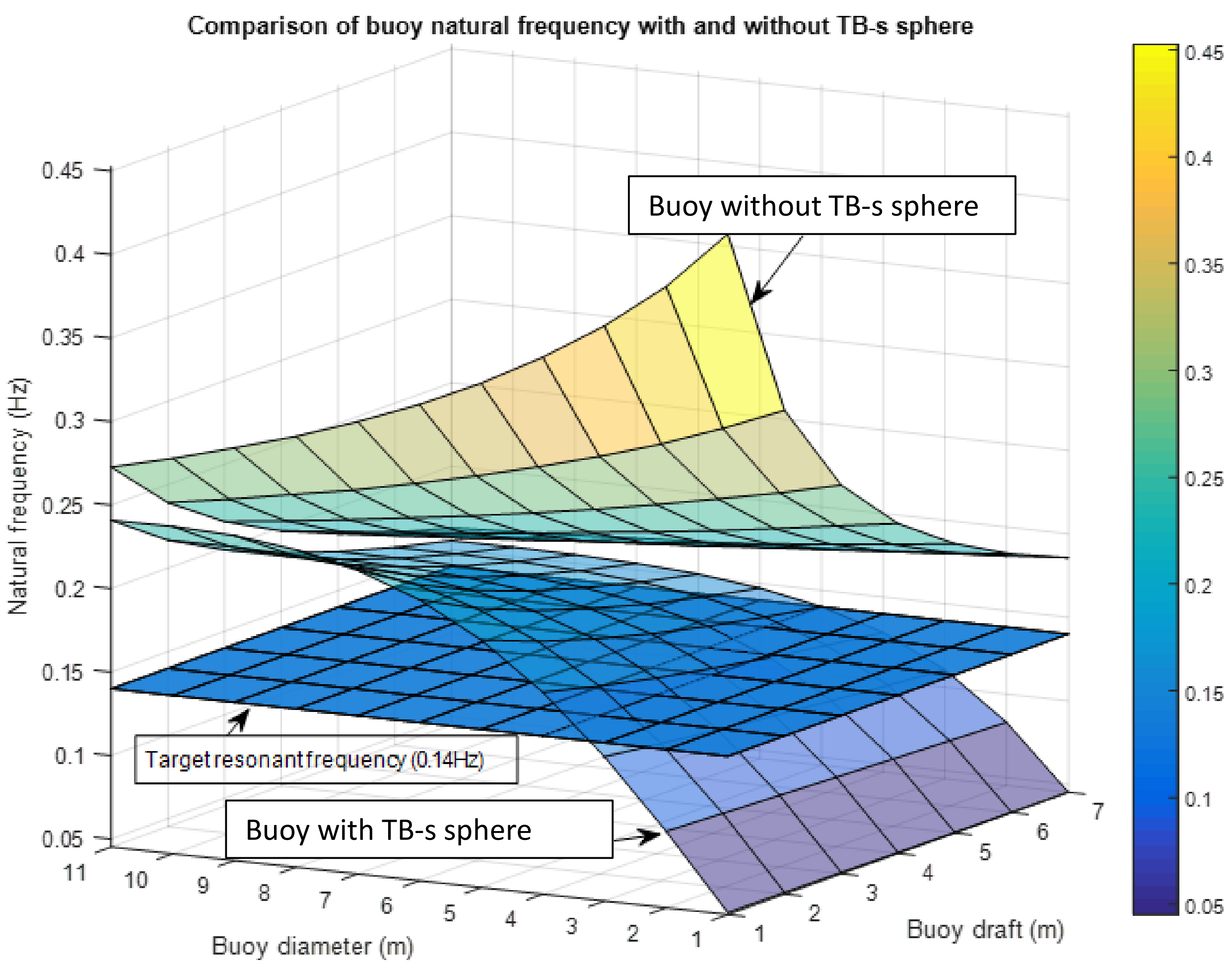
Using the TB-s concept

- Natural resonant frequency of simple point absorber for 25kW prototype does not coincide with desired wave frequency.
- Inclusion of TB-s sphere enables correct tuning of device without the use of springs.
  - $f_n = \frac{1}{2\pi}\sqrt{\frac{\rho g A_{wp}}{m+m_a}}$



[1] J. Engström, M. Eriksson, J. Isberg, and M. Leijon, "Wave energy converter with enhanced amplitude response at frequencies coinciding with Swedish west coast sea states by use of a supplementary submerged body," *Journal of Applied Physics,* vol. 106, p. 064512, 2009.

Effect of adding TB-s sphere



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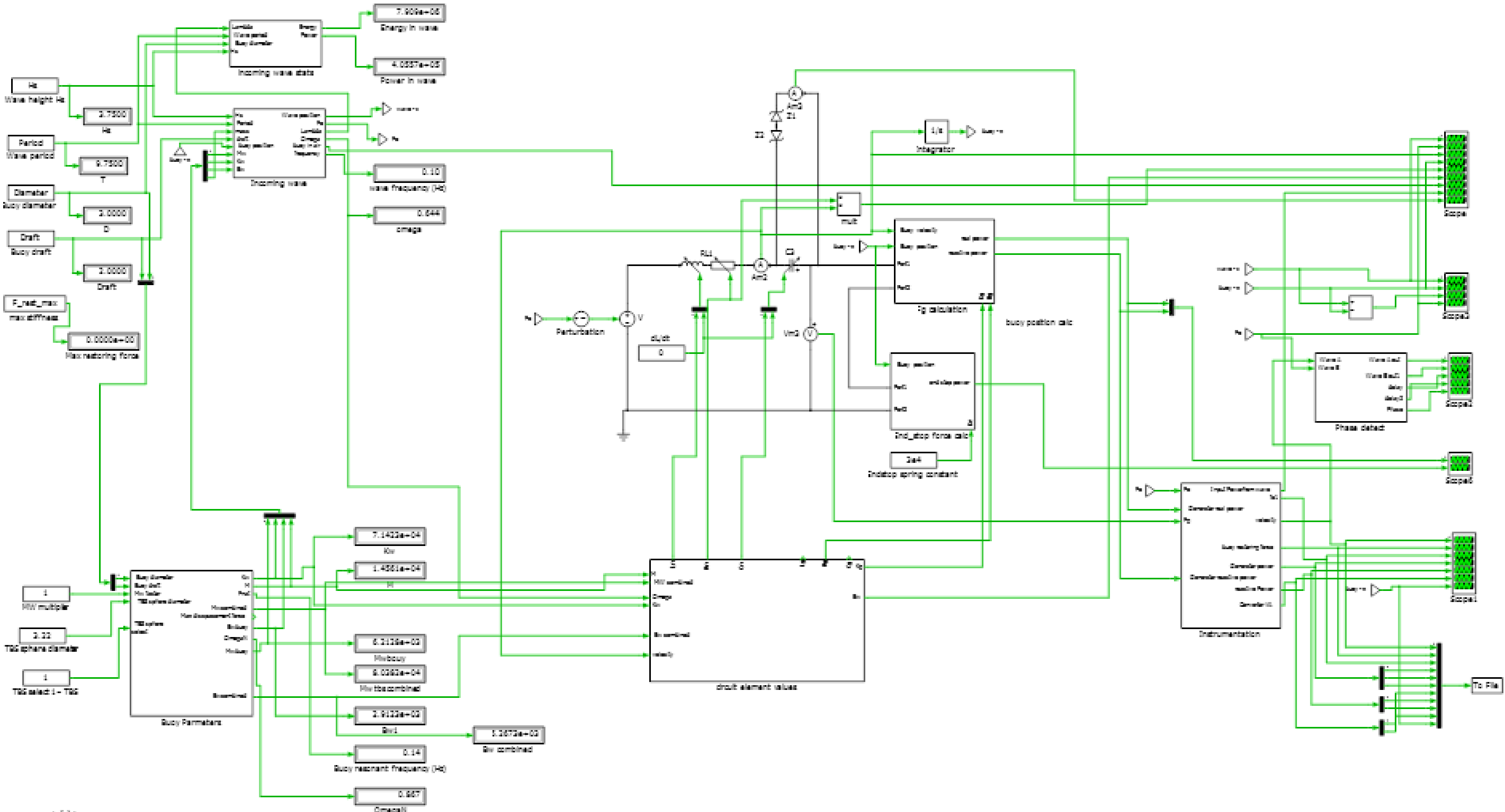
Model



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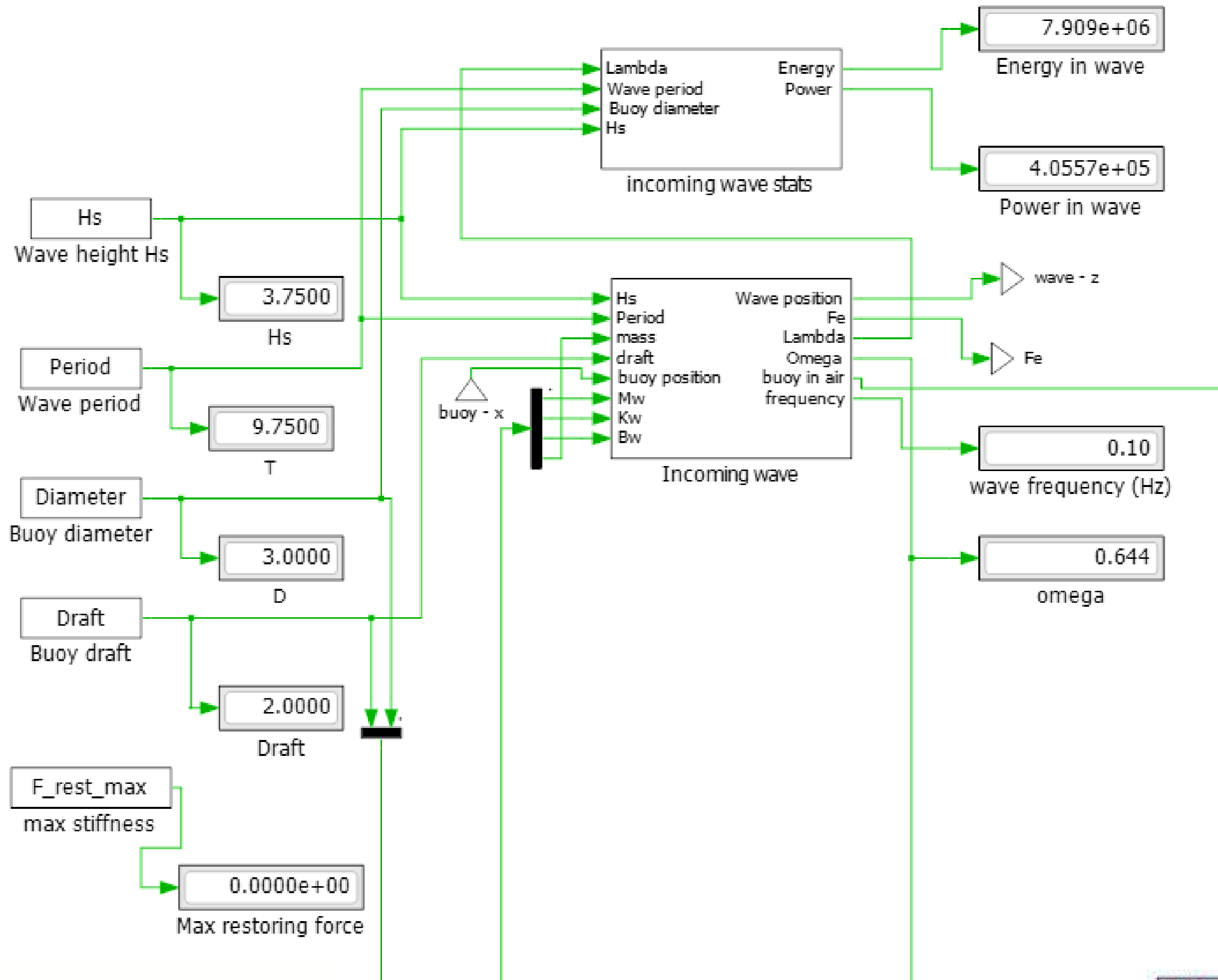
Wave force calculation



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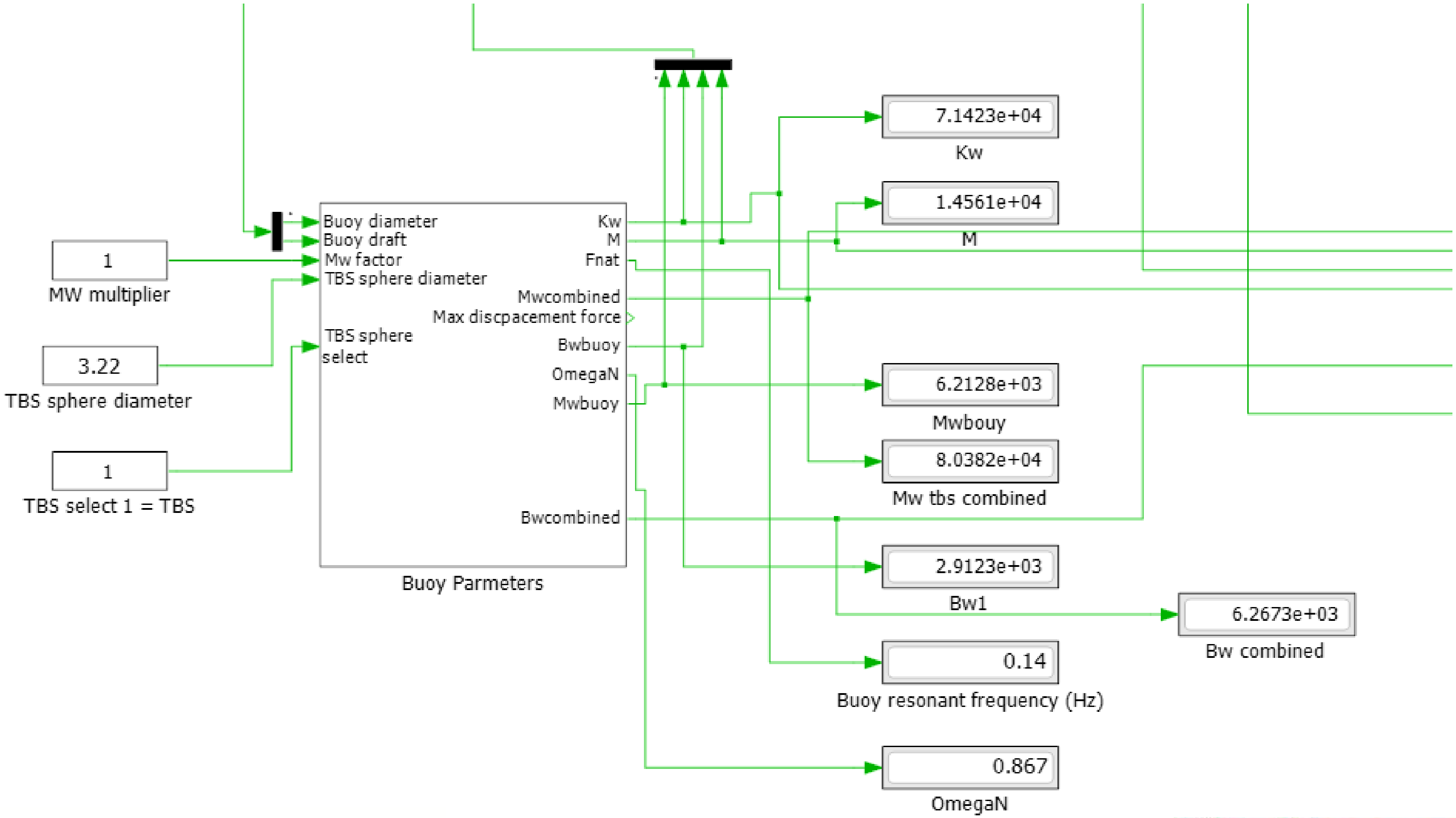
Buoy force calculation



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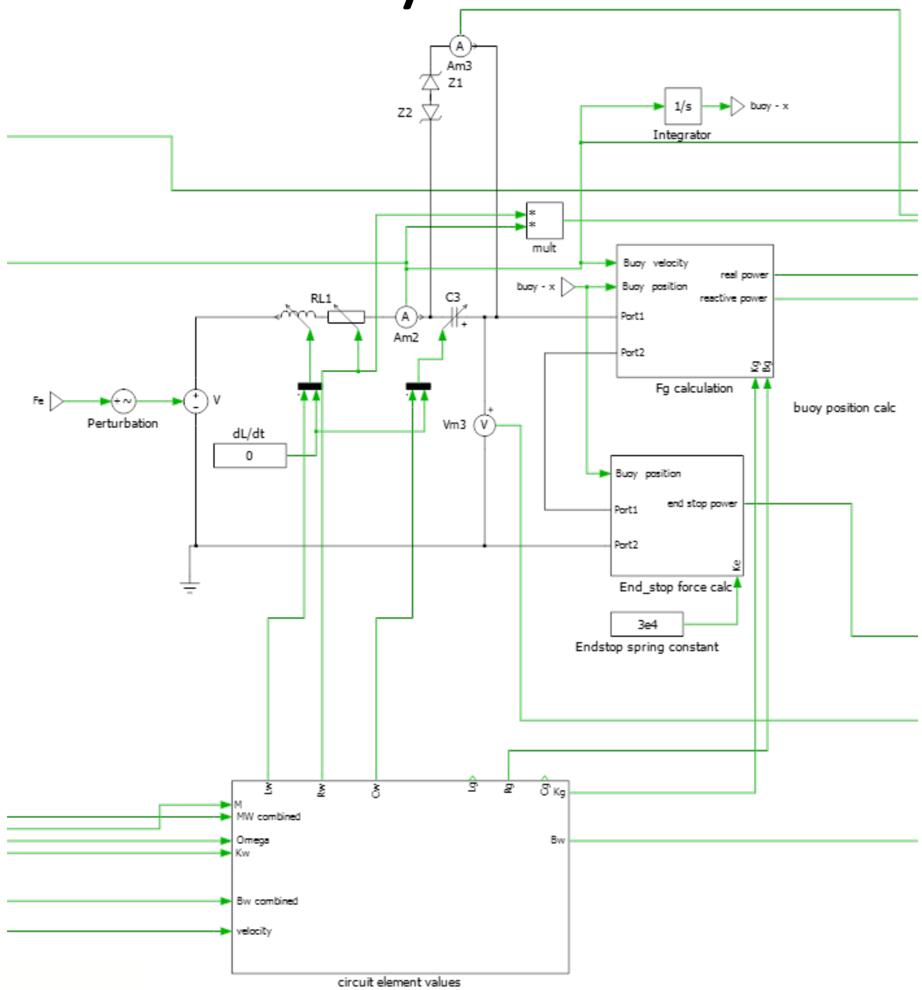
Buoy and PTO dynamic models



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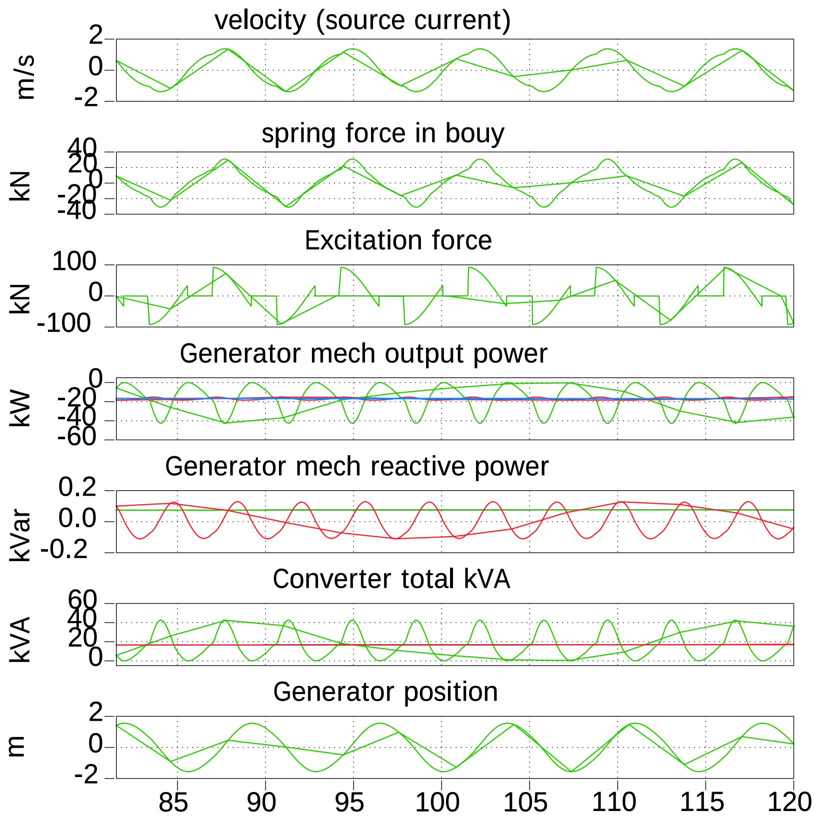
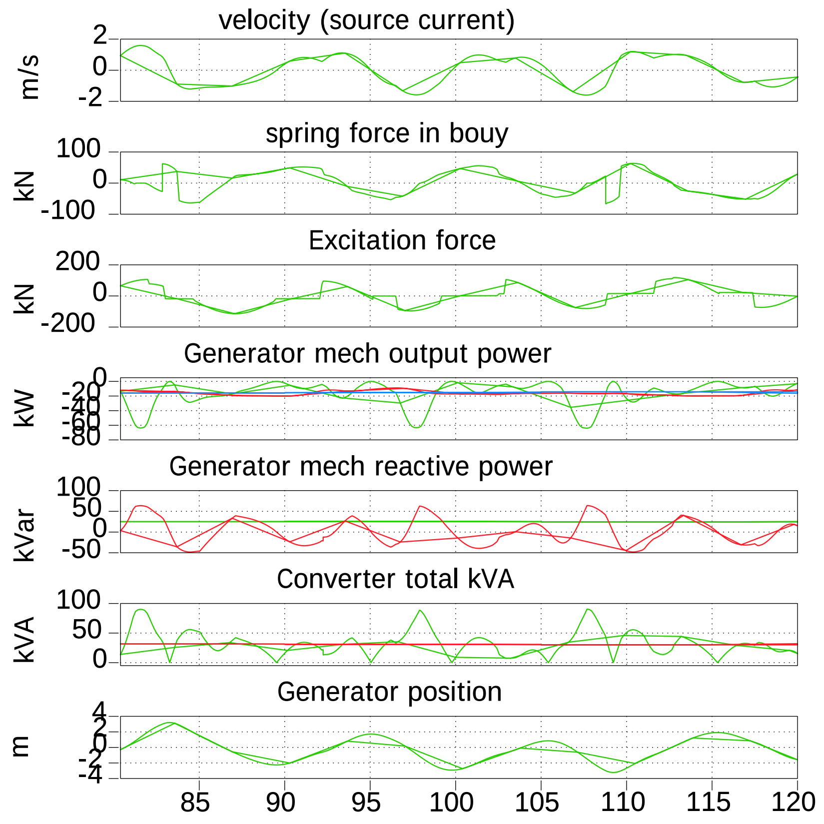
Example results

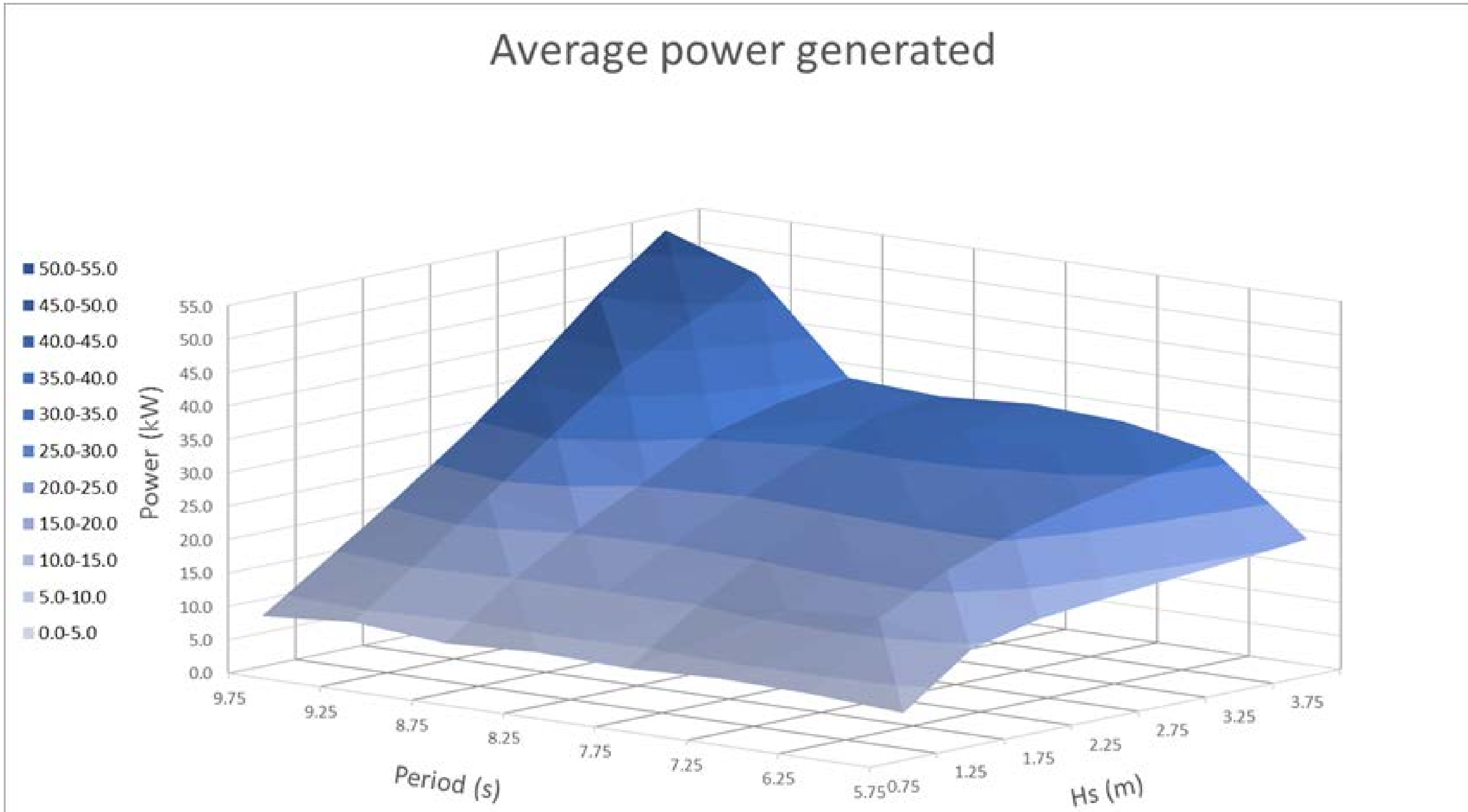
Hs = 2.75, T= 7.25s (resonance)

Hs = 2.75, T = 10.25s (off-resonance)



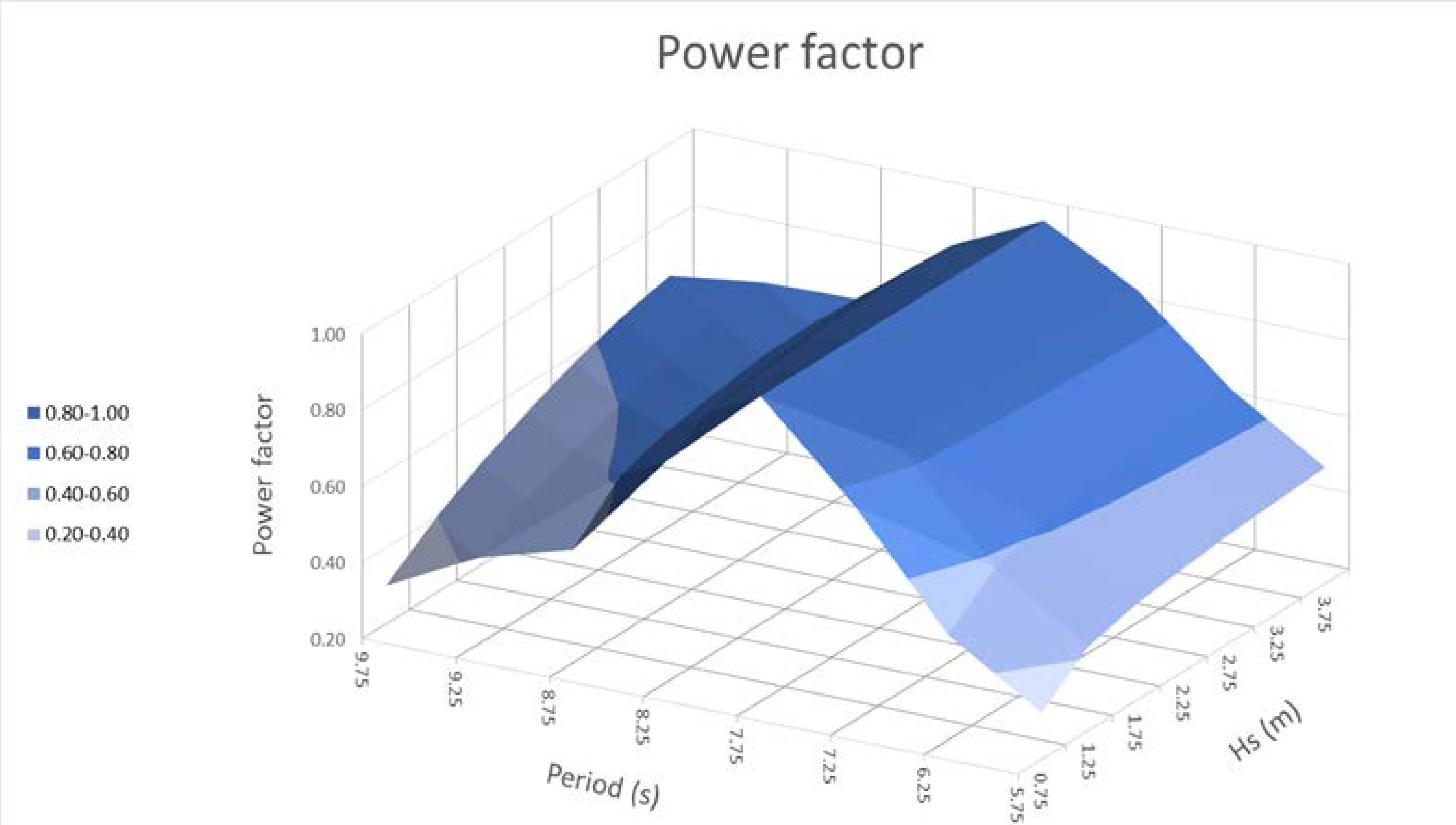


Power predictions



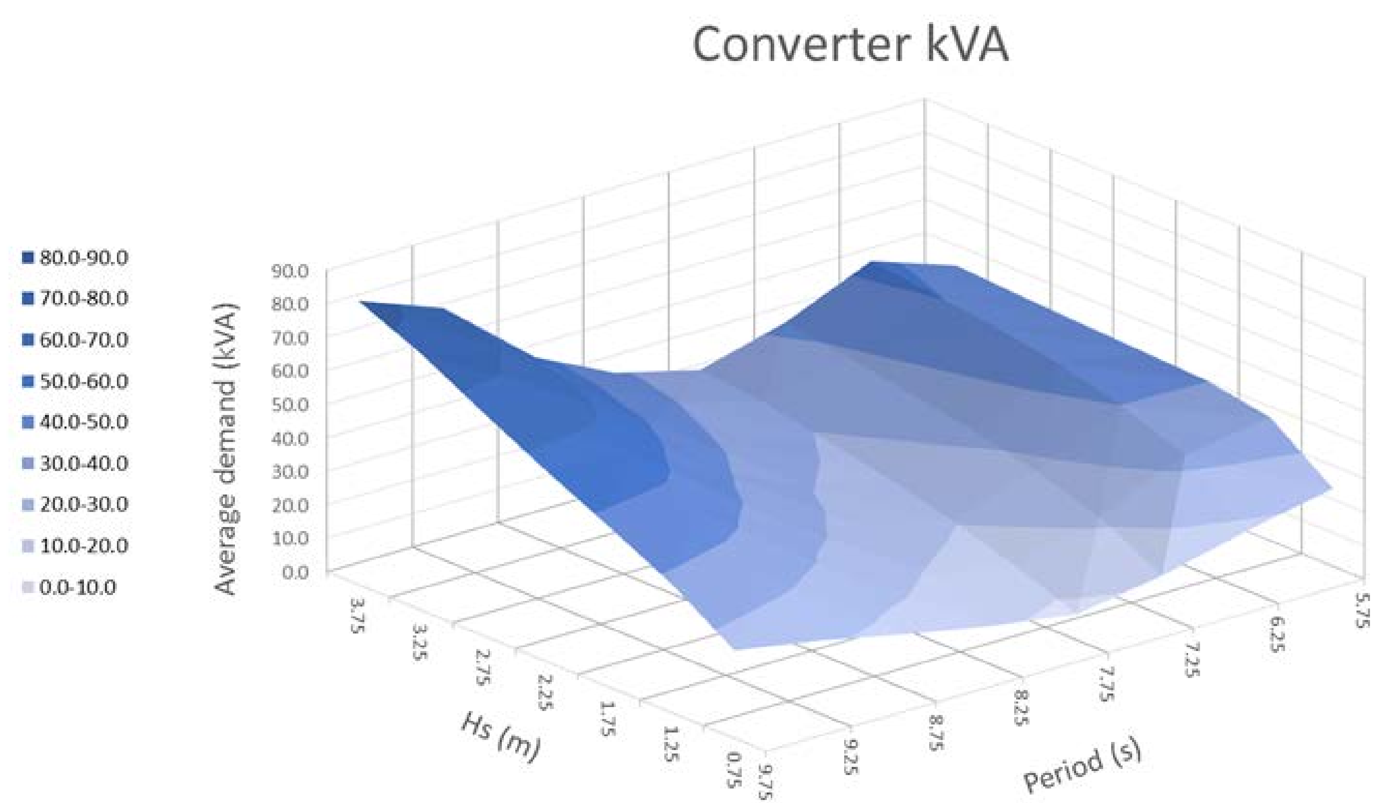
3m diameter, 2m draft buoy with 4.4m diameter TB-s sphere

PTO reactive power



3m diameter, 2m draft buoy with 4.4m diameter TB-s sphere

Converter kVA requirements



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Conclusions

- A 3m diameter, 2m draft point absorber with a 4.4m diameter TB-s sphere is capable of delivering 25kW in selected sea-state for E-drive case study.
- Converter rating of 80kVA is required, assuming ideal generator, to deliver useful range with expected range of sea-states for this WEC.
- Behaviour in confused seas, optimal PTO tuning, energy storage and control all require further analysis. This work feeds into EDU wave to wire model for validation.

Questions

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