Modeling and Control for Wave Energy Converters

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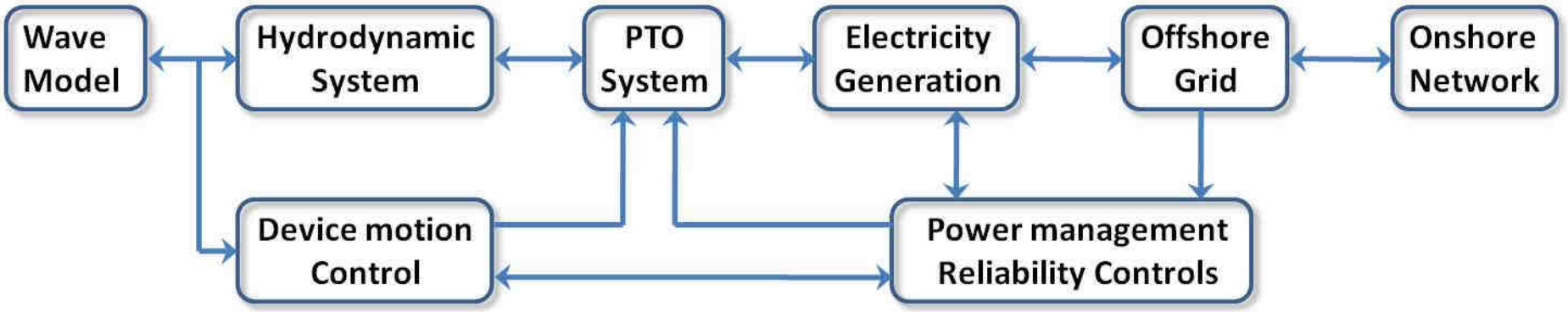
Modular Wave-2-Wire Model



Aims:

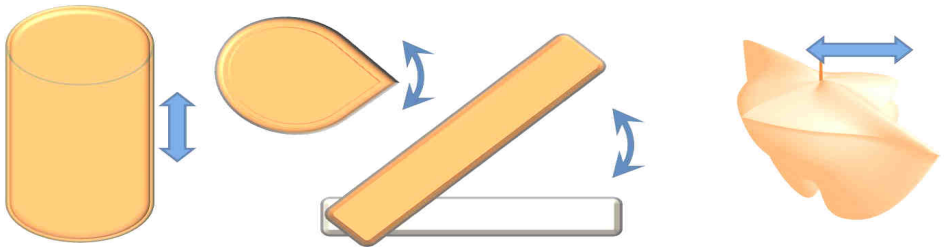
Investigate Control Strategies for Optimal Energy Capture and Electricity Production

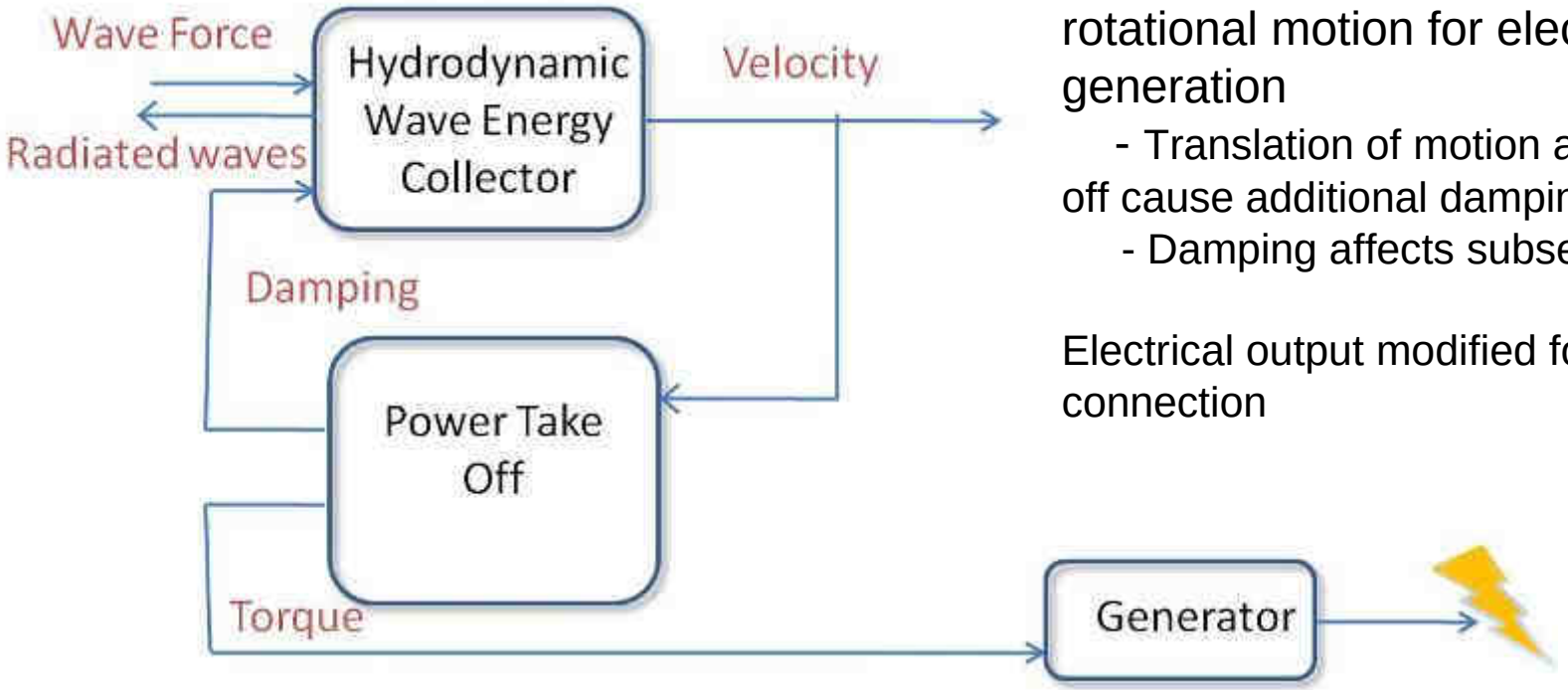
- -Single device
- -Array of devices

Utilise realistic mechanistic models of Hydrodynamics, Mechanical & Electrical machines

Develop Hierarchical Control elements for efficiency, reliability, fault detection, maintenance & survivability.

A Generic Wave Energy Converter





Hydrodynamic model translates wave force into device motion

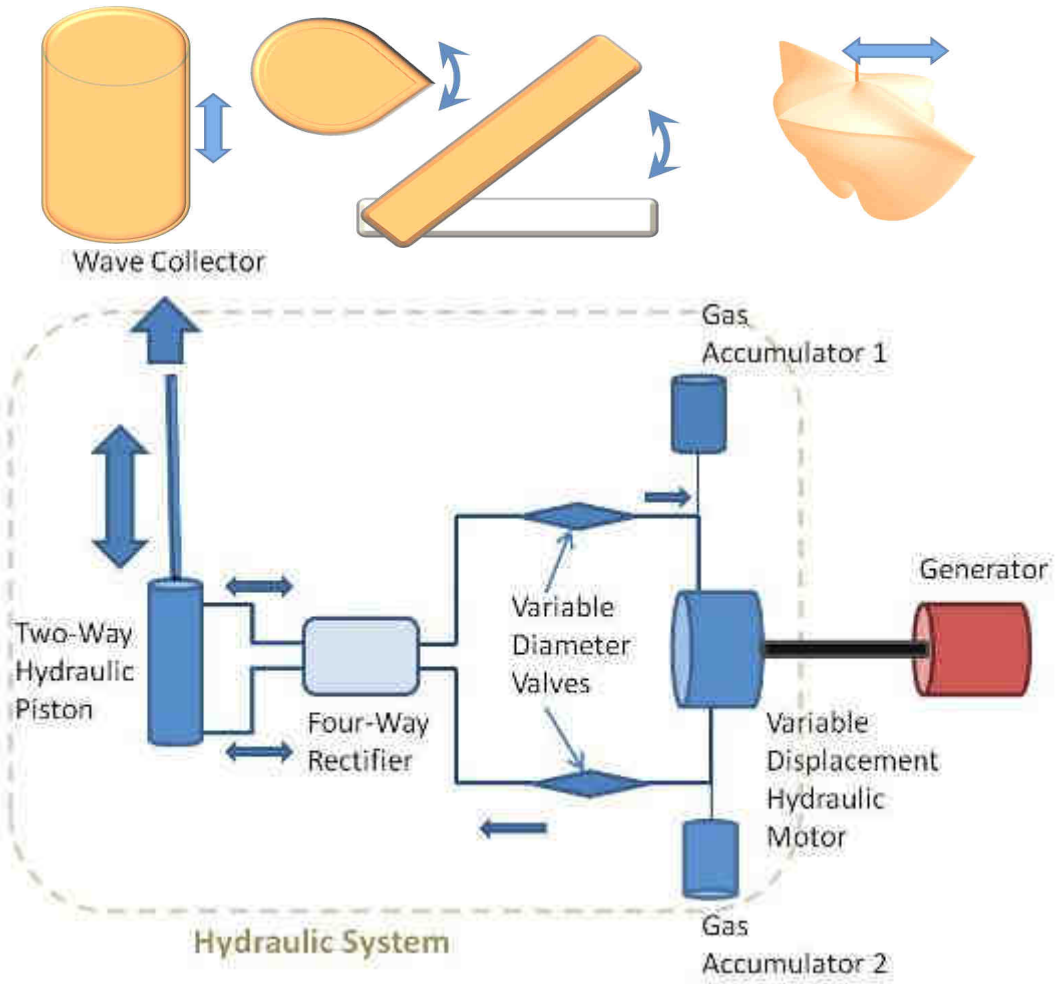
- Subsequent motion modifies sea state

Device's linear motion translated to rotational motion for electricity generation

- Translation of motion and Power-take-off cause additional damping
- Damping affects subsequent motion

Electrical output modified for grid connection

Simulation of a simple Hydraulic Power Take Off system with a Variable Displacement Hydraulic Motor



Motion of wave collector directly drives **piston**

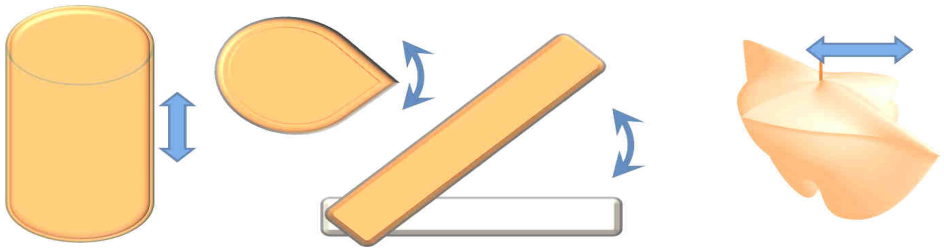
Hydraulic fluid flow rectified to ensure one way flow through **motor**

Fluid returns to piston
Varying valve diameter impedes flow, affects damping force

The PTO acts to produce a **control** force

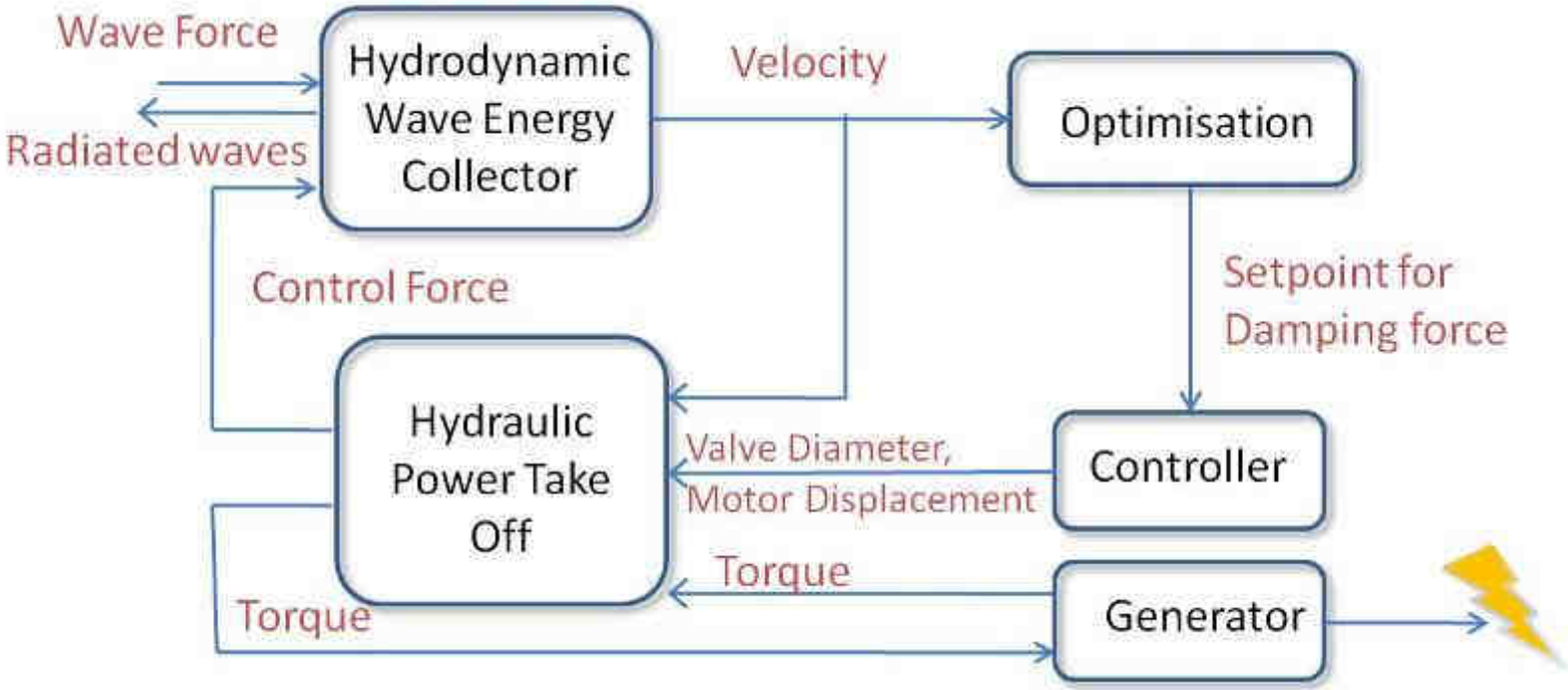
Can be used to **control motion** of Device in changing sea state

A Generic Wave Energy Converter

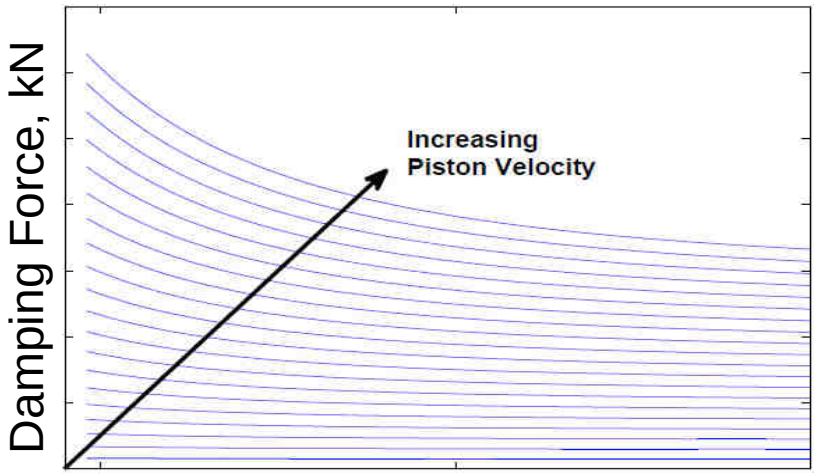


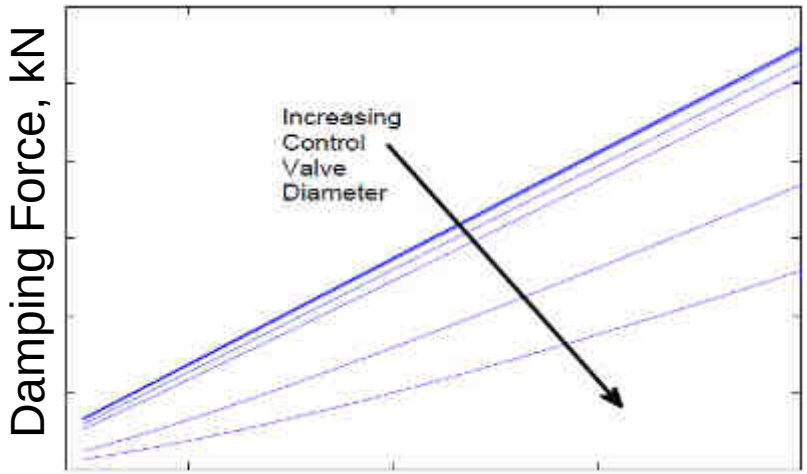
Modular in design :

- Incorporates *realistic* Mechanistic models
- Adaptable with various control strategies & Power Take Off Technologies
- Add additional modules i.e. Mooring damping

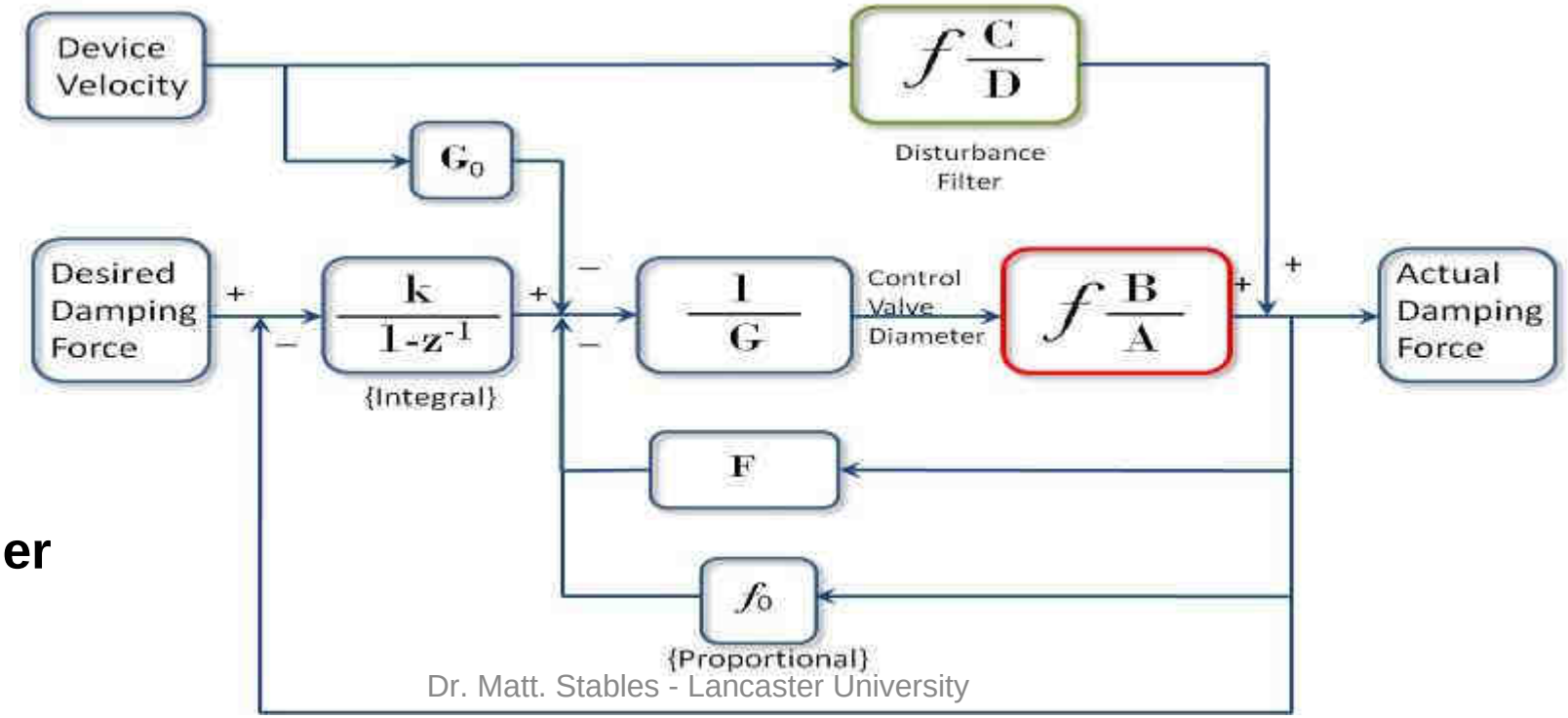


Hydraulic PTO system dynamics





Linear Controller



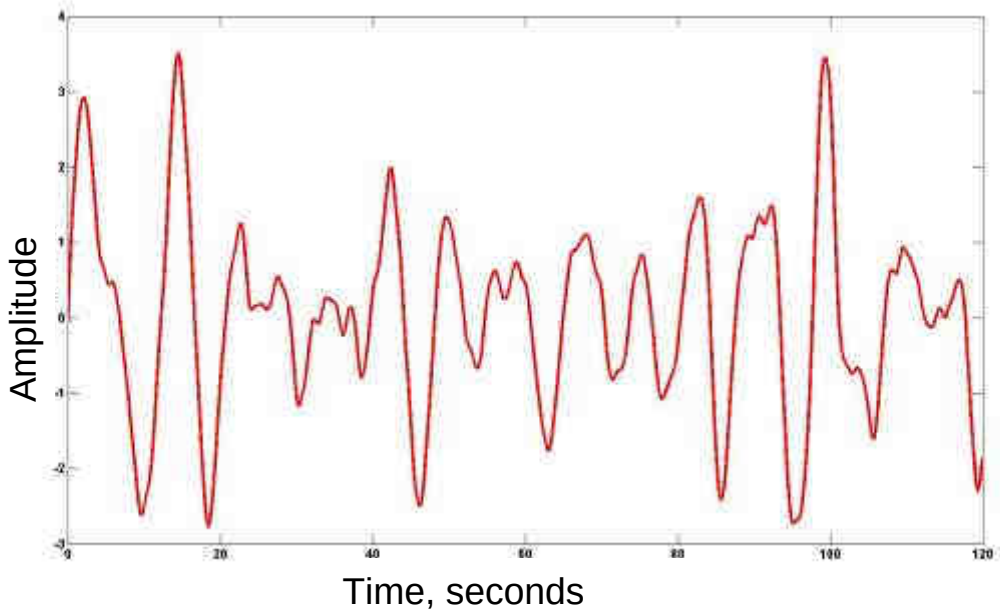
Illustrative Example

Device: Large cylinder constrained to 1 degree of freedom

Volume 500 m^3

Displaced mass ~500 tonnes

Sea State: North Atlantic JONSWAP multi frequency irregular wave



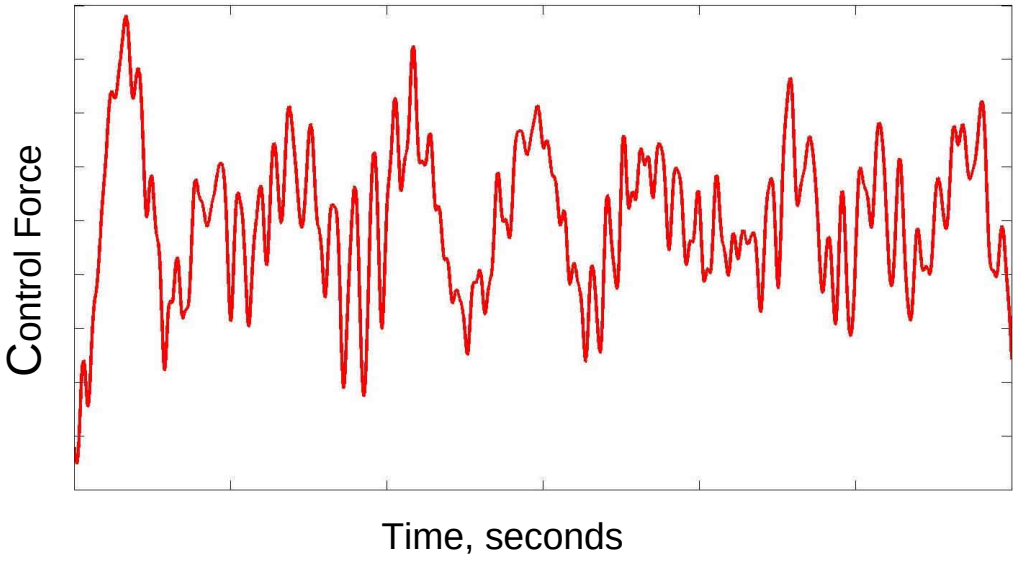
Control Strategy: Phase Control.

Optimal damping for single frequency wave is well understood

E.g. Budal & Falnes

Device optimally damped in same manner but for 500 frequencies simultaneously

Andy McCabe



Illustrative Example

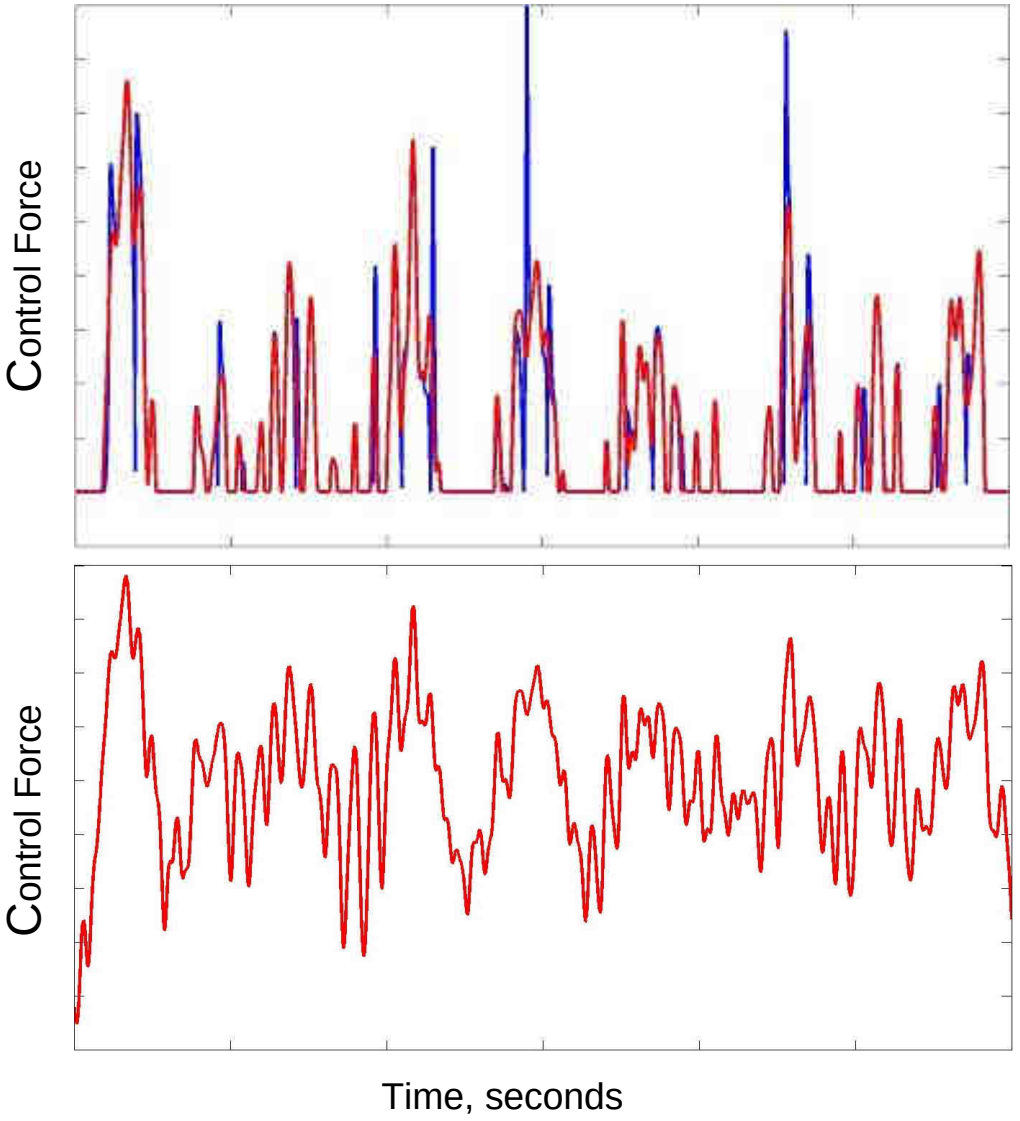
Linear Control of Damping Force

Hydraulic PTO unable to *ADD* power

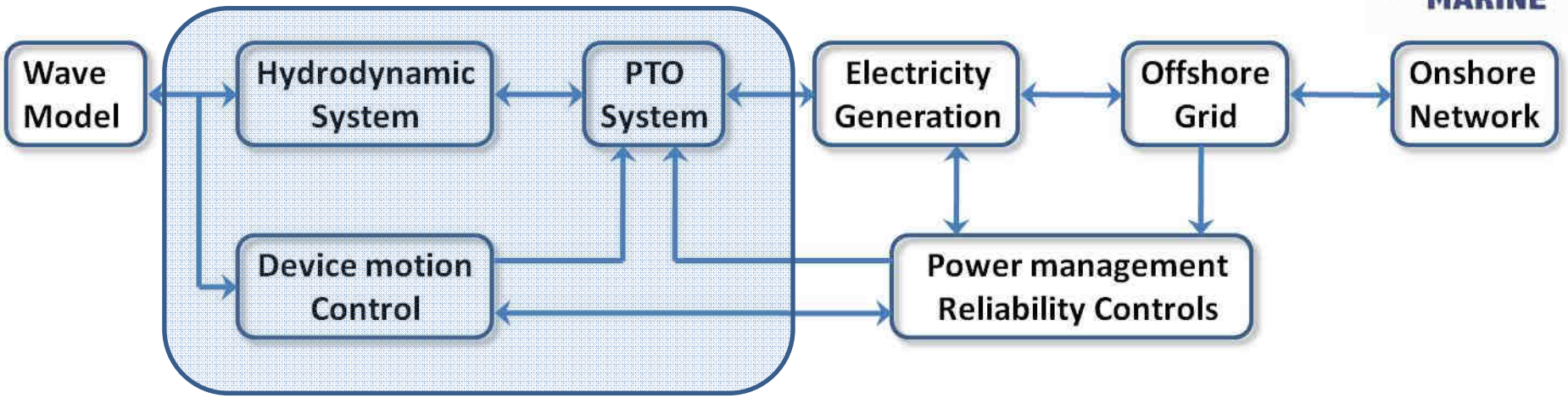
Actual PTO damping matches desired damping

Optimal Damping - Red
Achieved damping - Blue

Control Strategy	Power Captured
Optimal	736 kW
Constant	1.84 kW
No Control	1.2 kW

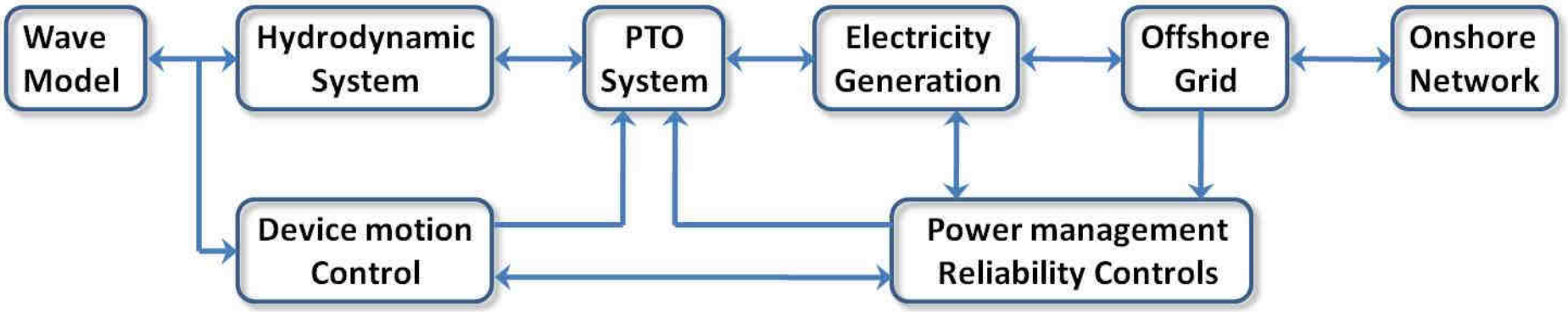


Achievements to Date



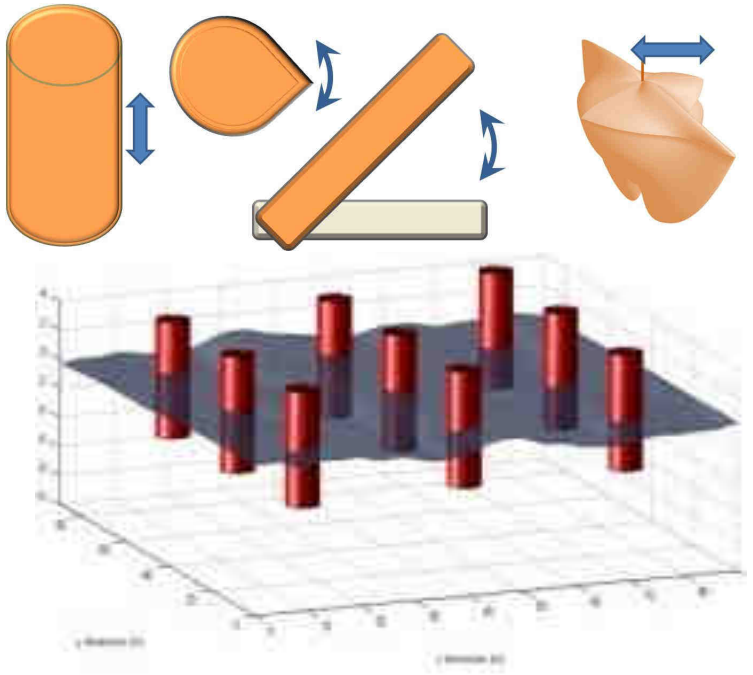
- Successfully implemented multiple modules Wave-2-Wire model
- Demonstrate optimal control strategies
- Utilised various hydrodynamic models
- Realistic Hydraulic PTO models of increasing complexity
- Simple and advanced controllers

Future Work



Continue development and utilisation of modular Wave-2-Wire model

- Hydrodynamic **ARRAY** models
- Multi-mode Hydrodynamic models
- Improved PTO models
- Improved Non-Linear Controllers
- Provide realistic control capability for overall **Wave Farm** control strategy
- Provide realistic values for Power management



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Questions?