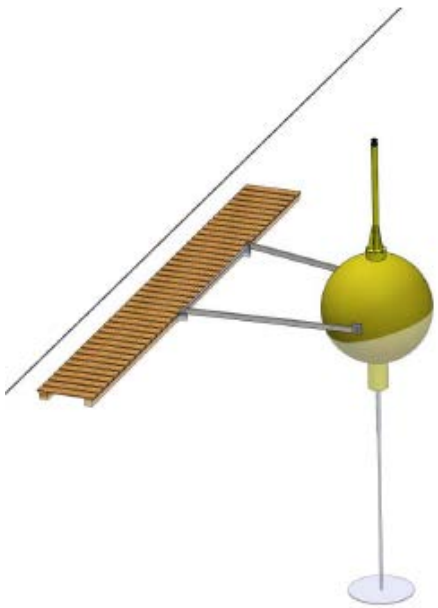

Ocean Energy
Light buoy

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Ocean Energy Light buoy - Background

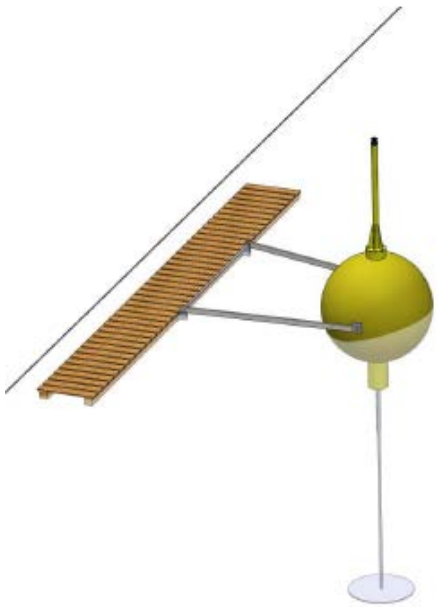
- The project is in cooperation with the Norwegian company “Ocean Energy”
- The aim of the project is to develop a self powered LED light for marking of fish farms
- Existing solutions run on batteries and a lot of maintenance is required

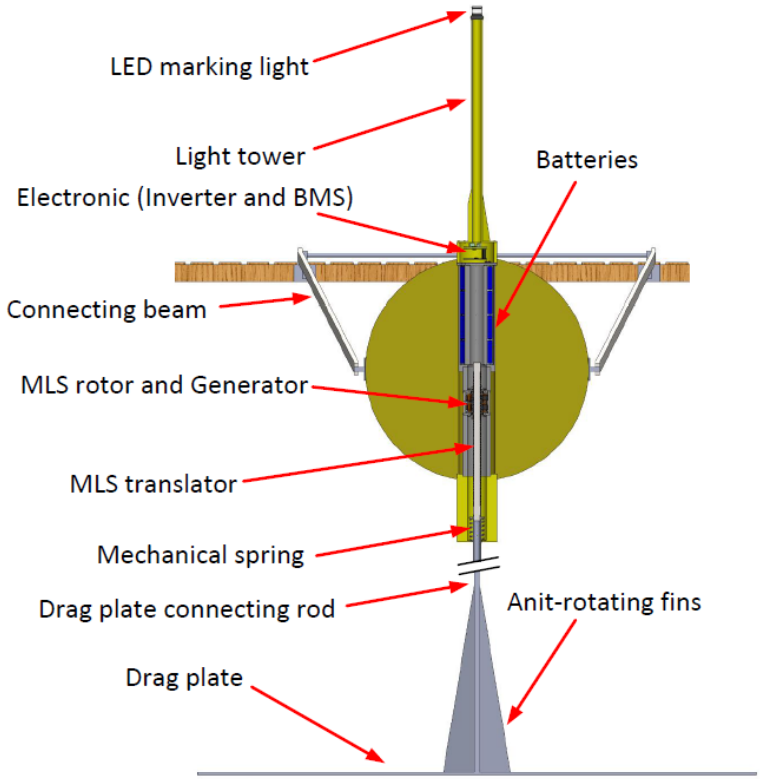
Norwegian fish farm

Commercial marking solution with batteries

Ocean Energy Light buoy - System

- A small wave energy converter is designed consisting of the following main components:
  - Magnetic lead screw unit
  - Frequency converter
  - Lithium ion battery

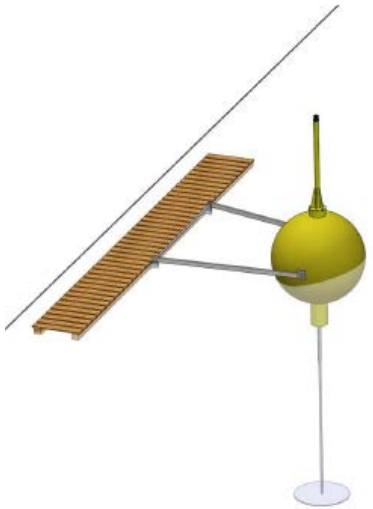




System overview

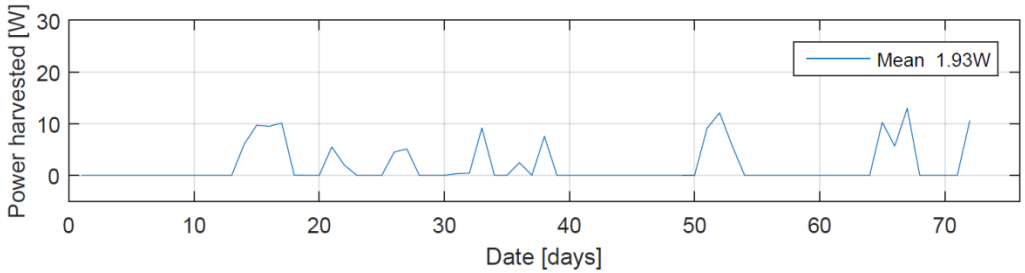
Ocean Energy Light buoy - System

- System overview
  - When the waves is lifting the buoy up and down is a linear movement between the buoy and the drag plate
  - A magnetic lead screw convert the linear movement into a high rotational movement.
  - A PM machine connected to a frequency converter convert the rotational movement into a DC Power
  - The Power is used to make the LED light at the top flash
  - A lithium ion battery mounted inside the buoy is used as a energy buffer for periods without waves

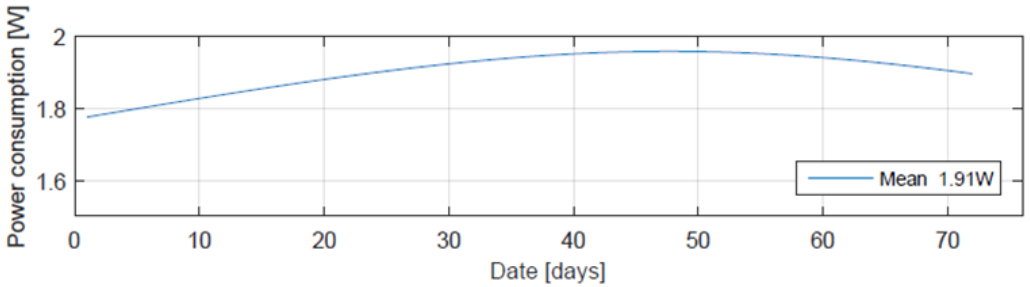


Ocean Energy Light buoy - System

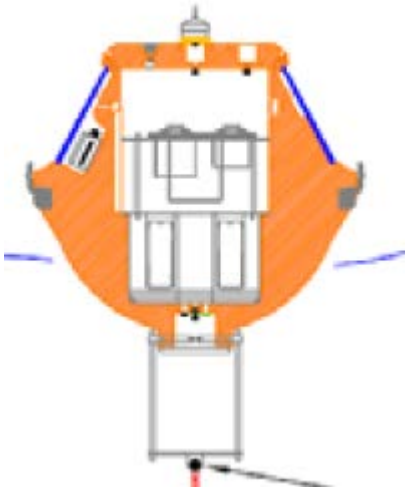
- Before the system is designed we measured waves in Norway
- The measured waves is used as input to the design model
- The first design iteration gave a mean harvest of 1.93W



- The power consumption of the LED light and electronics is estimated to:



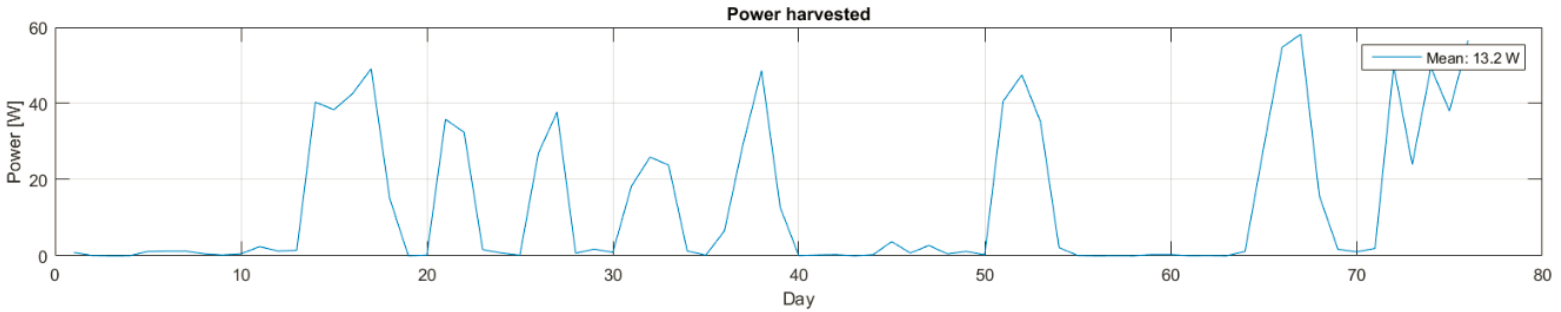
- The consumption varies, because the LED light is turned off during the day



Drawing of measurement buoy

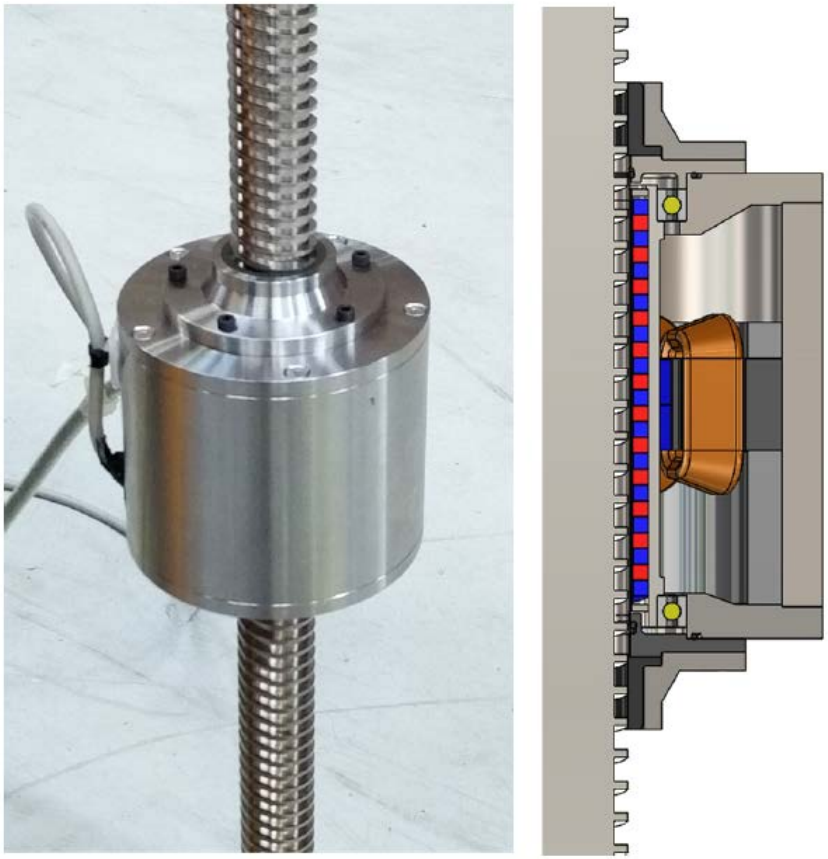
Ocean Energy Light buoy - System

- In the second iteration of the design the mean harvested power was increased to 13.3W (mainly the maximum current of the inverter was increased)



Ocean Energy Light buoy Components

- Magnetic lead screw (MLS) unit
  - The purpose of the MLS is to convert the relative slow linear velocity between the float and drag plate to a high speed rotational velocity
  - On the outside of the MLS rotor is the magnets for the generator mounted
- The magnetic lead screw is a reluctance type with the following specifications:
  - Stall force 800 N
  - Lead 14 mm / rev
  - Rotor diameter 32mm
  - MLS airgap 1.1mm
  - MLS rotor inertia 2.61 $kg\ cm^2$
  - MSL eq. mass 52 kg

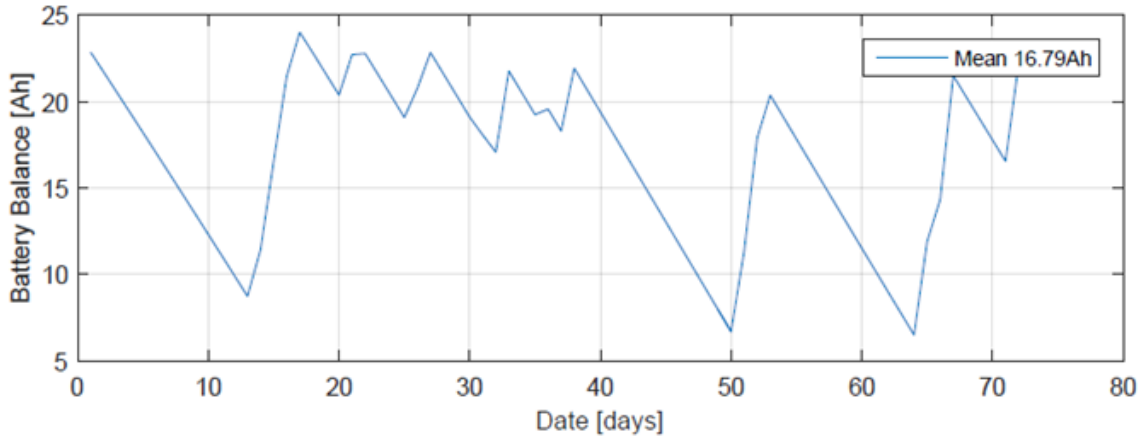


Ocean Energy Light buoy Components

- Test of the MLS unit

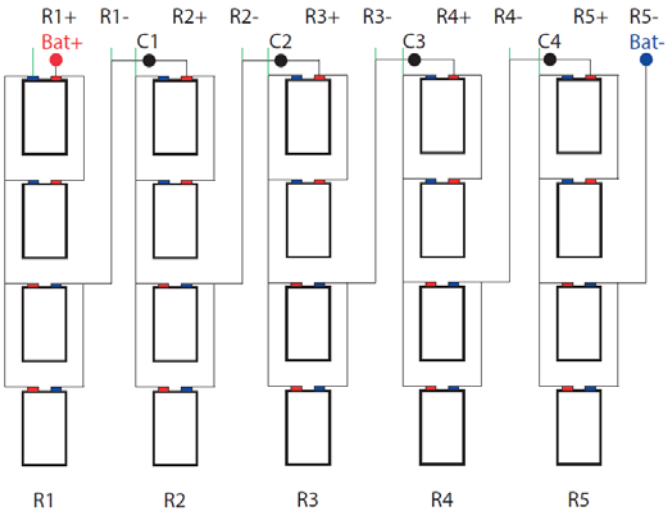
Ocean Energy Light buoy Components

- Lithium ion batteries
  - The purpose of the lithium ion battery is to supply power for the LED light at calm sea
  - The size of the battery pack is dimensioned from the calculated mean power harvest. (Iteration one)
  - The pack size is 24Ah at 37V
  - The battery is discharged to 27% state of charge



Ocean Energy Light buoy Components

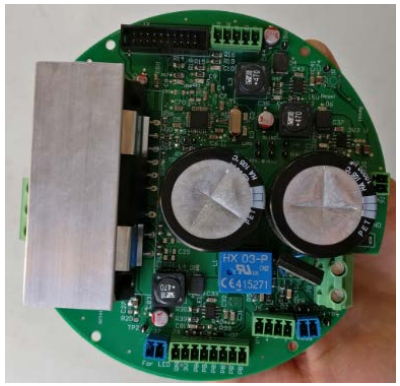
- Battery pack
  - 5 racks
  - Each rack consist of two cells in parallel and two in series

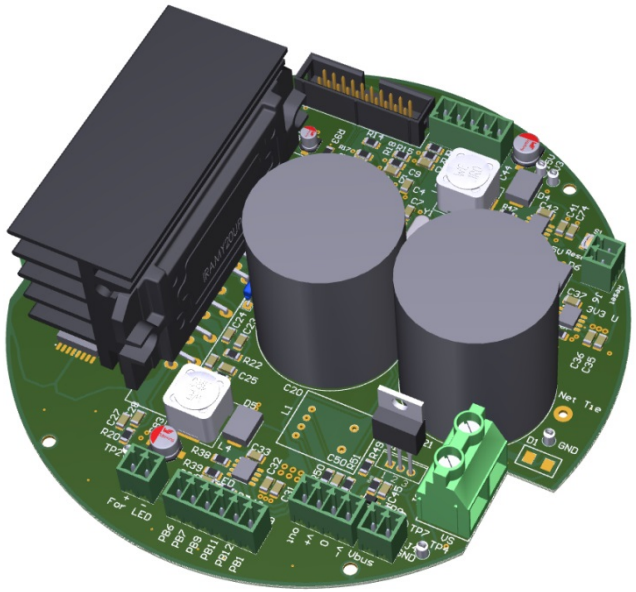


Ocean Energy Light buoy Components

Frequency converter Design

- A four layer PCB is designed with the following main components
  - Iram power module 30A RMS
  - µ-controller stm32f103
  - Switch mode DC-DC converters
  - DC link capacitors
  - Current measurements
  - Backup battery for the processor CR2032





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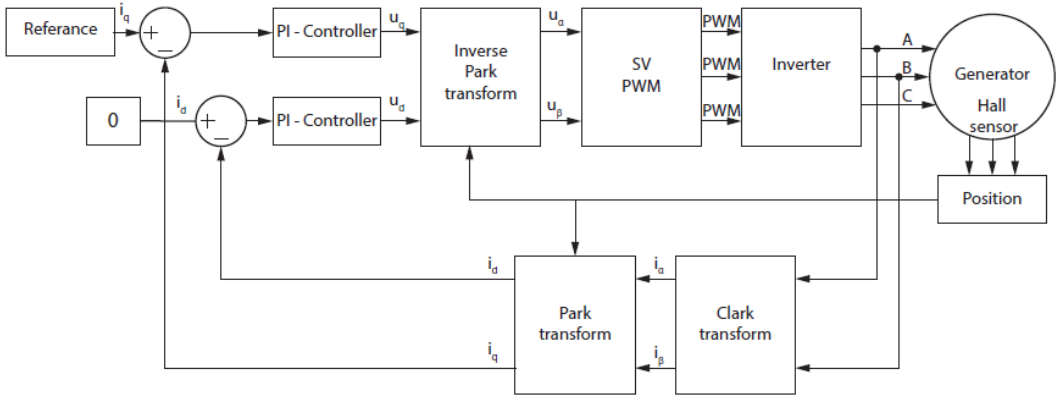
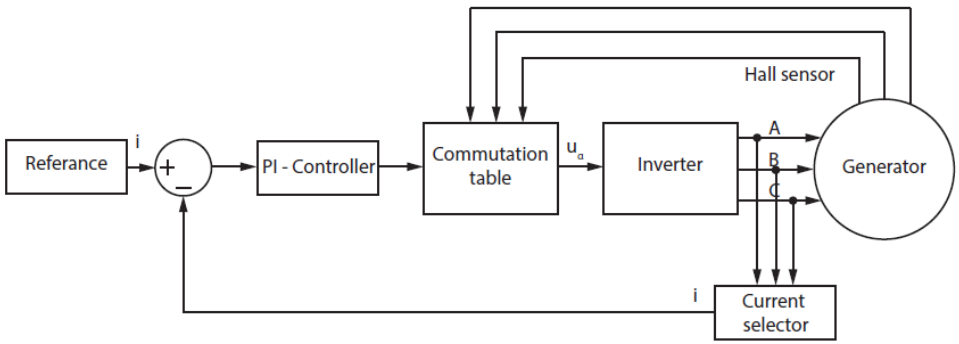
Control strategy

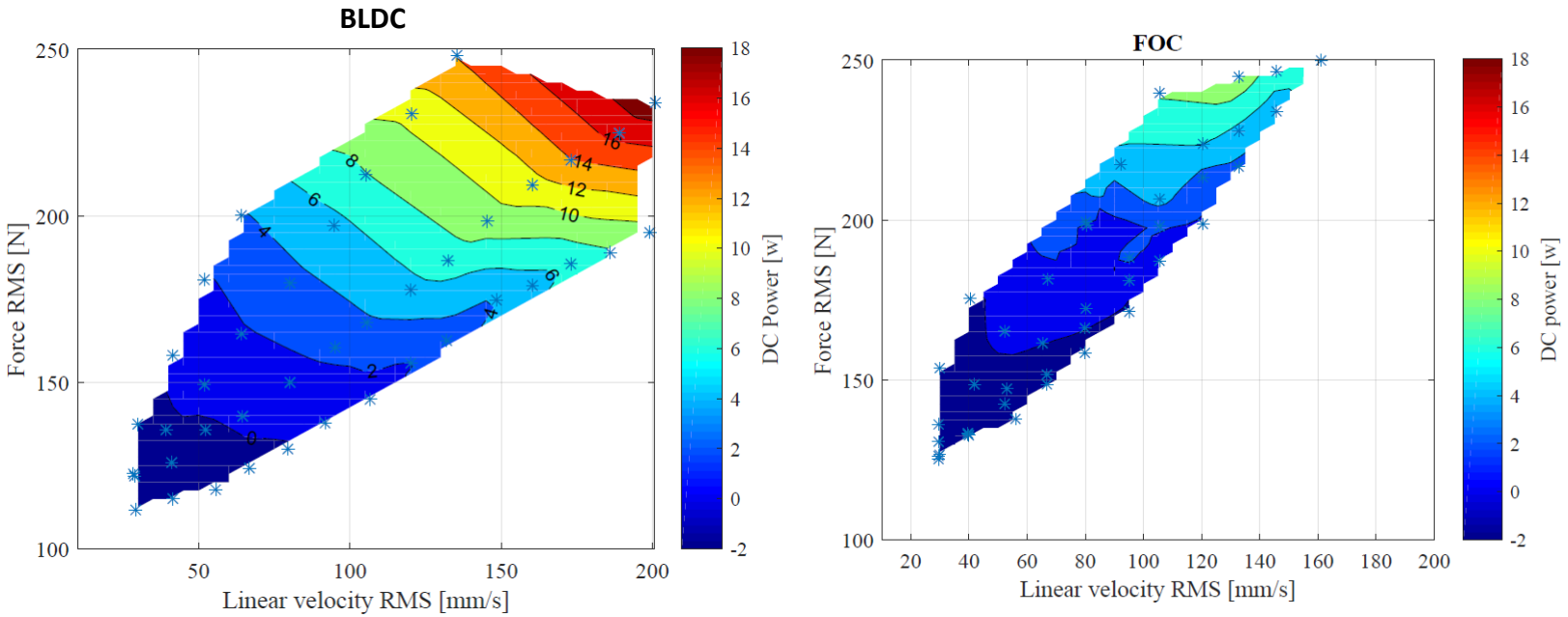
- Two different control strategies are implemented and tested.
- Brushless DC (BLDC) with square wave phase currents
- Field Oriented Control (FOC) with sinusoidal phase currents
- In both cases is the reference calculated so the system operate as a linear damping system
- $T_{eq} = \left(\frac{\lambda}{2\pi}\right)^2 \dot{\theta}_{MLS} C_s$





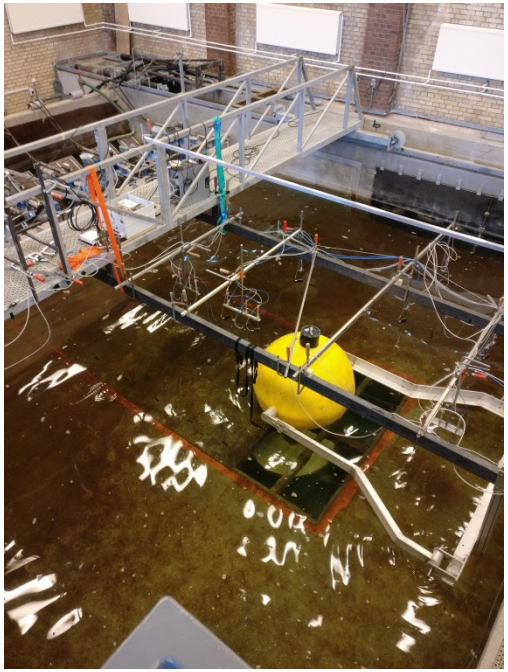
Linear test stand test

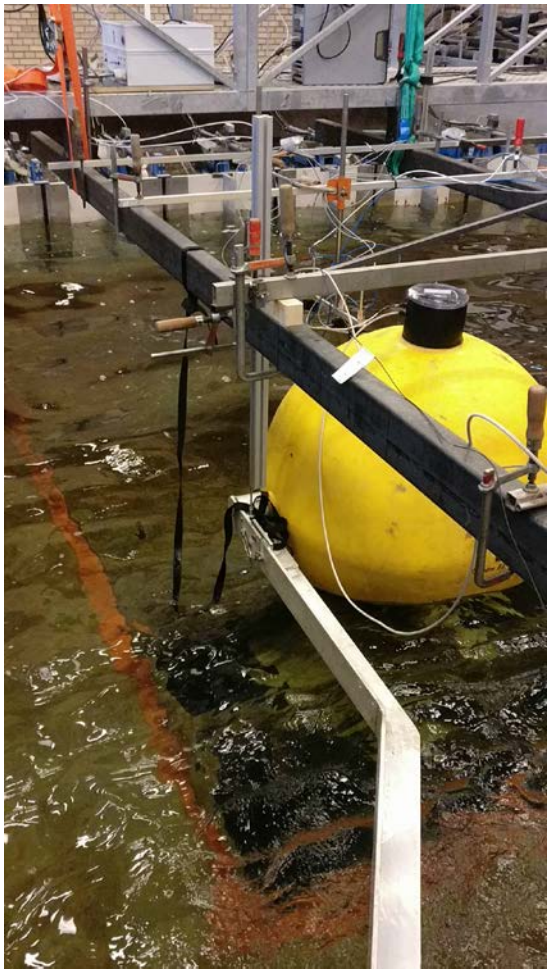
- The complete drive system (MLS, generator, inverter, and battery) is tested in the linear test bench in the workshop
- The system is tested with both control strategies, BLDC and FOC



Wave tank test of the system

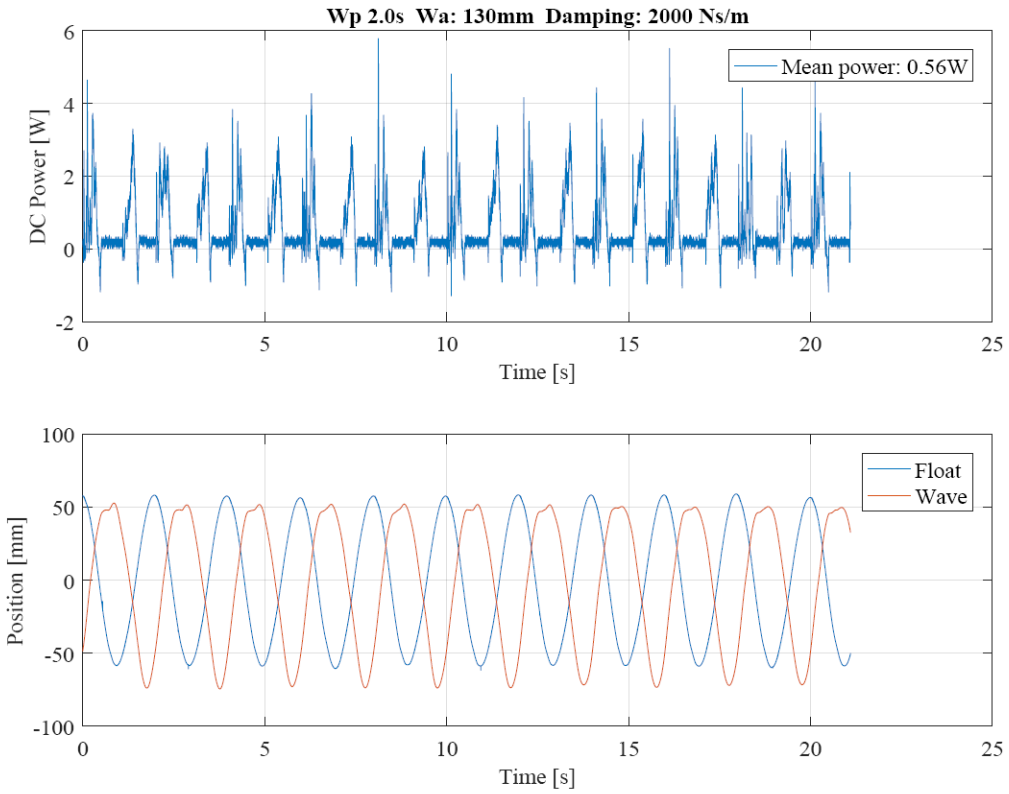
- The buoy mounted in the wave tank





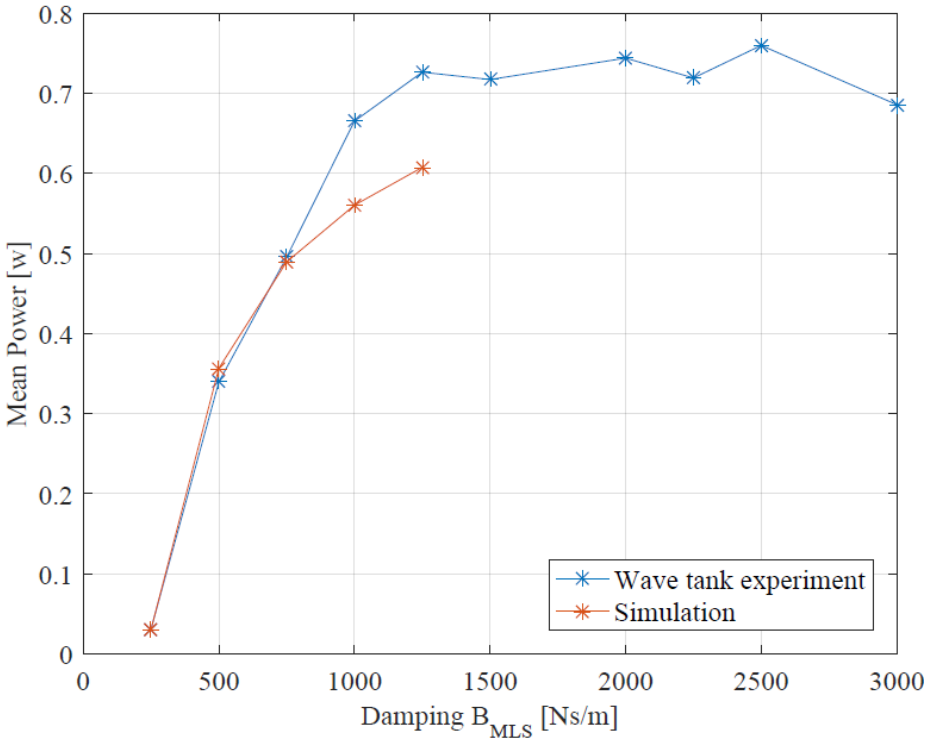
Wave tank test of the system

- The waves are considered as small
  - Period 2s
  - Amplitude 130mm
- The drag plate size was reduced from 120cm to 100cm to make the mounting possible
- The area of the drag plate is proportional to the drag force
- The results was used to validate the model



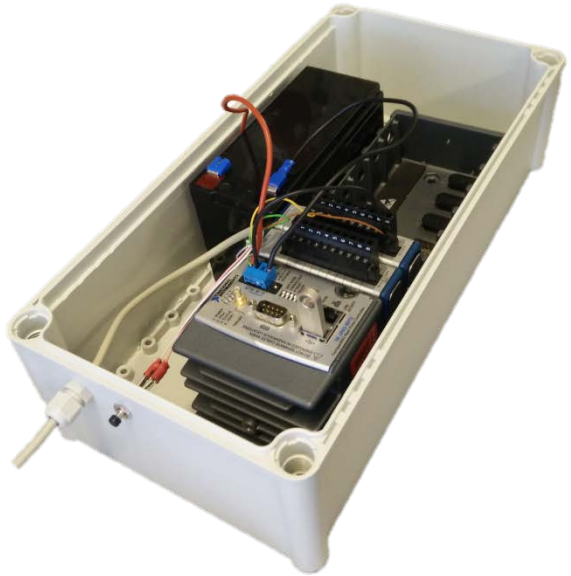
Wave tank test of the system

- Simulated results vs experimental



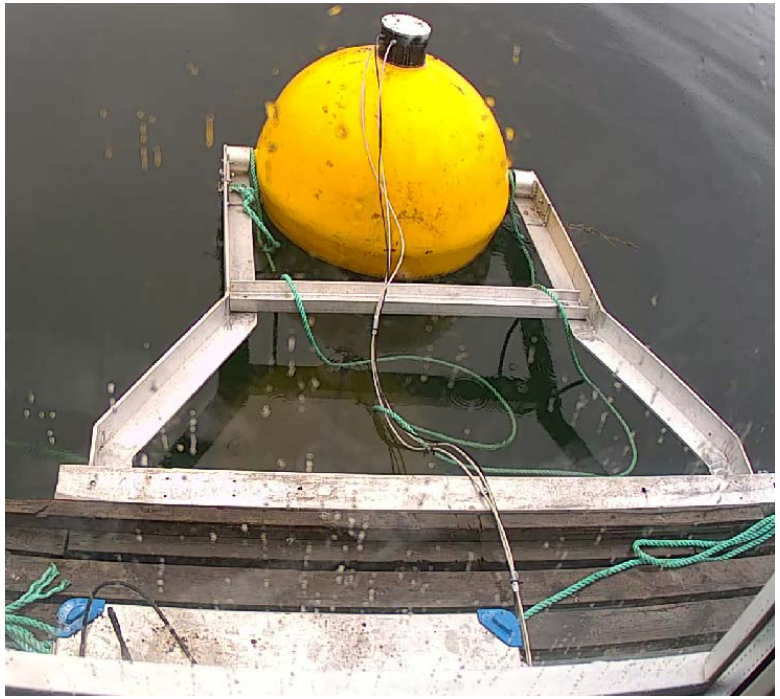
Data acquisition

- A LabVIEW data acquisition system is developed
  - For monitoring the amount of harvested energy
  - For monitoring the battery voltage
- A high frequency data logger
  - For capturing dynamics, (voltage, current, hall senor states)
- A “mean data logger” where mean values of voltages and currents are logged.



Trip to Norway for test in the sea

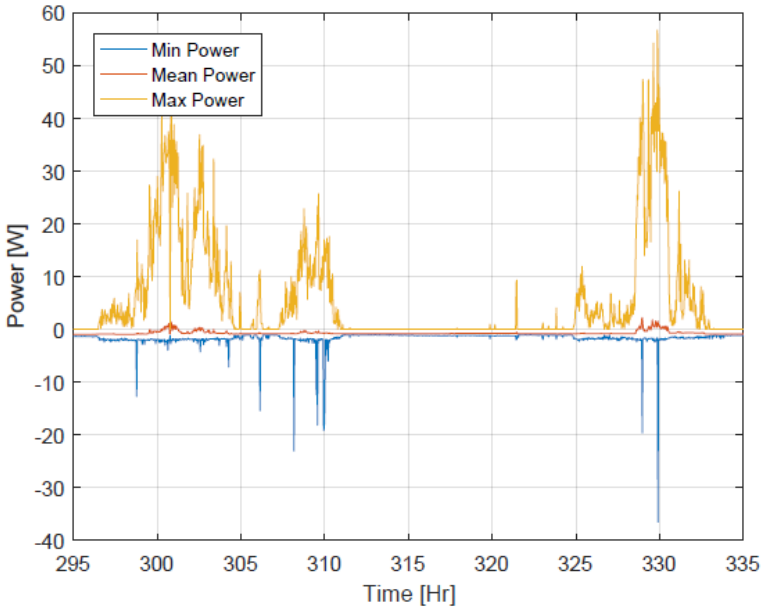
- The buoy was updated and returned to Norway where it currently is in live test.

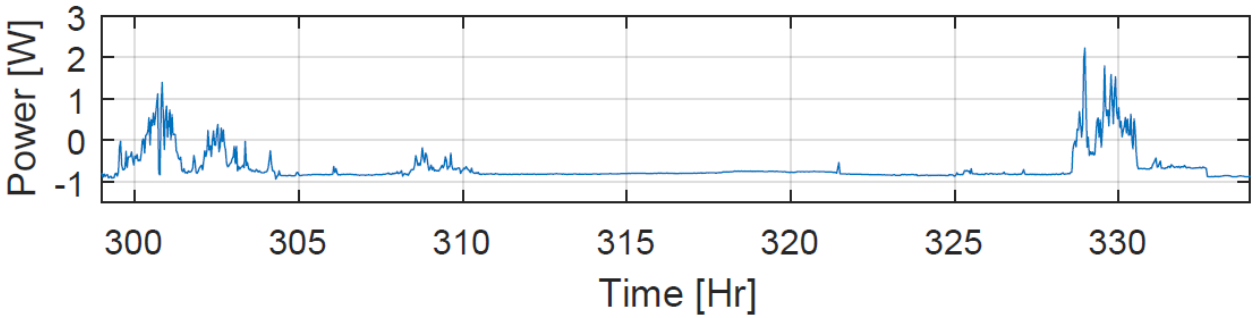


The buoy in Norway

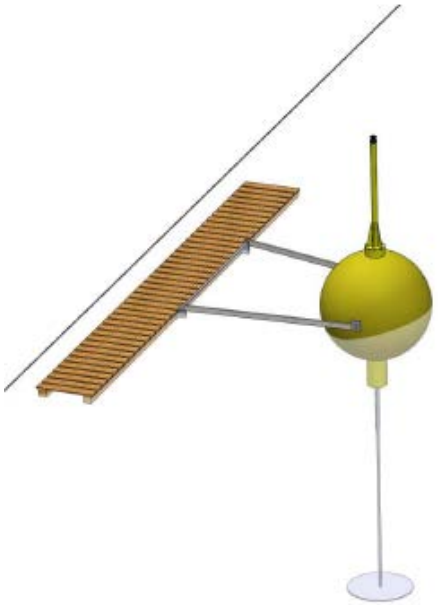
Trip to Norway for test in the sea

- Results so far
  - Each data point is a mean value for a period of 2 minutes





Thank you for your attention



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