Ocean Harvesting TECHNOLOGIES

Reducing the cost of energy for wave power

Hydraulic collection system for wave energy converter arrays with power smoothing and electricity generation in a central tower

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About OHT

- OHT was founded in 2007 and develops an innovative system for wave energy converter arrays. The system comprises a hydraulic collection system from the WEC´s to a central tower with a novel energy storage technology that smoothes the collected power before conversion to electricity.
- OHT is specialized in system design, energy storage, hydraulics and computer simulations. OHT´s strategy is to work with a small and efficient organization in close collaboration with WEC developers, a system integrator to manage supply chain, research institutions and universities.
- OHT´s business model is to be a technology supplier and/or license technology and systems for wave energy arrays, either as a supplier to the WEC companies, their infrastructure partner or directly to the project developer.

Wave power challenge

- The peak power captured from a large wave is in the order of 15-20 times higher than the average power captured in a year. Peak power equals cost and average power the revenues.
- WEC's with hydraulic power take-offs often use a fixed displacement hydraulic cylinder in combination with hydraulic accumulators to smooth power before the generator. The damping force is however difficult to control since it depends on the level of stored energy in the accumulator, which result in poor power capture performance.
- WEC's with mechanical power take-offs have control of the damping force through the generator and can capture more than twice as much energy from the waves, but energy smoothing before the generator is difficult.
- The power density of generators is low and they are less efficient in variable load conditions compared to hydraulic cylinders. Power smoothing before the generator can reduce cost and improve efficiency of the system, but must be done in a way that does not compromise the power capture performance.

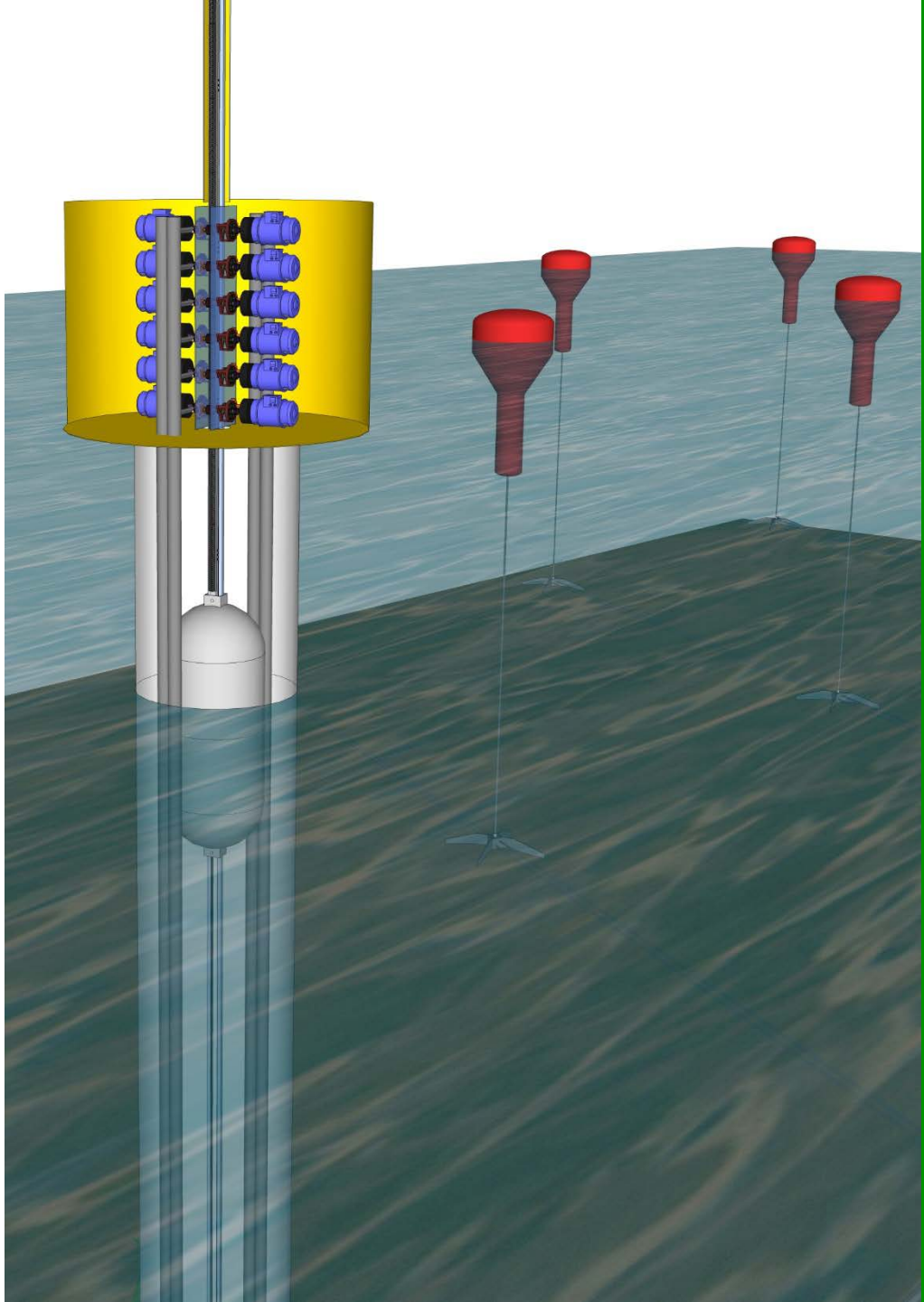
OHT´s technology offer

OHT offers a hydraulic collection system that reduces the LCoE for wave energy converter (WEC) arrays.

- **Damping force control technology for WEC´s with hydraulic PTO´s improves power capture performance**
- **Replacing on board electricity generation with hydrualic collection and centralized electricity generation reduces CAPEX**
- **Novel energy storage in the form of a counter weight reduces CAPEX, improves efficiency and enables constant power output in any sea state**

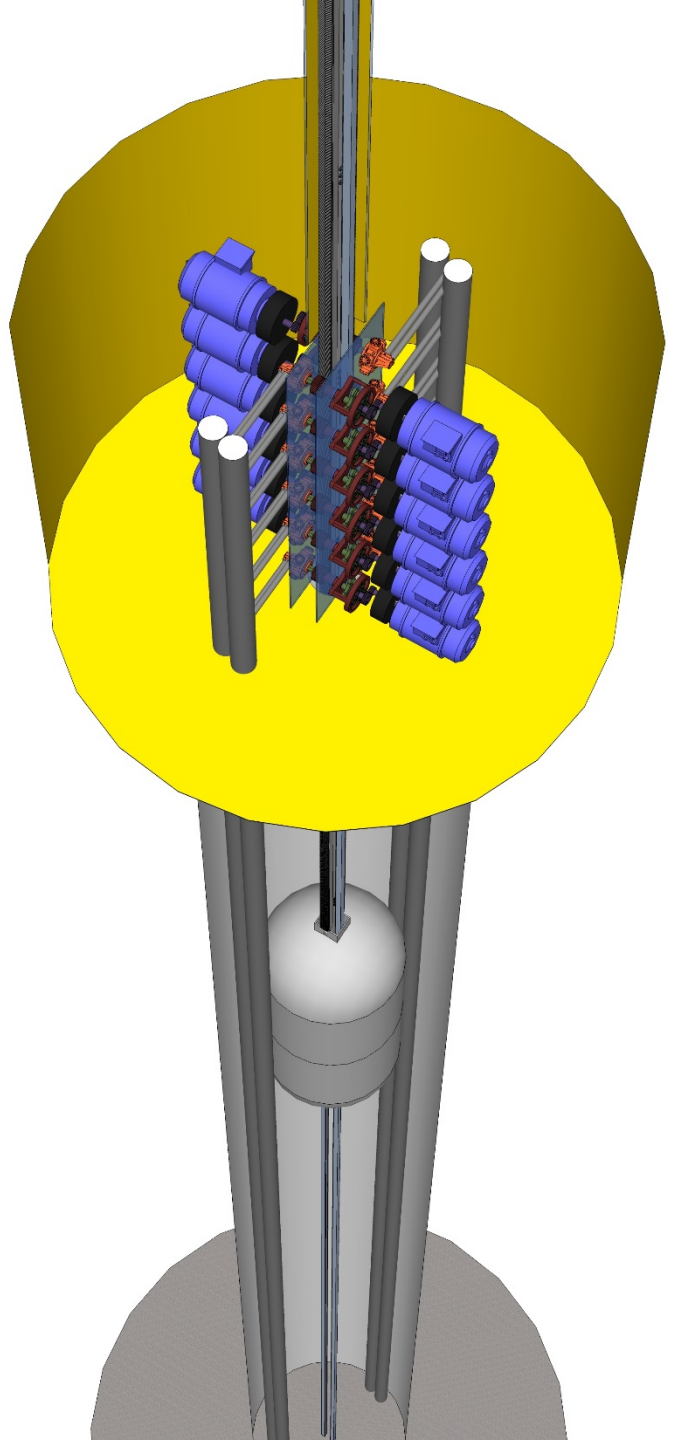
The hydrualic collection system and tower are generic and most types of WEC´s can be adapted to connect to it.

Scalable design from current 10 MW to 50 – 100 MW. Commercial arrays may have several towers.



10 MW Collection tower specification

- 10 MW continuous (±5%) output power and up to 42 MW peak power input to the hydraulic motors.
- 16 drive train modules are connected to a common 60 meter long rack and lifts a 500 ton weight in the gravity storage.
- Each drive module comprises hydraulic radial piston motor, planetary gearbox, rack pinion, flywheel and generator.
- Target to show > 80% wave-to-wire efficiency.
- Preliminary scalable up to 50-100 MW for commercial arrays.
- The tower is a CFG (Crane free gravity) foundation used for offshore wind turbines that can be floated to the installation site. This technology supports installation depth down to approx. 100 meters.
- The weight in the gravity storage is implemented as a steel container that is filled with ballast when the tower is installed.



Working principles of the gravity storage

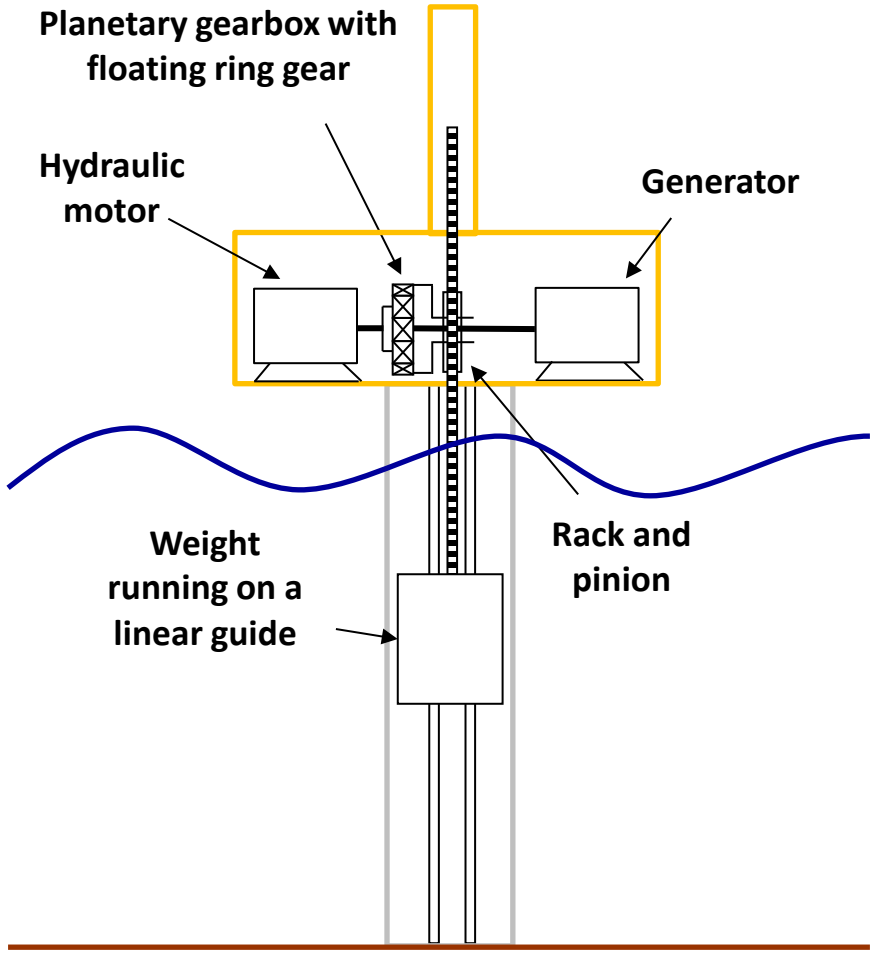
An hydraulic motor is connected to the carrier (input shaft) of a planetary gearbox, the sun (output shaft) is connected to the generator and the floating ring gear is connected to a rack and pinion drive.

The weight in the gravity storage gives a constant torque in the gearbox, and constant pressure to the hydraulic system.

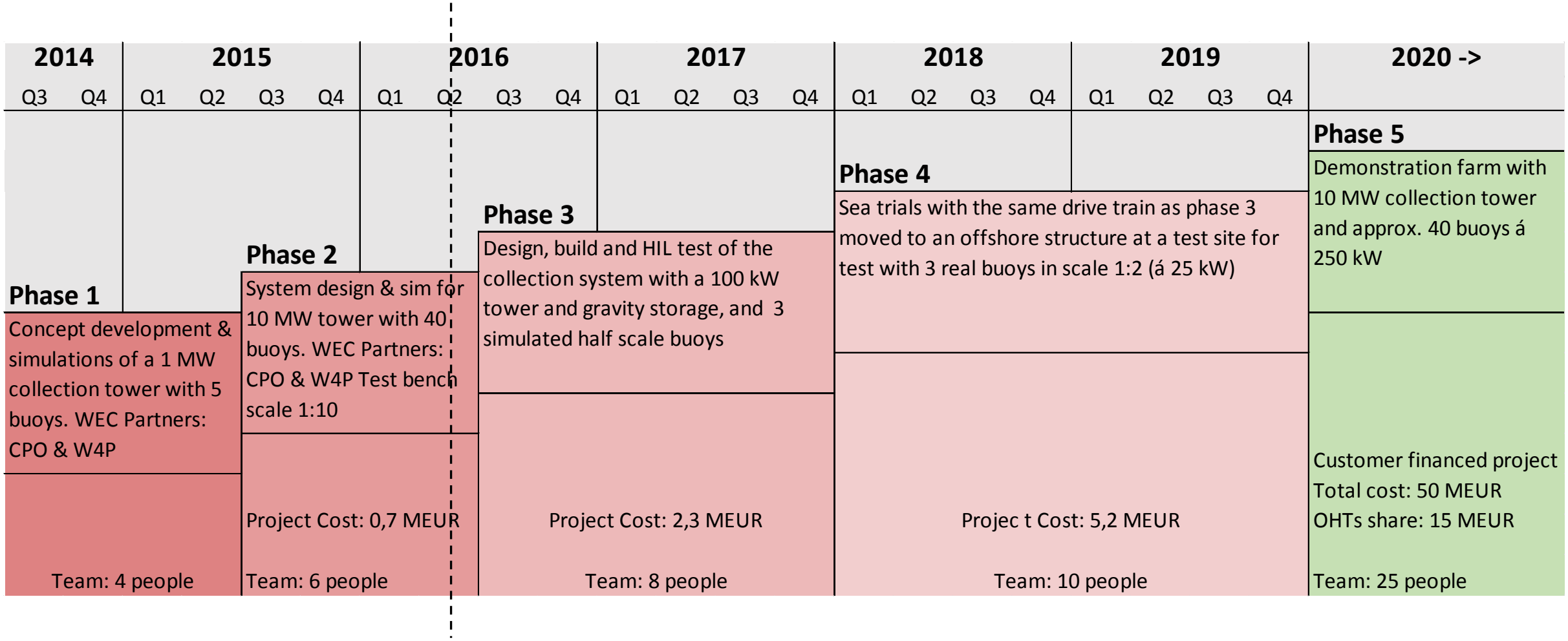
The generator is controlled to operate with a constant speed, that gives a power output that matches with the average energy in the current sea state.

When the input power (speed) of the hydraulic motor is higher than the output from the generator, the ring gear is forced to rotate forward to lift the weight in the accumulator.

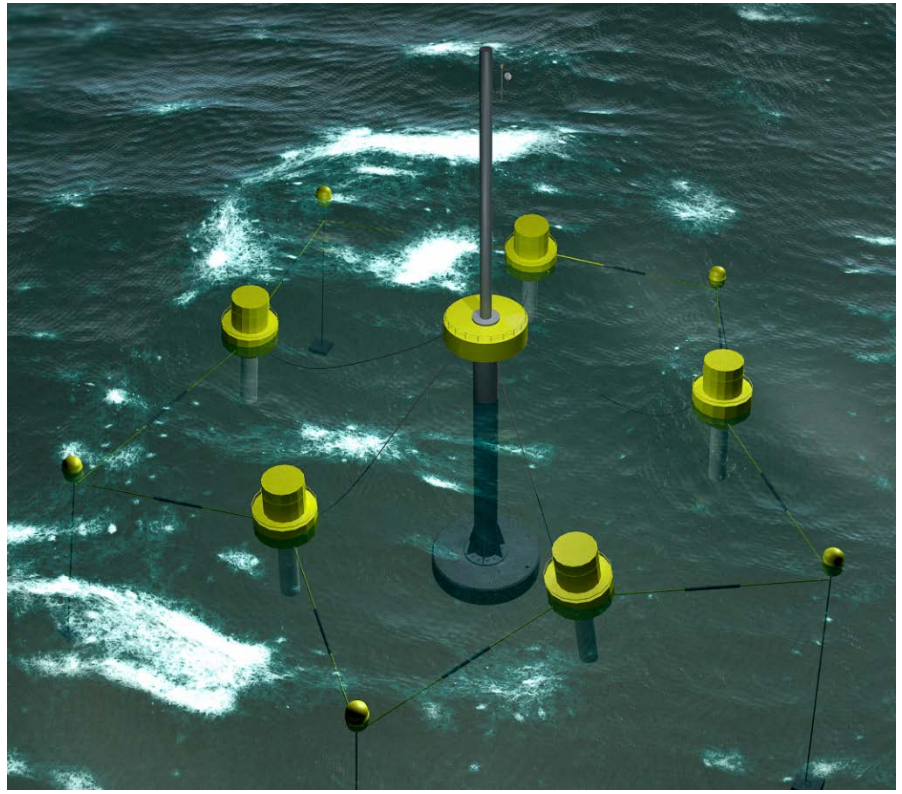
When the input power is less than the output, the ring gear rotates in the opposite direction to maintain a constant speed on the generator.



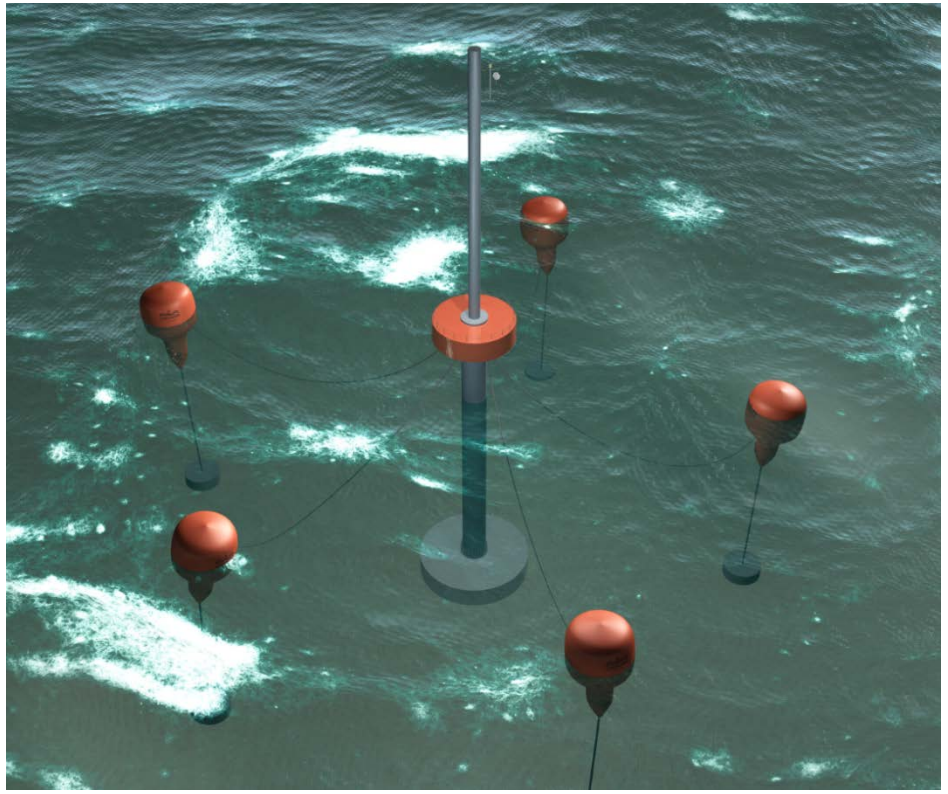
OHT roadmap



Phase 1 – Concept evaluated with simulations in collaboration with Waves4Power och CorPower

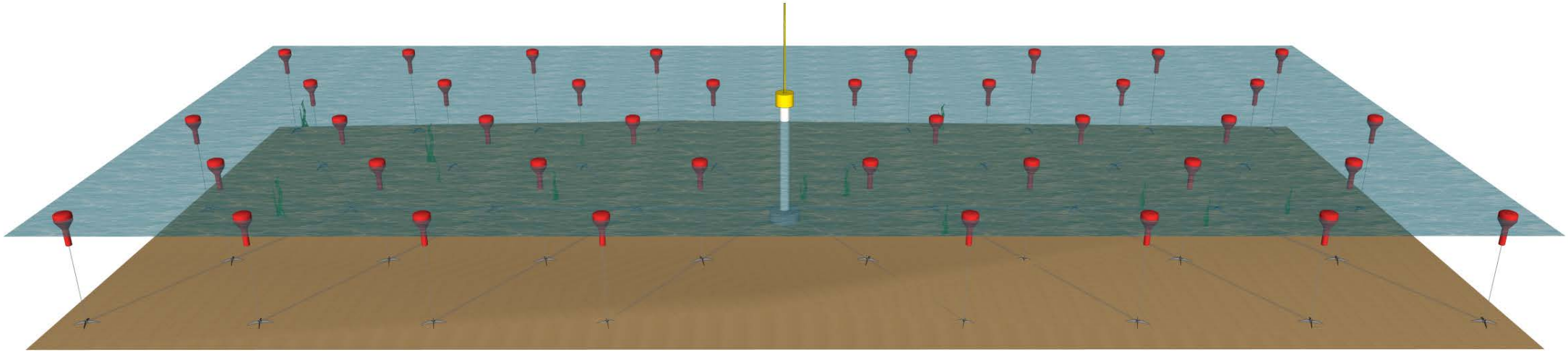


Two-bodied point absorber with a water piston in a water column provides a smart by-pass function that reduces end stop loads and secures survival.



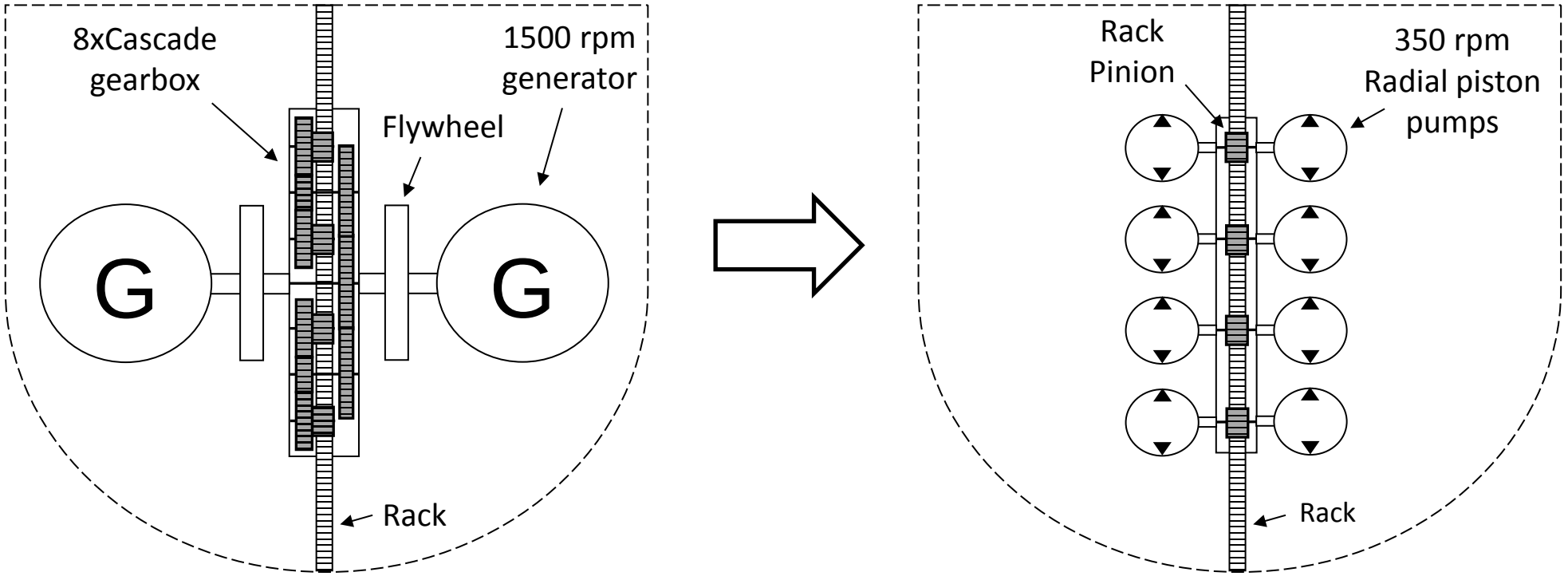
High performance light weight WEC with bi-directional power capture, rack and pinion drive with flywheel damping/smoothing and WaveSpring phase control.

Phase 2 – System design of 10 MW array in collaboration with CorPower and Waves4Power



- System design based on standard components for a 10 MW demonstration arrays comprising 40-50 buoys from CorPower resp. Waves4Power connected to OHT´s collection tower with gravity storage technology.
- Simulation models are extended to the full array, MPC controller is developed to improve the control of the gravity storage and implement wave-by-wave damping force control in the buoys, loss modelling is improved and more complete.
- Evaluate if CorPowers power take-off can be applied in Waves4Powers buoy to improve power capture.

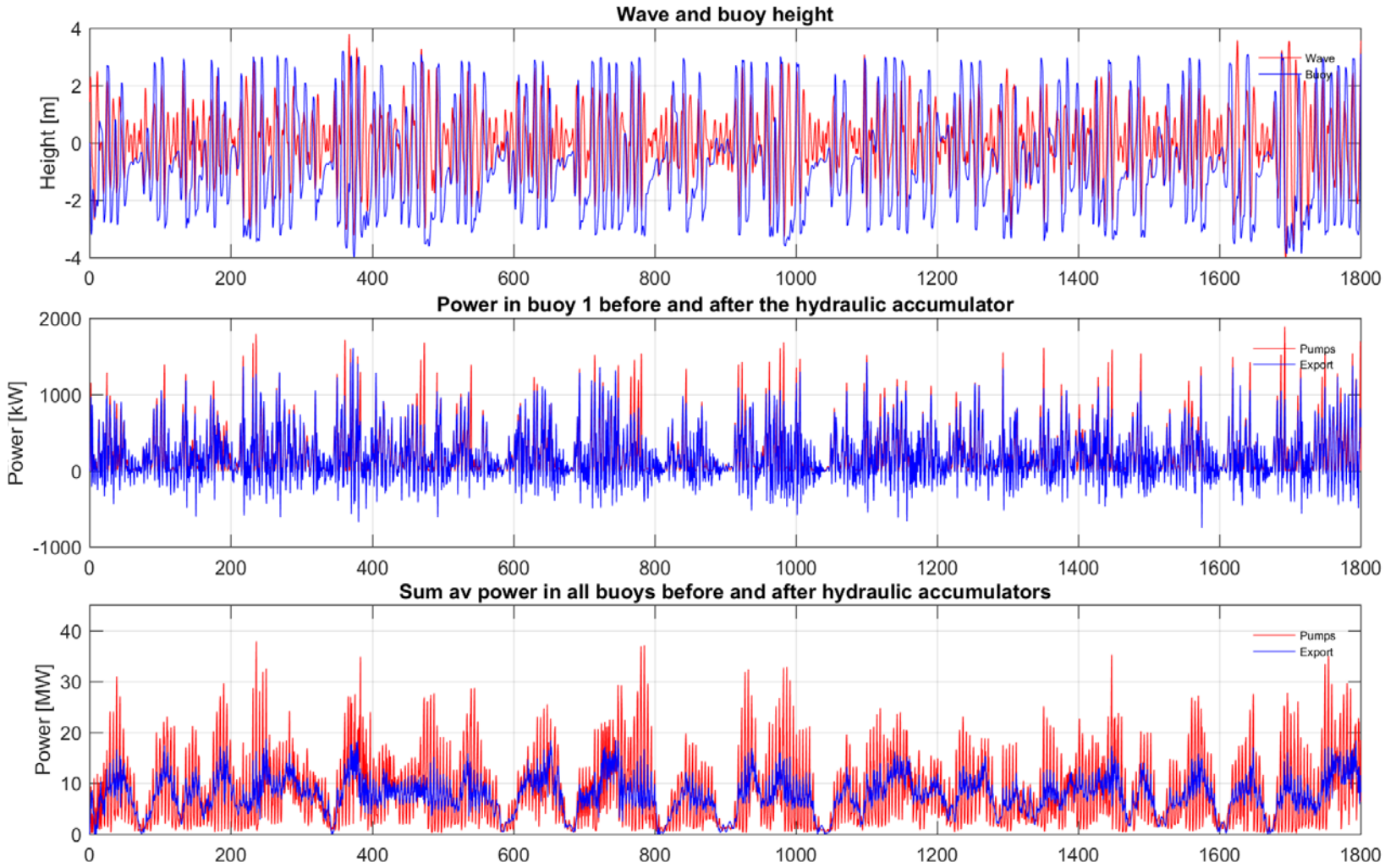
Proposed adaptation of CPO WEC for hydraulic collection



- Efficient damping force control through multiple fixed displacement hydraulic pump units and constant system pressure.
- Hydraulic radial piston pumps have x10 higher power density compared to generators despite the lower speed, and are more efficient in variable load conditions.

Phase 2: Simulation of array with 40 CorPower buoys

Constant damping force



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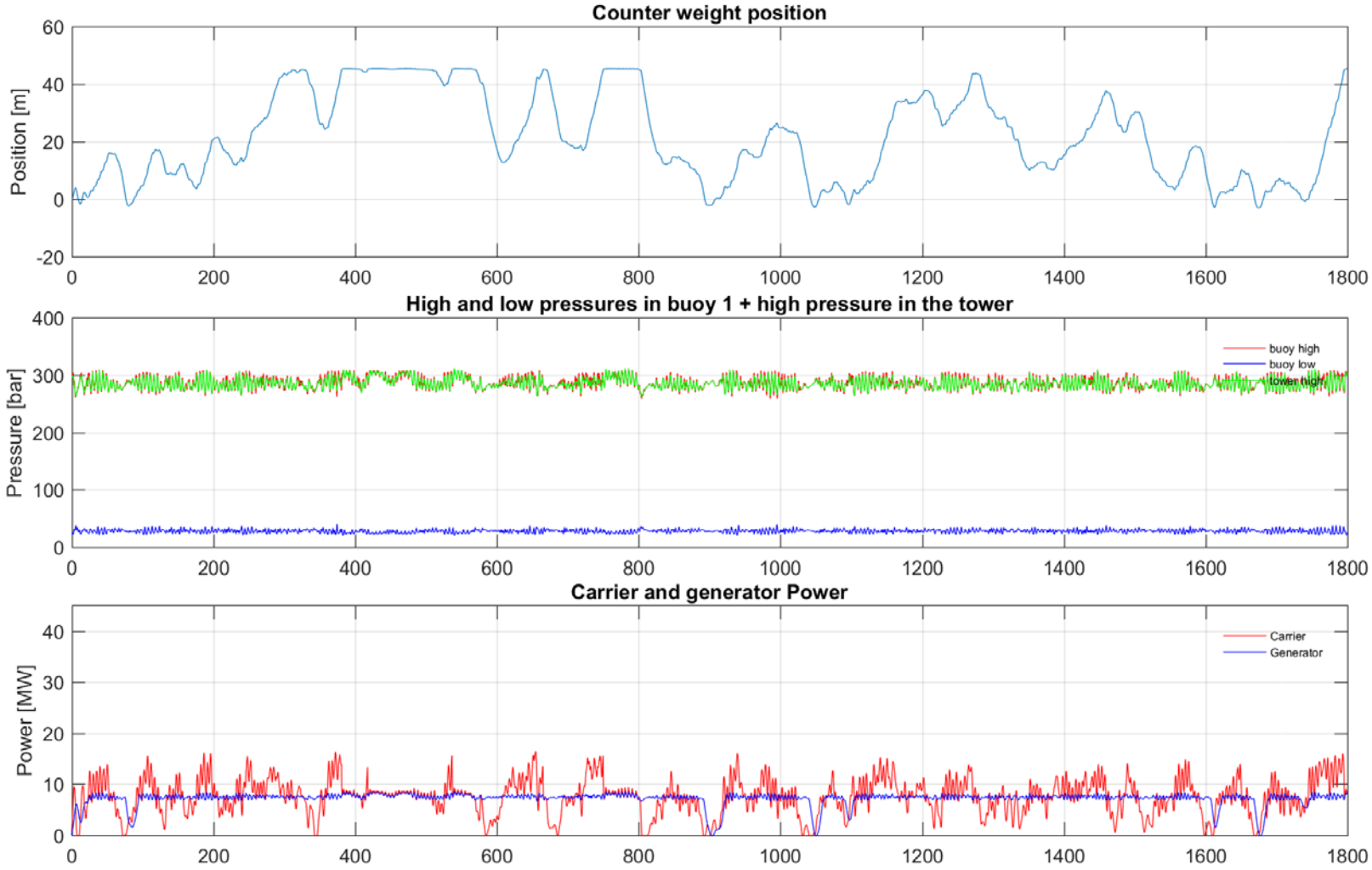
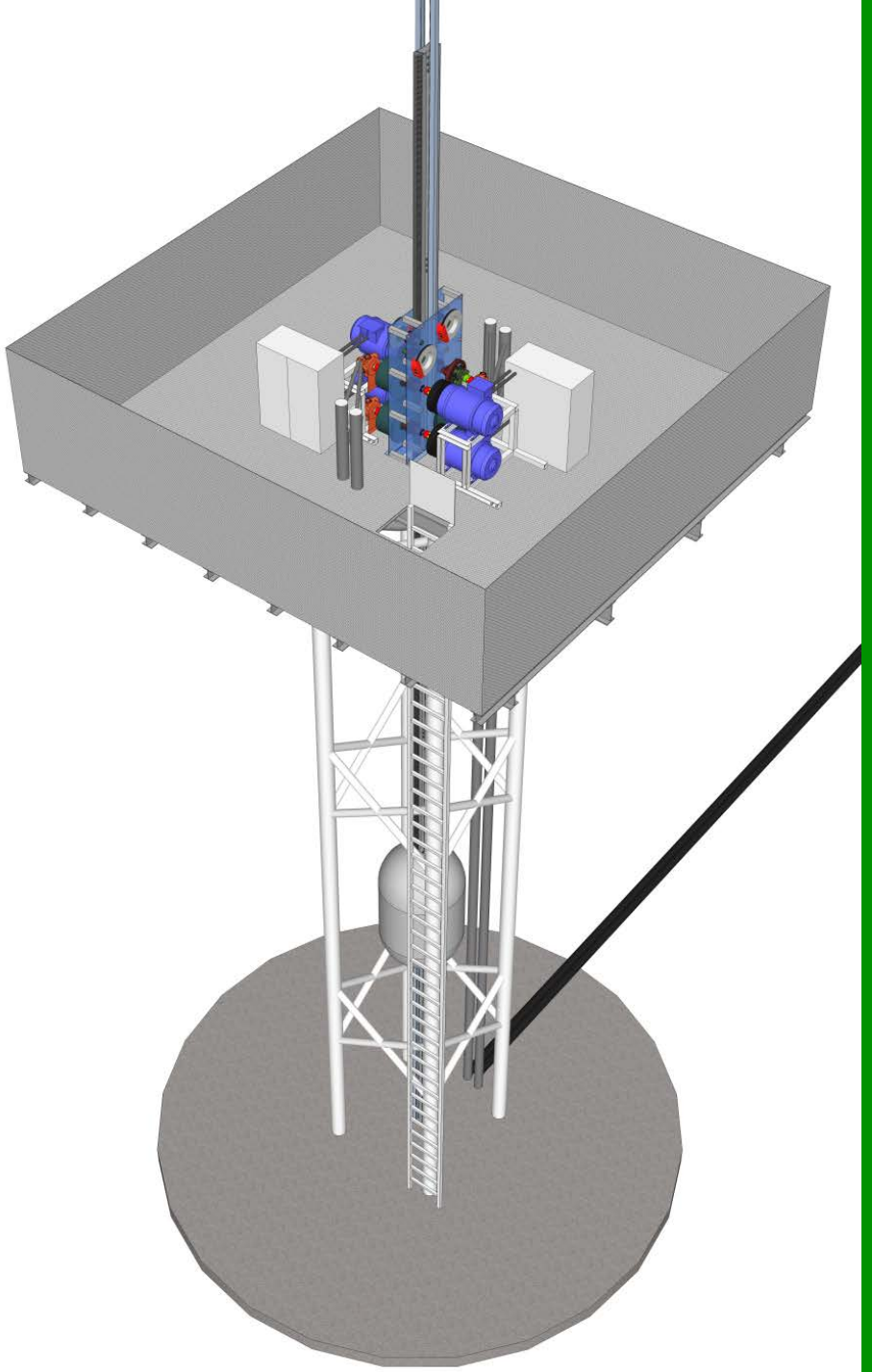


Phase 2 – Upgrade of small scale functional test rig

- Functional test rig for collection tower drive train sized for 3 buoys in scale 1:10.
- Hardware in the loop simulations with simulated buoys dynamically connected to the test rig.
- Hydraulic circuit to be installed to simulate input flow to one drive train module, comprising radial piston motor, gravity storage and PM generator.
- Active and passive spill functions to limit the maximum position of the counter weight.
- Linear guide to be installed for the weight with safety end stop bumpers.

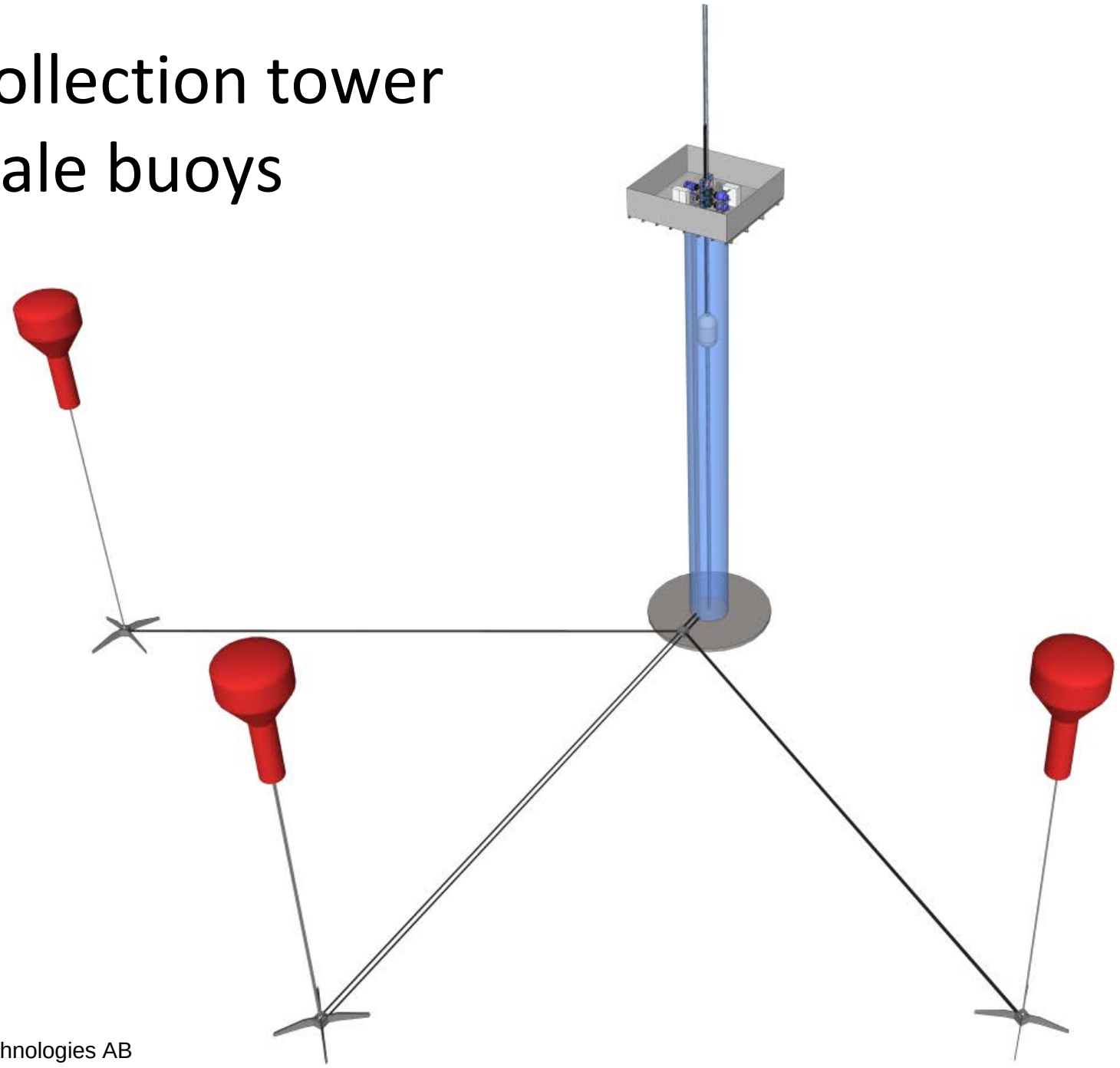
Phase 3 – Half scale proof of design test rig

- Collection tower sized for 3 half scale buoys for dry testing, with same base functionality as the phase 2 test rig.
- Rated for 750 kW peak hydraulic input and 100 kW continuous electrical output.
- Gravity storage with 10 ton weight and 9 meter stroke length.
- The drive train is comprised of four drive train modules connected to a common gear rack.
- Disc break system secures the weight during service and in case of failure modes.

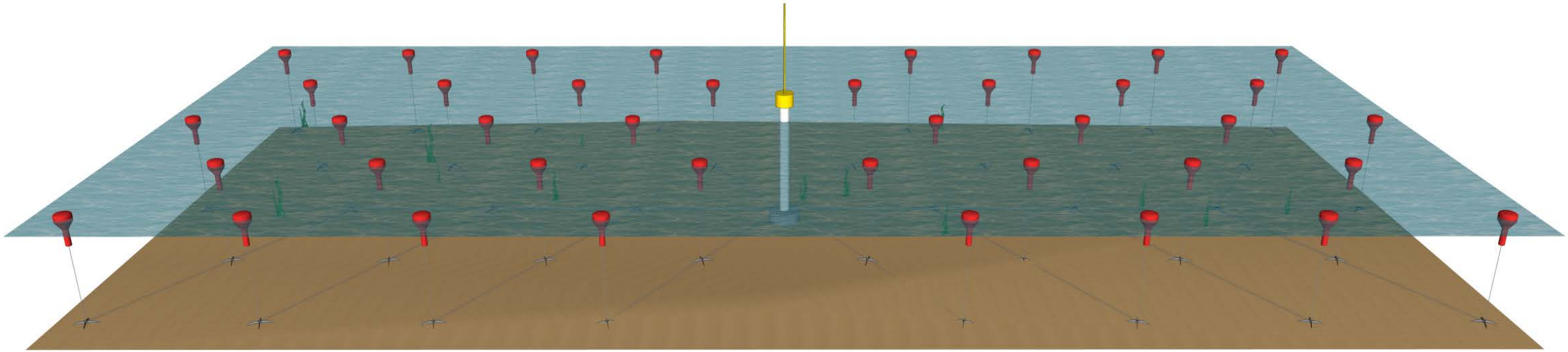


Phase 4 – Sea trial of collection tower with three half scale buoys

- Collection tower connected to 3 half scale WECs in a sea trial.
- PTO in WEC´s modified with radial piston pumps.
- Tower drive train from phase 3 moved to offshore structure, rack extended for 20 meter stroke length.
- Collection system with piping on the sea bed and dynamic connection to buoys installed.



Phase 5 – Sea trial of 10 MW WEC array



- Phase 3 and 4 will validate the system functionality and design with three half scale buoys connected to a 100 kW tower.
- In phase 5, the system will be scaled up to a 10 MW tower with 40-50 buoys to demonstrate the technology at full scale.

Thank you for your attention!