Clean Electricity Generation

Capturing Wave Energy with Nodding Ducks

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Introduction:

This document proposes a method for generating electricity from wave power; it uses nodding ducks to pump water through a turbine to drive an alternator. The capital cost is expected to be around £UK 120,000 to £UK 180,000 per megawatt in one-off quantities, depending on wave-power; this will reduce with quantity manufacture. Much of the equipment is made from recycled plastic; the only metal parts are turbine, alternator, anchor cables and electricity cables. Very low technology is employed so the running costs are minimal and such systems could be used in developing countries with limited technology support infrastructures.

Those living in land-locked countries, and those where the wave power is very limited should look at two other documents: "Electricity from Kites" and "Electricity from Disused Cooling Towers", both by the same author as this document, see references below.

Wave Capture with Nodding Ducks:

Nodding ducks are used to pump sea-water onto a raft containing the power generation equipment. Water is drawn from the dark zone, about 70 metres depth or more, but well above the sea-floor; this is to minimise the sea-life drawn through the pumps. The simplest and most reliable design would use a diaphragm or bellows pump of 50 to 150 cm across, (depending on the local wave power), located under one of the pair of nodding ducks, driven by an adjustable lever arm mounted under the other. The whole thing can be made from recycled plastic. The water is conducted through a manifold connecting the entire array of nodding ducks to turbine/alternator sets mounted on floating rafts distributed along the array.

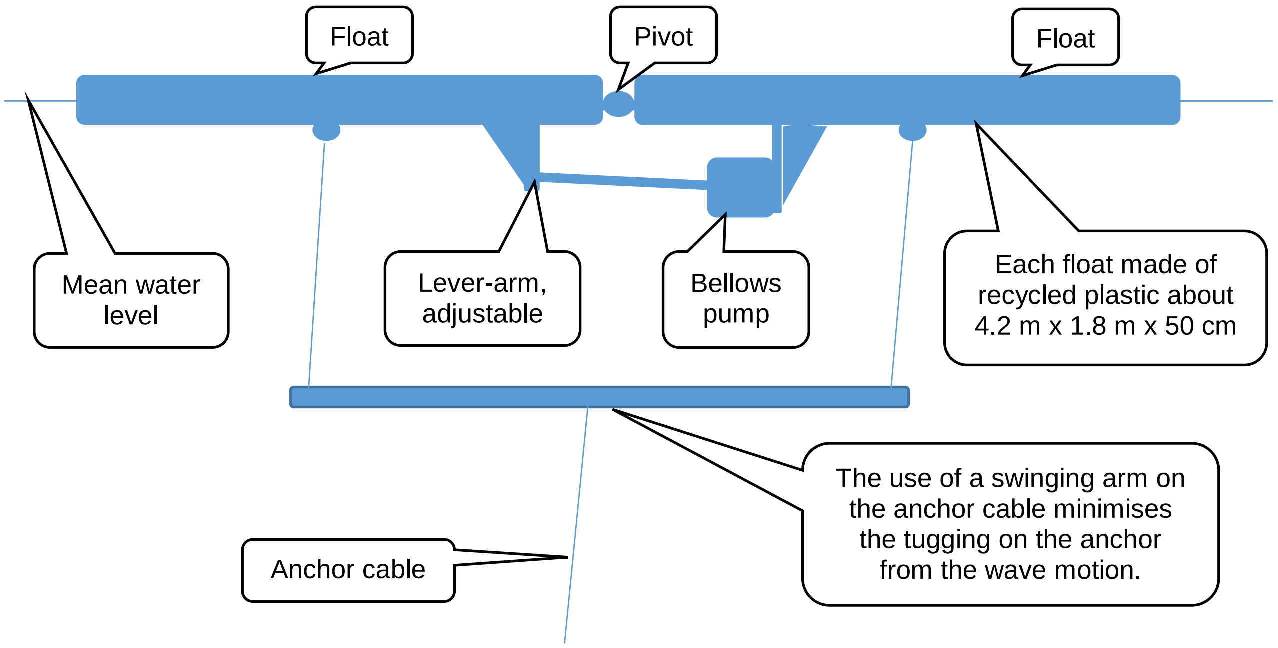
The average energy per metre of wave front varies greatly around the world, and peaks in latitudes of 30°-70° north and south of the equator with typical values of 30-70 kW/m off coasts facing large oceans, and up to 100kW/m in a few areas. Each array of nodding ducks, (two rows of ≈550 pairs of floats, each about 8-10 m long and 1.8 m wide and intercepting a wave-front of 1 km), would be capable of capturing about 15% of the available wave energy at that location. Capturing 15% of 40 kW/m with such an array would generate about 6 MW; a few areas could more than double that. The water turbines and alternators are mounted on small rafts distributed along the array of nodding ducks. The power output of the alternator is rectified and transmitted ashore as DC through the underwater two-core cable, (DC suffers no capacitive losses in an underwater cable), then connected to the on-shore electricity grid via a grid-tied inverter. Please note that it is not recommended to use a single core DC cable with the sea as the return path because of the destructive effect on sea-life.

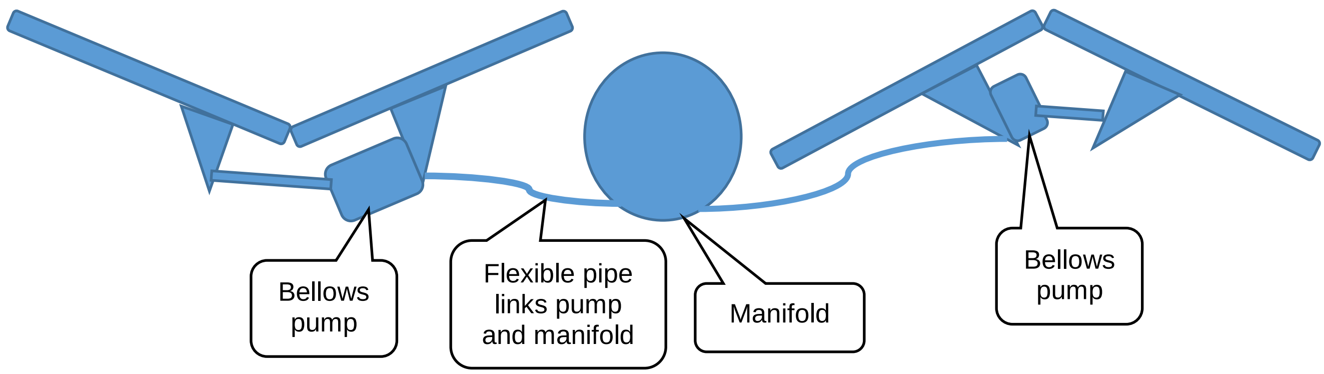
The manifold pipe has an internal closed-cell flexible foam sausage along its length occupying about 40% of the cross-sectional area at atmospheric pressure, (≈10% of the cross-section when in service). This ensures that the pipe will float and acts as a hydraulic accumulator to absorb pressure fluctuations caused by variations in the wave arrival pattern at the array of nodding ducks. Each pump connection into the manifold has a built-in flap valve (non-return valve) to facilitate maintenance and minimise the impact of pump or flexible pipe failure.

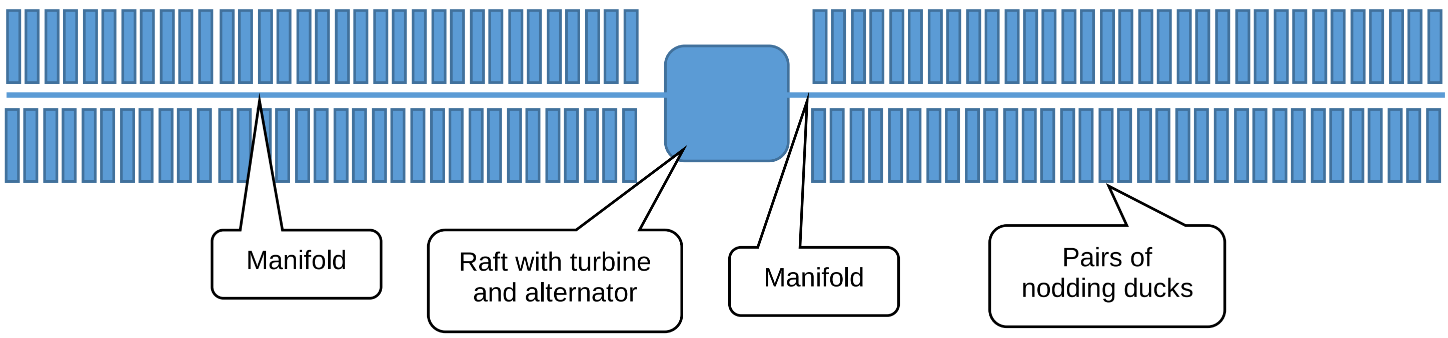
Each megawatt of power requires around 250,000 tonnes of water per day, (≈2.9 m^3/sec), pumped through the turbine at a pressure of around 4 bar; this is equivalent to about 180 m of the 1000 m array. Each nodding duck thus needs to pump 0.15 cu m per wave cycle into a pressure of 4 bar. A 1km long array of nodding ducks can pump about 1.35 million tonnes per day at 4 bar in a sea with a wave energy of 40kW/m generating about 5.4 MW of electrical power.

The capital cost per megawatt for a single system is expected to be about £UK 120,000 to £UK 180,000, depending on wave power. Larger arrays or manufacture in quantity would give a lower cost per megawatt. This is far cheaper than wind turbines or any of the currently available wave generation systems. Far cheaper per megawatt than fossil fuelled or nuclear power plants. Also wave-power is far more dependable than wind-power.

Diagrams:







The technology is deliberately simple to minimise maintenance costs and to ensure that these systems could be installed off the shores of countries with limited access to a sophisticated technology infrastructure. Maintenance would consist of routine changing and cleaning of filters on each pump suction, (once a week), and the periodic, (annual), removal of each pair of nodding ducks for inspection and cleaning or replacement if required. It is estimated that a team of 15-18 people, (including 3 scuba divers), could perform all of the on-site maintenance work for six 1km arrays of the type described here. The cost of this manpower is likely to be about ½ UK penny per kWh, (0.6¢US). A spare turbine/alternator raft should be kept in storage. If one fails, it can be replaced from storage, and the faulty one towed away for repair. Disconnection and reconnection of the high voltage DC cable will require a properly qualified electrical engineer, brought in on contract when needed.

For reasons of marine safety, each array of nodding ducks should be fluorescent yellow or orange on the upper surface with masts at intervals supporting radar reflectors and solar powered warning strobe lights. It is proposed that gaps of at least half a kilometre should be left between adjacent arrays of nodding ducks for sea-going vessels to reach harbours.

Research has shown, (see references), that the wave energy recovers after about 30 km, thus several lines of these arrays could be employed across the whole width of the continental shelf.

There is a problem with electricity grid stability in the UK and many other countries with large electricity grids. This limits the amount of electrical power from renewable resources that can be put into the grid. In Scotland, which has plentiful renewable electricity resources, about 75% of the available renewable power is unused because of this. Please see the proposal: “Electricity Grid Stability” in the references section, which provides a solution to this problem and will enable maximum utilisation of renewable electrical power resources.

Secondary benefits:

As the two rows of nodding ducks would reduce the shore-side wave energy by about 15%, installing them to protect areas of land suffering from serious coastal erosion would have obvious secondary benefits.

These arrays would be attractive to colonies of seals and could provide suitable breeding and basking sites. Having a few seals on a pair of nodding ducks makes almost no difference to the efficiency of conversion of wave energy into hydraulic energy. The seals may obstruct the regular filter changing procedure; those changing the filters should carry some buckets of fish to attract the seals away from the filter access hatches.

The extensive use of recycled plastic in the manufacture of these systems would help to clean up the environment which is becoming increasingly polluted with discarded plastics, and would provide valuable employment and income in many third-world countries.

Such rafts could provide a safe haven in an emergency for the passengers and crew of a vessel that is sinking or has a fire on board.

The sheltered habitat under the nodding ducks would be attractive to fish and other marine life forms, thus providing opportunities for local fishermen as well as for the seal colonies.

References:

https://www.ecowavepower.com/ provides maps and lists showing wave-energy potential per metre of wave-front across the globe.

https://waves-energy.co/maps/ provides maps and lists showing wave-energy potential per metre of wave-front across the globe.

https://www.researchgate.net/publication/279476108 Wave_energy_conversion_and_the_marine_environment_Colonization_patterns_and_habitat_dynamics: Olivia Langhamer, 2009

The next three documents are all by the same author as this document and they can be found on http://www.intint.co.uk/environ.html .

Electricity Grid Stability:

Electricity from Kites:

Electricity from Disused Cooling Towers: