WAVECO

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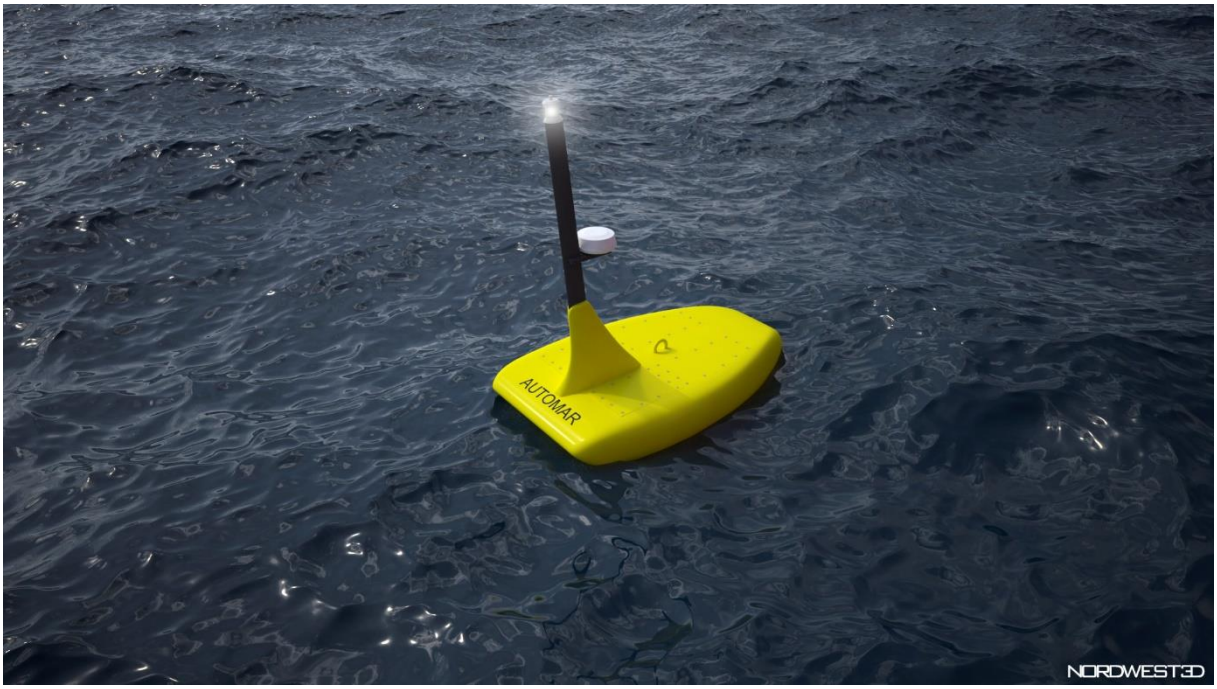
TECHNICAL DESCRIPTION

Prepared by Waveco AS

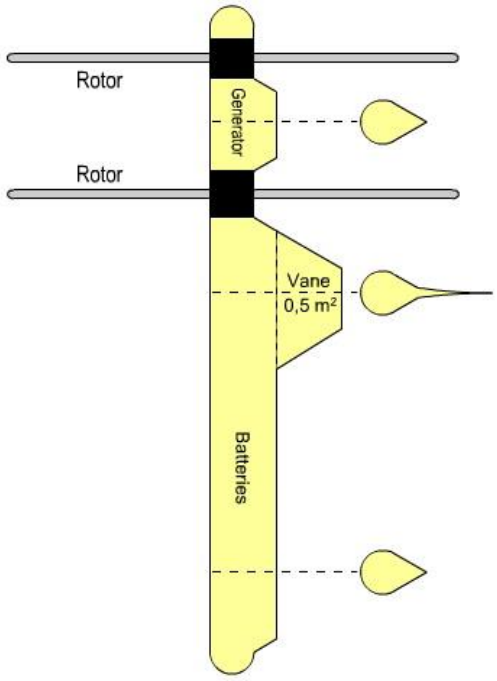
Content

The proposed technology

Automar is an unmanned surface vessel that can remain in a fixed position without anchoring for years, powered by energy from a wave energy converter that hangs in a cable under the vessel, below the wave zone, i.e. at up to 100 meters depth. Both the vessel and the turbine are designed to exert the least possible resistance to wind, waves, and ocean currents. Thrusters on the vessel will



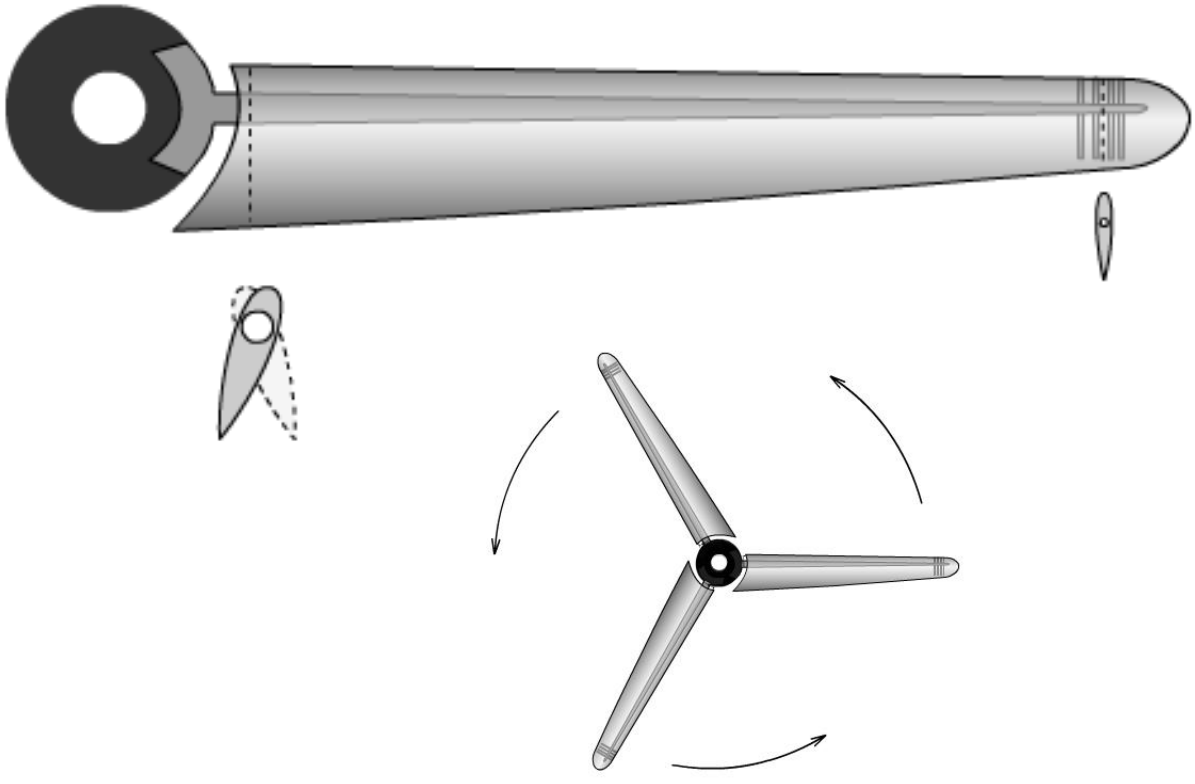
provide the necessary propulsion to maintain the position. Payload will also be powered by the turbine.

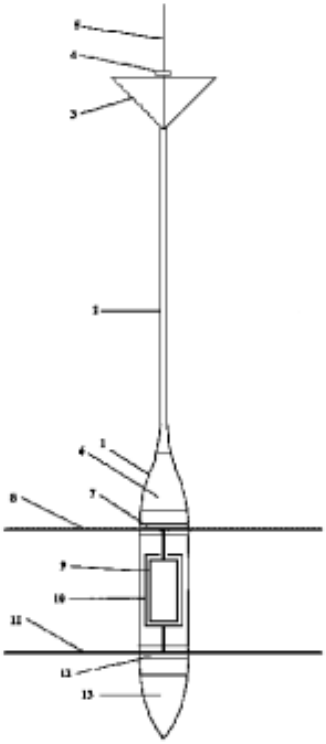


Operating principle

The surface vessel is the size of a small recreational boat, about 5 m long with a flat deck and a low freeboard. Two electric thrusters on the stern operate independently and can control the vessel based on GPS signals.

The turbine is a 6 m long vertical body with two rotors in the upper part surrounding a generator, and a large modular battery section in the lower part. Foil-shaped cross-section and a vane, in combination with the large weight in the lower part, ensure that current in the sea affects the turbine inclination as little as possible. The two rotors rotate opposite to each other, each of them the same way all the time. This is due to innovative flexible twisting turbine blades developed by Waveco, shown below.





Current state of development

The wave power turbine was granted a patent in Norway on 2016.07.25. See figure on the left.

A model was built in 2017 and tested in the Stadt Towing Tank by students from the University College of Western Norway in 2018.

Dutch Marine Energy Centre (DMEC) did a computer analysis of the turbine blade concept in 2020. This resulted in a conference publication for the European Wave and Tidal Energy Conference in Plymouth September 2021.

In 2021, NORCE Norwegian Research Center analysed the Automar concept with regard to the relationship between calculated energy production from the turbine and the energy requirement for maintaining the position and for payload. The conclusion was that the turbine would cover the need under average wave and current conditions in the North Atlantic.

Installation strategy

Automar with turbine can be deployed in a calm sea area with sufficient depth on a coast at about the same latitude as its destination. If sufficient wave action along the route, it will go to the desired position. The speed through water will be about 0.3 m/s on average. Speed over ground will depend on sea currents. When it reaches the position, it will stop and stay there. Energy will then be allocated only to station holding and payload.

The use of Automar is restricted to sea areas with a significant annual average of wave energy. Such areas will be found in the westerly wind belts between about 40 and 60 degrees latitude of the northern and southern hemispheres. But there will be long periods of calm weather even there. Therefore, Automar must have a large battery backup that is charged during normal and stormy periods and used during quiet periods.

Maintenance

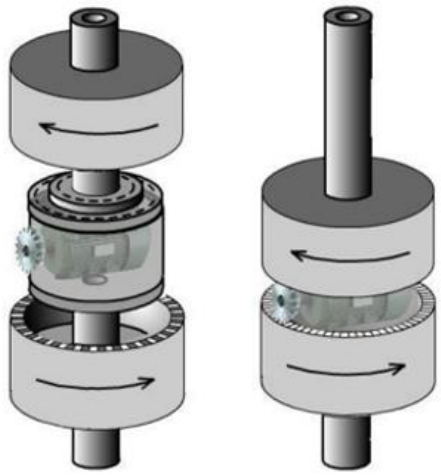
The autonomous system, with float, cable, and turbine, is designed to operate in the open sea for decades, with no maintenance other than visits for cleaning and anti-fouling surface treatment every two or three years. This can be combined with payload adjustments.

If the system fails to hold the position, for example due to long calm periods and strong currents, it will work its way back to the position when conditions improve.

If the propulsion stops working, for any reason, for example fishing gears in the propeller, Automar will drift off. Provided that the power supply is still intact, the rest of the system will continue to take measurements, send position and sensor data, and notify ship traffic of its position. Sooner or later, it must be visited for the problem to be fixed. If so, it will work its way back to the position.

Innovativeness

- Automar will be the only product that can deliver un-moored decade-long presence in deep-sea areas far from land without the need for refuelling or charging.
- The double counter-rotating turbine with flexible double-twisted turbine blades is patented.
- The turbine blades, developed by Waveco and analysed by DMEC, are more efficient than competing unidirectional turbine blades.
- The generator solution developed by Waveco addresses the need to keep the generator and electrical components safely away from salt water.
- The generator solution utilizes the counter-rotation of the two rotors to double the rotational speed of the generator.
- The generator solution enables the use of inexpensive general purpose generators.
- The battery modules is located in the lower part of the turbine. Here, the large weight is an advantage since it helps to keep the cable to the surface straight at all times, and the turbine body vertical.



Principle sketch of generator location.

- The number of battery modules can be adjusted to suit the assignment.

Prior development

Power performance

We built a model of the turbine with a diameter of 1 meter and four turbine blades on each rotor. The efficiency was measured by towing it through a long towing tank with different speeds and different braking forces on the rotors. This was done in Stadt Towing Tank in Norway. The Dutch Marine Energy Center (DMEC) used the raw data to calculate the Power Coefficient (Cp) and arrived at 27% at a tip speed ratio (TSR) of 2.5.

This is relatively low, which DMEC assumes is due to two factors:

1. The turbine blades were made of a random material with too much flexibility.
2. The blade tips were bulky and constituted a significant drag.

With the right rigidity in the blade material and perfectly designed blade profile, Cp is assumed to reach at least 35% for a three-bladed rotor at TSR 5.5.

Theoretical analysis

- 2014: *Global Maritime AS* did an assessment based on the original idea, funded by *Innovation Norway*.
- 2020: *Dutch Marine Energy Centre* made a computer analysis of the Waveco turbine blade and an assessment and cost estimation of the Automar concept, both funded by *Interreg North West Europe Marine Energy Alliance*.
- 2021: *NORCE Norwegian Research Centre* carried out an analysis of the Automar concept funded by the *Research Council of Norway*.

Survivability

Modes of operation

Automar is a self-governing and self-sufficient system. Data control based on signals from navigation satellites and an inertial measurement system regulates the two electric thrusters so that the drone stays in the same position regardless of weather, wind, and current conditions. The need for energy for this comes from the turbine in the depth.

The need for energy will largely correspond to the supply of energy from the turbine. When the weather is bad and the need for energy is greatest, there are also a lot of waves and a lot of energy is produced.

This positive relationship applies to wind and waves, but not ocean currents. Long periods of low wave energy in combination with strong ocean currents will be challenging. A large battery pack is therefore needed to collect energy during energy-positive periods to cover for periods of negative energy balance. The longer such periods are expected to last, the larger the battery pack must be. In the wind belts in the north, the summer seasons can have long low-energy periods. This is not the case in southern seas, which have high wave energy conditions throughout all seasons.

The turbine must be heavy enough for the cable to be tight. Jerks due to slack must be avoided. Otherwise the system has no end stop problem.

The propellers of the surface drone must be protected to prevent contact with floating debris.

The surface drone must be equipped with navigation light, radar reflector and an AIS transmitter to avoid being run down by ships.

Affordability

Observation sensors will not be included in the deliveries to the customers, only the platform equipped with instrumentation for course tracking, station holding, navigation and telemetry.

DMEC did an estimation of the CAPEX shown in the tables below.

Product (small series)	**Number**	**euro/hour**	**euro/product**
Series production	20		
Insourcing all components:			
catamaran with compartment and mast			30000
solar system			10000
drive train			25000
battery system			22000
subwave turbine complete			15000
controls			15000
instrumentation			25000
Assembly	300	60	18000
Total production cost price			***160000***

Selling price of Product		Percentage	euro/product
Production cost price			160000
Marketing		25%	40000
Service		15%	24000
Financing		10%	16000
Insurance		10%	16000
Overhead (all other company costs)		30%	48000
Margin		30%	48000
R&D costs			44500
Total sales price			***396500***

Operating costs, OPEX, are covered by customers and will largely depend on equipment and use.

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