VERSION Intermediate
PROJECT NUMBER JOR3-CT98-7027

Wave energy ready to contribute to EU's sustainable electricity production

Wave Dragon, – a 4 MW wave energy converter – is now ready for real sea testing

The Objectives

Wave energy has a possibility to contribute considerably to the development of a fossil fuel free power production. More than 30 % of the electricity consumption within EU can be covered by wave energy. Wave energy will also raise the value of wind based power production considerably as wave energy in the North Sea lasts up to 6 hours after the wind has slowed down, and in the Atlantic Ocean this figure is much bigger. This means that the utilization of wave energy can minimize the problems faced by grid operators in relation to predictability and grid balance concerns caused by the wind power. As a result of this, the combined sustainable power production from wind and wave will need a smaller back-up from traditional power plants than a system without the wave power part.

Until now wave energy has only been little explored, which is caused by the relatively large costs for developing and testing the necessary technology. Another reason is that only with the recent introduction of the EU action plan for renewable energy it became possible to attract commercial partners for the development. The team behind the Wave Dragon project has tested a scale model 1:50 in order to have as many tests performed as possible before entering the more expensive part of the development program. The scale tests are necessary in order to optimise the construction, find the right regulation technique for the system, and to develop a suitable high efficient low-head axial turbine.

The Project

The Wave Dragon is a floating slack-moored 4 MW wave energy converter of the overtopping type. It basically consists of two wave reflectors focusing the waves towards a ramp. Behind the ramp there is a large reservoir where the water that runs up the ramp is collected and temporally stored. The water again leaves the reservoir through a number of hydro turbines, which converts the potential energy in the stored water into power. The Wave Dragon is designed to maximise the energy content in the water that overtops into the reservoir, which is in contrast to most other marine structures, whose design are aimed at minimising overtopping and the damage that can result from heavy overtopping. The task of optimising the overtopping from reflected waves that runs up a sloped ramp is therefore quite unusual. The combined and patented system of curved wave reflectors and the doubly curved ramp, which is utilised in the Wave Dragon is state of the art within overtopping wave energy converters.

The Wave Dragon can be deployed at water depths above 20 meters. Arrays of Wave Dragon units will be established in groups of 50-200 resulting in a power plant with a rated power of 150-600 MW. This compares well to the capacity of traditional power plants based on fossil fuels.

The primary objective of the Wave Dragon turbine project was to develop a technique where standard hydro turbines could be used in offshore wave energy converters of the overtopping type. Some modifications have been foreseen, as variations of head and flow in wave energy converters are much different from what is standard for a hydro power plant. During the project it showed up that the only way of optimising the turbine was to test a scale model not less than in scale 1:3.5. The test program was modified accordingly. The designed turbine has no moving parts apart form the rotor, and still this very robust design has an outstanding high performance with efficiencies around 90 % in the whole pressure head range utilised in the Wave Dragon.

Utilising wave energy is a completely new business, and no established industry exists. The Wave Dragon concept is characterised by combining existing, mature technologies, e.g. hydraulics and turbine technology in a novel way. It was therefore necessary by the establishing of the project team that partners from different industries were involved. Further on it was essential to choose companies willing to deviate somewhat from their daily business. At the same time the companies had to be among the leaders within their respective business area. During the project two partners have left – one because the deviation from daily business was too large, the other caused by the very bad business conditions for small hydropower in the world.

Axial turbines of the Kaplan/propeller type have been in commercial use for decades in traditional hydropower plants. They are very reliable and have small maintenance costs can even be utilized in streams that only give very low head for the turbines. However, real serial production of hydropower turbines has never been established, because the market for a single type/size turbine has been much to small to make this happen. A combined market for a one-type turbine for wave energy converters and small run off the river type hydro power plants opens up for large-scale serial turbine production.

In spite of the fact that the Wave Dragon to a high degree is based on well-proven technologies, the wave reflector principle in combination with the doubly curved ramp profile has obtained international patents. The Wave Dragon also differs from other known wave energy converters by having a high energy storage capacity due to the large water reservoir ensuring an unusual stable power production and a high conversion efficiency.

The Wave Dragon Test company has the right to use these patents. This development company is owned by the project partners, securing that the unique and protected design of Wave Dragon will be further developed to a commercial power production plant. The patents ensures that it will be possible to attract the necessary funding from venture companies etc. to establish a full scale prototype of the Wave Dragon .

The Results: Technical
The hydraulic response to different wave climate has been studied, and a model developed, which gives the possibility to design a Wave Dragon for different placements around the EU and other parts of the world.

A hydro turbine with no movable parts besides the rotor has been developed and a scale model 1:3.5 tested, with a high efficiency over the whole head range. The turbine itself has possibilities for use in run off the river systems with low head and variable flow, an area of interest for many countries around the world.

The survivability of the Wave Dragon has been proved by tests with 100-year storm waves as found in the North Sea with a significant wave height of 10 m and a wave peak period of 14.1 seconds.

Grid connection requirements have been established, and a regulation strategy for the turbines has been developed, which is essential for the future deployment of Wave Dragon.

The results open up for test of a 57 m wide model in scale 1:4.5 in real sea with a power production of 20 kW, a necessary step before deployment of a prototype.

The Results: Economic, Social & Environmental
The planned development for the next fifteen years contains five phases, which consist of the model test in the scale 1:4.5, a full scale prototype, pilot projects with several units, a 50-unit park in commercial operation, and from 2011 deployment of 6 parks each consisting of 100 units. If all these phases are followed, 12 TWh annual power production from Wave Dragon parks is expected, thereby substituting 8,000 Mt/year CO_2.

A 4 MW Wave Dragon unit in the Danish part of the North Sea will produce 11,000 MWh/year (2750 full load hours) and the expected production cost for year 2016 is 40 €/MWh. A production three times higher than this can be obtained in the Atlantic. The current situation of wave energy can be compared to the development of wind turbines in the early 1980s, and the future expected cost for wave energy is comparable to today's cost for wind energy.

A successful deployment will allow establishment of a whole new industry. The impact on job creation will during a 15 years period be of the same size as today's wind industry. For the first period new jobs equivalent to more than 6,000 man-years are expected. Most of the jobs will be established in areas where the offshore oil and gas industry is going to decrease its activities.

Improving the Programme and Project Management
The project approach has been optimal and only minor changes would have been introduced if the project should be repeated with the present knowledge.

It can be recommended to the Commission to implement a smooth and quick procedure for changes to the contractual project program when for instance preliminary test results calls for a change.

Information

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Web Site:	www. spok.dk
Partners:	Löwenmark F.R.I, DK EMU (now SPOK ApS), DK Kössler Ges.m.b.H., A Mogens Balslev A/S, DK BeltElectric ApS, DK Eltra A.m.b.a., DK Armstrong Technology Associates, UK VeteranKraft AB, S Technical University Munich, Laboratory for Hydraulic Machinery, D Aalborg University, Hydraulics and Coastal Engineering Laboratory,DK University College Cork, Dept. of Applied Mathematics, Hydraulic & Maritime Research Centre, IRL
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