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Published in:
Proceedings of the International Offshore and Polar Engineering Conference

Publication date:
2000

Document Version
Early version, also known as pre-print

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INTRODUCTION

Over the recent years wave energy has gradually been brought into focus, as it has become clear that the fossil energy resources are limited, and cause large environmental problems, e.g. CO_2 pollution. On this background a number of different wave energy converters have been proposed. In Denmark the government decided to appropriate 20 mill. DKK (approx. 2.7 mill. EUR) to the development of wave energy devices over two years, 1998-1999, and the European Community (EC) also supports the development through the JOULE-CRAFT program. Among the wave energy concepts receiving financial support from both programs, is the Wave Dragon. The Wave Dragon is a floating wave energy converter of the overtopping type, developed by Erik Friis-Madsen from the Danish engineering company Löwenmark.

PRESENTATION OF THE WAVE DRAGON

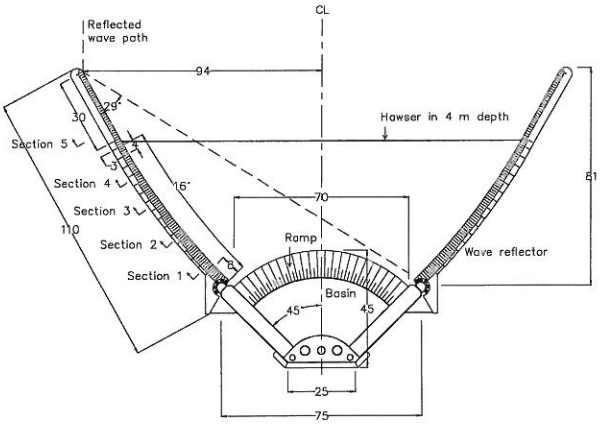

Figure 1: Plan view of the Wave Dragon. Measures are in m.

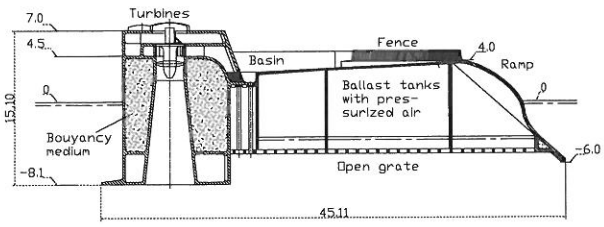

Figure 2: A cross section of the ramp and basin part of the Wave Dragon. Measures are in m.

The Wave Dragon wave energy converter can briefly be described as consisting of three components (see Figure 1 and 2):

- Two wave reflectors for focusing the waves.
- A ramp leading the waves to the reservoir by overtopping.
- A number of low head turbines for converting the hydraulic head and flow into electricity.

The Wave Dragon is based upon technique presently known and available at industrial standard. Though, certain parts of Wave Dragon are technically innovative to such a degree that a patent is expected.

The offshore floating platform will be placed typically at 20 to 50 meters water depth, which in the Danish part of the North Sea is equivalent to 25 - 100 km from the coastline. The cost of transmission of the power to the coast forces the developer of the Wave Dragon to think in large-scale power production. A typical wave energy power plant of the Wave Dragon type will consist of 200 modular units of each approximately 1 MW as a mean value (max. power of 4 MW). Thus, each unit will produce ~10 GWh/year, Löwenmark et al., 1998

HISTORY OF THE WAVE DRAGON CONCEPT

The inventor Erik Friis-Madsen initiated the development of the Wave Dragon in 1986. In the early years he developed the principle of the Wave Dragon, and in 1995 an application for patent was submitted, Löwenmark, 1995.

During the following years a number of preliminary studies were performed, Birckner, E., 1995, Rolsted, C., 1996, Hansen, B. N. & Jørgensen, B, 1998 and Nielsen, A. & Kofoed, J. P., 1997 and Andreasen, M. & Lauridsen, H., 1999.

Using these findings the Wave Dragon design was slightly modified and a test programme formulated. This test program, financed by the Danish Wave Energy Program, consists of thorough investigations of:

- Movements of the floating structure.
- Mooring forces and forces in the reflectors.
- Overtopping/amount of captured energy.

These tests were carried out at the Hydraulics and Coastal Engineering Laboratory, Aalborg University, 1998-1999, using a floating 1:50 scale model of the Wave Dragon, build by the Danish Maritime Institute.

The tests showed large pitch motions resulting in less overtopping than expected. Hereafter, the Wave Dragon was further developed, resulting in an improved hydraulic performance.

In 1997 an application for the EU Exploratory Award was formulated, Löwenmark & Ossberger, 1997. The resulting research application and feasibility study was published 1998 (Löwenmark & EMU, 1998 and Löwenmark et al., 1998).

In this feasibility study it was stated that the price of electricity produced by the Wave Dragon will be 0.07 – 0.11 EUR/kWh.

As a continuation of the work performed under the Danish Wave Energy Program and on the basis of the research feasibility study, the EC has granted funding (1 mill. EUR) for a project called *Low-pressure Turbine and Control Equipment for Wave Energy Converters (Wave Dragon)* under the Non-Nuclear Energy RTD Program (JOULE-CRAFT). Partners in this project are:

- Löwenmark, Denmark.
- Ossberger Turbinenfabrik GmbH, Germany.
- Hälleryd Turbiner AB, Sweden.
- Balslev Consulting Engineers A/S, Denmark.
- Belt Electric, Denmark.
- Elsamprojekt A/S, Denmark (owned by the utility Elsam).
- EMU, Denmark.
- University College Cork / HMRC, Ireland.
- Aalborg University / Hydraulics and Coastal Engineering Laboratory, Denmark.
- Armstrong Technology, Great Britain.
- Veteran Kraft AB, Sweden.
- Technical University Munich / LHM, Germany.

The objective of this project is to optimise the hydraulic performance, structural design, design of configuration, control and regulation of the turbines, and design of electrical component and connection to grid. Aalborg University, University College Cork / HMRC and Löwenmark performs optimisation of the hydraulic performance, structural design is dealt with by Armstrong Technology, design of configuration, control and regulation of the turbines is done by Ossberger Turbinenfabrik, Veteran Kraft and Technical University Munich, and design of electrical component and connection to grid is done by Balslev, Belt Electric and Elsamprojekt. EMU is manager of the project.

This project is presently ongoing and will be concluded by the end of 2000.

FUTURE DEVELOPMENT

After conclusion of the EC project the building of a 1:3 scale model is being planned for launch at a test site in inner waters somewhere in Denmark. This is considered a necessary step before building a full-scale prototype in order to achieve experience with especially controlling the turbine, necessary maintenance, etc. The funding necessary to realise this step of the development is expected to amount to 3 mill. EUR, and fundraising is currently being carried out by EMU.

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