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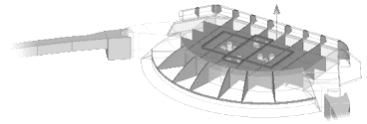
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Power production experience from Wave Dragon prototype testing in Nissum Bredning: 2003 to 2005 – Summary note



Project:

*Sea Testing and Optimization of Power Production on a Scale 1:4.5 Test Rig of the
Offshore Wave Energy Converter Wave Dragon*

according to EU ENERGIE contract no. ENK5-CT-2002-00603

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December, 2005





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Power production experience from Wave Dragon prototype testing in Nissum Bredning: 2003 to 2005 - Summary note

by

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December, 2005

Introduction

The first Wave Dragon prototype power production testing started May 2003 and ended temporarily primo 2005. In the mentioned period Wave Dragon was situated in a corner of Nissum Bredning with relative little amount of wave energy. Main purpose of the tests was demonstration of survivability and availability. During the coming weeks Wave Dragon will be moved to a more exposed part of Nissum Bredning for further testing.

The hydraulic power absorption and the electric power production have verified, what was predicted from comprehensive tests in wave basins at Aalborg University, 1999-2003. The tested laboratory model was built in scale 1:11.5 of the Nissum Bredning prototype.

Prototype availability has continuously been improved during the test period. From August 2004 to January 8th 2005 power production availability was 71-87% with continuous normal operation and tests series. All other systems had near 100% availability in that period.

Based on the prolonged test runs with the prototype it can therefore be concluded that the power production performance of the Nissum Bredning prototype is in line with or even better than predicted. The results verify that the calculated power performance potentials for full scale Wave Dragons, which forms the basis for the Wave Dragon feasibility studies, are not only realistic but can be expected to be exceeded, when the prototype is up scaled 4.5 times or more to match a North Sea wave climate or Atlantic or Pacific wave climates.

Wave Dragon power production estimates:

Location	Wave Climate Yearly average	Unit size, opening width	Yearly power production
Nissum Bredning, 2003 – 2005	0.3 kW/m	57 m	12 Mwh
Nissum Bredning, 2006 -	0.5 kW/m	57 m	30 MWh
North Sea	24 kW/m	260 m	12 GWh
North Sea / Atlantic	36 kW/m	300 m	20 GWh
Atlantic	48 kW/m	390 m	35 GWh

Wave Dragon prototype power production performance

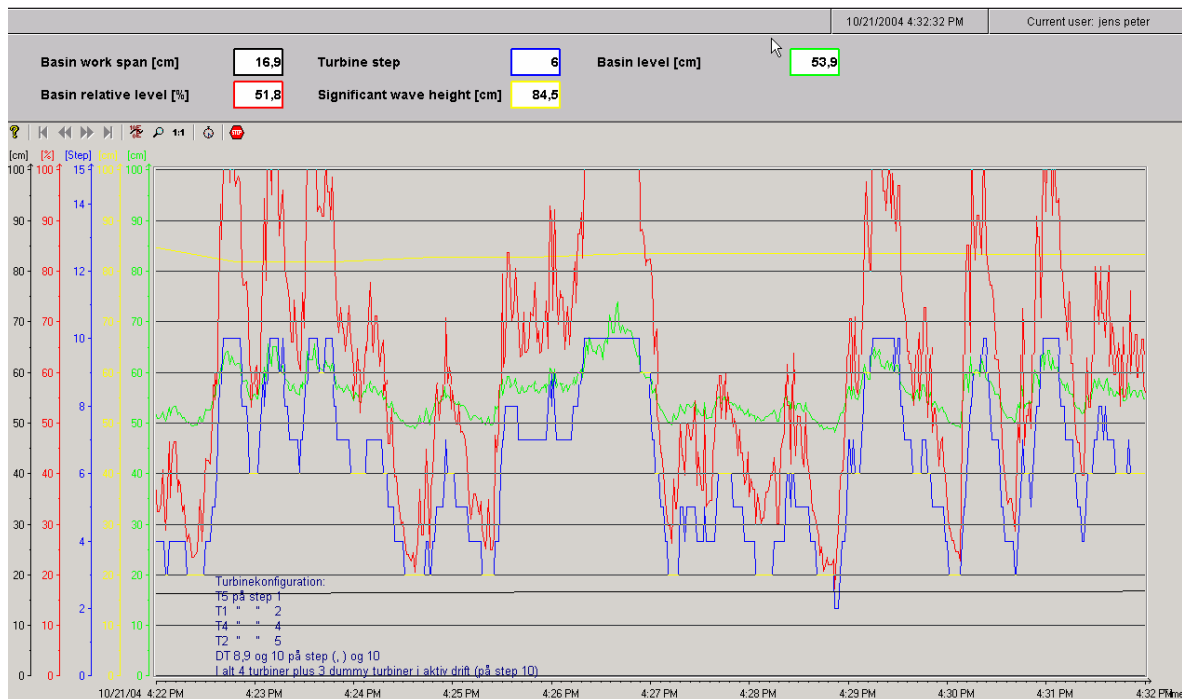


Figure 1. SCADA data.

Figure 1 show a sample of data output from the SCADA system. It illustrates how turbine operation follows the water level in the reservoir and thus overtopping. In the example given above the three cylinder-gate turbines and the siphon turbine are running almost continuously and the main part of overtopping/water level variation is handled by the dummy turbines.

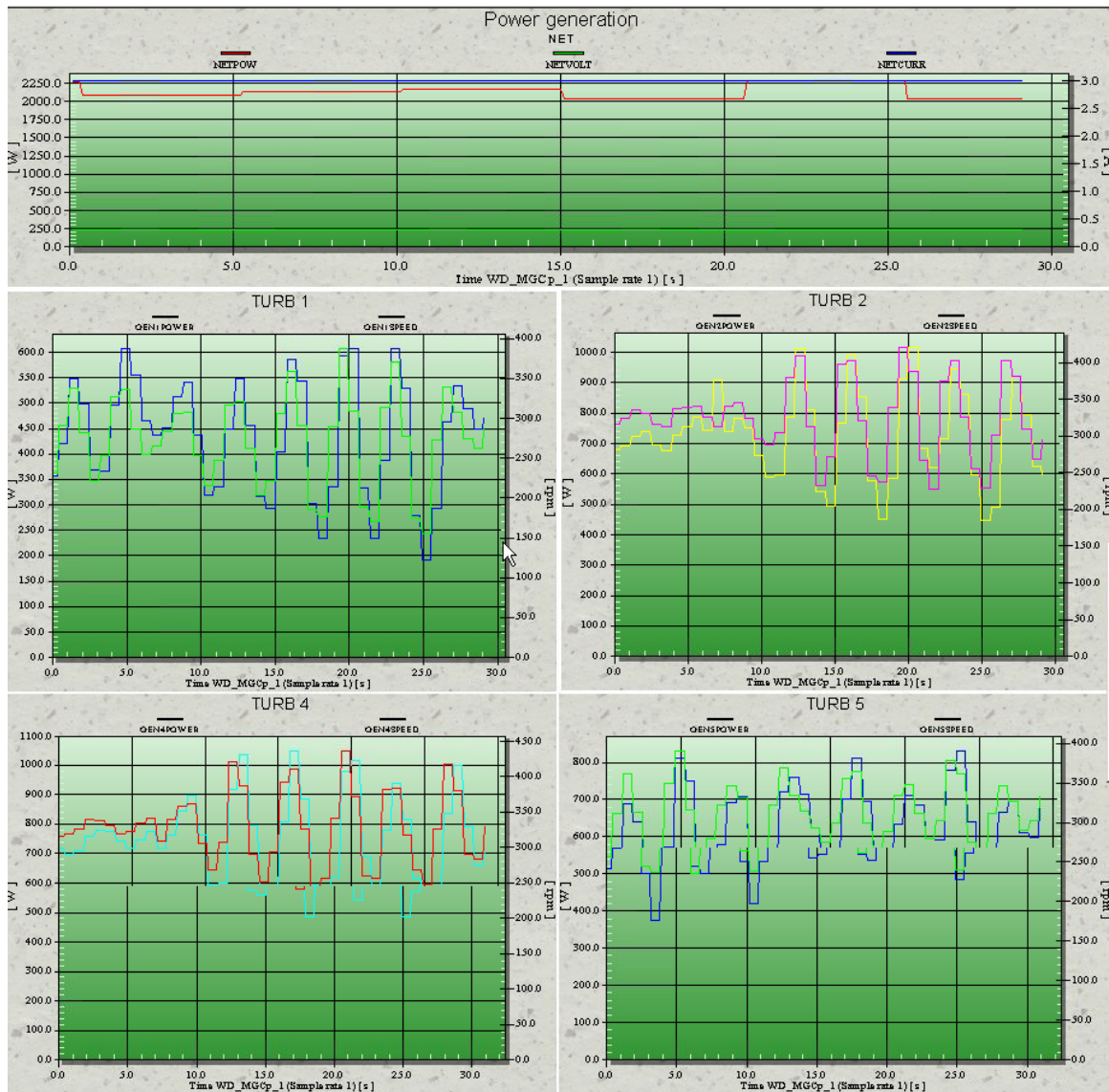


Figure 2. Individual turbine production.

Figure 2 illustrates power production from the four individual active turbines (cylinder gate and siphon) and the aggregated power production put on grid. This sample covers about 30 sec.

To illustrate the variation in power production from the Wave Dragon prototype a period from Oct. 21st 22:31 to Oct. 23rd 4:31 is shown in figure 3. Wave Dragon is equipped with a multiply of turbines to optimise conversion of absorbed wave energy to electrical power. This results in frequent start and stop of the individual turbines. In figure 3 it is shown that although waves are unpredictable in time domain, as well as in size, the multiple turbines setup smoothen out power delivered from Wave Dragon.

04.10.21 22:31 - 04.10.23 4:31

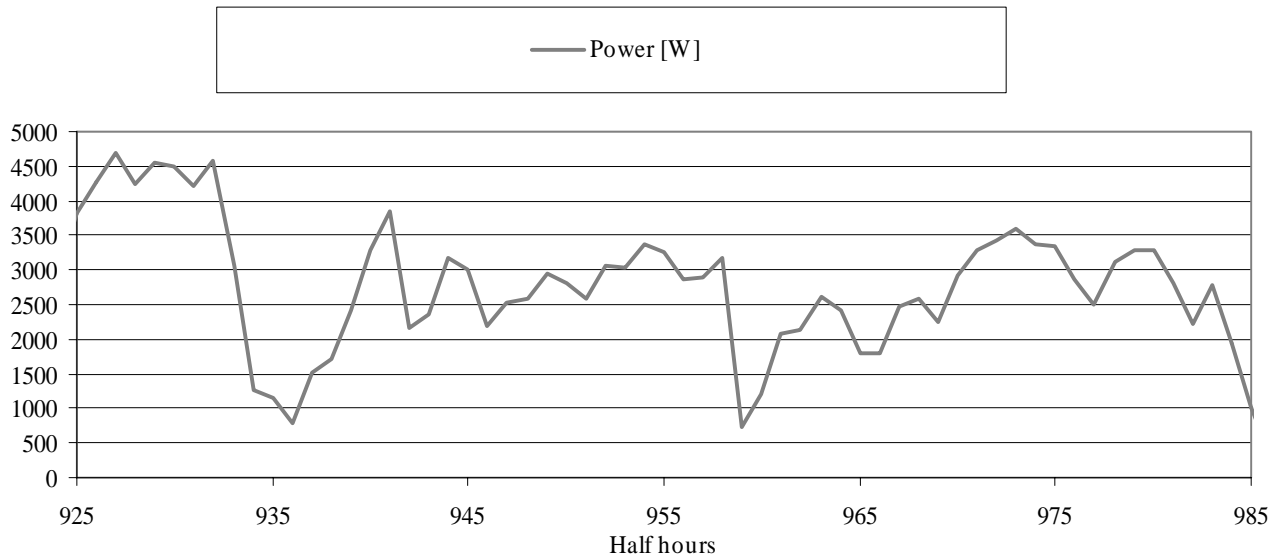


Figure 4. Power production.

In Figure 5 measured prototype data for 10 days in December 2004 are compared to expression based on laboratory tests. As it can be seen from the graph the measured data are situated around the predicted line. The reasons for the general scatter and the data points falling below the predicted line are as follow:

- 25 % of the time December 2004 the prototype was out of service and for 27% of the time sub-optimum tests were carried out.
- Wrong turbine/generator speed caused by equipment not delivered as specified (26% loss in efficiency).
- Platform stability control still under development.
- For conditions where the crest freeboard is low compared to wave height the limited capacity of the turbines and reservoir occasionally lead to spilling of overtopped water.
- Non-optimal alignment toward the waves caused by the back anchor restriction on prototype.
- Measuring uncertainties.

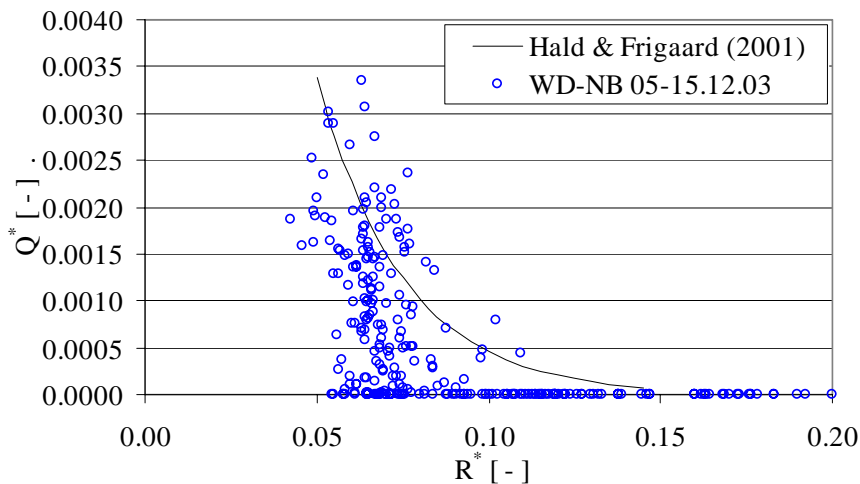


Figure 4. Overtopping data.

The important thing to notice in figure 4 is that several points are above the prediction line, as this shows that the overtopping performance, in certain circumstances, is better than predicted from the model tests. As it can be seen from the figure +50% energy absorption is possible within the present set up. Thus, the overall conclusion is that Wave Dragon prototype energy absorption even at this relatively early point of development is in line with or above the predicted level.

Wave Dragon prototype availability

Monthly operating experience of the power production systems from May 2003 until end of 2004 is summarised in figure 5 below. This reflects time logged in the PLC system where the Wave Dragon's power production system has been in active operation, either

- “Continuous operation” mode which covers longer periods where the prototype has been in automatic production mode. Not necessary aiming at optimum power output.
- When carrying out specific test runs (labelled “Testing”). This covers tests of control systems and tests of hydraulic response, i.e. effect on floating level and stability.

The additional time has been spent on

- Re-construction and re-configuration activities (labelled “Re-construction”)
- Waiting time (labelled “Out of operation”). This covers as an example holidays and simply evenings and nights in the periods without a working automatic fire extinguishing systems (insurance question). In these periods power production has been stopped.

The Wave Dragons power production system referred to covers turbines, generators and inverters and rectifiers plus PLC system.

Please note that a close to 100% availability has been achieved for other Wave Dragon systems, like the auto floating level and stability system and the remote control and communication systems.

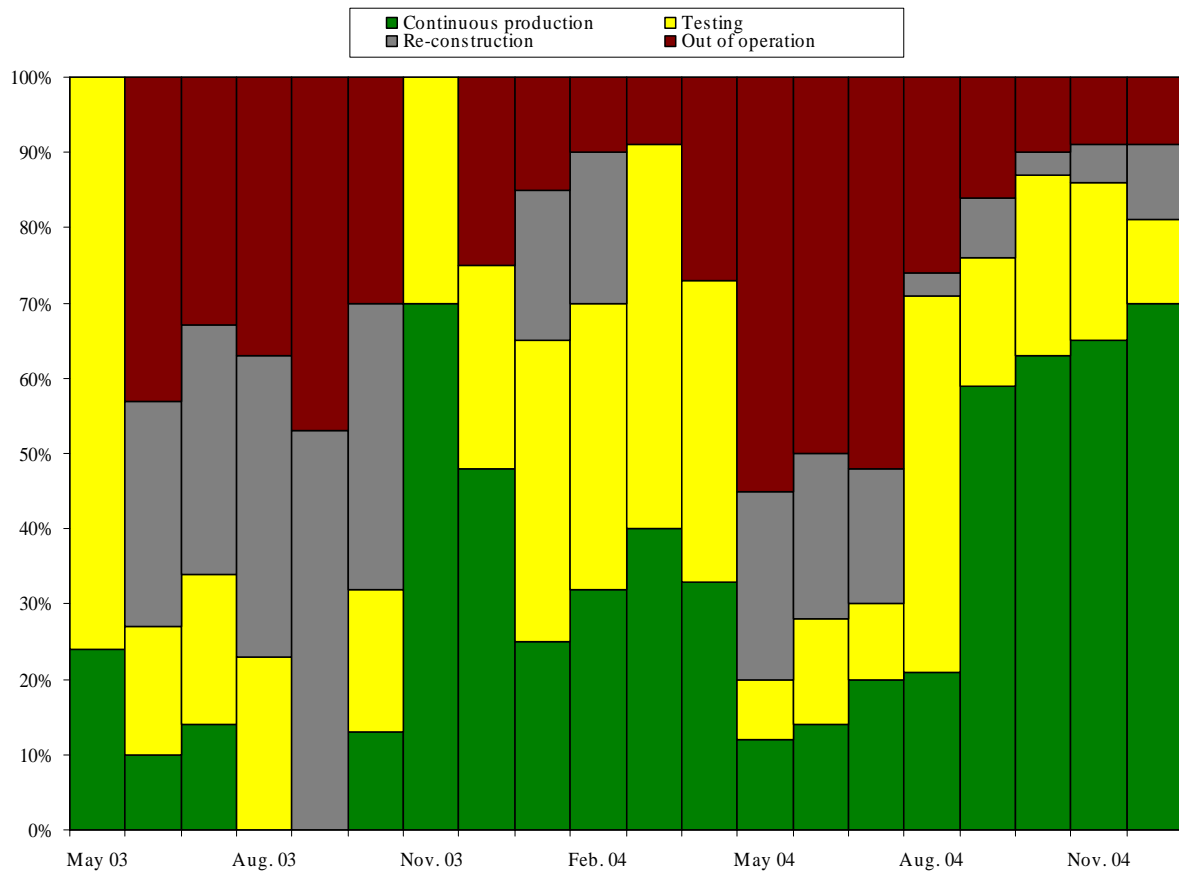


Figure 5. Availability.

1. The period from May 2003 to August 2003 was the initial testing period for all systems with one turbine/generator plus three dummy turbines.
2. September 2003 six turbines were installed offshore and the PM generators in February 2004
3. October 2003 to January 2004 extensive testing and continuous operation test was carried out followed by control system modifications.
4. February 2004 the delayed PM generators were mounted and 7 turbines/generator plus 3 dummy turbines were subsequently tested.
5. May – July 2004 was apart from summer holidays spent on repair and re-construction activities.
6. From August 2004 and the rest of 2004 was one more or less continuously operating experience. **Availability: 71%-87%.**