SIXTH FRAMEWORK PROGRAMME
PRIORITY 6.1
SUSTAINABLE ENERGY SYSTEMS

Project no. 019831

WAVESSG

Full-scale demonstration of robust and high-efficiency wave energy converter

STREP

Thematic Priority 6.1

Final publishable executive summary

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Start date of project: 01.12.2005 Duration: 30 months

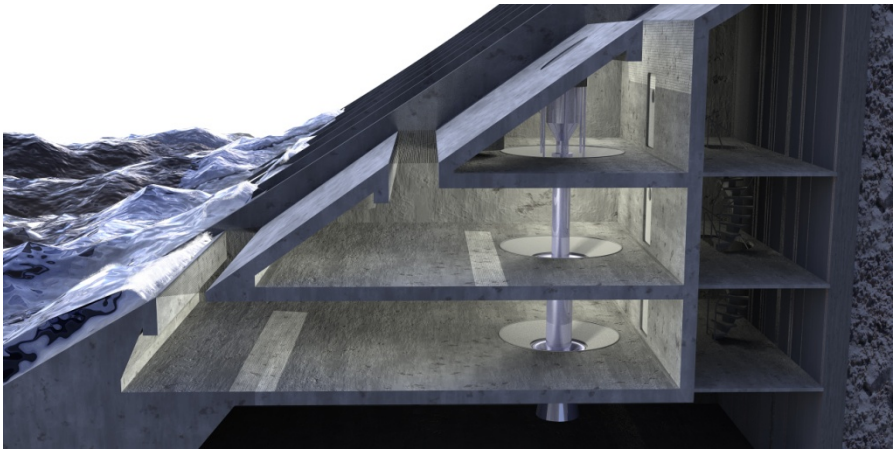
Monika Bakke, Wave Energy AS (WEAS) Revision: 00

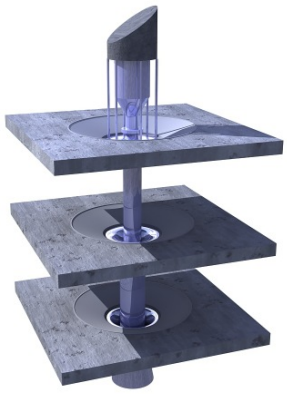
Project summary

In the short term, the Kyoto protocol and the RES Directive promotes the use of renewable energy sources (RES), and in the long term the decreasing reserves of fossil fuels will urge the use of RES. Wave energy is a renewable and pollution-free energy source that has the potential to contribute with 2,000 TWh/year of the world's energy production. Sea waves have one of the highest energy densities among the RES. Today, the biggest challenge in harvesting wave energy is obtaining reliability of the technology and bringing the cost down.

Wave Energy AS (WEAS) planned to carry out a pilot project of the SSG wave energy converter at the island of Kvitsøy, Norway. The pilot structure will be a full-scale 10m wide module with approximately 200kW installed capacity.
The prototype of the SSG includes three reservoirs for capturing the ocean energy and is constructed as a robust shoreline device. The patented multi-reservoir concept ensures that a variety of waves are utilized for energy production, resulting in a high degree of efficiency.
Concurrently with the design of the SSG, WEAS is also developing a patented multi-stage water turbine (MST), specifically designed to further optimize the efficiency of the SSG converter.
The special design turbine enables utilization of the different heights of water with only one turbine wheel.
This will minimize the number of start/stop sequences on the generator resulting in a smoother energy supply to the grid and an increased overall efficiency.

The following pictures illustrate the SSG and the MST concept:





Project objectives

The main objective of the present project is to operate at full-scale one module of the SSG converter in 19 kW/m wave climate, including turbine, generator and control system.

The specific objectives of the project are:

- To design a full-scale 150 kW technical prototype of the innovative MST turbine technology
- To manufacture, test and install a full-scale 150 kW technical prototype of the innovative MST turbine technology into the SSG structure
- To design a full-scale 150 kW generator and control system equipment
- Measure performance data of the SSG wave energy converter including the structure in a period of up to six months for reliability and life time assessment

- To manufacture, test and install a full-scale generator and control system equipment for grid connection and annual production of 200,000 kWh of renewable and pollution-free electricity, corresponding to 20,000 kWh/m
- Obtain a hydraulic efficiency of at least 39 % for the shoreline application
- Obtain a wave-to-wire efficiency of more than 25 % during the test period
- Obtain 96 % availability of plant (with regard to operational hours)
- Obtain 85 % availability of production (with regard to wave climate)

The project consortium consists of the following partners:

Wave Energy AS	WEAS	Norway
Aalborg University, Hydraulics and Coastal Engineering	AAU	Denmark
Technical University of Munich	TUM	Germany
Ganz Transelektro	GANZ	Hungary
Municipality of Kvitsøy	KVITSØY	Norway
Norwegian University of Science and Technology	NTNU	Norway
IKM Gjerseth Elektro	IKM	Norway

Work performed

The main focus at the start of the project was to develop and design the optimum lay out for the mechanical and electronic system in the SSG. Main factors have been system reliability and overall efficiency.
Above activities include addressing important fundamental questions related to turbine design, turbine control equipment, measuring and monitoring requirements, generator type, control system design and grid connection.

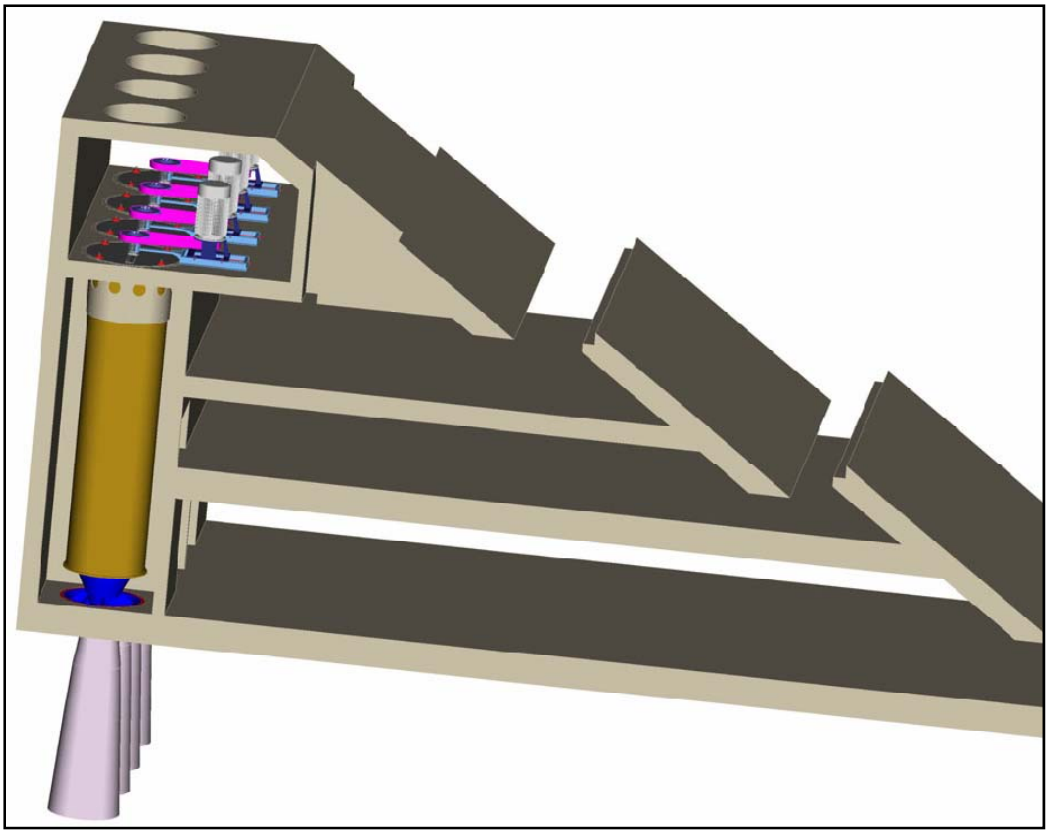
A relatively wide scope of solutions has been taken into consideration and evaluated.
Comprehensive work has been carried out on turbine design related activities. In addition to work to define the turbine configuration and lay-out, a lot of hours have been spent on mechanical design challenges, as the SSG will be equipped with the new and innovative multi-stage turbine (MST).

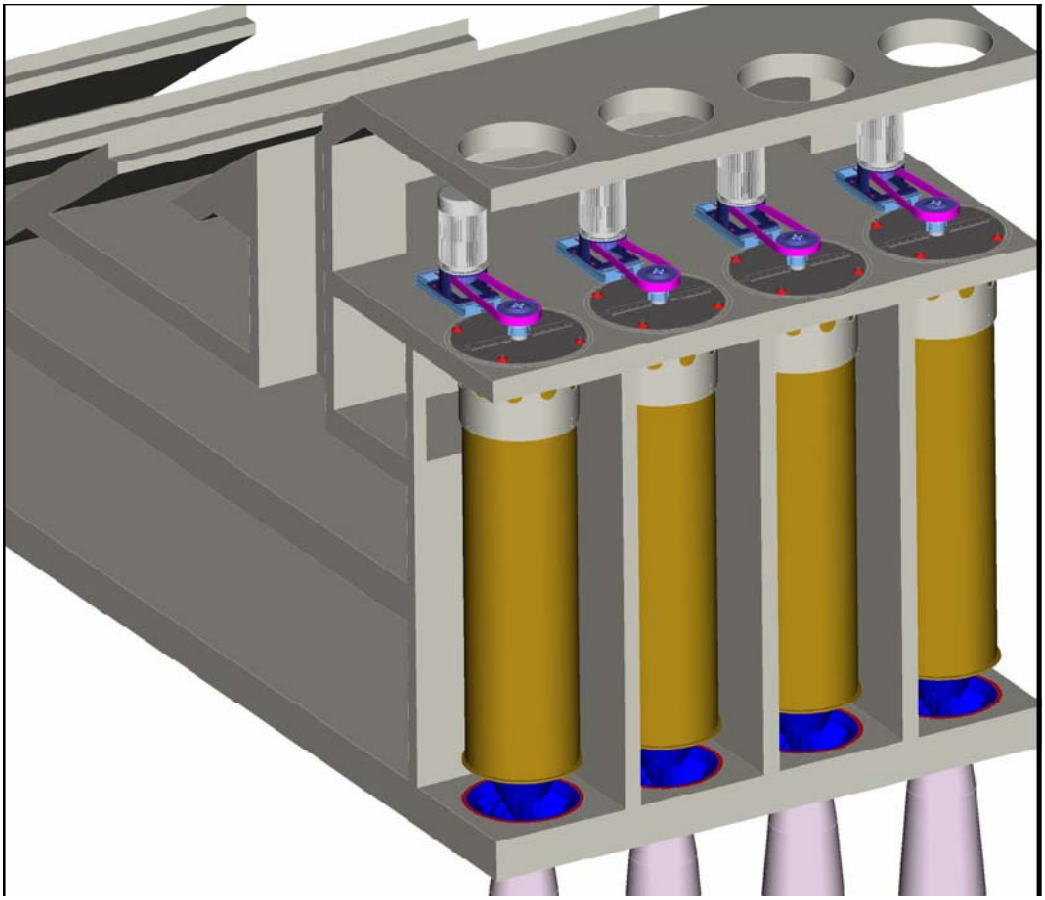
Turbine layout

It was in the project proposal planned to equip the Kvitsøy pilot plant with one single Multi Stage Turbine (MST). However, during the development of the MST it became apparent that this turbine principle has some development and design challenges that were difficult to solve, resulting in a much longer development phase than anticipated.
It was decided to carry out the design of an alternative solution with Kaplan turbines to avoid a delay in the construction and installation of the SSG pilot structure.
As the MST is a very important part of the project was it also determined to continue to work for a solution on the design challenges and aim towards the possibility to include the MST in the pilot plant for testing purposes, in addition to the Kaplan turbines.

Kaplan turbine design

Detail design of turbine and turbine control devices for the Kaplan solution has been carried out and model test have been performed in order to determine the operating performance for the turbines. Manufacturing drawings have been completed.
A tender for the production of the turbines were announced and turbine manufacturer selected.



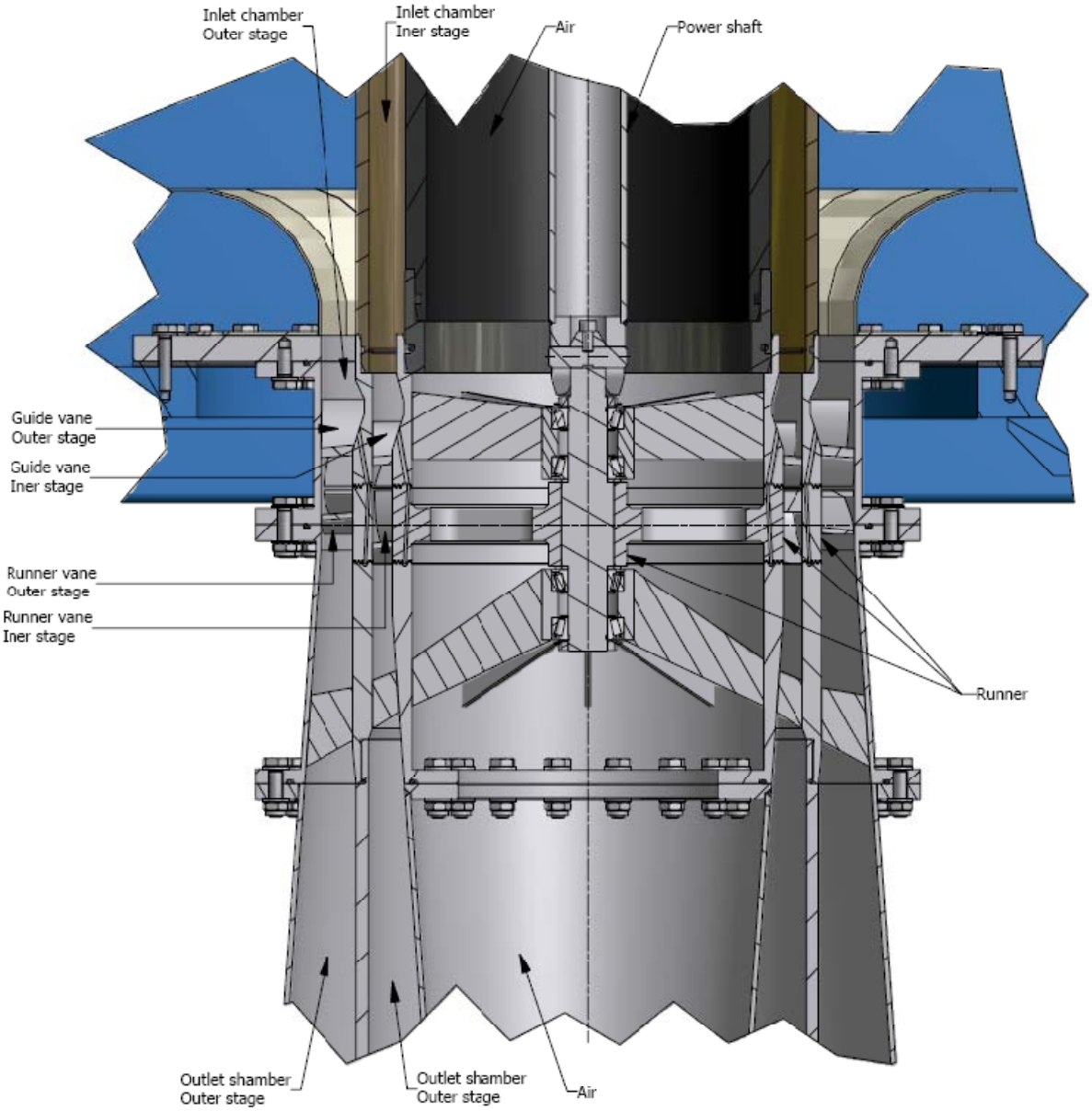


Picture1: 3D sketch of Kaplan turbine implementation in SSG pilot structure

MST Turbine design and testing

The main challenge in the development of the MST has been the design of a labyrinth seal to avoid air intrusion. This seal is located between each chamber in the interface between the runner and the guide wanes and between the runner and the draft tubes. A solution for a new type labyrinth seal for the MST turbine has been developed and tested. The labyrinth seal have been integrated into the design of the MST.

Successful in-house testing have been performed on a 1:4 scale two-stage model of the MST at the NTNU`s water laboratory proving that patented concept works.



Picture2: MST turbine design

Surveillance and monitoring system

The University of Aalborg has carried out the planning and design of the instrumentation, data acquisition and control system specifications required for the SSG pilot plant.

The data acquisition system will enable evaluation of the whole spectrum of waves, processing significant wave height, peak periods and energy periods.
The data acquisition system for these significant parameters will be installed in front the SSG location at a distance of approximately 100 m.

System specification also includes measurement of the power in the overtopping, the power in the reservoirs, the power in the turbine, power of generator and power to the grid.

Data acquisition system for reservoirs sensors will enable the evaluation of the
long term average, average over three transmitters of reservoir water level relative to reservoir bottom, mean water level in reservoirs MWL and crest height relative to MWL
Therefore, all the 3 reservoirs will be equipped with three pressure transducers located at 1.5 m from the walls to read from each the water level and to extrapolate the mean value.
One pressure transducer will be allocated to measure the tail water level. Including the transducers for measuring forces on the ramp, a total of 19 pressure transducers.

The system will be designed to allow for the possible incorporation of data from other sources.
Wave measurement data and other data from the web, such as information from weather stations will need to imported from a separate PC.

Generator and control system

The generator configuration and design has been designed based on the turbine lay-out and structure design requirements.
It was decided to use asynchronies generators, vertical frame. In will in order to achieve the best efficiency it has been decided to use 8-pole generators on the turbines for the lower reservoir, and 6-pole generators for the middle and upper reservoir.
Belt drive transmission between turbine and generator.

The synchronizing of the generator to the grid will be controlled by a soft starter.
The soft starter is used in order to avoid high inrush currents. Each generator will be equipped with a soft starter and an encoder in order to measure the rpm. The signal from the encoder will be transferred to a PLC to ensure that the generators will be connected to the grid in the right moment.

Testing of this process was carried out in the IKM laboratory to ensure that this functioned in accordance with the criteria from the grid owner (Lyse Nett).
Test results were as expected and in accordance with the requirements for the system.

Use and dissemination of knowledge

The activities regarding using and disseminating the knowledge has mainly been connected to presenting technical papers/articles at relevant conferences and project presentations for potential wave energy project developers and European energy companies.
Presentations have also been given to both local and national authority representatives.

A project specific website has been established. The website includes general project information available for the public, but also protected area with detailed information only available for representatives in the consortium.

The address of the project public website is www.wavessg.com

In addition to the project presentations has also project posters and flyers been handed out at conferences and in meetings.

Results

In despite of the fact that a building permit was already granted for the construction of the pilot plant did objection letters from a private individual against the construction raise uncertainty in regards to the earlier given approval.
An official complaint against the construction approval was delivered to Kvitsøy municipality by the same individual.

The design of the mechanical and electrical equipment for the SSG pilot plant was at this stage completed, and the same for the projecting and design of the structure.
The next step would have been the production of different components and construction preparations on location.

The project consortium could at this point not see any other alternatives than to stop all equipment investments. The manufacturing of the turbines was stopped in the beginning of November 2007.
Investment in equipment and start of construction could not be duly justified with the uncertainty on the outcome of the objection process.

The objection was denied twice by the Municipality of Kvitsøy but was then taken further to the regional commissioner in Rogaland.

The regional commissioner in Rogaland denied the objection against the WAVESSG plant in March 2008, but the same individual that delivered the earlier mentioned complaints have now taken it further and delivered objections against the above decision to the Norwegian department of Environment and Energy.

This situation is still unsolved, and even with a project prolongation would there not be a guarantee that a final permit to start construction would be given in the near future.
The project consortium could therefore not see any other alternatives but to stop the WAVESSG project completely.

Even though the project consortium had to stop the project before the SSG pilot could be installed and tested have a lot of important development activities and objectives been reached.
The individual partners in the consortium have gained important knowledge through addressing and solving the design challenges in the project. The most important milestone is that the many challenges on the design of the patented MST turbine were solved and that successful testing proved the turbine concepts functionality.

The experience gained throughout the project will be very beneficial in the further development of the SSG concept and in the search for a new location to carry out testing on a full scale pilot of the SSG and the MST system.

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