Final report
Avtal-13-329
Guiding Device with a lateral force damper for a Submerged Wave Energy Converter

A. Savin
Inst. för Teknikvetenskaper, Uppsala Universitet

*Slutrapport till Ångpanneföreningens Forskningsstiftelse. December, 2014

Contents

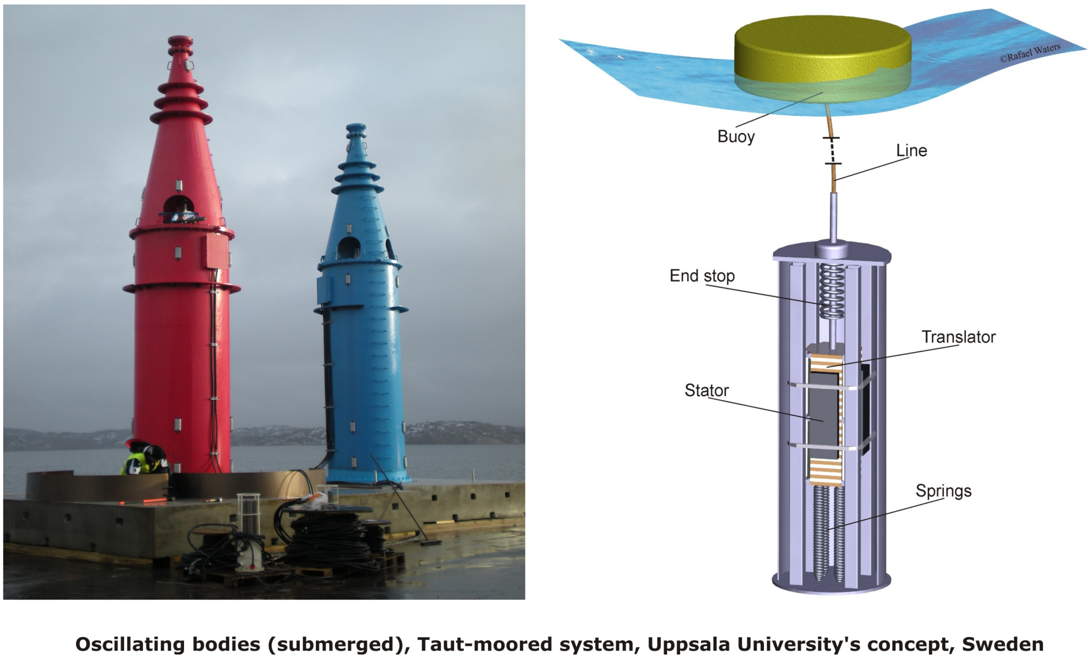


Figure 1: A concept for wave energy conversion

1 Introduction

At the Swedish Centre for Renewable Electric Energy Conversion, Ångström Laboratory, Uppsala University a concept for wave energy conversion has been developed and the first full-scale generator was launched offshore outside the Swedish west coast in March 2006 [1, 2, 3, 4, 5].

The wave energy concept that has been tested in the Lysekil project differs in many aspects from earlier attempts.

Wave climate at the Lysekil wave energy research site is relatively calm in comparison to other off shore places in the world. However, available wave power resource of the Skagerrak, outside the Swedish west coast, can still be a viable source of renewable energy from a technical and economical perspective, mainly due to the high density of the energy stored in ocean waves [2].

The wave energy converter (The WEC) consists of a linear direct drive generator placed on the sea floor as shown in Fig. 1.

At a translator speed of 0.7 m/s and connected to a load of 4 Ohm, the efficiency of the generator is 86 % [4].

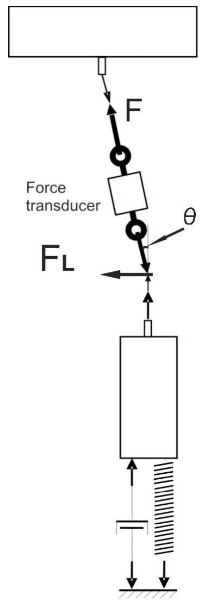


Figure 2: Friction between the funnel and the connection line

The generator is protected against the water by the outer structure. The water depth at the designated site is 25 metres. The height of the generator is 9.4 m, the diameter of the outer cylindrical structure is 1.6 m. A rotation resistant hoist rope made out of compacted strands was used as the connection line in all previous experiments [6].

Many components were modified in terms of weight reduction and more effective energy conversion. Nevertheless, the guiding device had very similar design in all WECs. It consists of a super structure with a funnel on the top.

The connection line passing through the guiding device is bending when the floating buoy is located with some angle with the generator. Friction occurs between the guiding device and the connection line due to the lateral force F_l, see Fig. 2. The friction contributes to a loss of energy which reduces the efficiency of the wave energy converter.

Hence, the service live of the connection line directly depends on fretting wear. Maximize the service live of the connection line and the guiding system is of importance for energy production. Minimize fretting wear is a major task in this case.

The purpose of this project is to develop a new type of guiding system for a linear direct driven permanent magnet generator where friction will be minimized by rolling friction.

2 Full scale experimental site outside Lysekil

The experimental facility outside the west coast of Sweden is presented at www.el.angstrom.uu.se under the heading Wave Power Project Lysekil, where additional project information also is available, including related scientific publications. The location of the research site is shown in Fig. 3.

The Lysekil research site was evaluated as one of four tests sites in Europe where it is possible to evaluate the commercial potential of a wave power technology by the the International Energy Agency, IEA, see the IEA OES report for (*2009*[1]).

It is then possible to test: - multiple units performance - device array interactions - power supply interaction - environmental impacts issues - full technical and economic due diligence

Figure 3: Location of the research site

3 Report

A first prototype of the (GD) with a lateral force damper has been calculated and designed in SolidWorks program. Fig. 4 shows a CAD assembly over a new Guiding Device (GD). Each roller inside the guiding device

[1]IEA-OES. International Energy Agency Implementing Agreement on Ocean Energy Systems, OES-IA, Annual Report 2009. IEA-OES executive committee

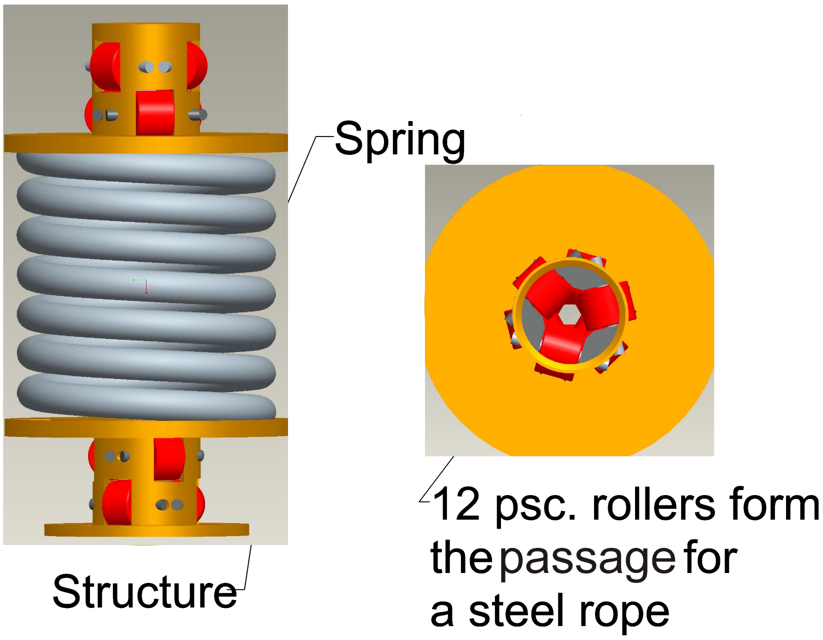


Figure 4: Guiding device with a lateral force damper

rotate around a respective axis and is arranged to form a rolling passage system for the connection line.

With such a construction the connection line is able to roll on rollers instead of friction with the GD. Hence, the efficiency will increase as well as the wear of the connection line will be reduced.

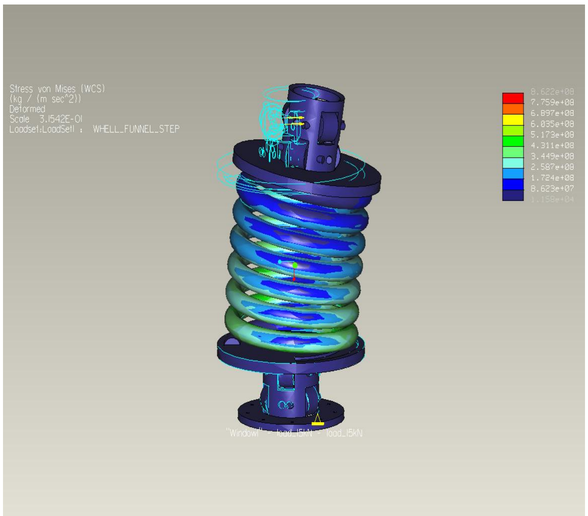
A powerful spring is used as a lateral force damper. The lateral force on the guiding device is minimized by lateral displacement of the spring, and as a result the wear of the connection line is reduced.

The GD was also simulated in terms of stress distribution as well as displacement of upper part of the GD under working load. Fig. 5 shows simulation results for both stress and displacement. It can be observed that max stress in the GD under loading is within permitted limits for the material. Displacement of the upper part of the GD is within permitted position.

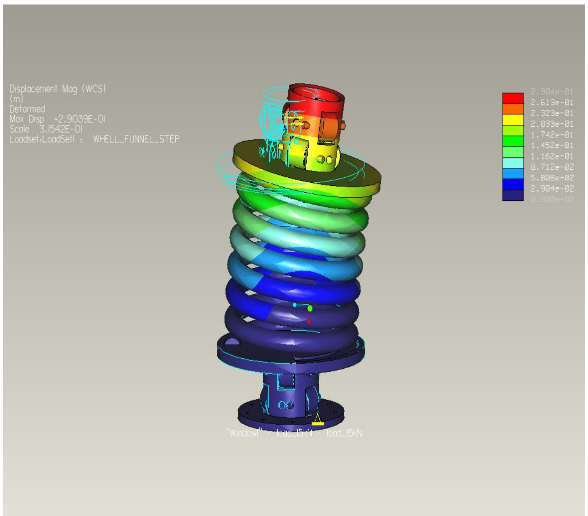
Special wheels covered with with a Vulkollan compound have been chosen. Contact stresses between the wire and the wheel have been calculated even in case of wearing of Vulkolan compound. The level of contact stresses are within permissible limit and wheel will still rotate but not slide even in case of complete wearing of Vulkolan compound. Aluminum anodes have been chosen to protect axis and wheels from corrosion. Wheel were even placed in salt water over 3 month. Wheel rotated on axis without any problem after experiment.

All components have been mounted to form the new GD. Fig. 6 shows the new GD after painting. It needed careful inspection after each step of building. Mounting have not been a trivial process. Most difficult was to find fastener solution for the spring. It has be done by heating ends of the spring to a high temperature and bending to 90 degree, see Fig. 6(b).

The new GD has also been introduced to the Crown Princess Viktoria during her visit to our



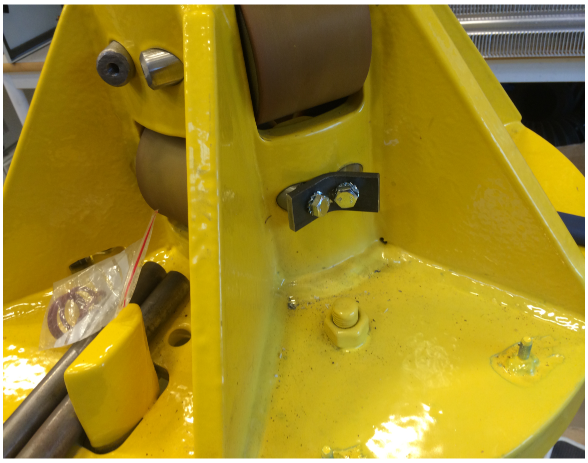
(a)



(b)

Figure 5: a) Stress distribution in the GD under loading, b) Displacement of upper part of the GD under loading.

(a)



(b)

Figure 6: a) The new GD after painting, b) Detailed view of an upper part of the GD.

lab, see Fig. 7.

In a previous wave power experiments at the Swedish west coast, a funnel with a smooth shape had been used. This solution is currently in use. The connection line for such a funnel is housed in 2 layers of jacketing compounds. Firstly, the steel wire is housed in a PEX jacketing compound. Secondly, the wire is covered with a braided Dyneema compound.

Cost of a connection line covered with two layers of material much higher than without covering.

The new GD allows using a connection line without any jacketing compound. Parameters of importance in this case are flexibility and high breaking strength of the connection line.

Figure 7: The Crown Princess Viktoria is visiting our lab. On the photo Professor Mats Leijon shows the new guiding device for the WEC to the Crown Princess.

The steel wire Powerplast 32 mm (with tensile strength of wire = 1960 N/mm^2), FZ, a rotation resistant hoist rope made out of compacted strands with minimum breaking load = 930 kN was used in this experiment, see Fig.8.

The WEC L6 has been chosen to test the new GD in full scale operation, see Fig.9(a).

Divers with a boat for underwater work provided the project with disconnection of the old GD from the generator, connection of the new GD as well as connection of the floating buoy, see Fig.10, 11, 12.

Full scale offshore experiment at the Swedish west coast with a new GD is ongoing now. Evaluation of results will be done and documented.

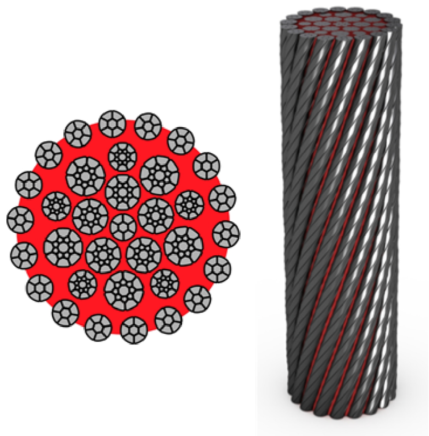


Figure 8: The steel wire Powerplast with minimum breaking load = 930 kN.

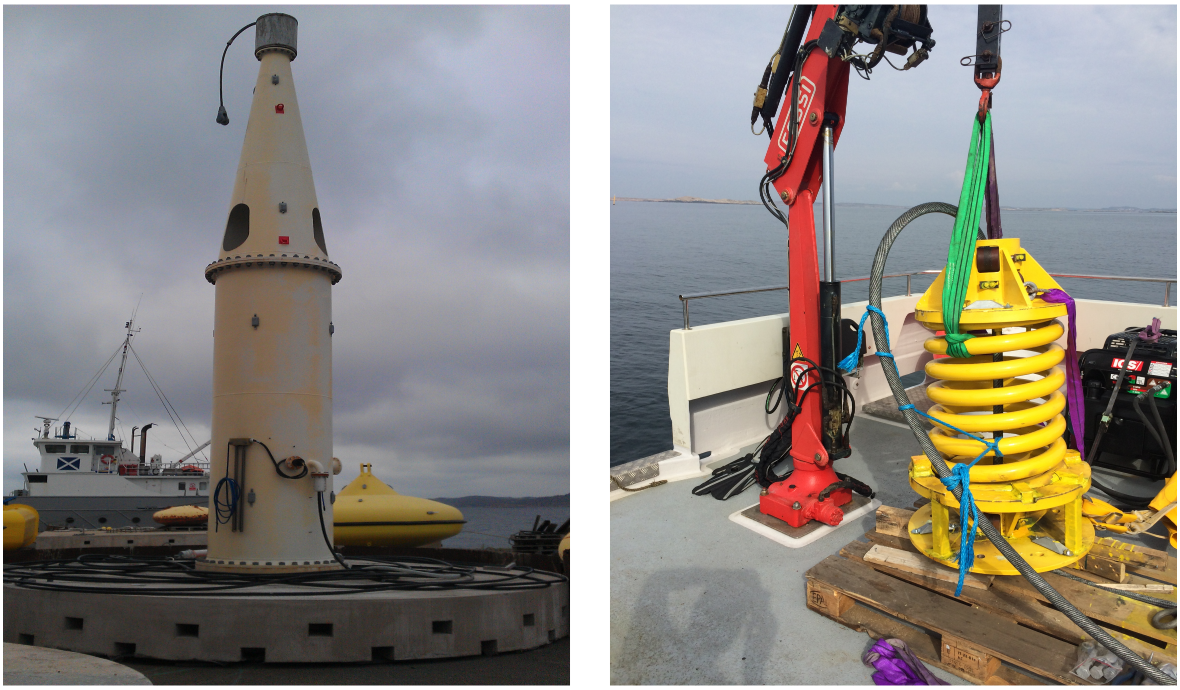
4 Remarks

The main emphases in this project is an innovation proposal for the guiding device in terms of minimizing of wear of the connection line and especially for increasing the service life of the WEC.

The lateral force from the waves is to be absorbed by the powerful spring with minimum wear at the contact surface.

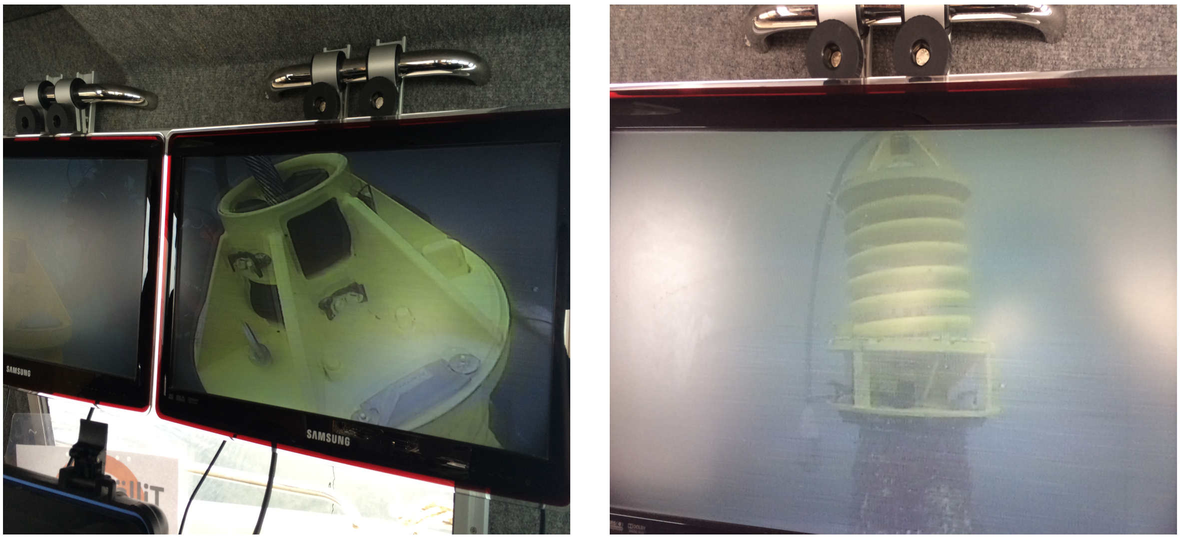
The research in this area is of importance because a search for new solutions for generation of energy is becoming more and more important for our future.

Presented innovation proposal has strong industrial relevance. The project is a step that may influence future design of wave energy devices in terms survivability in a hard wave climate and cost-effective renewable energies.



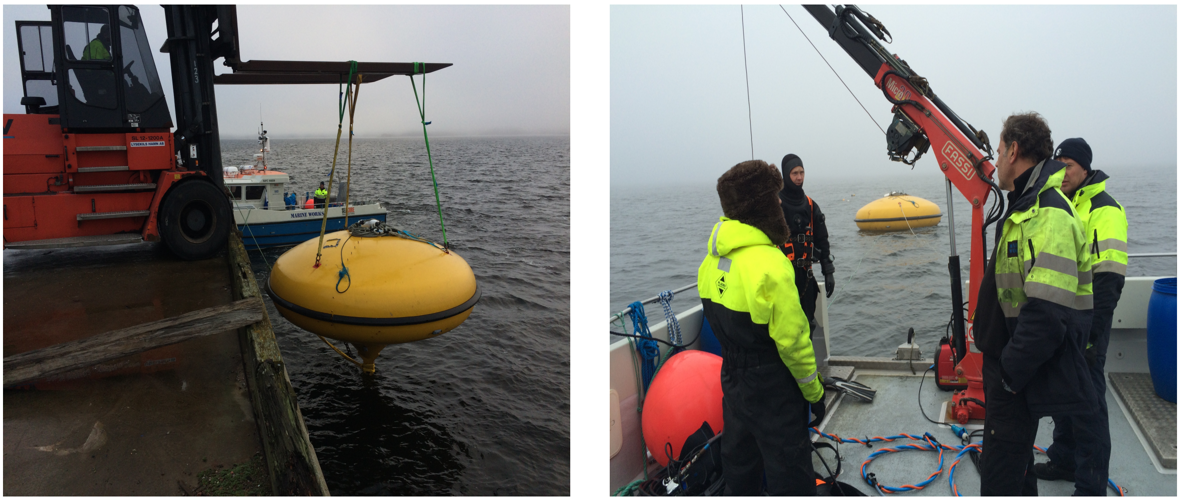
(a) (b)

Figure 9: a) The wave energy converter L6, b) The GD before connection to L6



(a) (b)

Figure 10: a) Guading of connection from the boat b) The GD is connected to L6



(a) (b)

Figure 11: a) The floating buoy, b) Transport to the research site

(a) (b)

Figure 12: a) The buoy is connected to the L6, b) The GD is ready for experiment

5 Acknowlegements

I would like to thank Ångpanneföreningens Forskningsstiftelse for financial support.

References

[1] Leijon, M., Bernhoff, H., Ågren, O., Isberg, J., Sundberg, J., Berg, M., Karlsson, K. E., and Wolfbrandt, A., MARCH 2005. "Multiphysics simulation of wave energy to electric energy conversion by permanent magnet linear generator". *IEEE transactions of energy conversion, Vol.20, No.1, pp.219–224*.

[2] Leijon, M., Bernhoff, H., Berg, M., and Ågren, O., 2003. "Economical considerations of renewable electric energy production-especially development of wave energy". *Renewable Energy, Vol.31, pp.1309–1319*.

[3] Leijon, M., Boström, C., Danielsson, O., Gustafsson, S., Haikonen, K., Langhamer, O., Strömstedt, E., lberg, M. S., Sundberg, J., Svensson, O., Tyrberg, S., and Waters, R., 2008. "Wave energy from the north sea: Experiences from the Lysekil research site". *Surveys in Geophysics, Volume 29, pp.221−240*.

[4] Boström, C., Waters, R., Lejerskog, E., Svensson, O., Stålberg, M., Strömstedt, E., and Leijon, M., April 2009. "Study of a wave energy converter connected to a nonlinear load". *Oceanic Engineering, Volume 34, Issue 2, pp.123–127*.

[5] Leijon, M., Waters, R., M.Rahm, Svensson, O., Boström, C., Strömstedt, E., Engström, J., Tyrberg, S., Savin, A., Gravråkmo, H., Bernhoff, H., Sundberg, J., Isberg, J., Ågren, O., Danielsson, O., Eriksson, M., Lejerskog, E., Bolund, B., Gustafsson, S., and Thorburn, K., January-February 2009. "Catch the wave to electricity". *IEEE Power and Energy Magazine, Volume 7, Issue 1, pp.50–54*.

[6] Savin, A., Svensson, O., Strömstedt, E., Boström, C., and Leijon, M., May 31-June 5 2009. "Determining the service life of the steel wire under a working load in the wave energy converter (WEC)". *Proceedings of the 28th International Conference on Ocean, Offshore and Arctic Engineering, Hawaii, USA, OMAE2009–79164, Volume 4: Ocean Engineering; Ocean Renewable Energy; Ocean Space Utilization, Parts A and B, pp.839–844*.