CHEMICAL ENGINEERING TRANSACTIONS Volume 18, 2009
Editor Jiří Klemeš
Copyright © 2009, AIDIC Servizi S.r.l., ISBN 978-88-95608-04-4 ISSN 1974-9791
DOI: 10.3303/CET0918015

A new emerging energy technology - Pelamis – Demonstration of the assessment by EMINENT tool

Igor Bulatov, Simon J Perry, Jiří J Klemeš
Centre for Process Integration, CEAS, The University of Manchester,
Po Box 88, Manchester, M60 1QD, UK, igor.bulatov@manchester.ac.uk

Over the last few years there has been an increasing amount of research and technology development associated with low or even zero based carbon emitting energy sources. More recently volatility in the price of oil and gas, and concerns with energy supplies, has increased the number of potential solutions to the problems of low carbon energy sources and stable and secure supply chains. New energy supply technologies should be the most appropriate under different economic conditions and different locations and scales. This is a difficult and time consuming problem. A novel early stage energy technology assessment tool has been developed during the EC DG TREN sponsored EMINENT project. This tool enables the evaluation of potential emerging energy technologies and to compare their economic and environmental impact with current technologies. The paper describes a case study which demonstrates how the EMINENT software tool can be used to effectively assess a new emerging energy technology – Pelamis - in the context of providing additional supply to the energy network. The Pelamis technology is a hinged contour device which follows the motion of the waves and creates power from the motion at the joints. Analysis of a Pelamis module of 750kW capacity has been carried out under local conditions for a pre-defined energy chain.. The technology was initially entered into the database of the EMINENT tool and then used for the analysis. A similar pattern was carried out for an existing technology for a similar energy chain. Economic, energy and environmental criteria of the two technologies were then compared. The paper also demonstrates how novel training methods can be used to increase the rate of technological dissemination in the market.

Keywords: early stage technologies, EMINENT, Pelamis, renewable energy, energy from waves

1. Introduction

The availability and price of primary energy resources and the geographical conditions, demand and price differ worldwide. There is a need to evaluate the impact of Early Stage Technologies (ESTs) within a regional/national/local energy supply system. The EMINENT tool has been developed enabling evaluation of ESTs within different geographical and economic contexts and described by Klemeš et al (2007, 2009).

Please cite this article as: Bulatov I., Perry S. and Klemes J., (2009), A new emerging energy technology - pelamis – demonstration of the assessment by eminent tool, Chemical Engineering Transactions, 18, 105-110 DOI: 10.3303/CET0918015

A range of different technologies exist to meet the world energy requirements. Ever increasing emphasis is being made on the development of sustainable forms of energy generation. Hydro-electricity is already quite widely used and wind and biomass energy industries are rapidly growing but there are other also opportunities.

In this work the EMINENT tool has been used to analyse one particular emerging technology – the Pelamis Wave Energy Converter.

The ocean is an enormous source of untapped energy. This resource has been of interest for many years. The recent energy price fluctuations as well as steadily growing sustainability concerns have reignited the interest to this source of energy and the technologies that can harness it. There are several forms in which the ocean energy comes: waves, currents and geothermal vents. Waves and currents have been considered so far.

Wave energy is a form of concentrated solar energy. Part of the energy of winds which blow over large areas of water is converted into wave energy. The wind speed, time length and the distance over which it blows determine the amount of energy transferred in the form of wave size. Original solar power of typical levels of 100 W/m^2 is converted to wave power levels of ca 10-50 kW per m of the wave length (Boud 2003). Estimates show that the wave power potential of the entire ocean is in the approximate range of 8-80 TWh/y (1-10 TW) see Muetze and Vining, 2006. Fig 1 shows the wave power levels around the world. It can be seen that the best potential locations can be found in 30-60 degrees latitude zones where strong storms are quite frequent.

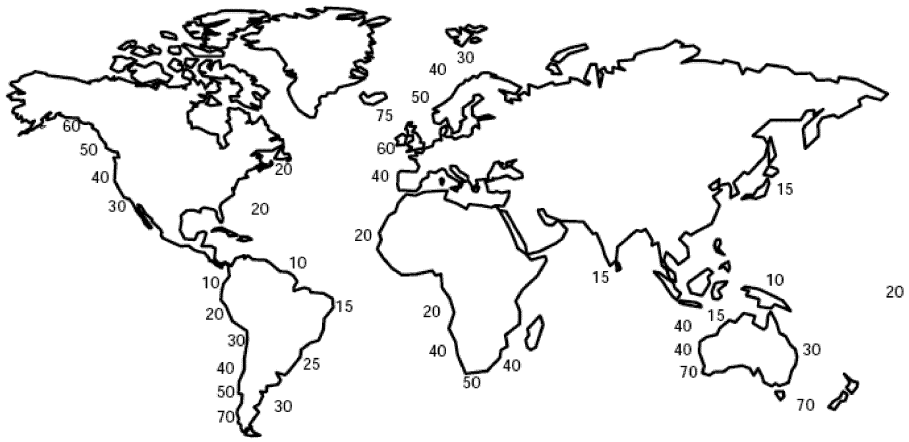

Figure 1. Wave power levels (in kW/m) world-wide (Boud, 2003)

Further, Fig 2 shows the wave height distribution in metres around the UK, Ireland and adjacent areas.

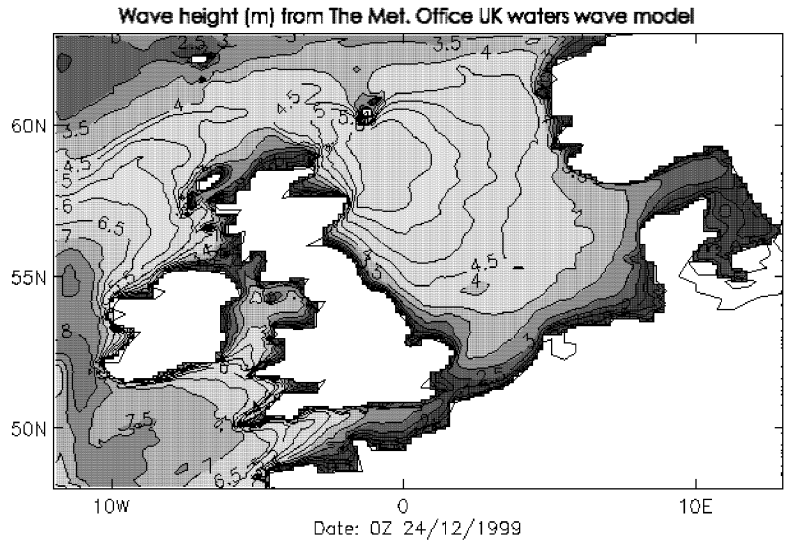

Figure 2. Wave heights (in m) around the UK, Ireland and adjacent areas (Energy Systems Research Unit, 2009).

2. Pelamis Wave Energy Converter

The Pelamis Wave Energy Converter - Fig. 3 (Pelamis Wave Power, 2009) was developed by Pelamis Wave Power Ltd (previously Ocean Power Delivery). The device is a semi-submerged structure composed of cylindrical sections linked by hinged joints. The wave-induced motion of these joints is resisted by hydraulic rams, which pump high-pressure fluid through hydraulic motors via smoothing accumulators. The hydraulic motors drive electrical generators to produce electricity. Power from all the joints is fed down a single umbilical cable to a junction on the sea bed. Several devices can be connected together and linked to shore through a single seabed cable.

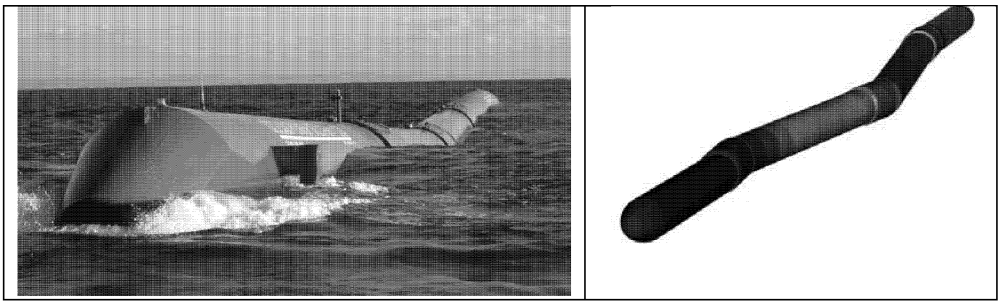

Figure 3. Pelamis Wave Converter and graphical representation of it model simulated (Pelamis Wave Power, 2009)

Current units are 140 m long and 3.5 m in diameter with 3 power conversion modules per machine. Each unit is rated at 750 kW. Conditions of the installation site affect the amount of energy produced by Pelamis. Depending on the wave resource, Pelamis machines on average produce 25-40 % of the full rated output over the course of a year.

Each machine can provide sufficient power to meet the annual electricity demand of approximately 500 homes (Pelamis Wave Power, 2009).

The units provide 'hands free operation. No maintenance is needed to be carried out offshore and no offshore intervention is required. According to the developers it has a 'built in' survivability. The technology has been developed and tested for a number of years, so it has been verified and insured.

The first stage of production is manufacturing power conversion modules which contain power capture systems. The module consists of a fabricated and painted steel structure that is populated with systems that include motor generator set, hydraulic cylinders, accumulators, reservoirs and electrical control cabinets. These systems are delivered to the module population facility where they are installed, assembled and the completed power conversion module commissioned. The main structural fabrication consists of steel tubes, nose and yoke sections. The nose section is installed with transformer, switchgear and control systems and is commissioned. Each tube is fitted with cabling and connecting transits as well as ballast to ensure the correct displacement and trim of the machine.

The machine is assembled of modules and tube segments which are joined together. These joints can be made both on land and in the water depending on the facilities used. The fully assembled machine then undergoes quayside commissioning prior to sea-trials and on-site installation at the wave farm.

The offshore infrastructure consists of three main components which are necessary to install: (i) mooring spreads, (ii) subsea power cables and (iii) latch assembly which connects the main moorings to the dynamic cables. The latch assembly provides a single point to connect the Pelamis units to both the main moorings and the power cables. All components and sub-systems within the Pelamis power take-off and conversion systems have been modularised and are less than 4 t in weight. Pelamis machines are operated via a bespoke Supervisory Control and Data Acquisition (SCADA) system with the capability of project operation to be incorporated within clients existing generator operating platforms.

Pelamis has been designed to be a fault tolerant generating system with the incorporation of multiple levels of redundancy throughout all systems (structural, moorings, hydraulics, electrical and control) and with all failure paths ending with inherently safe modes so that the survivability, station-keeping and in most cases; generating functionality of the system is not compromised. This unique, fault tolerant capacity is central to operating and maintaining a generator in the harshest of environments, where opportunities for maintenance interventions can be very limited, especially through heavy storm seasons (Pelamis Wave Power, 2009).

There are several projects both ongoing and planned which involve Pelamis device deployment: (i) Aguçuadoura, Portugal (Power Technologies, 2009) – the first multi-unit wave farm, with three machines in operation, (ii) planned Orcadian Wave Farm, UK – four Pelamis machines planned to be installed in Orkney mainland, Scotland, (iii) Wave Hub, UK – the UK first offshore facility for the demonstration and proving of the operation of arrays of wave energy generation devices (Pelamis Wave Power, 2009).

2. Pelamis analysis in EMINENT tool

The EMINENT software tool has been applied to assess possible energy supply chains with Pelamis and to evaluate each of them based on weighting factors given by the user. It consists of integrated resource, and demand EST database managers, databases on resources, demand and EST as well as the analysis tool. Pelamis data has been first entered into the EST database. Fig 4 shows a section of the EST database manager.

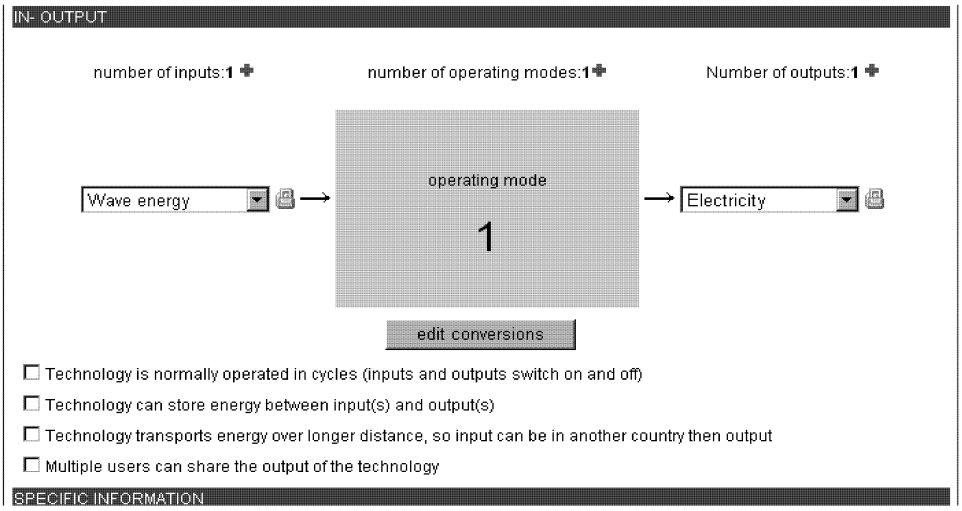

Figure 4. EST manager in EMINENT tool.

The resource data are then entered into the resource database (Fig 5). The wave potential of the Orkney Islands was chosen as a resource. The demand data were then input into the tool. For the purpose of the analysis 7,700 households in Orkney Islands (Office for National Statistics, 2009) were chosen as a demand side. The results are be presented in Table 1.

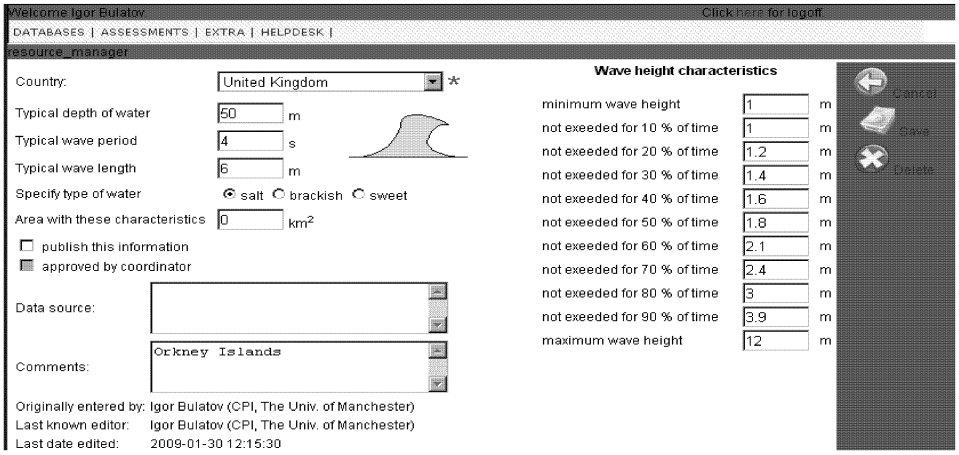

Figure 5. Resource database manager in EMINENT tool

Table 1 Major result parameters of EMINENT analysis

Parameter	Value
Total investment for single end user (€/y)	50336.7
Total depreciation for single end user (€/y)	3355.8
Total maintenance for single end user (€/y)	503.4
Total costs for single end user excl shadow costs (€/y)	3859.1
Total CO2 emission for single end user (kg/y)	0.0
Non renewable energy used (MWh)	0.0
Specific costs (€/MWh delivered)	865.3
Full load hours limitation of resource	11532.8
Full load hours usage of resource	433.0
Power of resource (kW)	10.3
Energy from resource (kW)	4.5

2. Conclusions

The need for new energy technologies to replace heavy carbon based fuels by reducing emissions, especially CO2, can be successfully evaluated using the EMINENT software tool. The Pelamis Wave Energy Converter has been analysed and it has been shown to be a viable technology for the conversion of an extensive renewable energy source, based on the analysis of the results from a small local geographical area. The EMINENT software tool indicates that if the Pelamis system is widely adopted the energy source would provide effective renewable energy on a much larger scale.

References

Boud R., 2003, Status and Research and Development Priorities, Wave and Marine Accessed Energy, UK Dept. of Trade and Industry (DTI), DTI Report # FES-R-132, AEAT Report # AEAT/ENV/1054, United Kingdom

Energy Systems Research Unit, 2009, website accessed 14/01/2009 www.esru.strath.ac.uk/EandE/Web_sites/01-02/RE_info/wave%20power.htm.

Klemeš, J., Bulatov, I., Koppejan, J., Friedler, F, Hetland J., 2007, In V. Plesu, P. S.Agachi (Eds.), Novel Energy Saving Technologies Evaluation Tool, T5-142, 17th European Symposium on Computer Aided Process Engineering—ESCAPE17, Bucharest: Elsevier B.V. Ltd. pp. 1035–1040.

Klemeš J., Bulatov I., Koppejan J., 2009, Novel Energy Saving Technologies Evaluation Tool, Computers and Chemical Engineering 33,751–758

Muetze A. and Vining J. G., 2006, Ocean wave energy conversion – a survey, Proceedings of the 41st IEEE IAS Annual Conference, 3, 1410-1417, Tampa, FIN

Office for National Statistics, 2009, www.statistics.gov.uk/StatBase/xsdataset.asp?vlnk=3062&More=Y, website accessed 14/01/2009.

Pelamis Wave Power, 2009, www.pelamiswave.com/content.php?id=161, website accessed 14/01/2009

Power Technologies, 2009, www.power-technology.com/projects/pelamis/, website accessed 14/01/2009