

Robin Wallace welcomed everyone and introduced the day by giving some background to Energy research in Edinburgh and across Scotland, where the Joint Research Institutes ensure that we have the biggest collection of energy researchers in Europe, if not the world, located in Scotland. He urged everyone not to dismiss any ideas and hoped there would be many fruitful discussions leading to long-term collaborations.

Problem 1 was presented by Sondre Jacobsen (SJ) of Pelagic Power Ltd talking about their W2Power project. He outlined the design of their device which aims to harness more power through less infrastructure by combining wave pumps with wind turbines. The concept is in early stage verification, pending a 1/40 scale prototype. Calculations and estimates they wish to explore further are:

- Forces generated onto the structure from one wave pump
- How will the arrays of wave pumps affect the overall stability of the semi-submersible construction
- What effect on stability and vibrations will the wind turbines have on the construction
- What kind of vibrations, interference or other transient stresses can arise when both wave pumps and wind turbines engage and are in operation
- How irregular waves, swells and wind and other transient forces affect the overall construction and operation
- Forces on moorings and effects on stability from mooring
- Dimensions of mooring

RC commented that the semi submersible device design was very good though wondered what happened if 1 wind turbine breaks?

SS commented on vertical versus horizontal wave buoys.

SJ replied that he was referring to the the Langlee device that has just won a large licensing deal with the Turkish government

SS then asked why the wave buoys were vertical and not horizontal

SJ explained that horizontal wave pumps were the CEOs area of expertise

SS remarked that he had some comparison graphs indicating the efficiency of the horizontal compared to the vertical

SJ agreed that horizontal was very efficient and that it would be advantageous if they combined them

AP asked how they managed to resist destruction of the device given the considerable forces the device must be placed under

SJ replied that it was the combination of the units as well as the stability of the triangle like design. He also added that it was a strength of the design that it could utilise standard turbine parts

RC remarked that the strength of the design was the number of components linked to one cable to which SJ agreed

JV wondered how the water pumps worked

SJ explained that they pump sea water into the feedline

SF enquired about the relative efficiency of the pump system, particularly compared to linear electrical generators

SJ agreed that efficiency could be improved by other methods but the current design was simple and inexpensive when compared to linear generators in each buoy. All buoys pumped water into one feedline, so power smoothing and redundancy was built-in. Also, the Pelton wheel will be located well above the water line, in one of the legs, and so the working parts can be considered to be safely above the water surface

SS disagreed with this last point, suggesting the whole power take-off system needed to be thought of as underwater

There was some discussion relating to the requirement of the Norwegian government that oil platforms are connected to land for power and DI explained that the reason for this was that to meet the Kyoto agreement the Norwegian government needed to impose this rule. SF commented that the application highlighted by SJ of connecting these devices to oil platforms would also be useful for oil fields where there was not enough gas to run them

JS wondered if you could add solar power to get even more for less and also enquired about the bending motion and forces on the pillar

SJ said there was a sway mooring and that when wind exceeds a certain level the turbines shut down and agreed that if the project is a success and the final devices (90mx90m) are launched then space on the platform could be rented out for, for example, solar panel use

AP asked whether the adjustment of the device for prevailing wave and wind delivery was passive or active

SJ explained that the wind would move the device and the turning would be accomplished by the device being well behind the mooring. Given the wind alignment and the triangular arrangement of the wave pumps, at least 2 sides of the triangle would always be active

SS commented that there would be a direct force from the wave trying to make the device move to which SJ agreed and said there was some flexibility in being able to turn the turbines

DI asked about interaction between the floats to which SJ replied that they didn't understand how this might work and would appreciate any help

DI also asked about the impact of biofouling inside the water power transmission

SJ agreed it could be a problem though they felt it would easily be solvable using certain coatings etc and that it was not a major concern

Problem 2 was presented by Roger Cox (RC) of Ocean Flow Energy Ltd talking about their Evopod project. Areas on which they wish to collaborate include:

- Resolving forces and moments under steady state conditions to better understand the drivers for scaling up the design of a floating tethered device
  - Turbine drag
  - Hull and strut drag
  - Mooring tensions passing through buoy and yoke
  - Reaction torque passing through gearbox and generator into the hull
  - Buoyancy forces resulting from change in immersion of struts
- Extend the modelling to cover the dynamic response of the free floating body under time varying tidal flow conditions (eddies etc)
  - Using OrcaFlex model but extended to cover issues such as torque reaction and time varying current speed
  - Develop independent model if OrcaFlex cannot handle issues
- Correlate the numerical model to the physical measurements taken from the 1/10th scale device at Portaferry

MM enquired about movement with tidal direction as well as what happens to the electrical power.

RC replied that there was a swivel about which the machine rotated in a horizontal plane as the tide reversed. Also, the electrical power was monitored and burnt off by a resistive heater in the device

SS wondered how close the devices could be placed and RC said that it was very close but at a cost of generating less power

SS wondered if they would crash into one another if they were too close. RJ responded that his boss has calculated farm dimensions taking this into account and how close they can be situated also depends upon the depth at that location

SJ enquired whether that was considering in front or side by side layout and RJ replied that the farm design considered was a 2D array

JS wondered if you really needed the 2 connections in the current device design to which RJ responded that there was a risk of seaweed clogging with a 1 joint design and it might be too rigid

JS suggested it would eliminate side-to-side motion although RJ countered that the width of the device eliminated this

JS asked if universal motion at a universal joint might be possible and RC commented on the possible torque reaction and that this was something that was a problem in the Orcaflex model as it doesn't sit at an angle there

SF asked about the electrical connection to the shore

RC explained that the next plan is to trial a bigger grid connected device in which the buoy will be connected by an electrical slip ring

SF enquired about how a variable speed generator would link to a fixed 50Hz system and RC said they aimed to step up the voltage on Evopod itself but not by much

SF commented that connecting an array would give rise to interesting effects and RJ replied that in an array an island substation would be used

SF suggested holding a variable frequency and stepping up to allow use of a smaller cable and RJ responded that he would be interested in more advice on this topic

MM suggested a permanent magnet gear box and RC was worried about the hydraulics though he thought a direct drive would be great and that they'd love to test one

MM asked about the waves and current interaction and its influence on power

RC replied that that they hadn't measured the waves yet as a lot of memory was needed to record wave data

DI remarked that measuring as much as possible now was a really good idea and would lead to subsequent cost savings

DP asked about site analysis and the suitability of medium or large sized estuaries

RC replied that the device was tested in a broad, shallow entry sea lough with a strong current. Some research has been done into the best sites for tidal stream in the Shetlands and the Orkneys

SF wondered what size of generating capacity was needed to make the device economic and VK replied around 1MW. RC thought the requirement for isolated communities would be smaller

SJ asked about what kind of tides the device could deal with

RC replied the device could survive heights of 0-10m with a generating capability at max 4m/s and viability being achieved with average flow rates of 1.5m/s

DF asked about the range and RC said it was around 1.5m though this was a proportion of the total depth

DF enquired about the ACDP positioning and RC replied there were 4 moorings and relatively little movement

DF wondered why the two parallel struts, which make up the yoke, could not be modelled in Orcaflex as two parallel lines connected to the swivel joint and Evopod by pivot joints

RC replied that there is no pivot junction option in Orcaflex

MS asked about extreme waves such as the 16ft waves found in the Pentland Firth

RC commented that using the model the anchor size could be defined

VK wanted to know if there was any damage to the sea bed and whether any environmental impact was observed due to chain drag and RC agreed this would be interested to know and thought that the rotation would provide less scour

JS commented that the chain will wear and RC agreed that a large chain would be needed for the seabed

AP asked what RC thought the common problems for the industry were and whether companies could tackle them together, e.g. mooring? Were there any other priority problems? RC wasn't sure and said he would discuss this further with his boss

AW asked about the costs of a full scale device were compared with a 1/10<sup>th</sup> scale model and RC replied that the steel for fabrication was a minor cost when compared to the costs for installation and testing, especially due to the expensive instrumentation

MM asked when a full scale prototype would be tested. RC said the next device would not be full scale but around 35kw

DI asked about where testing would take place but RC was not allowed to be more precise than East Scotland

MM wondered how well N rail software compared and RC said it was good

Problem 3 was presented by Ben Child (BC) from the University of Edinburgh and related to interactions within arrays and whether intra-array effects could ever be exploited for constructive interference. DI added that the issue of sheltering effects and inter-array interactions were also of interest.

JV asked about the differences between the 2 approaches taken by Ben in modelling and whether the 2<sup>nd</sup> still used the same assumptions. BC replied that in the genetic algorithms (GA) method assumptions were not used and the whole thing was solved which was very computationally expensive

JV enquired what happened if you removed the minimum restraint in the GA method – would it collapse? BC replied that there was a singularity when devices overlap that causes the GA method to predict infinite power

BB wondered if device shape influenced the results and BC agreed that it would

JV asked how well linear theory applied to real device and BC commented that although it can't fully answer all the questions it has been a useful starting point for considering array behaviour

SJ asked how big the power differences between destructive and constructive interference could be. BC said that device placement for constructive interference could yield 77% more power and badly placed devices could lose up to 60%

AP enquired about the stroke of the device and BC commented that the theory didn't really apply at resonance of 3-4 times the incident wave height

JBS wondered if it was based on plane incoming waves and DI suggested that it was probably not but long swell waves could be approximated by plane waves

SS suggested an alternative way of plotting the results to maximise commercial interest since it was the section of the graph that was commercially viable that was of interest and by plotting  $2pk_a$  against the inverse more useful information would be immediately obvious

BC commented that one advantage of plotting against  $2ak$  as he had done was the ease of being able to spot patterns in the data though JBS didn't think this really applied in the interesting range between 0 and 1

SS mentioned closely packed ducks and that there was no difference in total power when below the power limit since when closely packed they grabbed what was radiated from their neighbours. All were needed for high wave power but were not necessary otherwise. A closely packed spine on the same mooring was considered the best solution

MM asked if some tuning was assumed and BC said it was. MM wondered then how edge effects were considered and BC agreed the simplified model didn't deal with this

VK wondered if a dramatic difference would be observed with modes other than just heave

BC said by allowing movement in different modes this would change the optimal locations and for very close devices a broader interference pattern would be observed. For further apart devices they need to be in exactly the right place to exploit interference

VK enquired about how applicable the model was to real seas and whether given the modelling challenges was it not just best to place them randomly

BC said some calculations had been done using the whole spectrum and that some research agrees that there is no point in trying to maximise good interactions and the best solution is to put them far apart to minimise bad interactions. If the objective is to smooth power the arrangement doesn't matter and the number of them is important

JS asked about the Q factor spectrum and BC agreed this could be an interesting approach

JV wondered if it would be possible to use a few devices and some obstacles to focus the waves

BC agreed this could be possible though commented on the difference between scattered versus radiated waves

EM commented on the difference between the 2.5 BC obtained in his result when aiming for 0.8 tuning and wondered if you could optimise at 0.2 and hopefully get 0.8

BC said that optimising the arrangement and optimising with regard to k were not the same thing as total power was quite small and Q very sensitive therefore it would be difficult to do the above successfully

JBS and BC discussed dividing by the Q factor and plotting power. EM suggested normalising for energy and JBS commented that  $Q_{\text{factor}}/\text{power}$  represents the real power

SS remarked that 60m sizes were very big.

DF asked about scattered and radiated waves in the animation and BC replied that the amplitude was the sum of both of them and the incoming wave. There is a small effect on the free surface amplitude and it is hard to observe the elevation change but there is a change in power

RC wondered how this would apply to the SJ device and BC said there would be different effects as it is orientated and there are close absorbers so it would be easier to exploit good interactions