Engineering Study of Tidal Stream Renewable Energy Generation and Visualization: Issues of Process Modelling and Implementation

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Abstract. Tidal stream energy has the potential to make a significant contribution to energy mix in the future. Accurate modelling and visualisation of both tidal resource and array layout enhances understanding of in-stream tidal behaviour leading to improvements in site identification and optimal positioning of individual turbines. A realistic representation of blade loading conditions will aid designers and manufacturers in creating more robust devices and improve survivability. The main barriers to large scale deployments of tidal arrays are the costs associated with manufacturing, installation and maintenance. Therefore, presently tidal energy is not competitive on cost with more established renewable technologies. The current position paper investigates and reports on resource modelling, site selection, selecting optimal array configurations and the design and manufacture of devices for tidal stream renewable energy generation. This is aimed at developing models to reliably simulate real conditions, enhance understanding of tidal processes, flow regimes and device survivability issues.

Keywords: Tidal stream energy · Tidal turbines · Tidal resource · Visualisation · Modelling

1 Introduction

Renewable energy generation is growing in relevance due to the dual issues of continuing global warming and national security of electrical supply. A largely untapped potential resource is ocean energy which has the global potential to supply 170 TW of electricity annually [1]. Of the currently available technologies to extract energy from the oceans only tidal range, which takes advantage of the vertical height difference between high and low tide, is at a mature stage of development [2]. A nascent alternative tidal technology exists which seeks to exploit horizontal fluid motion and is less intrusive than tidal range installations [3], in stream tidal turbines, and operates using the same basic principle as a wind turbine using seawater as the operating fluid rather than wind [4].

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Tidal science is a developed field of study and the predictable nature of tidal motions overcomes stochastic issues faced by other renewable technologies, most notably wind and wave [5]. Predictability provides an advantage not only for grid management but also for accurate financial forecasting which is a key obstacle to the widespread installation of tidal stream turbine arrays [1]. Within the UK there is a desire to progress deployment of tidal stream technology and the Crown Estate, responsible for the seabed around the UK, has leased 26 zones suitable for tidal stream arrays. If these projects are all realised, installed tidal stream capacity in the UK could reach 1200 MW [6].

Wave and tidal technologies are expected to make considerable contributions to the future of global electricity generation [5]. Ocean wave energy, much like wind energy, is stochastic in nature. The study of tidal flow is an established science and the effects of the Moon and Sun are well understood allowing accurate tidal forecasts [3, 5]. It has been argued [7, 8] that for this reason tidal energy is more reliable than other offshore energy sources. Also, the predictability of tidal energy provides an advantage for grid management as tidal output can be integrated more easily due to accurate forecasting. The sustainable integration of tidal energy as a major contributor to the renewable mix would require the development of devices which can operate in deep water (>50 m) and can extract energy from slower moving currents (<2 m/s) than currently possible, this will enable deployment a much greater area and reduce competition amongst developers for the most attractive sites.

The forecast is that early that early deployment of tidal stream turbines will lead to competitiveness being reached sooner and this is important to reduce the relative importance of fossil fuels. It is important therefore that industry should prioritise R&D to improve device efficiency rather than focusing on the identification of cost cutting measures. They also promote the development of energy storage techniques and smart grid networks which will aid the increased penetration of all intermittent renewable energy.

2 Tidal Range Technology and Science

In-stream tidal devices are designed to capture the horizontal motion of the tide, tidal range technology exploits the vertical motion of the tidal cycle. A dam is constructed across a bay or estuary which experiences a large tidal range (>5 m). Sluice gates at the dam base control fluid flow; these are kept closed until a sufficient head is built up across the dam wall. The gates are opened and water flows from the high side to the low side and in doing so passes through turbines which spin to produce electricity. Power is generated following both the flood and ebb tides with the high water being on the ocean side of the dam during flood tides and water being held within the bay during the ebb tide [3]. Variations on the scheme include tidal lagoons, reefs and tidal fences, all of which operates using the same principle.

The most established tidal range plant is La Rance in France which has been in operation since 1967 and generates 480 GW hrs per year. A 720 m long barrage separates the river estuary from the ocean and twenty-four 10 MW reversible turbines are installed along its length. The power plant combines two-way operation with pumped storage to act as a reserve [2, 3]. The basin captures a 22 km^2 water area with the dam doubling as a road link and the installation has become a popular tourist attraction.

2.1 Tidal Levels and Parameter Descriptions

The regular rise and fall of the water level of the ocean is principally caused by gravitational and centrifugal forces which are a result of the proximity of the Earth to the Moon and the Sun [3]. When the water flows towards the shore it is called a flood tide while the receding water is called the ebb tide. This occurs on at least a diurnal (daily) basis in all areas of the world and for coastal areas in northwest Europe the tide exhibits strongly semi-diurnal (twice daily) behaviour [3, 9].

High tide on earth occurs "in line" with the Moon and conversely low tide is + experienced at +/−90° relative to the Moon. A second major influence is that of the Sun, because the Sun is much further from Earth the gravitational force it exerts is around 0.45 that of the Moon. When the Earth, Moon and Sun system is in alignment the gravitational effects of the Moon and Sun are combined to form a high tidal range (a spring tide), when the Moon and Sun are at 90˚ to one another, as viewed from Earth, the gravitational effects of the Moon are counteracted by those from the Sun, leading to an exceptionally low tidal range (a neap tide) [3].

The velocity at which the tidal water flows varies from zero m/s at periods of slack water to a maximum value which occurs halfway between periods of slack water [3]. A mathematical description of the tide is that it exhibits a sinusoidal behaviour and is made up of a number of harmonics each with a varying degree of influence. The principle influences of the Moon (M2 – lunar semi-diurnal) which has a period of 12.42 h and Sun (S2 – solar semi-diurnal) which has a period of exactly 12 h are the largest constituents. The tide is also affected by local bathymetry, ocean currents, weather and density gradients. The period of M2 results in high tide occurring approximately 50 min later each day [9]. The relationship between the M2 and S2 constituents means that a spring – neap cycle lasts approximately 14.75 days. Tidal asymmetry is a result of the influence of M4 (lunar quarter-diurnal) constituent which is largely a consequence of local bathymetry [9]. The relationship between the phases of M2 and M4 could potentially lead to a tidal resource only providing maximum output for one cycle per day even in a strongly semi-diurnal region.

2.2 The Cost of Ocean Energy

Cost is seen as a major barrier to the wide scale deployment of ocean energy technology [10]. In order to improve investor confidence accurate resource assessment and forecasting models are required [6] (Fig. 1).

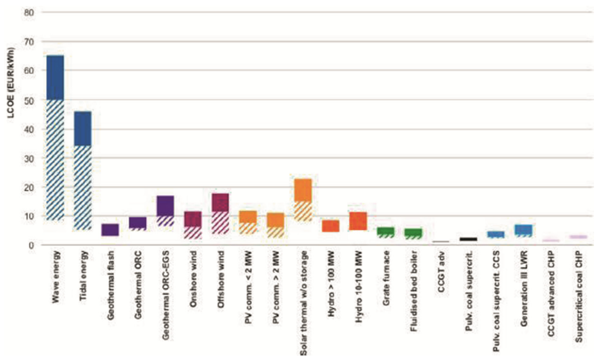

Fig. 1. Cost of Ocean Energy (Blue LHS of chart) vs other forms of electricity generation [11]

Cost reduction should be a target for the in stream tidal energy industry and reliable visual models for resource assessment and assessing the impact of turbine arrays on flow regimes should be developed. These could help to eliminate the current dependence on costly and time consuming empirical data collection. There is also a need to improve device manufacturing techniques, accurate modelling of blade loading conditions will expedite blade and tower design consensus thus enabling greater supply chain competition. While models which accurately portray the cyclic nature of tidal loading will help to improve design for survivability and improve understanding regarding the detrimental effects of seawater ingress, particularly when designing with composite materials.

3 Technology Design and Implementation

There are three main types of devices for capturing the energy contained in tidal streams. They include (i) horizontal axis tidal turbine, (ii) vertical axis tidal turbine and (iii) reciprocating or hydrofoil devices [3]. Each of the designs attempt to extract the kinetic energy contained in the tidal and convert this to rotational motion via rotor blades which in turn produces electricity from a generator.

Devices which are installed at greater depths can have larger sweet areas and therefore capture more tidal energy. However this comes with greater installation costs [8]. The principle of operation is similar to that of a wind turbine. Seawater is much denser than air and typically travels at lower speed. The turbine must generate electricity during both flood and ebb tides and be capable of withstanding structural loads [3]. The tidal turbine blades are of a hydrofoil design. This facilitates the extraction of energy from fluid flow.

3.1 Current Guidelines

In general, the most promising areas are found in ocean channels or straights where tidal flow is forced through a narrow cross section e.g. the Pentland Firth (Scotland) or Alderney (English Channel). Using Fig. 2. [12] it is possible to identify those sites around the UK where tidal flow velocities are greatest, these are the most attractive sites for development. There is also a challenge when classifying the tidal velocity at a particular site as velocities will vary within the water column and across the cross section due to local bathymetry [13], therefore an average velocity is not sufficiently accurate to allow a developer to position turbines. For the reasons outlined above the European Marine Energy Centre (EMEC) have produced guidelines for resource assessment which recommend a developer conduct extensive onsite measurements when identifying a potential tidal site [14].

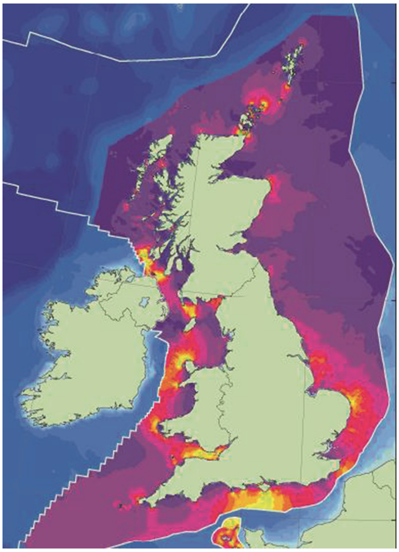

Fig. 2. Peak Flow for a Mean Spring Tide (areas in yellow have high velocity flow i.e. >2 m/s) (Color figure online)

A challenge posed by the approach of EMEC is the time consuming and expensive installation of measurement apparatus. The development of advanced models to quickly and accurately predict tidal flows will benefit both site developers and academics by allowing the analysis of a greater number of potential sites without the need for extensive onsite measurements.

Velocity is of interest because the power output of a tidal turbine is related to the cube of water velocity, the power available at the rotor is found from,

$$P_t = \frac{\rho \cdot A_r \cdot v^3}{2} \tag{1}$$

Where P_t is the power available at the turbine rotor (W), ρ is the density of seawater (kg/m^3), A_r is the swept area of the rotor blades (m^2) and v^3 is the velocity of the seawater (m/s) passing through A_r.

There are a number of observers who highlight that looking purely at maximum flow velocities during the site selection process is superficial [15], these authors encourage a leasing strategy which reflects the need for phase diversity between tidal sites in order to provide a firm supply of electrical energy onto the national grid.

3.2 Blades Variation and Energy Capture

Tidal turbine blades are of a hydrofoil design in order to extract energy from a fluid flow. This is similar to the working principle of a wind turbine but with tidal stream devices the ratio between the density of the fluid and the blade's material is much closer to 1 [16]. For purposes of comparison, loads experienced by a tidal turbine's blade is much greater than those experienced by a wind turbine blade. There is the need for greater understanding of the loads faced by blades as unsteady loading may exceed steady state loading by up to 15% during a tidal cycle. Not all the power available to the turbine can be converted into electricity. The power equation must be adapted to reflect device efficiency. This is done with the inclusion of a capacity factor (C_p) into Eq. 1 as an expression for electrical power (P_E), given by:

$$P_E = C_p \frac{\rho * A * v^3}{2} \tag{2}$$

For present technology, a value of 0.35 has been suggested as a reasonable value for C_p, measured value of 0.285 has been reported [17, 18] and very recently when conducting field measurements of a full scale (50 kW) horizontal axis turbine at Strangford Lough, a maximum Cp value of 0.35 has been recorded [19]. Design stability is a crucial step for development of supply chains and the reduction of costs associated with manufacturing.

Visualisation is important at all stages of design. Industry must define clear guidelines on survivability and reliability requirements by implementing universal standards for designers and manufacturers to meet This leads to enhanced cooperation amongst stakeholders [1, 20]. Horizontal axis tidal turbines have been shown to be the most developed and proven technology. Over 76% of global research and development investment in tidal technology has been dedicated to developing horizontal axis devices [20]. This is also the most extensively proven technology with devices connected to the UK grid over the most recent period of six years.

There are two variations of the horizontal axis design. They include (i) devices which have a yawing mechanism enabling them to face into the direction of the tidal current and (ii) devices where the blades are placed on one side of the supporting structure and rotate through 180 degrees to extract energy from both sides [21]. Studies undertaken with the former have shown tower structures always interfere with fluid flow. Placing the rotor downstream during either flood or ebb tends to pose a significant issue due to blades passing through the sheltered area. This is minimized by increasing the clearance distance between rotor blades and the tower. Studies of the effects of loading two, three and four blade horizontal axis turbine models have been reported [22] and they suggest possible methods to improve energy extraction before the blade reaches its optimal setting.

4 Resource Assessment and Modelling

A two stage approach has been suggested for when analysing a site's potential as tidal resource [9]. Initially only the M2 and S2 constituent harmonics are considered to establish the character of a site. This is followed by the next step which is one of developing the model to include the effects M4 and the other lesser tidal harmonics. The European Marine Energy Centre (EMEC), have published guidelines for tidal site developers in which they advocate the use of extensive onsite measurements as part of a resource assessment [23]. The challenge this poses is that the offshore deployment of measurement apparatus is a costly and time consuming endeavour. Another technique involves the use of two methods which utilise recorded current speeds, at a known vertical distance from the seabed, to estimate flow in the water column. The Van Veen and von Karman approaches each use a dimensionless factor, found from experiment, to extrapolate a known tidal stream velocity to any desired height in the water column. The availability of accurate tidal stream charts in some regions offer the prospect of using known surface currents to extrapolate to depths where turbines are located.

4.1 Site Location and Description

The north coast of Antrim is an area with a high velocity flow regime. Alternative methods to investigate resource availability are explored in this paper. We attempt establishing the velocity profile without the need for extensive field studies by using existing publications and data to conduct resource assessments. In this paper we relied on known surface currents to estimate flow regime in the water column and utilised tidal range over a known area to calculate volumetric flow, which can then be simulated using a computational fluid dynamics (CFD) model. Regional flow regimes during flood tides are a result of underwater features and the Rathlin Island headland. These divide water flowing from the ocean with a disproportionate volume flowing through an area off the north Antrim coast. High velocity ebb tides are a consequence of flow direction with most of the fluid volume exiting the Irish Sea through the northern channel originating from the region of tidal resonance to the west of England. A comparison is then made with flow through a bend in a pipe, where the external radius witnesses a higher flow regime than the internal radius.

4.2 Methodology and Use of Surface Flow Charts

Published tidal stream charts for the northern channel are available at: http://www.visitmyharbour.com/articles/3166/hourly-tidal-streams-around-the-n-of-ireland-and-sw-of-scotland. The charts are produced for recreational sea users such as light sailing and kayaking. The charts show flow magnitude and direction at 13 hourly intervals. Time is referenced from six hours before high water at a regional control port to six hours after high tide, for UK and Irish waters the control port is Dover (England). The surface velocities are presented as maximum and minimum values, to correspond with spring and neap tides, all other velocities are assumed to fall within these boundaries.

Fig. 3. Area of Irish Sea filled from the Northern Channel

The present study area is shown outlined in black in Fig. 3. It encompasses a total area of 13,540 Km^2 with a water area of approximately 12,990 km^2. There are eight zones with differing tidal range within this area.

Another method used to estimate the velocity profile at a site was to use knowledge of tidal range over a known area to calculate the volume of fluid flow during the tidal cycle. Tide tables are available for ports around the world and have been calculated by recording tidal range over a long period and combining the constituent harmonics to extrapolate forward. Tidal range data is widely and freely available in the form of tide tables. The National Tide and Sea Level Facility (NTSLF) record live data for tidal range at selected ports around the UK and these are accessible online at http://www.ntslf.org/data/uk-network-real-time. Live data can be compared with tide table to validate the accuracy of tidal range forecasts. Tidal data for February 2016 has been used to analyse the resource potential of a site located in the Northern Channel which connects the Irish Sea with the North Atlantic Ocean. The Irish Sea (Fig. 4 red box) is a body of water separating Ireland from Britain which is connected to the North Atlantic Ocean by channels to the north and south. Tide tables are available for ports in this region, tidal stream charts are also available for both the flood and ebb tides. The tide is funnelled through a narrow cross section just off the coast of north Antrim (Fig. 4 blue box) as a result this area shows promise as a potential high energy tidal site.

Fig. 4. Irish Sea Showing points of interest in understanding tidal behaviour (NTSLF.org, 2016) (Color figure online)

In order to characterise tidal flow in the area of interest it is first necessary to develop an understanding of the behaviour of the tidal regime in the region. It is established that north western European shelf seas are strongly semidiurnal and this is confirmed by the tide tables for the region. As a result of the tidal regime in the Irish Sea there are four points of interest during the fortnightly tidal cycle. They include the Spring high tide, the Spring low tide, the Neap high tide and the Neap low tide. Analysis of the data shows that high water occurs at similar times at all ports within the Irish Sea's main body of water. This posed the difficulty associated with estimating volume flow through each channel based on the timing of high and low tide at various ports.

4.3 Tidal Range Data and Tidal Charts

In order to develop the required models, without using onsite measurements, available tidal range data and published surface tidal velocity charts should be exploited. Studies have been conducted [24], which seek to determine flow velocity using conservation of mass methods. The principle is, the tidal volume which flows into a body of water must have come through a channel which connects that body with the ocean.

A review of tidal charts reveals that the Irish Sea fills from both the north and south simultaneously, therefore the total height gained, as measured by onshore tidal range monitors, must have entered from these two channels (high tide). The tide then exits simultaneously through the same two channels resulting in a lower sea level (low tide). This cycle of high and low tide is repeated twice every day due to strongly semidiurnal tidal behaviour in the region with maximum (spring) and minimum (neap) tides occurring on a biweekly cycle (Fig. 5).

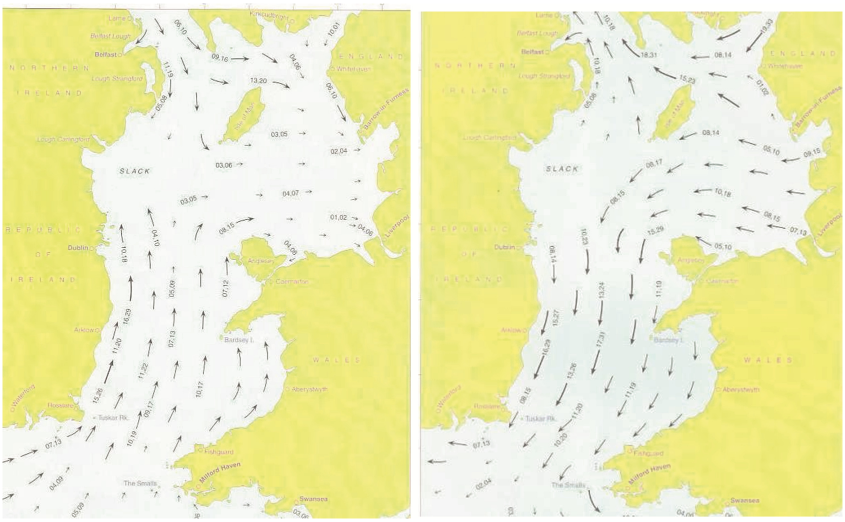

Fig. 5. Flood & Ebb Tides in Irish Sea (source: http://www.visitmyharbour.com, 2016)

The ability to accurately visualise this flow enables a greater understanding of tidal behaviour and of the mathematics required to describe it. Both tidal range and tidal flow exhibit sinusoidal behaviour, as a result the volume of water which flows during a tidal cycle ranges from a maximum value at peak flow to zero during periods of slack water. In order to describe something which changes over time differential calculus is the most appropriate tool. Vennell developed the relationship:

$$A_B * \frac{dh}{dt} = Q$$

Where Q is the volumetric flow (m^3/s) required to rise the water level by h (m) in the body of water AB (m2). This simple relationship can be used to calculate volumetric flow through a channel which connects an enclosed body of water with the ocean and was developed to analyse a Norwegian Fjord.

To accurately model tidal flow, once volumetric flow is known, requires only accurate information regarding channel bathymetry and seafloor composition. NASA's satellites have accurately measured the earth's surface and ocean contours with the files being publicly available and coefficient of friction is known for many seafloor types. It can only be a matter of time before models of tidal flow are developed which are sufficiently accurate to eliminate the current need for extensive onsite data collection.

5 Array Layout

In order to maximise the potential of high energy tidal sites it is likely that turbines will be grouped together into arrays, much in the same way wind turbines are often grouped together to form wind farms. Tidal arrays will face challenges due to their harsh operating environment and the loads created by a dense operating fluid. The following must be taken into consideration in an array layout:

5.1 Wake Interactions

Visual models which show wake interactions will be of great importance to tidal site developers as the available resource at each turbine can be significantly affected by any upstream turbines [9]. The effect is not always negative and studies suggest it is possible to exceed the Betz limit when siting a turbine within a tidal array due to the venturi effect of funnelling water between turbines [17], and while this could lead to greater output it will also lead to greater loads being experienced at the rotor blades. Any induced wake effect will be a compromise between maximum output and device survivability.

5.2 Blade Behaviour

Due to the significant loads created by seawater, blade designs and manufacturing methods will be a crucial aspect of maintaining device performance during operation. Fluctuations in water velocity create much greater loads than those experienced in wind turbines. In order to prevent damage to blades it is important to develop increased understanding of blade deformation and vibration in order to improve modelling and simulation leading to improved blade designs. Current studies are considering whether to allow turbine blades to flex under stress before reaching their optimal design [20] such research exposes the high level of concern over loading conditions for turbines placed in the open ocean. An accurate model which can visually represent realistic conditions at sea would be invaluable for design and R&D practitioners, and would permit reliable simulations which are much less costly and time consuming than sea trials or other physical testing regimes.

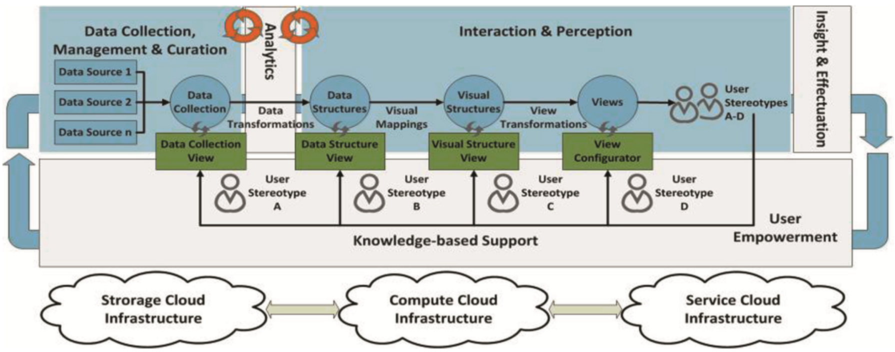

Fig. 6. The IVIS4BigData Reference model. Source: Bornschlegl, et al. (2016) [25]

5.3 Sediment Transport

A potential adverse environmental impact of installing a tidal array is the effect on local sediment transport due to a reduction in flow velocity. Modelling work has been conducted in the Pentland Firth where a number of tidal arrays are planned to be installed. A major challenge when investigating the possible localised impacts of a tidal array is a lack of commercial scale developments and at present there are no sizable tidal stream installations anywhere in the world, as a result it is likely that the first sites to be developed will be monitored extensively to ascertain environmental impacts.

It is difficult at present to imagine a model which could accurately simulate all environmental effects of reduced tidal flow and channel blockage, however a visual model to predict regular issues such as sediment transport or more stochastic events, that is, marine megafauna interaction may be possible in the future with more practical experience and monitoring of tidal stream arrays.

6 Results, Visualisation and Discussion

6.1 Visualization and the IVIS4BigData Reference Model

The IVIS4BigData reference model [25] applied to our current work provides a framework consisting of interlinked set of clearly defined concepts in the generation and visualization of tidal stream renewable energy for improved modelling and implementation. It helps clarify issues and promote clear communication in relation to design, development and implementation. The present research involves the collection, management and curation of data drawn from a range of sources, some of which include EMEC (European Marine Energy Centre), tidal stream charts published online and reports issued by UK and Irish Waters control port in the UK. Some of the other sources also include the live data and those generated using algorithms developed with computer programs as programs Python, Java (Fig. 6).

Analysis systems (Matlab® and Mathematica™) are used for data transformation. 2D and 3D plots from tables of data generated are then utilised for visualisation of information for the provision of knowledge-based support for the various categories of users enabling and empowering development and deployment of services for the public, business and community sectors. In the world of tidal stream renewable energy generation and visualization, the IVIS4BigData reference model seems to help provides means of developing useful models that serve to create standards, educate, improve communication, create clear roles and responsibilities for all those involved. It also allows comparison between developments in different systems and practices.

6.2 Results Analysis and Discussions

Maximum daily tidal flows occur between 3–4 h before and after high water, approximately 25% of all flow is accounted for during one hour of the cycle. The total mass displaced was multiplied by 25% to model the flow during this period. An accurate representation of bathymetry is required to simulate flow through the northern channel. There are a number of sources of data which provide latitude and longitude co-ordinates and water depth. Google Earth is one of the possible sources of information. NASA's Radar Shuttle Topography Mission (RSTM) and the European Marine Observation and Data Network (EMODnet) offer reliable bathemetry data files available for download and use. These files are in various sformats (.asc,.emo,.mnt,.sd,.xyz,.hdr,.tfw,.prj). Manually sampled water depth obtained from the EMODnet's site over an approximate 80 km × 60 km grid from 55.00 to 55.75 Northings and from −5.50 to −6.50 Eastings, as a Matlab plot is shown in Fig. 7. Other available software applications can used, they include ANSYS, Solid Edge etc.

The magnitude of the tide is realistic with the model predicting a maximum neap flow velocity of 1.17 m/s. This numerical value is the correct order of magnitude and shows there is at least some potential to the method. Accurate bathymetry for a large distance upstream is a necessary model parameter. Modelling the ebb tide proved more successful as this is not heavily influenced by upstream bathymetry but by the positions of the large landmasses which were more easily represented when creating model geometry. The volumetric and mass flow rates calculated produce velocity estimates which were in the correct order of magnitude producing reasonable representations of realistic conditions during tidal cycle.

7 Conclusion

The ability to generate 3D models, which accurately reflect real world behaviour, is of great interest to practitioners in tidal stream energy. Visualisation of flow regimes will aid understanding of tidal flow allowing academics and students to better understand and describe behaviour, while this will also assist site developers who can assess a greater number of sites without the need for extensive onsite monitoring as is presently required.

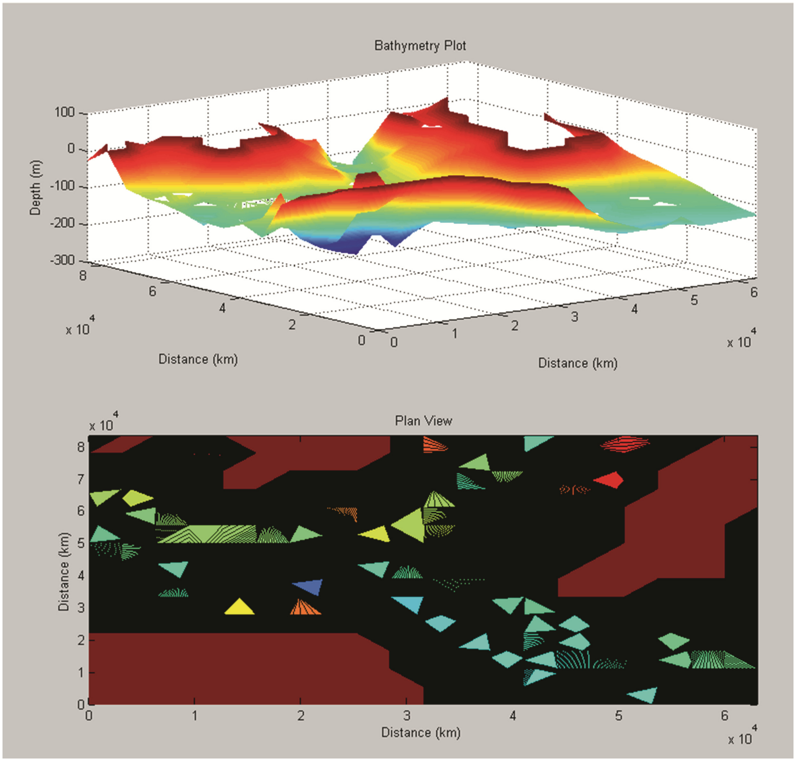

Fig. 7. Matlab plot of bathymetry data sample.

One of the benefits of an accurate resource modelling technique based on volume flow is that it allows more sites to be evaluated at less cost and greater speed. Volume flow can be calculated even in complex tidal regions. This has been demonstrated in the case of the northern Irish Sea. However, the method is believed would be best applied in a region with only one connecting channel with the ocean.

Those designing major components will benefit from models which can show blade and support structure loading conditions, allowing for design and reliable simulations without extensive physical validation which is both costly and time consuming. Site developers will be able to model many alternative array configurations using realistic and robust CFD models to establish optimal array configuration at each specific site. This will be a compromise between maximum efficiency of each individual turbine versus the output from the entire array and the acceptable in service loading on turbines. Although performance sensitivity is low for all turbine designs tested to date, the magnitude of deflection are found to be significantly influenced by pitch angle of the blade. Further studies and modelling are needed to establish whether blades should be intentionally designed to flex under loading before reaching their optimal configuration with consideration also being given to tower-rotor interactions and the effect of small perturbations, that is, deviations from regular state, on fatigue life [16].

In the future both academia and industry will benefit from robust, reliable models which accurately map out a 3D environment representing a potential tidal stream site. Greater understanding of the practicalities will lead to innovative solutions to challenges presented by the harsh operating environment and allow divergence of design for turbines and major subcomponents, leading to a competitive supply chain. The ultimate goal is to reduce costs and enable tidal stream turbines to become cost competitive with other forms of energy. If this is achieved the predictable behaviour of the tides can be exploited and managed to produce vast quantities of firm electrical energy onto the UK national grid over the coming years.

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