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Utilization of the ocean energy waves and tides

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[2,3,4]*Mechanical, PIET DS(1ST)Shift*

Abstract*- Energy is an important source for social and economic development for world. As a result of the generalization of agricultural, industrial and domestic activities the demand for energy has increased remarkably, especially in emergent countries. This has meant rapid grower in the level of greenhouse gas emissions and the increase in fuel prices, which are the main driving forces behind efforts to utilize renewable energy sources more effectively, i.e. Energy which comes from natural resources and is also naturally replenished. Despite the obvious advantages of renewable energy, it presents important drawbacks, such as the discontinuity of generation, as most renewable energy resources depend on the climate, which is why their use requires complex design, planning and control optimization methods. Fortunately, the continuous advances in computer hardware and software are allowing researchers to deal with these optimization problems using computational resources, as can be seen in the large number of optimization methods that have been applied to the renewable and sustainable energy field. This paper presents a review of the current state of the art in computational optimization methods applied to renewable and sustainable energy, offering a clear vision of the latest research advances in this field.*

Keywords*-Renewable energy systems; Optimization; Multi-criteria decision analysis; Design; Planning; Control.*

I.INTRODUCTION

Tidal currents are being recognized as a resource to be exploited for the sustainable generation of electrical power. The high load factors resulting from the fluid properties and the predictable resource characteristics make marine currents particularly attractive for power generation. These two factors makes electricity generation from marine currents much more appealing when compared to other renewables. Marine current turbine (mct) installations could also provide base grid power especially if two separate arrays had offset peak flow periods. This characteristic dispels the myth that renewable energy generation is unsuitable on a large scale.

II. REVIEW OF LITERATURE

A renewable is most powerful energy so it is utilized for generation of electricity. The natural power of the ocean has inspired awe since the dawn of mankind. Mariners and others who deal with the forces of the sea have learned to understand the potentially destructive powers of ocean waves as well as the regularity and predictability of the tides.

III. NEED AND IMPORTANCE OF STUDY

Tidal energy extraction is complex and many device designs have been proposed. It is helpful to introduce these designs in terms of their physical arrangements and energy conversion mechanisms. Water turbines, like wind turbines, are generally grouped into two types: vertical-axis turbines, in which the axis of rotation is vertical with respect to the ground (and roughly perpendicular to the water stream), horizontal-axis turbines, in which the axis of rotation is horizontal with respect to the ground (and roughly parallel to the water stream.)

IV. STATEMENT OF THE PROBLEM

The natural power of the ocean has inspired awe since the dawn of mankind. Mariners and others who deal with the forces of the sea have learned to understand the potentially destructive powers of ocean waves as well as the regularity and predictability of the tides. Ocean waves and tides contain large amounts of kinetic energy, derived from the winds and gravitational pull of the sun-earth-moon system. Even though early civilizations developed devices to convert waves and tides into mechanical energy, the technology to cost-effectively convert ocean waves and tidal flow into electrical energy is still in its early stages. Waves are created by waves blowing over a fetch of ocean as depicted below. Tidal changes in sea level occur as earth rotates beneath the elliptical ocean envelope which is produced by solar and lunar gravitational forces as depicted in below. Wave energy, although variable, can be predicted days in advance. Tidal power, also variable, can be predicted into the indefinite future. This predictability is important to electrical grid dispatchers who must balance the changing demand with the supply

V.HISTORY OF TIDAL ENERGY-

- 787: simple technique of a waterwheel by the Spanish, French, and British
- 1966: "la rance" tidal power plant went in operation.
- 2001: British parliament states "the world can no longer neglect the massive potential of wave and tidal energy"
- 2002-present: large investments in research and prototypes spark proposals in turkey, china, and United States; among others

VI.HISTORY OF WAVE ENERGY-

- 1799: first patent of a device designed to use ocean waves to generate power.
- 1910: first oscillating water column was built by bochaux-praceique to power his house.
- 1940s: Yoshiro masuda experimented with many concepts of wave power.
- 2004: wave power was delivered to an electrical grid for the first time.

VII. OBJECTIVE

The primary objectives of the study are as follows:-
(i) To determine the theoretical tidal marine current energy resource in Irish waters and tocalculate the theoretical power available from this resource. This will be referred to as the"theoretical resource".
(ii) To identify and investigate sites which have the potential for efficient resource using existing and anticipated generating technology. This will be referred to as the "technical resource".
(iii) To identify and investigate sites which , after taking physical constraints into account, have the greatest potential for exploitation. This will be referred to as the "practical resource".
(iv) To identify and investigate sites which, after taking environmental and legislative constraints into account, have the greatest potential for exploitation. This will be referred to as the "accessible resource".
(v) To identify and investigate sites which, after taking commercial viability constraints into account, have the greatest potential for exploitation. This will be referred to as the "viable resource".
In pursuit of the primary objectives the following matters have also been investigated.

VIII. HYPOTHESIS

- Waves are caused by a number of forces, i.e. Wind, gravitational pull from the sun and moon, changes in atmospheric pressure, earthquakes etc. Waves created by wind are the most common waves. Unequal heating of the earth's surface generates wind, and wind blowing over water generates waves.
- This energy transfer results in a concentration of the energy involved: the initial solar power level of about 1 kw/m2 is concentrated to an average wave power level of 70kw/m of crest length. This figure rises to an average of 170 kw/m of crest length during the winter and to more than 1 mw/m during storms.
- Wave energy performance measures are characterized by diffuse energy, enormous forces during storms, and variation over wide range in wave size, length, period, and direction.
- Wave energy is an irregular and oscillating low-frequency energy source that must be converted to a 60-hertz frequency before it can be added to the electric utility grid.

IX. RESEARCH METHODOLOGY

For the calculation of tidal and marine current energy resource the generic renewable energy resource ranking system as used in previous studies has been adopted to provide consistency with these studies. The resource categories and the corresponding values are set out.
The predicted electricity demand for the republic of Ireland and NorthernIreland in the year 2010 currently stands at 42 twh/year. Theoretical resource the gross energy content of tidal and marine currents in the zone between the 10m depth

contour and the 12 nautical mile territorial limit is referred to as the theoretical resource. The theoretical tidal energy resource has been determined using computational modeling of current flows around Ireland. The accuracy of the models has been verified using current meter data taken at four locations around the coastline. The theoretical resource has been calculated from the formula, (peak) p(mean) =1/2 ρ KS kn v to be 230 twh/year which represents over 5 times the predicted electricity consumption in Ireland for the year 2010. However, technological limitations, physical, environmental and commercial constraints make it impracticable to extract all of this energy. When the technological limitations are applied to the theoretical resource, the resultant resource is referred to as the technical resource.

The technical resource was calculated in a similar way to the theoretical resource, but only areas where the peak tidal velocities are greater than 1.5m/s have been included. Based on existing technology the device efficiency has been limited to 39% and the resource has been calculated between the 10m water depth contour and the 12 nautical mile territorial limit. Tidal energy technology is in the early stages of development with various generating systems currently being researched. Fourteen variations of the four basic turbine configurations have been reviewed and their generating efficiency has been assessed. Supporting structures for the generating devices and the electrical power transmission system for shore connection have also been reviewed.

Although currently limited by support structure technology to a depth of 40m, turbines in the "horizontal axis rotational group" were found to be the most advanced. With existing technology, turbines become uneconomic with tidal currents below 2.0m/sec but with further development economic generation at lower velocities should be practicable. It is anticipated that these constraints will be overcome with future research. Research indicates that existing electrical and subsea cabling technology as used in offshore wind power development is sufficiently advanced and should be directly applicable to tidal current farms without major modification. Assuming that present technical restraints, such as water depth, can be overcome the technical resource has been calculated to be 10.46 twh/year which represents approximately 25% of the predicted electrical consumption for the year 2010. This technical resource is however constrained by practical, physical and other interference. The resultant resource is referred to as the practical resource. Practical resource the practical resource was determined by limiting the technical resource by the following constraints: water depth between 10m and 40m, peak tidal velocity greater than 1.5m/s, outside shipping lanes, military zones, disposal sites and outside areas containing pipelines and cables. Detailed modeling of seven sites chosen for further study was carried out to determine the practical resource. For this purpose the type and number of turbines were chosen for each site after examination of water depth and physical constraints. The practical resource was then calculated in a similar way to the theoretical resource and this amounted to 2.633 twh/year. This represents 6.27% of the predicted electrical consumption for the year 2010. The practical resource is however restricted by man-made, institutional and regulatory constraints giving a further reduction in the resource and this is referred to as the accessible resource. Accessible resource the constraints which have lead to the accessible resource are mainly environmental in nature. The research included a desk study carried out with statutory bodies to determine the possible environmental issues which could arise from the development of tidal power. Benthic ecology, fishing grounds, marine mammals, visual impact and effect on recreational use of coastal waters were found to be the primary issues. The environmental constraints will be specific to each site and a generic reduction in the resource has not been estimated as a full environmental impact assessment will be required for each individual site. For the purpose of this study, the accessible and practical resource are therefore the same at 2.633 twh/year. The final constraints on the theoretical resource which have been investigated are those concerning commercial viability. These and previous constraints have lead ultimately to the viable resource.

The viable resource was determined by limiting the technical resource by the following constraints: water depth between 10m and 40m, mean maximum spring tide current exceeding 2.5m/s and turbine rotor size

Of 7m less than average water depth. The commercial constraints include development costs, scale, resource distribution, market reward, timing and other risk which will be variable over time. The techno-economic model developed by marine current turbines ltd was used to determine the viable tidal energy resource and provide costing for particular sites. The model was validated against known industrial costs including cost functions for a range of bought-in components. Lifecycle costs based on a discounted cash flow analysis using a discount rate of 8% over 20 years was calculated by the model.

Levellised costs varied widely around the coast from 4.5 cent/kwh to 19.6 cent/kwh. The viable tidal energy resource was calculated to be 0.915twh/yr which represents 2.18% of the predicted electricity consumption for the year 2010. It was concluded that the technology is nearing a level of maturity which will accommodate this level of energy extraction by around 2010.

There are many similarities between wind and tidal current generating systems both in terms of devices and the nature of the driving force. Compared to wind technology, tidal systems are in their infancy and there have been only a small number of prototype scale demonstrations of plant with an installed capacity of over 100kw. It is expected to take several years before items of equipment are produced for purchase and installation. Three of the most significant technology demonstrations have taken place during the past two years and two of these are ongoing. None of the demonstration units is a pre-production prototype and all research teams plan to build and test larger systems before going into production. Tidal current generators are not yet developed at the size necessary for large scale exploitation of the resource. Companies with small scale demonstration prototypes are expected to develop these to sufficient size to generate from the resource by 2010. First generation devices will be limited to water depths between 10m and 50m. Second generation devices should appear after a period of approximately ten years and should be capable of operating in depths exceeding 50m.

X. RESULTS

Summary

1. The technical resource has been calculated for areas where the peak tidal velocity is greater than 1.5m/s and is equal to 10.46twh/yr. which represents approximately 25% of the predicted electrical consumption for the year 2010.
2. Tidal current machines are in the early stages of development with only a few examples at reasonable size having been demonstrated to date.
3. Existing electrical and subsea cabling technology as used in offshore wind power developments is sufficiently advanced and should be directly applicable to tidal current farms without major modification.
4. Extensive research into tidal energy technology is still required if economic electricity generation is to be achieved with peak tidal velocities of 1.5m/s.

XI.DISCUSSION

A detailed description of tidal energy devices and associated technology is provided elsewhere in the report. However, the following points are relevant to the impact which these devices may have on the marine and coastal environment:-

>technical assessments indicate that initially turbines will be constructed with foundations on the seabed thus limiting the location to a maximum water depth of 40 metres. The number of turbines per site could be in the 5nr to 50nr range.

>for safety reasons it is expected that the area within a tidal farm will not be navigable. Given the potential number of turbines in an array and the distance required between turbines (300-500 metres), ships, fishing boats, and recreational boats may be excluded from the farm area.

>each array of turbines will be linked with an underwater network of cables. Power from the farm will be taken ashore and from that point will be conveyed to the national grid by overhead or underground cables. The provision of overhead power lines may give rise to particular concerns in sensitive coastal landscapes.

XII.FINDINGS

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XIII.RECOMMENDATION/SUGGESSION

The first stage of the investigation was to generate a range of preliminary environmental impacts associated with the issues outlined above. The preliminary considerations have included the following:-

- benthic ecology
- fisheries and spawning grounds
- marine mammals
- recreational users
- migrating and other sea birds
- the visual character of the coast
- underwater archaeology
- the effects of cable connections on and close to the coast

Each of the preliminary issues are dealt with below in the context of potential environmental impact and recommendations are made on action that can be taken to ensure that these issues are addressed in any future development of tidal energy.

Benthic ecology

The benthic ecology in the vicinity of the marine current turbine may be affected by the foundations and seabed disturbance associated with installation of devices.

An application for a tidal energy facility should be supported by a detailed ecological assessment of the site and its environs. Fisheries and spawning grounds.

Three types of stock should be considered:-

- highly mobile stocks including cod and whiting
- inshore stocks including whelk and razor shell
- migratory stocks including sea trout and salmon.
- The impact of tidal energy devices should be considered under the following:-
- theaffect of the structures and related cabling on existing stocks or their food sources.
- the physical disruption or reduction in available fishing grounds.
- the impact of structures and cabling on habitats such as spawning gravel for herring.

Impact on the fishery in Irish waters may affect not only fishermen from Ireland and the uk but also significant numbers from Belgium, France, and the Netherlandsmarine mammals. There are significant numbers of cetaceans and seals in Irish coastal waters. For example in the shannon estuary there is a colony of bottlenose dolphins. Vertical and horizontal axis turbine devices could cause problems for marine mammals in terms of collisions and impact on their echo sounding ability. The impact of turbines on marine mammals during construction and operation will need to be fully investigated as part of any application.

XIV. SCOPE OF FURTHER RESEARCH

Tidal energy devices are still in their early stages of development and many aspects of the technology require further research including;

> full scale monitoring of the flow regime, turbulence, vertical velocity field distribution and resulting device performance to verify and further develop 3d numerical models of the system.

> Wave current interaction, its effect on the tidal stream resource and how machines perform in pulsating or even reversing flows.

> Measurement of the upstream and downstream wakes of machines and the longitudinal spacing of lines of devices with different blockage coefficients. Several existing tidal energy devices are reported to be only economic when operating at velocities greater than 2.0m/s. It is imperative that future development concentrates on reducing

This minimum operating velocity if the resource is to be competitive with other forms of renewable energy.

XV.CONCLUSION

There are many similarities between wind and tidal current generating systems both in terms of devices and the nature of the driving force. Compared to wind technology, tidal systems are in their infancy and there have been only a small number of prototype scale demonstrations of plant with an installed capacity of over 100kw. It is expected to take several years before items of equipment are produced for purchase and installation. Three of the most significant technology demonstrations have taken place during the past two years and two of these are ongoing. None ofthe demonstration units is a pre-production prototype and all research teams plan to build and test larger systems before going into production. There is very little published data on the performance of tidal current systems either at model or prototype scale. Consequently most of the available information is sourced from company literature and the world wide web. Generally, this information has not been reviewed in the technical literature in the past, systems have been developed for river current energy. For example floating water wheels have been used in Europe since the 12th century on rivers such as the Danube. This system was reportedly used on the Thames in the late 16th century to pump water. In recent years some small scale systems suitable for tidal currents have been developed and tested on rivers.

Tidal mills have been used for centuries and there have been a number of tidal barrages constructed in the past forty years but these have been excluded from this study as they involve the impoundment of water in either man made or natural catchments. Consequently tidal current generators are not yet developed at the size necessary for large scale exploitation of the resource. Companies with small scale demonstration prototypes are expected to develop these to sufficient size to generate from the resource by 2010. In addition there is also a

Range of design concepts which are being developed at model scale prior to small scale prototype development. However, these are mostly variations in engineering detail of equipment currently being demonstrated or to be demonstrated in the near future. They are not expected to make significant changes in either performance or cost. The most important developments are expected to be in the design of cost effective plant which can exploit more of the resource which exists inwater depths of 50m and more.

XVI.CLASSIFICATION

Tidal current generators are classified in terms of the form of motion of the primary interface with the water and are either rotational or oscillatory. Using linear momentum theory, systems using hydrodynamic lift are shown to be three times more efficient than drag machines. Consequently,

Drag machines have not been considered in this study. The rotational devices with lifting, aerofoil section blades can be supported on either horizontal or vertical axes. Similarly the hydrofoil devices can oscillate either vertically or laterally. Consequently there are four basic configurations for tidal current systems and the range of devices described in the following sections are variations in terms of support structure or mooring system, detailed engineering design and method of secondary power conversion.

The classification is therefore summarized as follows;

>primary motion – rotational or oscillatory,

>orientation of the prime mover – horizontal or vertical,

>sea bed connection – moored or fixed structure,

>type of secondary converter – mechanical, hydraulic, electrical.

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