IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 9, Issue 7, July 2021

DOI 10.17148/IJIREEICE.2021.9728

COMPUTER APPLICATIONS IN TIDAL AND WAVE ENERGY

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Abstract: The oceans of the earth offer vast amounts of renewable energy. The interaction of the sun-moon-earth system causes ones of the strangest phenomena called tides. The rise and fall of the tides – in some cases by more than 12 m – creates potential energy, and the ebb and flow currents create kinetic energy. Both forms of energy can be harvested by tidal energy technologies as renewable energy. The installation, operation and maintenance of ocean energy devices are relatively expensive. One promising improvement options is usage of modelling tools to improve array layout and design which will lead to increased device array efficiency and reduction of costs. This review provides an overview over the current state of research in the field of ocean energy. In particular, the authors focus on research beyond technology or technological improvements. This article also highlights areas where research gaps exists and where future research efforts should be directed to.

Keywords:Tidal energy, modelling tools, ebb, array configuration.

I. INTRODUCTION

The oceans of the earth represent a vast source of renewable energy. In general, ocean energy can be divided into six types of different origin and characteristics: ocean wave, tidal range, tidal current, ocean current, ocean thermal energy, and salinity gradient. And further three types of tides are : diurnal, semidiurnal and mixed. Diurnal tides(daily) present one single high and low water during a period of a lunar day of 24 hours and 50 minutes and occur in the Gulf of Mexico, Southeast Asia and the coast of Korea, semidiurnal tides(twice a day) present two high and two low waters during a lunar day with periods of 12 hours and 25 minutes and is common along the Atlantic coast of North America and the mixed tides that presents two unequal high and two unequal lows waters and generally have periods of 12 hours and 25 minutes. In a lunar month this type of tide that is common on the Pacific Ocean coast of the United States can experience semidiurnal and diurnal tides characteristics. In 1964 Davis classified the tidal ranges as: microtidal with tidal range less than 2 meters, mesotidal withtidal range between 2 and 4 meters and macrotidal with tidal range of more than 4 meters. An advantage of both tidal range and tidal current energies is that they are relatively

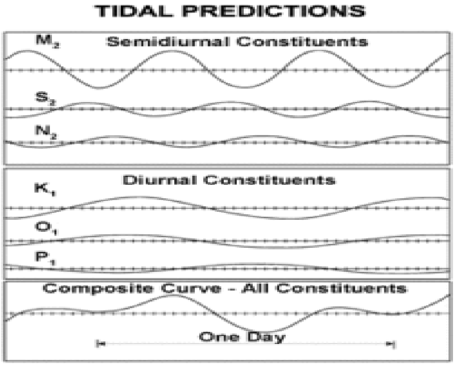

Fig. 1 Tidal Predictions

predictable with daily, bi-weekly, biannual and even annual cycles over a longer time span of a number of years. Energy can be generated both day and night. Furthermore, tidal range is hardly influenced by weather conditions. Meanwhile, due to tidal cycles and turbine efficiency, the load factor of a conventional tidal barrage is around 25%, which leads to high cost of energy. Improvement in turbine efficiency, in particular innovative reversible turbines for ebb and flood generation, should provide a significant increase in energy yield. The ocean energy industry has made significant progress in recent years but is still at very early stage with some advanced prototypes that are currently being tested . Existing challenges include further development of the technology to prove reliability and robustness and to reduce costs but also deployment and risk reduction.

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II. TIDAL ENERGY TECHNOLOGY DEVELOPMENT

Tidal energy technologies have advanced considerably over the past few years and there are a number of ongoing full-scale demonstration projects. Horizontal and vertical axis tidal turbines currently use blades that are positioned either in parallel (horizontal) or perpendicular (vertical) to the direction of the flow of water. The turbines are similar to designs used for wind turbines, but due to the higher density of water the blades are smaller and turn more slowly than wind turbines. Furthermore, they have to withstand greater forces and movements than wind turbines. Tidal range technology has a number of options for power generation:

1. One way power generation at ebb tide: A reservoir is filled at flood tide through sluice gates or valves that are closed once the tide has reached its highest level. At the ebb tide, the water in the reservoir is released through the turbines and power is generated. With this single cycle, power is generated for only four hours per day. Annapolis in Canada is an ebb generation plant.

2. One way power generation at flood tide: At flood tide the sluice gates are kept closed to isolate the reservoir while at its lowest level. When the tide is high, the water from the sea-side flows into the reservoir via the turbines, thus generating power. The disadvantage of this cycle is that it has less capacity and generates less electricity, and it may be ecologically disadvantageous as the water level in the impoundment is kept at a low level for a long time. Sihwa is a flood generation plant.

3. Two way power generation: Both incoming and outgoing tides generate power through the turbines. This cycle generates power for four hours twice daily. However, reversible turbines are required. La Rance is an ebb and flood generation plant; bulb turbines can also pump water for optimisation.

4. Tidal lagoons are similar to tidal barrage, except that they are not necessarily connected to the shore but could sit within the ocean. Environmental impact assessments of the proposed tidal lagoon in Swansea Bay suggest that lagoons would have lower environmental impacts than tidal barrages.

5. Ultra-low-head tidal techniques is a new application under development, which focused on harvesting energy from low head tidal differences of less than 2 metres (m). As for example, the tidal barrage project in the Gravelingen Lake in the Netherlands.

6. The use of tidal fences would consist of a number of individual vertical axis turbines that are connected to each other within a fence structure (Godfrey, 2012). The fence itself could be placed between the mainland and a nearby island, or between two islands (as proposed at the San Bernardino Straits in the Philippines). These applications are in their early stages of development and there are no prototypes being tested in the water at present.

7. Hybrid forms of tidal energy can be found in the form of multi-purpose platforms where both tidal current and tidal range technologies are used for electricity generation. These platforms are in an early developmental and innovative stage. Another technical aspect for tidal current technologies is their deployment in the form of farms or arrays. Individual generator units are limited in capacity, therefore multi-row arrays of tidal turbines need to be built to capture the full potential of tidal currents. However, turbines have an impact on the current flows, so the configuration in which they are placed is a critical factor to determine their potential yield and output.

Tidal current technologies can also be used to generate electricity from ocean currents. Ocean currents, although slow, are a continuous flow that can provide a steady production that is not driven by the tidal cycles. Although there are currently no ongoing projects, studies have been widely undertaken, for example in Florida.

The concept of floating offshore platforms is currently being studied but no commercial application is foreseen in the near future. A recent development is called “dynamic tidal power” (DTP). It consists of a 30-60 kilometre (km) long dam that runs perpendicular to the coast line. At the end of the dam, there is a barrier forming a large “T” shape. The dam interferes with the oscillating tidal waves on either side of the dam and creates a height difference between the water levels. This height difference creates potential energy, which can be converted into electricity using the low-head turbines that are being used in tidal range generators. The largest and newest multi-functional tidal barrage in the world is the Sihwa dam in north-eastern South Korea, which became operational in 2012 with a capacity of 254 MW in a formerly closed sea-arm by creating openings in an existing sea defence and installing hydro-turbines. This project is a relevant example for a combined tidal range solution, where in the end the priority was placed on ecological water quality improvement.

III.INSTALLATION

So far, only a few full-scale devices have been installed and thus practical experience is limited . However, the ocean energy sector can build on technology and knowhow from other offshore energy technologies. Installation equipment from the oil and gas industry might be used but it could be too expensive since for ocean energy projects, the installation costs are responsible for a high share of investment costs. Installation of ocean energy devices has to be easy and fast in order to reduce costs for the installation process . In the case of tidal devices, this is also an

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important prerequisite because installation has to be performed during slack tide which means a limited time period. The installation process and costs for wave and tidal devices will significantly depend on the location. For example, shore based wave energy converters might need solid foundations and heavy infrastructure. The same is the case for bottom-mounted tidal devices which demand substantial foundations. The mooring of floating devices with drag-anchors seems to be a very economical solution while in some cases the sea-bed characteristics will demand other and more expensive mooring types such as pin piled mornings . Only few papers have tried to establish models or tools to assess resource needs for installation requirements in terms of time and cost.

IV. OPERATION AND MAINTAINANCE

Ocean energy devices will operate in harsh environments. Demands on survivability and reliability are high since the economic impacts due to failures can be significant. Maintenance costs for ocean energy devices will be high as for any other offshore technology and have a high share of lifetime costs . The most common issues ocean energy devices will face are bio-fouling (moorings, floating or submerged parts of the device) and corrosion . Research needs to develop special coatings that prevent bio-fouling and corrosion but also sealing materials and electric insulation materials for saline environments. Developers aim at reducing maintenance intervals by creating very robust devices and designing devices for ease-of-maintenance.

Current research tries to model the reliability and possible failure rates of ocean energy devices. For example, Thies et al. developed a methodology to simulate component reliability and failure rates under defined operational conditions . Device testing in environments that can produce the same conditions as in real waters is a prerequisite for assessing device and component reliability . Also array design parameters (e.g. device spacing) impacts on maintenance activities and costs and this is not very well understood so far. An important aspect that has to be taken into account when designing ocean energy devices and developing ocean energy projects is that maintenance and repair activities can only be carried out in favourable weather conditions. Weather window analyses study the levels of access in terms of a number of weather characteristics (e.g. wave heights, wind speed). Inaccessibility of ocean energy devices for maintenance and repair might require other maintenance strategies such as onshore maintenance in order to ensure economic viability of projects.

V. FUTURE RESEARCH

Arrays of ocean energy converters have not been installed yet. However, models have been created that allow capturing the effects of arrays on hydrodynamics as well as power output. Since no long-term experience with devices is available concerning commercial operation and maintenance, there are only a few articles published that try to assess the resource needs for installation (e.g. time, cost). Array design parameters such as device spacing might have an impact on operation and maintenance activities and costs: this is not very well understood so far. Concerning reliability and performance, current research tries to model the reliability and possible failure rates of ocean energy devices

VI. CONCLUSION

This study has reviewed the state-ofresearch in tidal energy, focusing on wave and tidal current. Modelling approaches for resource assessment and forecasting are already very advanced and have been performed for many regions of the world. However, this should be widened to accommodate conflicting or competing use of the marine environment such as fishing, shipping, offshore wind, habitat protection and also technical limitations (e.g. grid connection). control strategies is needed since it offers a great potential for cost reduction due to increased absorbed energy while allowing meeting grid codes requirements. No long-term experience with devices is available concerning commercial operation and maintenance and few articles try to assess the resource needs for installation (e.g. time, cost). Array design parameters such as device spacing might have an impact on operation and maintenance activities and costs.

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