Analysis of the impact caused by sea level rise on tidal energy development and coastal areas

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Abstract. Global warming has long been an important issue. Melting glaciers are one of its hazards, along with rising sea levels. Besides, tidal energy as an increasingly significant renewable energy has grasped people's attention more than before. However, global warming has a remarkable effect on the power production from the tide. There are also some other effects which the rising sea level will have on the nearby coastal areas. It may interfere the tidal amplitude, tidal line, tidal cycle and the tidal surge, and each element will affect the efficiency of the tidal power plant. In this paper, the effects of rising sea level on tidal power are analyzed and some adaptation strategies to help the local communities are proposed.

Keywords: Tidal energy, Sea level rise, Coastal areas, Ecosystem.

1. Introduction

Nowadays, global warming is a well-known issue and many scientists are finding ways to deal with the drawbacks it caused. According to the IPCC's most recent sea level rise forecasts, the world will rise 0.43m to 0.84m under different circumstances by 2100 [1]. Also, the contribution to the seas shows a monotonic trend, rising from an average value of 0.31mm similar to 1992-1996 to 1.85 mm for 2012-2016 [2].

Tidal energy is widely used around the world as a clean energy source. However, sea level rise will affect the development and utilization of tidal energy to varying degrees such as tidal amplitude, tide line and tidal surge. It will enhance the likelihood of sea-level rise extremes and bring damage to coastal infrastructure and town flooding [3].

In this paper, the relationship between sea level rise and tides is delved. The analysis results will provide scientific basis for governors and decision makers to support sustainable tidal management and the development of coastal communities. Furthermore, it will provide practical and policy basis for environmental protection and sustainable development [2].

2. Factors affecting energy productivity of the tidal energy plants

2.1. Increase of the tidal amplitude

The force produced by the moon is exposed on the Earth and it produces tidal energy. Thereby, as the sea levels rise and volume of water rises, the tidal range becomes pronounced. The rising tidal range has a mixed effect on coastal areas. The benefit of rising tidal amplitude is the increase in energy production. Since the differences in water level increases with each tidal cycle, the tidal power plants can produce more energy in the same amount of time. This can improve the efficiency of power generation and increase energy production. Nonetheless, although the increase tidal range has large potential, it is concentrated in just few regions like Patagonian shelf. Through the global tidal atlas and 0D modelling, the tidal resource is calculated. It has 913 TWh with high potential for complementary phased sites. A certain amount of optimization including incorporating pumping, two-way operation etc. can increase the capacity factor over 20% without lowing the productivity [4].

However, there are also some drawbacks of the tidal amplitude. The first one is the challenges in the design and engineering of the tidal equipment in the coastal power plants. The greater water flow forces require more powerful and durable structures to withstand water shock. The second one is the

environment impact. The increased tidal amplitude will impact on shoreline and intertidal system. In turn, it will affect the coastal ecosystem and harm the diversity of the marine animals in that region. For instance, it will create tidal barriers fragment habitats and alter hydrodynamics to the detriment of fishes. This is shown on the main research is based on fish passage, tidal flux restoration and environmental flows [5].

2.2. The tide line moved up

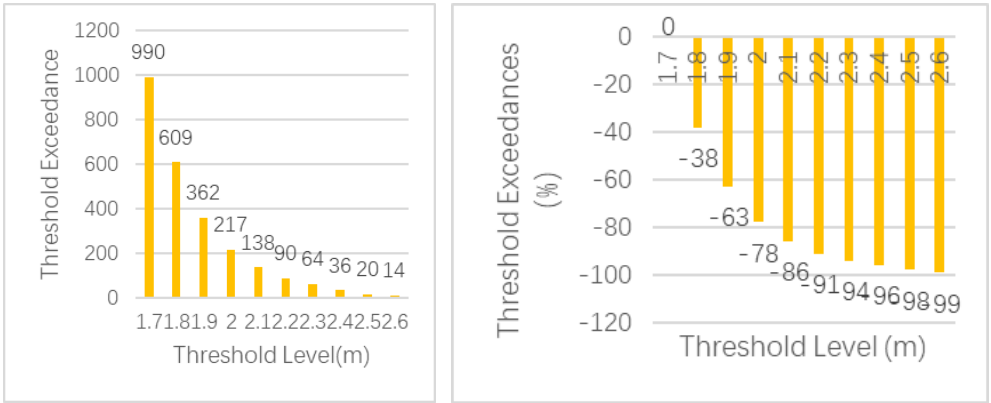
Since sea levels and rising and the general knowledge of the heat expands and the cold contracts, the volume of ocean water continues to increase based on melting glaciers. This will move the tide line up and have a series of effects.

Firstly, it will increase the risk of damages to the facilities. Due to some power plants are usually built in coastal areas near the tidal line, a rising tide line increases the risk of tidal power plants being inundated by sea water, especially the old facilities. Moreover, some infrastructure such as tidal surge generators and other equipment are affected because they are usually built on the seabed near the sea level. If the tide line increases, the turbine might be unstable even be destroyed [6].

Secondly, the construction costs will increase. Since the risks of damage is increase, people are finding ways to solve these difficulties. However, taking additional flood control and protection measures costs many fees. Nevertheless, barricade impoundments spanning estuaries are often shorter than lagoons impounding equal volumes due to less expensive civil engineering. This can provide us some information to judge the location and method to the tidal energy production [6].

2.3. Increased tidal surge

First of all, there is some security risks. Since these tidal equipments need people to operate and maintain, the crew may in danger if the surge is increased. Storm surge barriers frequent establish water level thresholds that, in order to ensure worker safety, maintenance work must halt at when they are reached or exceeded. Fig. 1 displays the threshold breaches number and the percentage variation. The outcomes revealed that the threshold for maintenance had been surpassed 991 times, with 13% of those incidents occurring within the maintenance season. This will cause safety problems [7].



(a) (b)

Figure 1. (a) Exceeded number over each threshold level (b) percentual variation in threshold exceedances across various threshold levels [7].

Secondly, it will cause failure in water distribution and wastewater collection pipes. It should be considered carefully because it will affect the human health and environment. The quantitative evaluation of anticipated changes in iron pipe failure rates due to the conduct of sea-level rise and sea water intrusion. It illustrates how the integrity of collecting pipes is affected by sea level rise. This is due to the fact that the rate of pipe failure is influenced by pipe characteristics, environmental factors, and system parameters. Additionally, as salinity rises, underground water's electrical conductivity

will rise, which will accelerate corrosion. Moreover, the lifespan of the iron pipe is decreased, and corrosion rate is increased due to the presence of dissolved oxygen and chloride ion [8].

2.4. Impact on geological processes

Firstly, it will cause the wetland to decrease. A study analyzes how regional sea level rise affects wetland dynamics and it demonstrates that 10% or more of the coastal wetlands in Bangladesh, India, and Myanmar are under risk, compared to fewer than 1% of the wetlands in northern Australia [9]. On the other hand, wetlands near the North Sea shore, where we may collect data from built infrastructure, have no chance of evolving landward and might become extinct permanently. In Fig.2. it will show the rates of wetland loss risk in different regions around the world. Hence, the decline of wetland is caused by the distortion of tide [9].

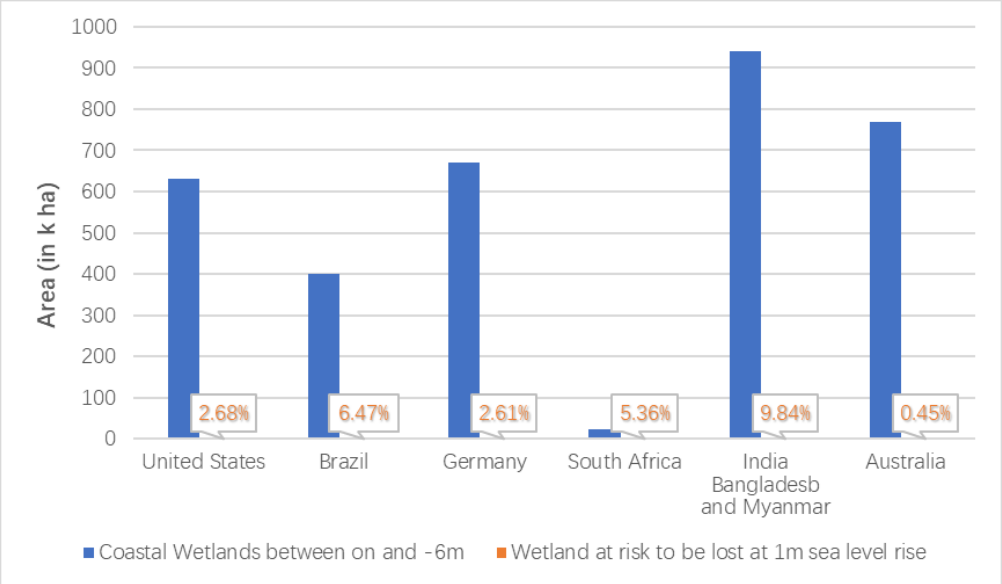


Figure 2. Changes of area of coastal wetland with different sea level in different region [9].

Besides, the rise of sea level will result in the increase in underground water. Since underground water has significant impacts on the geotechnical construction and the stability and safety of underground structures, the fluctuation of the underground water caused by global warming cannot be overlooked. Increased low flow and local groundwater inundation are not affected by sea level rise, which has little impact on overall water storage [10]. This may in turn cause the floods where water is abundant and droughts where water resource is scarce. Thereby, it may lead to the distortion in the ecosystem in coastal areas.

3. Mitigating sea level rise

3.1. Equipment upgrade and adaptive design

Due to the risk for some facilities of being eroded or inundated, there is some research focusing on the engineering of these facilities. Two-way generation and pumping are advantageous to the protection of the intertidal area because of their good fit with the full tidal range, according to a comparison analysis in terms of energy production, flood protection, human marine activities and some environmental aspects [6].

3.2. Comprehensive use of a variety of new energy to achieve functional stability

Since the renewable energy like tidal energy has some uncertainty and instability, researchers are pay more attention on the comprehensive use of the renewable energy for gathering energy from the tide and sea wind [11]. In Fig.3, it shows the model and analysis of the 2-DOF system's performance. The two-degree energy harvester grabs a performance improvement of 12.7% higher than the typical

one-degree energy harvester while possessing a 48% decrease in the maximum displacement. The recommended system functions to its fullest capacity with respect to of converted power, energy translation productivity, adaptability toward input velocity, vibration reliability, and flexibility regarding energy mix. As a result, under the conditions of rising sea levels, this technology can overcome the difficulties in the design and engineering of the tidal facilities [11].

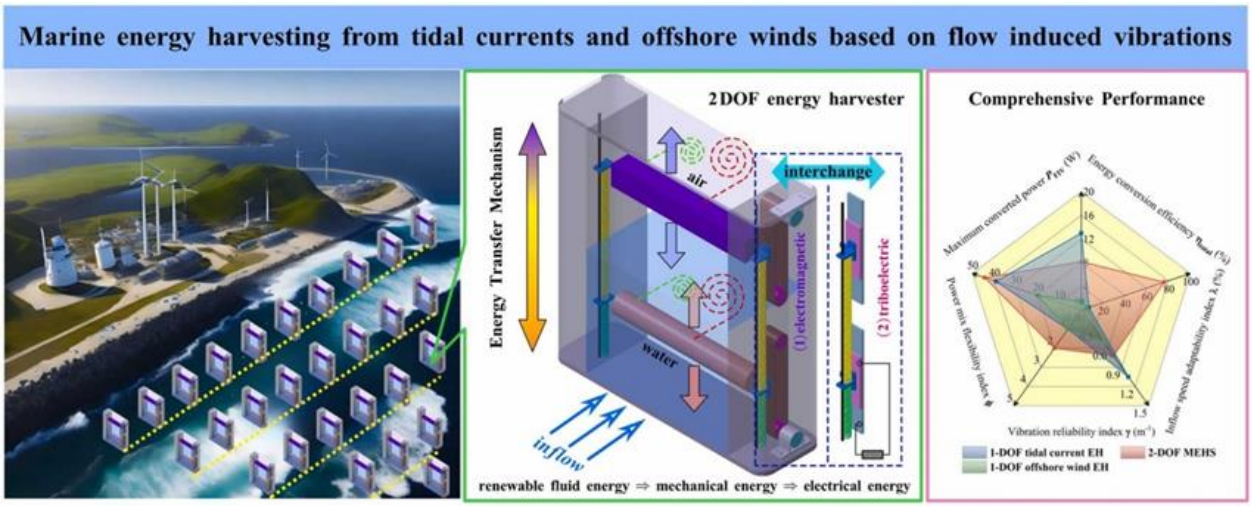


Figure 3. The application diagram in coastal area, model demonstration and comprehensive performance evaluation analysis of 2-DOF system [11].

3.3. Using natural flood defenses

The unmanaged realignment (uMR) of flood defenses is a natural breach. They offer a chance to evaluate the realignment sites' pattern change in a 'natural' way, without any substantial site design, engineering, or landscaping characteristics. The researchers choose five locations among the ten most recent instances of uMR on the English coast since 1996 to compare to the natural saltmarsh. They then look at how the area's morphology changed after that. Before the site was broken, they had more streams, but they lacked complicated creek morphology and topographic diversity. Table 1 shows the topographic properties of uMR. In addition to potentially lowering capital expenditures for maintaining coastal defenses, uMR also offer environmental benefits such as more environmentally friendly shoreline flood protection, carbon storage, water quality administration, residences for young aquatic species, plus more [12].

Table 1. Topographic characteristics of the five unmanaged realignment sites [12].

Name		Rugosity	Number of Creeks	Creek Density (m/ha)
Great Orcheton Fields	Natural	0.09	33	360
	Pre-breach	0.06	107	260
	Breach +3Years	0.06	122	274
	Breach +12 Years	0.07	134	284
Hazlewood Marshes	Natural	0.05	70	226
	Pre-breach	0.03	393	278
	Breach +3Years	0.04	391	269
	Breach +7 Years	0.04	387	279
Cattawade	Natural	0.09	47	707
	Pre-breach	0.06	428	1065
	Breach +2Years	0.05	352	760
Horsey Island	Natural	0.08	147	237
	Pre- breach	0.05	444	264
	Breach +3Years	0.04	461	264
Southmoor	Natural	0.03	79	92
	Pre-breach	0.04	15	102
	Breach +1Year	0.04	18	101

4. Conclusion

In this paper, the relationship between sea level rise, tidal energy and coastal areas is investigated. It is concluded that sea-level rise will affect tidal amplitude, tidal line, tidal surge and surrounding geological structure. The main benefit is increased power generation. However, there are more challenges such as corrosion of tidal equipment, rising costs, safety risks, efficiency of wastewater collection pipes, loss of wetlands and uneven distribution of underground water. Therefore, some suggestions are put forward to solve the above problems. Equipment upgrades and adaptive design can overcome the problem of tidal equipment corrosion. The integrated use of a variety of new energy sources can solve the problem of tidal instability. Natural flood defenses can solve environmental problems by enabling coastal areas to repair by themselves. In the future, more specific studies of effects of sea level rise on tidal energy development and coastal areas can be conducted according to the classification of climate and region.

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