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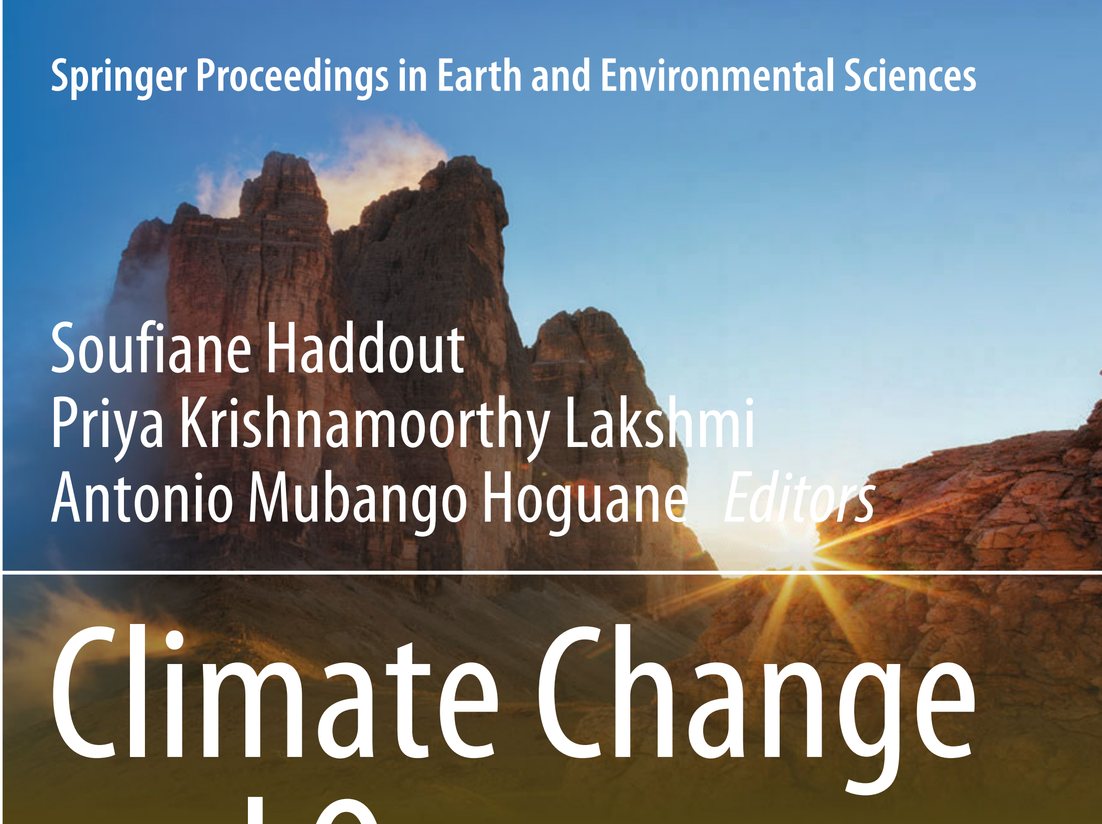

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Climate Change and Ocean Renewable Energy

Springer

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Climate Change and Ocean Renewable Energy

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One of the main objectives of this book is to present selected papers from the 1st International Conference on Climate Change and Ocean Renewable Energy (CCORE-2022), which focuses on climate change and ocean renewable energy research. This book contains the most cutting-edge research directions and achievements regarding climate change and the environment (resources, energy, etc.). All the papers have been subjected through rigorous review process to meet the requirements of international publication standard.

Preface

The *1st International Conference on Climate Change and Ocean Renewable Energy (CCORE 2022)* was held virtually on November 5, 2022, due to the outbreak of the global pandemic (COVID-19). There are many restrictions and regulations that have been imposed on countries around the world, so the virtual conference was arranged in compliance with them. To avoid physical contact spreading the COVID-19, such restrictions were put in place. There were over 30 presentations during the online conference, represented many countries including: *Morocco, India, Croatia, Bangladesh, Philippine, UK, US, Mozambique, Singapore, Indonesian, Kazakhstan, and Turkey*.

A key feature of CCORE 2022 was the opportunity for academics and engineers to exchange ideas and present research findings related to ocean renewable energy and climate change. This conference will provide an excellent opportunity to update knowledge in these fields. There were two sessions at the conference with keynote speakers, oral presentations, and an online discussion board. In the first part, keynote speakers were each allocated 30–45 min to hold their speeches. Eleven expert researchers were invited from many countries to deliver the keynote speeches: *Dr. Noemi Vergopolan* from Princeton University-USA, *Dr. Philipp Thies* from University of Exeter-UK, *Dr. Mary Ann Quirapas-Franco* from Energy Studies Institute, National University of Singapore, *Dr. Sony Junianto* from Electronic Engineering Polytechnic Institute of Surabaya (EEPIS), Indonesia, *Dr. Zhansaya Bolatova* from Almaty University of Power Engineering and Communication, Kazakhstan, *Dr. Tri Retnaningsih Soeprobowati* from Universitas Diponegoro-Indonesia, *Dr. Gökçen Uysal*, from Eskişehir Technical University-Turkey, *Dr. Samet Öztürk* from Bursa Technical University-Turkey, *Dr. Surendran Udayar Pillai* from Centre for Water Resources Development and Management-India, *Dr. Nagababu Garlapati* from Pandit Deendayal Petroleum University-India, and *Dr. Omar Farrok* from Ahsanullah University of Science and Technology- Bangladesh. Their insightful speeches had triggered heated discussions in the both sessions of the conference. Then in the second part, faculty, scientists, and research scholars were given about 5–10 min to perform their oral presentations. Every participant applauded this conference for disseminating useful and insightful knowledge in the field of climate change and ocean energy.

The proceedings is a compilation of the accepted papers and represents an interesting outcome of the conference. Topics include but are not limited to the following areas: climate change impacts on Ocean renewable energy, renewable energy technologies (e.g., coastal and offshore wind, waves, tides, ocean currents, salinity gradient power, impact of climate change on water resources and river management, ocean thermal energy conversion (OTEC), hydro power systems (HPS), etc.), global environmental change and ecosystems management, prediction modeling and decision support tools, physical oceanography, hydrology and climate change, and other related topics. All the papers have been subjected through rigorous review process to meet the requirements of international publication standard. We would like to acknowledge all of those who supported CCORE 2022. The help and contribution of each individual and institution were instrumental in the success of the conference. In particular, we would like to thank the organizing committee for its valuable inputs in shaping the conference program and reviewing the submitted papers. We sincerely hope that the CCORE 2022 turned out to be a forum for excellent discussions that enabled new ideas to come about, promoting collaborative research. We are confident that the proceedings will help create new technologies not only through scientific and engineering discoveries, but also by providing unique research references.

The Committee of CCORE 2022

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Prof. Mike Elliott is Director of International Estuarine & Coastal Specialists (IECS) Ltd. and also Professor of Estuarine and Coastal Sciences at the University of Hull, UK. He was Director of the former Institute of Estuarine & Coastal Studies (IECS) at the university from 1996 to 2017. He is Marine Biologist with a wide experience and interests, and his teaching, research, advisory, and consultancy include estuarine and marine ecology, policy, governance, and management. Mike has published widely, co-authoring/co-editing 20 books/proceedings, and >300 scientific publications. This includes co-authoring 'The Estuarine Ecosystem: ecology, threats and management' (with DS McLusky, OUP, 2004), 'Ecology of Marine Sediments: science to management' (with JS Gray, OUP, 2009), and 'Estuarine Ecohydrology: an introduction' (with E Wolanski, Elsevier, 2015). He was Editor and Contributor to the 'Coasts and Estuaries: the Future' (Wolanski, Day, Elliott and Ramachandran; Elsevier, 2019), Fish and Fisheries in Estuaries (Whitfield, Able, Blaber & Elliott; Wiley, 2022), and the Treatise on Estuarine & Coastal Science (Eds.-In-Chief - E Wolanski & DSMcLusky, Elsevier). He has advised on many environmental matters for academia, industry, government, and statutory bodies worldwide. Mike is past-President of the international Estuarine & Coastal Sciences Association (ECSA) and is now Vice-Chair of Future Earth Coasts and Co-Editor-in-Chief of the international journal Estuarine, Coastal & Shelf Science; he currently is or has had Adjunct Professor and Research positions at Murdoch University (Perth), Klaipeda University (Lithuania), the University of Palermo (Italy), Xiamen University (China), and the South African Institute for Aquatic Biodiversity. He was awarded Laureate of the Honorary Winberg Medal 2014 of the Russian Hydrobiological Academic Society. He is also Member of many national and international committees linking marine science to policy.

Prof. David Bowers is Emeritus Professor of Physical Oceanography at Bangor University in the UK. He studied Physics at Manchester at the tail end of the 1960s and came to oceanography as a mature student during an oil crisis in the mid-1970s. He obtained his Masters and PhD degrees at the University College of North Wales and worked on Postdoc at Flinders University in Australia before taking up a post as Lecturer at Bangor. He retired in 2016 as Head of physical oceanography at Bangor with a career researching tides, turbulence, particle flocculation, and marine optics. He has written several books and is currently finishing a popular science account of the oceanography of shelf seas.

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Contents

Development and Utilization of Ocean Renewable Energy

Zero Carbon Emission Based Electrical Power Plant by Harvesting Oceanic Wave Energy: Minimization of Environmental Impact in Bangladesh

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Abstract. Fossil fuels are mostly utilized for producing electricity in many countries including Bangladesh, which emit bulk amount of greenhouse gases. At present, about 3% electricity is produced in Bangladesh from renewable energy sources (RESs) viz. solar, wind, hydro, and bioenergy to reduce the emission level. In this paper, an oceanic wave energy based direct drive linear generator is proposed to produce electrical power. As the oceanic wave energy converter results almost zero carbon emission it can mitigate the adverse environmental impact. Mathematical model of the wave energy and linear generator are presented. The proposed generator design and its working principle are described. The generated voltage, armature current, power generation, magnetic flux linkage, and mechanical force are plotted. Load profile of the generator are also presented. High graded magnetic materials are applied to the proposed generator to reduce the conversional power loss. Simulation results show that the proposed generator produces approximately 5.44 kW of electrical power (maximum) where the peak voltage of the proposed generator is 198.5 V. Therefore, the oceanic wave farm can be constructed with several linear generators to produce sufficient electricity and mitigate negative environmental impact. As the harvesting of oceanic wave energy does not require any land area, the corresponding impact of using the land area can be avoided which is another benefit of using it. Moreover, the proposed power generation scheme can be supportive not only for Bangladesh but also for the countries that have adjacent ocean and plan to achieve net zero emission target.

Keywords: Environmental impacts · Linear generator · Oceanic wave energy · Renewable energy sources

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1 Introduction

Environmental issues are one of the key concerns as well as significant consideration in electricity generation. Generally, electricity is produced in various countries including Bangladesh by mostly utilizing fossil fuels such as coal, natural gas, diesel etc. [1]. Fossil fuels are very harmful for our planet due to their properties of greenhouse gas emission. Nowadays, some renewable energy sources (RESs) viz. solar, wind, hydro, bioenergy etc. are being applied to extract electricity. But they also emit greenhouse gas although its quantity is lower than the emission of fossil fuel. Another newly developed renewable energy, oceanic wave energy is being harvested in different leading countries for producing electricity. It has a lower amount of environmental impact than the other RESs. In addition, the availability and energy density of oceanic wave are the highest among the RESs [2].

Already, the potential of oceanic wave energy has been estimated for harvesting purposes. But it is executed considering global perception. Sometimes, it is done based on some countries and continents. The potential of the deep water of the EU is found 320GW [3]. Generally, a wave energy converter, electrical generator, and power electronic devices or converters are required for harvesting oceanic wave energy.

Recently, direct drive linear generators (DDLGs) are being developed by scientists and researchers for harvesting oceanic wave energy. The development is conducted in various aspects such as minimization of reluctance of the magnetic core, enhance the efficiency, and reducing core loss. Reluctance of the stator of a DDLG is minimized for enhancing the output power and minimizing the core loss by modifying the stator design [4]. A linear generator is analyzed to generate electricity efficiently even at low translator speed by multi-physical coupling [5]. Besides, core loss of a linear generator is reduced by applying a high graded magnetic core [6, 7].

Generally, it is found that most of the electricity is produced by fossil fuels in the small country with high population and lower economy such as in Bangladesh [1]. Although some RESs [8] namely solar and wind energy are being utilized in Bangladesh for electricity generation and minimization of the environmental impacts. The RES based power plants require large amount of land area. But the country has no sufficient land for installing the RES based power plants. It is analyzed that the problem can be solved by utilizing oceanic wave power as Bangladesh has the world's largest continuous natural sea beach. Therefore, it has sufficient amount of energy potential which can be harvested to meet the energy demand and reduce the environmental pollution. In this paper, an oceanic wave-based power station is proposed for Bangladesh as an example of this category of the country.

In this paper, a linear generator is designed and analyzed by ANSYS/Maxwell software. The mechanical force is applied to the translator of the linear generator through a simulation environment. Mathematical model of the oceanic wave and linear generator are presented in detail. Then the generated voltage of the linear generator, magnetic flux linkage, electrical power, current flow, and mechanical force are plotted with respect to time. Additionally, magnetic field intensity and flux density are illustrated with rainbow spectrum to observe the flux distribution. From the simulation results it is found that the proposed linear generator produces enough electrical power compared to its size.

2 Challenges for Electrical Power Generation

There are two challenges found for the production of electricity worldwide. First one is the availability of fuels and the other is the environmental challenge. At present, coal, oil and natural gas are being widely applied for electricity generation in the world as shown in Fig. 1 [9]. Besides the fossil fuel several countries also utilize RESs for the same purpose.

In addition, the fuel stock is decreasing day by day. For this reason, the utilization rate of the fuels would go downward in the future as shown in Fig. 1. In spite of the fact that hydroelectricity is the oldest renewable energy system in the world, which was utilized widely. But there is no significant progress of it as it is treated to be harmful for the environment. According to the forecast [9], like hydroelectricity, the utilization rate of nuclear energy would not be increased until 2050 globally. On the other hand, utilization rate of renewable energy is rapidly increasing as observed in Fig. 1 because of its clean and environment friendly nature.

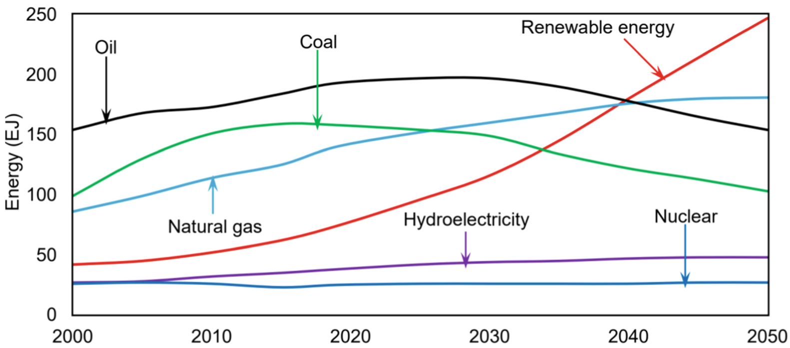

Fig. 1. Global energy consumption (2000–2050)

Nowadays, solar, wind, bioenergy, geothermal, hydropower, tidal etc. are implemented to the electricity sector in Bangladesh. Some environmental impacts are found for utilizing RESs which are mentioned in the next section.

3 Environmental Impact of the Conventional Power Plant

Most of the conventional resources are very detrimental owing to the emission of huge amount of greenhouse gases. Although the severity differs from source to source. Generally, the emission rate of natural gas is lower than both of oil and coal. However, they emit more of less amount of greenhouse gas. The electricity generation and total GHG emission in Bangladesh are plotted in Fig. 2 [10].

From here it is found that the rate of emission is increasing with the increase of electricity generation. The emission rate of natural gas is approximately half of the coal. For reducing the emission, RESs can be employed to produce electricity. But they contain comparatively lower impacts than fossil fuels. At present, solar, wind, hydro, biomass and bioenergy are utilized in the country as presented in Fig. 3 [8]. It is seen that solar energy is the highest utilized renewable source in the country.

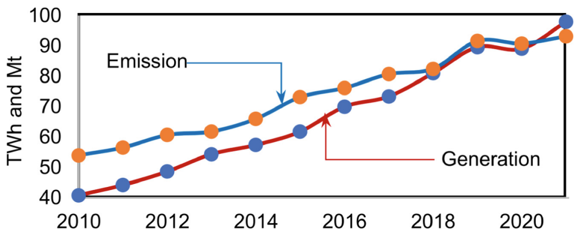

Fig. 2. Electricity generation and GHG emission in Bangladesh

The amount of GHG emission because of using coal, diesel, and natural gas is summarized in Table 1 [11, 12]. On the other hand, there is some environmental impacts for utilizing the RESs which are tabulated in Table 2. It is found from this table that some of the RESs require a huge amount of land and they are liable for different environmental impacts. The problem can be solved by utilizing oceanic wave energy for producing electricity. Bangladesh has sufficient (around 5–10 kW/m) wave energy potential as found in [20]. The potential and proposed system for the country is presented in Fig. 4. Land is not necessary for harvesting this kind of renewable sources. In addition, it has no remarkable environmental impacts such as in solar, wind, hydropower, and biomass energy which are being utilized in Bangladesh at present.

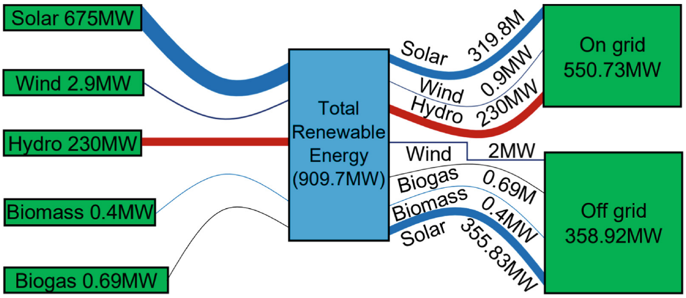

Fig. 3. Utilized RESs in Bangladesh

4 Overview of Oceanic Wave Energy Conversion

Bangladesh is a small country and there is scarcity of fossil fuels and some of the RESs as well. As it has one of the longest sea shores in the world, oceanic wave energy can be very significant candidate for the country to generate electricity, minimizing adverse environmental impact, and ensure energy security. In addition, it contains the highest

Table 1. GHGs emission for utilizing fossil fuels

Fuel	GHG emission parameter	GHG emission (gCO_2/kWh)
Diesel	Carbon dioxide	760
	Carbon monoxide	5
	Unburned hydrocarbons	0.21
	Particulate matters	0.0293
	Sulphur dioxide	1.8
	Nitrogen oxide	4.55
Coal	Carbon dioxide	900
	Sulphur dioxide	7.07
	Nitrogen oxide	4.28
Natural gas	Carbon dioxide	566
	Carbon monoxide	1.86
	Particulate matters	0.0525
	Nitrogen oxide	3.9

Table 2. Environmental impacts for using different RESs

RES	Environmental impacts
Solar	32–82 g CO_2 emits per kWh [13], high initial cost, output power variation is high [14], require large amount of land [13]
Wind	Make noise [15], hampers and kills the birds, high output power variation, low availability, emits 29.5 g CO_2 per kWh [16], visual disturbance [15]
Hydropower	Emits 31.2 gCO_2 per kWh [17], low potential, low energy density, high transmission cost, responsible to increase the temperature of local environment [18]
Biomass	Emits greenhouse gas 45.84 g CO_2 eq/MJ [14], huge amount of water is required, low energy density, requires large amount of land [19]

availability as well as energy density than the other RESs. The wave power is calculated by

$$P_{wave} = \rho g^2 A^2 T_w / 64\pi \qquad (1)$$

where P_{wave} defines the power of oceanic waves, ρ is the density of ocean water, g means the gravitational acceleration constant, A denotes the wave height, and T_w is the wave energy period. At present, the US, UK, Canada, Australia, China, Portugal, Sweden, and some other countries are producing electricity from the source.

There are several types of converters for harvesting oceanic wave energy, such as point absorber, Archimedes wave swing, oscillating water column, oscillating wave

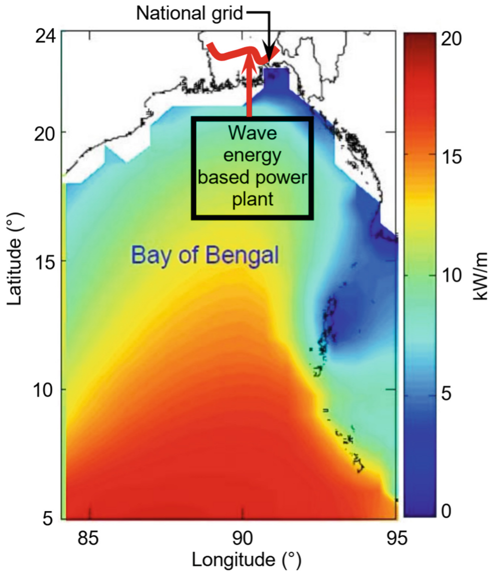

Fig. 4. Proposed power plant along with wave energy potential in Bangladesh [20]

surge, overtopping device, bulge head wave energy converter, submerged pressure differential, attenuator, and rotating mass. Point absorber is popularly applied to the conversion process. There are two types of generators applied to the converter. One is traditional rotary electrical generator and another is a direct drive linear generator. Rotational generator requires a complex gear box arrangement that drives the rotor of the generator. But the DDLG does not require complex gear box unit. Therefore, its construction is much easier than the conventional generator. For such reasons, it is popularly employed to the point absorber converter as shown in Fig. 5.

The DDLG has mainly two parts. First one is the translator as shown in the left-hand side of Fig. 5 and other one is the stator which is placed very close to the translator. Although the stator is shown in the right-hand side, but in practice, it is placed on both sides of the translator for balancing purpose. One side of the translator is joined with a floating buoy through a rod with high tensile strength and the opposite side is joined with the base through the spring. The base is basically used for mooring purpose. With the propagation of oceanic wave, the translator moves with the buoy in vertical direction. Because of the relative motion between the stator and translator, electromotive force is induced in the stator by Faraday's laws of electromagnetic induction. Then the generated ac power is converted to dc power. Because the frequency and voltage of the induced electromotive force are not the same as load or grid side power system. Further, an inverter is applied to convert the dc power into ac power to produce required voltage and frequency. Then a step-up transformer is applied to increase the voltage to the required level. Finally, it supplies the ac power to the load or grid.

In general, oceanicwave is modeled assinusoidalwaveform. Although the oceanic wave is not exactly sinusoidal, butbecause of approximation, complexity can be avoided for the simulation of linear generators. The commonlyused vertical velocity range of