A SHORT REVIEW OF MARINE RENEWABLE ENERGY: GENERATION, STORAGE, AND APPLICATIONS

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Received: 27 Feb. 2024; Revised: 19 Mar. 2024; Accepted: 23 Mar. 2024

ABTRACT

Renewable energy is a sustainable and green energy converted from renewable energy resources in the nature. There is a huge amount of renewable energy resources in the ocean that can be changed into useful energy like electricity, store for long time use, or apply in the daily energy consumption. These marine renewable energies (MRE) include wave energy, ocean thermal energy, tidal energy, ocean current energy, salinity gradient energy, and offshore energy. With a big area, the oceans have been prospected that it brings endless renewable energy sources for social development and human demand. The renewable ocean energy shows many advantages of sustainable energy, clean energy, and non-carbon dioxide emissions by generating from wave and water in the ocean with an enormous amount of natural energy resources. The MRE can service at many areas of off-shore, on-shore, and remote areas where need energy to drive daily living demands. The MRE reveals some disadvantages such as the influence of daily, monthly, season, and period of time. The solutions have been developed to solve the limitations of the MRE such as developing the storage method to store energy for long time use or making the balance of the output performance to improve quality of the renewable energy. The MRE has also received many concerns from countries by promulgating policies, strategies, and plans to develop the renewable ocean energy such as green economy development, blue economy strategy, carbon dioxide emission reduction, and encouragement of using marine renewable energy. This paper reviews current marine renewable energy with its generation, storage, and application. The work also mentioned some advantages, disadvantage, policies, strategies, and solutions to encourage the development of the renewable ocean energy in over the world. The results hope that it will be spread development, exploitation, and application of marine renewable energy in the near future.

***Keywords**: Marine renewable energy, energy storage, generation, application, sustainable energy*

I. INTRODUCTION

Marine renewable energy (MRE) is a sustainable, no greenhouse gas, and green energy that is converted from renewable energy resources in the nature such as sunlight energy, wave energy, geothermal energy, hypo-power, and biomass energy [1]. While traditional energy comes from fossil sources by burning materials that shows many disadvantage effects of carbon dioxide emission, environmental pollution, climate change, and human health problems. In 2021, the renewable primary energy increased about 5.1 exajoules (EJ), the annual increase is of about 15% higher than that of 9% in 2020 [2]. The world energy outlook 2022 report showed that the global electricity demand rises quickly from 18548 (Terawatt-hours) TWh in 2010 to 33733 TWh in 2030 and 62159 TWh in 2050 with the 2050 net zero emissions (NZE) scenario [3]. The report also showed the global electricity supply of 21539 TWh in 2010 to 37723 TWh in 2030 and 73232 in 2050 by the 2050 NZE scenario with the renewable share of 20%, 61%, and 88%, respectively, as shown in Table 1 [3]. The results show that the renewable energy supply increasing significantly with 88% share of global energy supply in 2050 with the strategy of the 2050 NZE scenario. Figure 1 shows the types of marine renewable energy

including wave energy, ocean thermal energy, tidal energy, ocean current energy, offshore energy, and salinity gradient energy. There are many technologies and methods focused on conversion marine renewable energy resources into useful energy such as applying the geotechnical method and constitutive model in analysis of the MSR array [4]. The MRE resources can be converted into useful renewable energy like electricity to use on-shore ore off-shore areas, store in battery for long time use, and apply in the human activities [5]. Marine renewable energy can be penetrated into the power grid to enlarge the electrical applications [6]. Many countries have been gave strategies and approaches to apply MRE in the economy and industry such as developing MRE strategy in Canada [7], using renewable energy technology and device to extract marine renewable energy form the ocean in Ireland [8]. This paper reviews current marine renewable energy with its generation, storage, and applications. The results hope that it will be spread exploitation and application of marine renewable energy in the near future.

Table 1 The 2050 global electricity scenario by demand and supply (TWh) [3]

	2010	2021	2030	2050
Global electricity demand	18548	24700	33733	62159
Global electricity supply	21539	28334	37723	73232
Renewables share	20%	28%	61%	88%

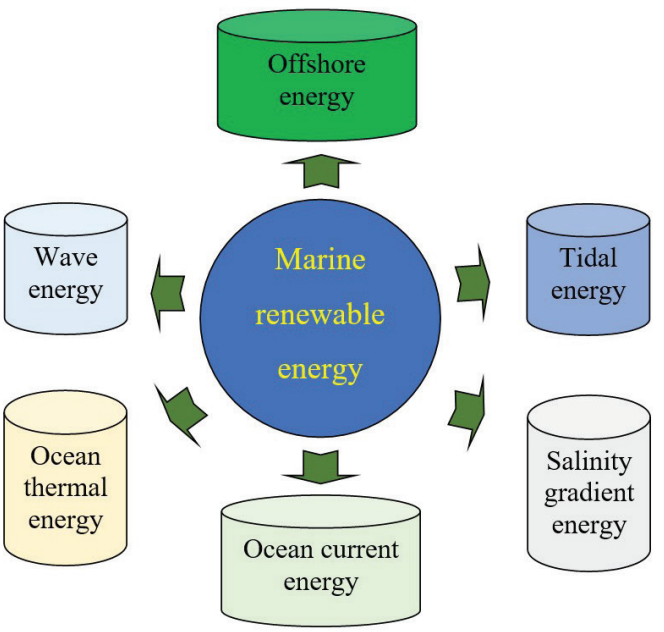

Fig. 1. The marine renewable energy types: wave energy, ocean thermal energy, tidal energy, ocean current energy, salinity gradient energy, and offshore energy.

II. MARINE RENEWABLE ENERGY GENERATION (MREG)

Marine renewable energy generation occupies a really important place in the renewable energy generation map. There are many methods and techniques that have been developed to convert renewable energy resources into electrical energy. The ocean stores a huge amount of renewable energy sources that is always available for generating renewable energy such as wave energy, ocean thermal energy, tidal energy, ocean current energy, offshore energy, and salinity gradient energy. Wave energy is a potential renewable

resources to produce renewable energy. This energy resource attracts many research groups to find the methods and techniques to convert it into useful energy such as designing a hybrid energy conversion system to extract the ocean waves and currents into electricity [9], developing a U-oscillating water column to convert wave energy into electrical power [10], using a pitching wave energy converter to harvest wave energy into electrical energy [11], using a hybrid nanogenerator module to harvest wave energy including triboelectric nanogenerator (TENG), electromagnetic generator, and piezoelectric nanogenerator [12], constructing a spherical triboelectric nanogenerator to transform water wave energy into electricity[13].

Renewable energy is generated from ocean thermal energy that also received many concerns such as building a model with thermodynamic optimization to improve output performance of an ocean thermal energy conversion system [14], developing an ocean thermal energy conversion with tri-generation system to produce energies of ammonia, cooling, and electricity [15]. Tidal energy is a potential candidate for marine renewable energy production such as using a submerged tidal energy device to evaluate the output performance of the tidal energy converter [16], building a mesh framework to generate renewable energy from tidal flow for coastal ocean model [17].

Some more marine renewable energy resources and technologies have also received positive attentions to collect renewable energy from nature such as developing a tethered dual rotor turbine model for ocean current conversion technique [18], studying the ocean current energy harvesting by an oscillating-wing wingmill converter [19], using reverse electrodialysis technology to harvest renewable energy from salinity gradient energy [20, 21], developing the technologies to collect offshore energy [22, 23]..

III. MARINE RENEWABLE ENERGY STORAGE (MRES)

Energy storage is one of the most important duties of marine renewable energy field to improve fluctuation phenomena and power quality. The fundamental marine energy storage system can be explained in a graphic model as shown in Figure 2. The MRES technologies are now listed as compressed air energy

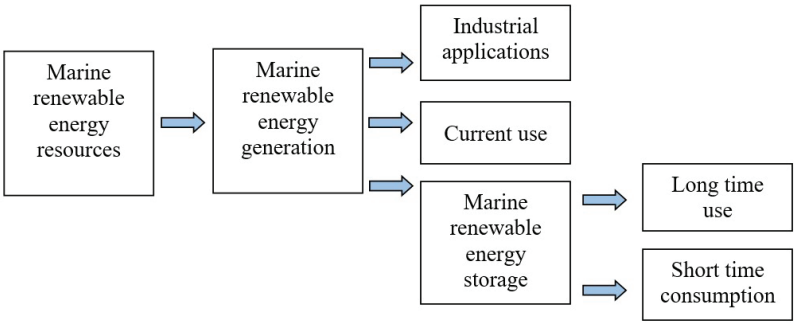

Fig. 2 The fundamental marine energy storage system.

storage, pumped hydro storage, battery energy storage, gravity energy storage, buoyancy energy storage, and battery energy storage [5]. These techniques have been attracted many attentions such as supporting energy storage systems for offshore renewable energy [24], giving storage solutions and technologies for marine renewable energy system like sodium-sulphur for high energy battery and disturbance reduction of the power [25], building a storage system for symbiotic offshore energy to enhance competitive advantages of the offshore systems [26], developing a novel management strategy for hybrid power system of offshore, marine current, battery, and ultracapacitor components [27].

IV. MARINE RENEWABLE ENERGY APPLICATIONS

There are many practical applications by

using a power from marine renewable energy with positive advantages of green energy, non-gas emissions, and saving environment. The outstanding characteristics of marine renewable energy lead to attentions of research groups such as applying in the power grid system [6], powering distributed sensors by power from ocean current energy conversion device [28], supplying the power for ocean robot by marine renewable energy [29], applying in the shipping industry with a hybrid energy model of renewable energy and fuel cell energy [30], developing electric power supply for remote area in the ocean by using the marine renewable energy generator [31], supplying the power for an island by the marine renewable energy system [32]. Figure 3 shows some applications of marine renewable energy and some others renewable energy in the strategies of powering energy for remote communities [33].

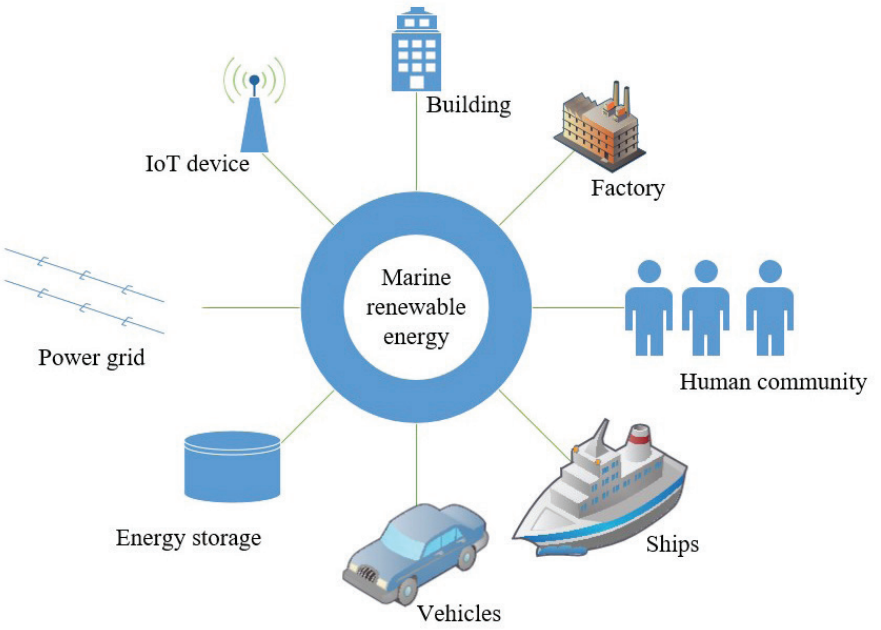

Fig. 3 Some applications of the MRE and renewable energy [33].

V. RENEWABLE OCEAN ENERGY ASSESSMENT

Renewable ocean energy provides a huge benefit to our society via supporting renewable energy resources for daily use. Ocean energy can extract many energy sources into electricity like ocean thermal energy, wave energy, tidal energy, salinity gradient energy, ocean current energy, and offshore energy. The energy source shows many advantages to attract researchers converting MRE into useful energy. The ocean energy features many advantages such as the renewable and clean energy characteristics by generating from natural movement of wave and water in the ocean, the power generation ability of a huge amount of energy resources from the ocean, flexibility in the developing technologies to harvest energy from the ocean [34], and reducing the carbon dioxide emission [35]. The energy flow predictability is a good advantage of the MRE due to the natural cycle, season cycles, daily, and period of time that relate to the change of renewable resources like wave or tide. The resilience ability of energy sources is also a strong advantage of MRE to penetrate the power to power grid or support useful energy to human communities [36]. The MRE can be setup to service off-shore, on-shore, and remote areas. The MRE is powerful energy resources for countries with long coastal like Vietnam. However, MRE reveals some disadvantages of the distance from the power plant to the human communities, the dangers for species living in the water from collecting

energy actions in the ocean, and the power quantity depending on the weather condition. These advantages and disadvantages are key input parameters to support development of marine energy harvesting technologies to improve the quantity and quality of the output performance of the power such as developing theoretical calculation method, modeling simulation model, designing a new harvesting design, and optimizing the energy collecting model [37, 38]. One good example solution is that uses storage technology to store energy, to balance output performance, and to transport to remote areas [39, 40]. Besides, national policies need to be catch with the rapid development of marine renewable energy such as successful policies from the United States, China, and India to increase the renewable energy production, promote green economy development, and reduce carbon dioxide emission [41], strategy to develop proper technologies to collect marine energy in Pakistan [42], and developing the blue economy plan from using of marine renewable energy [43].

VI. CONCLUSION

This paper reviews current marine renewable energy with its generation, storage, and applications. Marine renewable energy is vast that is natural available in the ocean such as wave energy, ocean thermal energy, tidal energy, ocean current energy, and salinity gradient energy. These energy resources can be changed into useful energy like electricity, store for long time use, or apply in the daily energy consumption. The renewable ocean energy shows many good characteristics of renewable, clean, and non-carbon dioxide emission energy resources to develop sustainable economy and society in over the world. The renewable ocean energy has a lot of advantages such as clean energy, sustainable energy, and non-carbon dioxide emissions by producing from water and wave that got available in the ocean with an extreme amount of the natural energy sources. The marine renewable energy can support to many regions such as on-shore, off-shore, and remote areas where use energy to cover all of activities in the daily living. The ocean renewable energy shows some limitations such as effects of daily, monthly, season, and period of time. The marine energy has also got many attentions from countries by promulgating policies, strategies, and plans to develop the renewable ocean energy such as green economy development, blue economy strategy, carbon dioxide emission reduction, and encouragement of using marine renewable energy. Many solutions have been applied to solve the disadvantages of the ocean renewable energy such as using the storage method to store energy for long time use or balancing the output performance to improve quality of the renewable energy. The oceans have been prospected that it brings endless renewable energy sources for social development and human demand. The results hope that it will be spread harvesting technologies, exploitation, and application of marine renewable energy in the near future.

ACKOWLEDGEMENTS

This work was partially sponsored by Higher Education Sprout Project, Ministry of Education to the Headquarters of University Advancement at National Cheng Kung University (NCKU), Taiwan. It was also supported in part by Hanoi University of Industry, Vietnam.

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