

Utilization of Ocean Wave Energy as a Sustainable Renewable Energy Alternative

Iin Dwi Putri^{1*}, Eka Azkha Rosidah²

¹Global Scholarly Research, Indonesia

²State Islamic University of Makassar, Indonesia

Abstract: Ocean wave energy is one of the renewable energy sources that has the potential to be developed as an alternative to meet the increasing energy needs. Sea waves have mechanical energy that can be converted into electrical energy through various Wave Energy Converter (WEC) technologies. The use of this energy can be one of the efforts to reduce dependence on fossil fuels and support the development of cleaner and more sustainable energy systems. The potential of wave energy is also influenced by wave characteristics, water conditions, and the location of technology application. The development of marine wave energy technology still faces various challenges, such as energy conversion efficiency, relatively high construction and maintenance costs, as well as marine environmental conditions that are dynamic and can cause corrosion and damage to devices. Therefore, it is necessary to develop technology that is able to increase the efficiency, reliability, and resilience of the system to marine environmental conditions. In addition to technical aspects, location selection, environmental impact, and economic aspects also need to be considered in the application of marine wave energy systems. The utilization of ocean wave energy has the opportunity to support the diversification of renewable energy sources and reduce the environmental impact of conventional energy use. The development of technology that is more efficient, resistant to the marine environment, and economical can increase the sustainable application of wave energy. With an integrated approach between technological, environmental, and economic aspects, marine wave energy can become one of the parts of the renewable energy system in the future.

Keywords: Ocean Wave Energy; Renewable Energy; Wave Energy Converter; Electrical Energy; Sustainability

1. Introduction

The world's energy needs continue to increase in line with population growth, industrial development, and technological advancements. So far, energy needs are still largely met through fossil energy sources such as coal, petroleum, and natural gas which are limited in number and produce emissions that have an impact on the environment. This condition encourages the development of renewable energy sources that are more environmentally friendly and can be used in the long term. One of the renewable energy sources that has great potential is energy derived from ocean waves [1].

Ocean waves have mechanical energy that is formed due to the interaction of wind with the sea surface. This energy can be converted into electrical energy using Wave Energy Converter (WEC) technology. This technology works by utilizing up-and-down movements, oscillations, or wave movements to drive mechanical systems that then generate electrical energy. Compared to some other renewable energy sources, wave energy has interesting characteristics because the ocean is available in a large area and waves can occur repeatedly [2].

Despite its potential, the use of ocean wave energy still faces various challenges in its application. Dynamic ocean conditions, relatively high investment costs, technological efficiency, corrosion, and maintenance needs are some of the factors that need to be considered. Therefore, the development of wave energy not only requires effective conversion technology, but also considers environmental, economic, and system resilience aspects. Based on these conditions, the use of ocean wave energy needs to be studied as one of the renewable energy alternatives that can support the sustainability of the energy system in the future [3].

* Corresponding author.

E-mail address: iindwiputrisudirman@gmail.com (I. D. Putri).

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2. Discussion of the Main Problem

The main problem in the use of ocean wave energy is the efficiency of energy conversion. Sea waves have characteristics that are not always the same because they are influenced by wind speed, wind direction, depth of water, weather conditions, and geographical characteristics of an area. These changes cause the amount of energy available to fluctuate so that the conversion device must be able to adapt to different wave conditions. If the technology is not designed correctly, the energy that is successfully converted into electricity can be lower than the potential wave energy available [4].

Another problem is related to the extreme conditions of the marine environment. The Wave Energy Converter device must be able to operate in an environment that contains salt water, high humidity, currents, large waves, and weather changes. These conditions can cause corrosion and accelerate component damage, increasing the need for maintenance. In addition, the installation of the device at sea requires a strong construction and installation system to be able to withstand wave loads and remain functional for a long period of time [5].

From an economic perspective, the development of marine wave energy also still faces relatively high investment, installation, operation, and maintenance costs. Infrastructure placed in the sea requires special equipment and installation methods, while the maintenance process can be more difficult compared to energy facilities on land. These problems can affect the competitiveness of wave energy against other renewable energy sources. Therefore, the development of simpler, durable, efficient, and easy-to-maintain technology is one of the important needs to increase the application of marine wave energy [6].

3. Review and Criticism of Existing Approaches

Various technological approaches have been developed to convert wave energy into electrical energy, such as oscillating water columns, point absorbers, attenuators, and overtopping devices. Each technology has different working principles and characteristics and can be adapted to specific water conditions. This approach shows that wave energy technology has opportunities to be developed through various conversion concepts. However, there is no single technology that can be considered suitable for all marine conditions because the characteristics of waves and the environment of each location are different [7].

One approach that needs attention is improving system efficiency through design optimization and site selection. Device development often focuses on the ability to generate energy under certain wave conditions, but the long-term performance of the device and changing environmental conditions must also be considered. In addition, the use of complex technologies can increase efficiency, but at the same time it can increase construction and maintenance costs. As such, the success of a technology should not only be judged on the amount of energy produced, but also on its reliability, service life, cost, and ease of maintenance [8].

Existing approaches also need to consider environmental and sustainability aspects more comprehensively. The installation of wave energy devices in the sea has the potential to interact with ecosystems, shipping activities, fisheries, and other uses of marine space. Therefore, technology development should be accompanied by environmental studies and proper location planning. An approach that integrates technical, economic, and environmental aspects will provide a stronger basis for determining technology that is suitable for the conditions of a region [9].

4. The Author's Perspective or Argument

Ocean wave energy has the opportunity to be part of the diversification of renewable energy, especially for regions that have adequate wave resources. Its development should not be seen as a substitute for all available energy sources, but as one of the additional sources that can complement the renewable energy system. The optimal use of wave energy can help reduce dependence on fossil energy sources and expand the utilization of the energy potential available in the marine area [10].

The development of Wave Energy Converter (WEC) technology needs to be geared towards achieving a balance between efficiency, durability, cost, and ease of maintenance. Technology with high efficiency but requiring large operating and maintenance costs may not necessarily be widely applicable. Therefore, innovation needs to be directed at a simple design of devices, having resistance to corrosion and marine environmental loads, and being able to adapt to changes in wave characteristics. The selection of location is also an important factor because the potential of the available energy must be proportional to the cost of building and maintaining the facility [11].

The sustainability of wave energy development also needs to consider the social and environmental

conditions around the implementation site. Planning that involves environmental impact assessments, coastal community activities, fisheries, and the use of marine space can reduce potential conflicts in their implementation. By combining technological innovation, site planning, economic considerations, and environmental protection, the use of wave energy can be developed in a more targeted manner. This approach can improve the reliability of the technology while supporting a more sustainable energy system [12].

5. Conclusion

Ocean wave energy is one of the renewable energy sources that has the potential to be used as a source of electrical energy. Energy derived from wave movement can be converted using various Wave Energy Converter technologies with different working principles. Its use can support the diversification of energy sources and reduce dependence on fossil energy. However, this potential still needs to be supported by the development of technology and application strategies that are in accordance with the conditions of the marine environment.

The main challenges in the development of wave energy include conversion efficiency, dynamic marine conditions, corrosion, investment costs, installation, and device maintenance. The various technologies that have been developed have their own advantages and limitations so that the selection of technology must be adjusted to the characteristics of the location and energy needs. In addition, the application of technology needs to consider the possible impact on the marine environment and community activities in coastal areas.

Thus, the utilization of ocean wave energy has the opportunity to become one of the components in a sustainable renewable energy system. Further development needs to be directed at increasing the efficiency and durability of devices while reducing construction and maintenance costs. The integration between technological innovations, the selection of the right location, economic considerations, and environmental protection are important factors in the success of its implementation. With this approach, marine wave energy can be developed more effectively to support future energy needs.

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