

The Effect of Wave Height and Wave Period on the Energy Generated

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Abstract: Ocean wave energy is one of the renewable energy sources with significant potential as an alternative for electricity generation. The amount of energy contained in ocean waves is influenced by several key parameters, particularly wave height and wave period. This article aims to analyze the effects of wave height and wave period on the amount of energy that can be generated through wave energy conversion. The method used in this study is a literature review by examining the basic concepts of wave energy, ocean wave characteristics, and the relationship between wave height, wave period, and the resulting energy. Theoretically, an increase in wave height significantly increases the amount of energy because wave energy is proportional to the square of the wave height. Meanwhile, wave period also affects the available wave power, meaning that waves with greater height and longer periods have higher energy potential. The results of the review indicate that wave height and wave period are important parameters in determining the potential of ocean wave energy. Understanding these parameters is essential for the planning and development of Wave Energy Converter (WEC) technology so that wave energy can be utilized effectively and efficiently as a renewable energy source.

Keywords: Wave Energy; Wave Height; Wave Period; Ocean Energy; Wave Energy Converter (WEC)

1. Introduction

Ocean waves are one of the potential sources of renewable energy that can be utilized to support the increasing demand for electrical energy. Unlike fossil fuels, wave energy is a renewable resource that is continuously generated by natural processes in the ocean. The movement of ocean waves contains mechanical energy that can be converted into electrical energy using wave energy conversion technologies, such as the Wave Energy Converter (WEC). The development of wave energy technology has attracted increasing attention because the ocean covers a large part of the Earth's surface and contains considerable energy potential. In addition, wave energy can provide an alternative source of electricity, particularly for coastal and offshore areas that have suitable wave conditions. The utilization of ocean wave energy can therefore contribute to the diversification of renewable energy resources and reduce dependence on conventional energy sources [1].

The amount of energy available from ocean waves is influenced by several physical characteristics, particularly wave height and wave period. Wave height represents the vertical distance between the crest and trough of a wave, while wave period describes the time required for successive wave crests to pass a fixed point. These two parameters play an important role in determining the amount of energy and power that can potentially be extracted from ocean waves. Higher waves generally contain greater amounts of energy, while longer wave periods can increase the amount of wave power available under certain conditions. Therefore, an understanding of wave characteristics is necessary to evaluate the potential of a particular ocean area for wave energy utilization [2].

The availability of wave energy is not constant because ocean conditions continuously change due to wind speed, weather conditions, water depth, seasonal variations, and geographical location. These changes can affect the performance of WEC systems and the amount of electrical energy that can be generated. A suitable WEC must be capable of responding to variations in wave conditions while maintaining effective energy conversion. Therefore, the analysis of wave height and wave period is important not only for estimating the available wave

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energy but also for supporting the design, selection, and optimization of wave energy conversion systems [3].

Understanding the relationship between wave characteristics and energy availability can provide valuable information for identifying areas with good potential for wave energy development. It can also help engineers determine the appropriate characteristics and operating conditions of WEC systems. Through proper analysis and utilization, ocean wave energy has the potential to become an important component of sustainable marine renewable energy development. Therefore, this study focuses on examining the relationship between wave height, wave period, and the amount of energy or power available from ocean waves, as well as its implications for the utilization of Wave Energy Converter technology [4].

2. Materials and Methods

The main problem discussed in this study is how wave height and wave period affect the amount of energy that can be generated from ocean waves. Ocean waves contain mechanical energy that can be converted into electrical energy using wave energy conversion technology. However, the amount of available energy is not constant because ocean wave characteristics vary depending on weather conditions, wind speed, water depth, and geographical location. These variations make ocean waves a dynamic renewable energy resource that requires careful analysis before being utilized for electricity generation. The characteristics of ocean waves can change over time due to seasonal and environmental conditions, resulting in fluctuations in the amount of energy that can be captured by a wave energy conversion system. Therefore, understanding the physical characteristics of ocean waves is an important step in estimating the potential energy available in a particular marine area. Wave height and wave period are two important parameters that determine the amount of energy transported by ocean waves, making their analysis essential for evaluating the feasibility and effectiveness of wave energy utilization [5].

Wave height is one of the most important factors affecting the amount of energy contained in ocean waves. The greater the wave height, the greater the energy available for conversion. The relationship between wave energy and wave height is proportional to the square of the wave height. This means that an increase in wave height can cause a significant increase in the energy contained in the wave. Therefore, areas with relatively high and consistent wave heights have greater potential for ocean wave energy utilization. A higher wave height indicates that the waves contain greater mechanical energy, which can provide more energy for a Wave Energy Converter (WEC) to capture and transform into electrical energy. However, extremely high waves may also create greater loads on the conversion system and affect its operational stability and structural safety. For this reason, wave height needs to be considered not only in estimating the amount of available energy but also in designing a reliable and efficient wave energy conversion system [6].

In addition to wave height, wave period also affects the amount of energy that can be utilized. Wave period is the time required for two consecutive wave crests to pass a fixed point. A longer wave period generally results in greater wave power when other wave parameters remain constant. Therefore, both wave height and wave period need to be considered when determining the energy potential of a particular ocean area. Wave period is closely related to the frequency of ocean waves and describes how frequently the wave cycles occur at a specific location. Waves with longer periods generally carry more energy over time and can provide favorable conditions for energy extraction by a Wave Energy Converter (WEC). The variation of wave period can also influence the operating performance of the conversion system because different WEC technologies are designed to respond effectively to particular ranges of wave periods. Consequently, analyzing wave period together with wave height is important to obtain a more accurate estimation of available wave power and to support the selection and design of an efficient wave energy conversion system [7].

The interaction between wave height and wave period is also an important issue in the design and operation of a Wave Energy Converter (WEC). A WEC must be able to respond effectively to different wave conditions in order to capture and convert wave energy into electrical energy. If the wave characteristics are not properly considered, the energy conversion system may not operate efficiently and may experience difficulties under changing sea conditions. The combination of wave height and wave period determines the amount of wave power that can be available for conversion at a particular location. Changes in either parameter can influence the performance and energy output of the WEC, making it necessary to evaluate both parameters simultaneously during the design process. A WEC should therefore be designed to operate within the range of wave conditions commonly found in its intended location. In addition, the system needs to maintain reliable performance when wave conditions fluctuate due to changes in weather and oceanographic conditions. Proper consideration of wave height and wave period can help optimize the energy capture efficiency, reduce operational limitations, and improve the overall reliability of the wave energy conversion system [8].

Therefore, understanding the effects of wave height and wave period is essential for determining the

potential of ocean wave energy. An analysis of these parameters can provide useful information for selecting suitable locations, designing wave energy conversion systems, and improving the effectiveness of energy utilization. The main focus of this study is consequently to examine the relationship between wave height, wave period, and the amount of energy or power available from ocean waves. By analyzing these wave characteristics, the study can provide a clearer understanding of how changes in wave conditions influence the potential energy that can be extracted from the ocean. The results of this analysis are expected to support the identification of wave conditions that are suitable for efficient energy conversion and to provide useful information for the development of Wave Energy Converter (WEC) technology. Furthermore, this study can contribute to a better understanding of the utilization of ocean waves as a renewable energy source and provide a basis for further research on the optimization of wave energy conversion systems in different marine environments [9].

3. Results

The results of the analysis show that wave height and wave period have a significant influence on the energy and power available from ocean waves. Based on the theoretical calculations, an increase in wave height results in a substantial increase in wave energy because wave energy is proportional to the square of wave height. Therefore, waves with greater heights contain considerably more energy than waves with lower heights under the same environmental conditions [10].

The analysis also shows that wave period affects the amount of wave power available for energy conversion. For the same wave height, an increase in wave period results in an increase in wave power. This indicates that waves with longer periods have greater energy transport potential and can provide more energy for a wave energy conversion system. The combined effect of wave height and wave period becomes more apparent when both parameters increase simultaneously [11].

For example, assuming a seawater density of 1025 kg/m^3 and gravitational acceleration of 9.81 m/s^2 , a wave with a height of 1 m has a theoretical energy density of approximately 1.26 kJ/m^2 . When the wave height increases to 2 m, the energy density increases to approximately 5.03 kJ/m^2 . This demonstrates that doubling the wave height results in approximately four times the wave energy [12].

Furthermore, the calculated wave power also increases with both wave height and wave period. A wave with a height of 1 m and a period of 5 s has a lower theoretical power potential than a wave with the same height and a period of 10 s. When both wave height and period increase, the available wave power increases considerably. These results demonstrate that wave height and wave period are important parameters in assessing the potential of ocean wave energy [13].

Overall, the results indicate that wave height has a particularly strong influence on wave energy because of its squared relationship, while wave period directly influences the amount of power transported by the waves. These findings emphasize the importance of considering both parameters in the planning and design of Wave Energy Converter (WEC) systems to achieve effective and efficient energy conversion [14].

4. Discussion

The results demonstrate that wave height is one of the most influential parameters in determining the amount of energy contained in ocean waves. Wave energy increases proportionally to the square of wave height, meaning that even a moderate increase in wave height can produce a significant increase in available energy. Therefore, areas with higher wave heights have greater potential for wave energy utilization. This relationship indicates that wave height should be carefully considered when assessing the energy potential of a particular marine area. A small variation in wave height can result in a considerable difference in the amount of energy that can be captured by a Wave Energy Converter (WEC). However, higher wave heights may also produce greater mechanical loads on the WEC components, requiring the system to have sufficient structural strength and stability. Therefore, the increase in available energy must be balanced with the technical requirements needed to ensure safe and reliable operation. In addition, wave height can vary significantly due to weather conditions, wind speed, seasonal changes, and local oceanographic characteristics. Consequently, long-term wave data are important for obtaining a more representative assessment of the available energy and for determining suitable operating conditions for wave energy conversion systems [15].

Wave period also has an important role in determining the power available from ocean waves. A longer wave period generally allows more energy to be transported by the waves over a given period of time. When wave height remains constant, an increase in wave period can result in higher wave power, making the period an important parameter in assessing wave energy resources. In addition, wave period provides information about

the frequency and characteristics of wave motion, which can influence the response of a wave energy conversion device. A WEC that is designed for a specific range of wave periods may perform differently when exposed to waves with shorter or longer periods. Therefore, consideration of wave period is necessary to ensure that the energy conversion system can operate effectively under the prevailing wave conditions. Variations in wave period over time should also be considered when evaluating the long-term potential of ocean wave energy. The interaction between these parameters can produce significant differences in the amount of energy that can potentially be extracted from the same marine area. Therefore, wave energy assessment should consider both parameters simultaneously to obtain a more accurate representation of the available resource. This approach can also help identify locations where wave conditions are relatively favorable and consistent for energy conversion. A comprehensive analysis of wave height and wave period can consequently support more effective planning and optimization of wave energy utilization [16].

The combined effect of wave height and wave period provides a better understanding of the overall energy potential of ocean waves. Waves with both greater heights and longer periods generally provide higher power potential than waves with lower heights and shorter periods. This relationship shows that evaluating only one wave parameter is not sufficient when determining the suitability of a location for wave energy development. The interaction between these parameters can produce significant differences in the amount of energy that can potentially be extracted from the same marine area. Therefore, wave energy assessment should consider both parameters simultaneously to obtain a more accurate representation of the available resource. This approach can also help identify locations where wave conditions are relatively favorable and consistent for energy conversion. A comprehensive analysis of wave height and wave period can consequently support more effective planning and optimization of wave energy utilization [17].

These wave characteristics also have important implications for Wave Energy Converter (WEC) systems. The design and performance of a WEC need to be adapted to the wave conditions at the installation site so that the available energy can be captured effectively. Variations in wave height and period can affect the amount of energy captured, the operating conditions of the device, and the structural loads experienced by the system. A WEC must therefore be capable of responding to different wave conditions while maintaining stable and reliable operation. The selection of an appropriate WEC technology should consider the dominant wave characteristics and the expected range of environmental conditions at the installation site. Proper matching between the WEC characteristics and the available wave resource can improve energy capture efficiency and reduce the risk of inefficient operation. In addition, consideration of extreme wave conditions is important to ensure that the system can withstand variations in sea conditions and maintain its structural integrity [18].

Overall, the findings confirm that wave height and wave period are fundamental parameters in the assessment and utilization of ocean wave energy. Understanding their relationship can support the selection of suitable locations and the development of more effective wave energy conversion systems. Further studies using actual wave measurements and different sea conditions are needed to obtain a more detailed assessment of the performance and energy potential of WEC technology. Long-term observations can provide more representative information about seasonal and temporal variations in wave characteristics. Such data can also be used to estimate the consistency of energy availability and evaluate the potential energy output of a WEC over an extended period. In addition, future research can consider other factors such as water depth, wave direction, device efficiency, and environmental conditions to obtain a more comprehensive evaluation. These considerations are important for supporting the practical development and optimization of ocean wave energy as a renewable energy resource [19].

5. Conclusion

The analysis concludes that wave height and wave period are important factors affecting the energy and power potential of ocean waves. Wave height has a strong influence because wave energy is proportional to the square of wave height, meaning that an increase in wave height can significantly increase the available energy. Meanwhile, wave period also affects the amount of wave power that can be utilized for energy conversion, with longer periods generally providing greater power potential under similar wave conditions. The results show that changes in wave height and wave period directly influence the amount of energy available for conversion into electrical energy. Therefore, these two parameters should be carefully considered when assessing the potential of ocean wave energy in a particular location.

The findings also indicate that the combination of greater wave height and longer wave period can provide higher energy potential for Wave Energy Converter (WEC) systems. Understanding the characteristics and variations of ocean waves is essential for selecting suitable locations and designing efficient and reliable energy conversion systems. Proper consideration of wave conditions can improve the ability of WEC technology to

capture available wave energy while maintaining safe and stable operation. Ocean wave energy therefore has considerable potential to support the development of renewable energy, particularly in coastal and marine areas with suitable wave characteristics. Further research using field measurements and actual wave data is recommended to obtain more accurate information about energy potential and WEC performance under different ocean conditions.

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