Offshore Platform Operational Risk Management in Extreme Weather Conditions

Part of the Book Series "Maritime Engineering"

Economic, Social, and Environmental Aspects of Ocean Current Turbine Installations in the Indonesian Strait

Abstract

The development of tidal current power plants in Indonesia's straits not only considers technical aspects but also carries significant implications from economic, social, and environmental perspectives. From an economic standpoint, the initial investment for installing tidal current turbines is relatively high, particularly regarding foundational construction, submarine cable installation, and supporting infrastructure. Nevertheless, the potential for stable and sustainable energy can yield long-term benefits by reducing dependence on fossil fuels and enhancing energy security across the archipelago. Furthermore, this project has the potential to stimulate local economic growth through job creation at the construction, operational, and maintenance stages. From a social perspective, the development of tidal current turbines must take into account interactions with coastal communities, particularly fishermen and shipping lane users. The presence of turbines may affect fishing activities and navigational access, necessitating inclusive and participatory marine spatial planning. On the other hand, the provision of reliable electricity can improve the quality of life for coastal communities, open opportunities for small industry development, and support equitable development in remote areas. Meanwhile, from an environmental standpoint, the installation of tidal current turbines has a relatively lower impact compared to fossil fuel-based power plants, yet still requires thorough assessment. Potential impacts include changes in local current patterns, disturbances to marine biota habitats, and risks to fish and marine mammal migration. Additionally, bio fouling and structural deterioration can disrupt operations and necessitate the use of environmentally friendly materials and technologies. Therefore, a comprehensive environmental impact analysis and appropriate mitigation strategies are essential to ensure that tidal current energy development proceeds sustainably and in harmony with the conservation of Indonesia's marine ecosystems.

Andi Muhammad Ikram[1]*, Misganaw Abebe Baye[2]

[1]Department of Ocean Engineering, Hasanuddin University, Indonesia
[2]Kunsan National University, Republic of Korea

*Correspondence author:
ikramam23d@student.unhas.ac.id

Keywords: Economy, Environment, Indonesian Strait , Renewable Energy, Society, Tidal Turbines.

This work is licensed under a Creative Commons Attribution 4.0 International License.

1. Introduction

As the world's largest archipelagic nation, Indonesia comprises more than 17,000 islands separated by straits and waters with complex current dynamics [1]. Indonesia's geographical position between the Pacific and Indian Oceans gives rise to the Indonesian Throughflow, a large-scale water mass movement flowing from the Pacific to the Indian Ocean through various strategic straits. This phenomenon generates significant and relatively predictable kinetic energy potential from ocean currents, particularly in strait areas with narrowing cross-sections.

In the context of energy transition and carbon emission reduction, harnessing tidal current energy has emerged as one of the most promising renewable energy alternatives. Unlike wave energy, which is heavily influenced by sea surface conditions, ocean currents tend to exhibit more stable and periodic characteristics, especially tidal currents. Tidal current turbines operate on the principle of converting the kinetic energy of water flow into mechanical energy, which is subsequently transformed into electrical energy through a generator. This technology offers the advantage of high energy density, owing to the fact that the density of water is considerably greater than that of air.

Several straits in Indonesia, including the Larantuka Strait, Lombok Strait, and Sunda Strait, are known to possess sufficiently high current velocities, making them viable candidates for tidal current turbine installations. Nevertheless, the development of this technology must also take into account a range of economic, social, and environmental considerations. From an economic perspective, the substantial initial investment required for infrastructure construction, turbine installation, and submarine power transmission systems represents a primary challenge, despite the long-term benefits it may offer through sustainable energy supply and reduced fossil fuel operational costs. From a social standpoint, the presence of tidal turbines may affect the activities of coastal communities, particularly fishing and shipping, thereby necessitating a participatory planning approach to prevent conflicts over marine spatial use.

Furthermore, from an environmental perspective, the installation of tidal current turbines has the potential to impact marine ecosystems, including alterations to local current patterns, disturbances to biota habitats, and risks to the migration of marine organisms. At the same time, this technology offers the considerable advantage of significantly lower carbon emissions compared to conventional power plants. Therefore, a comprehensive environmental assessment and appropriate mitigation strategies are imperative to safeguard the integrity of marine ecosystems.

Based on the aforementioned background, this paper aims to examine the economic, social, and environmental dimensions of tidal current turbine development across Indonesia's straits. By understanding local characteristics and applying a multidimensional analytical framework, it is hoped that sustainable planning approaches and implementation strategies can be formulated to support the advancement of marine resource-based renewable energy in Indonesia.

2. Materials and Methods

This study employs a descriptive-analytical approach aimed at examining the feasibility of tidal current turbine development in Indonesia's straits, with a particular focus on the Bali Strait, through economic, social, and environmental perspectives. The research methodology is conducted through a literature review and analysis of secondary data relevant to the conditions of the study area. The literature review encompasses economic engineering theory for energy investment assessment, regulations governing marine spatial use and coastal community protection, as well as principles of sustainable marine environmental management related to tidal current turbine installations.

The data utilized in this study consist of secondary data covering economic, social, and environmental parameters. From an economic standpoint, an investment feasibility analysis is carried out using the methods of Net Present Value (NPV), Benefit-Cost Ratio (BCR), Internal Rate of Return (IRR), and Payback Period (PP) to evaluate the financial viability and profitability of the project. From a social perspective, the analysis is focused on the conformity with applicable regulations in the study area, including marine spatial planning and the protection of coastal community rights, to ensure that tidal turbine development does not disrupt local economic

activities such as fishing and shipping, nor infringe upon the rights of local communities.

Meanwhile, from an environmental perspective, the analysis is conducted to assess the potential impacts of tidal turbine installation on environmental quality, including changes in marine water conditions, disturbances to marine ecosystems and biota, as well as indirect effects on air quality and overall environmental balance. These data are analyzed comprehensively to determine whether tidal current turbine development in the Bali Strait can be carried out in a feasible, sustainable manner without exacerbating the environmental and social conditions of the region.

3. Results

Based on the findings of the literature review, this study examines the development of tidal current turbine installations in the Bali Strait from an integrated economic, social, and environmental perspective. From an economic standpoint, the project feasibility is analyzed using key financial indicators, namely Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback Period (PP). NPV is employed to assess the difference between the present value of project benefits and costs, IRR indicates the rate of return on investment, BCR illustrates the ratio between benefits and costs, while PP denotes the time required to recover the initial investment. The results of this analysis serve as the basis for determining whether the tidal current turbine project is financially viable for development in the region.

From a social perspective, the development of tidal current turbines is evaluated based on its impacts on the welfare of coastal communities, gender equality, local participation, human rights protection, and the continuity of local culture. A well-designed project is expected to improve energy access, generate employment opportunities, and encourage community involvement in the planning and operational processes. Furthermore, it is essential to ensure that project implementation does not give rise to social inequality, does not disadvantage vulnerable groups, and continues to respect the cultural values and local wisdom of the surrounding communities.

Meanwhile, from an environmental perspective, the assessment is focused on the potential impacts related to greenhouse gas emissions, air pollution, soil pollution, climate change, and biodiversity. Tidal current turbines generally offer the advantage of generating clean energy with low carbon emissions; however, potential local impacts such as disturbances to marine ecosystems and water quality must still be thoroughly analyzed. Therefore, a comprehensive evaluation is conducted to ensure that the installation does not degrade environmental conditions and continues to uphold the principles of sustainable development.

Overall, the project evaluation is carried out based on a number of key indicators, including greenhouse gas emissions, energy efficiency, energy availability and affordability, social impacts, community welfare improvement, production costs, economic added value, biodiversity conservation, as well as water and air quality. This approach provides a holistic overview of the feasibility of tidal current turbine development, enabling investment decisions and implementation to be carried out in a precise, balanced, and sustainable manner.

4. Discussion

Based on the results of tests conducted by Tonny et al. in the Bali Strait, the technical analysis revealed that the maximum electrical power potential is generated at an installation depth of approximately 3 meters below sea level. This indicates that, from a technical standpoint, the installation of tidal turbines has the potential to generate electrical energy optimally, as shown in Table 1.

Table 1. Power Potential Data Over 15 Days in the Bandung Strait (Tonny et al., 2015)

Depth/time	Total Power (watt)
28 m	5502.41
23 m	21289.81
18 m	60984.99

Depth/time	Total Power (watt)
13 m	95125.32
8 m	83532.14
3 m	94463.23

The assessment of the feasibility of developing tidal turbines in Indonesia's straits, particularly in the Bali Strait, is not based solely on technical aspects but must also take into account three key aspects: economic, social, and environmental. These three aspects form the basis for ensuring that the planned project is sustainable, profitable, and does not cause significant negative impacts.

From an economic perspective, project feasibility is analyzed using several key financial indicators, namely Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback Period (PP). NPV is used to determine the net present value of the project's benefits by accounting for the time value of money, as shown in Table 2.

Table 2. Economic Feasibility Parameters for Tidal Turbines

Parameter & Rumus		Syarat Kelayakan
NPV	$NPV = \sum_{t=0}^{N} \frac{CF_t}{(1+R)^t}$	NPV > 0
IRR	$NPV = 0$	IRR > 0 IRR > tingkat suku bunga (MARR)
PP (Payback Period)	$PP = \frac{Investasi\ Awal}{Arus\ Kas\ Tahunan}$	PP < umur proyek
BCR	$BCR = \frac{\sum Benefit}{\sum Cost}$	BCR ≥ 1

From a social perspective, project feasibility is determined based on its impacts on the surrounding communities, encompassing improvements in community welfare, gender equality, local participation in planning and operational processes, human rights protection, and the continuity of local culture. A feasible project is one that is capable of delivering tangible benefits to the community without disrupting primary livelihoods such as fishing, while continuing to respect local social and cultural values. In this regard, a literature review analysis is required to collect relevant data, including population growth rate data and electricity consumption data, which will be processed and used as a reference for predicting the future utilization of tidal current energy.

Meanwhile, from an environmental perspective, feasibility is assessed in terms of impacts on greenhouse gas emissions, air pollution, soil pollution, climate change, and biodiversity. Tidal current turbines hold significant potential as a source of clean energy with low emissions; however, it must be ensured that their installation does not damage marine ecosystems, does not deteriorate water quality, and does not disturb the habitats of marine biota. In this regard, design considerations are of critical importance in order to maximize positive environmental outcomes, particularly with respect to whether the tidal current turbine design in the Bali Strait occupies a substantial amount of space, and whether the turbines potentially pose a risk to the marine ecosystem of the Bali Strait.

As the basis for the feasibility study evaluation, key indicators are employed encompassing energy efficiency, energy availability and affordability, greenhouse gas emissions, social impacts, community welfare improvement, production costs, economic added value, biodiversity conservation, as well as water and air quality. Through this approach, the feasibility of tidal current turbines can be assessed comprehensively, enabling their implementation to proceed optimally, sustainably, and to deliver broad-ranging benefits.

5. Conclusions

The straits of Indonesia hold significant potential for the development of tidal current power plants. Nevertheless, their implementation continues to face various technical challenges, particularly at the installation stage. One of the primary factors that must be taken into consideration is oceanographic conditions, encompassing the characteristics of ocean currents, tides, waves, and water depth. These parameters serve as the foundation for determining the appropriate power generation system design, specifically whether a floating system or a fixed structure would be more suitable. Therefore, a comprehensive oceanographic study is essential to ensure a safe, efficient, and sustainable design.

Beyond the technical aspects, the development of tidal current turbines must also be examined from an integrated economic, social, and environmental perspective. From an economic standpoint, project feasibility needs to be analyzed using indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback Period (PP) to ensure that the investment yields adequate and sustainable returns. From a social perspective, the development project must be capable of improving community welfare, promoting local participation, upholding human rights, and respecting local cultural values without giving rise to conflicts over marine spatial use. Meanwhile, from an environmental standpoint, the installation of tidal current turbines must take into account its impacts on greenhouse gas emissions, air quality, water quality, and biodiversity so as not to cause ecological damage.

Accordingly, the success of tidal current power plant development in Indonesia is not solely determined by technical excellence, but also by the balance achieved among economic, social, and environmental dimensions. A comprehensive and sustainable approach serves as the fundamental key to ensuring that this technology can deliver long-term benefits for national energy needs as well as the development of coastal regions.

References

[1] Badan Informasi Geospasial, “Pulau Indonesia bertambah jadi 17.380, mengapa angkanya berubah setiap tahun?,” SIPULAU–BIG, Dec. 13, 2024. [Online]. Available: https://sipulau.big.go.id/news/11.

[2] T. Adamtheoyana, Purwanto, and W. S. Pranowo, “Potensi energi arus laut pada berbagai kedalaman untuk pembangkit listrik di Selat Badung, Bali,” Jurnal Oseanografi, vol. 4, no. 1, pp. 262–269, 2015.

[3] R. M. Ariefianto, R. N. Hasanah, and Wijono, “Optimasi turbin arus laut tipe V-shaped blade dengan mempertimbangkan blade aspect ratio dan solidity,” Jurnal Teknologi, vol. 15, no. 1, pp. 1–12, 2023, doi: 10.24853/jurtek.15.1.1-12.

[4] H. Palippui, Energi Non Konvesional, 1st ed. Makassar, Indonesia: Professor Line, 2023.