Technical Aspects and Installation Challenges of Ocean Current Turbines in the Indonesian Strait

Abstract

The straits of Indonesia possess unique hydrodynamic characteristics resulting from the interaction of tidal currents, the Indonesian Throughflow, and the influence of seasonal monsoons. These conditions make the straits a potential location for the development of turbine-based ocean current power plants. This study discusses the technical aspects and challenges of installing ocean current turbines in Indonesian straits by reviewing key parameters such as current velocity, water depth, seabed characteristics, turbulence, and wave and wind loads. The technical analysis covers the selection of turbine types (horizontal-axis and vertical-axis), foundation systems (monopile, gravity-based, or mooring systems), subsea power transmission systems, and integration into the onshore power grid. The main challenges identified include seasonal current variability, the potential for biofouling and corrosion due to the tropical marine environment, the complexity of installation in waters with strong currents, port infrastructure limitations, and navigation safety aspects in active shipping lanes. Additionally, environmental and social factors such as impacts on marine ecosystems and fishing activities are also important considerations in planning. The study's findings indicate that, technically, the installation of ocean current turbines in the Indonesian straits is feasible, but requires an adaptive design approach, comprehensive oceanographic studies, and installation strategies that account for local conditions. With proper planning, this technology has the potential to become a reliable and sustainable source of renewable energy for Indonesia's archipelago.

Andi Muhammad Ikram*

Department of Ocean Engineering, Hasanuddin University, Indonesia.

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

Keywords: Hydrodynamics, Indonesian Straits, Installation Challenges, Ocean Current Turbines, Renewable Energy.

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 (BIG, 2024). Indonesia's geographical position between the Pacific and Indian Oceans gives rise to the Indonesian Throughflow a large mass of water flowing from the Pacific to the Indian Ocean through various strategic straits. This phenomenon generates significant and relatively predictable kinetic energy potential, particularly in strait regions with narrowing cross-sectional flow.

In the context of energy transition and carbon emission reduction, ocean 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. Ocean current turbines operate on the principle of converting the kinetic energy of water flow into mechanical energy, which is subsequently converted into electrical energy through a generator. This technology offers the advantage of high energy density, owing to the fact that water has a significantly greater mass density than air.

Several straits in Indonesia including the Larantuka Strait, Lombok Strait, and Sunda Strait are known to have sufficiently high current velocities, making them potentially viable sites for ocean current turbine installations. Nevertheless, the implementation of this technology is not without technical challenges. Complex hydrodynamic conditions, seasonal variations driven by monsoons, diverse seabed characteristics, and the influence of extreme waves and winds are all factors that must be carefully considered during the planning and design phases.

Beyond technical aspects, ocean current turbine installations also face operational challenges such as material corrosion in tropical marine environments, biofouling, difficulties in installation under strong currents, and the need for reliable submarine power transmission systems. Navigation safety and the potential impact on marine ecosystems are also critical considerations in project development.

Against this background, this paper aims to examine the key technical aspects and installation challenges of ocean current turbines in Indonesia's straits. By understanding local characteristics and existing constraints, it is hoped that appropriate design approaches and implementation strategies can be formulated to support the development of marine resource-based renewable energy in Indonesia.

2. Material and Methods

This study employs a descriptive-analytical approach aimed at examining the technical aspects and installation challenges of ocean current turbines in Indonesia's straits. The research method was conducted through a literature review and analysis of secondary data relevant to the hydrodynamic characteristics of Indonesian waters. The literature review covers the fundamental theory of ocean current energy, the working principles of current turbines, design and installation standards, as well as findings from previous studies related to the implementation of this technology across various regions.

The data used in this study are secondary data comprising information on ocean current velocity and patterns, water depth, seabed conditions, and environmental factors such as waves and the characteristics of tropical waters. These data were analyzed to describe the potential of current energy and the suitability of candidate sites in relation to the technical requirements for turbine installation.

3. Results

The results of the hydrodynamic analysis indicate that the primary parameters in the design of ocean current turbine installations are current velocity, vertical velocity distribution, hydrodynamic forces, and the interaction between currents and the seabed. Current velocity (V) is the most dominant factor, as the theoretical power potential is directly proportional to the cube of the velocity, as expressed in the power equation $P = \frac{1}{2}\mathrm{pAV}^3$. This demonstrates that even a small increase in current velocity will yield a significant increase in power output. Consequently, locations with stable and relatively high current velocities are decisive in determining the technical feasibility of turbine installation.

Beyond the magnitude of velocity, the vertical distribution of currents commonly referred to as vertical shear is also an important consideration. Variations in velocity at different depths give rise to differential loading on the rotor and turbine shaft. The resultant current velocity can be calculated from its horizontal components using the corresponding equation $V = \sqrt{\mathrm{U}^2 + \mathrm{V}^2}$. Where significant differences exist between water layers, the structural design must be capable of withstanding dynamic loads resulting from current fluctuations and turbulence. Such conditions are generally characterized by high Reynolds numbers ($Re = \frac{\text{pVL}}{\mu}$), indicating that the flow is turbulent and generates unstable forces on the structure.

From a structural perspective, the turbine will be subjected to drag force caused by the current flow, as expressed in the drag force equation $FD = \frac{1}{2}\text{pCD. AV}^2$. This force acts upon the rotor, support pile, and foundation, and must therefore be accounted for in the material strength and structural stability analysis. The greater the current velocity, the greater the force acting on the structure, increasing quadratically with velocity. Accordingly, foundation designs such as monopiles or gravity bases must account for maximum loading conditions during peak current events.

The interaction between currents and the seabed is also a critical factor, manifested through the bed shear stress parameter (τ = Cf ρ). This shear stress can trigger scouring phenomena around the turbine foundation, potentially compromising long-term structural stability. In shallow waters or areas with loose sediments, this analysis becomes particularly crucial prior to installation.

Overall, the hydrodynamic study reveals that the design of ocean current turbines depends not only on the magnitude of energy potential, but also on flow characteristics, turbulence patterns, and interactions with the surrounding environment. Current velocity determines power potential, while drag force, turbulence, and bed shear stress govern the safety and structural stability aspects. Therefore, a comprehensive hydrodynamic study must be conducted as a mandatory preliminary step before turbine installation, in order to ensure that the system can operate optimally and sustainably.

4. Discussion

The technical aspects of ocean current turbine design are determined by the hydrodynamics of the current, where such data are obtained from the processing of oceanographic data. In order to maximize turbine power output, areas with high current velocities are required. In addition, flow patterns are also essential in designing the turbine structure to ensure long-term durability. Based on the literature review, turbines are subject to drag force, which acts on the rotor, support pile, and foundation. Therefore, a design capable of minimizing drag force is necessary, raising the question of whether an ocean current turbine should be constructed as a floating structure or fixed to the seabed. With regard to oceanographic conditions in Indonesian straits, ocean current turbines have the potential to be deployed for renewable energy generation. An example of this can be seen in Table 1.

Table 1. Power Potential Data for a 15-Day Period 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
13 m	95125.32
8 m	83532.14
3 m	94463.23

Based on Table 1, the maximum potential for electricity generation in the Bandung Strait occurs at a depth of 3 meters; however, the drag force caused by the current velocity must be taken into account.

5. Conclusions

The straits in Indonesia hold significant potential for the development of tidal power plants. However, their implementation still faces various technical challenges, particularly during the installation phase. One of the key factors that must be considered is the oceanographic conditions, which include tidal current characteristics, tides, waves, and water depth. These parameters form the basis for determining the power plant system design whether a floating system or a fixed structure is more suitable. Therefore, a comprehensive oceanographic study is essential to ensure a safe, efficient, and sustainable design.

References

Adamtheoyana, T., Purwanto, & Pranowo, W. S. (2015). *Potensi energi arus laut pada berbagai kedalaman untuk pembangkit listrik di Selat Badung, Bali.* Jurnal Oseanografi, 4(1), 262–269.

Ariefianto, R. M., Hasanah, R. N., & Wijono. (2023). *Optimasi turbin arus laut tipe V-shaped blade dengan mempertimbangkan blade aspect ratio dan solidity*. Jurnal Teknologi, 15(1), 1–12. https://doi.org/10.24853/jurtek.15.1.1-12

Badan Informasi Geospasial. (2024, 13 Desember). *Pulau Indonesia bertambah jadi 17.380, mengapa angkanya berubah setiap tahun?* SIPULAU – BIG. Diakses dari https://sipulau.big.go.id/news/11