International Journal of Modern Achievement in Science, Engineering and Technology (IJSET)
ISSN 3023-459X
DOI: 10.63053/ijset.51

The Role of Marine Energy Production in The Development of Urban Infrastructure with Tidal Power Plants

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ARTICLE INFO

Keywords:
Tidal Power Plant, Marine Energy, Marine Structures, Urban Development

ABSTRACT

Marine structures, designed and built to develop urban infrastructure, play a very important role in improving access to marine resources, protecting beaches, and facilitating urban and marine communications. These structures can be influential in different parts of urban development. This article, marine energy production facilities with a focus on tidal power plants, which include types of tidal power plants, how they work, the effect of power plants on urban development, design and construction, advantages and challenges, and their comparison. Together with each other. Also, the contribution of each of the tidal power plants in marine energy production facilities is shown to provide a better understanding of the users of this article. These types of structures in addition to economic development and infrastructure improvement Transportation also help to protect the environment and the sustainable use of natural resources, which is why familiarizing and investigating these types of structures and the role they play in the development of urban infrastructure is of particular importance and needs Further investigations using numerical modelling and laboratory methods will be necessary to achieve accurate and reliable engineering results.

Introduction

Marine energy production facilities have been considered one of the most important means of using renewable energy in recent decades. Considering the increasing need for clean energy and the reduction of fossil resources, the use of resources such as wind and sea tides can help provide sustainable energy and reduce dependence on fossil fuels. Also, tidal power plants are considered one of the renewable energy sources that use the periodic changes in the water level of the seas and oceans to generate electricity. These power plants are built in areas with significant tidal changes and provide a stable and predictable source of energy due to regular tidal cycles. This article examines the operation of tidal power plants, the design and construction of power plants, the challenges and the mathematical relationships related to the production of energy from these power plants, and their effects on the development of urban infrastructure.

Marine energy production facilities
These facilities can be divided into two general categories, offshore wind energy facilities and tidal power plants, which will be explained below.

Offshore wind energy facilities
As one of the most important sources of renewable energy, offshore wind turbines operate using wind energy on the seas. These turbines generate electrical energy through installation in sea areas with high and stable wind speeds. The production power of an offshore wind turbine is calculated using equation:(1)

$$P = \frac{1}{2} \cdot \rho \cdot A \cdot v^3 \cdot C_p \quad (1)$$

where the Pproduction power is in watts$P$, sea water density (equal to 1025 kg/m3), Aturbine blade area, $v$wind speed in m/s andC_p Turbine power factor (usually between 0.3 and 0.5).

Considering that the production power of the turbine depends on the cube of the wind speed, sea areas with higher wind speed will have more energy production. For this reason, the correct location of the turbines is very important. In Figure (1) you can see the wind turbine diagram.

Figure 1. Sea wind turbine diagram

Tidal power plants
Tidal power plants generate electricity by using changes in sea level caused by tides. When the seawater rises or falls, this energy is converted into mechanical energy and then into electrical energy.
The production power of a tidal power plant can be calculated using equation.(2)

$P = \frac{1}{2} \cdot \rho \cdot g \cdot A \quad \cdot h^2$(2)

where the Pproduction power is in watts, ρHe density of seawater (equal to 1025 kg/m3), g is the acceleration of the earth's gravity (9.81 m/s2), A is the area of the tank in m2 and h is the elevation of the tide in m.
This relationship shows that the production power of the tidal power plant depends on the square of the height of the tide, so places with large water level changes are more suitable for these power plants. In Figure (2), you can see the graph of the power plant's production power according to the increase in the height of the

tide. In such a way the increase in the height of the tide is directly related to the increase in the production power of the tidal power plant.

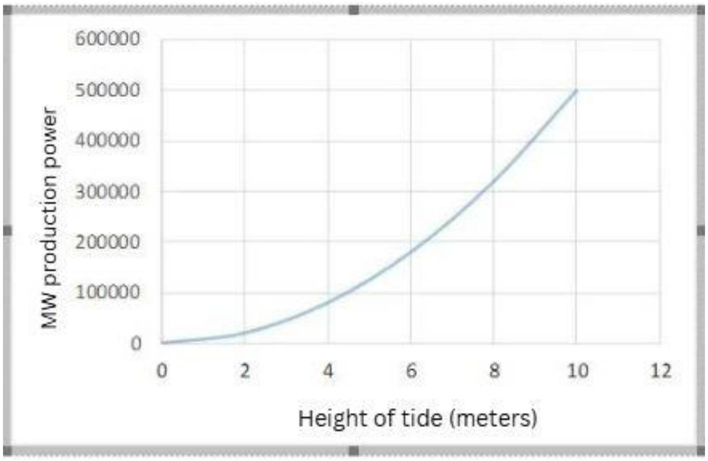

Figure 2. Changes in production power according to the height of the tide

This diagram shows that the power generation in a tidal power plant changes as a function of the height of the tide (h).

Tidal power plants and their role in urban infrastructure development

Tidal power plants are one of the renewable energy sources that use periodic changes in sea and ocean water levels to generate electricity. These power plants are built in areas with significant tidal changes and provide a stable and predictable source of energy due to regular tidal cycles. This article examines how tidal power plants work, mathematical relationships related to energy production from these power plants, and their effects on urban infrastructure development.

Diagram of the contribution of tidal power plants

In Figure (3), you can see an overview of the contribution of tidal power plants to marine energy production facilities. This diagram clearly shows the contribution of each type of power plant and gives a better understanding of the distribution of the contribution of different power plants. It helps.

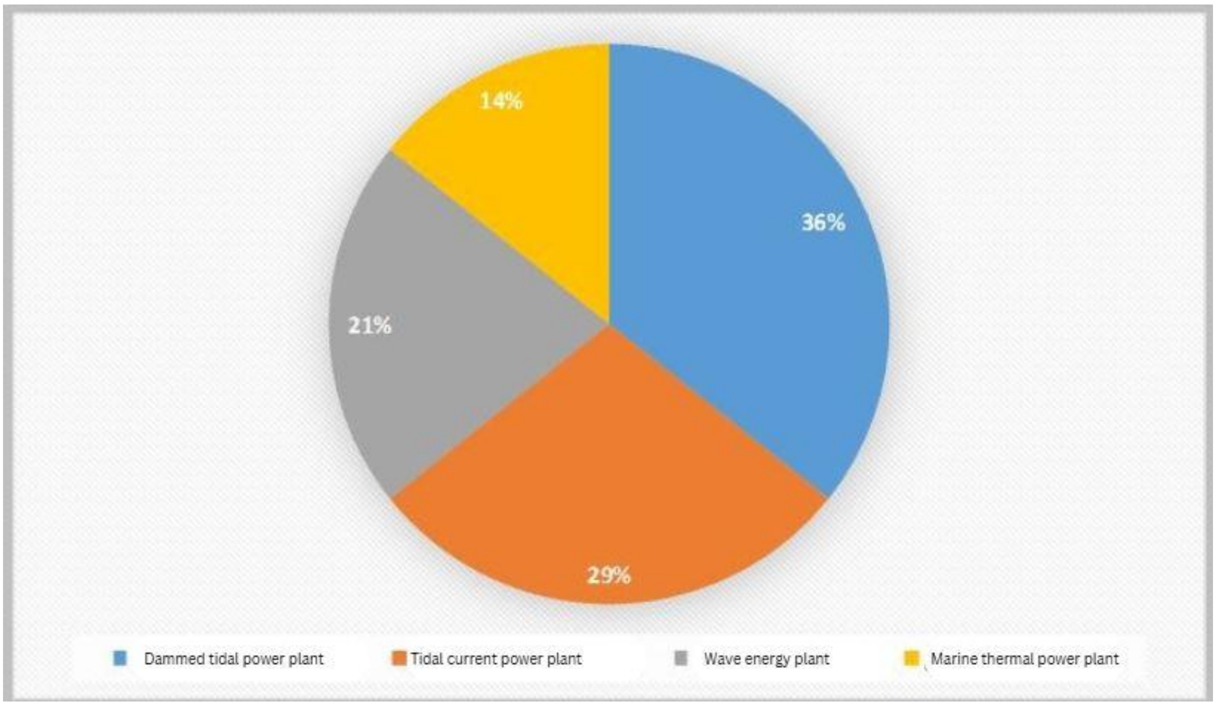

Figure 3. Contribution of power plants in marine energy production facilities

How tidal power plants work

Tidal power plants use the difference in sea water height during high tides. When the water level rises at high tide and then falls at low tide, these changes in water level are converted into mechanical power that is used to generate electricity. These power plants are divided into two main types: dam-tidal power plants and tidal flow power plants.

Figure (3) schematically shows the tidal power plant

Tidal Barrage power plant

Barrage tidal power plants are one of the oldest and most well-known types of tidal power plants that generate electricity by using the difference in sea level during high tide. These power plants control the flow of water by installing dams or barriers at the mouth of rivers or bays and produce electrical energy by passing water through turbines.

Performance of dammed tidal power plants

Dammed tidal power plants work by using a dam or barrier that is built at the entrance of bays, rivers or estuaries. This dam directs the flow of water into the bay during high tide, and then during low tide, the water is returned to the sea through turbines installed in the dam and electrical energy is generated. These power plants usually have several stages to produce electricity:

1. Mood stage: When the sea water rises (mood), the floodgates are opened and water flows into the reservoir or bay.
2. Low tide stage: When the water level (island) drops, the valves are closed and the water in the tank returns to the sea through the turbines. The flow of water through the turbines causes them to rotate and thus generate electrical energy.

Numerical calculation of energy production in dammed tidal power plant

The production power of a dammed tidal power plant is dependent on the changes in the height of the sea level during the tide, the volume of water that passes through the dam, and the speed of the water flow. The main mathematical equation for calculating the output power will be according to equation (2) mentioned above. This relationship shows that the production power is dependent on water density, earth's gravity, reservoir area, and most importantly, tidal height difference. The greater the difference in height h, the greater the production power.

Suppose the area behind the dam reservoir is equal to 2,000,000 square meters and the difference in the height of the tides is equal to 6 meters. Using equation (2), the production power will be equal to 362.97 megawatts, which means that this power plant will be able to produce 362.97 megawatts. Produce megawatts of power that can provide the energy needed by an average urban area.

Design and structure of Damodar tidal power plant

Dammed tidal power plants usually include the following sections:
1. Dam or barrier: This section is built as a wall at the mouth of a bay or river to control the flow of water.
2. Turbines: The turbines installed in the dam move the water as it leaves the reservoir, and this mechanical movement is converted into electrical energy.
3. Valves: These valves are used to control the flow of water between the sea and the tank. During high tide, the valves are opened to allow water to flow into the tank and closed during low tide to allow water to flow back through the turbines.

Effects of Dammed Tidal Power Plants on Urban Infrastructure Dammed tidal power plants can have important effects on the development of urban and economic infrastructure in coastal areas. Some of these effects are:

1. Providing sustainable energy: These power plants can help provide sustainable and renewable energy for coastal cities. Due to regular tidal cycles, these power stations are a predictable source of energy.
2. Creating employment: The construction and maintenance of tidal power plants with dams requires specialized labour in various fields, including engineering, construction, and energy management. This can help create job opportunities and strengthen the local economy.
3. Enhancing transportation infrastructure: Dammed tidal power plants usually require the creation of roads, ports, and docks to transport equipment and materials. These infrastructures can help the economic and commercial development of coastal cities.
4. Flood management: Tidal power plant dams can play an effective role in flood control. These dams can manage water flow in emergencies and prevent devastating floods in urban areas.

Advantages of dammed tidal power plants:
1. Renewable and Clean: Tidal energy is a renewable resource and does not use fossil fuels, so it has less environmental impact.
2. Predictable: Unlike wind and solar energy which may be unstable, tidal energy is completely predictable and energy production can be planned.

Challenges of dammed tidal power plants:
1. High costs: the construction of dams and facilities related to dam-based tidal power plants require large investments.
2. Environmental effects: These power plants may have negative effects on coastal ecosystems and marine life. For example, dam construction can prevent the free movement of marine species and negatively impact the local ecosystem.

Tidal Stream Power Plants

Tidal current power plants, as one of the important sources of renewable energy, use the kinetic energy caused by tides to generate electricity. Instead of using dams, these types of power plants use turbines on the seabed that respond to the natural flow of water during high tides. Considering the increasing need for sustainable energy and reducing the environmental effects caused by fossil fuels, tidal power plants can play an important role in providing energy and improving urban infrastructure.

Performance of tidal current power plants

Tidal current power plants are designed by installing underwater turbines in areas with strong tidal currents. These turbines directly use the force of water flow to produce electrical energy. In other words, the kinetic energy of moving water is converted into mechanical energy, and then this mechanical energy is converted into electricity.

Numerical calculations of energy production in tidal power plants

The production power of tidal power plants depends on the water density, the effective area of the turbine, and the speed of the water flow. The main relationship for calculating the production power is the same relationship number (1). Suppose the turbine area is 60 square meters and the water flow speed is 3 meters per second. Also, assuming a power factor of 0.4 and using equation number (1), it can be concluded that a turbine in this power plant can produce about 3.32 megawatts of power.

Structure and components of tidal current power plants
1. Turbines: Underwater turbines act as the core of the power plant. These turbines produce mechanical energy by rotating the water flow.
2. Generator: The generator connected to the turbine converts mechanical energy into electrical energy.
3. Control system: This system manages the operation of the power plant and ensures that the energy production is optimal.

Effects of tidal power plants on urban infrastructure

Tidal power plants can have important effects on the development of urban infrastructure due to their specific characteristics:
1. Providing sustainable and renewable energy: These power plants can help reduce dependence on fossil fuels due to the production of energy from natural and renewable sources. This feature helps to provide sustainable energy for coastal cities and reduce the environmental impact of energy production.

2. Creation of employment and economic development: The establishment and maintenance of tidal power plants lead to the creation of job opportunities in various fields of engineering, construction, and energy-related services. This helps local economic growth.
3. Strengthening of transportation and communication infrastructure: The need for facilities and equipment to install and maintain these power plants may improve transportation infrastructure, such as roads and ports, which in turn will have a positive impact on local trade and communication.
4. Environmental impacts: Although tidal power plants have less environmental impacts than other energy sources, installing turbines on the seabed may affect marine ecosystems. Therefore, detailed environmental assessments are necessary before installing these power plants.

Advantages of tidal power plants:
1. Sustainability and renewable: Tidal energy is a renewable resource that can provide energy for a long time.
2. Low cost in the long term: By increasing productivity and reducing production costs, tidal power plants can become an economical option in the long term.
.3Non-destructive: These power plants are a better option for development due to not needing much land and less damage to the environment than other power plants.

Challenges of tidal power plants:
1. High initial costs: The costs of building and installing turbines and infrastructure equipment may be very high.
2. Impact on marine life: The installation of turbines may have negative impacts on the marine ecosystem and marine life.
3. Location limitations: The selection of suitable locations for the installation of these power plants depends on various factors including water depth, tidal currents, and environmental requirements.

Comparison of barrage and tidal current power plants
The characteristics of dammed tidal power plants and tidal current power plants are presented in Table.(1)

Table 1. Comparison of tidal power plants with dams and tidal flow

Tidal power plants	Dammed tidal power plants	Feature
Use of underwater turbines	Use of dams and valves	Energy production method
It has less impact than dams.	It can affect the marine ecosystem	Impact on the environment
less due to no need for a dam	higher due to the construction of the dam	Initial costs
Stable and low cost in the long run	Stable but requires regular maintenance	Sustainability and renewability
Dependent on natural water flows	More dependent on tides	Energy supply over time

Discussion and Conclusion

Marine energy production facilities, including tidal power plants, are very effective tools for providing clean and sustainable energy alongside urban infrastructure development. These facilities not only help to produce energy but can also help to improve the economic and environmental conditions of coastal areas. As one of the most effective and sustainable sources of renewable energy, tidal power plants have been able to help reduce greenhouse gas emissions and provide clean energy. In addition, the facilities of these power plants play an important role in the development of urban infrastructure in coastal areas. Using mathematical relationships to calculate the production power of these power plants helps to optimize their performance and increase energy efficiency. Considering the climate changes and the need for sustainable energy sources, tidal power plants are one of the basic solutions for the future of energy and urban development. Although there are environmental challenges and high initial costs in dammed tidal power plants, Their long-term benefits in the field of energy supply and reducing dependence on fossil fuels are significant. Also, the effect of tidal current power plants in providing energy and developing urban infrastructure is visible. Considering climate change and the need for sustainable energy sources, tidal current power plants can be recognized as

one of the main options in the future of energy.
Those interested in this field can check the feasibility and location of tidal power plants in areas that benefit from the sea and open waters. Also, with numerical modelling and accurate engineering simulations, things like stability can be determined. , analyze fatigue, useful life and operational optimization of power plants.

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